A Unified Cognitive Model of Visual Filling-In Based on an Emergic Network Architecture - Supplement

by

David Pierre Leibovitz

A **supplement** to the thesis submitted to the Faculty of Graduate and Postdoctoral Affairs in partial fulfillment of the requirements for the degree of

Doctor of Philosophy

in

Cognitive Science

Carleton University
Ottawa, Ontario

© 2013, David Pierre Leibovitz

A Unified Cognitive Model of Visual Filling-In Based on an Emergic Network Architecture - **Supplement**

This is **supplemental** material for the eight cognitive models and forty two tests of a thesis named "*A Unified Cognitive Model of Visual Filling-In Based on an Emergic Network Architecture*". This supplement contains detailed information about computational test subjects, stimuli, and results. The thesis contains extracts from the information contained herein. The models and tests are listed in the same order as in the thesis and with the same chapter/appendix identifiers.

For both computational subject and stimuli details, the appropriate parameter files are shown. These are fully described within the Emergic Simulation System portion of the thesis. The test results are available online in an animated format (Leibovitz, 2012a) that is ideal for exhibiting qualitative behaviour. It is an extremely compact format (one web page for each of the eight computational models), and has a few additional test results. It is available at

http://emergic.upwize.com/?page_id=26

This supplement merely extracts the animated results into a frame-by-frame account with precise timing information suitable for quantitative analysis and print publication. The thesis contains extracts of these frame-by-frame accounts.

The animated results contain an extra *Photoreceptor Changes* column that is not ordinarily shown in the thesis or supplement as it is not yet part of our cognitive theory. It demonstrates temporal edge detection and is merely the absolute difference in a photoreceptor's activation between two time ticks.

Some of these results have been previously introduced (Leibovitz, 2012b; Leibovitz & West, 2012).

Table of Contents (Top-Level)

Table of Contents (Top-Level) iv

Table of Contents v

List of Tables xi

List of Illustrations xiv

2 Chapter: An emergic model of filling-in for colour homogeneity 1

3 Chapter: An emergic model of filling-out for trans-saccadic integration 42

4 Chapter: An emergic model of filling-in after brief stimuli 115

5 Chapter: An emergic model of filling-in the blind-spot 163

Appendix A: An emergic model of filling-in for anorthoscopic perception 260

Appendix B: An emergic model of filling-in the foveal blue scotoma 309

Appendix C: An emergic model of filling-in during blinks 376

Appendix D: An emergic model of filling-in from imagination 426

References 467

Table of Contents

Table of Contents (Top-Level) .... **iv**

Table of Contents .... **v**

List of Tables .... **xi**

List of Illustrations .... **xiv**

2 Chapter: An emergic model of filling-in for colour homogeneity **1**

2.1 Subject details 1

2.1.1 Test 1, 2 & 4 subject 1

2.1.2 Test 3 subject 2

2.2 Stimuli details 3

2.2.1 Test 1a stimulus (Red) 3

2.2.2 Test 1b stimulus (Green) 3

2.2.3 Test 1c, 2 & 3 stimulus (Blue) 3

2.2.4 Test 4 stimulus 4

2.3 Result details 5

2.3.1 Test 1a results: Visual time sequence of homogeneous red filling-in 6

2.3.2 Test 1b results: Visual time sequence of homogeneous green filling-in 12

2.3.3 Test 1c results: Visual time sequence of homogeneous blue filling-in 18

2.3.4 Test 2 results: Visual time sequence of homogeneous blue filling-in under eye motion 24

2.3.5 Test 3 results: Visual time sequence of homogeneous blue filling-in under large RFs 30

2.3.6 Test 4 results: Visual time sequence of texture not filling-in 36

3 Chapter: An emergic model of filling-out for trans-saccadic integration **42**

3.1 Subject details ... 42

3.1.1 Test 1, 2 & 5 subject ... 43

3.1.2 Test 3 subject ... 44

3.1.3 Test 4 subject ... 45

3.2 Stimuli details ... 46

3.2.1 Test 1 stimulus: Simple surfaces (Love) ... 46

3.2.2 Test 2 stimulus: Natural image (Lena) ... 47

3.2.3 Test 3 stimulus: Dynamic image with surface gradients (Chaser) ... 48

3.2.4 Test 4 stimulus: Edge under varying RF sizes ... 49

3.2.5 Test 5 stimulus: Image masking under fast motion ... 49

3.3 Result details ... 50

3.3.1 Test 1 results: Simple surfaces (Love) ... 51

3.3.2 Test 2 results: Natural image (Lena) ... 62

3.3.3 Test 3 results: Dynamic image with surface gradients (Chaser) ... 73

3.3.4 Test 4 results: Edge under varying RF sizes ... 84

3.3.5 Test 5 results: Image masking under fast motion ... 95

3.3.6 Test 6 results: Drawing figures under planned eye movements under paralysis ... 104

4 Chapter: An emergic model of filling-in after brief stimuli ... 115

4.1 Subject details ... 115

4.2 Stimuli details ... 116

4.2.1 Test 1 stimulus: Simple surfaces (Love) ... 116

4.2.2 Test 2 stimulus: Natural image (Lena) ... 116

4.2.3 Test 3 stimulus: Dynamic image with surface gradients (Chaser) ... 117

4.2.4 Test 4 stimulus: Simple object (Square) ... 117

4.3 Result details ... 118

4.3.1 Test 1 results: Simple surfaces (Love) ... 119
4.3.2 Test 2 results: Natural image (Lena) ... 130
4.3.3 Test 3 results: Dynamic image with surface gradients (Chaser) ... 141
4.3.4 Test 4 results: Simplified object (Square) ... 152
5 Chapter: An emergic model of filling-in the blind-spot ... 163
5.1 Subject details ... 163
5.1.1 Test 1, 2 & 3 subject with dynamic eye ... 163
5.1.2 Test 4, 5, 6 & 7 subject with static eye ... 164
5.1.3 Test 8 subject with final saccade ... 165
5.2 Stimuli details ... 166
5.2.1 Test 1 stimulus: Simple surfaces (Love) ... 166
5.2.2 Test 2 stimulus: Natural image (Lena) ... 167
5.2.3 Test 3 stimulus: Dynamic image with surface gradients (Chaser) ... 167
5.2.4 Test 4 stimulus: Line static ... 168
5.2.5 Test 5 stimulus: Line across ... 168
5.2.6 Test 6 stimulus: Line in ... 169
5.2.7 Test 7 stimulus: Line static with background masked ... 169
5.2.8 Test 8 stimulus: ring around the blind spot ... 170
5.3 Result details ... 171
5.3.1 Test 1 results: Simple surfaces (Love) ... 172
5.3.2 Test 2 results: Natural image (Lena) ... 183
5.3.3 Test 3 results: Dynamic image (Chaser) ... 194
5.3.4 Test 4 results: Line static ... 205
5.3.5 Test 5 results: Line across ... 216
5.3.6 Test 6 results: Line in ... 227

5.3.7 Test 7 results: Line static with background masked 238
5.3.8 Test 8 results: Filling-in ring then saccade 249

Appendix A: An emergic model of filling-in for anorthoscopic perception 260

A.1 Subject details 260
A.2 Stimuli details 262
A.2.1 Test 1 stimulus: Simple surfaces (Love) 262
A.2.2 Test 2 stimulus: Natural image (Lena) 262
A.2.3 Test 3 stimulus: Dynamic image with surface gradients (Chaser) 263
A.2.4 Test 4 stimulus: Simple object (Square) 263
A.3 Result details 264
A.3.1 Test 1 results: Simple surfaces (Love) 265
A.3.2 Test 2 results: Natural image (Lena) 276
A.3.3 Test 3 results: Dynamic image with surface gradients (Chaser) 287
A.3.4 Test 4 results: Simple object (Square) 298

Appendix B: An emergic model of filling-in the foveal blue scotoma 309

B.1 Subject details 309
B.2 Stimuli details 310
B.2.1 Test 1 stimulus: Full white stimulus 310
B.2.2 Test 2 stimulus: Half white stimulus 311
B.2.3 Test 3 stimulus: Quarter white stimulus (for stationary eye) 312
B.2.4 Test 4 stimulus: Quarter white stimulus (for moving eye) 313
B.2.5 Test 5 stimulus: Arrow stimulus 314
B.2.6 Test 6 stimulus: Point stimulus 315
B.3 Result details 316
B.3.1 Test 1 results: Full white stimulus 317

B.3.2 Test 2 results: Half white stimulus ... 328

B.3.3 Test 3 results: Quarter white stimulus ... 339

B.3.4 Test 4 results: Quarter white stimulus with saccade ... 350

B.3.5 Test 5 results: Arrow stimulus ... 356

B.3.6 Test 6 results: Point stimulus with saccade ... 367

Appendix C: An emergic model of filling-in during blinks ... 376

C.1 Subject details ... 376

C.1.1 Test 1 & 2 stimulus ... 377

C.1.2 Test 3 stimulus ... 377

C.1.3 Test 4 stimulus ... 378

C.2 Stimuli details ... 379

C.2.1 Test 1 stimulus: Simple surfaces (Love) ... 379

C.2.2 Test 2 stimulus: Natural image (Lena) ... 379

C.2.3 Test 3 stimulus: Dynamic image with surface gradients (Chaser) ... 380

C.2.4 Test 4: Rapid and extended blinking (Square) ... 380

C.3 Result details ... 381

C.3.1 Test 1 results: Simple surfaces (Love) ... 382

C.3.2 Test 2 results: Natural image (Lena) ... 393

C.3.3 Test 3 results: Dynamic image (Chaser) ... 404

C.3.4 Test 4 results: Rapid and extended blinking (Square) ... 415

Appendix D: An emergic model of filling-in from imagination ... 426

D.1 Subject details ... 426

D.1.1 Test 1 subject (Quick) ... 426

D.1.2 Test 2 & 3 subject (Slow) ... 427

D.1.3 Test 4 subject (Slow & Distorted) ... 427

D.2 Stimuli details ... 428

D.3 Result details ... 430

D.3.1 Test 1 results: Imagine quickly ... 431

D.3.2 Test 2 results: Imagine slowly ... 440

D.3.3 Test 3 results: Imagine slowly with eye movement ... 449

D.3.4 Test 4 results: Imagine distorted ... 458

References ... 467

List of Tables

Table 1: Time sequence of homogeneous red filling-in 6

Table 2: Time sequence of homogeneous green filling-in... 12

Table 3: Time sequence of homogeneous blue filling-in... 18

Table 4: Time sequence of homogeneous blue filling-in under eye motion..................... 24

Table 5: Time sequence of homogeneous blue filling-in under large RFs 30

Table 6: Time sequence of texture not filling-in 36

Table 7: Time sequence of filling-out for simple surfaces 51

Table 8: Time sequence of filling-out for natural image 62

Table 9: Time sequence of filling-out for dynamic image with surface gradients 73

Table 10: Time sequence of filling-out with edge under varying RF sizes 84

Table 11: Time sequence of filling-out image masking under fast motion 95

Table 12: Time sequence of filling-out by planned eye movement under paralysis 104

Table 13: Time sequence of active visual memory decay for simple surfaces (Love)... 119

Table 14: Time sequence of active visual memory decay for natural image (Lena)...... 130

Table 15: Active visual memory decay results over time for dynamic image (Chaser)... 141

Table 16: Time sequence of active visual memory decay for simplified object (Square)... 152

Table 17: Time sequence of blind spot moving over simple surfaces (Love) 172

Table 18: Time sequence of blind spot moving over natural image (Lena) 183

Table 19: Time sequence of blind spot moving over dynamic image (Chaser) 194

Table 20: Time sequence of static line filling-in over blind spot 205

Table 21: Time sequence of line moving across blind spot while filling-in.................. 216

Table 22: Time sequence of line moving into blind spot then being filled-in................ 227

Table 23: Time sequence of static line over blind spot with background masked 238

Table 24: Time sequence of filling-in blind spot with ring then saccade....................... 249

Table 25: Time sequence of narrow slit filling-in over simple surface (Love) 265

Table 26: Time sequence of narrow slit filling-in over natural image (Lena)................ 276

Table 27: Time sequence of narrow slit filling-in over dynamic image with surface gradients (Chaser).. 287

Table 28: Time sequence of narrow slit filling-in over simple object (Square) 298

Table 29: Time sequence of filling-in full white stimulus over foveal blue scotoma 317

Table 30: Time sequence of filling-in half white stimulus over foveal blue scotoma 328

Table 31: Time sequence of filling-in quarter white stimulus over foveal blue scotoma 339

Table 32: Time sequence of filling-in quarter white stimulus with saccade over foveal blue scotoma 350

Table 33: Time sequence of filling-in arrow stimulus over foveal blue scotoma 356

Table 34: Time sequence of filling-in point stimulus with saccade over foveal blue scotoma 367

Table 35: Time sequence of simple surfaces (Love) with blinks 382

Table 36: Time sequence of natural image with blinks 393

Table 37: Time sequence of dynamic image with blinks 404

Table 38: Time sequence of simple object with rapid and extended blinking................ 415

Table 39: Time sequence of imagining quickly.. 431

Table 40: Time sequence of imagining slowly 440

Table 41: Time sequence of imagining slowly with eye movement 449

Table 42: Time sequence of imagining with distorted mosaic 458

List of Illustrations

Illustration 1: Stochastic retina for homogeneity testing 1

Illustration 2: Fine texture stimulus 4

Illustration 3: Stochastic retina mapped into part of the first level RF for filling-out testing 42

Illustration 4: Stochastic retina with varying RF sizes mapped into 1st level of RFs 45

Illustration 5: Trans-saccadic Test 1 Stimulus (Love) 46

Illustration 6: Trans-saccadic Test 2 Stimulus (Lena) 47

Illustration 7: Trans-saccadic Test 3 stimulus (Chaser) with overlay............................... 48

Illustration 8: Trans-saccadic Test 4 stimulus (Edge) with overlay 49

Illustration 9: Trans-saccadic Test 5 stimulus (Mask) with overlay................................. 49

Illustration 10: Photoreceptor mosaic of *person* used in “flash memory” tests 1-4 115

Illustration 11: “Flash memory” view of Love 116

Illustration 12: “Flash memory” view of Lena 116

Illustration 13: “Flash memory” view of Chaser 117

Illustration 14: Test 4 stimulus (Square) with view overlay.. 117

Illustration 15: Photoreceptor mosaic of *person* used in blind spot tests 1-3 163

Illustration 16: Photoreceptor mosaic of *person* used in blind spot tests 4-7 164

Illustration 17: Photoreceptor mosaic of *person* used in blind spot tests 8 165

Illustration 18: Blind spot Test 1 stimulus (Love) with overlay.................................... 166

Illustration 19: Blind spot Test 2 stimulus (Lena) with overlay 167

Illustration 20: Blind spot Test 3 stimulus (Chaser) with overlay 167

Illustration 21: Blind spot Test 4 stimulus (LineStatic) with overlay............................ 168

Illustration 22: Blind spot Test 5 stimulus (LineAcross) with overlay.......................... 168

Illustration 23: Blind spot Test 6 stimulus (LineIn) with overlay 169

Illustration 24: Blind spot Test 8 stimulus (Ring) with overlay 170

Illustration 25: Photoreceptor mosaic of *person* used in experiments 1-4..................... 260

Illustration 26: Test 1 stimulus (Love) with view overlay.. 262

Illustration 27: Test 2 stimulus (Lena) with view overlay.. 262

Illustration 28: Test 3 stimulus (Chaser) with view overlay.. 263

Illustration 29: Test 4 stimulus (Square) with view overlay.. 263

Illustration 30: Retina for foveal blue scotoma.. 309

Illustration 31: Half white stimulus 311

Illustration 32: Quarter white stimulus 312

Illustration 33: Quarter white shifted stimulus shown as view with overlay................. 313

Illustration 34: Blue arrow stimulus 314

Illustration 35: Point stimulus.. 315

Illustration 36: Test 1 & 2 subject – their photoreceptor and RF1 mosaics 377

Illustration 37: Test 4 subject – their photoreceptor mosaic.. 378

Illustration 38: Test 1 stimulus with view overlays.. 379

Illustration 39: Test 2 stimulus with view overlays.. 379

Illustration 40: Test 3 stimulus with view overlays.. 380

Illustration 41: Test 4 stimulus with view overlays.. 380

Illustration 42: Imagination Test 1 (Fast) person... 426

Illustration 43: Imagination Test 4 (Distorted) person 427

Illustration 44: Imagined rectangles... 428

2 Chapter: An emergic model of filling-in for colour homogeneity

These supplement the corresponding material in the thesis.

2.1 Subject details

Two virtual subjects were used in these experiments.

2.1.1 Test 1, 2 & 4 subject

The same virtual agent, termed *Person* in ECS, was used in Experiments 1, 2 and 4, and the contents of their description file follows. The meaning of the parameter names can be found in the thesis. In this particular case, the important and highlighted parameters ensure an L:M:S (Red:Green:Blue) cone ratio of 7:3:1.

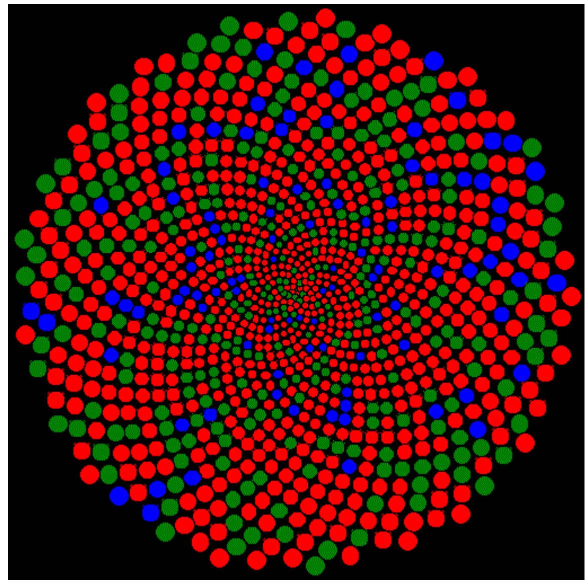


Illustration 1: Stochastic retina for homogeneity testing

```
[Person]
note =
srt = 10
sex = ai
age = 18
eyecount = 1
ipd = 0
vsize = 17.0
vieweyez = 30
r0conepix = 6
nodalpt = 17
r0coned = 0.5
r0red = 1
r0green = 1
r1coned = 3.0
r1red = 700
r1green = 300
r1blue = 100
blindx = 0.0
blindy = 0.0
blindr = 0.0
jitmin = 0.1
jitave = 0.7
jitmax = 0.9
p1_0_pixd = 2.0
p1_0_pix = 850
p1_0_scale = 2
p1_0_fanlat = 5.0
p1_0_fandwn = 1.0
p1_1_pixd = 4.0
p1_1_pix = 350
p1_1_scale = 2
p1_1_fanlat = 2.0
p1_1_fandwn = 2.0
p1_2_pixd = 8.0
p1_2_pix = 150
p1_2_scale = 2
p1_2_fanlat = 1.2
p1_2_fandwn = 1.5
```

2.1.2 Test 3 subject

This *Person* was similar to the previous one except for having larger and fewer RFs at the 2^{nd} and 3^{rd} layer. The contents of their description file follows. The meaning of the parameter names can be found in the thesis. In this particular case, the important and highlighted parameters ensure larger RF sizes – the only ones changed from above.

```
[Person]
note = Large RFs
srt = 10
sex = ai
age = 18
eyecount = 1
ipd = 0
vsize = 17.0
vieweyez = 30
r0conepix = 6
nodalpt = 17
r0coned = 0.5
r0red = 1
r0green = 1
r1coned = 3.0
r1red = 700
r1green = 300
r1blue = 100
blindx = 0.0
blindy = 0.0
blindr = 0.0
jitmin = 0.1
jitave = 0.7
jitmax = 0.9
p1_0_pixd = 2.0
p1_0_pix = 850
p1_0_scale = 2
p1_0_fanlat = 5.0
p1_0_fandwn = 1.0
p1_1_pixd = 16.0
p1_1_pix = 50
p1_1_scale = 2
p1_1_fanlat = 2.0
p1_1_fandwn = 2.0
p1_2_pixd = 64.0
p1_2_pix = 5
p1_2_scale = 2
p1_2_fanlat = 1.2
p1_2_fandwn = 1.5
```

2.2 Stimuli details

Test 1 had Red, Green & Blue stimulus conditions. The Blue stimulus was reused for both Test 2 and Test 3. Test 4 used a fine textured stimulus.

2.2.1 Test 1a stimulus (Red)

The meaning of these parameters is fully described in the thesis.

```
[World]
type = Lilac
Chaser
note = Red Patch
srt = 240
[Lilac Chaser]
llcount = 8
spacing =
0.434782608696
pad = 2.0
fg = #ff0000
bg = #ff0000
gamma = 1.0
grdcount = 2
grdwidth = 4
fixfg = # ff0000
fixsize = 1.0
fixwidth = 1
```

2.2.2 Test 1b stimulus (Green)

The meaning of these parameters is fully described in the thesis.

```
[World]
type = Lilac
Chaser
note = Green Patch
srt = 240
[Lilac Chaser]
llcount = 8
spacing =
0.434782608696
pad = 2.0
fg = #00ff00
bg = #00ff00
gamma = 1.0
grdcount = 2
grdwidth = 4
fixfg = #00ff00
fixsize = 1.0
fixwidth = 1
```

2.2.3 Test 1c, 2 & 3 stimulus (Blue)

The meaning of these parameters is fully described in the thesis.

```
[World]
type = Lilac
Chaser
note = Blue Patch
srt = 240
[Lilac Chaser]
llcount = 8
spacing =
0.434782608696
pad = 2.0
fg = #0000ff
bg = #0000ff
gamma = 1.0
grdcount = 2
grdwidth = 4
fixfg = #0000ff
fixsize = 1.0
fixwidth = 1
```

2.2.4 Test 4 stimulus

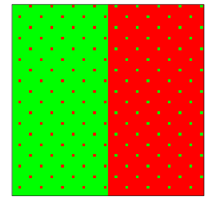


Illustration 2: Fine texture stimulus

The meaning of these parameters is fully described in the thesis.

```
[World]
type = Image
note = Textured Patches
srt = 200
[Image]
wx = 576
wy = 576
wbg = #000000
iname = Fine
Texture.gif
ix = 576
iy = 576
```

With image file “Fine Texture.gif” appearing as in Illustration 2).

2.3 Result details

In this section we tabulate a visual frame-by-frame account of results from all tests and their various conditions. Such a frame-by-frame account allows for the extraction of precise timing information useful for quantitative analysis. It takes 36 pages. All these results are reduced to a single web page of animated images, available at

http://emergic.upwize.com/?page_id=31

The animated account (Leibovitz, 2012a) is preferred as an overview showing behavioural dynamics of filling-in, and makes motion more salient. It also includes the results in greatest detail – they have been scaled down for print in this supplement, and even smaller in the chapter's *results and discussion* sections.

Each tabulated result has the following columns. **Time** numerically represents the time tick since the test has started, nominally 10ms/tick. All visual results in that table row are after the tick and computation have finished. **Stimuli** visually represents the stimuli presented to the virtual computer screen. None of the stimuli in this chapter are dynamic. The **Photoreceptor Mosaic** visually represents what the retina senses by looking at the stimuli. **Receptive Fields** at **Level 1**, **Level 2** and **Level 3**, visually represent the three level hierarchy of receptive fields showing their the functional size, not physical size.

2.3.1 Test 1a results: Visual time sequence of homogeneous red filling-in

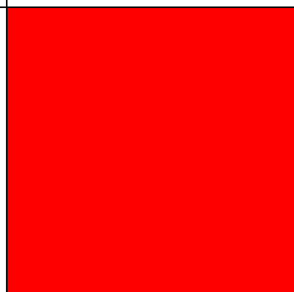
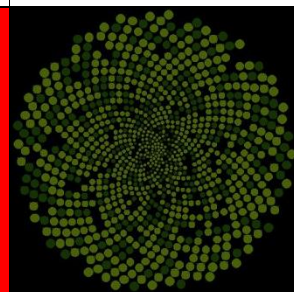
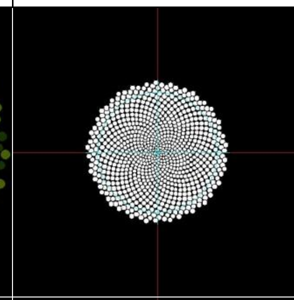
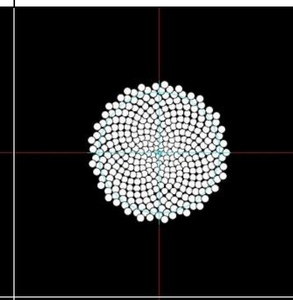
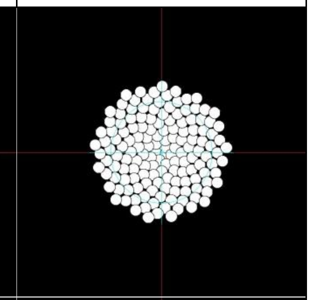
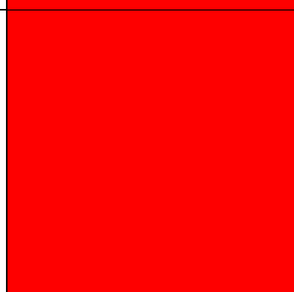
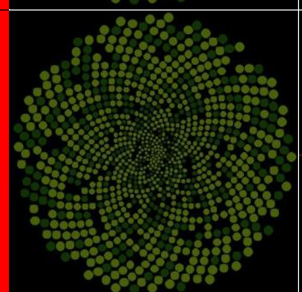
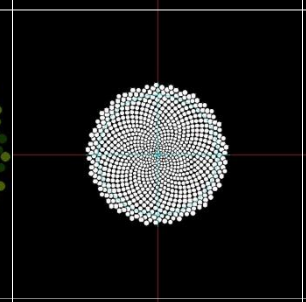
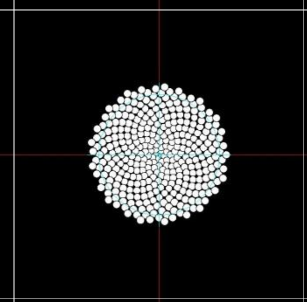
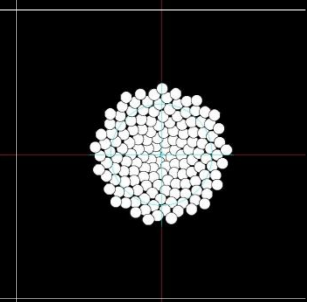
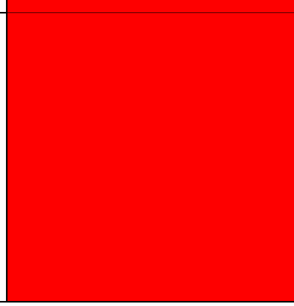
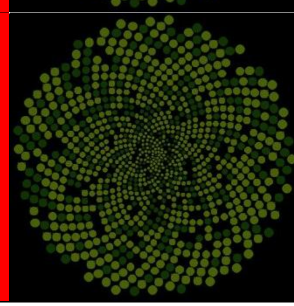
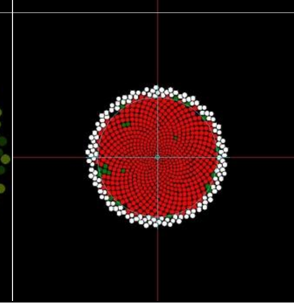
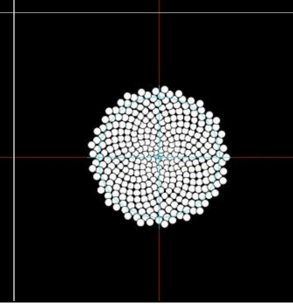
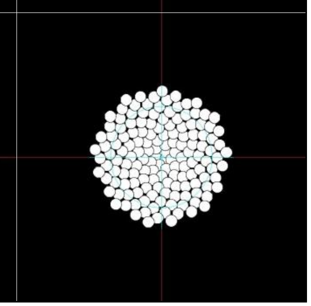
Table 1: Time sequence of homogeneous red filling-in					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
0					
1					
2					

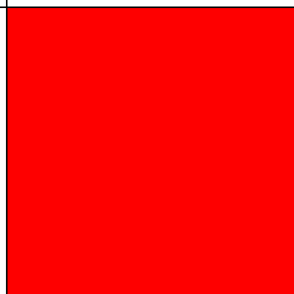
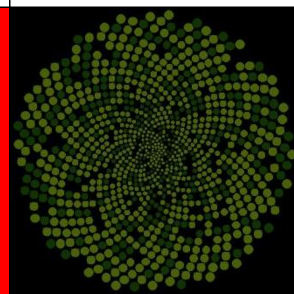
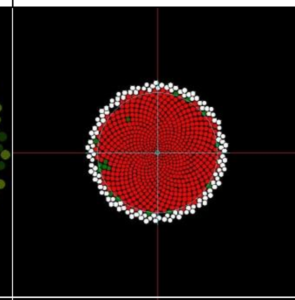
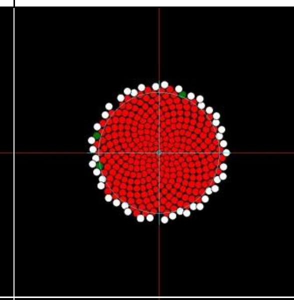
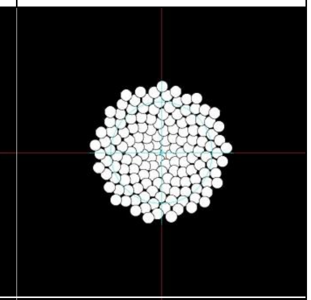
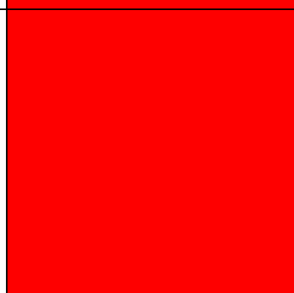
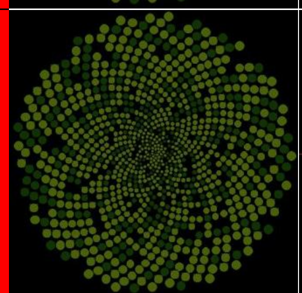
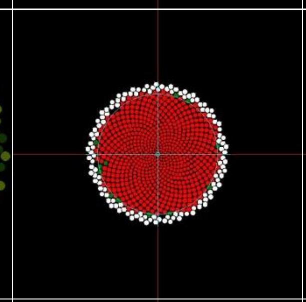
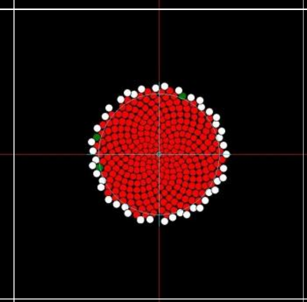
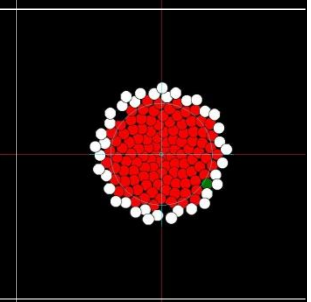
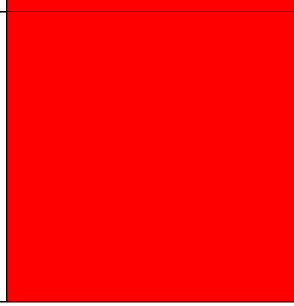
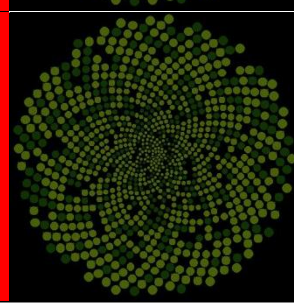
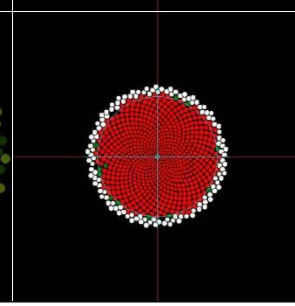
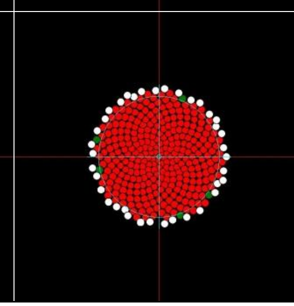
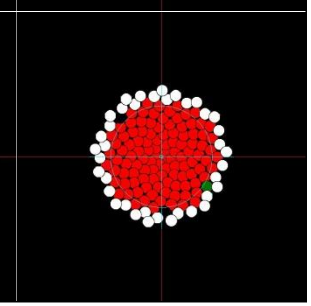
Table 1: Time sequence of homogeneous red filling-in					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
3					
4					
5					

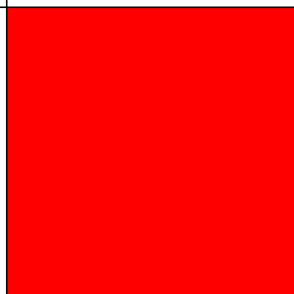
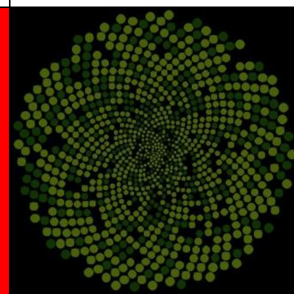
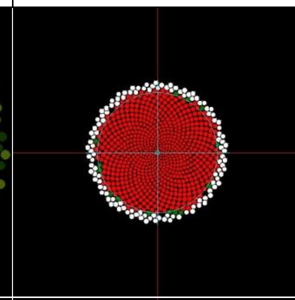
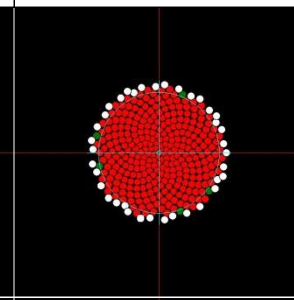
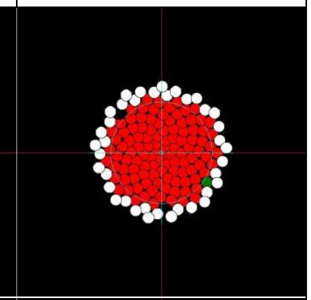
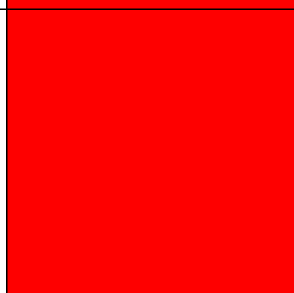
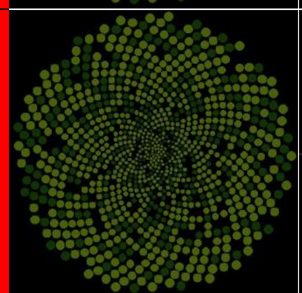
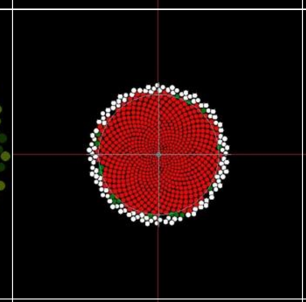
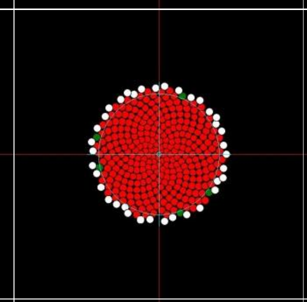
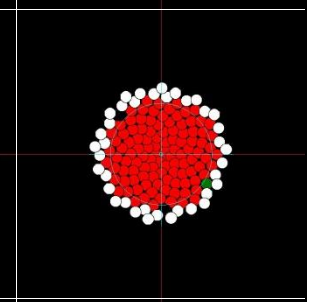
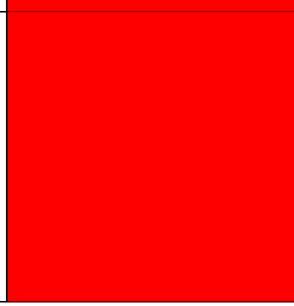
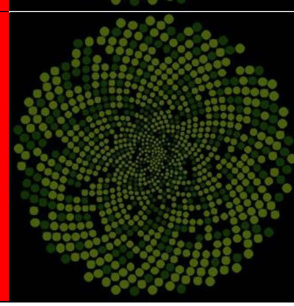
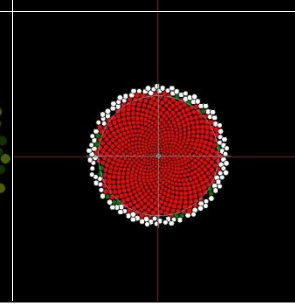
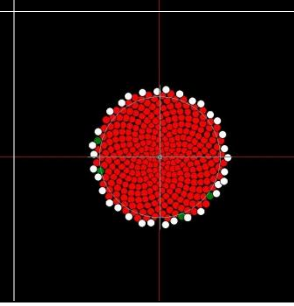
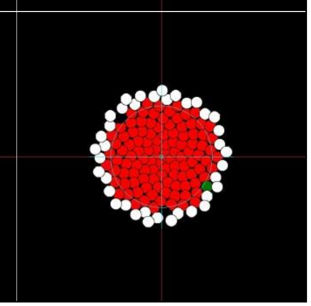
Table 1: Time sequence of homogeneous red filling-in					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
6					
7					
8					

Table 1: Time sequence of homogeneous red filling-in

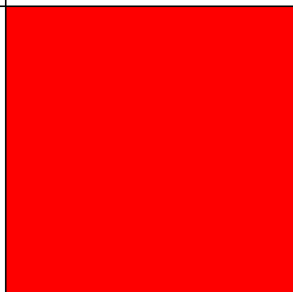
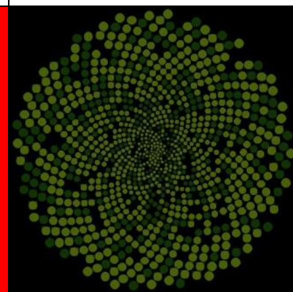
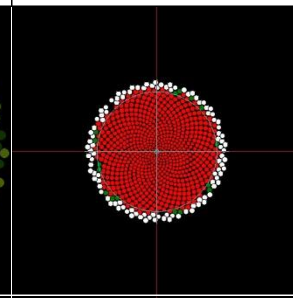
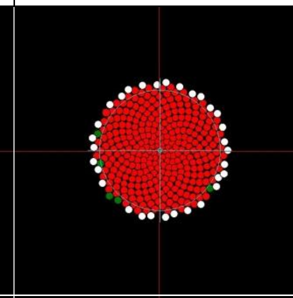
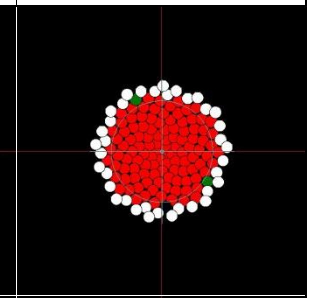
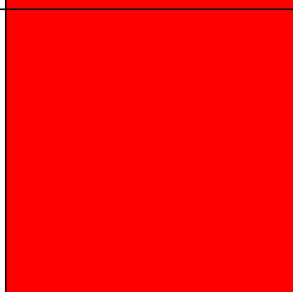
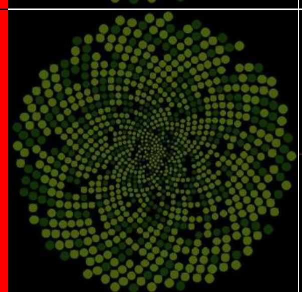
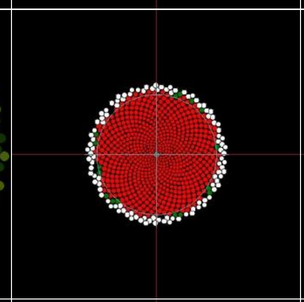
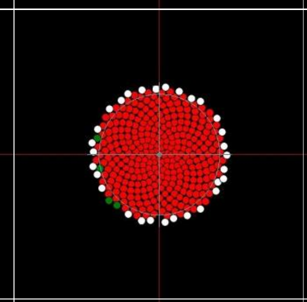
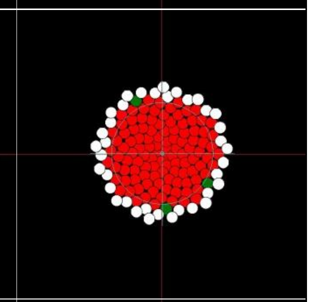
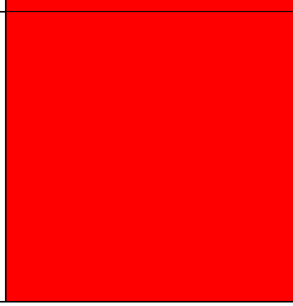
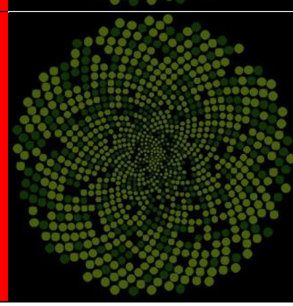
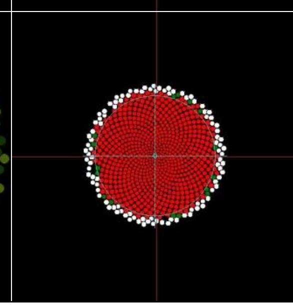
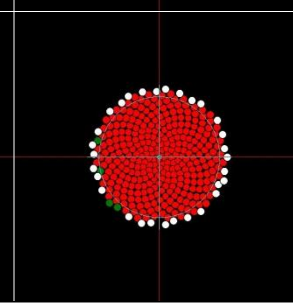
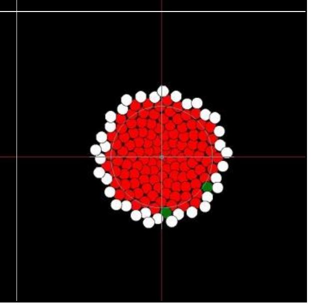
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
9					
10					
11					

Table 1: Time sequence of homogeneous red filling-in

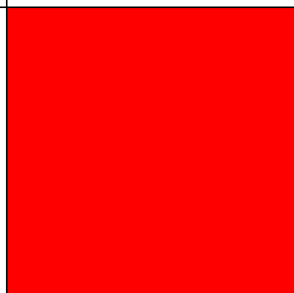
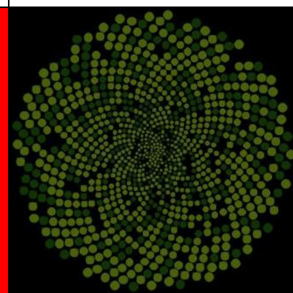
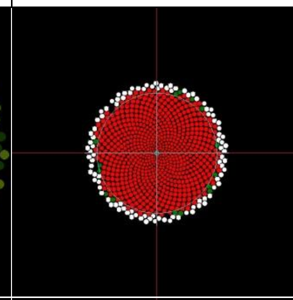
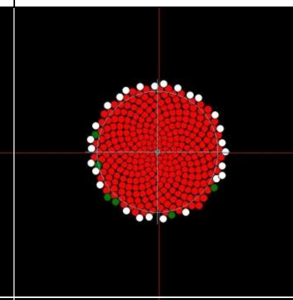
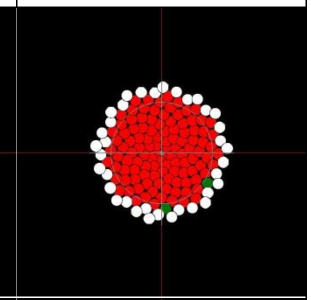
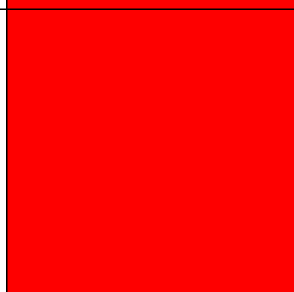
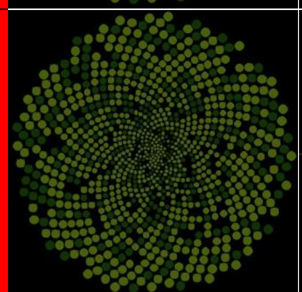
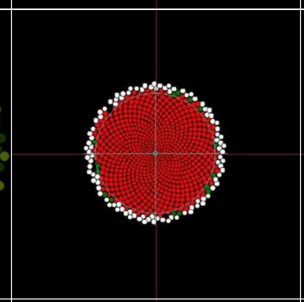
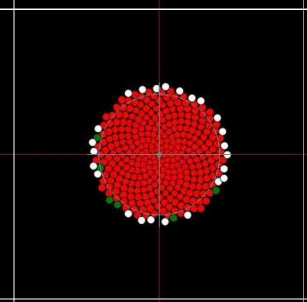
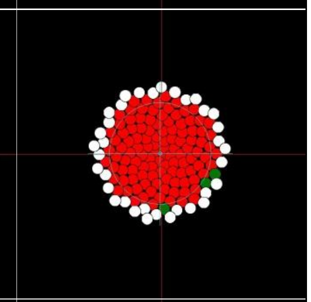
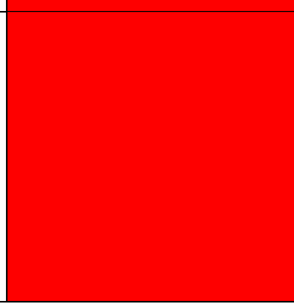
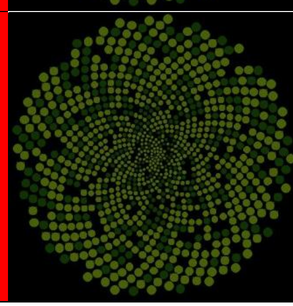
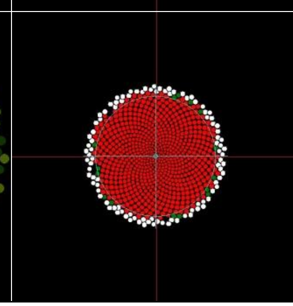
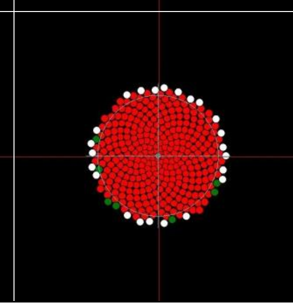
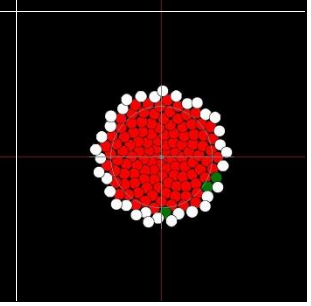
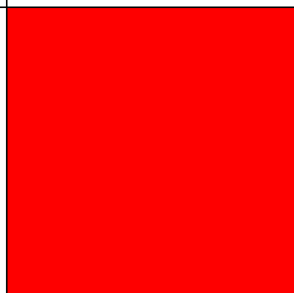
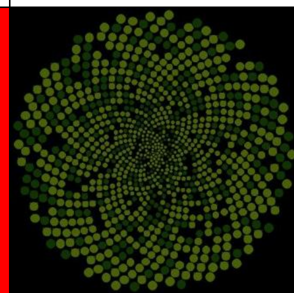
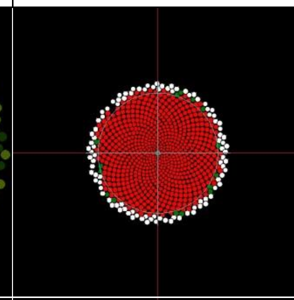
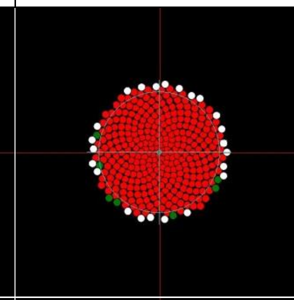
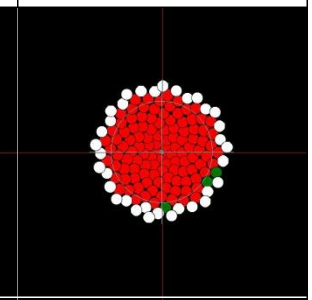
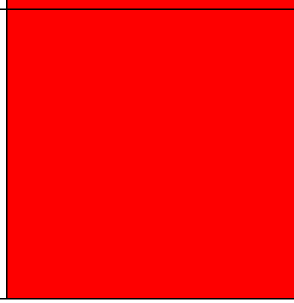
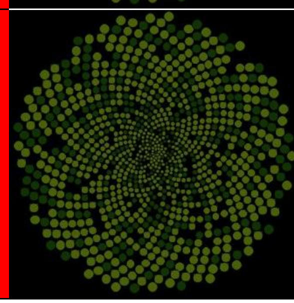
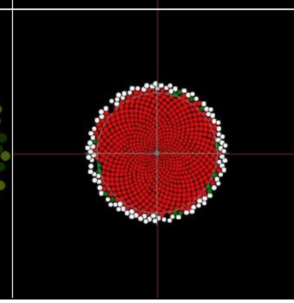
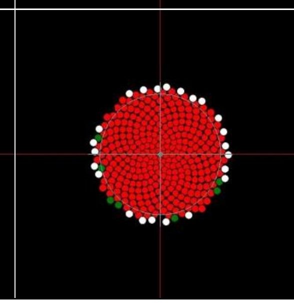
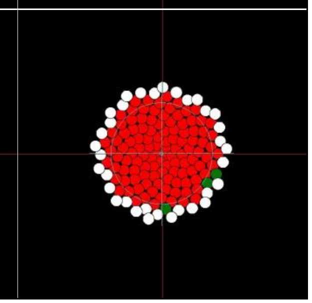
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields Level 1	Receptive Fields Level 2	Receptive Fields Level 3
12					
13					
14					

Table 1: Time sequence of homogeneous red filling-in					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
15					
16					

2.3.2 Test 1b results: Visual time sequence of homogeneous green filling-in

Table 2: Time sequence of homogeneous green filling-in

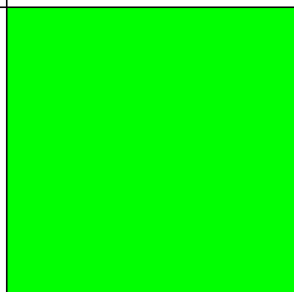
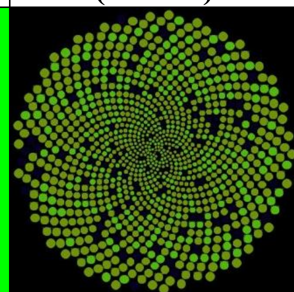
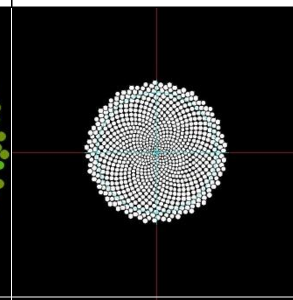
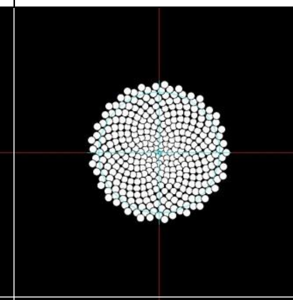
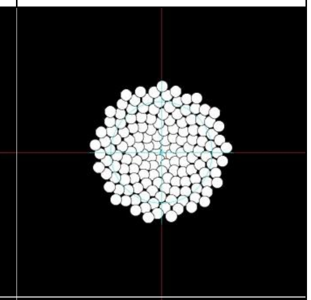
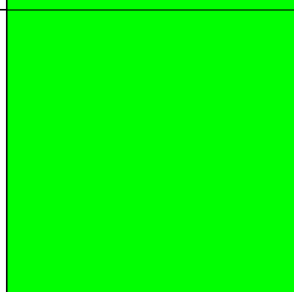
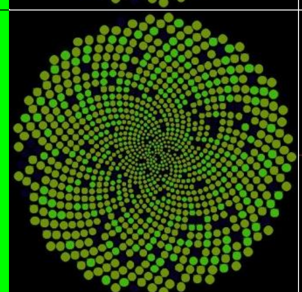
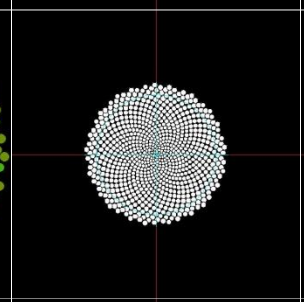
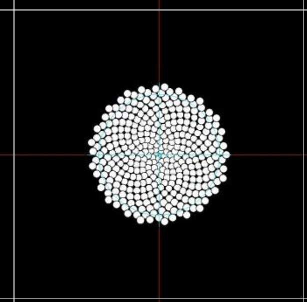
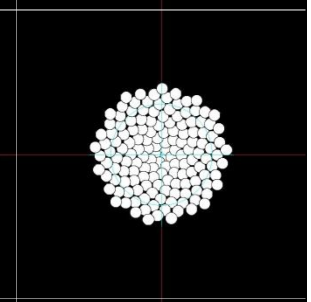
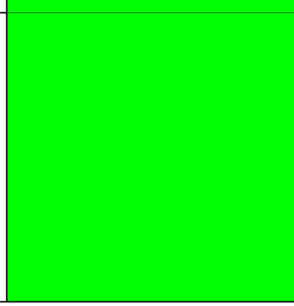
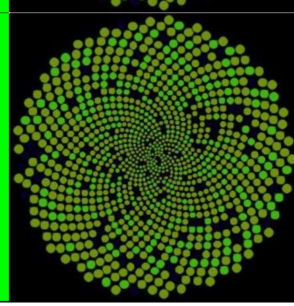
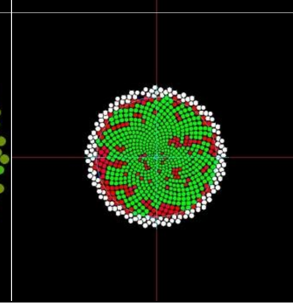
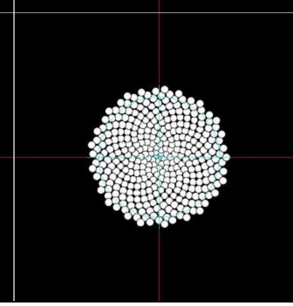
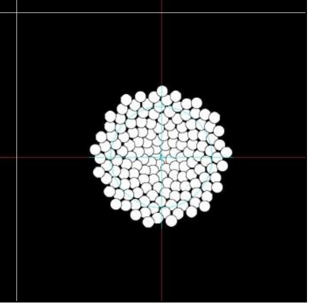
Time (ticks)	Stimuli	Photoreceptors (Level 0)	Receptive Fields		
			Level 1	Level 2	Level 3
0					
1					
2					

Table 2: Time sequence of homogeneous green filling-in

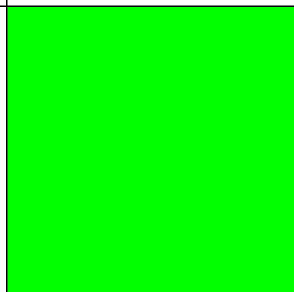
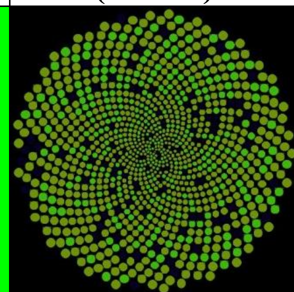
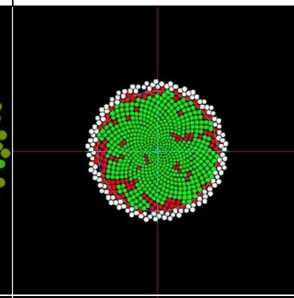
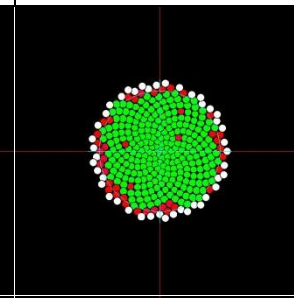
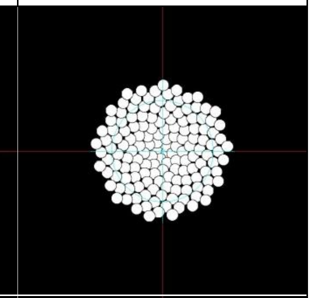
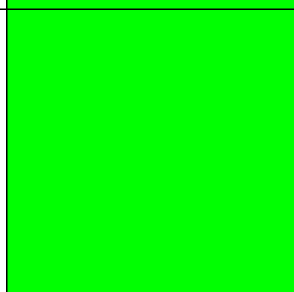
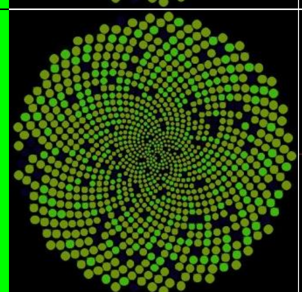
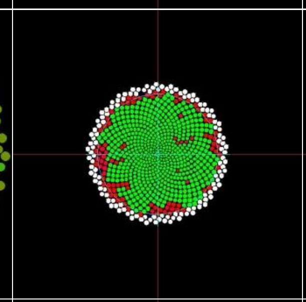
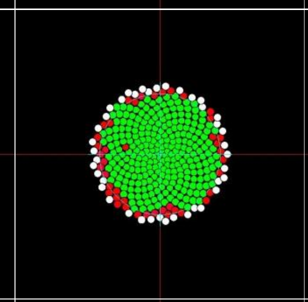
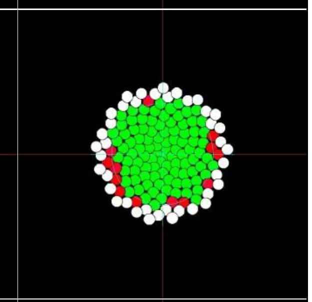
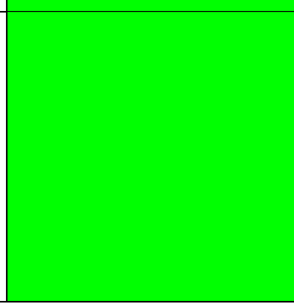
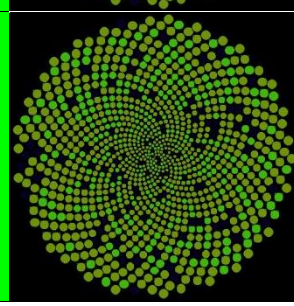
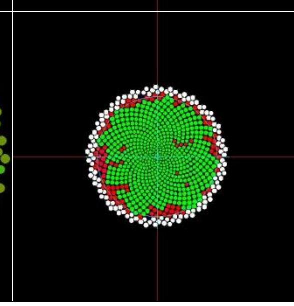
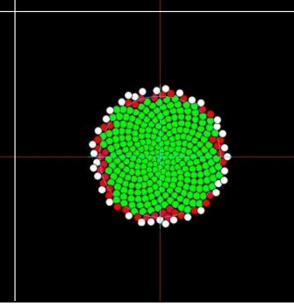
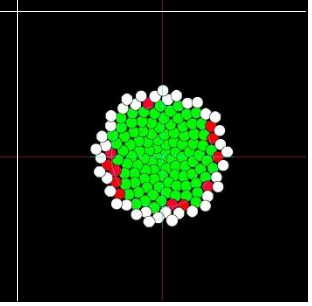
Time (ticks)	Stimuli	Photoreceptors (Level 0)	Receptive Fields		
			Level 1	Level 2	Level 3
3					
4					
5					

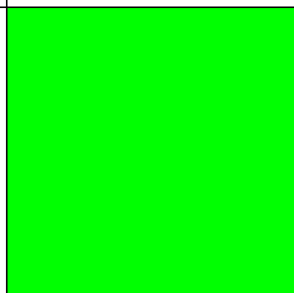
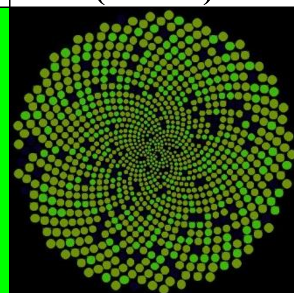
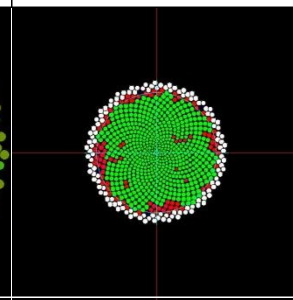
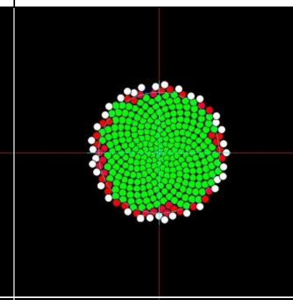
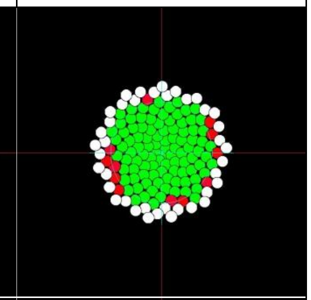
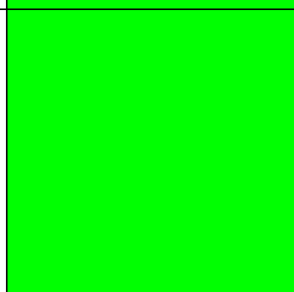
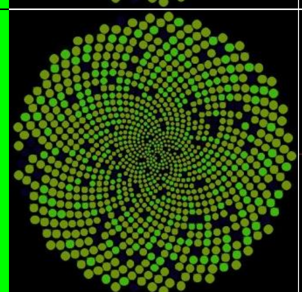
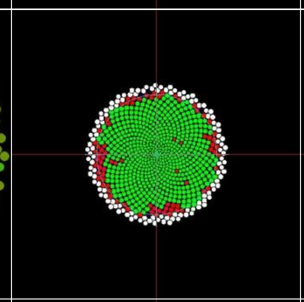
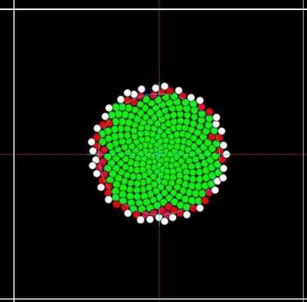
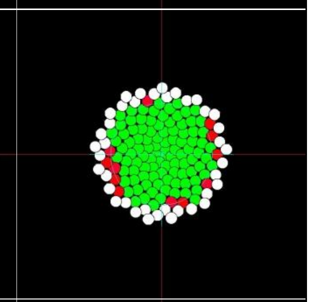
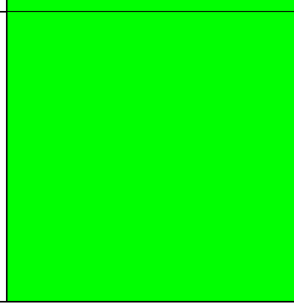
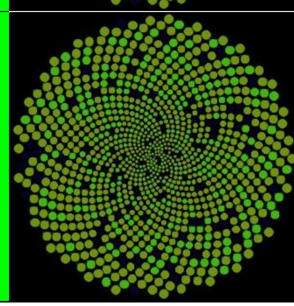
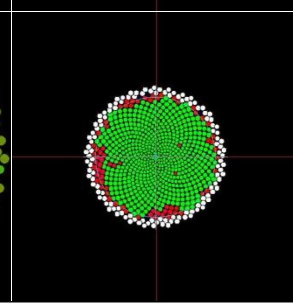
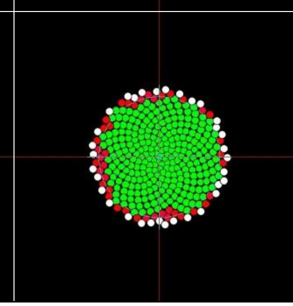
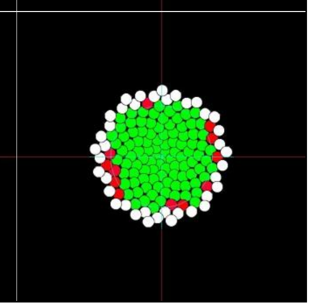
Table 2: Time sequence of homogeneous green filling-in					
Time (ticks)	**Stimuli**	**Photoreceptors (Level 0)**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
6					
7					
8					

Table 2: Time sequence of homogeneous green filling-in

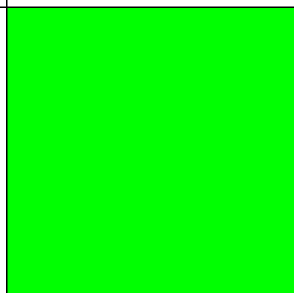
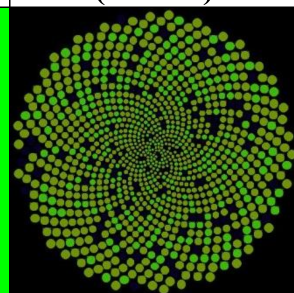
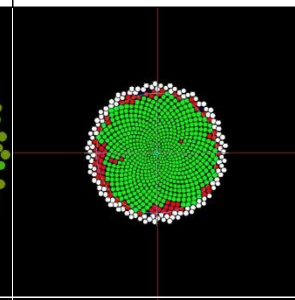
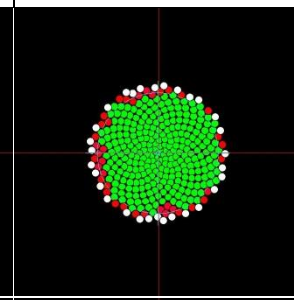
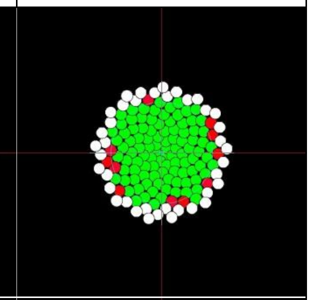
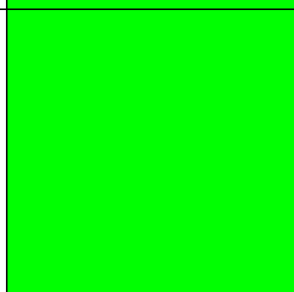
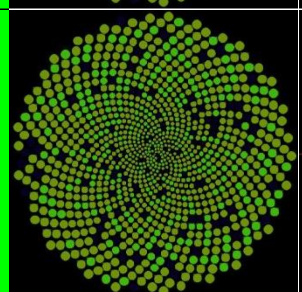
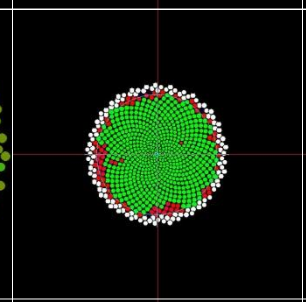
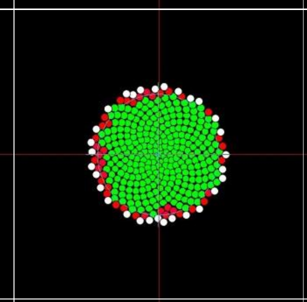
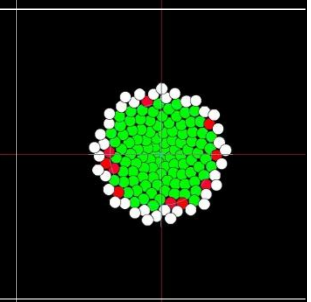
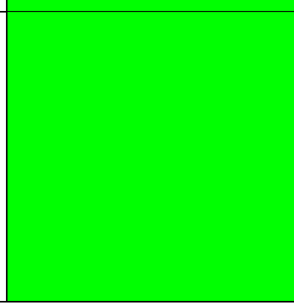
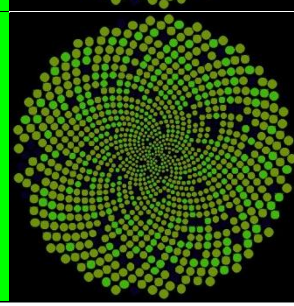
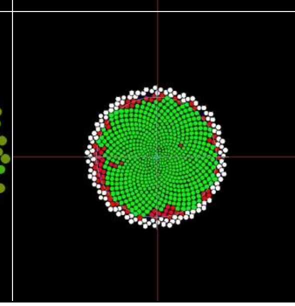
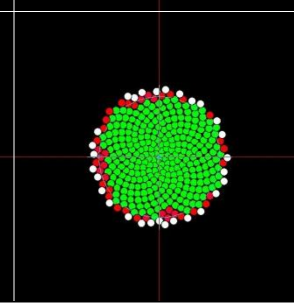
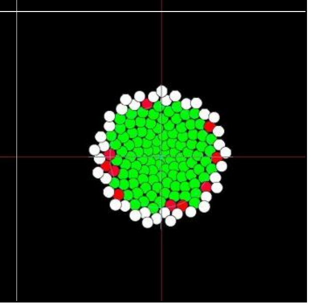
Time (ticks)	Stimuli	Photoreceptors (Level 0)	Receptive Fields		
			Level 1	Level 2	Level 3
9					
10					
11					

Table 2: Time sequence of homogeneous green filling-in

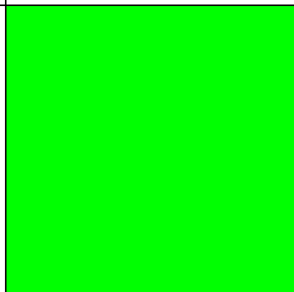
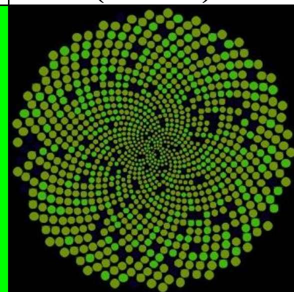
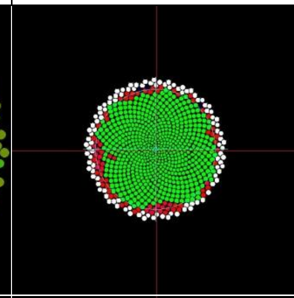
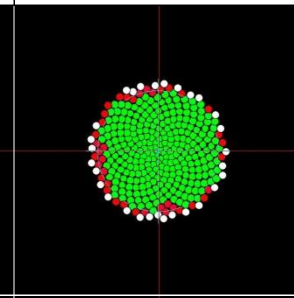
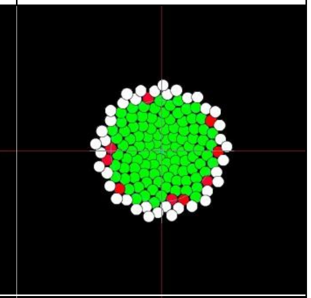
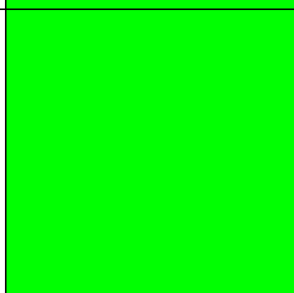
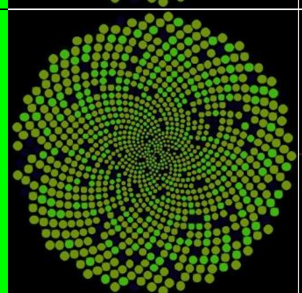
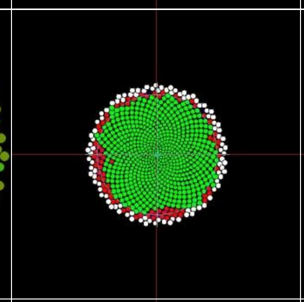
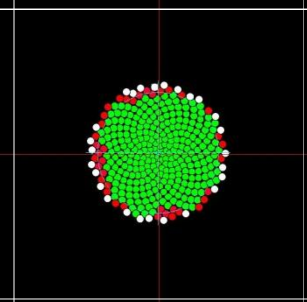
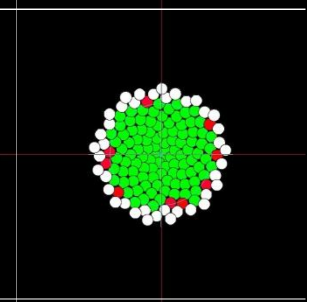
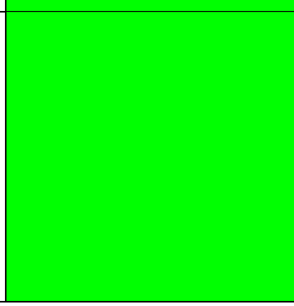
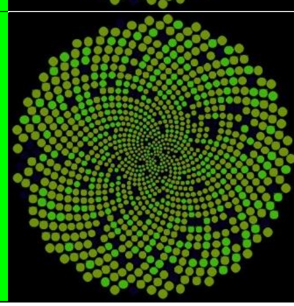
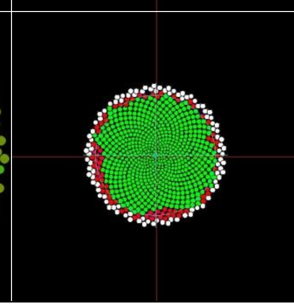
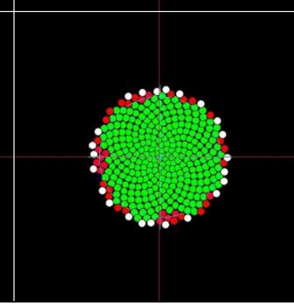
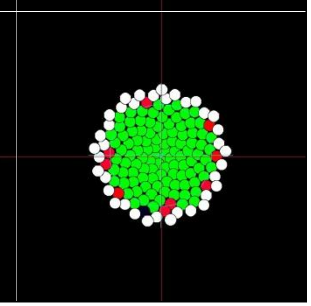
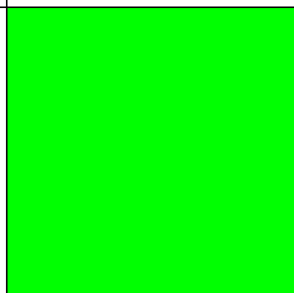
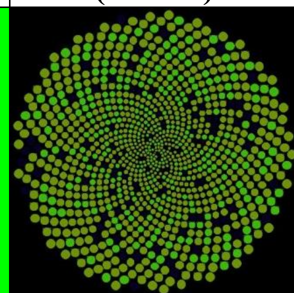
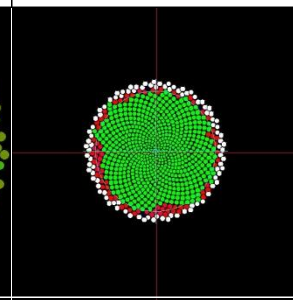
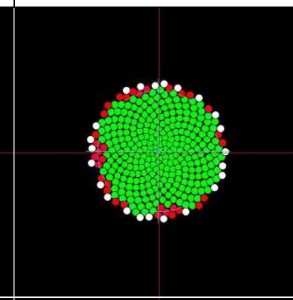
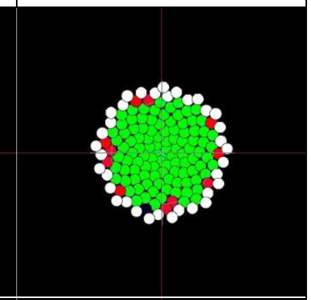
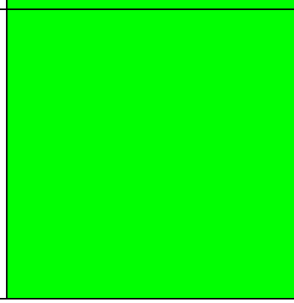
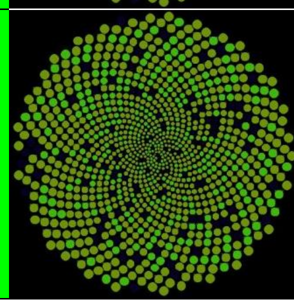
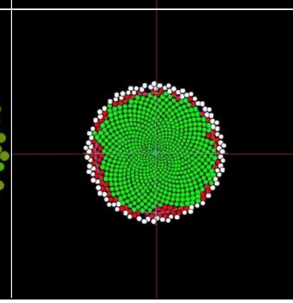
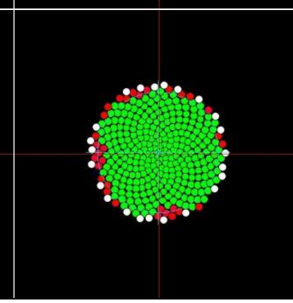
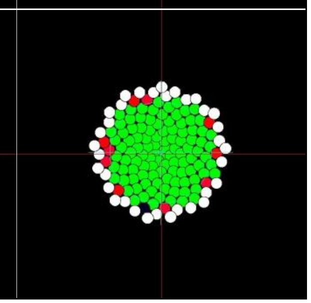
Time (ticks)	Stimuli	Photoreceptors (Level 0)	Receptive Fields		
			Level 1	Level 2	Level 3
12					
13					
14					

Table 2: Time sequence of homogeneous green filling-in					
Time (ticks)	**Stimuli**	**Photoreceptors (Level 0)**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
15					
16					

2.3.3 Test 1c results: Visual time sequence of homogeneous blue filling-in

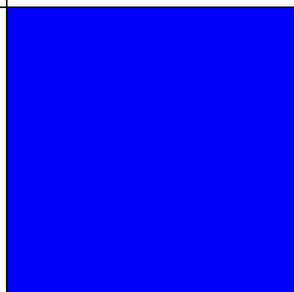
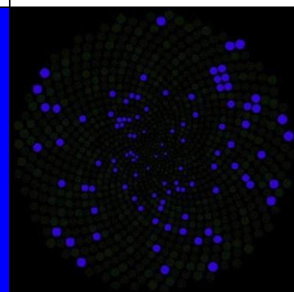
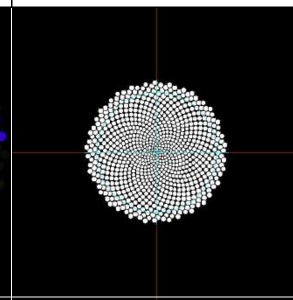
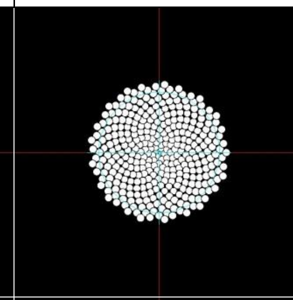
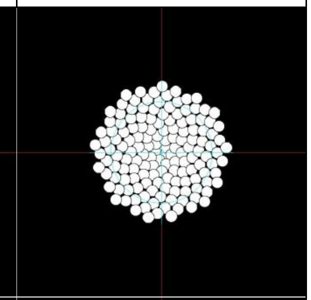
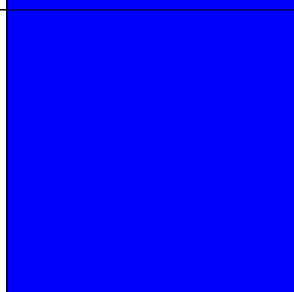
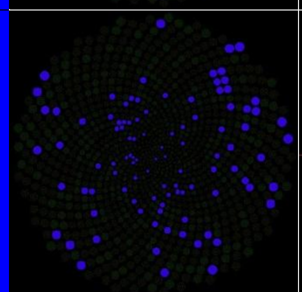
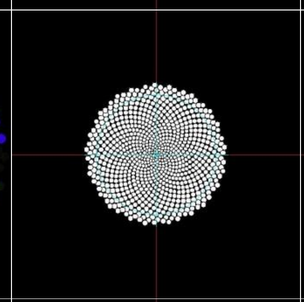
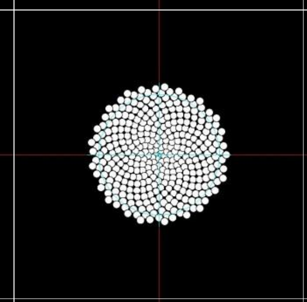
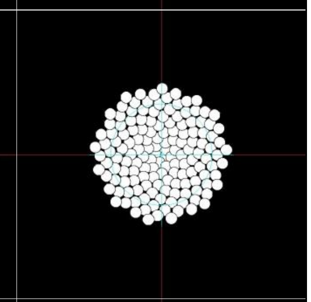
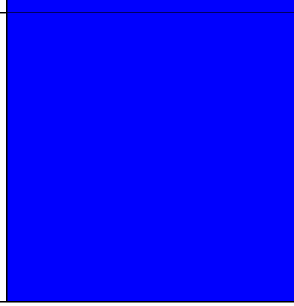
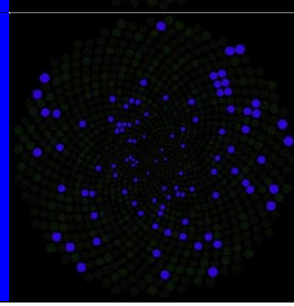
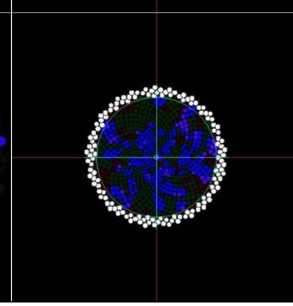
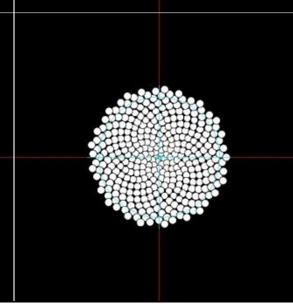
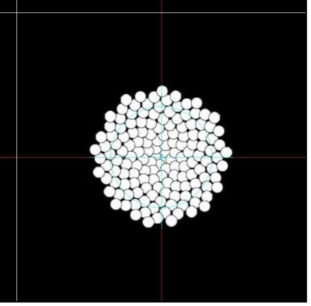
Table 3: Time sequence of homogeneous blue filling-in					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
0					
1					
2					

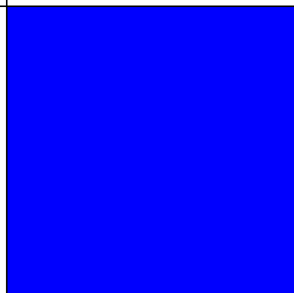
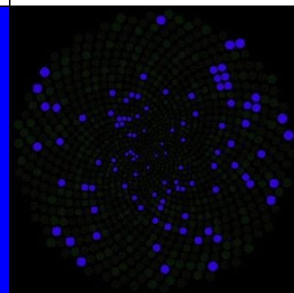
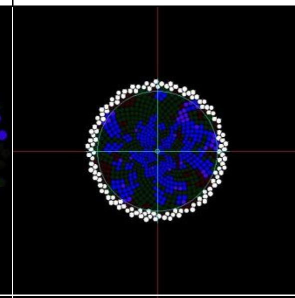
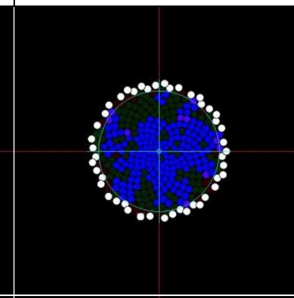
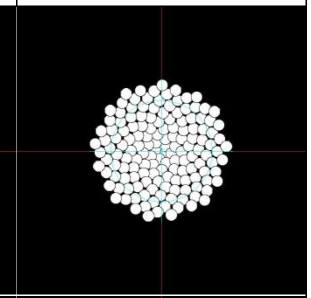
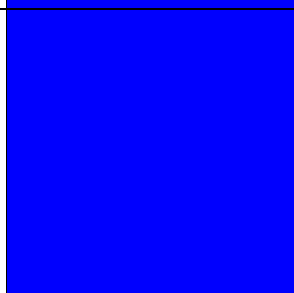
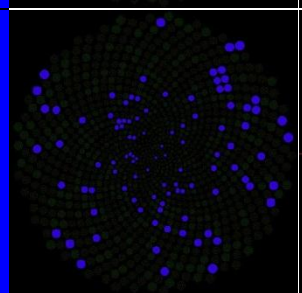
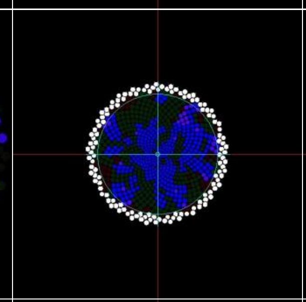
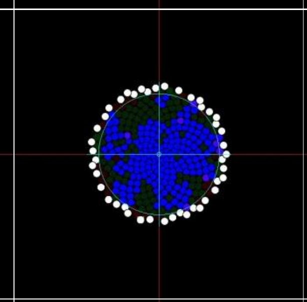
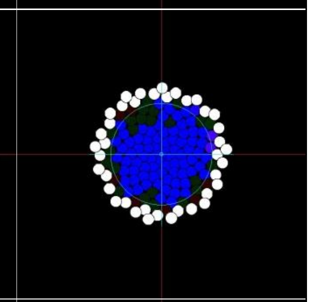
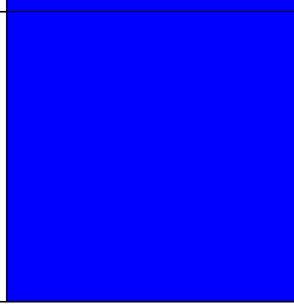
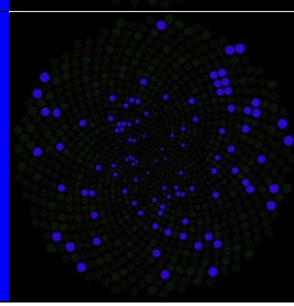
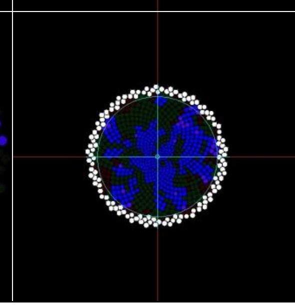
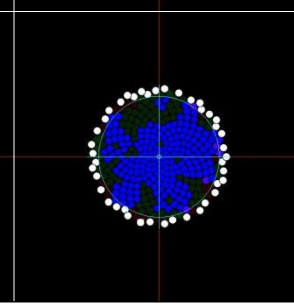
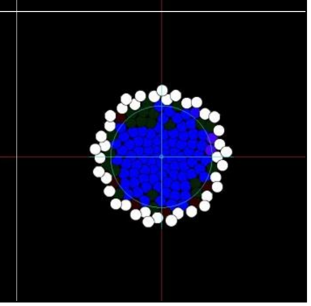
Table 3: Time sequence of homogeneous blue filling-in					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
3					
4					
5					

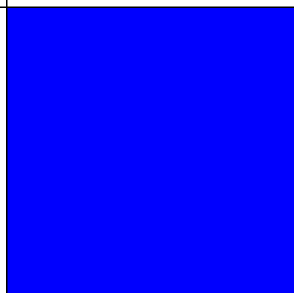
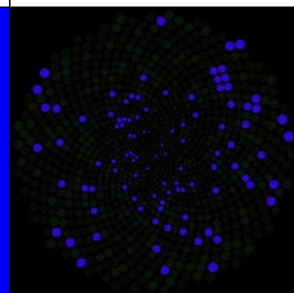
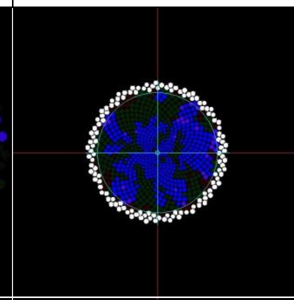
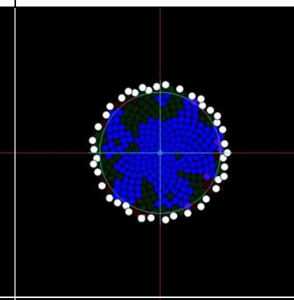
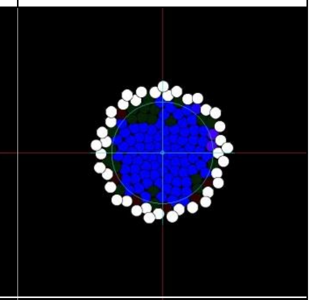
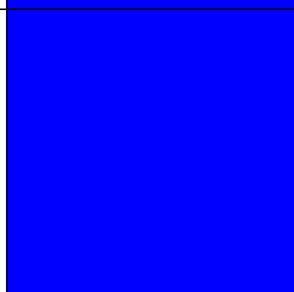
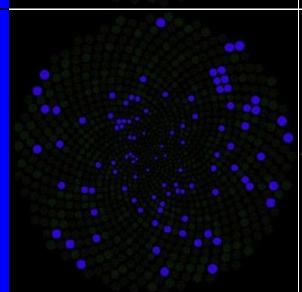
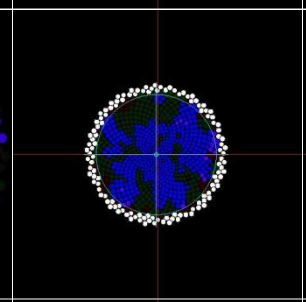
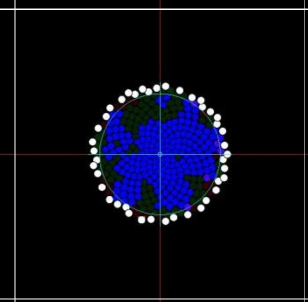
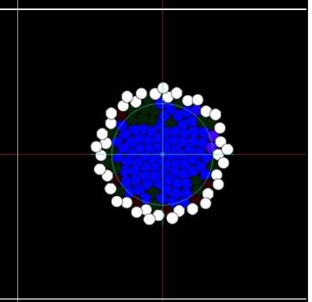
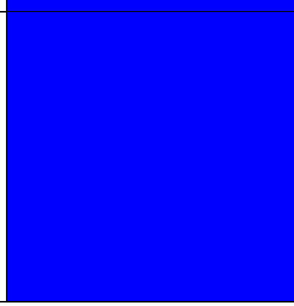
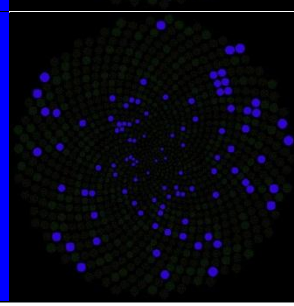
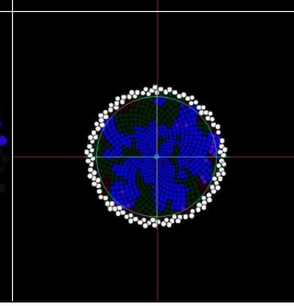
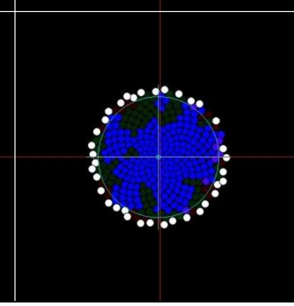
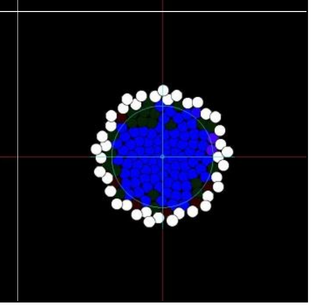
Table 3: Time sequence of homogeneous blue filling-in					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
6					
7					
8					

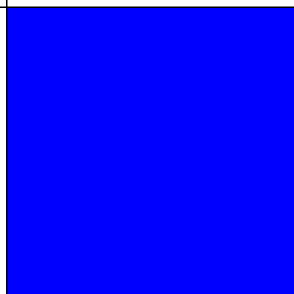
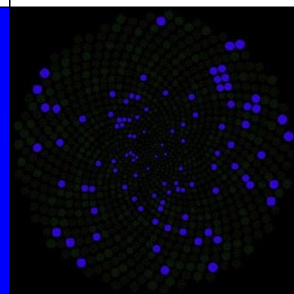
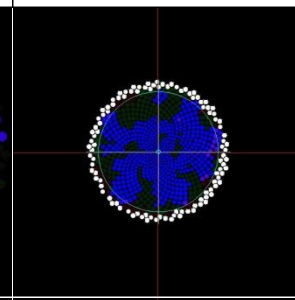
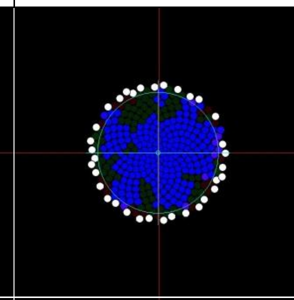
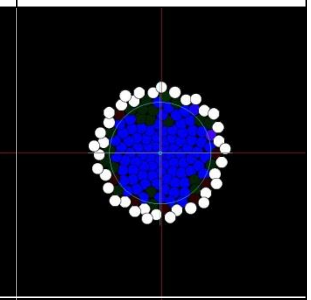
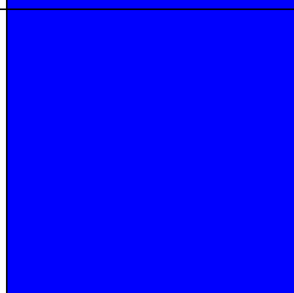
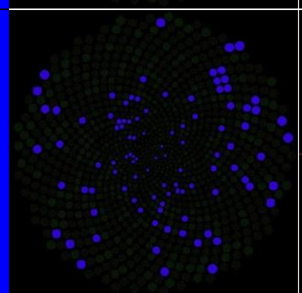
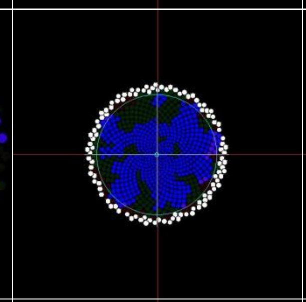
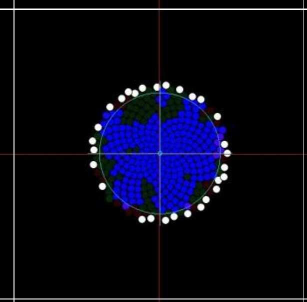
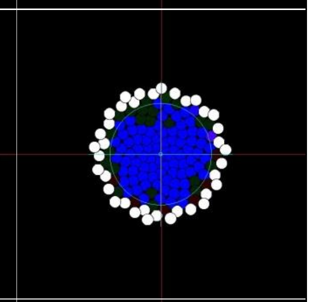
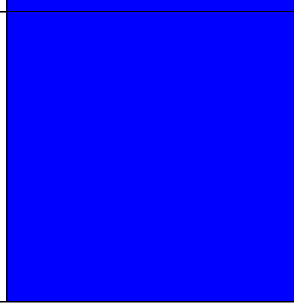
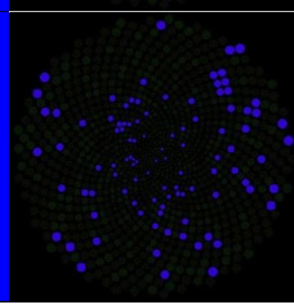
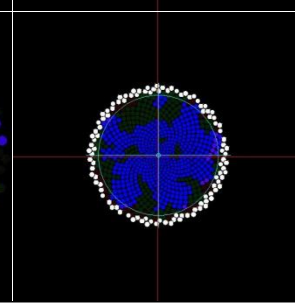
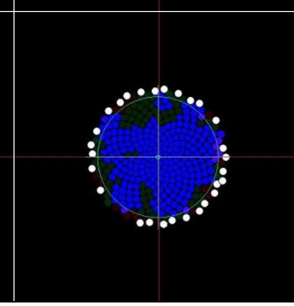
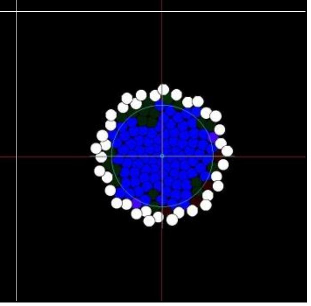
Table 3: Time sequence of homogeneous blue filling-in					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
9					
10					
11					

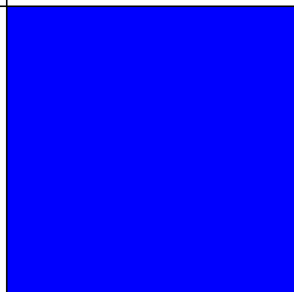
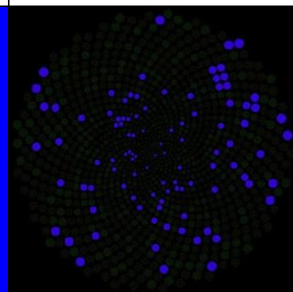
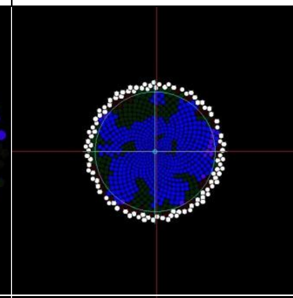
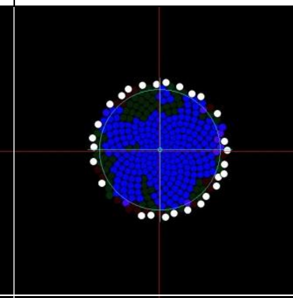
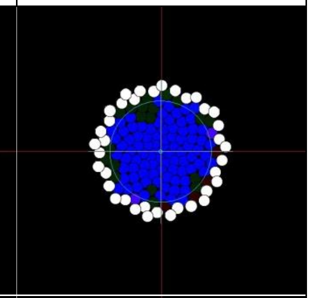
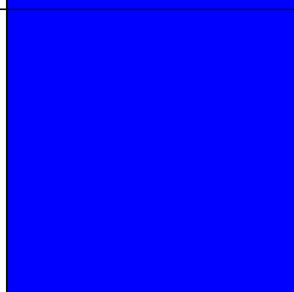
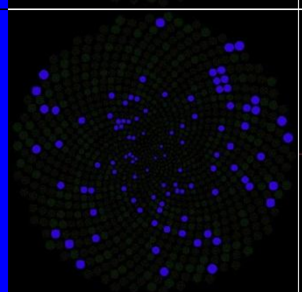
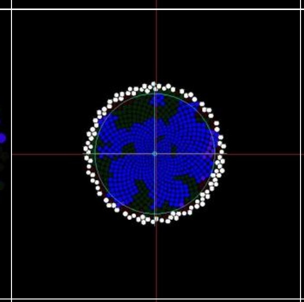
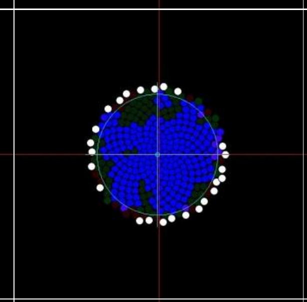
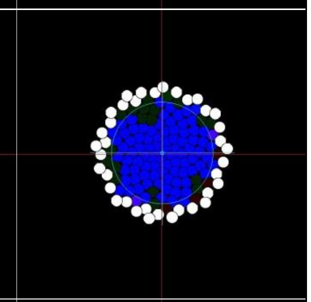
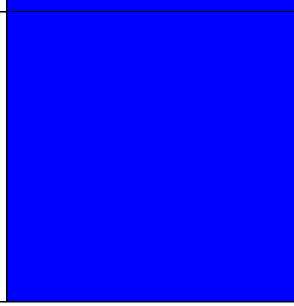
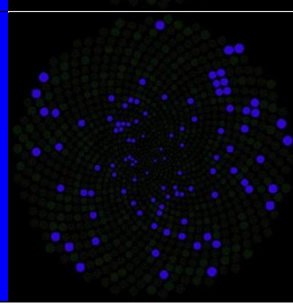
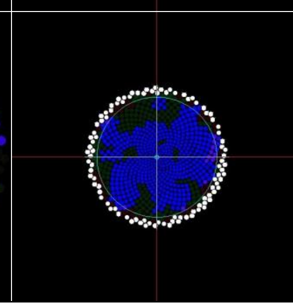
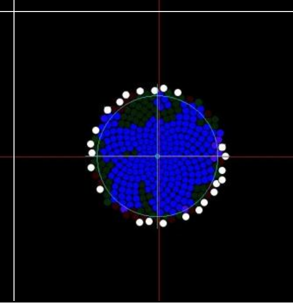
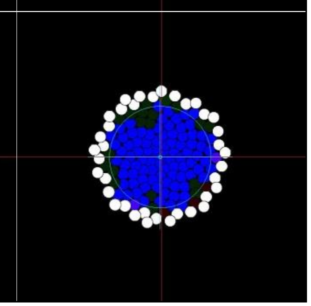
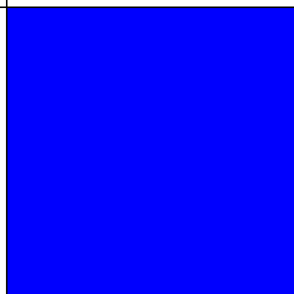
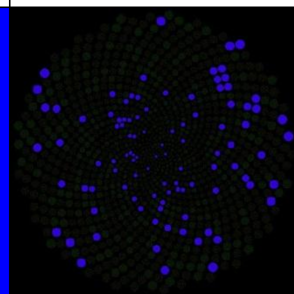
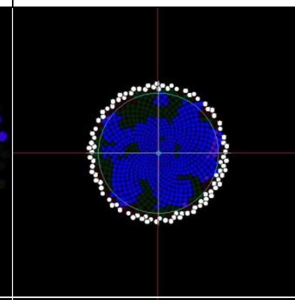
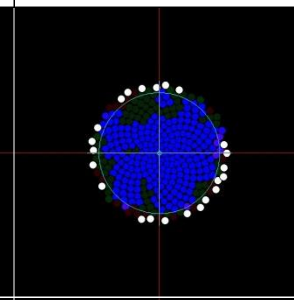
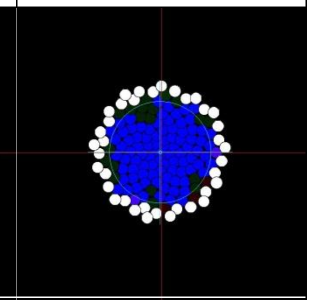
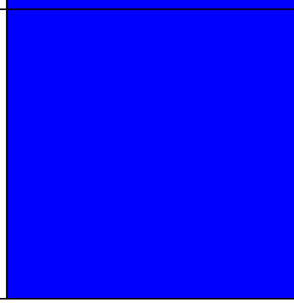
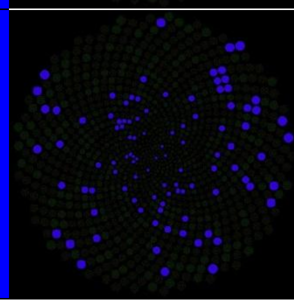
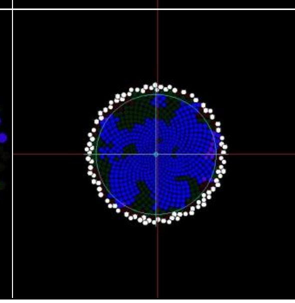
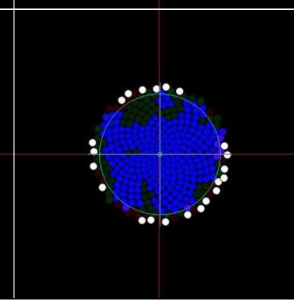
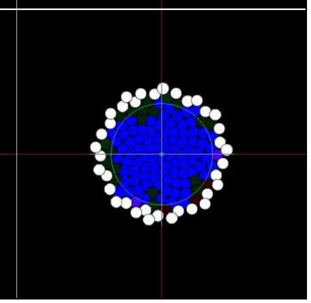
Table 3: Time sequence of homogeneous blue filling-in					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
12					
13					
14					

Table 3: Time sequence of homogeneous blue filling-in					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
15					
16					

2.3.4 Test 2 results: Visual time sequence of homogeneous blue filling-in under eye motion

Table 4: Time sequence of homogeneous blue filling-in under eye motion

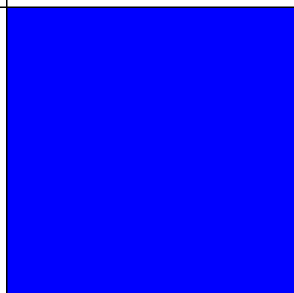
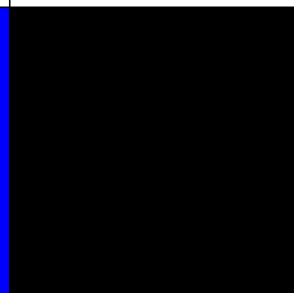
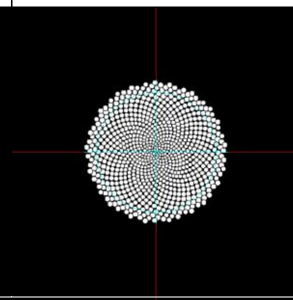
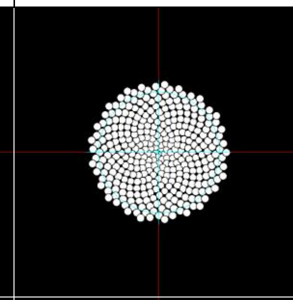
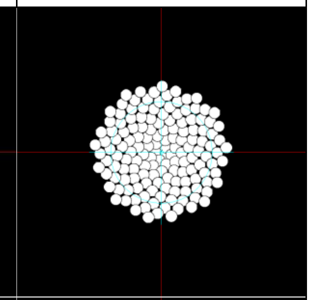
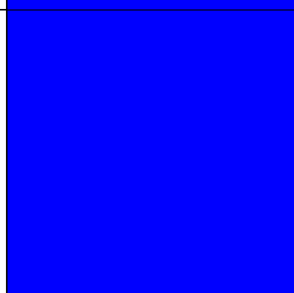
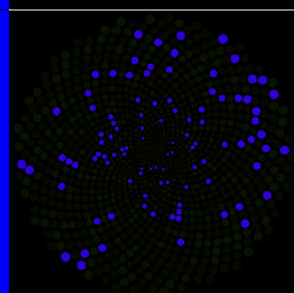
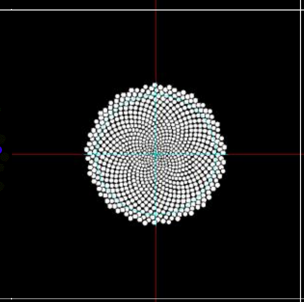
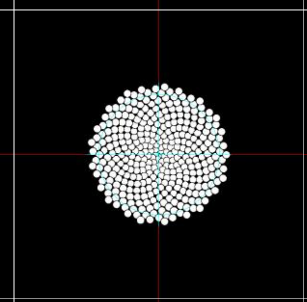
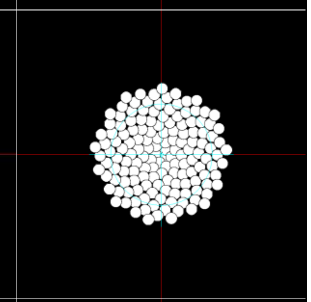
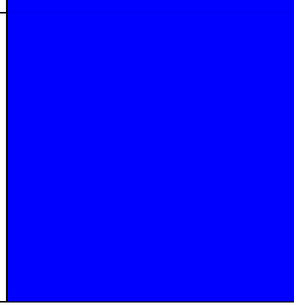
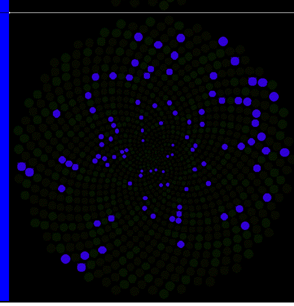
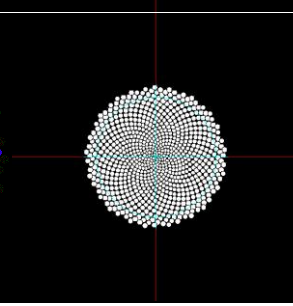
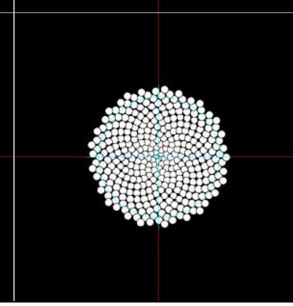
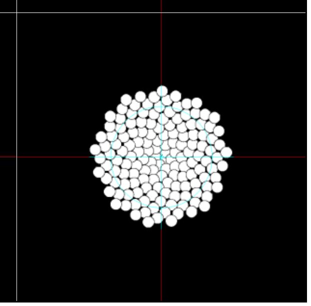
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
4					
5					
6					

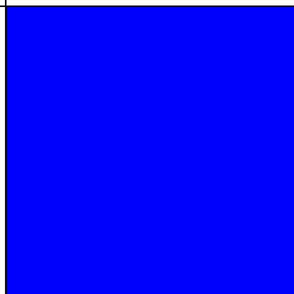
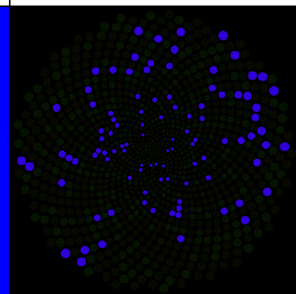
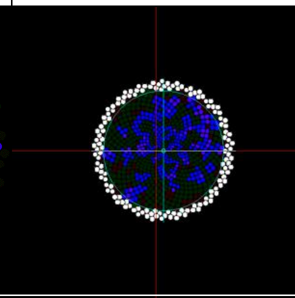
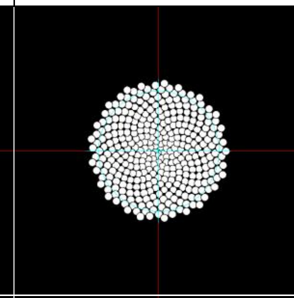
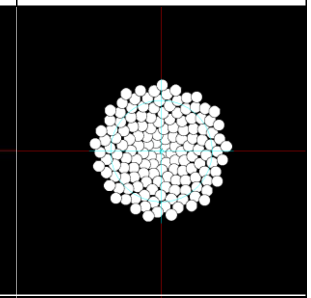
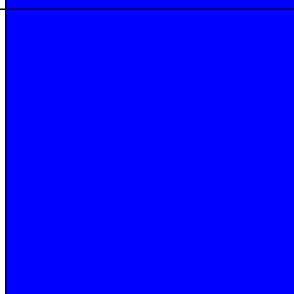
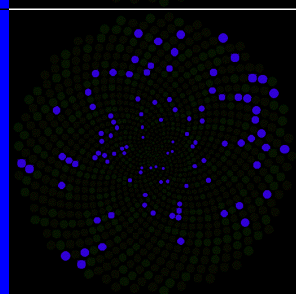
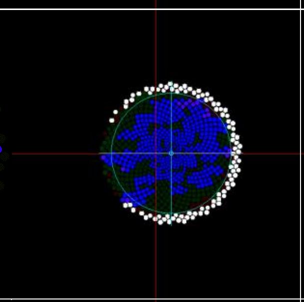
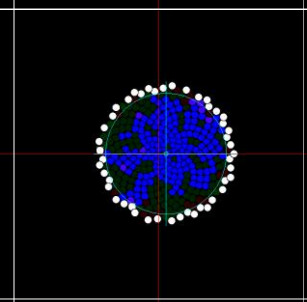
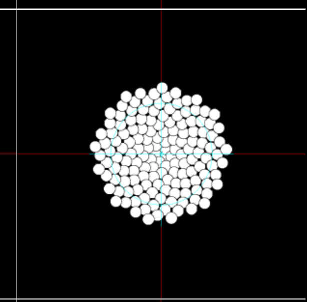
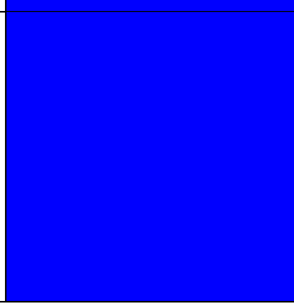
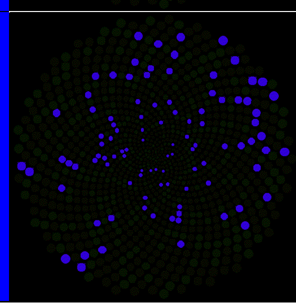
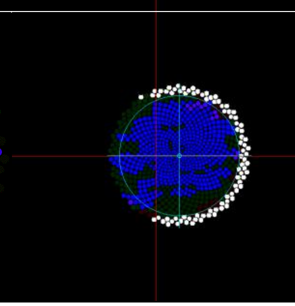
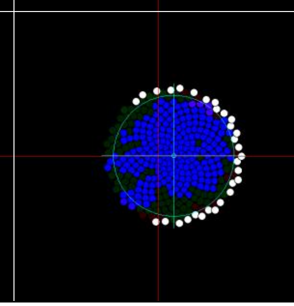
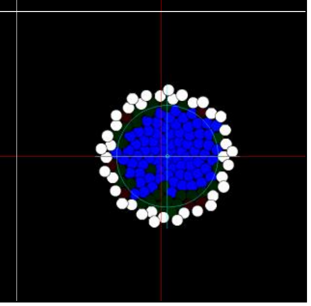
Table 4: Time sequence of homogeneous blue filling-in under eye motion					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
7					
8					
9					

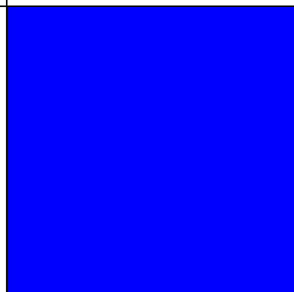
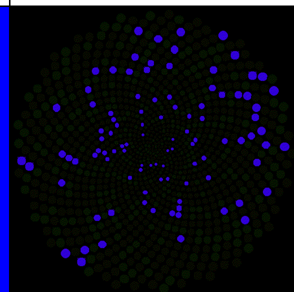
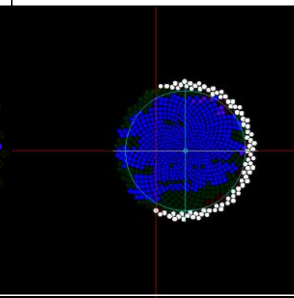
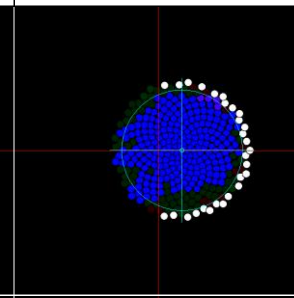
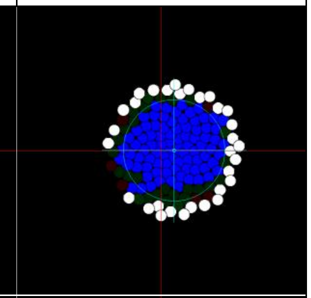
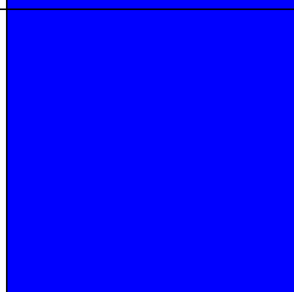
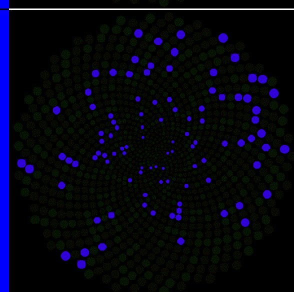
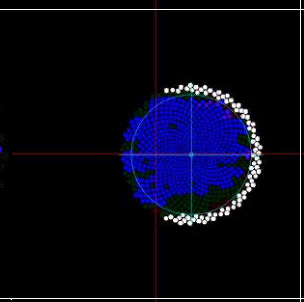
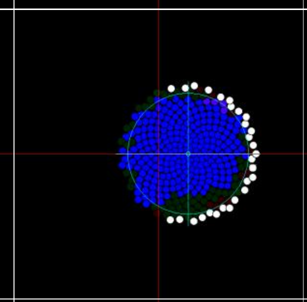
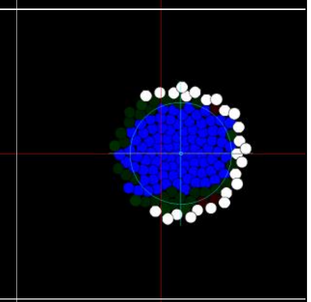
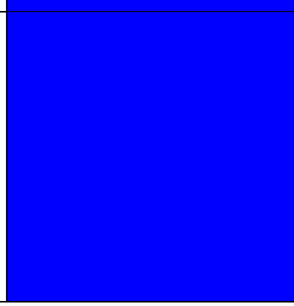
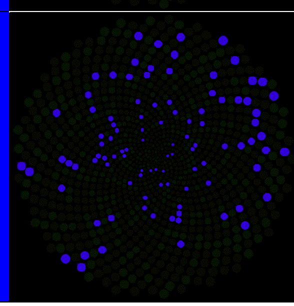
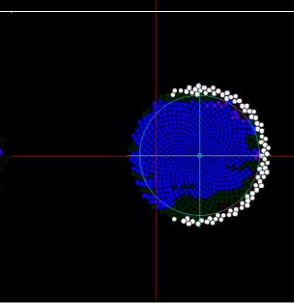
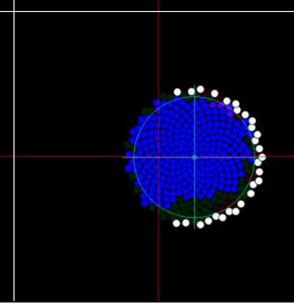
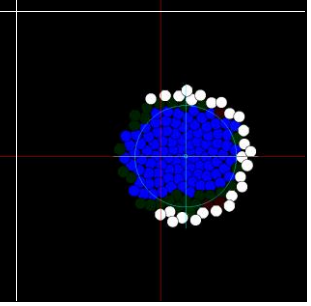
Table 4: Time sequence of homogeneous blue filling-in under eye motion					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
10					
11					
12					

Table 4: Time sequence of homogeneous blue filling-in under eye motion

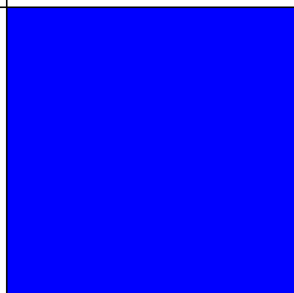
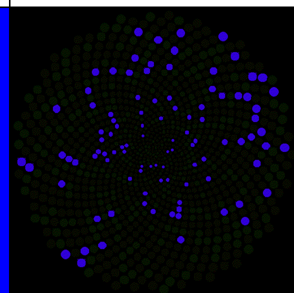
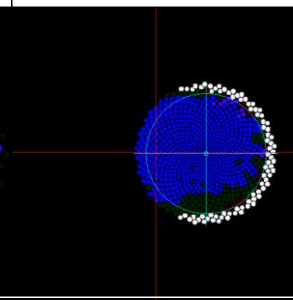
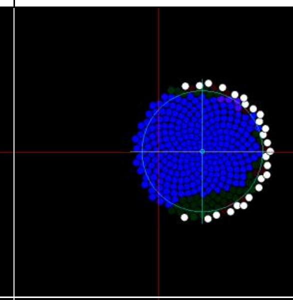
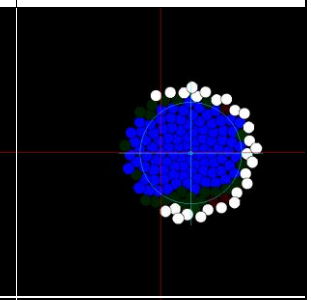
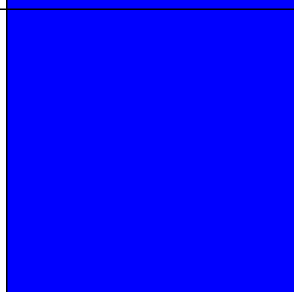
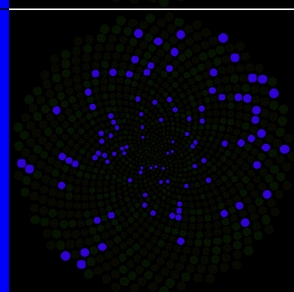
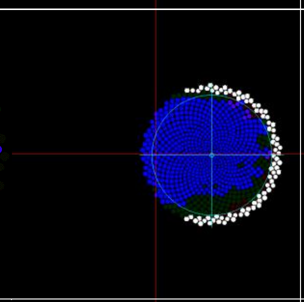
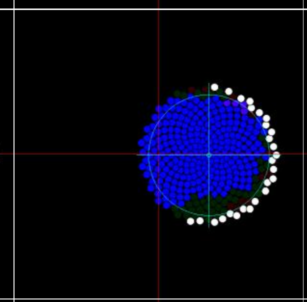
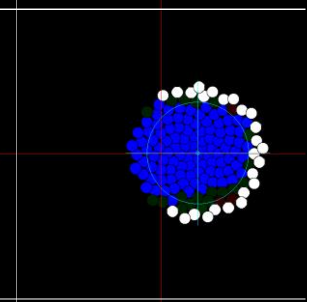
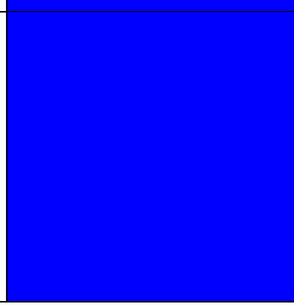
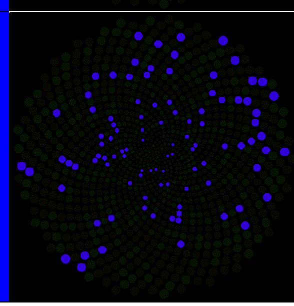
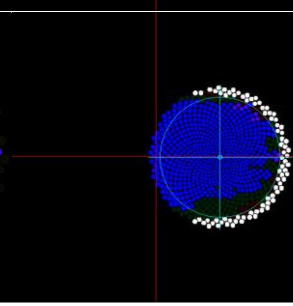
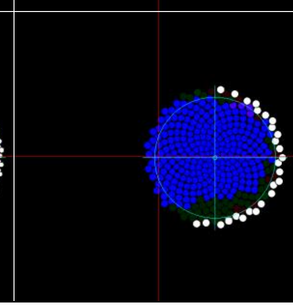
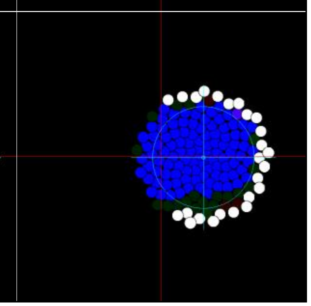
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
13					
14					
15					

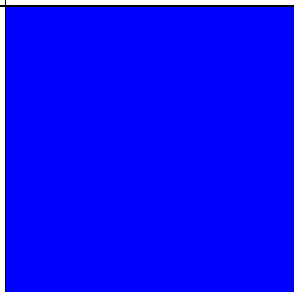
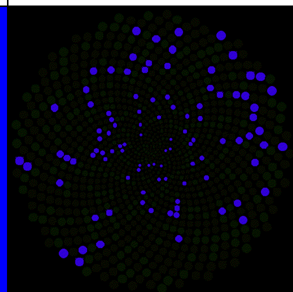
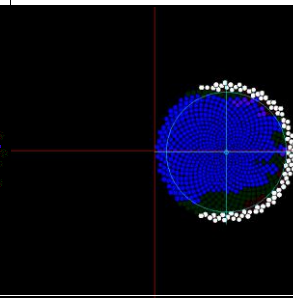
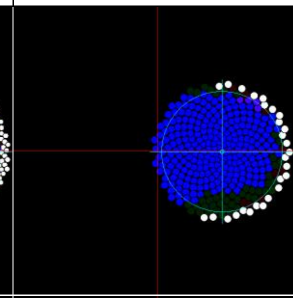
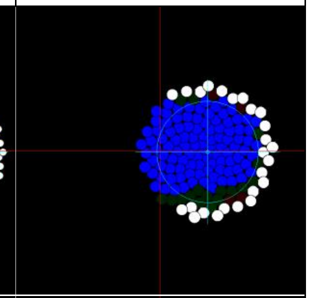
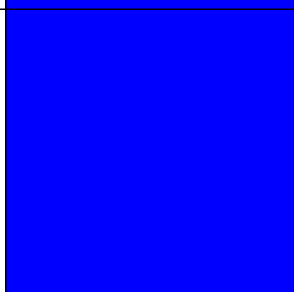
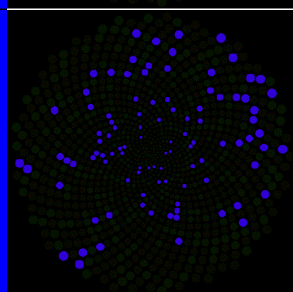
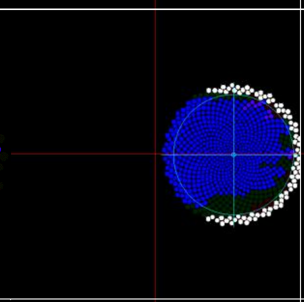
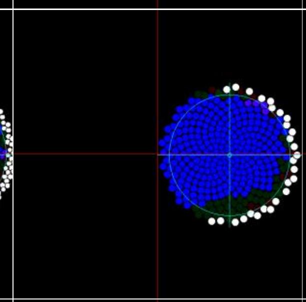
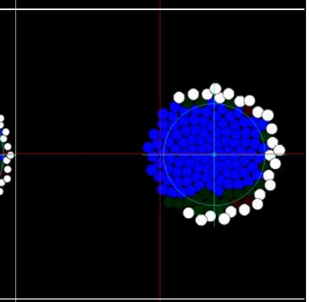
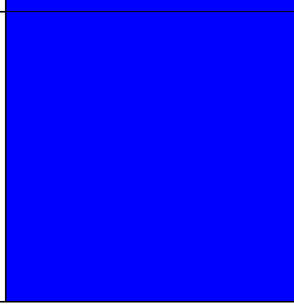
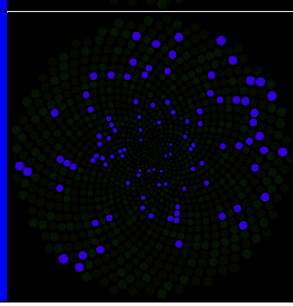
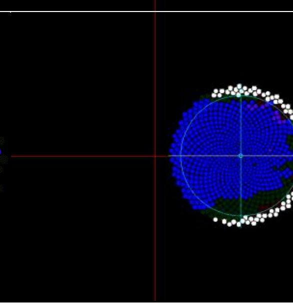
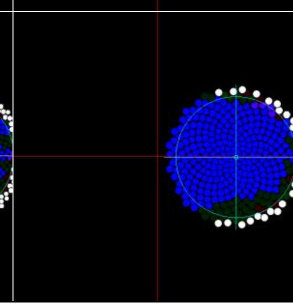
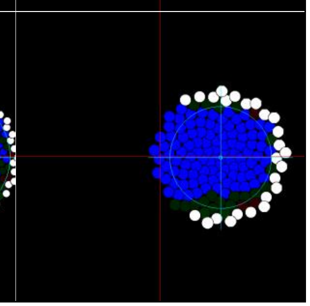
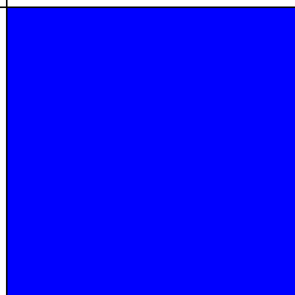
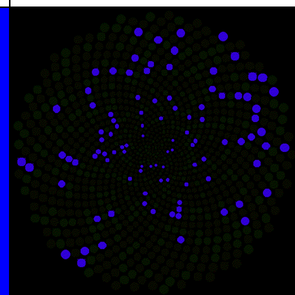
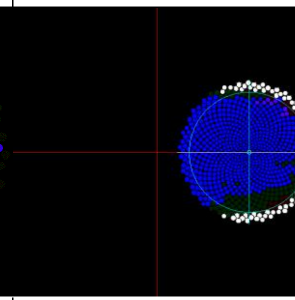
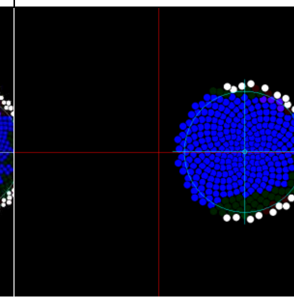
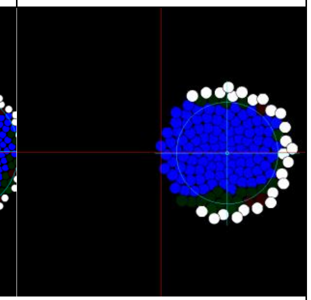
Table 4: Time sequence of homogeneous blue filling-in under eye motion					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
16					
17					
18					

Table 4: Time sequence of homogeneous blue filling-in under eye motion					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
19					
20					

2.3.5 Test 3 results: Visual time sequence of homogeneous blue filling-in under large RFs

Table 5: Time sequence of homogeneous blue filling-in under large RFs

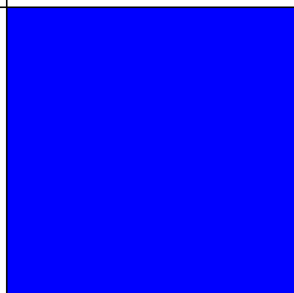
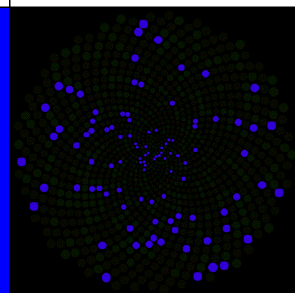
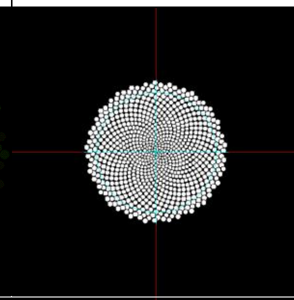
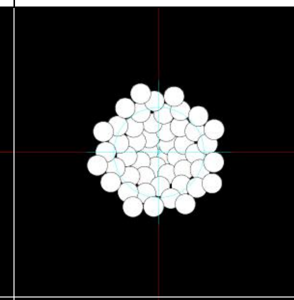
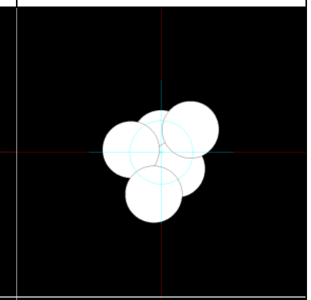
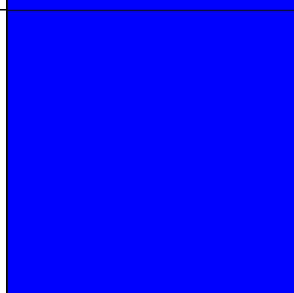
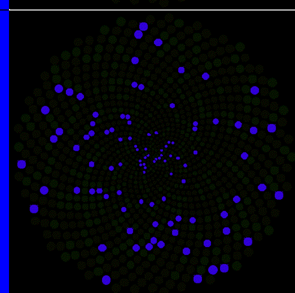
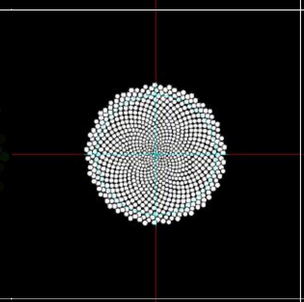
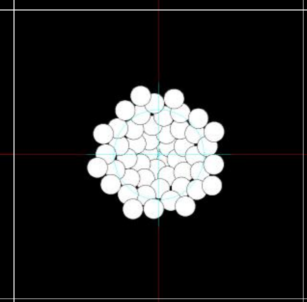
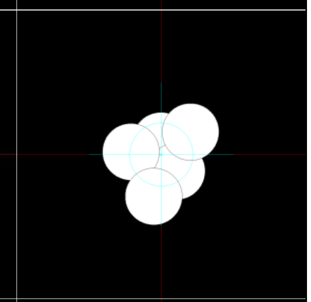
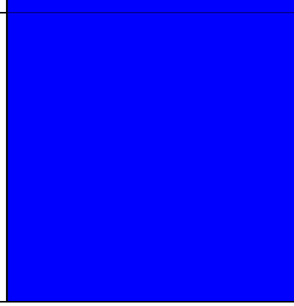
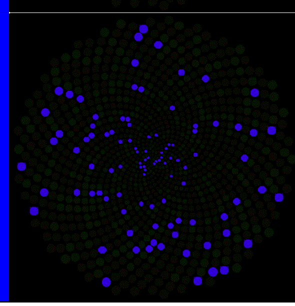
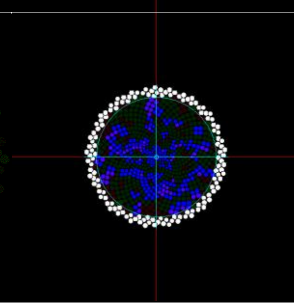
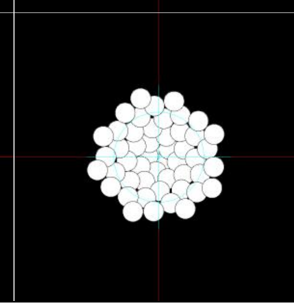
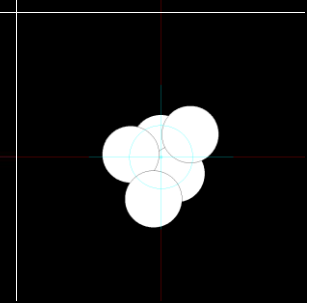
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
0					
1					
2					

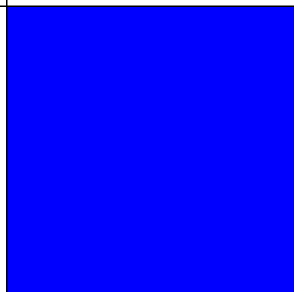
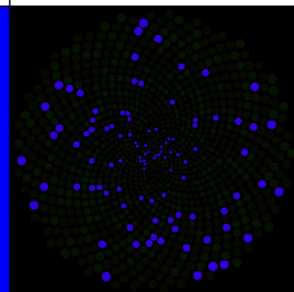
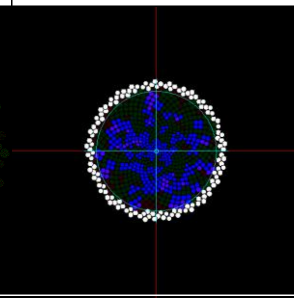
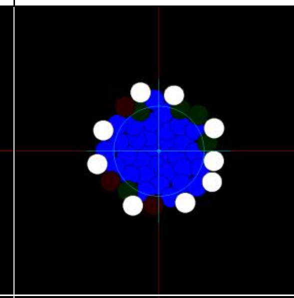
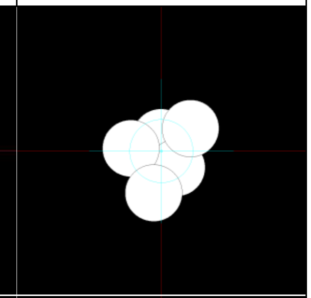
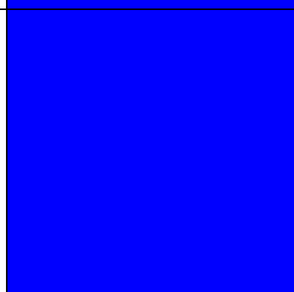
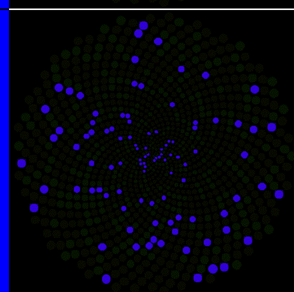
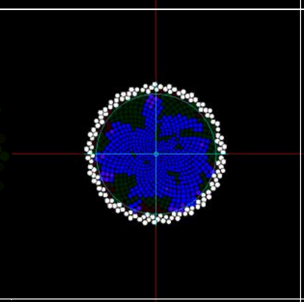
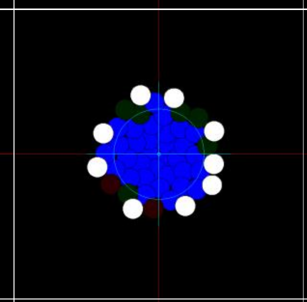
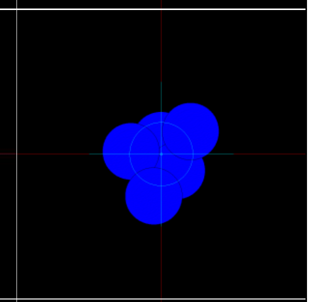
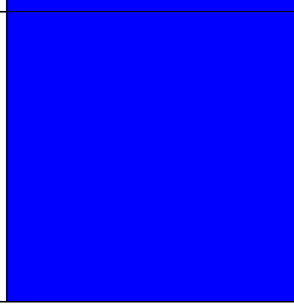
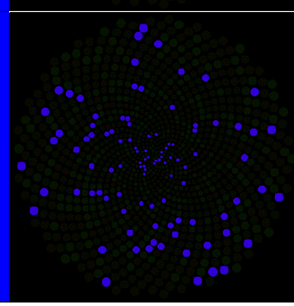
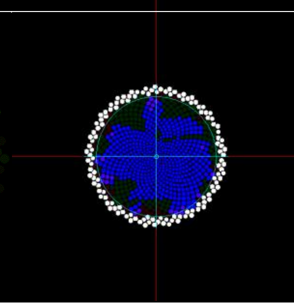
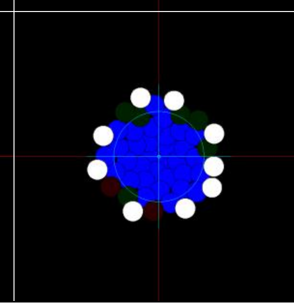
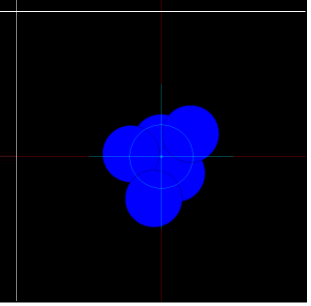
Table 5: Time sequence of homogeneous blue filling-in under large RFs					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
3					
4					
5					

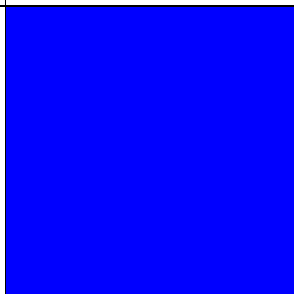
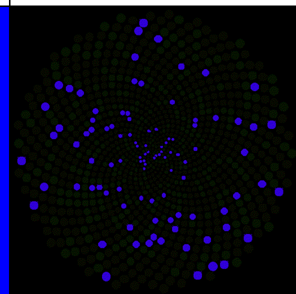
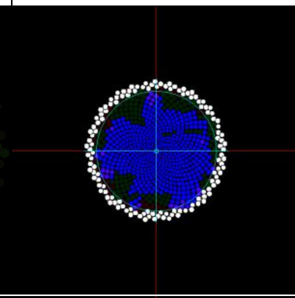
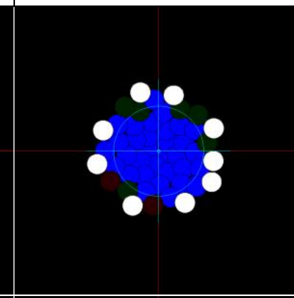
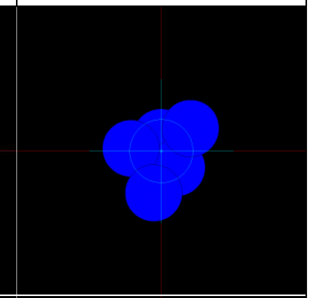
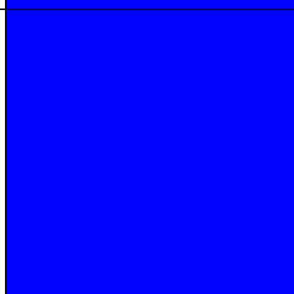
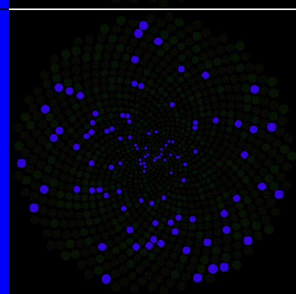
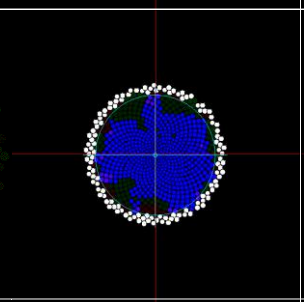
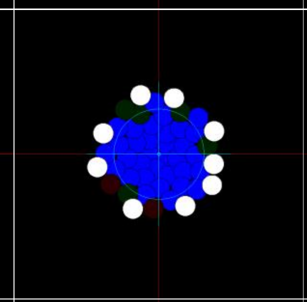
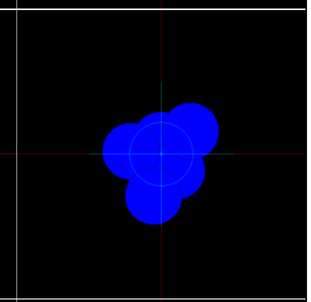
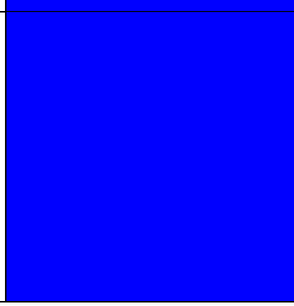
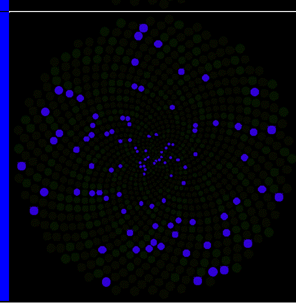
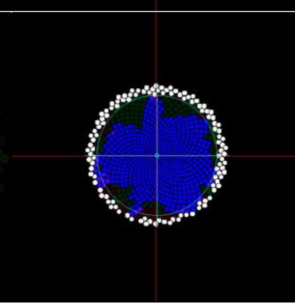
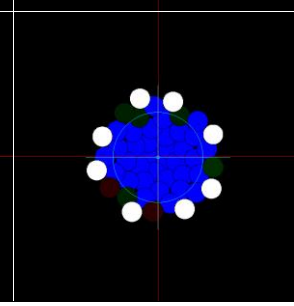
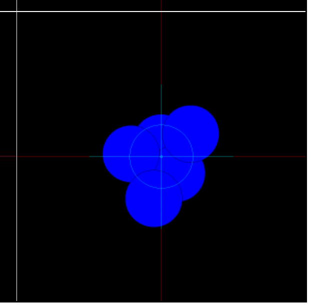
Table 5: Time sequence of homogeneous blue filling-in under large RFs					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
6					
7					
8					

Table 5: Time sequence of homogeneous blue filling-in under large RFs

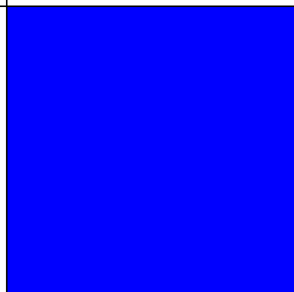
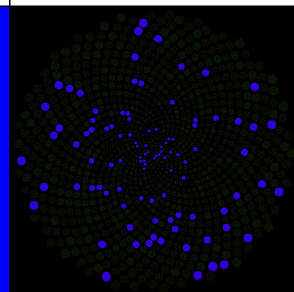
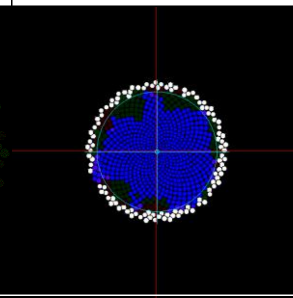
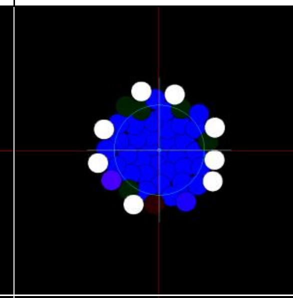
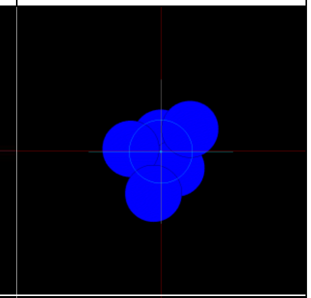
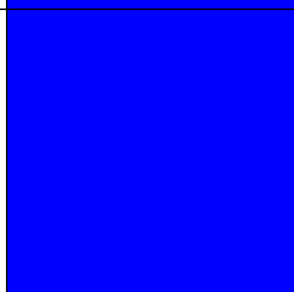
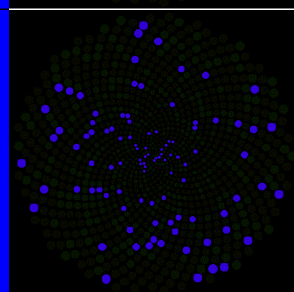
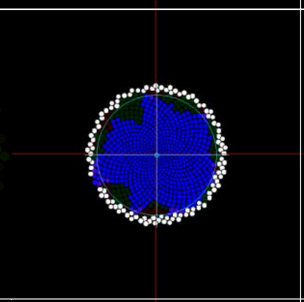
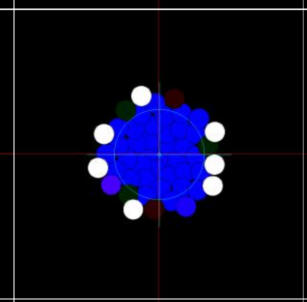
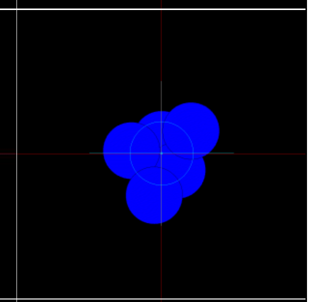
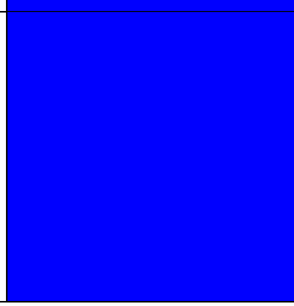
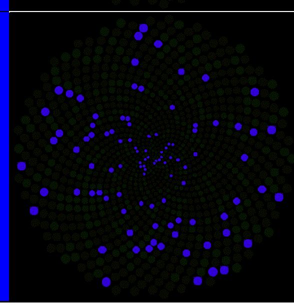
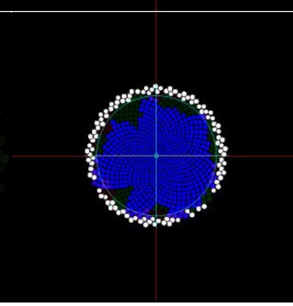
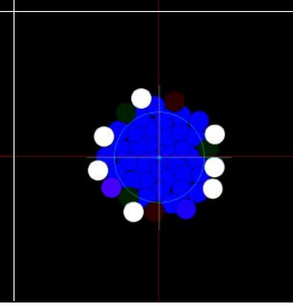
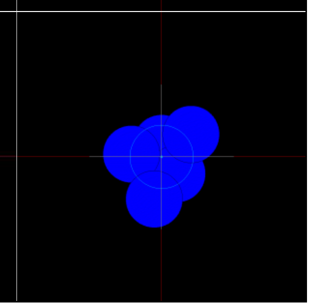
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields Level 1	Receptive Fields Level 2	Receptive Fields Level 3
9					
10					
11					

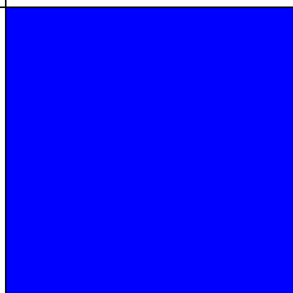
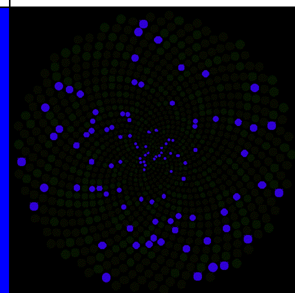
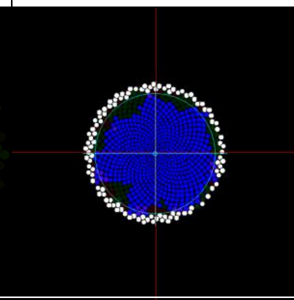
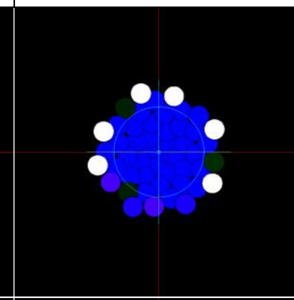
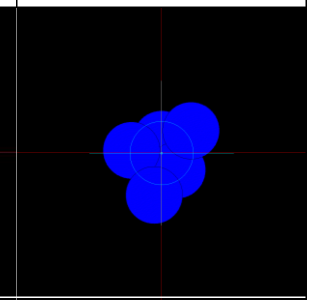
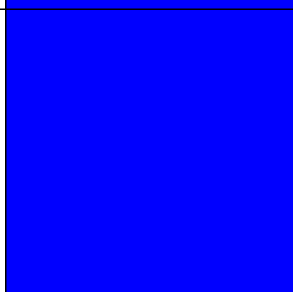
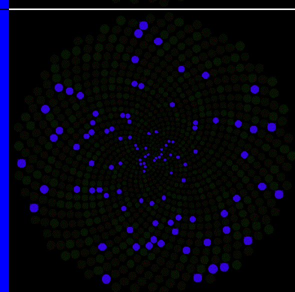
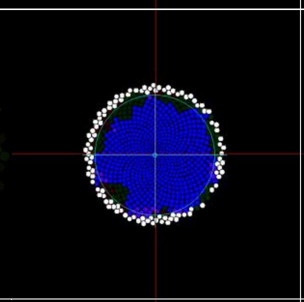
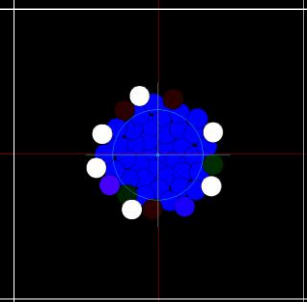
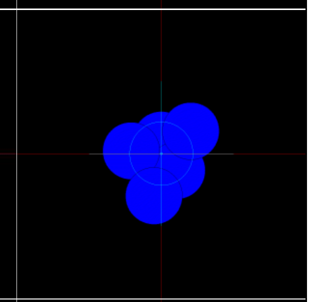
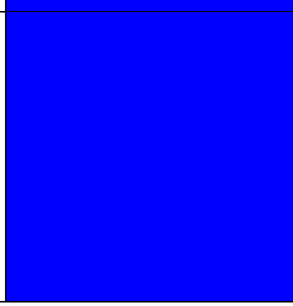
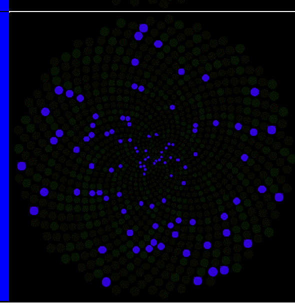
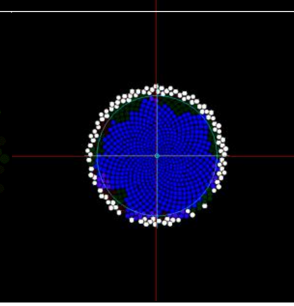
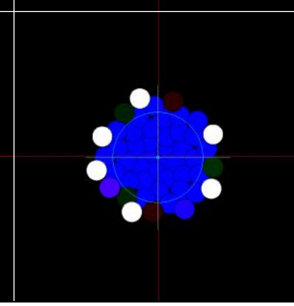
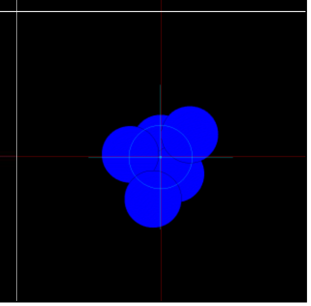
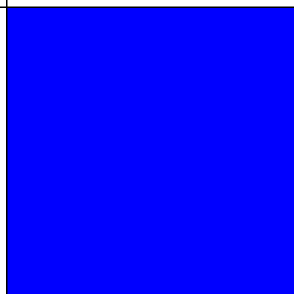
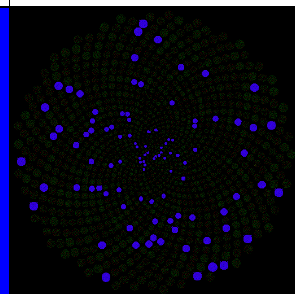
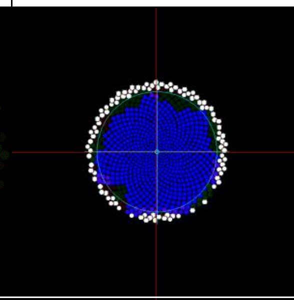
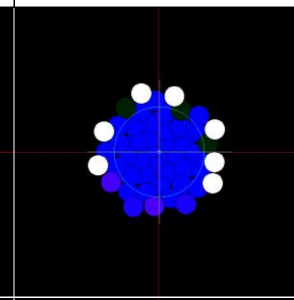
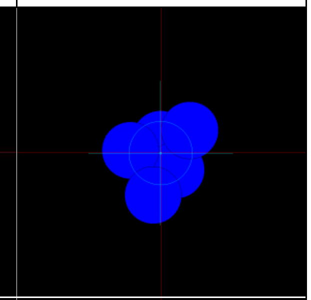
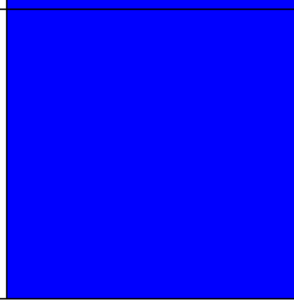
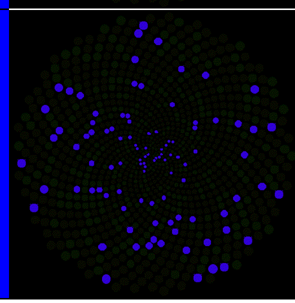
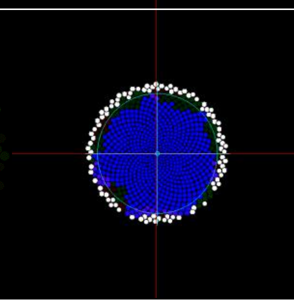
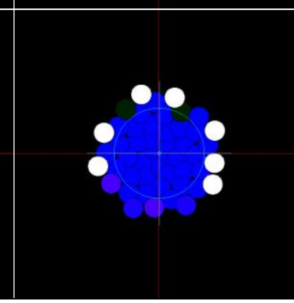
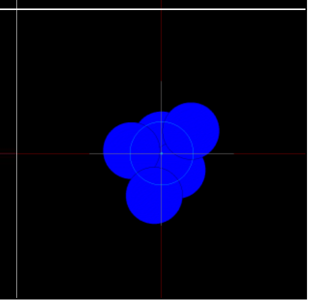
Table 5: Time sequence of homogeneous blue filling-in under large RFs					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
12					
13					
14					

Table 5: Time sequence of homogeneous blue filling-in under large RFs

Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
15					
16					

2.3.6 Test 4 results: Visual time sequence of texture not filling-in

Table 6: Time sequence of texture not filling-in

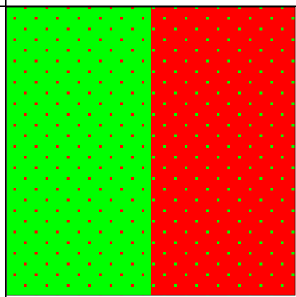
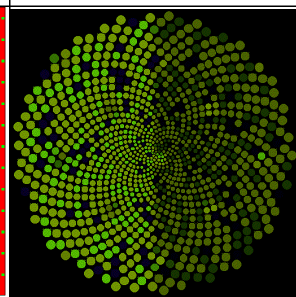
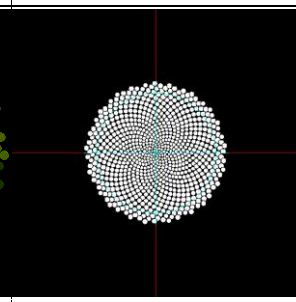
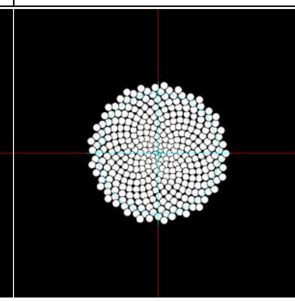
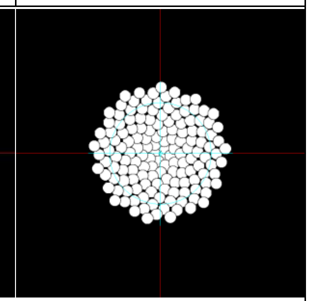
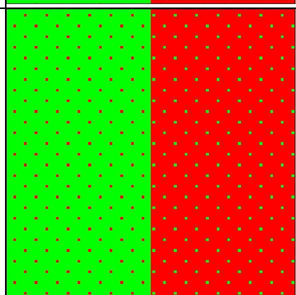
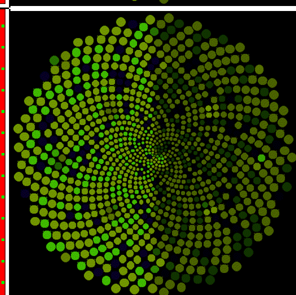
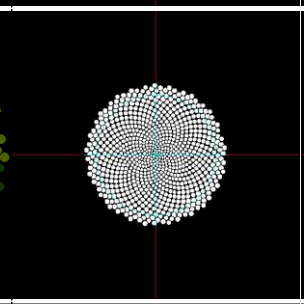
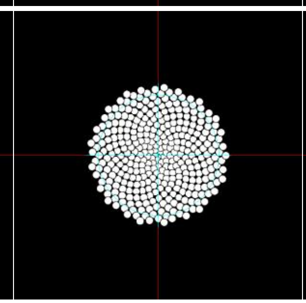
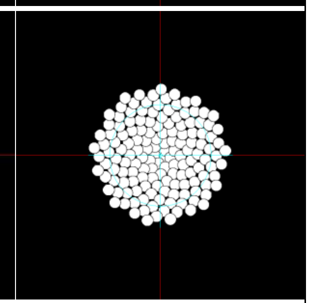
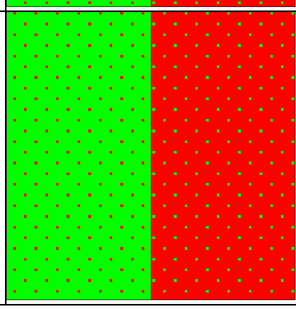
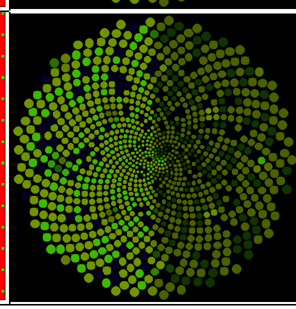
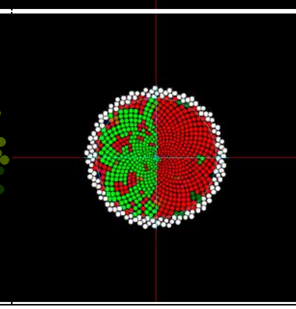
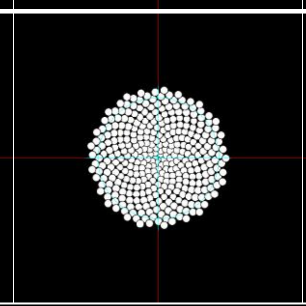
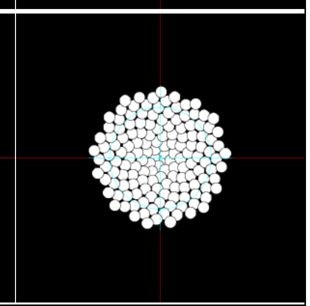
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields Level 1	Receptive Fields Level 2	Receptive Fields Level 3
0					
1					
2					

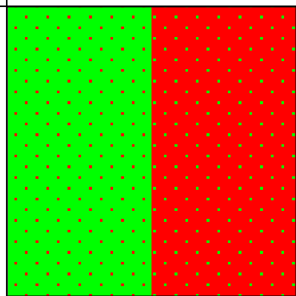
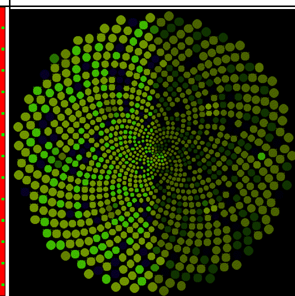
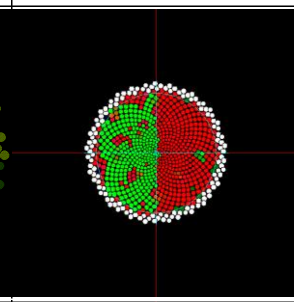
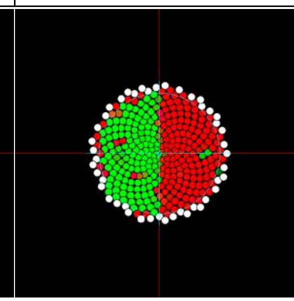
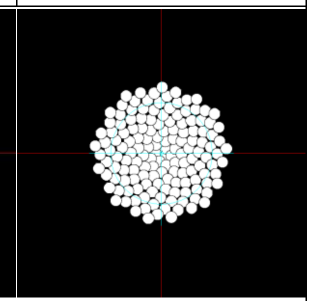
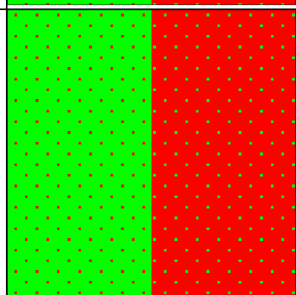
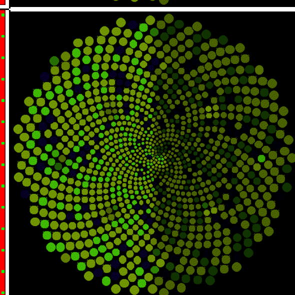
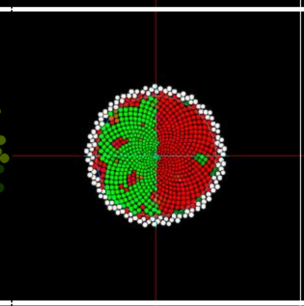
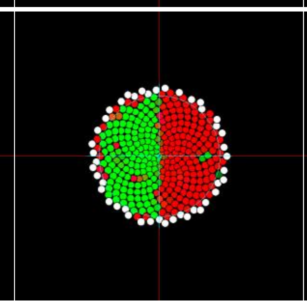
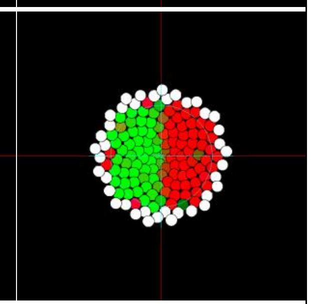
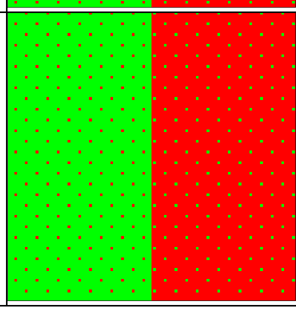
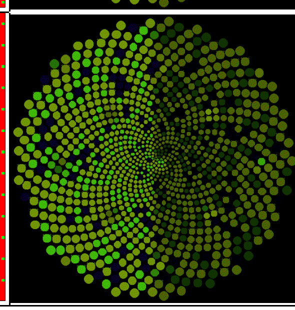
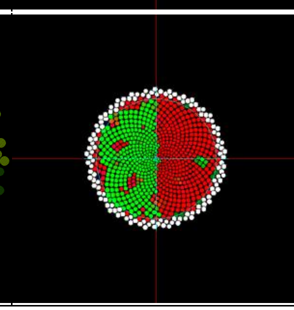
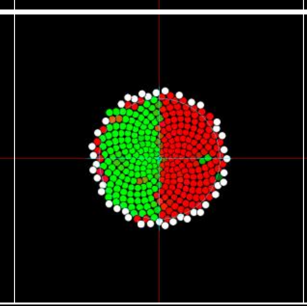
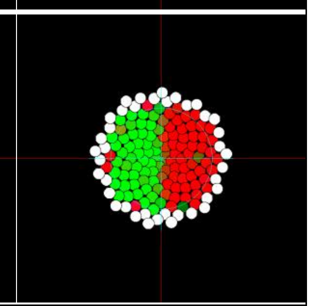
Table 6: Time sequence of texture not filling-in					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
3					
4					
5					

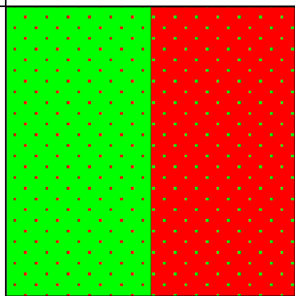
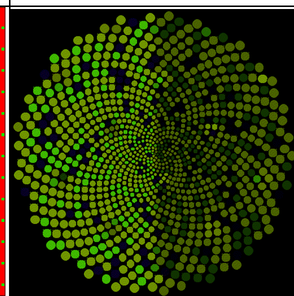
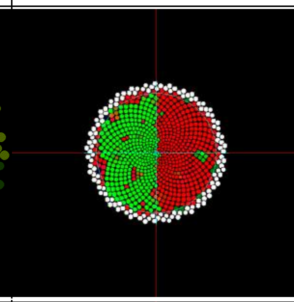
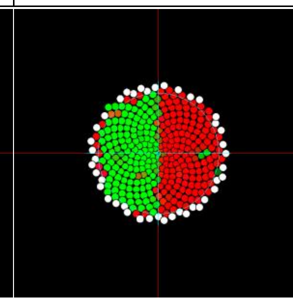
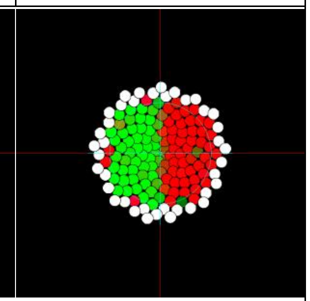
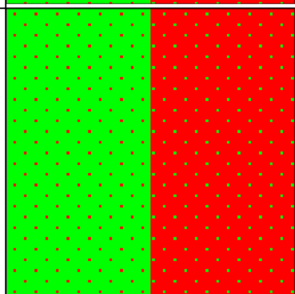
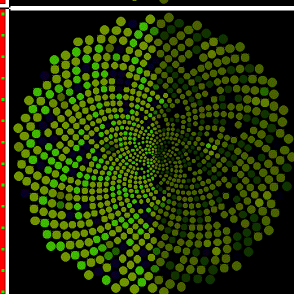
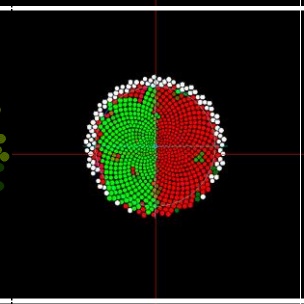
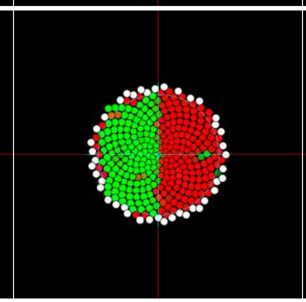
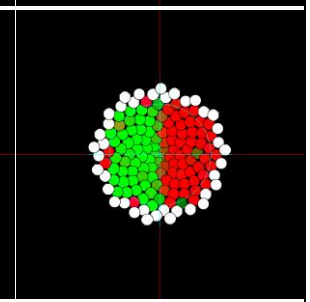
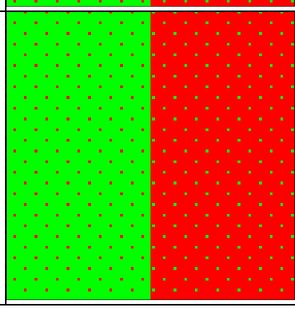
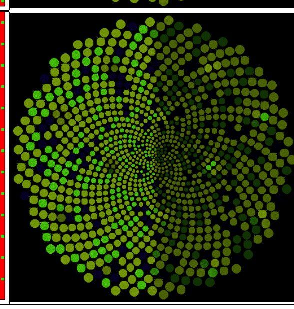
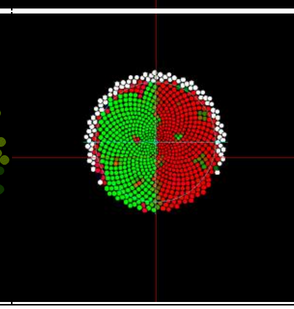
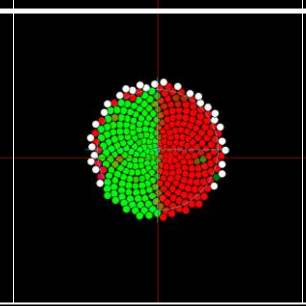
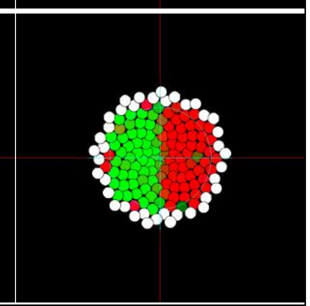
Table 6: Time sequence of texture not filling-in					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
6					
7					
8					

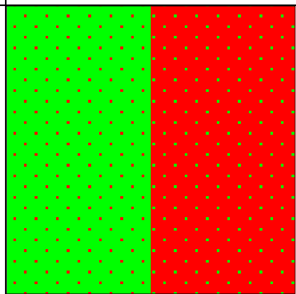
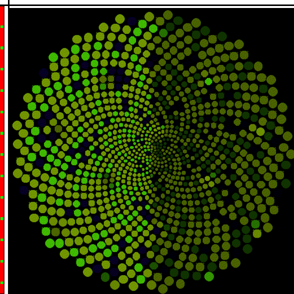
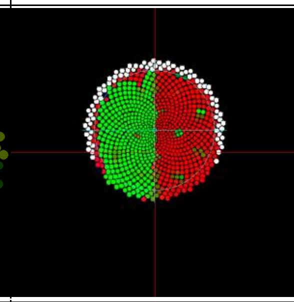
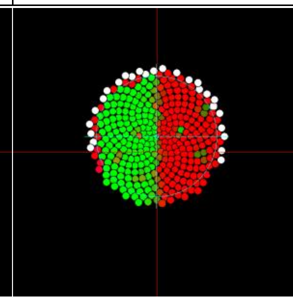
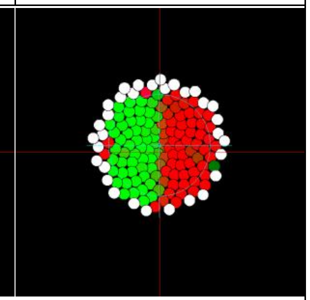
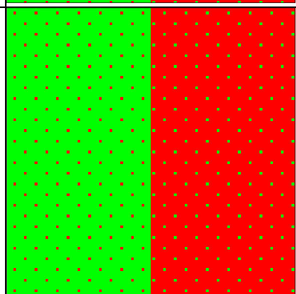
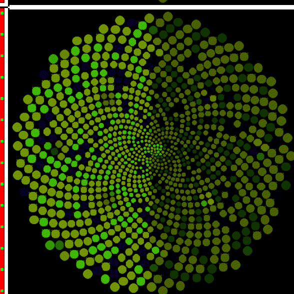
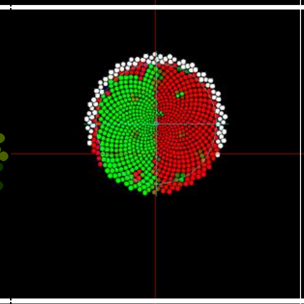
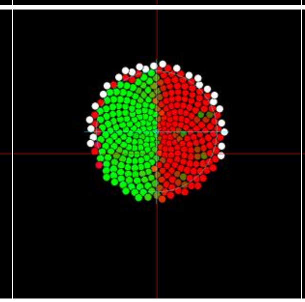
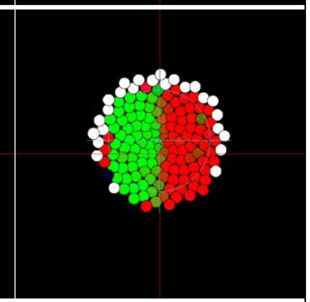
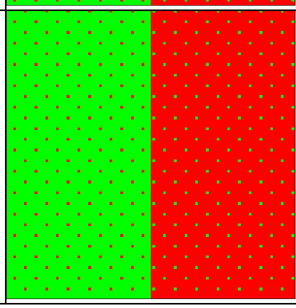
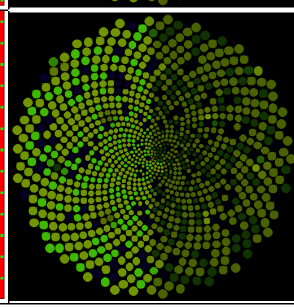
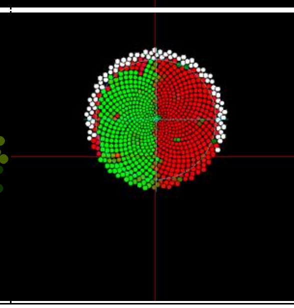
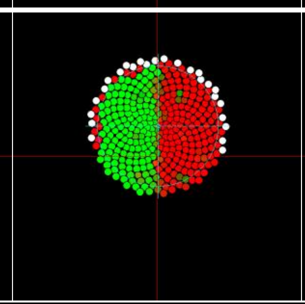
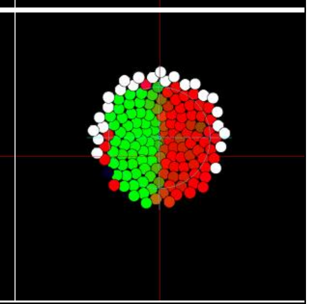
Table 6: Time sequence of texture not filling-in					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
9					
10					
11					

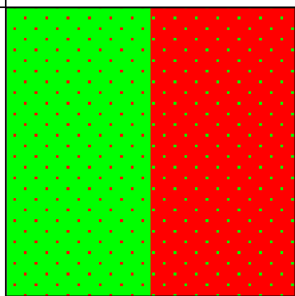
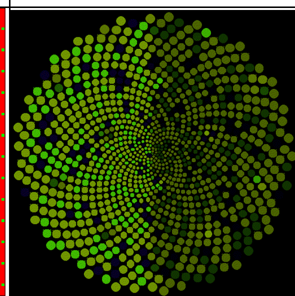
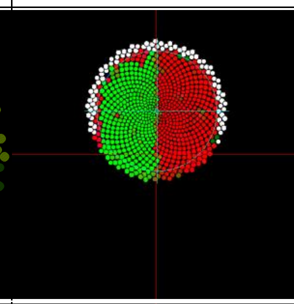
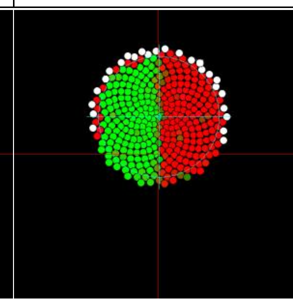
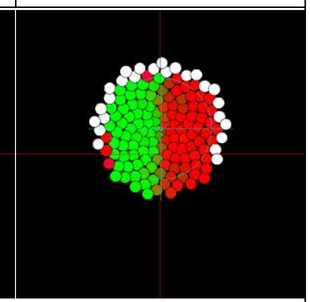
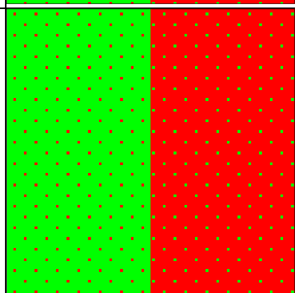
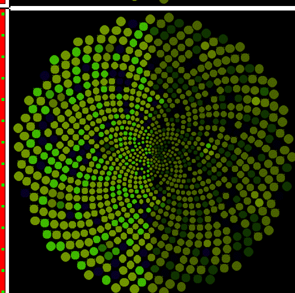
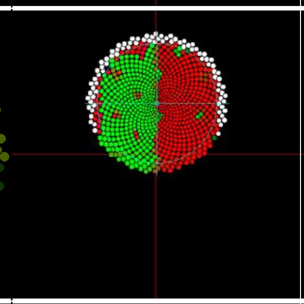
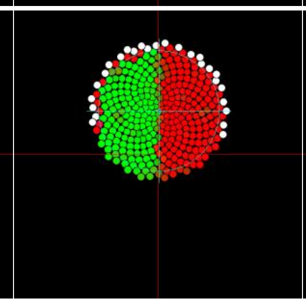
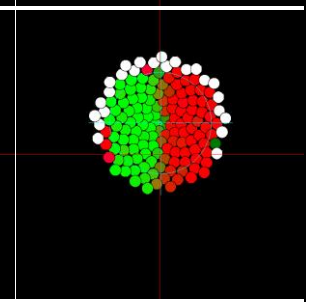
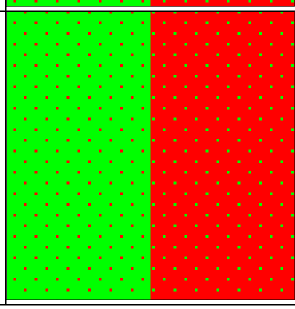
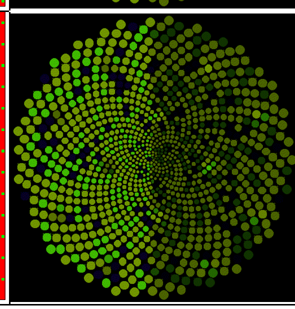
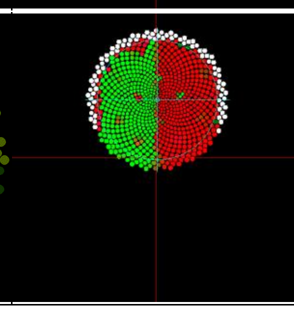
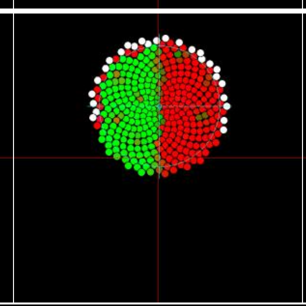
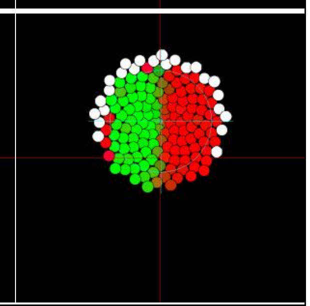
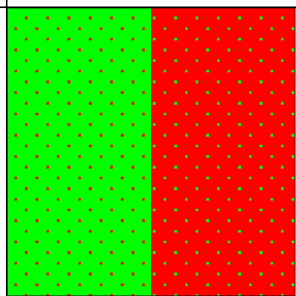
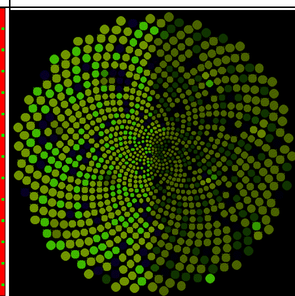
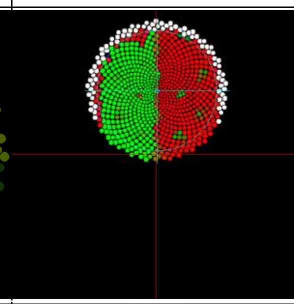
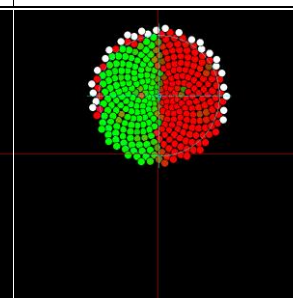
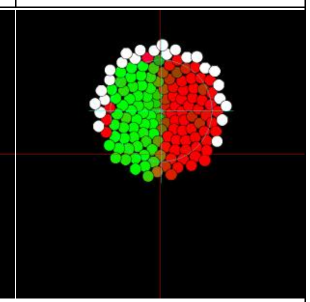
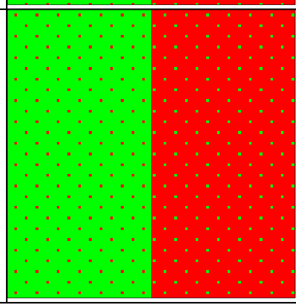
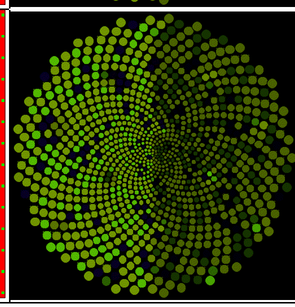
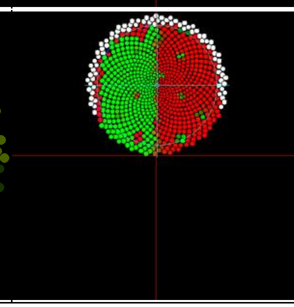
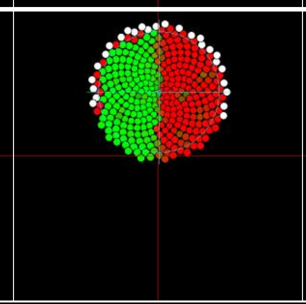
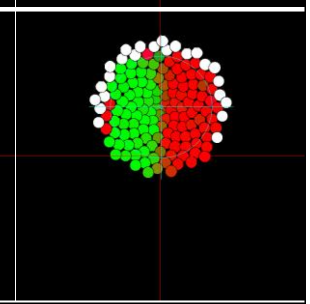
Table 6: Time sequence of texture not filling-in					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
12					
13					
14					

Table 6: Time sequence of texture not filling-in					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
15					
16					

3 Chapter: An emergic model of filling-out for trans-saccadic integration

These supplement the corresponding material in the thesis.

3.1 Subject details

Three virtual subjects were used in these experiments. Each is fully characterized by a set of developmental parameters that will be indicated next. The meaning of these developmental parameters can be found in the thesis. Note that development includes a stochastic component so that, for example, while the L:M:S cone ratio may be innately specified, the colour sensitivity type of individual cones is random.

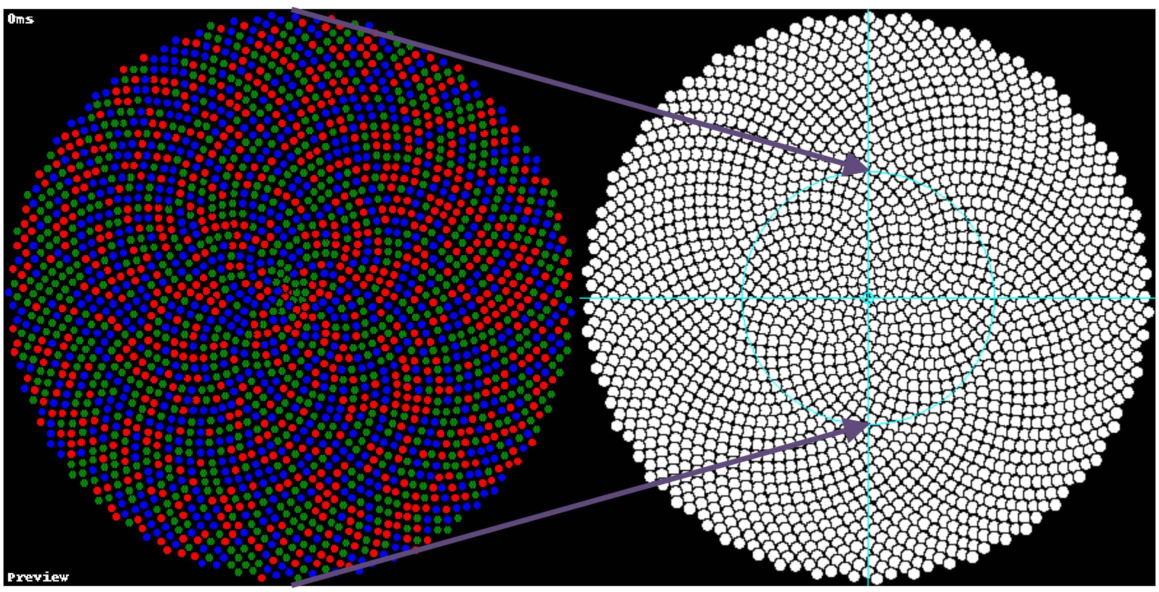


Illustration 3: Stochastic retina mapped into part of the first level RF for filling-out testing

3.1.1 Test 1, 2 & 5 subject

The same set of parameters was used in Test 1, 2 & 5 as shown below. The focus of these parameters is in having a large headcentric visual field beyond the retina (at each RF level), so other factors were simplified. For example, the L:M:S cone ratio was made 1:1:1 (although assignment is stull random), and the RF sizes were held constant. For Test 5, the indicated fan-out factors would influence the speed at which masking occurs.

```
[Person]
note = Filling-out
srt = 10
sex = ai
age = 18
eyecount = 1
ipd = 0
vsize = 17.0
vieweyez = 50
r0conepix = 4
nodalpt = 17
r0coned = 8.0
r0red = 1
r0green = 1
```

```
r1coned = 1.0
r1red = 800
r1green = 800
r1blue = 800
blindx = 0.0
blindy = 0.0
blindr = 0.0
jitmin = 0.1
jitave = 0.7
jitmax = 0.9
p1_0_pixd = 2.5
p1_0_pix = 2000
p1_0_scale = 2
```

```
p1_0_fanlat = 5.0
p1_0_fandwn = 2.0
p1_1_pixd = 3.0
p1_1_pix = 1390
p1_1_scale = 2
p1_1_fanlat = 2.0
p1_1_fandwn = 2.0
p1_2_pixd = 4.0
p1_2_pix = 782
p1_2_scale = 2
p1_2_fanlat = 1.2
p1_2_fandwn = 1.5
```

The developed field of view for the photoreceptors, and RFs at Level 1, 2 and 3 was 91.38′, 208.43′, 208.48′ and 208.45′ respectively.

3.1.2 Test 3 subject

This agent was identical to the one used in Test 1 & 2 except that one dynamic situational parameter was changed as indicated – the agent was positioned further from the virtual computer monitor.

```
[Person]
note = Filling-out
srt = 10
sex = ai
age = 18
eyecount = 1
ipd = 0
vsize = 17.0
vieweyez = 75
r0conepix = 4
nodalpt = 17
r0coned = 8.0
r0red = 1
r0green = 1
r1coned = 1.0
r1red = 800
r1green = 800
r1blue = 800
blindx = 0.0
blindy = 0.0
blindr = 0.0
jitmin = 0.1
jitave = 0.7
jitmax = 0.9
p1_0_pixd = 2.5
p1_0_pix = 2000
p1_0_scale = 2
p1_0_fanlat = 5.0
p1_0_fandwn = 2.0
p1_1_pixd = 3.0
p1_1_pix = 1390
p1_1_scale = 2
p1_1_fanlat = 2.0
p1_1_fandwn = 2.0
p1_2_pixd = 4.0
p1_2_pix = 782
p1_2_scale = 2
p1_2_fanlat = 1.2
p1_2_fandwn = 1.5
```

Ideally, in experimental papers, such situational parameters do not belong with Person and are better located with the stimuli. Technically, they are part of the agent/environment interaction. In these experiments, the parameter is fixed. In other experiments, the agent could conceivably choose to move closer or further away from the computer screen. It is a person's choice in this respect which is why it is located here.

3.1.3 Test 4 subject

This dichromatic agent had a retina whereby the smallest and largest cones varied by a factor of 4 as indicated in the highlighted parameter. As blue is not allowed in region 0, it was not used elsewhere. The stimulus was red/green only.

```
[Person]
note = Filling-out
srt = 10
sex = ai
age = 18
eyecount = 1
ipd = 0
vsize = 17.0
vieweyez = 30
r0conepix = 4
nodalpt = 17
r0coned = 8.0
r0red = 500
r0green = 500
r1coned = 4.0
r1red = 250
r1green = 250
r1blue = 0
blindx = 0.0
blindy = 0.0
blindr = 0.0
jitmin = 0.1
jitave = 0.7
jitmax = 0.9
p1_0_pixd = 6.0
p1_0_pix = 700
p1_0_scale = 3
p1_0_fanlat = 9.0
p1_0_fandwn = 4.0
p1_1_pixd = 8.0
p1_1_pix = 430
p1_1_scale = 3
p1_1_fanlat = 2.0
p1_1_fandwn = 2.0
p1_2_pixd = 10.0
p1_2_pix = 290
p1_2_scale = 3
p1_2_fanlat = 1.2
p1_2_fandwn = 1.5
```

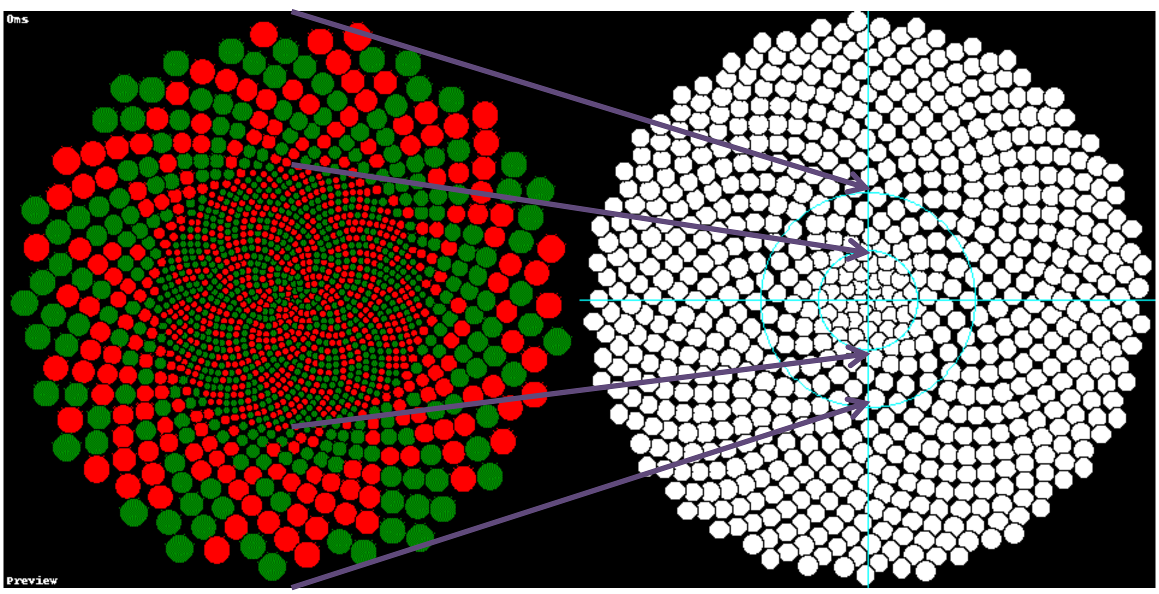


Illustration 4: Stochastic retina with varying RF sizes mapped into 1st level of RFs

3.2 Stimuli details

The first three experiments tested filling-out generically. Test 1 used a simple coloured surface stimulus – the block letters spelling LOVE; Test 2 used a natural image stimulus – a picture of Lena; and Test 3 used a dynamic image stimulus with surface gradients – a lilac chaser. Test 4 used a simple edge stimulus to test filling-out under varying topologies – to validate coordinate transformations. Test 5 used a wide image stimulus to test masking under fast eye motion.

3.2.1 Test 1 stimulus: Simple surfaces (Love)

This stimulus is used to test filling-out behaviour in a generic fashion using simple surfaces – the block letters spelling LOVE. The meaning of these parameters is fully described in the thesis. The content of file love.png appears in Illustration 5.

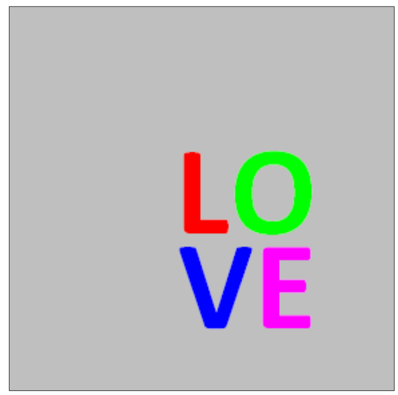


Illustration 5: Trans-saccadic Test 1 Stimulus (Love)

```
[World]
type = Image
note = Love
srt = 200

[Image]
wx = 256
wy = 256
wbg = #000000
iname = love.png
ix = 256
iy = 256
```

3.2.2 Test 2 stimulus: Natural image (Lena)

Illustration 6: Trans-saccadic Test 2 Stimulus (Lena)

This stimulus is used to test filling-out behaviour in a generic fashion using a natural image - a standard image library picture of Lena (Picard, 1995). The meaning of these parameters is fully described in the thesis. The content of file Lena.tiff appears in Illustration 6.

```
[World]
type = Image
note = Lena
srt = 200

[Image]
wx = 512
wy = 512
wbg = #000000
iname = Lena.tiff
ix = 512
iy = 512
```

3.2.3 Test 3 stimulus: Dynamic image with surface gradients (Chaser)

This stimulus (as viewed in Illustration 7) is used to test filling-out behaviour in a generic fashion using a dynamic image with surface gradients – the lilac chaser. The meaning of these parameters is fully described in the thesis. The virtual agent was monitored for 32 ticks (320ms), so this chaser with 8 lilacs needed to move the lilac gap every 40ms to complete an entire circuit of motion.

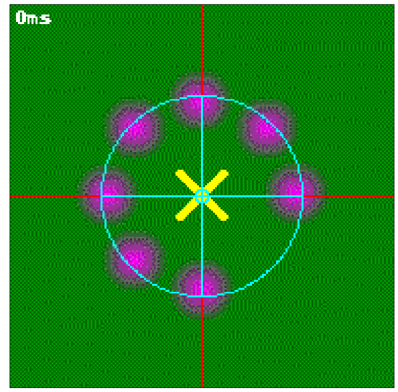


Illustration 7: Trans-saccadic Test 3 stimulus (Chaser) with overlay

```
[World]
type = Lilac
Chaser
note =
srt = 40
```

```
[Lilac Chaser]
llcount = 8
spacing = 0.1
pad = 1.0
fg = #ff00ff
bg = #007f00
gamma = 1.0
```

```
grdcount = 17
grdwidth = 1
fixfg = #ffff00
fixsize = 0.75
fixwidth = 2
```

3.2.4 Test 4 stimulus: Edge under varying RF sizes

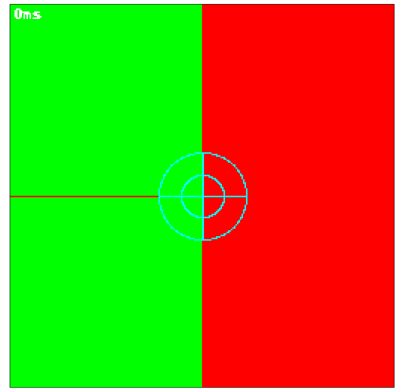


Illustration 8: Trans-saccadic Test 4 stimulus (Edge) with overlay

This simple edge stimulus is used to test the coordinate transformation capability of filling-out under a complex topology of varied RF sizes. The meaning of these parameters is fully described in the thesis. The content of file GreenRed.gif appears in Illustration 8 minus any overlay.

```
[World]
type = Image
note = Edge
srt = 200

[Image]
wx = 256
wy = 256
wbg = #000000

iname =
GreenRed.gif
ix = 256
iy = 256
```

The stimulus was red and green only, as a varying sized mosaic cannot be constructed with blue in the extreme center, to match biology (Wald, 1967).

3.2.5 Test 5 stimulus: Image masking under fast motion

Illustration 9: Trans-saccadic Test 5 stimulus (Mask) with overlay

This wide stimulus is used to test the image masking capability of filling-out when the eye accelerates to a fast speed. The meaning of these parameters is fully described in the thesis. The content of file Mask.png appears within Illustration 9 along with an overlay.

```
[World]
type = Image
note = Masking
srt = 200

[Image]
wx = 1008
wy = 96
wbg = #000000

iname = Mask.png
ix = 1008
iy = 96
```

3.3 Result details

In this section we tabulate a visual frame-by-frame account of results from all experiments. Such a frame-by-frame account allows for the extraction of precise timing information useful for quantitative analysis. It takes 64 pages. All these results are reduced to a single web page of animated images, available at

http://emergic.upwize.com/?page_id=86

The animated account (Leibovitz, 2012a) is preferred as an overview showing behavioural dynamics of filling-out, memory, masking, etc. and makes image stability more salient. It also includes the results in greatest detail – they have been scaled down for print in this supplement, and even smaller in the chapter's *results and discussion* sections.

Each table of results has the following columns. **Time** numerically represents the time tick since the test has started, nominally 10ms/tick. All visual results in that table row are after the tick and computation have finished. **Stimuli** visually represents the stimuli presented to the virtual computer screen, often with retinal overlays. The **Photoreceptor Mosaic** visually represents what the retina senses by looking at the stimuli. **Receptive Fields** at **Level 1**, **Level 2** and **Level 3**, visually represent the three level hierarchy of receptive fields showing their the functional size and placement, not physical size nor placement

3.3.1 Test 1 results: Simple surfaces (Love)

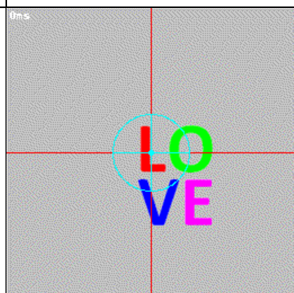
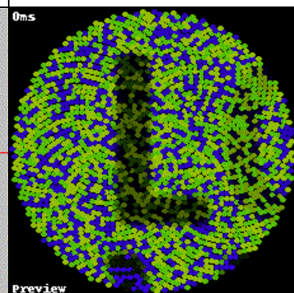
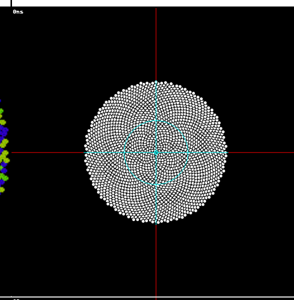
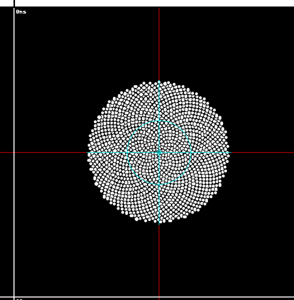
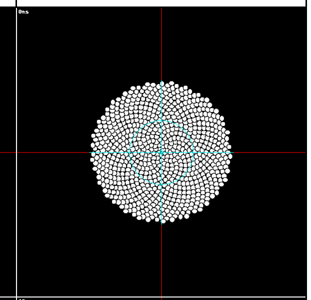
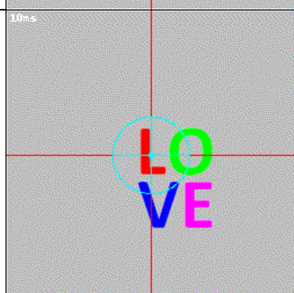
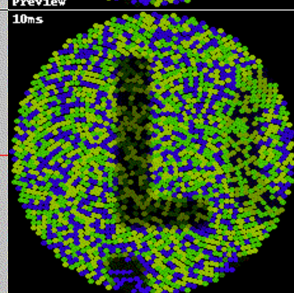
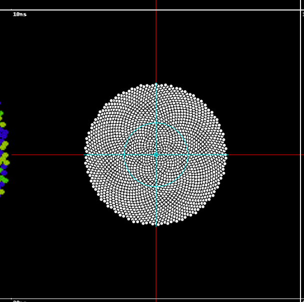
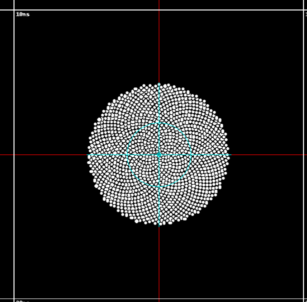
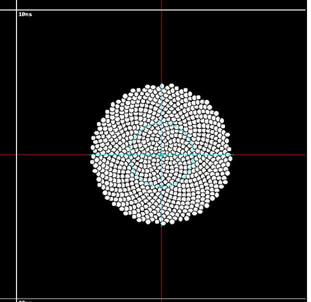
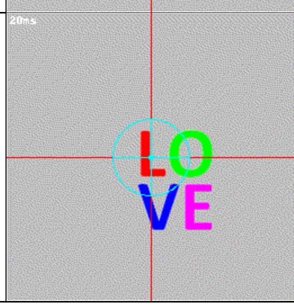
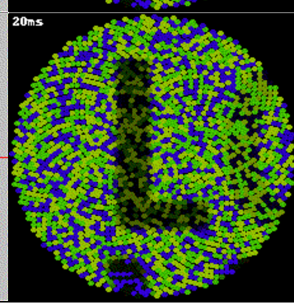
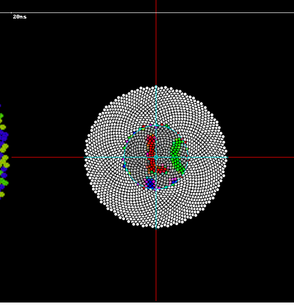
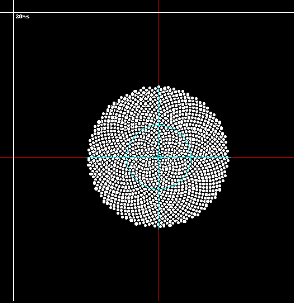
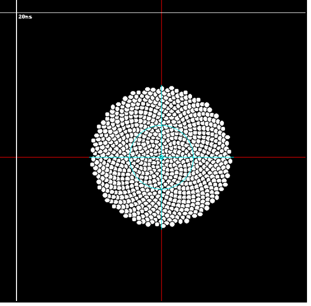
Table 7: Time sequence of filling-out for simple surfaces					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
0					
1					
2					

Table 7: Time sequence of filling-out for simple surfaces

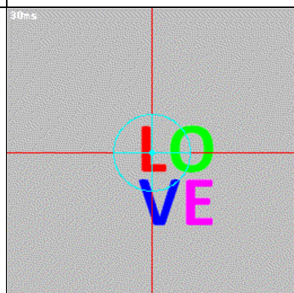
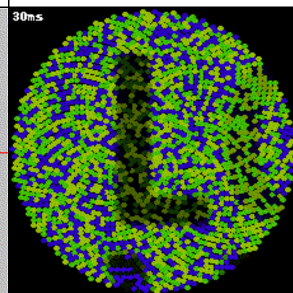
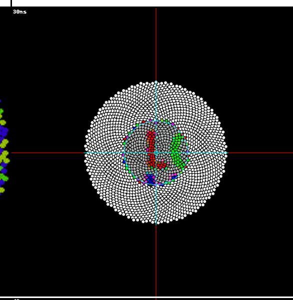
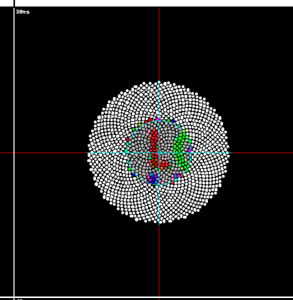
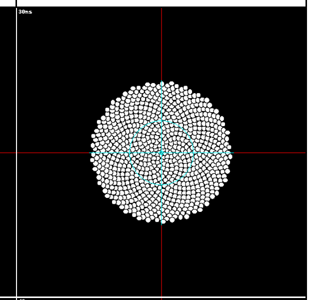
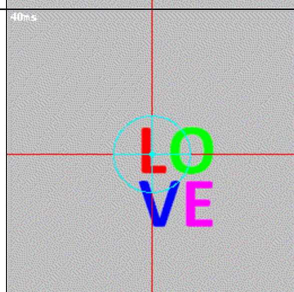
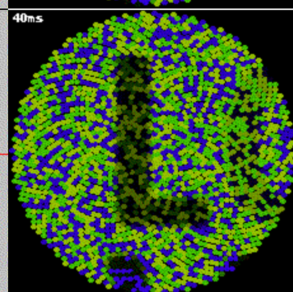
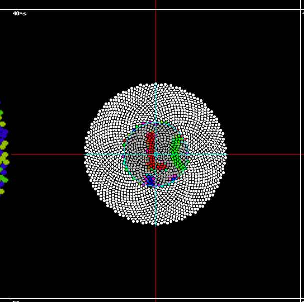
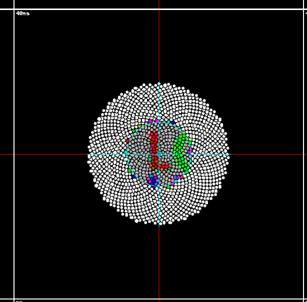
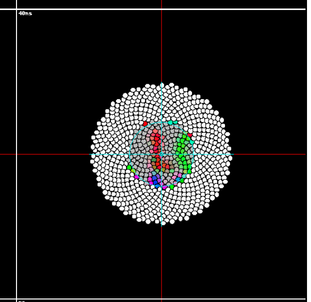
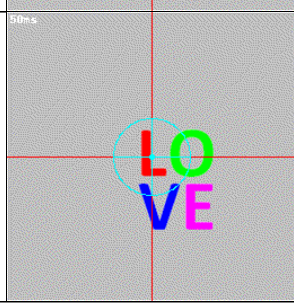
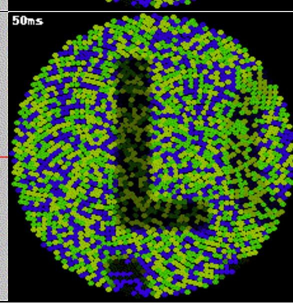
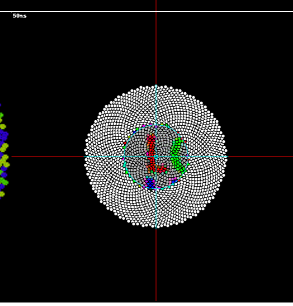
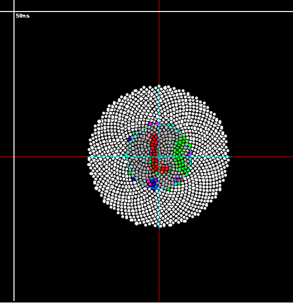
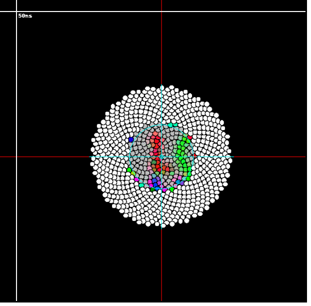
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
3					
4					
5					

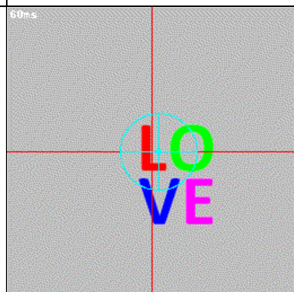
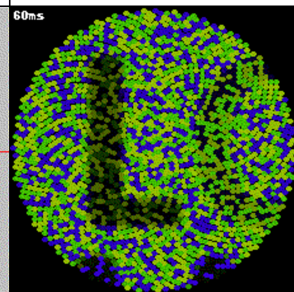
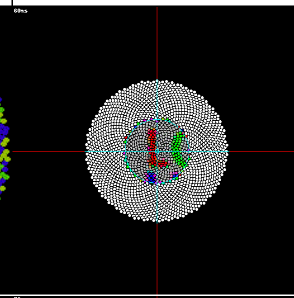
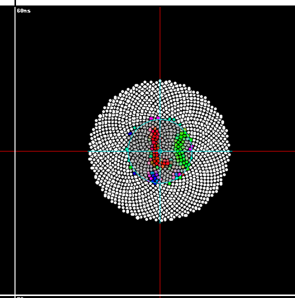
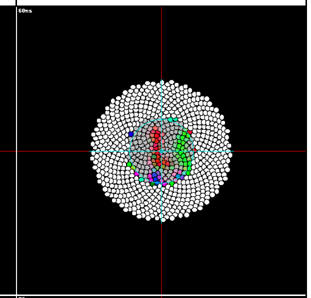
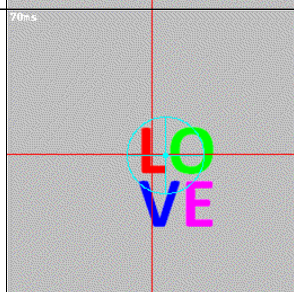
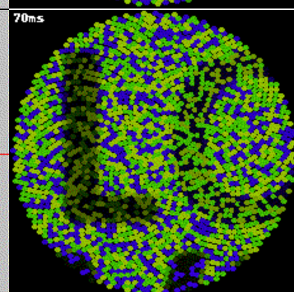
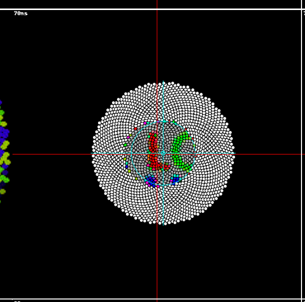
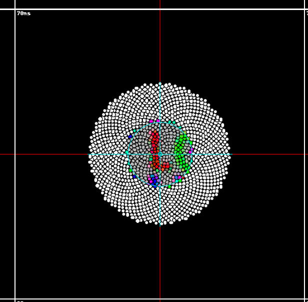
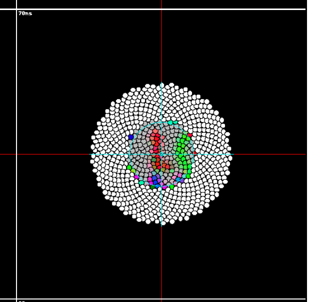
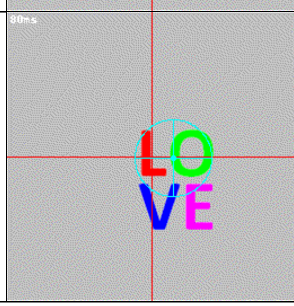
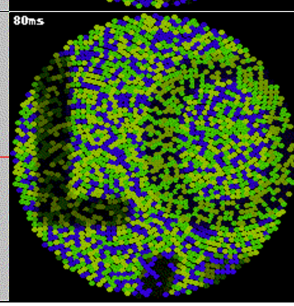
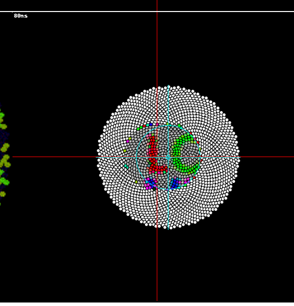
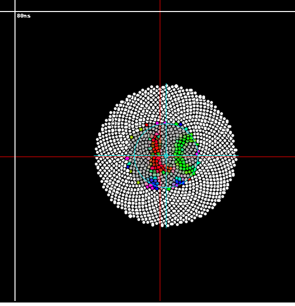
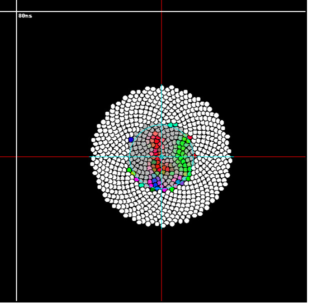
Table 7: Time sequence of filling-out for simple surfaces					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
6					
7					
8					

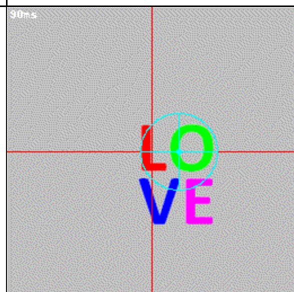
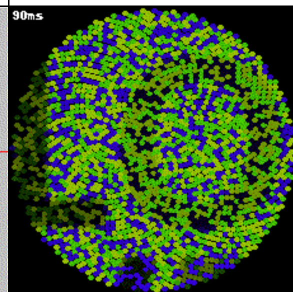
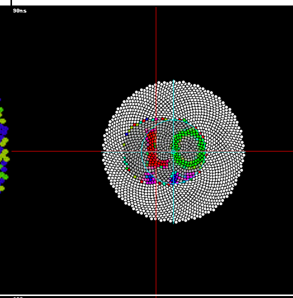
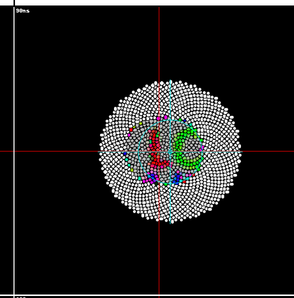
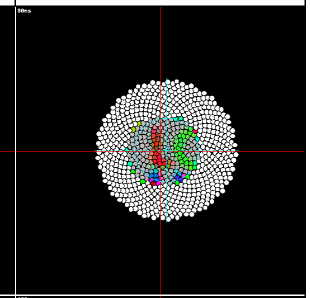
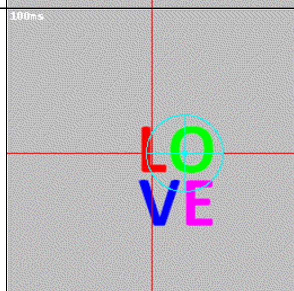
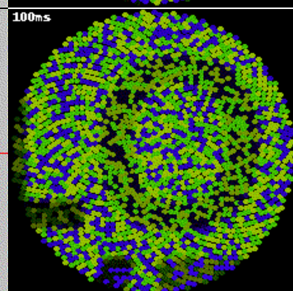
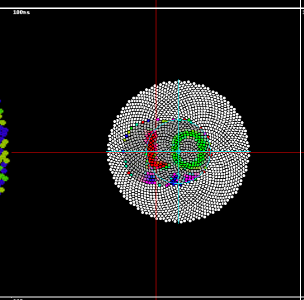
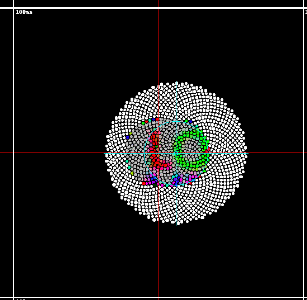
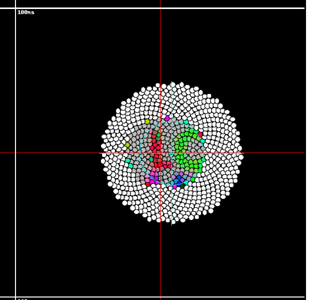
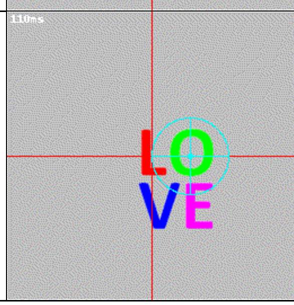
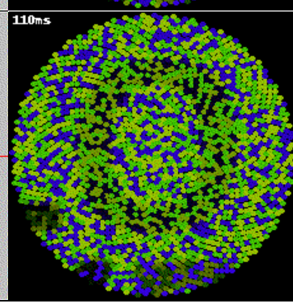
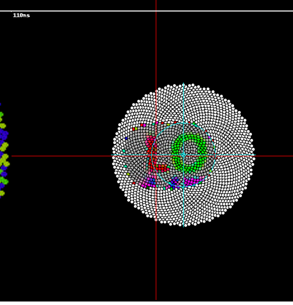
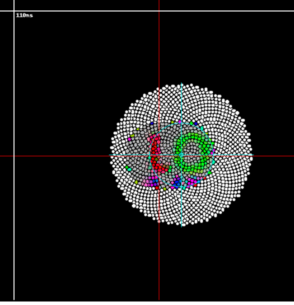
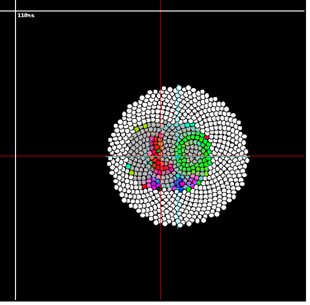
Table 7: Time sequence of filling-out for simple surfaces					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
9					
10					
11					

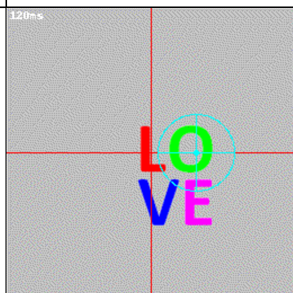
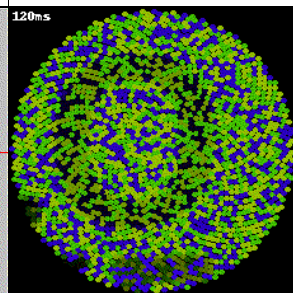
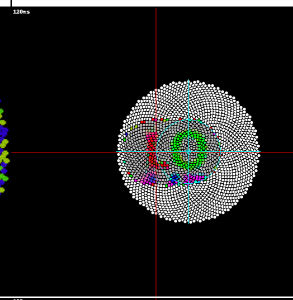
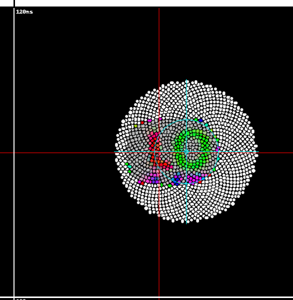
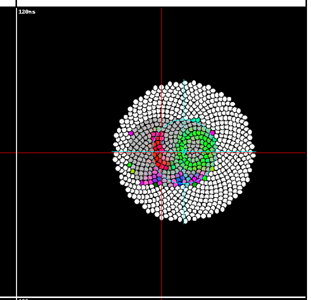
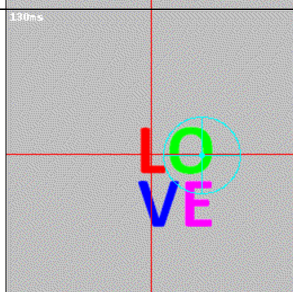
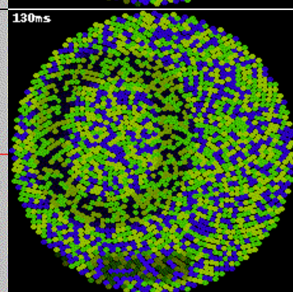
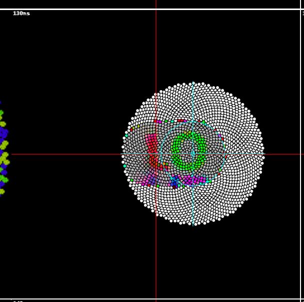
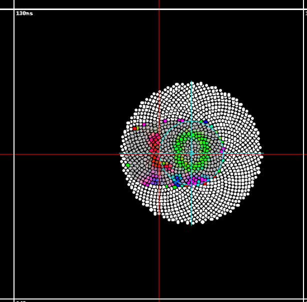
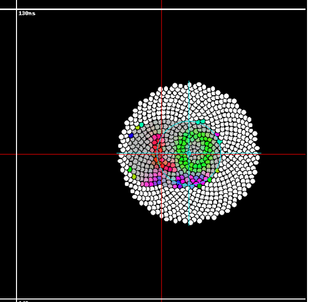
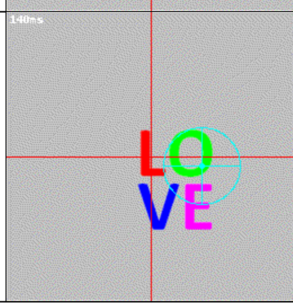
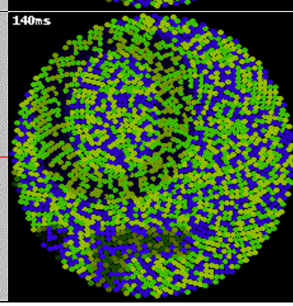
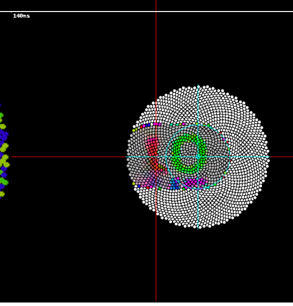
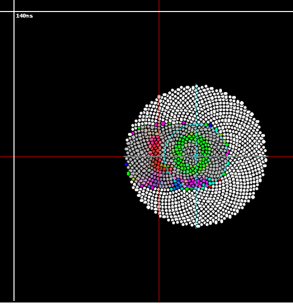
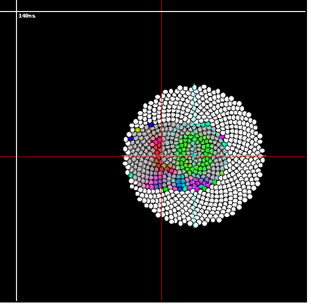
Table 7: Time sequence of filling-out for simple surfaces					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
12					
13					
14					

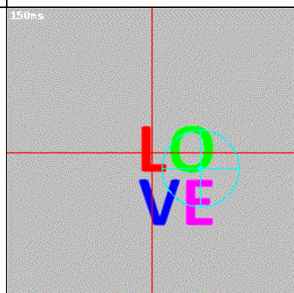
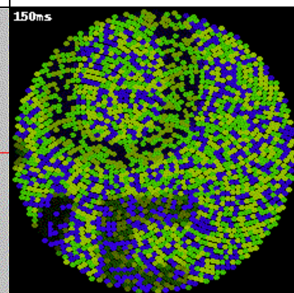
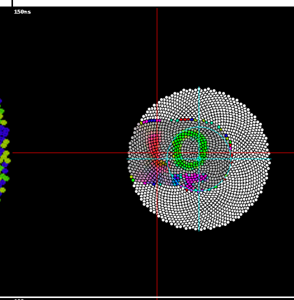
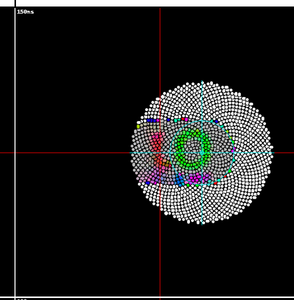
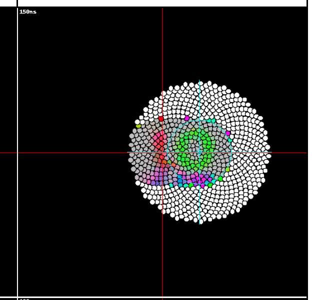
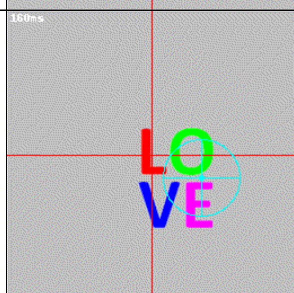
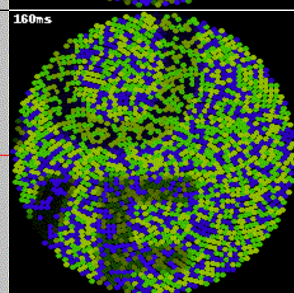
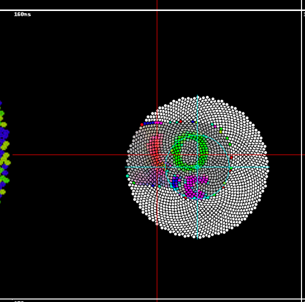
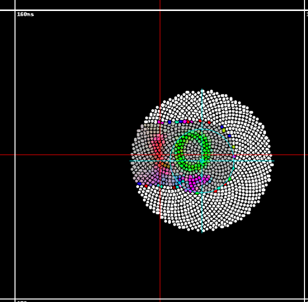
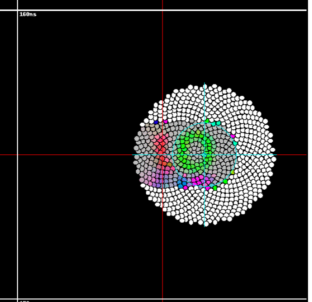
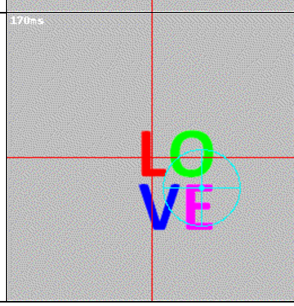
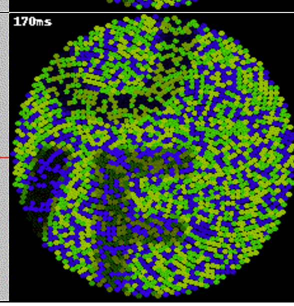
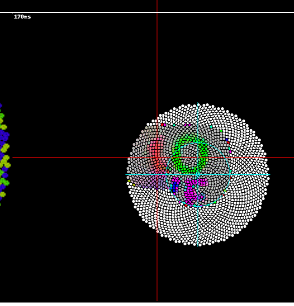
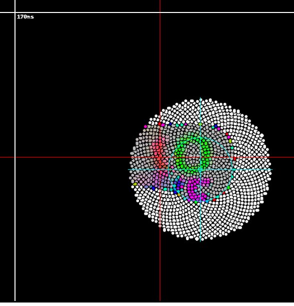
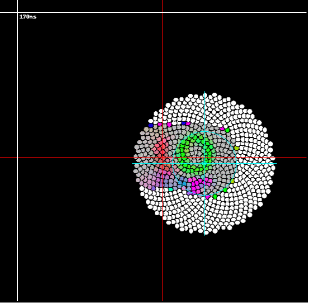
Table 7: Time sequence of filling-out for simple surfaces					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
15					
16					
17					

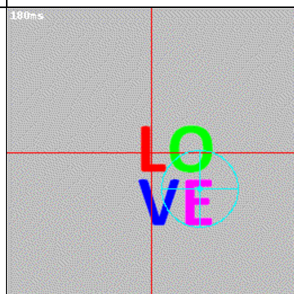
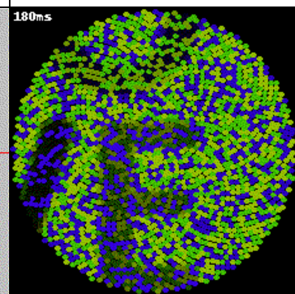
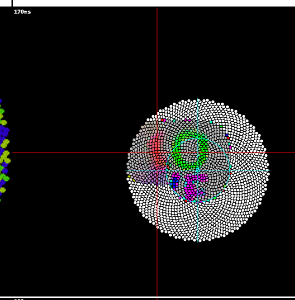
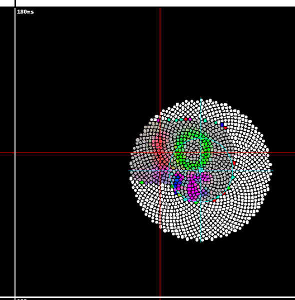
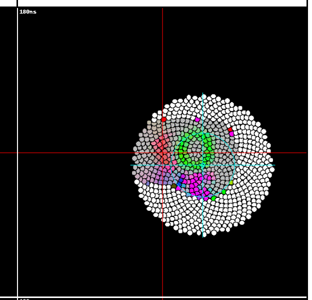
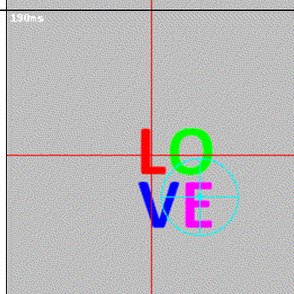
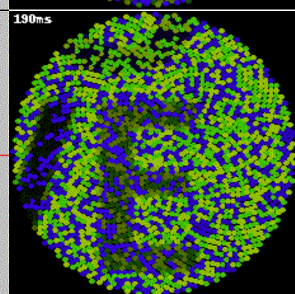
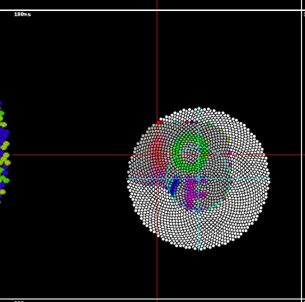
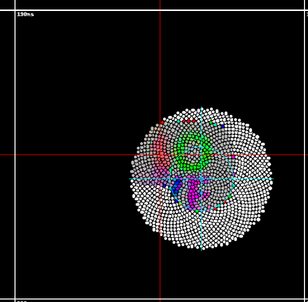
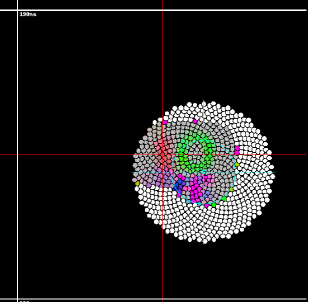
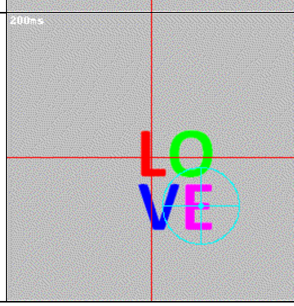
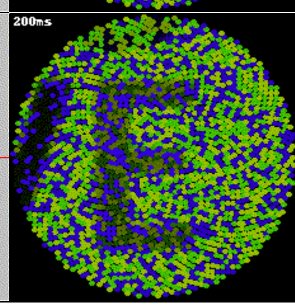
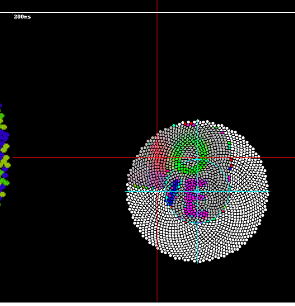
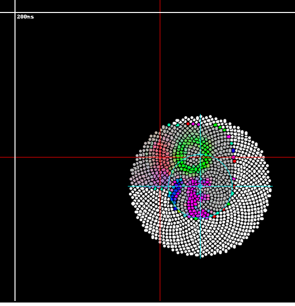
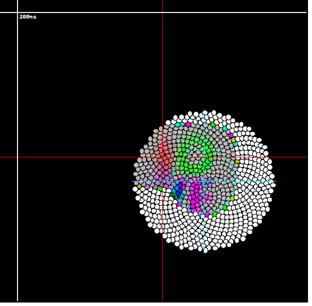
Table 7: Time sequence of filling-out for simple surfaces					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
18					
19					
20					

Table 7: Time sequence of filling-out for simple surfaces

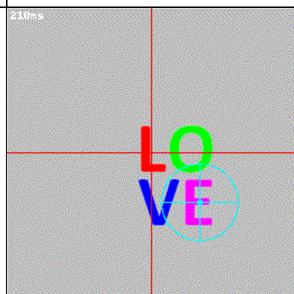
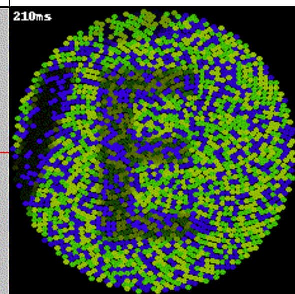
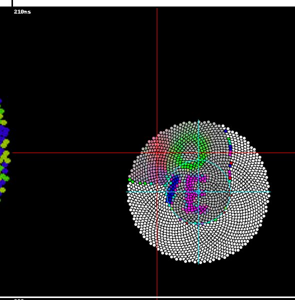
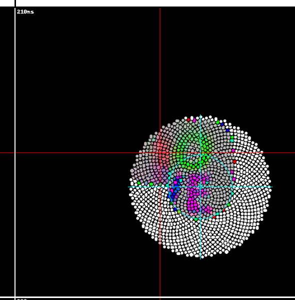
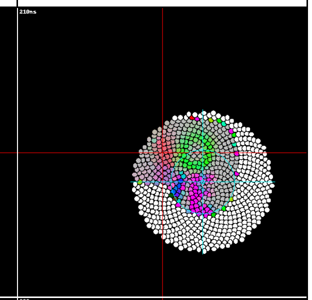
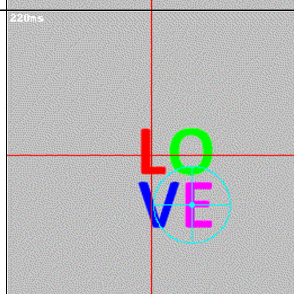
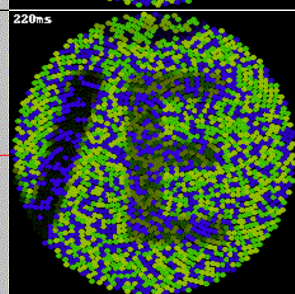
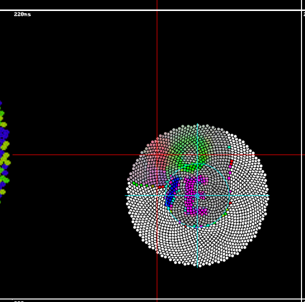
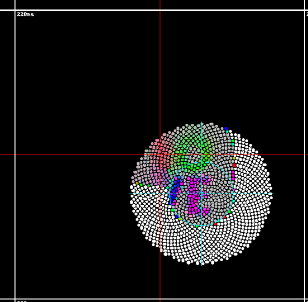
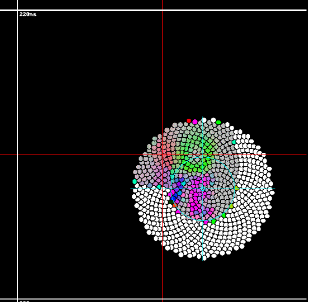
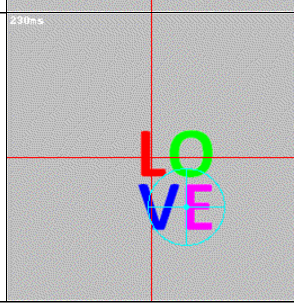
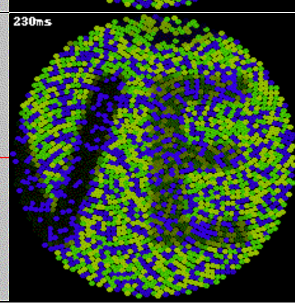
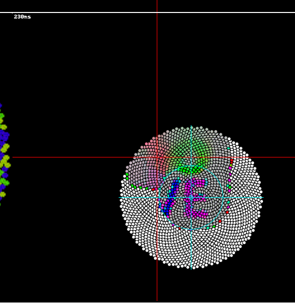
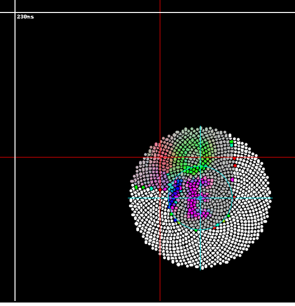
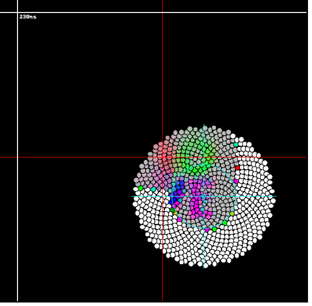
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
21					
22					
23					

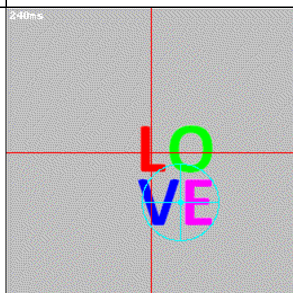
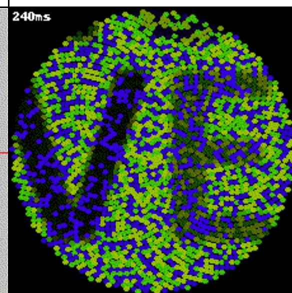
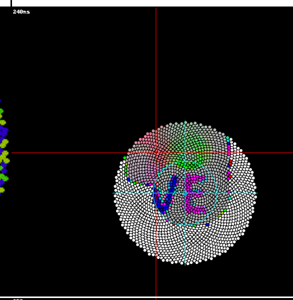
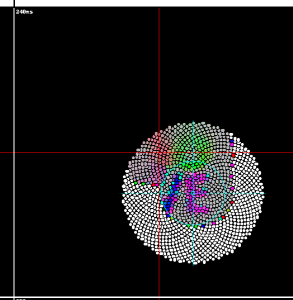
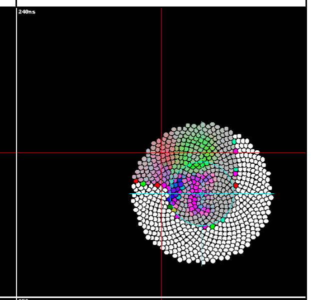
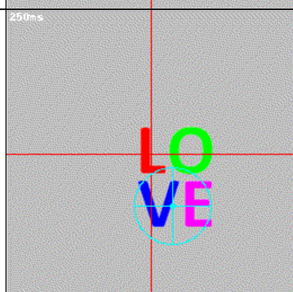
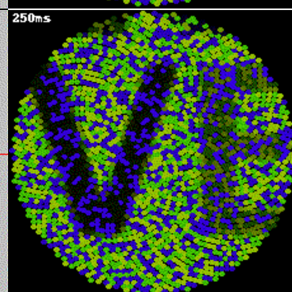
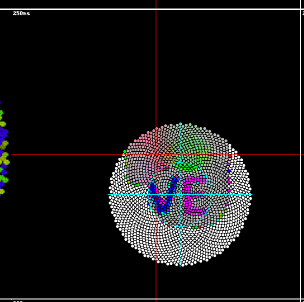
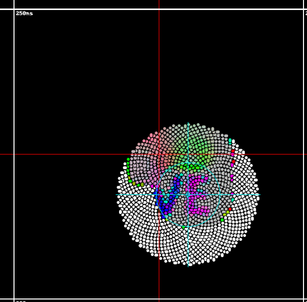
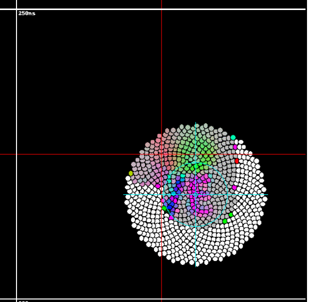
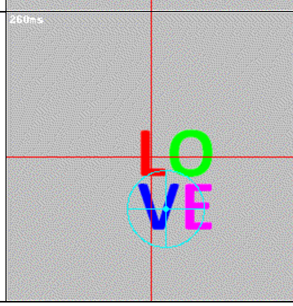
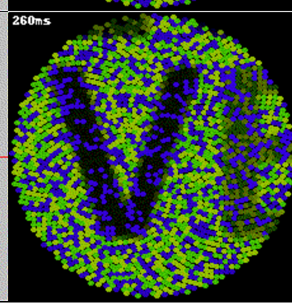
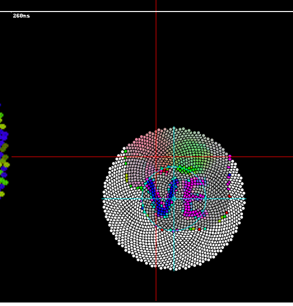
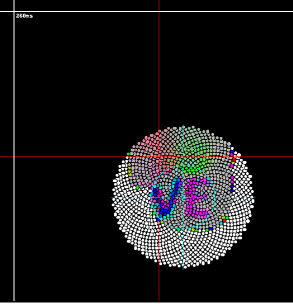
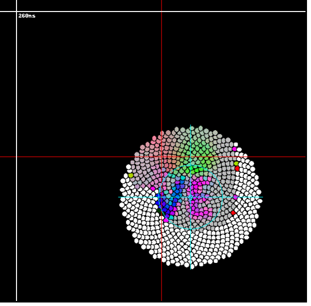
Table 7: Time sequence of filling-out for simple surfaces					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
24					
25					
26					

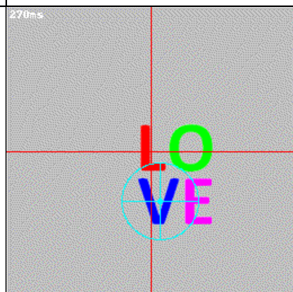
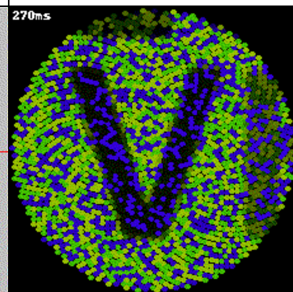
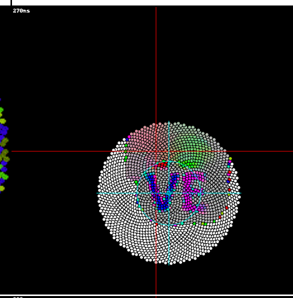
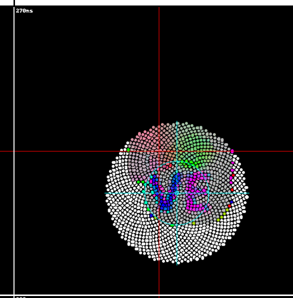
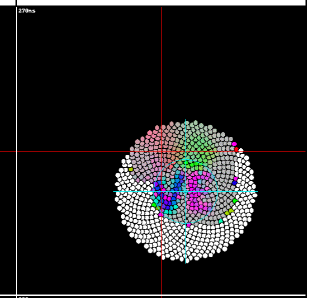
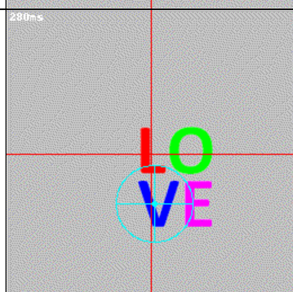
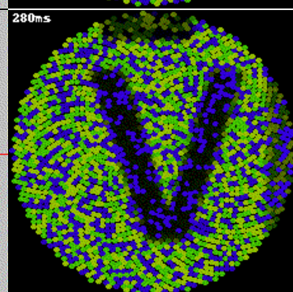
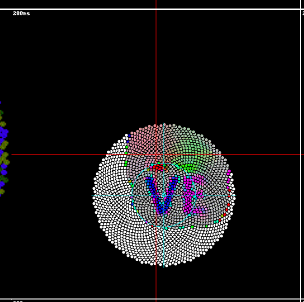
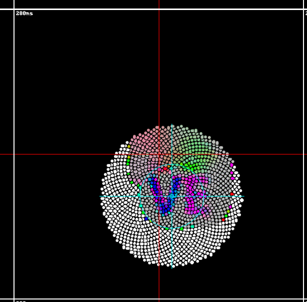
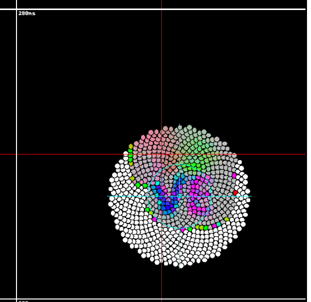
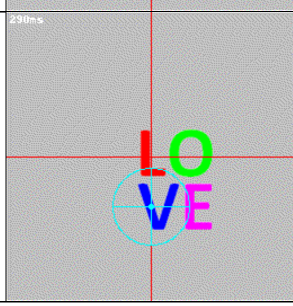
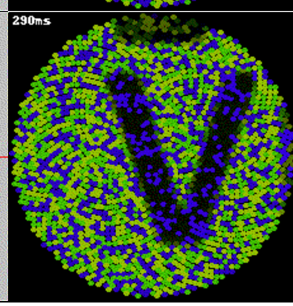
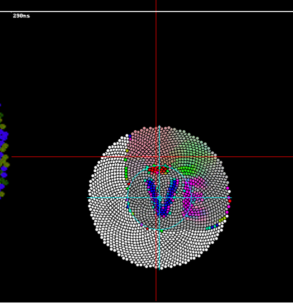
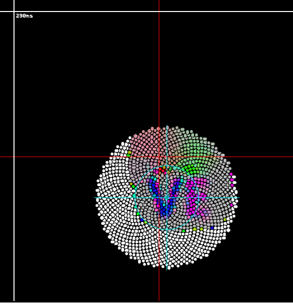
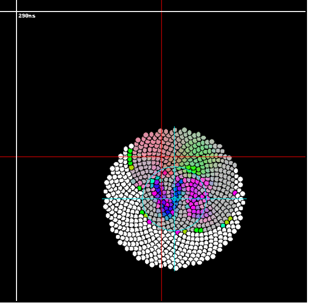
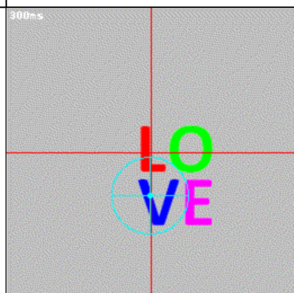
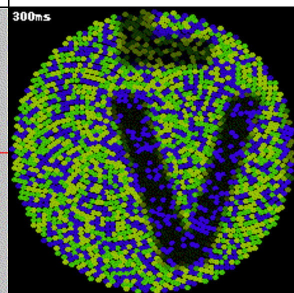
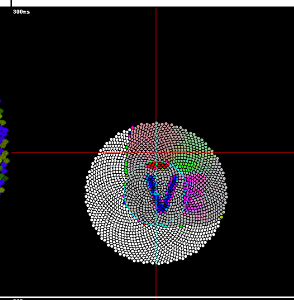
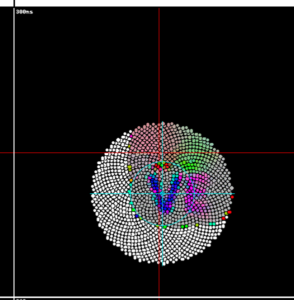
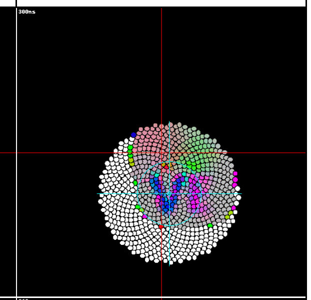
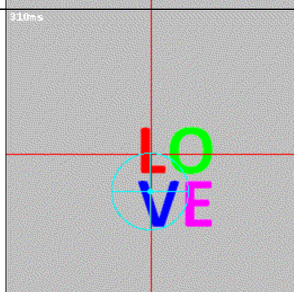
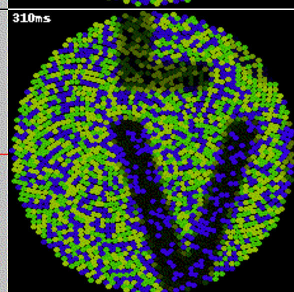
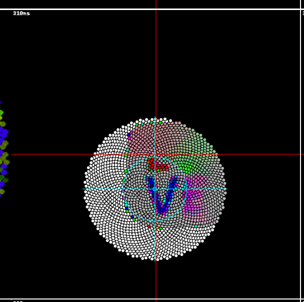
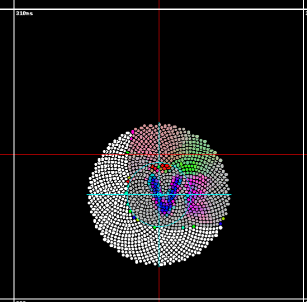
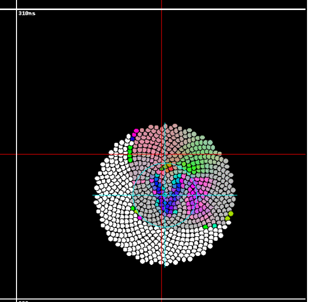
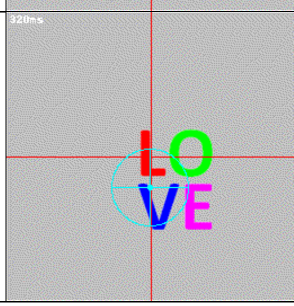
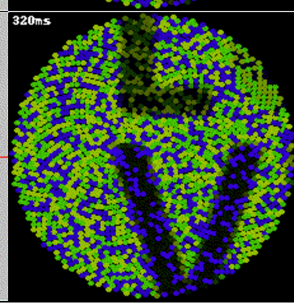
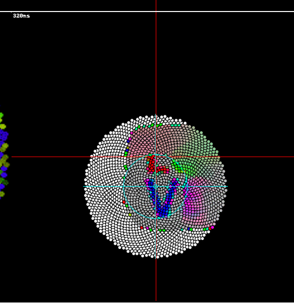
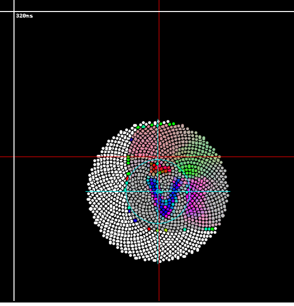
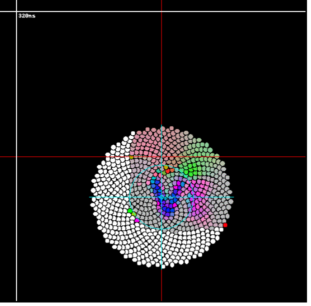
Table 7: Time sequence of filling-out for simple surfaces					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
27					
28					
29					

Table 7: Time sequence of filling-out for simple surfaces					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
30					
31					
32					

3.3.2 Test 2 results: Natural image (Lena)

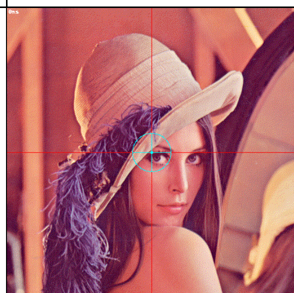
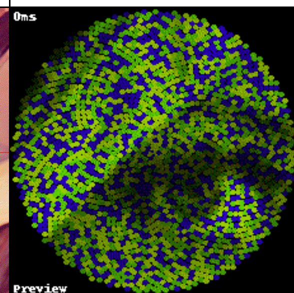
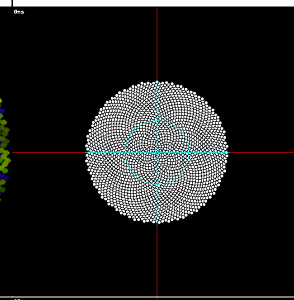
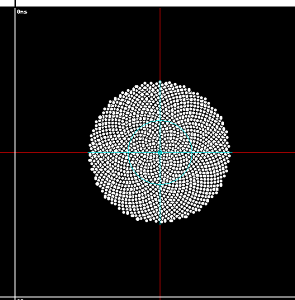
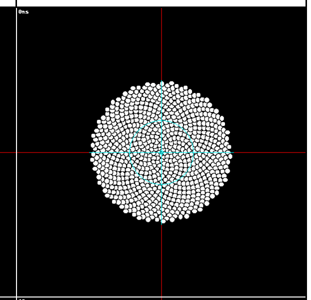
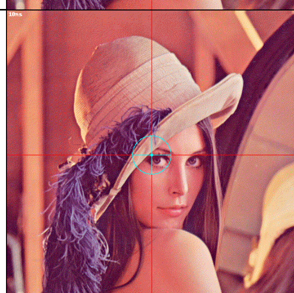
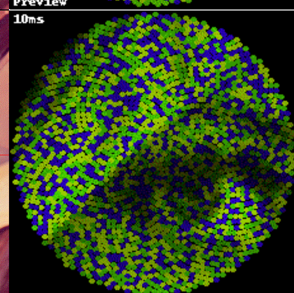
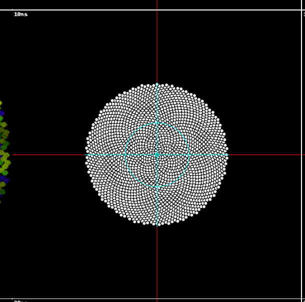
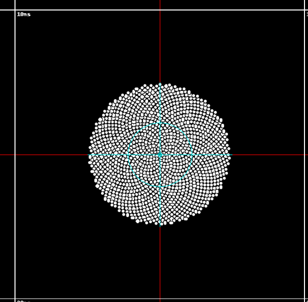
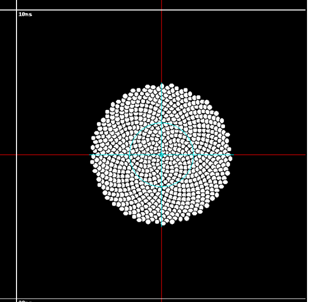
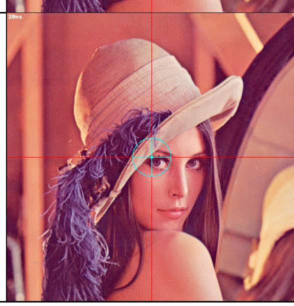
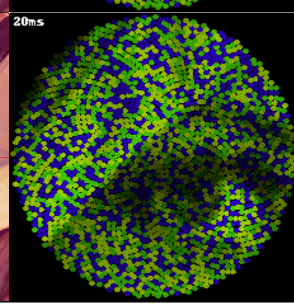
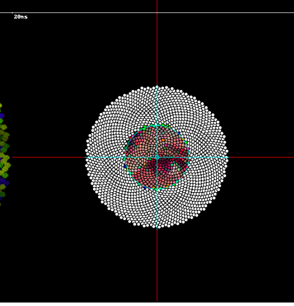
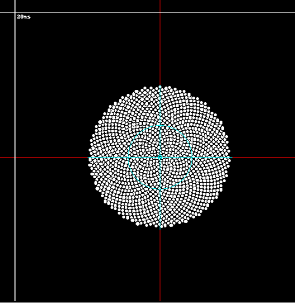
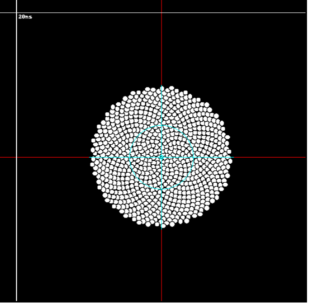
<table>
<tr><th colspan="6">Table 8: Time sequence of filling-out for natural image</th></tr>
<tr><th rowspan="2">Time (ticks)</th><th rowspan="2">Stimuli</th><th rowspan="2">Photoreceptor Mosaic</th><th colspan="3">Receptive Fields</th></tr>
<tr><th>Level 1</th><th>Level 2</th><th>Level 3</th></tr>
<tr><td>0</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>1</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

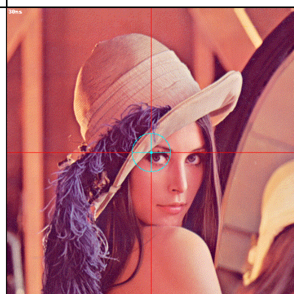
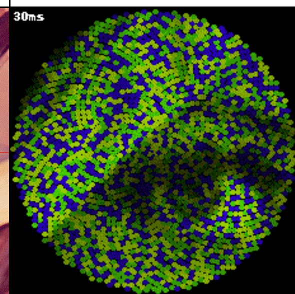
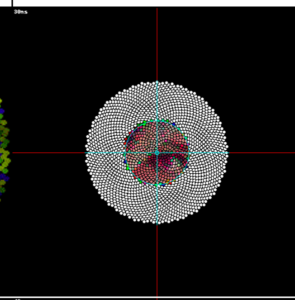
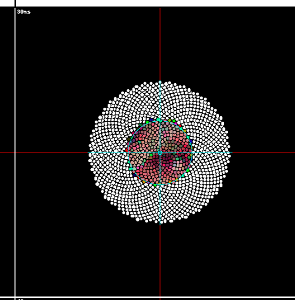
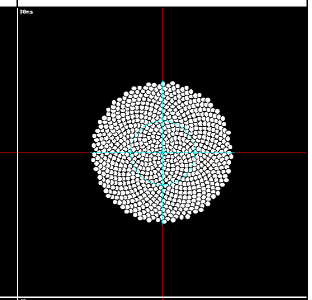
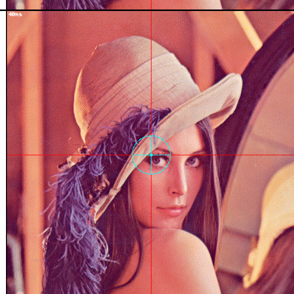
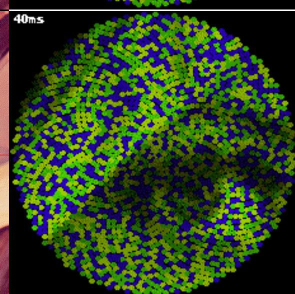
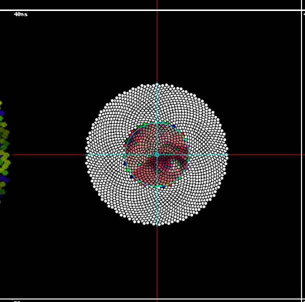
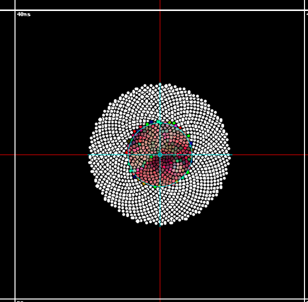
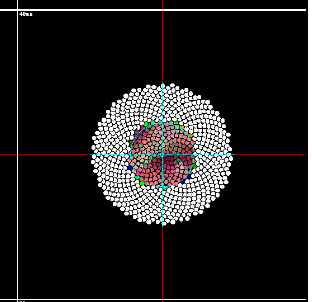
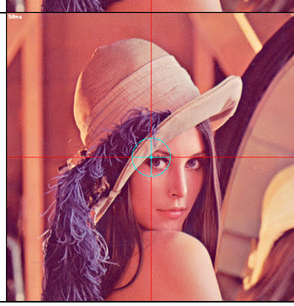
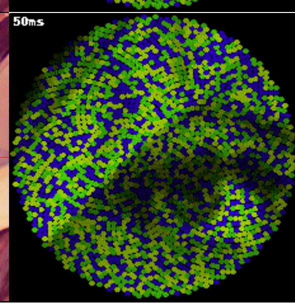
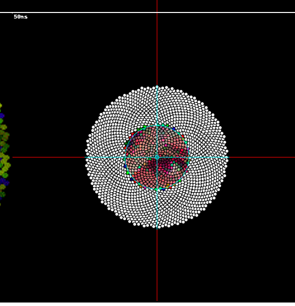
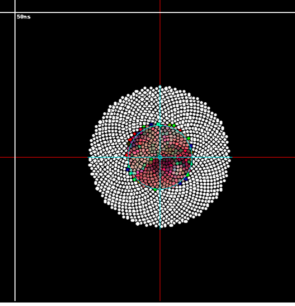
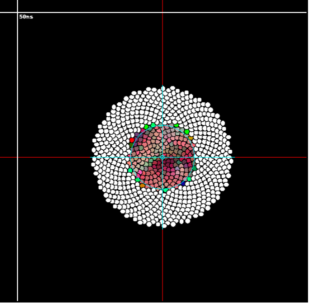
Table 8: Time sequence of filling-out for natural image					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
3					
4					
5					

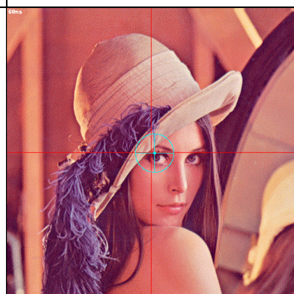
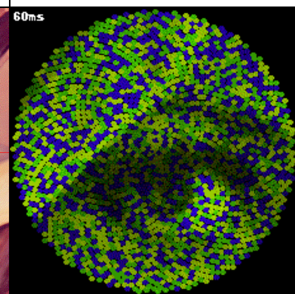
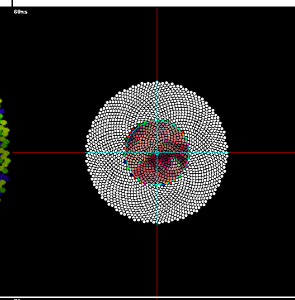
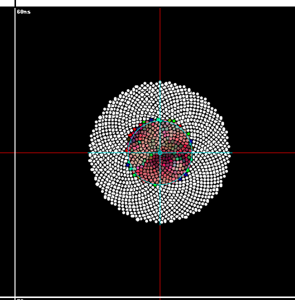
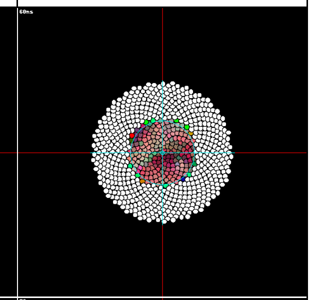
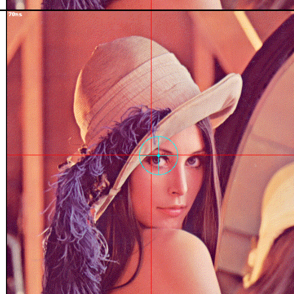
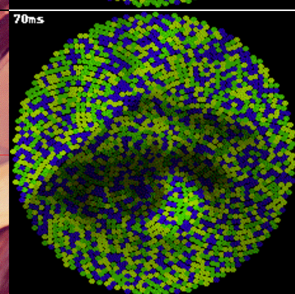
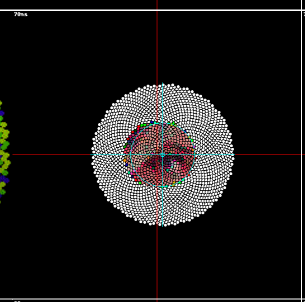
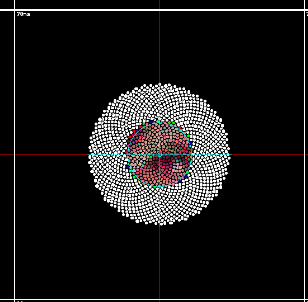
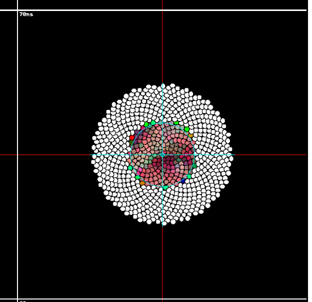
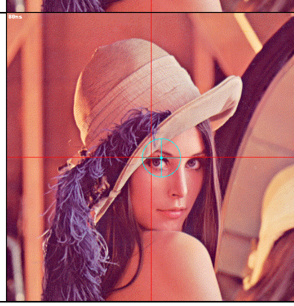
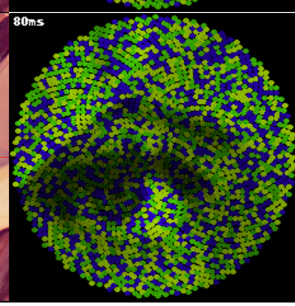
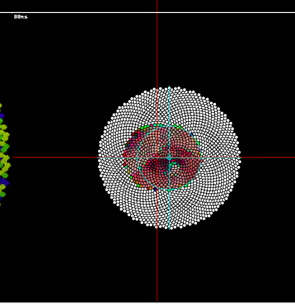
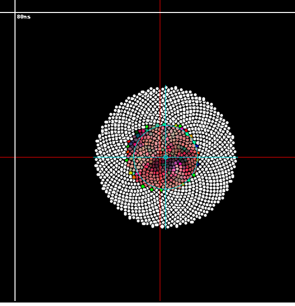
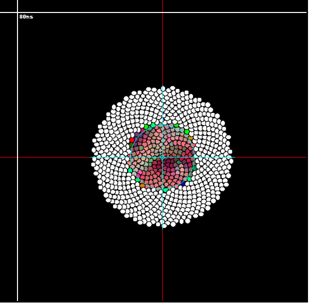
Table 8: Time sequence of filling-out for natural image					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
6					
7					
8					

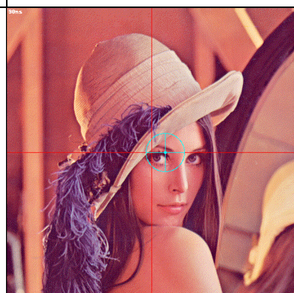
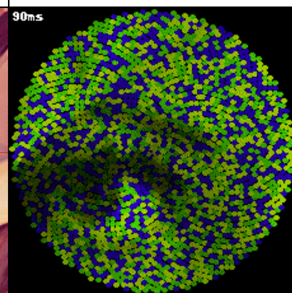
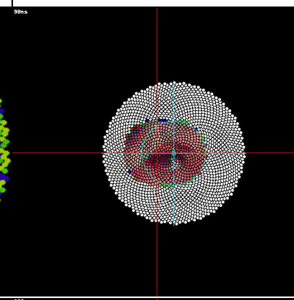
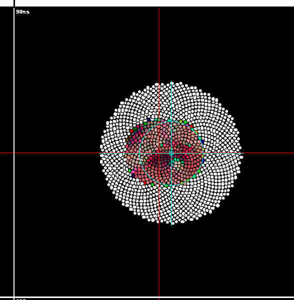
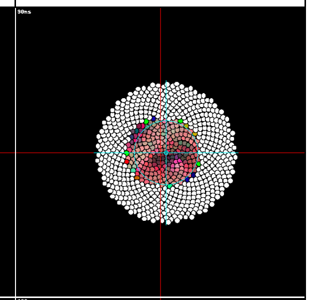
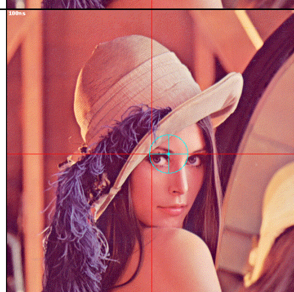
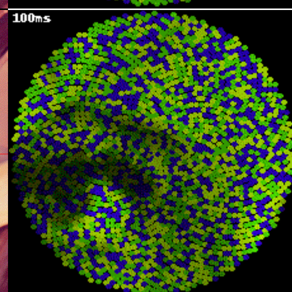
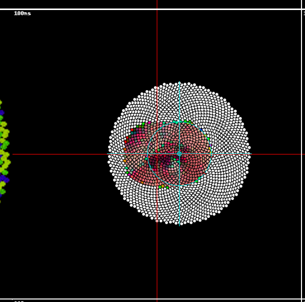
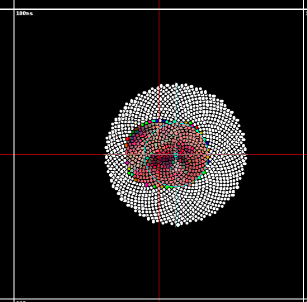
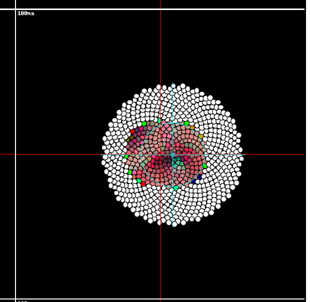
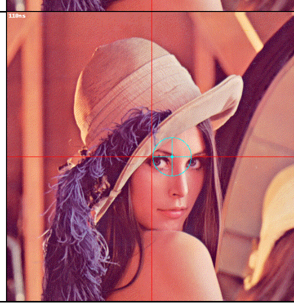
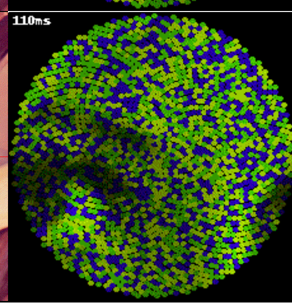
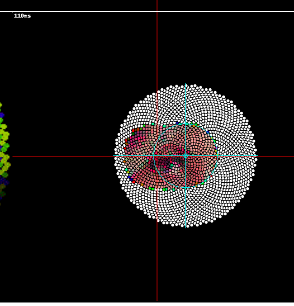
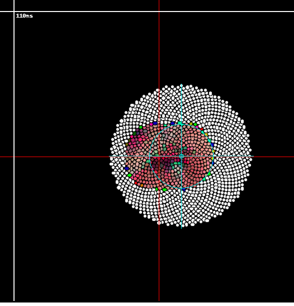
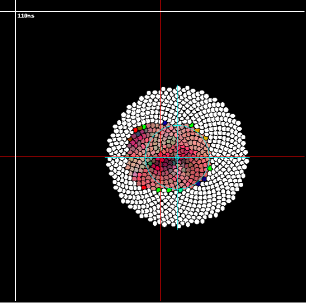
Table 8: Time sequence of filling-out for natural image					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
9					
10					
11					

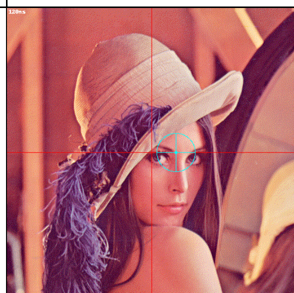
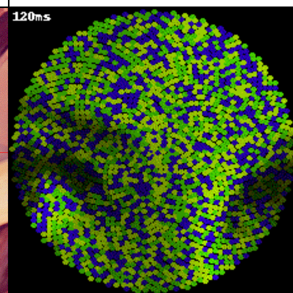
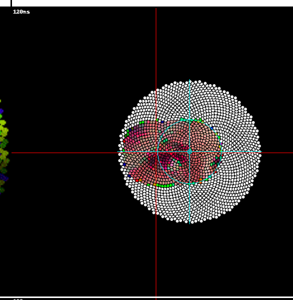
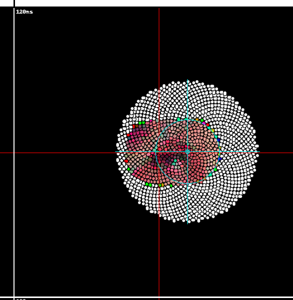
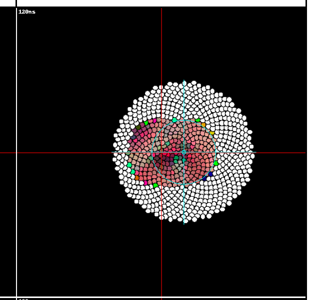
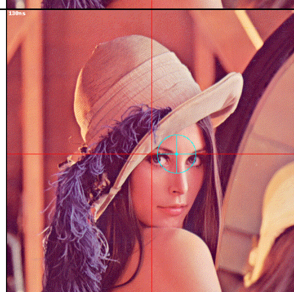
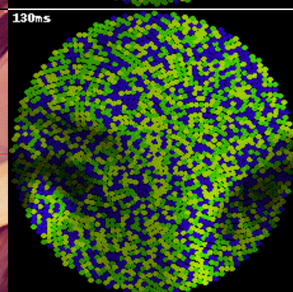
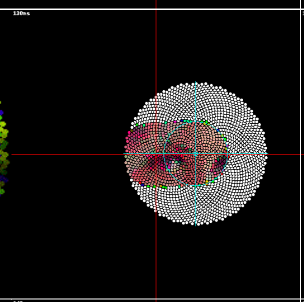
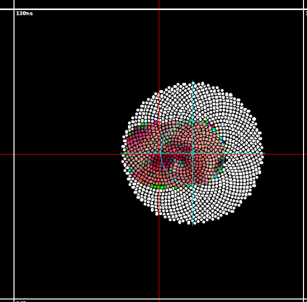
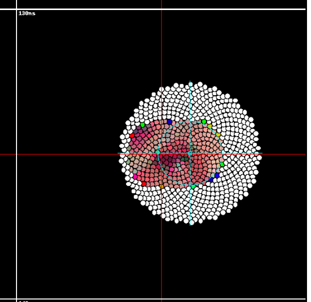
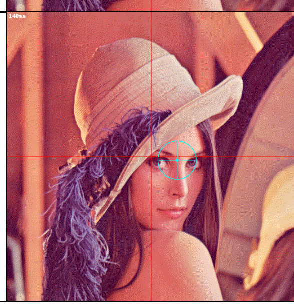
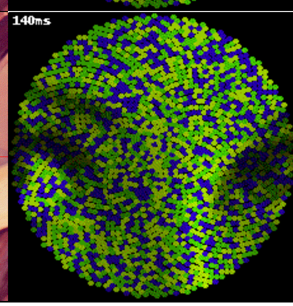
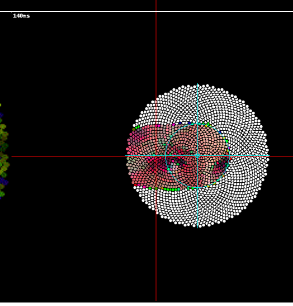
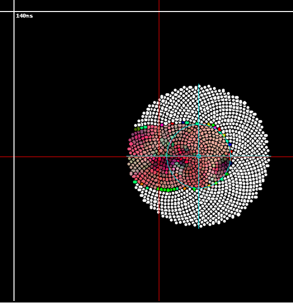
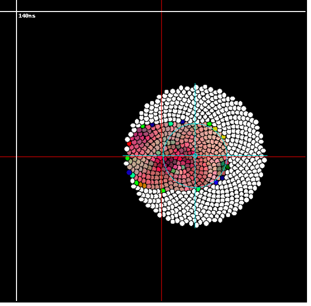
Table 8: Time sequence of filling-out for natural image					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
12					
13					
14					

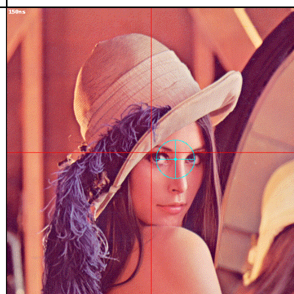
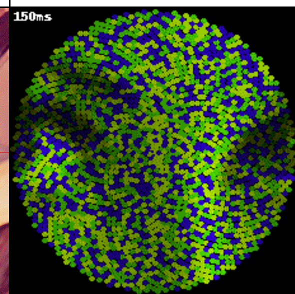
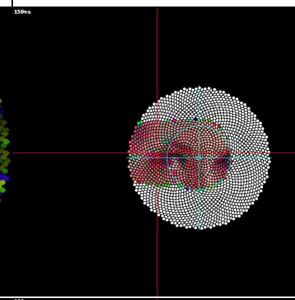
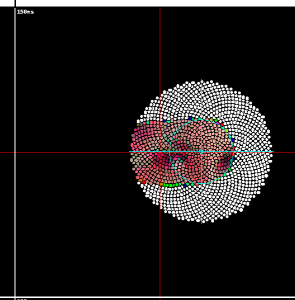
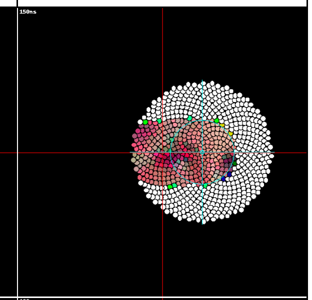
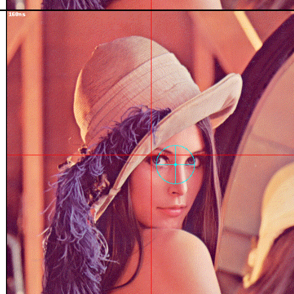
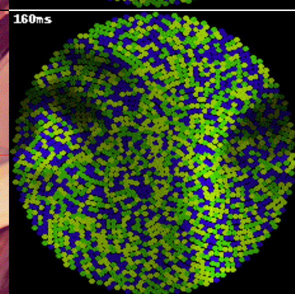
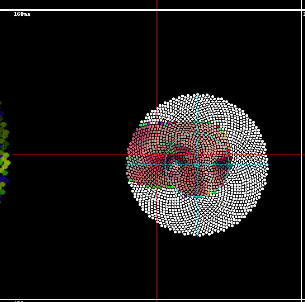
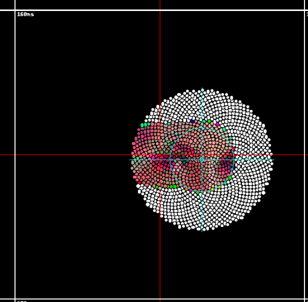
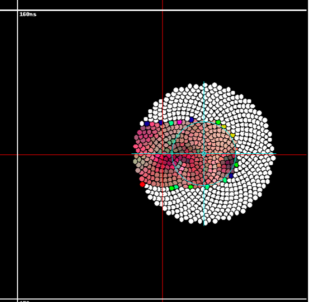
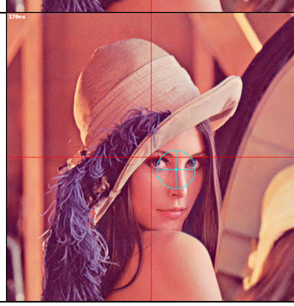
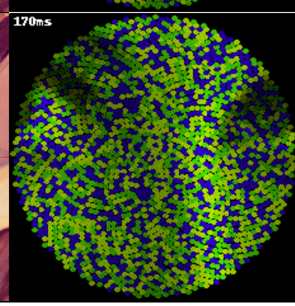
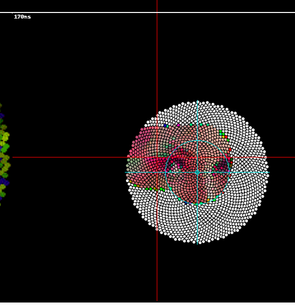
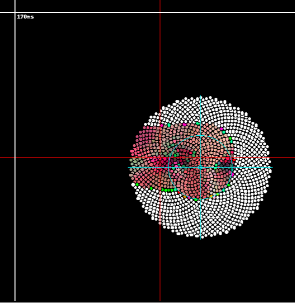
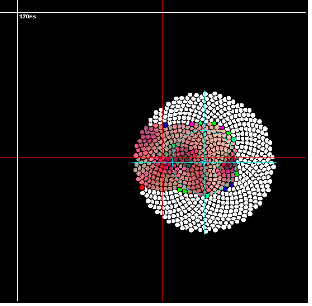
Table 8: Time sequence of filling-out for natural image					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
15					
16					
17					

Table 8: Time sequence of filling-out for natural image

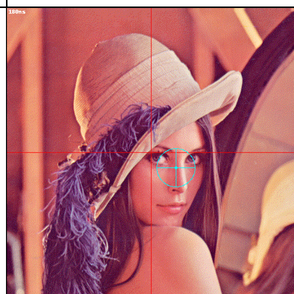
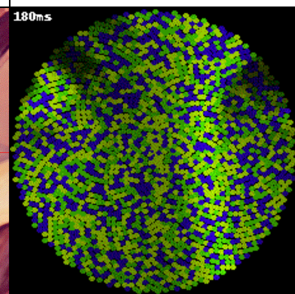
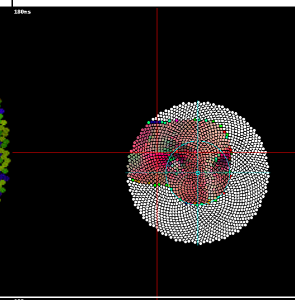
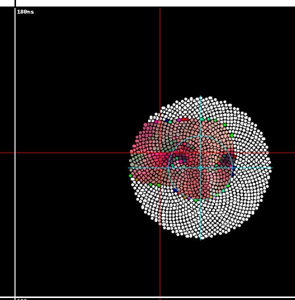
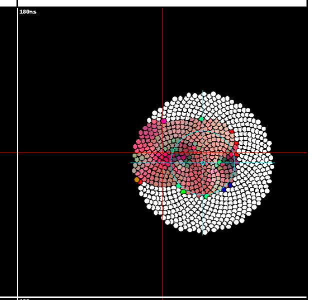
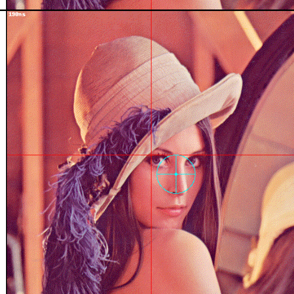
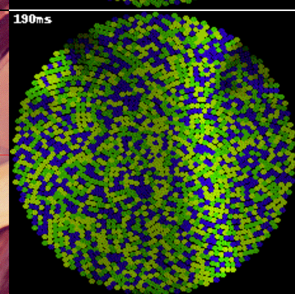
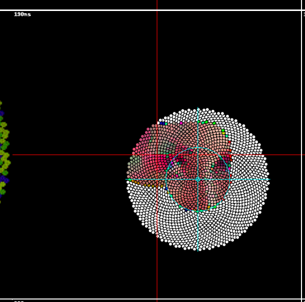
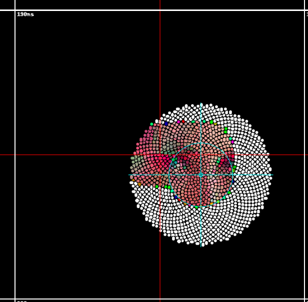
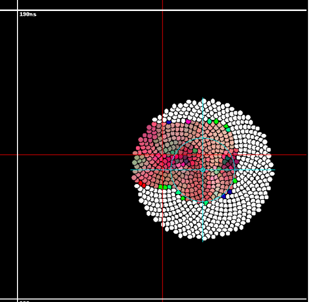
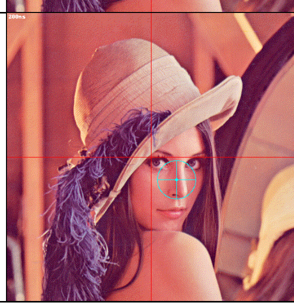
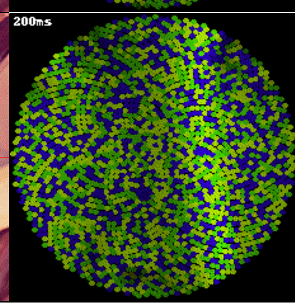
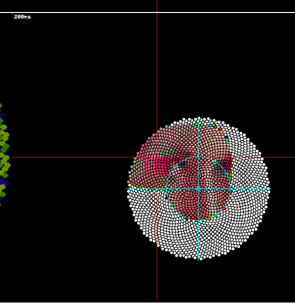
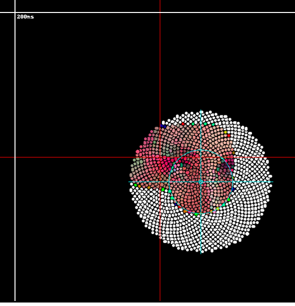
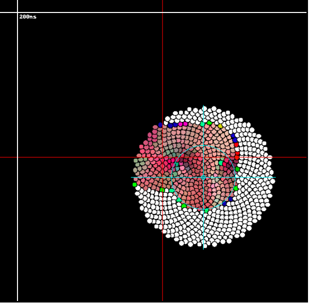
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
18					
19					
20					

Table 8: Time sequence of filling-out for natural image

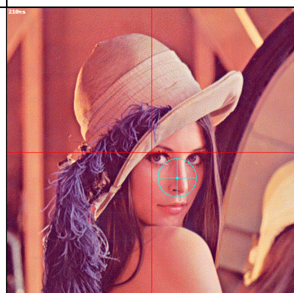
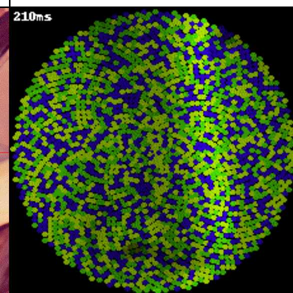
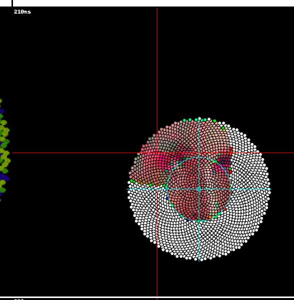
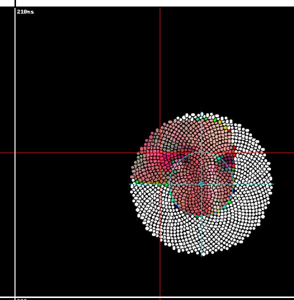
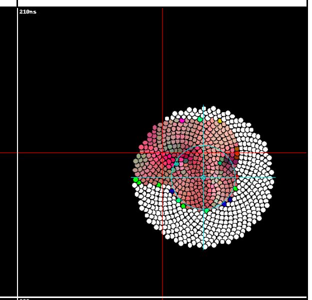
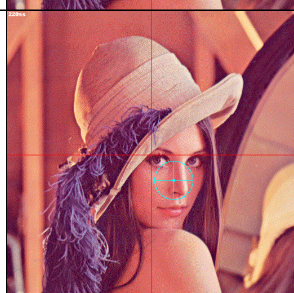
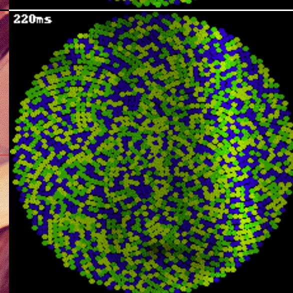
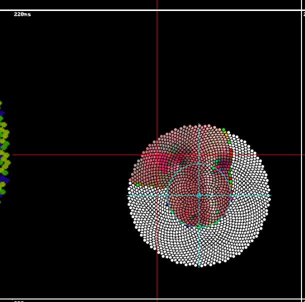
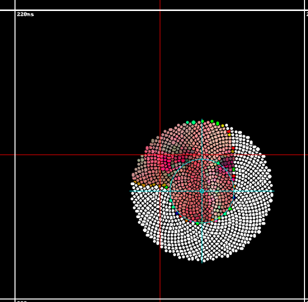
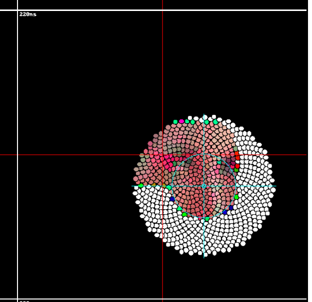
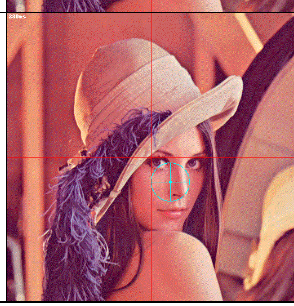
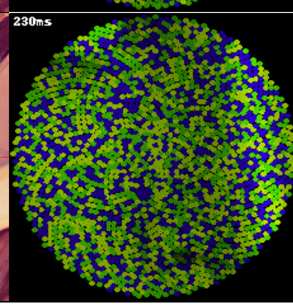
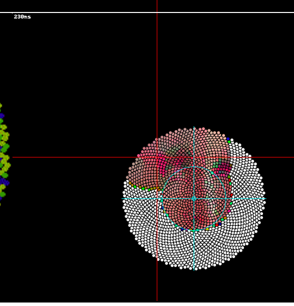
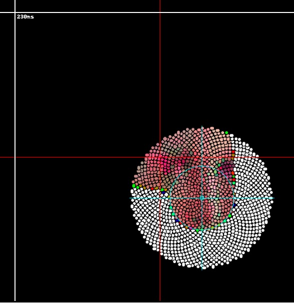
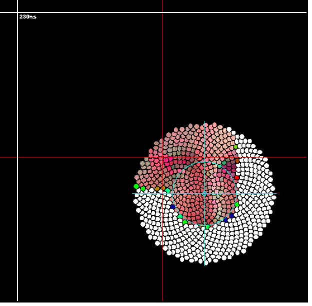
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
21					
22					
23					

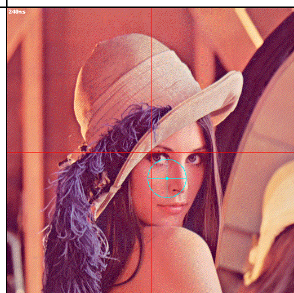
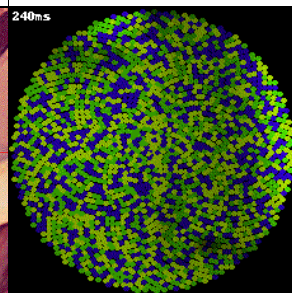
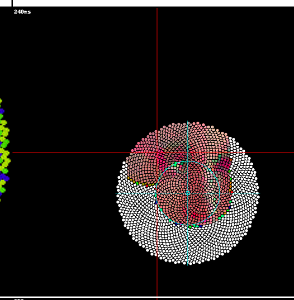
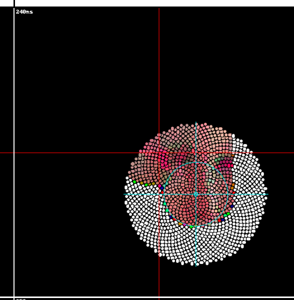
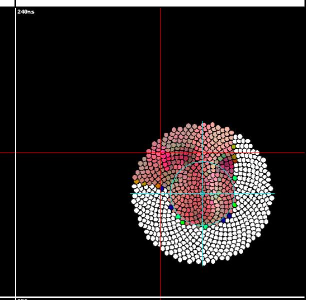
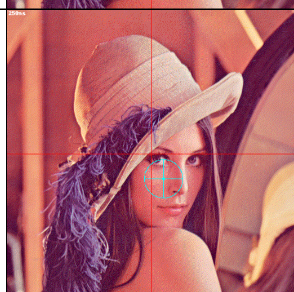
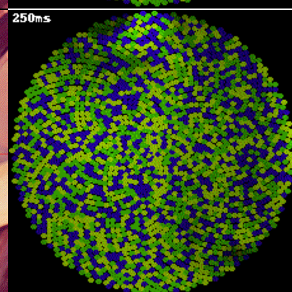
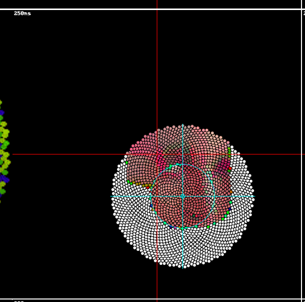
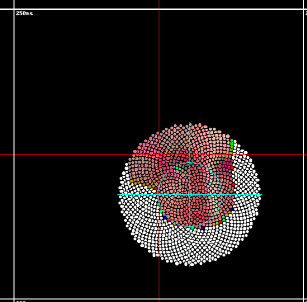
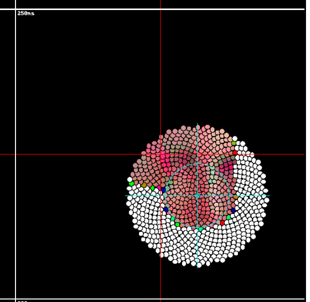
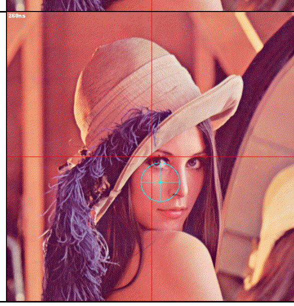
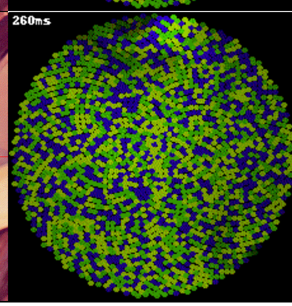
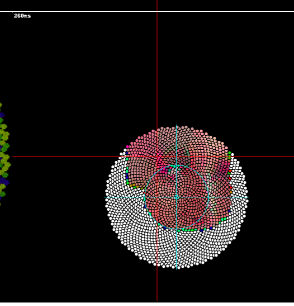
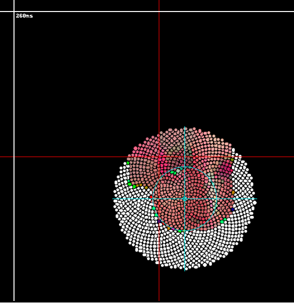
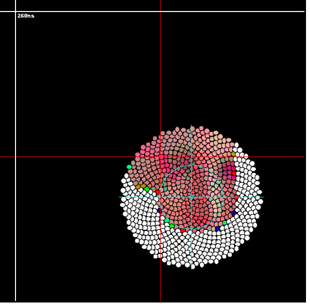
Table 8: Time sequence of filling-out for natural image					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
24					
25					
26					

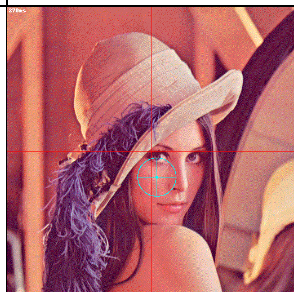
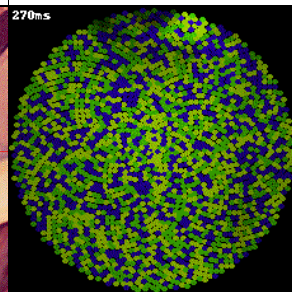
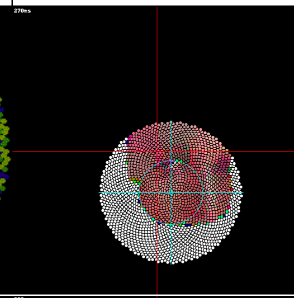
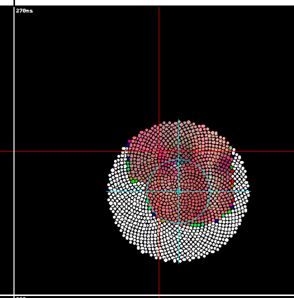
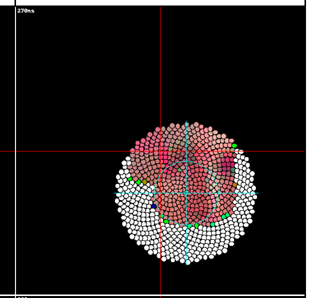
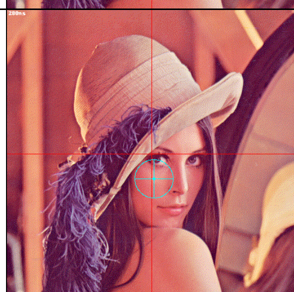
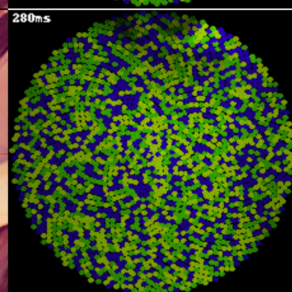
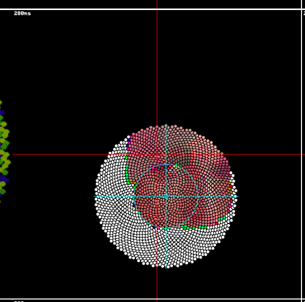
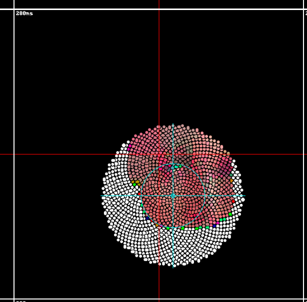
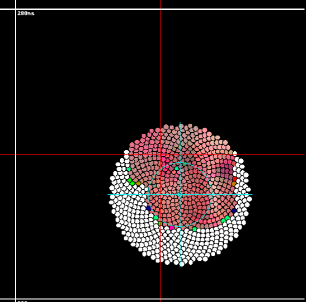
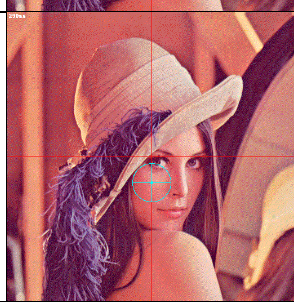
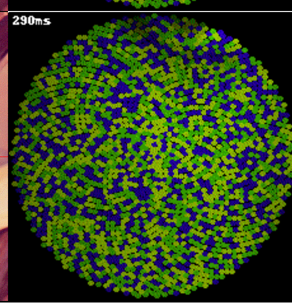
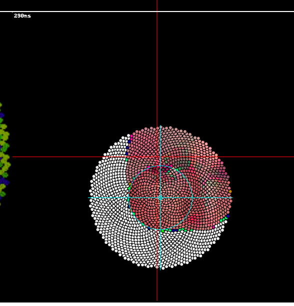
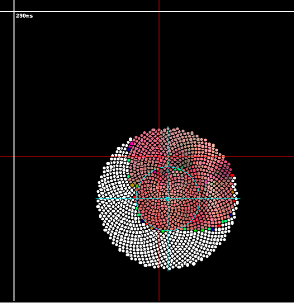
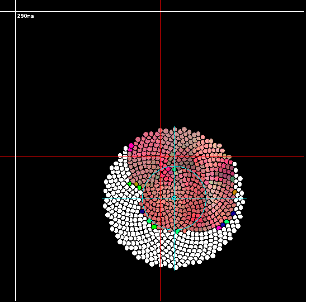
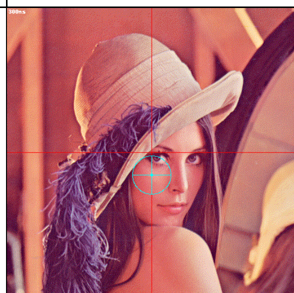
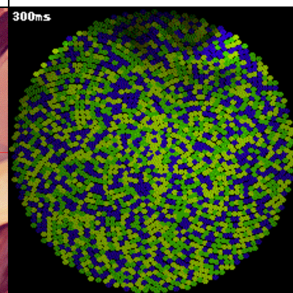
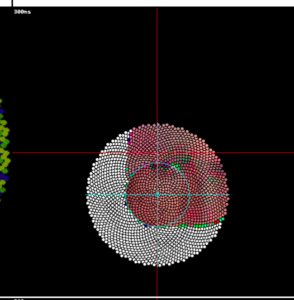
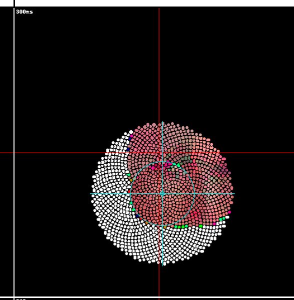
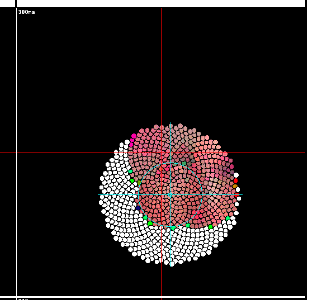
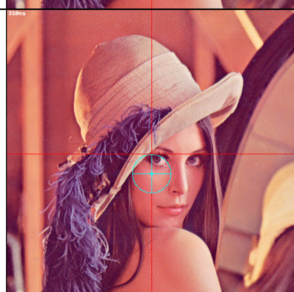
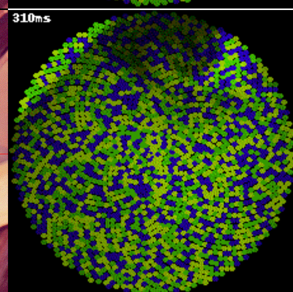
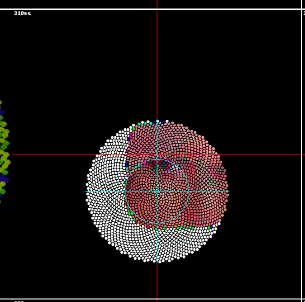
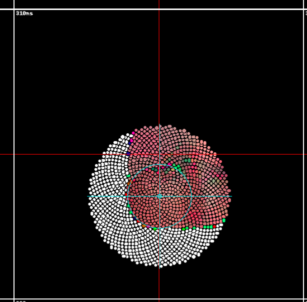
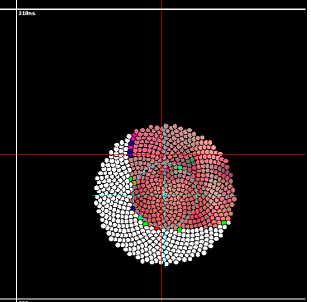
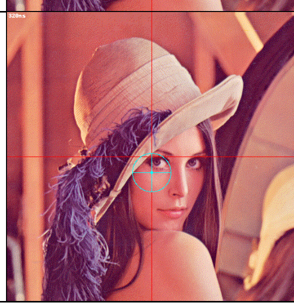
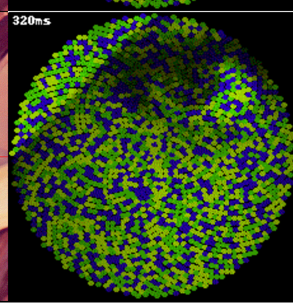
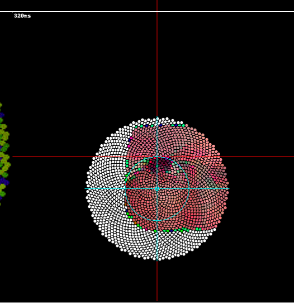
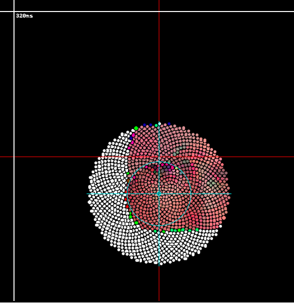
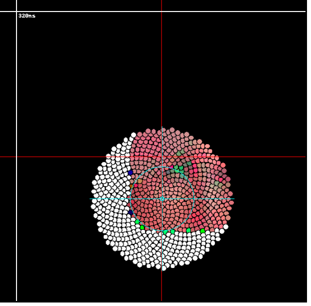
Table 8: Time sequence of filling-out for natural image					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
27					
28					
29					

Table 8: Time sequence of filling-out for natural image					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
30					
31					
32					

3.3.3 Test 3 results: Dynamic image with surface gradients (Chaser)

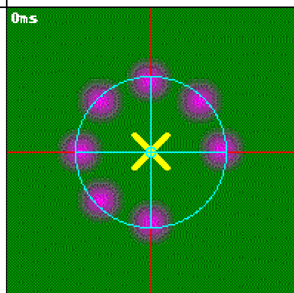
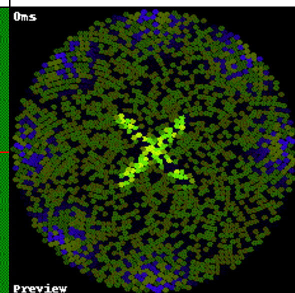
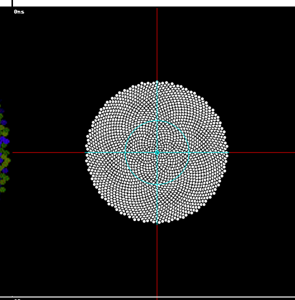
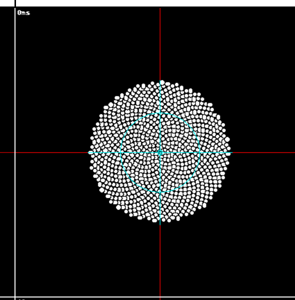
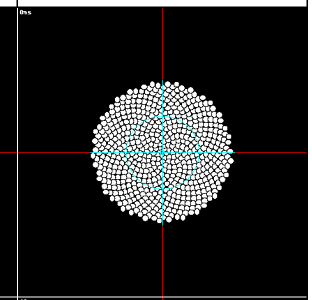
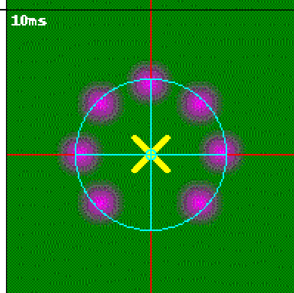
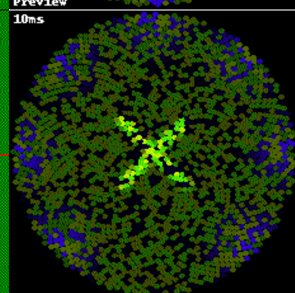
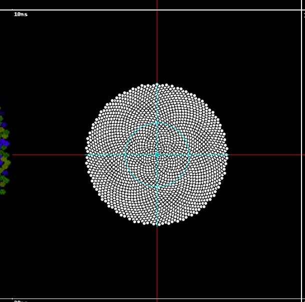
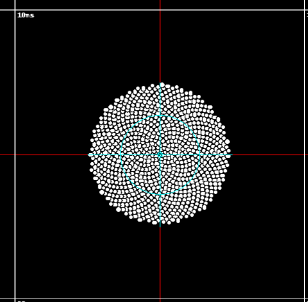
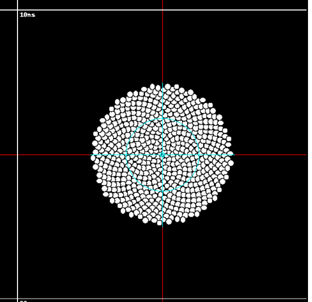
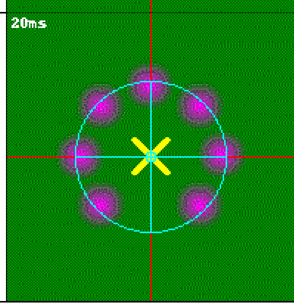
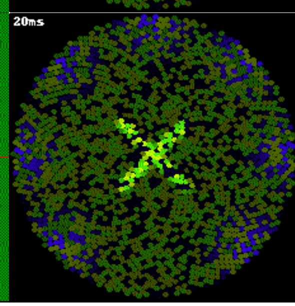
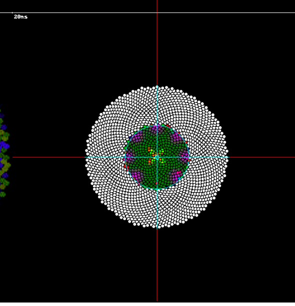
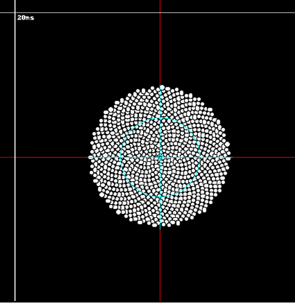
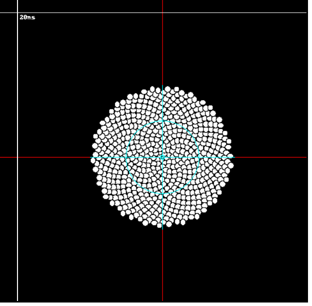
Table 9: Time sequence of filling-out for dynamic image with surface gradients					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
0					
1					
2					

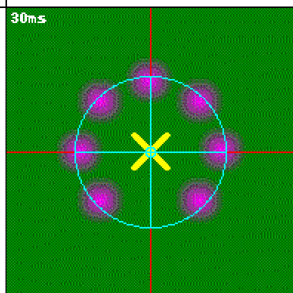
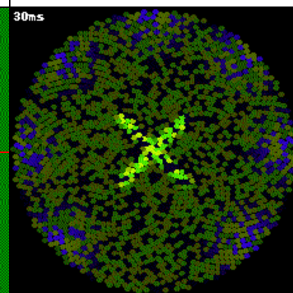
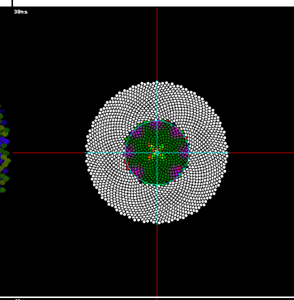
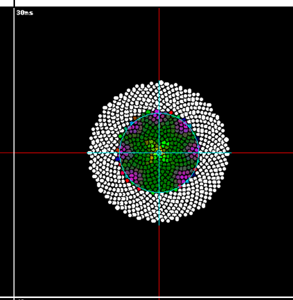
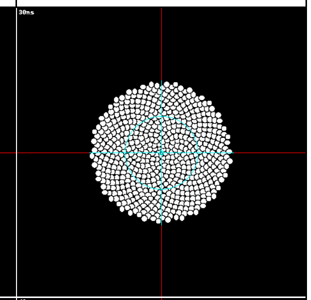
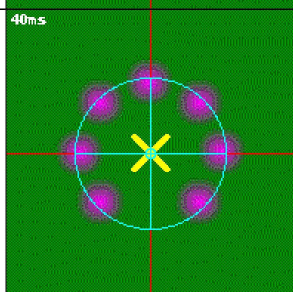
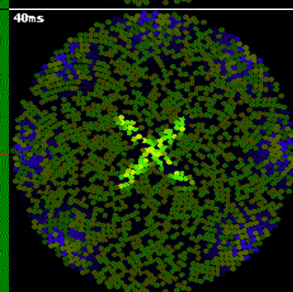
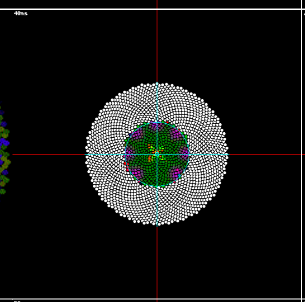
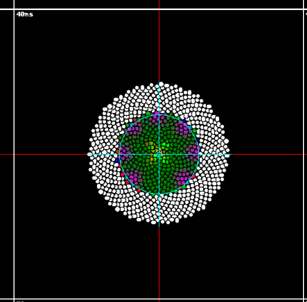
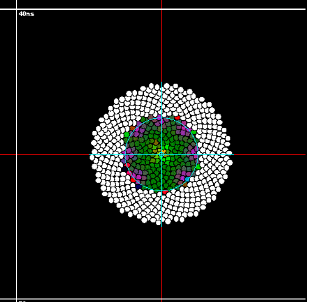
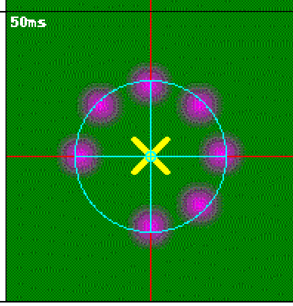
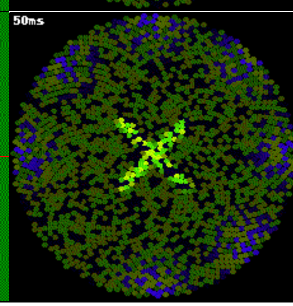
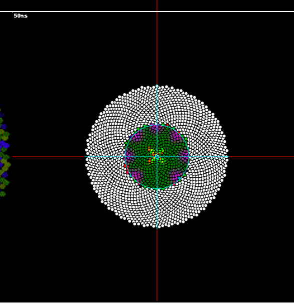
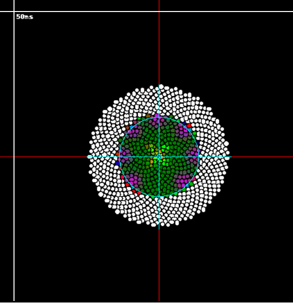
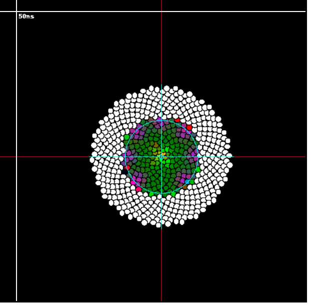
Table 9: Time sequence of filling-out for dynamic image with surface gradients					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
3					
4					
5					

Table 9: Time sequence of filling-out for dynamic image with surface gradients

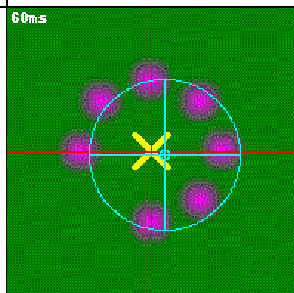
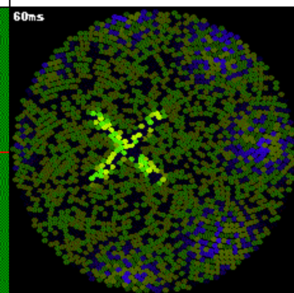
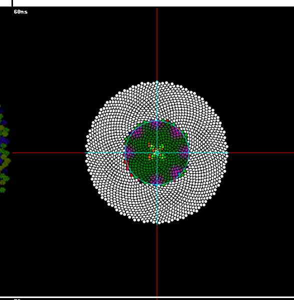
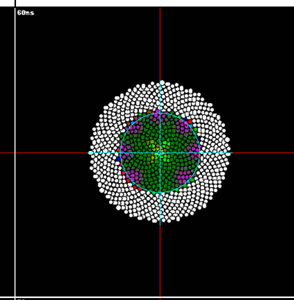
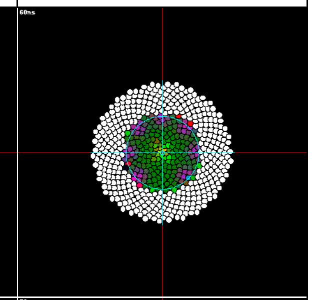
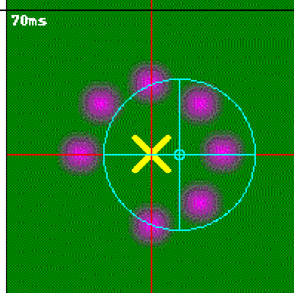
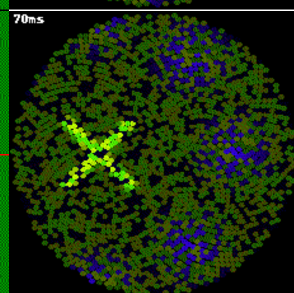
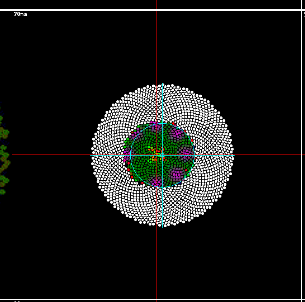
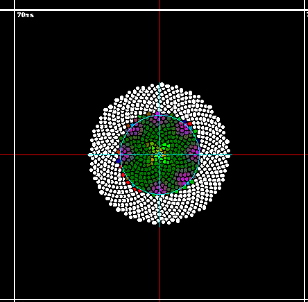
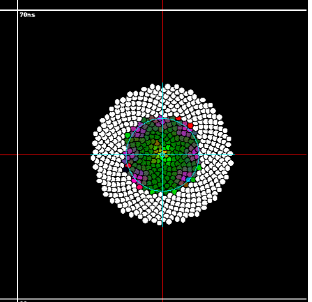
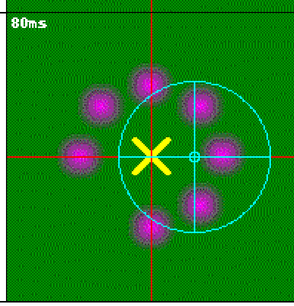
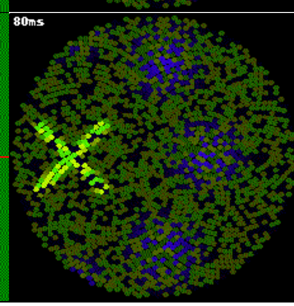
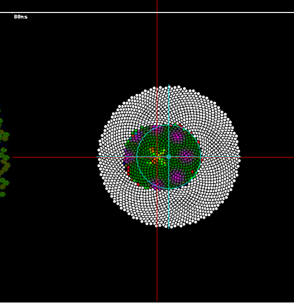
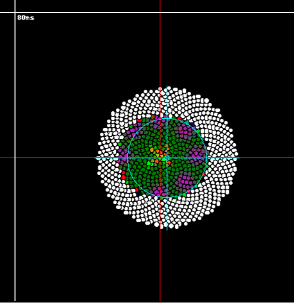
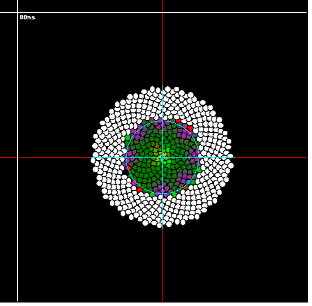
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
6					
7					
8					

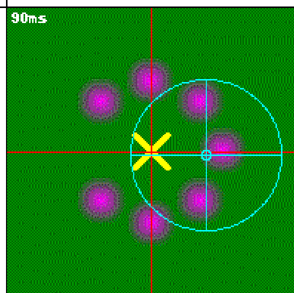
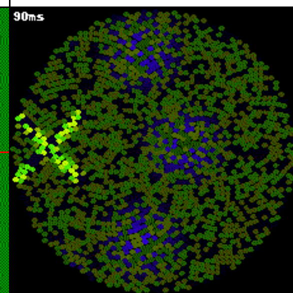
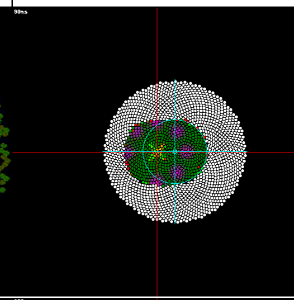
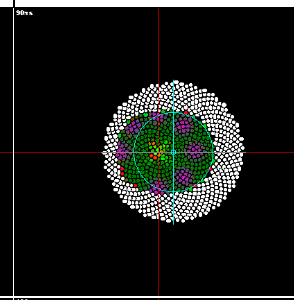
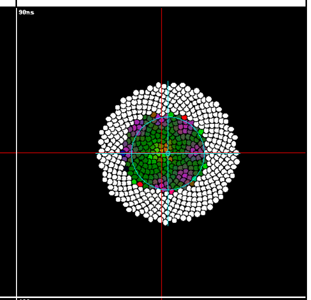
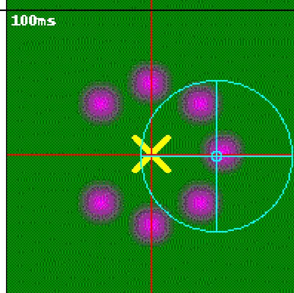
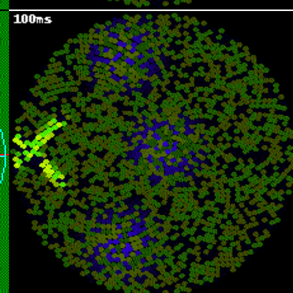
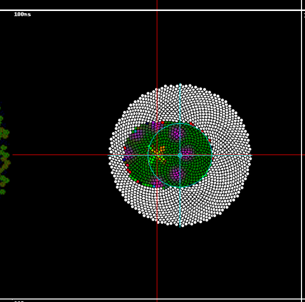
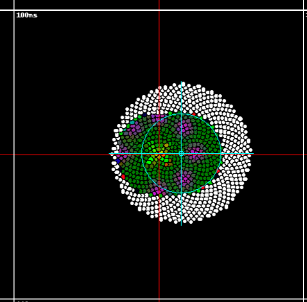
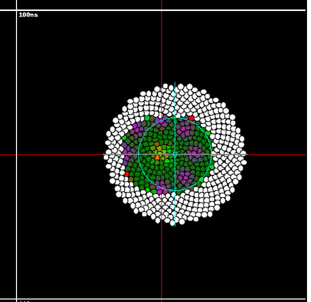
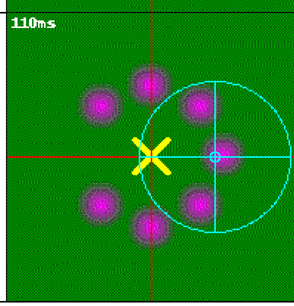
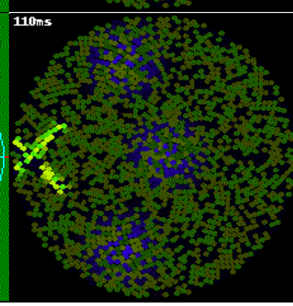
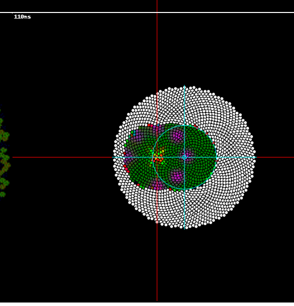
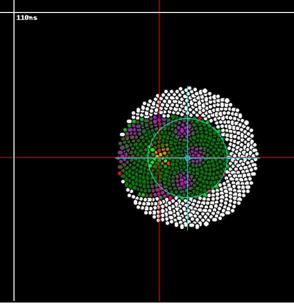
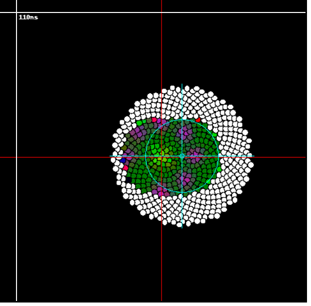
Table 9: Time sequence of filling-out for dynamic image with surface gradients					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
9					
10					
11					

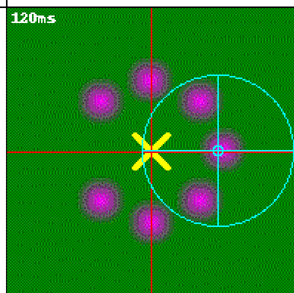
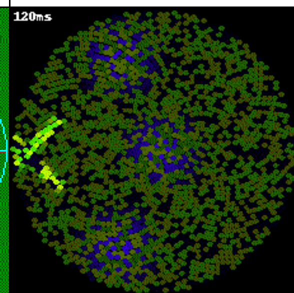
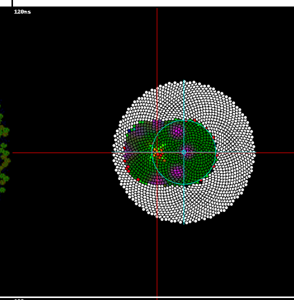
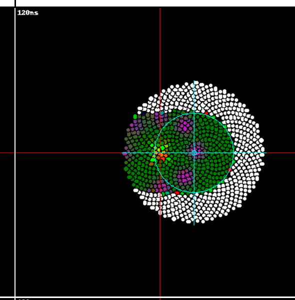
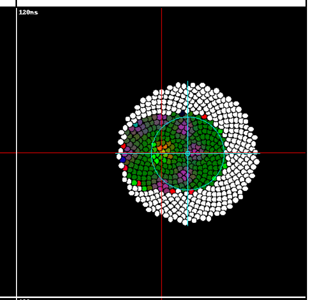
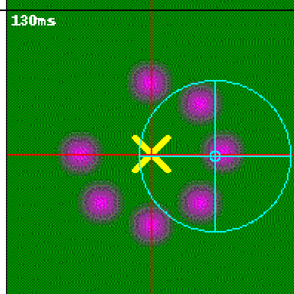
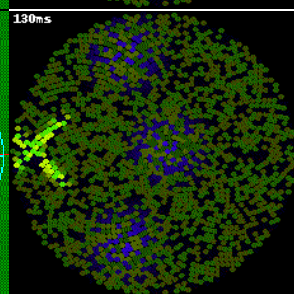
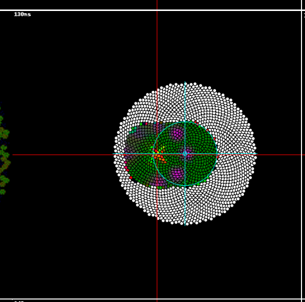
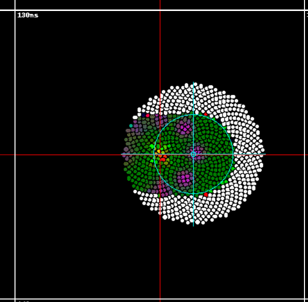
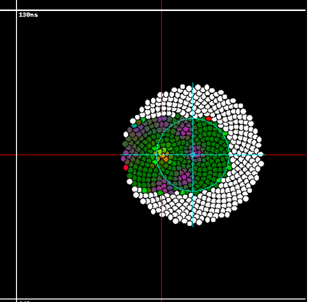
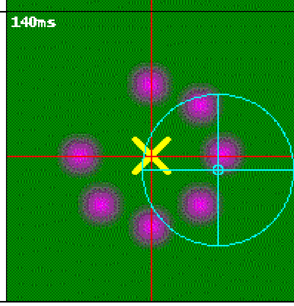
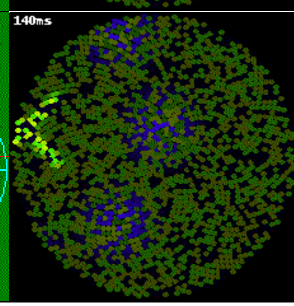
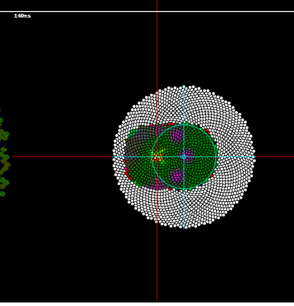
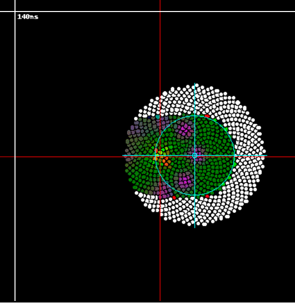
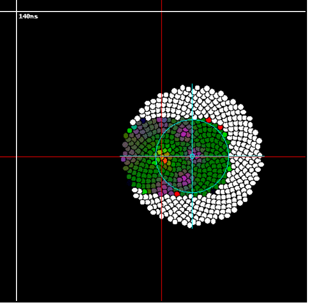
Table 9: Time sequence of filling-out for dynamic image with surface gradients					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
12					
13					
14					

Table 9: Time sequence of filling-out for dynamic image with surface gradients

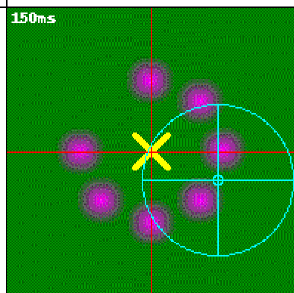
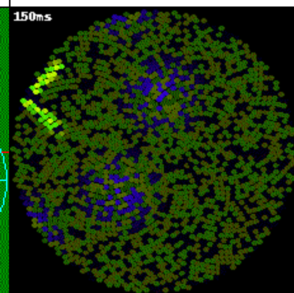
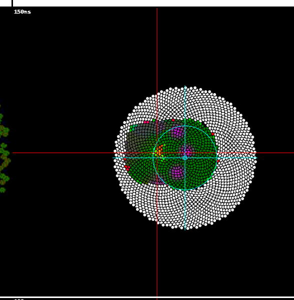
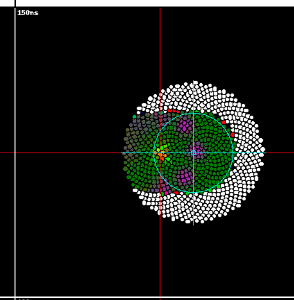
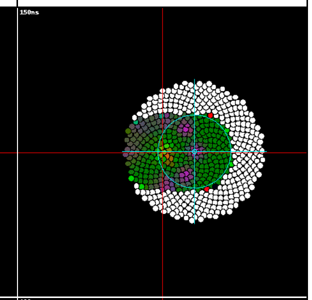
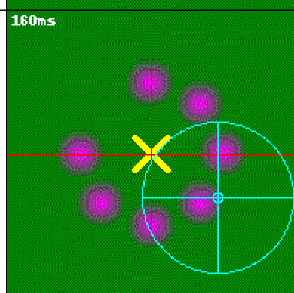
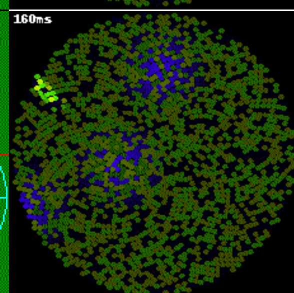
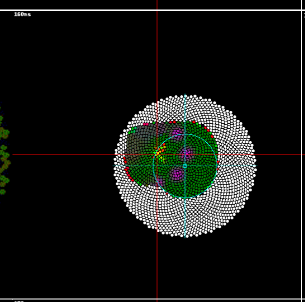
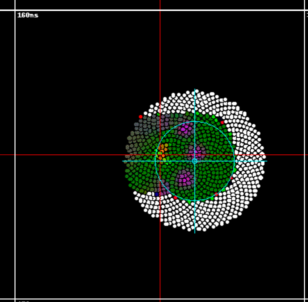
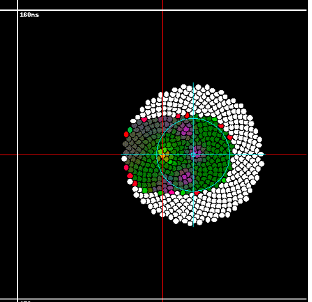
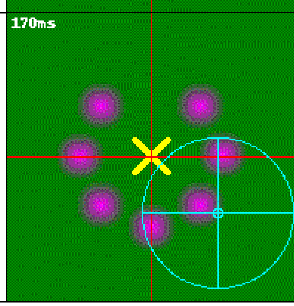
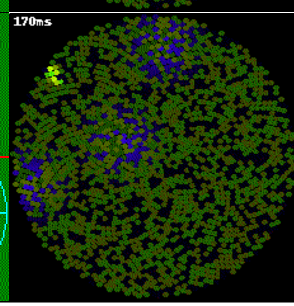
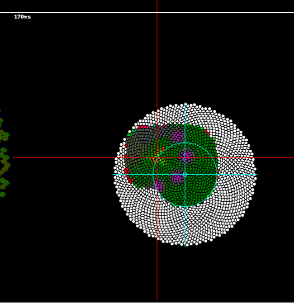
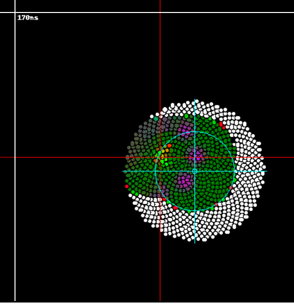
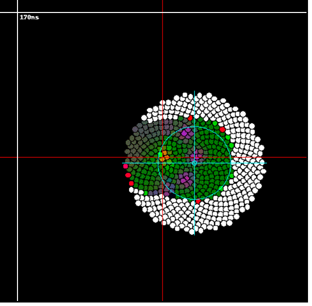
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
15					
16					
17					

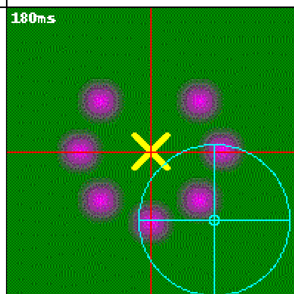
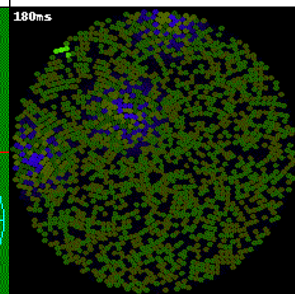
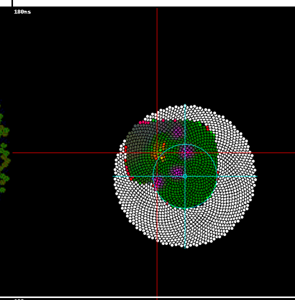
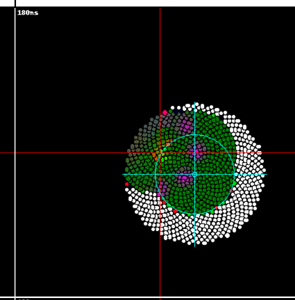
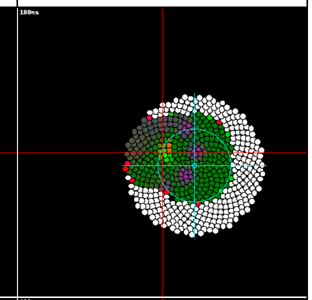
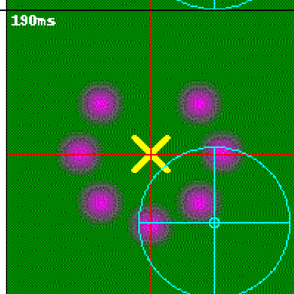
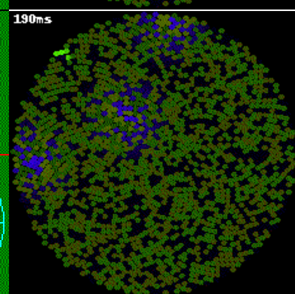
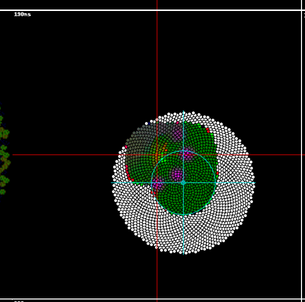
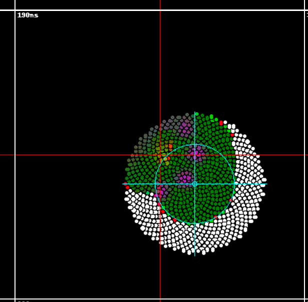
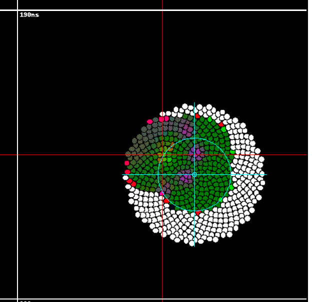
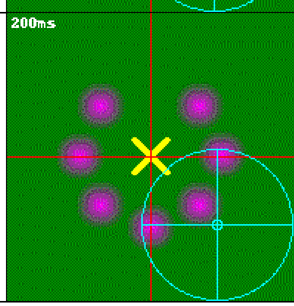
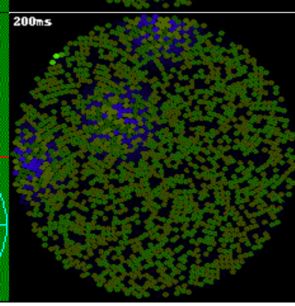
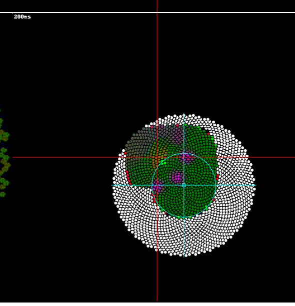
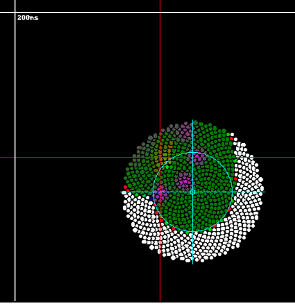
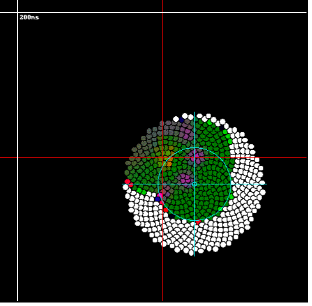
Table 9: Time sequence of filling-out for dynamic image with surface gradients					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
18					
19					
20					

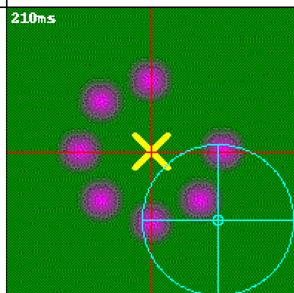
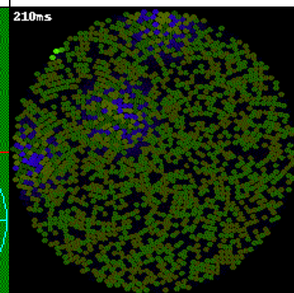
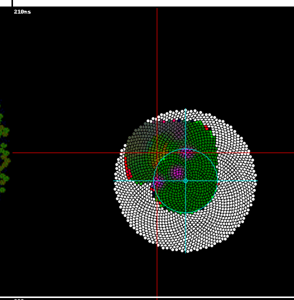
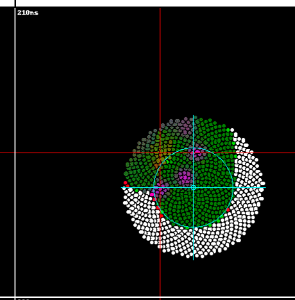
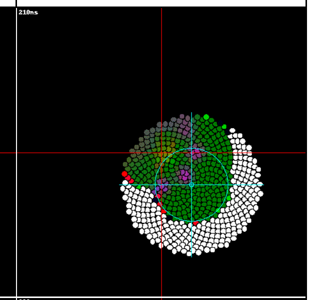
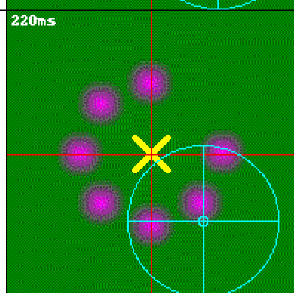
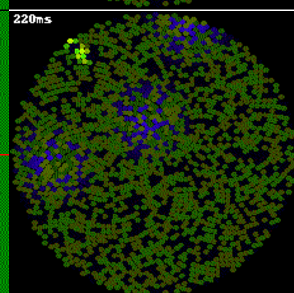
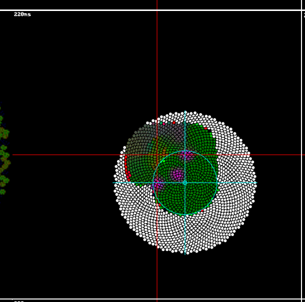
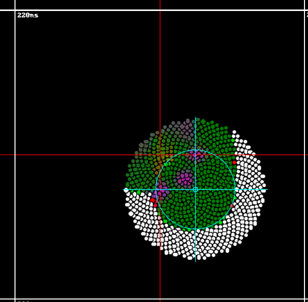
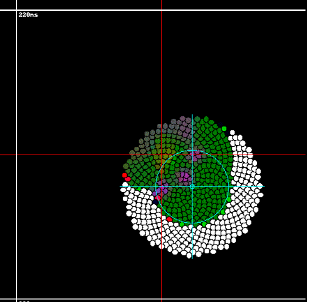
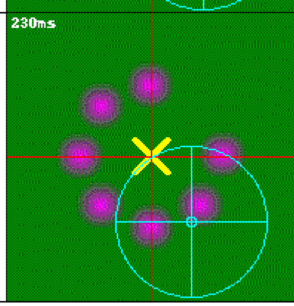
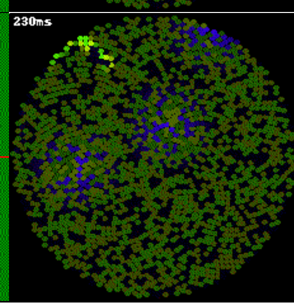
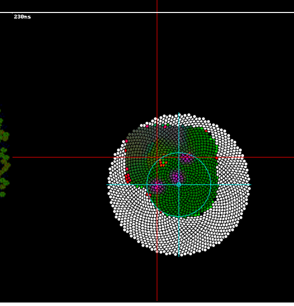
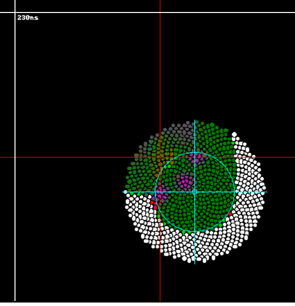
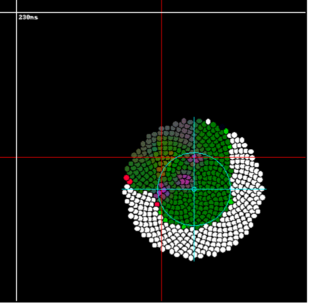
Table 9: Time sequence of filling-out for dynamic image with surface gradients					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
21					
22					
23					

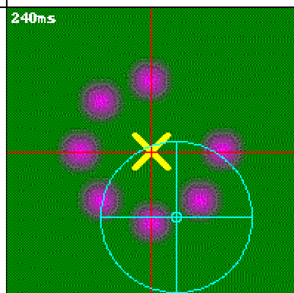
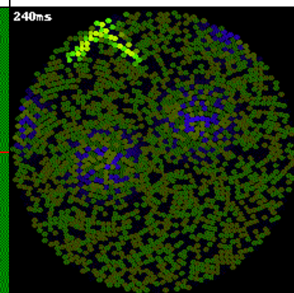
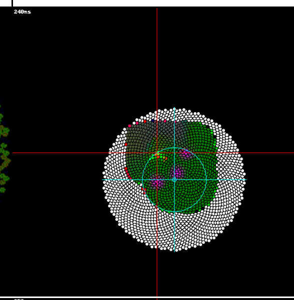
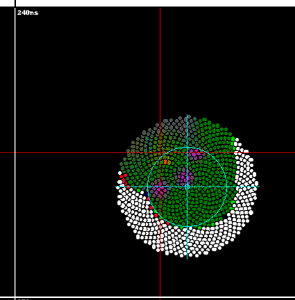
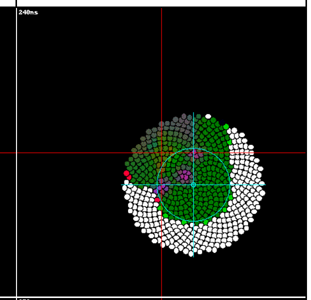
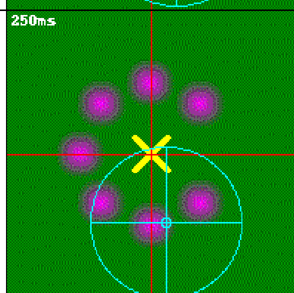
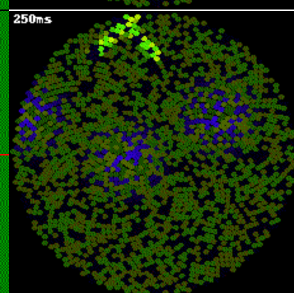
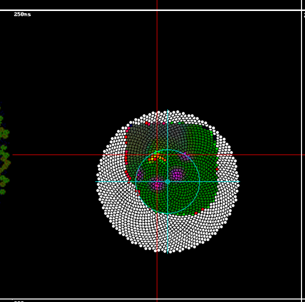
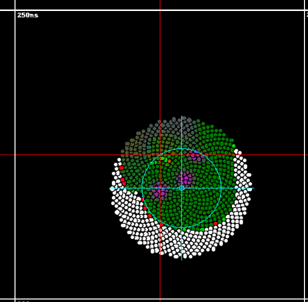
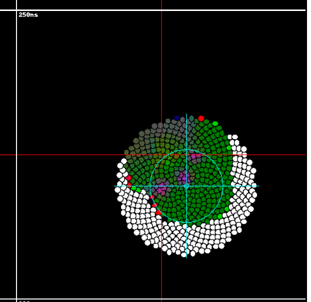
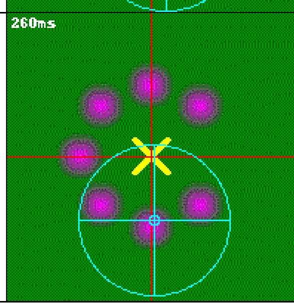
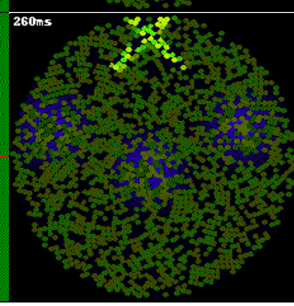
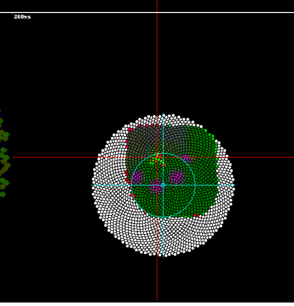
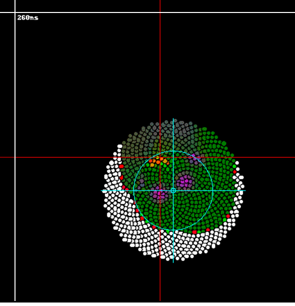
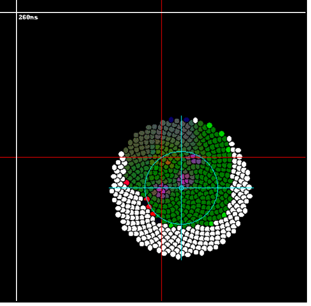
Table 9: Time sequence of filling-out for dynamic image with surface gradients					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
24					
25					
26					

Table 9: Time sequence of filling-out for dynamic image with surface gradients

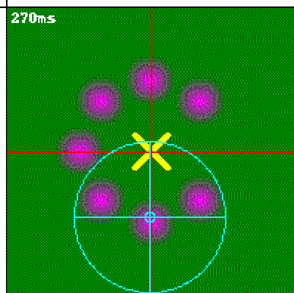
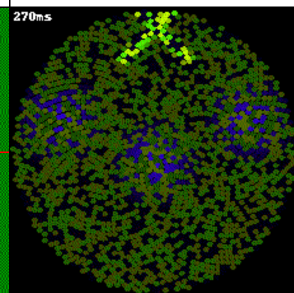
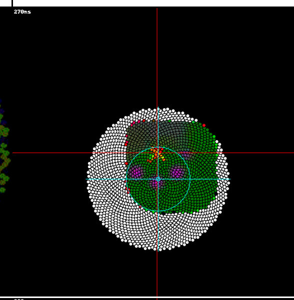
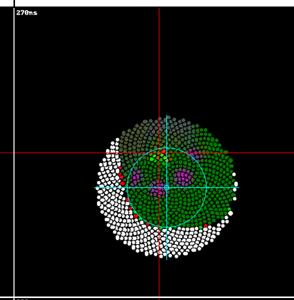
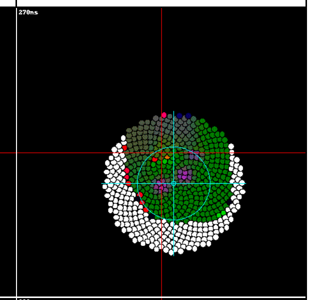
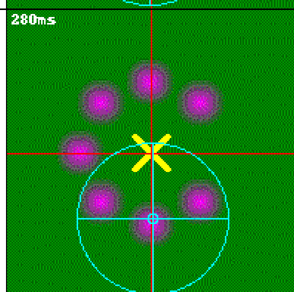
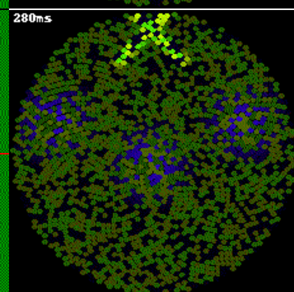
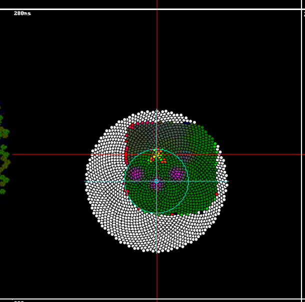
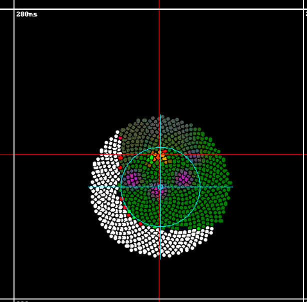
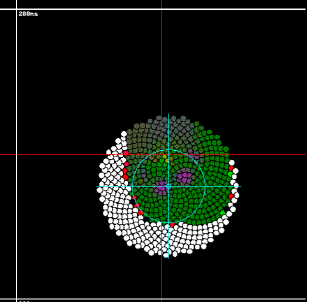
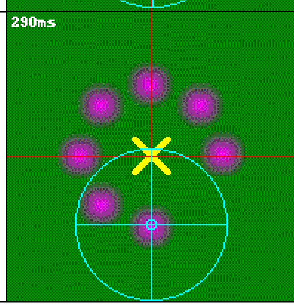
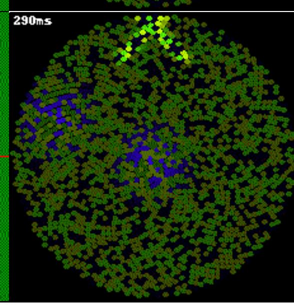
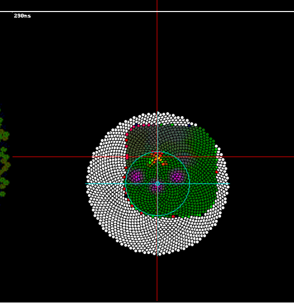
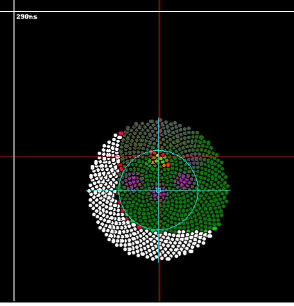
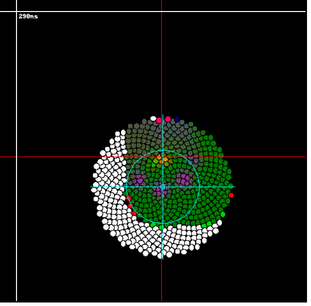
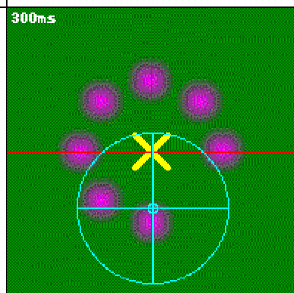
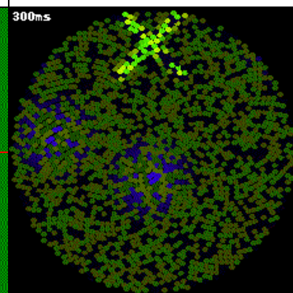
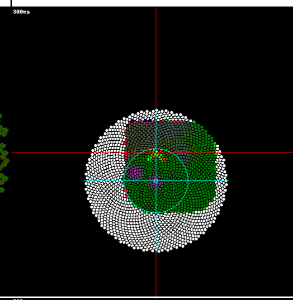
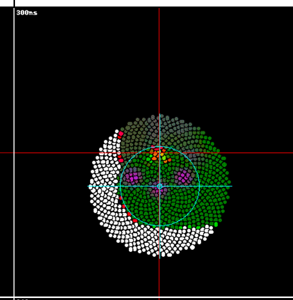
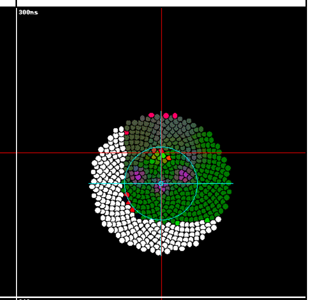
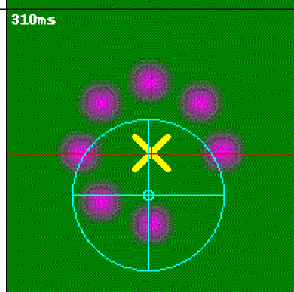
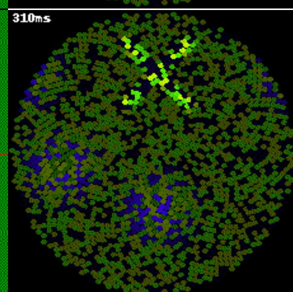
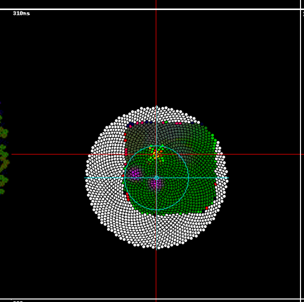
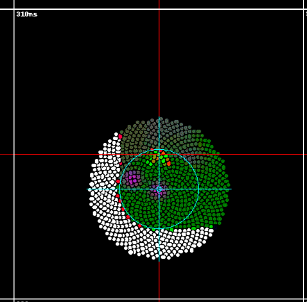
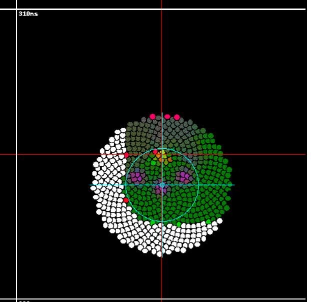
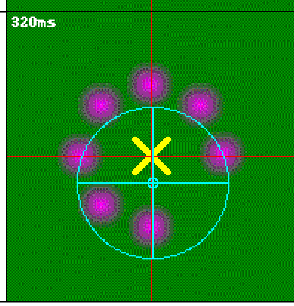
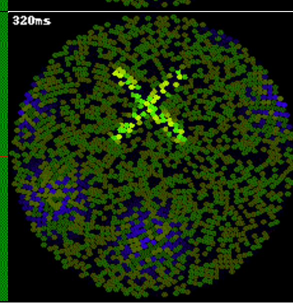
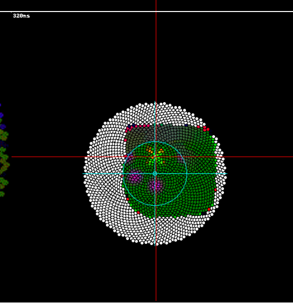
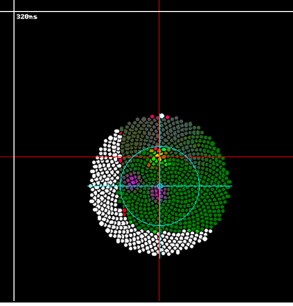
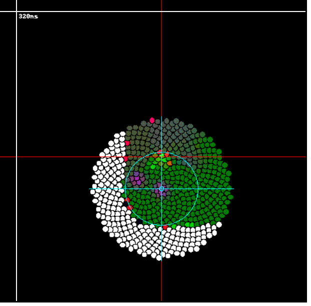
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
27					
28					
29					

Table 9: Time sequence of filling-out for dynamic image with surface gradients					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
30					
31					
32					

3.3.4 Test 4 results: Edge under varying RF sizes

Table 10: Time sequence of filling-out with edge under varying RF sizes

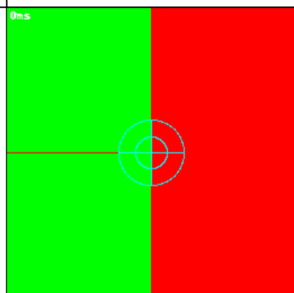
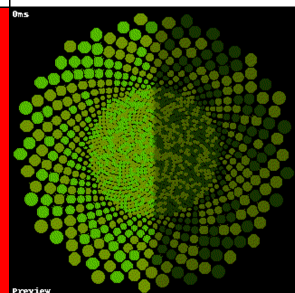
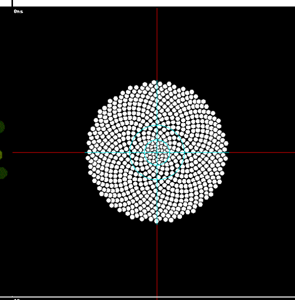
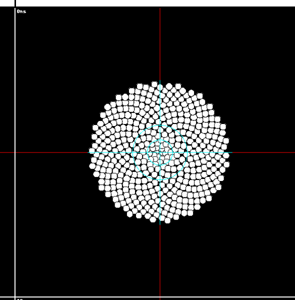
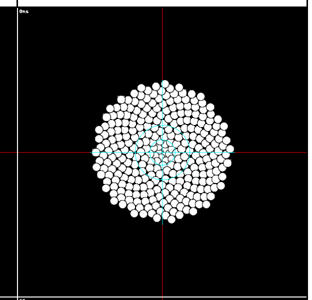
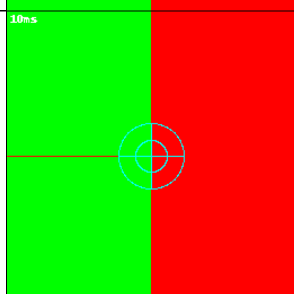
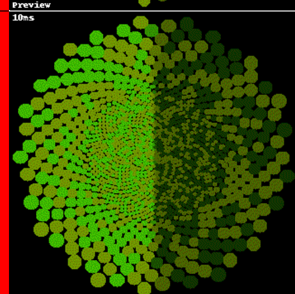
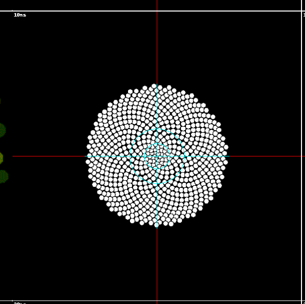
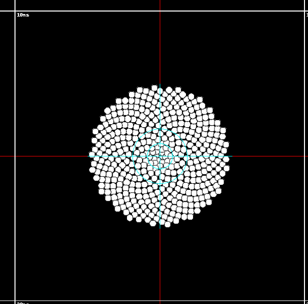
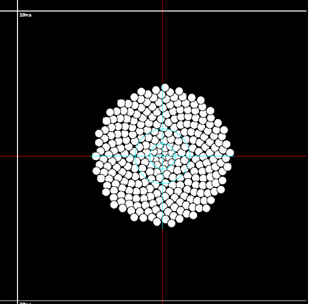
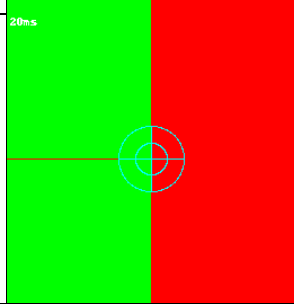
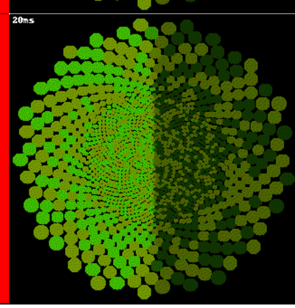
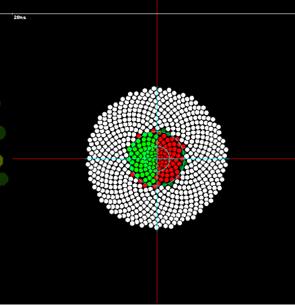
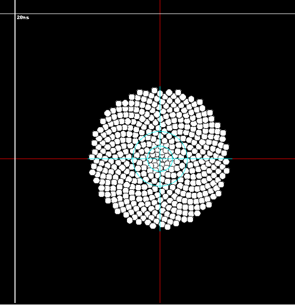
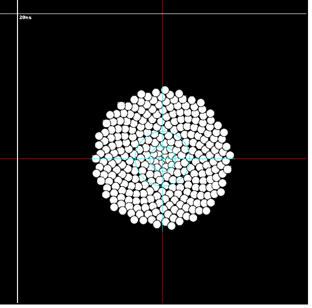
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
0					
1					
2					

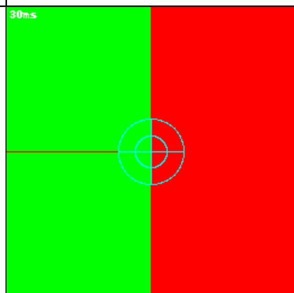
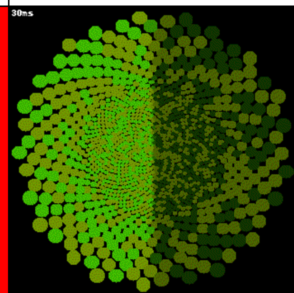
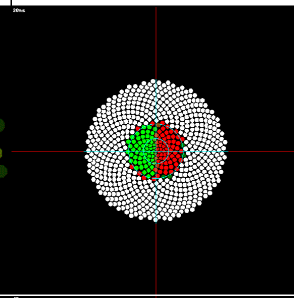
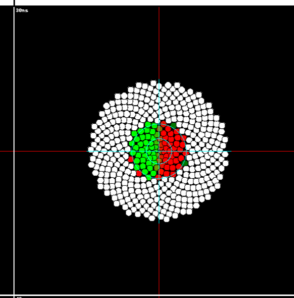
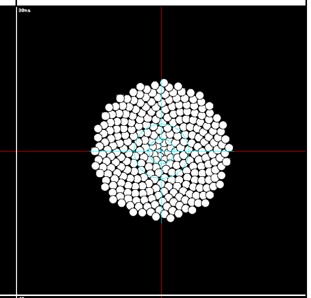
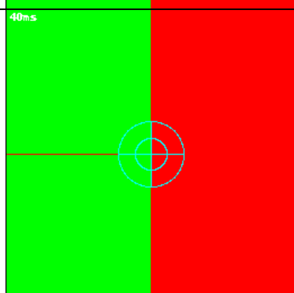
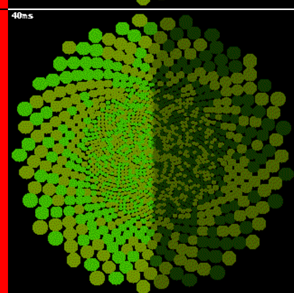
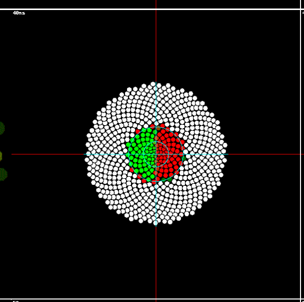
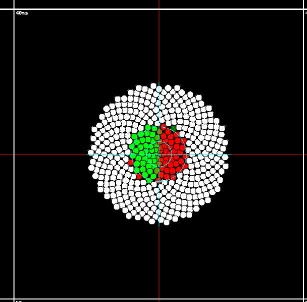
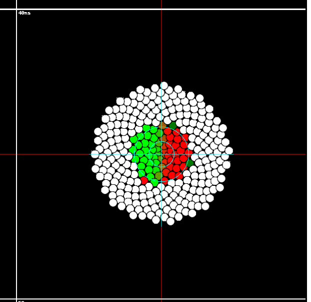
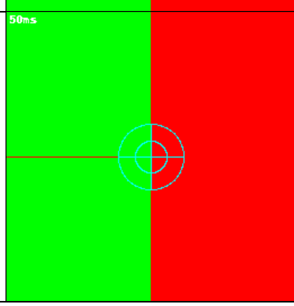
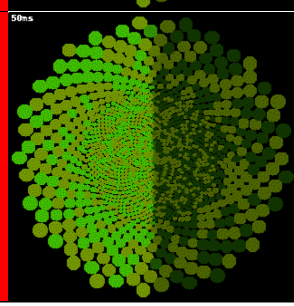
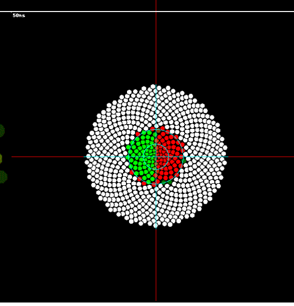
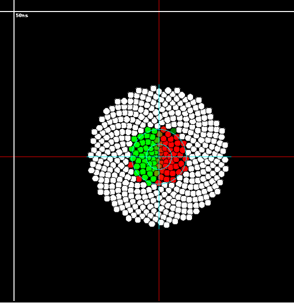
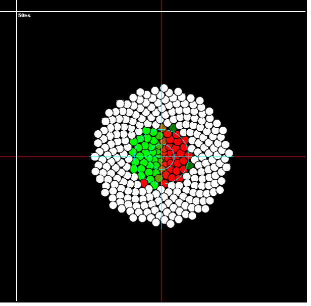
Table 10: Time sequence of filling-out with edge under varying RF sizes					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
3					
4					
5					

Table 10: Time sequence of filling-out with edge under varying RF sizes

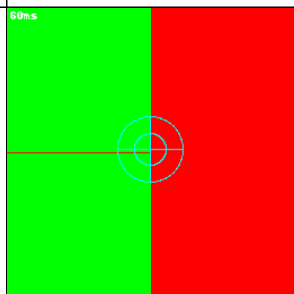
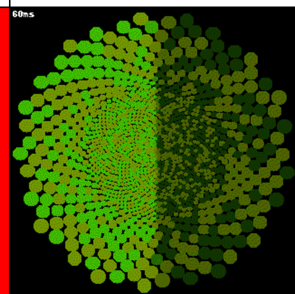
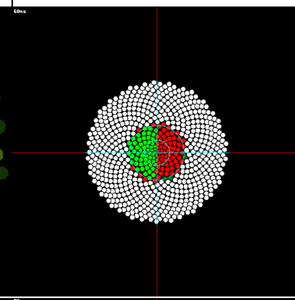
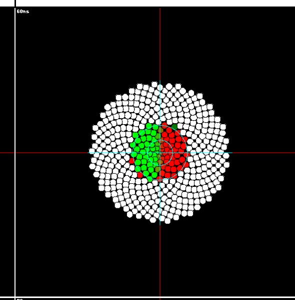
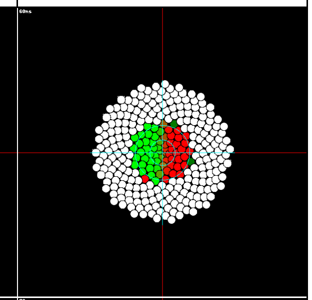
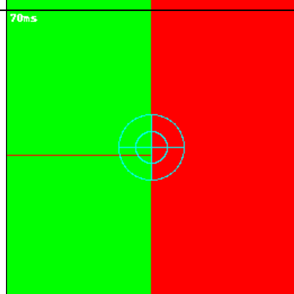
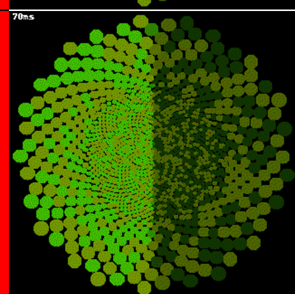
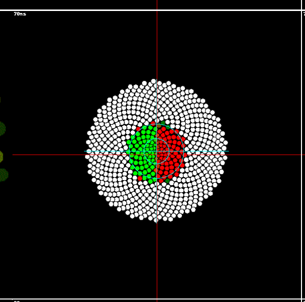
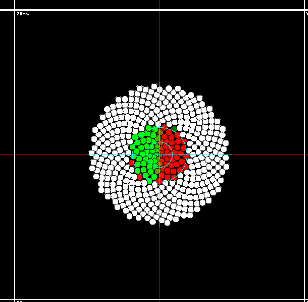
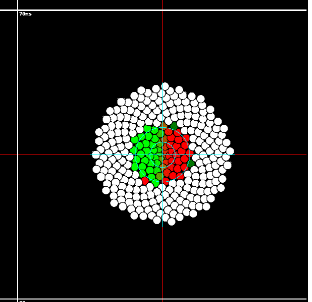
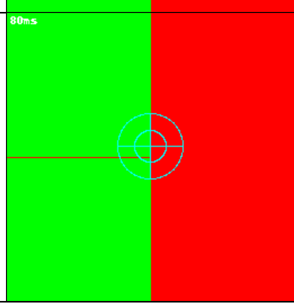
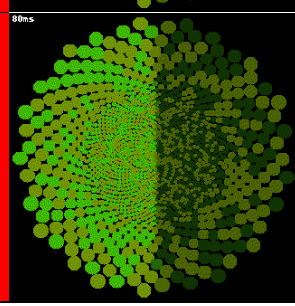
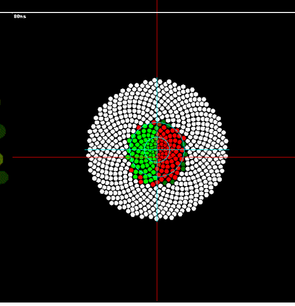
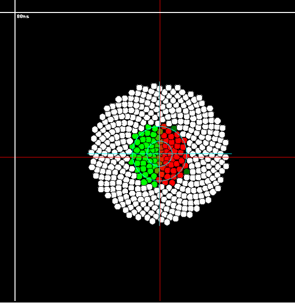
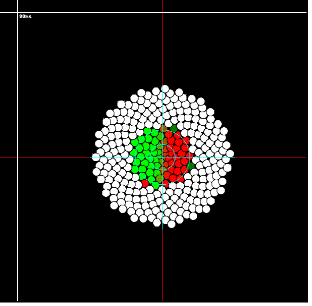
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
6					
7					
8					

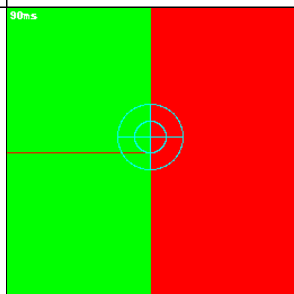
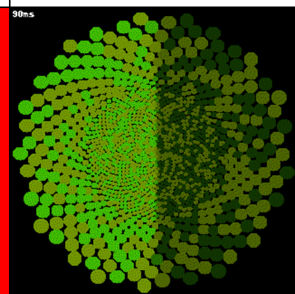
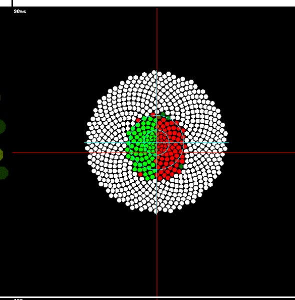
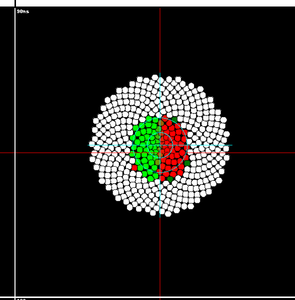
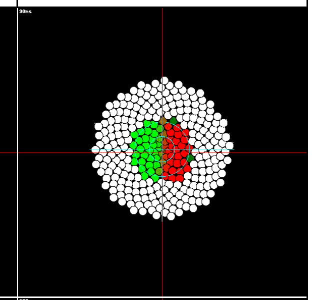
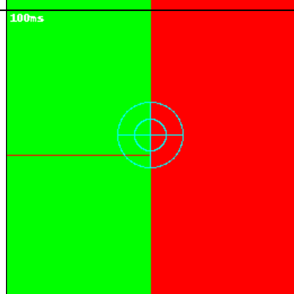
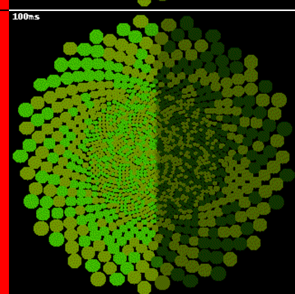
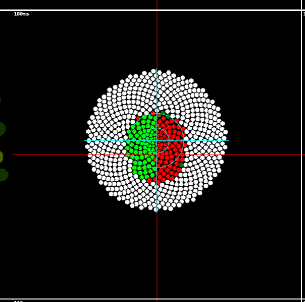
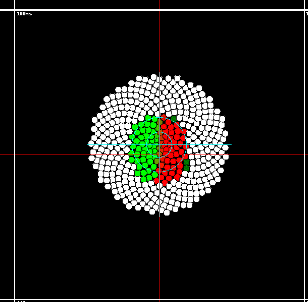
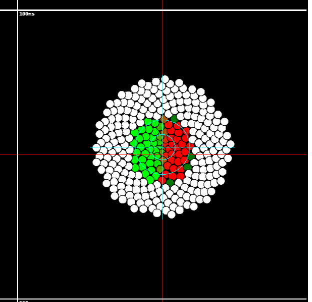
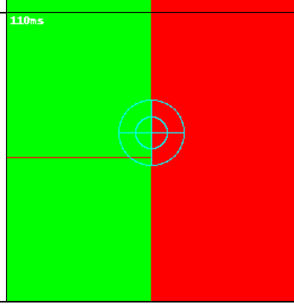
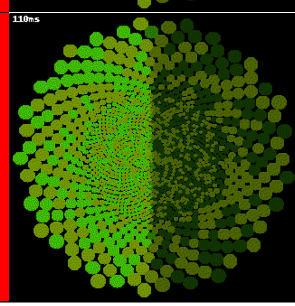
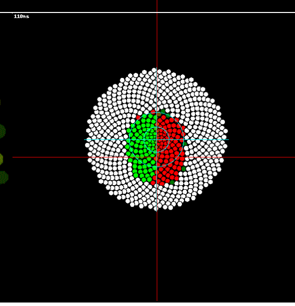
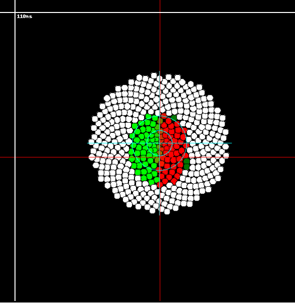
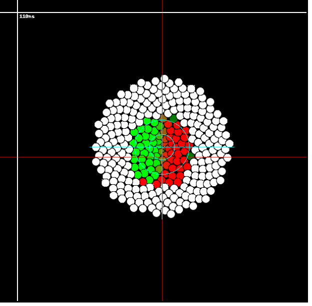
Table 10: Time sequence of filling-out with edge under varying RF sizes					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
9					
10					
11					

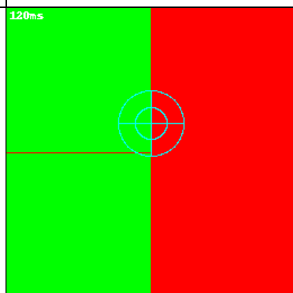
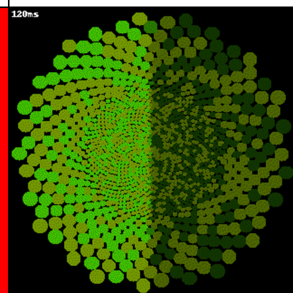
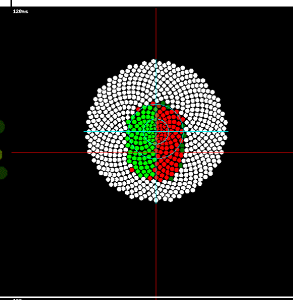
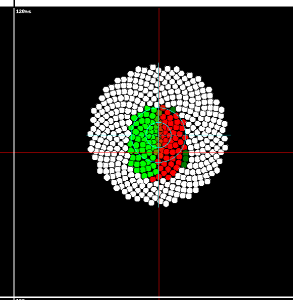
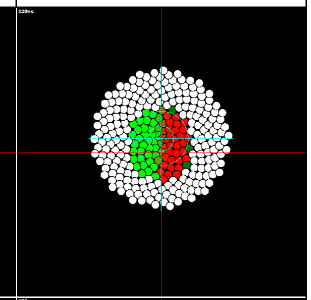
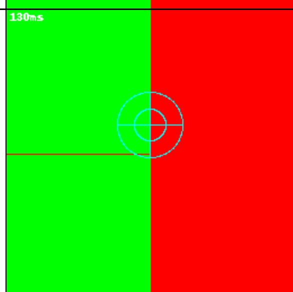
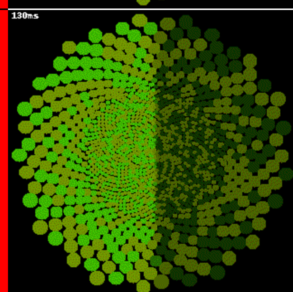
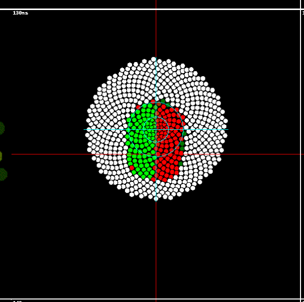
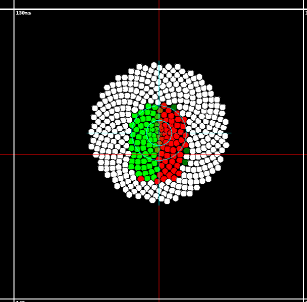
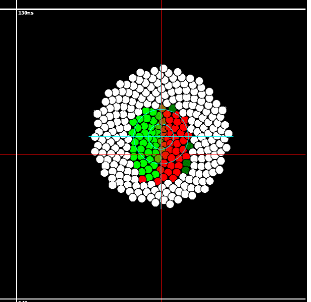
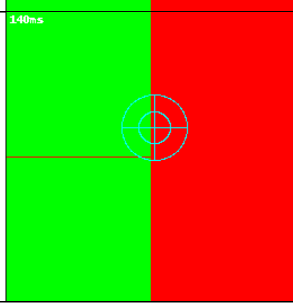
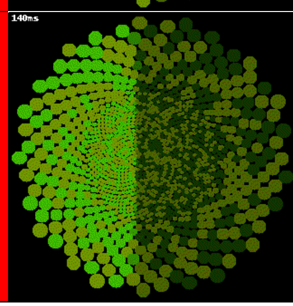
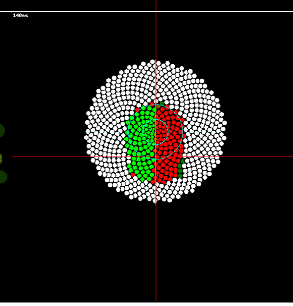
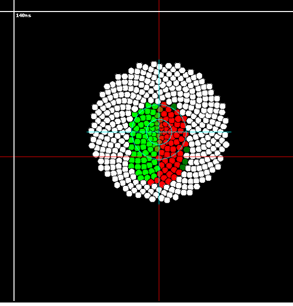
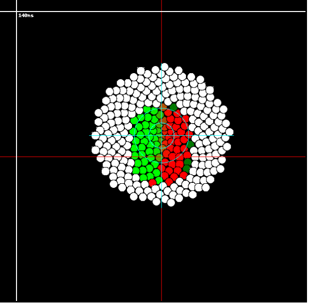
Table 10: Time sequence of filling-out with edge under varying RF sizes					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
12					
13					
14					

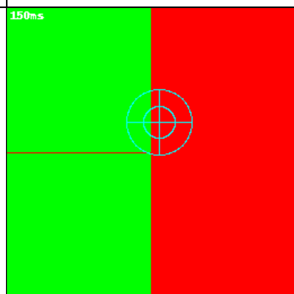
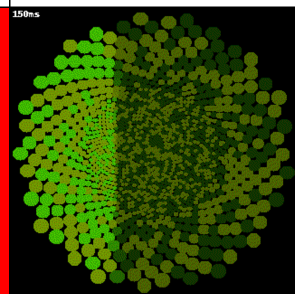
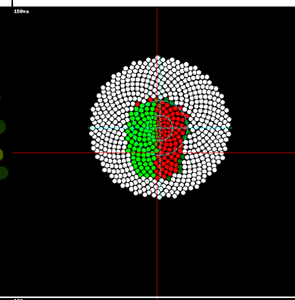
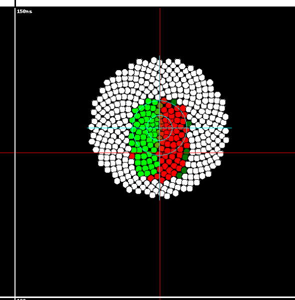
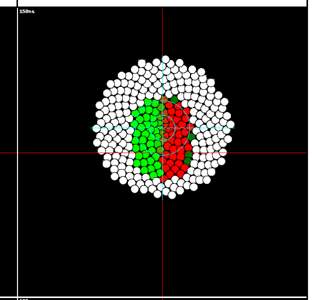
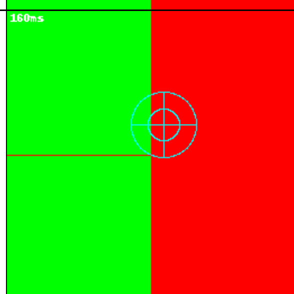
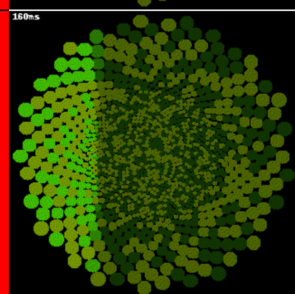
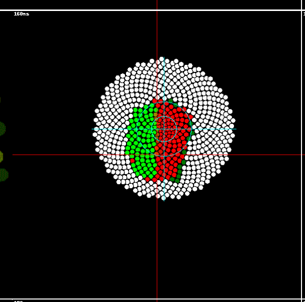
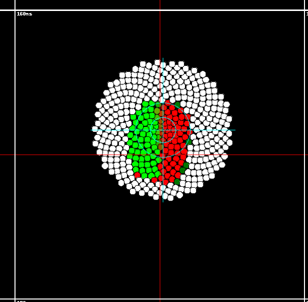
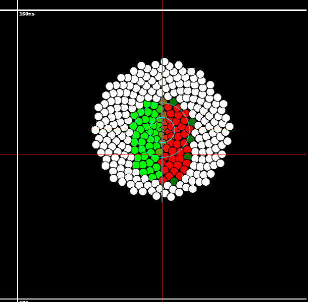
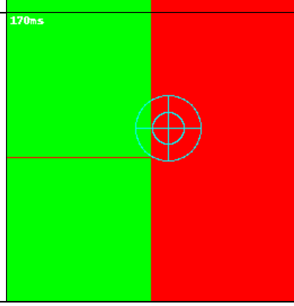
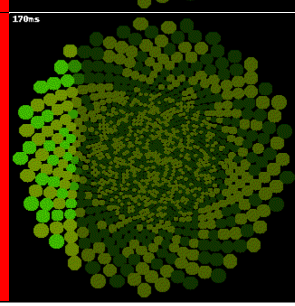
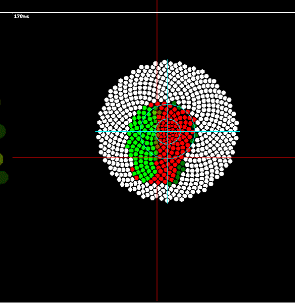
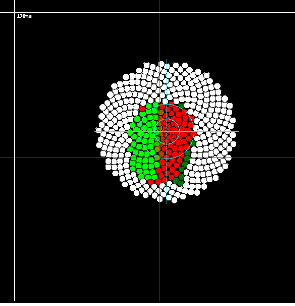
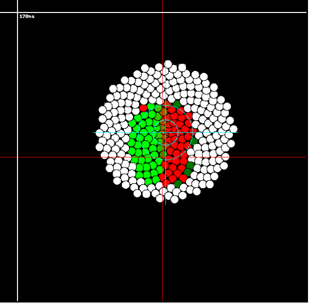
Table 10: Time sequence of filling-out with edge under varying RF sizes					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
15					
16					
17					

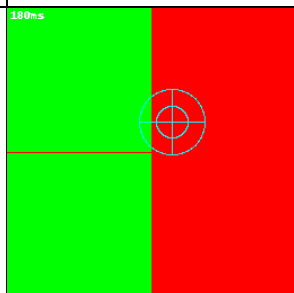
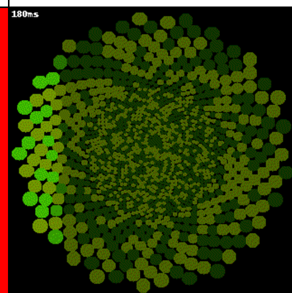
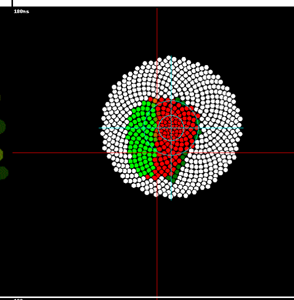
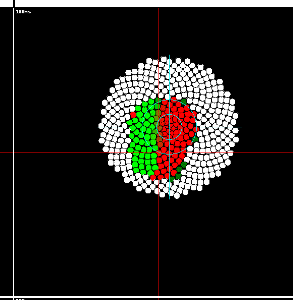
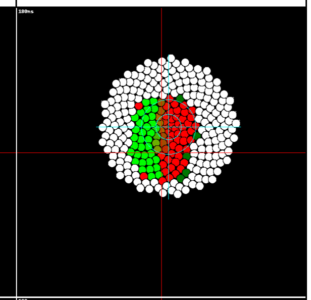
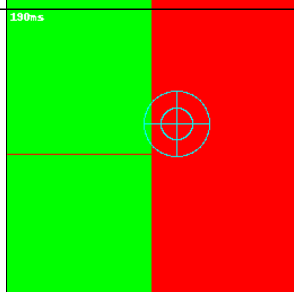
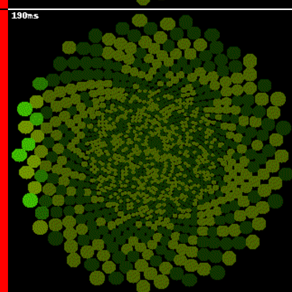
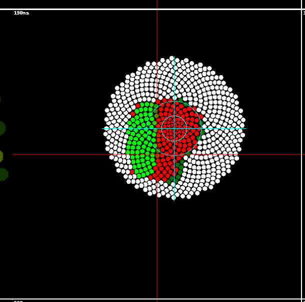
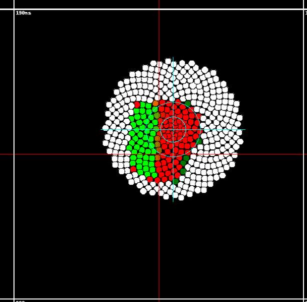
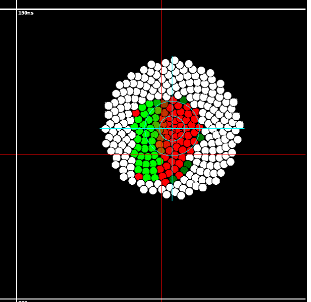
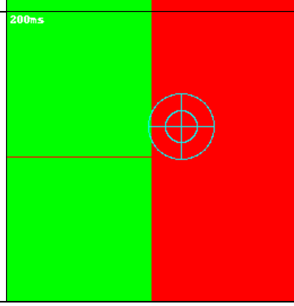
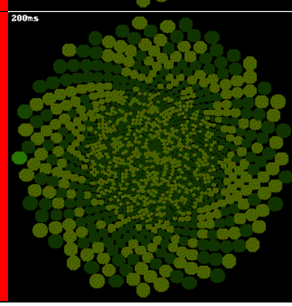
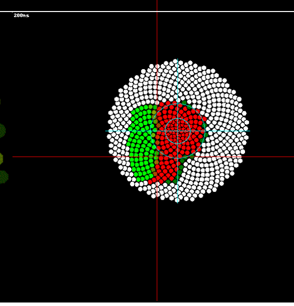
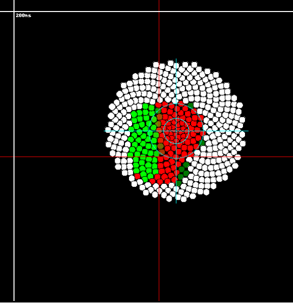
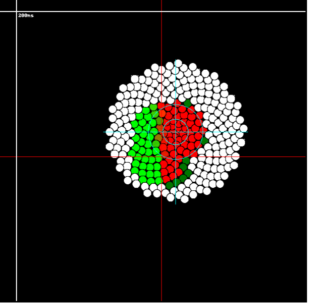
Table 10: Time sequence of filling-out with edge under varying RF sizes					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
18					
19					
20					

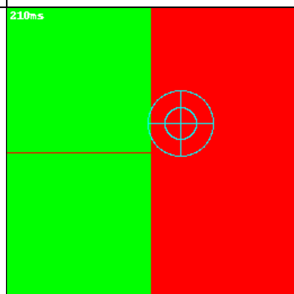
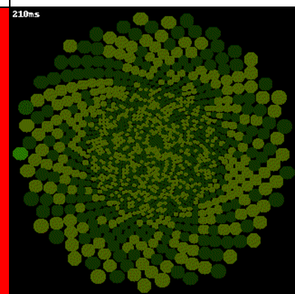
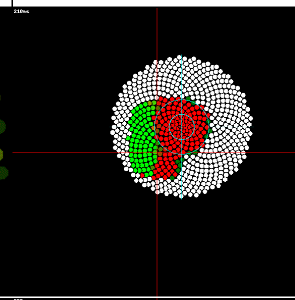
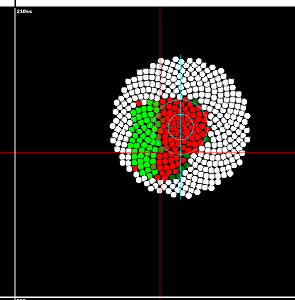
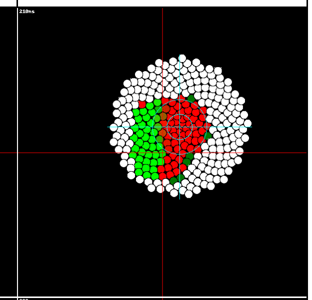
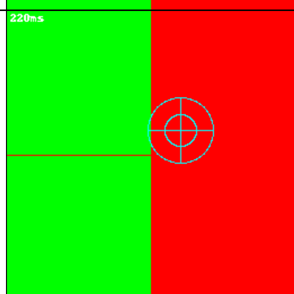
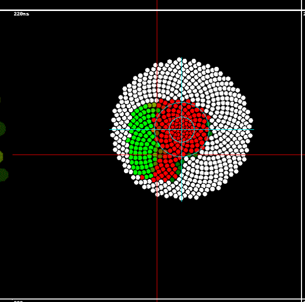
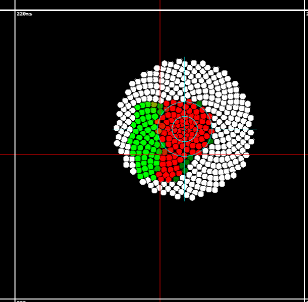
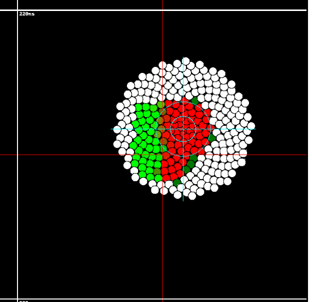
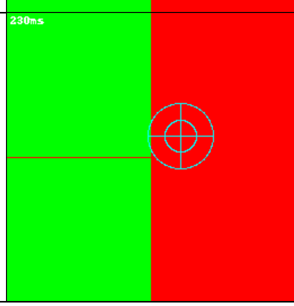
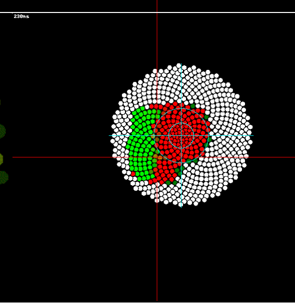
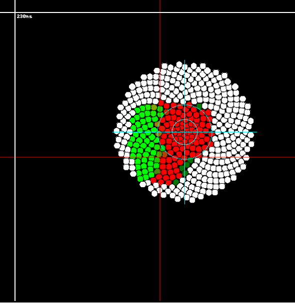
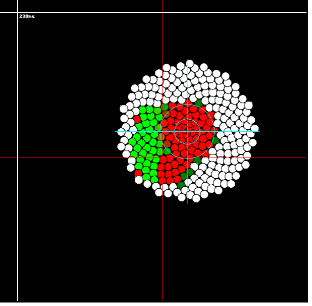
Table 10: Time sequence of filling-out with edge under varying RF sizes					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
21					
22					
23					

Table 10: Time sequence of filling-out with edge under varying RF sizes

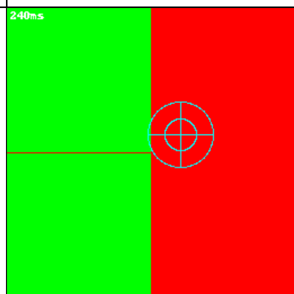
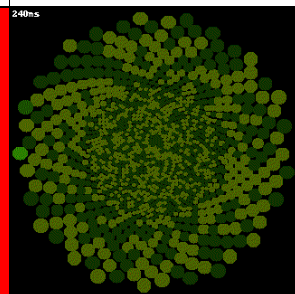
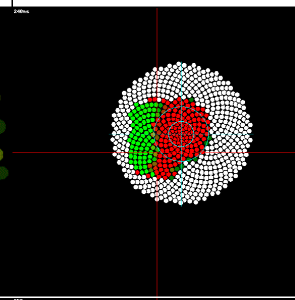
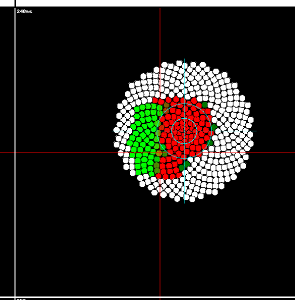
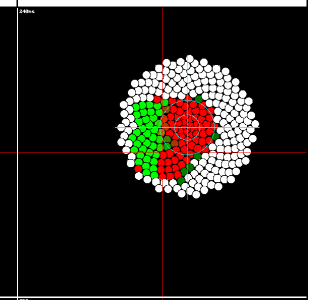
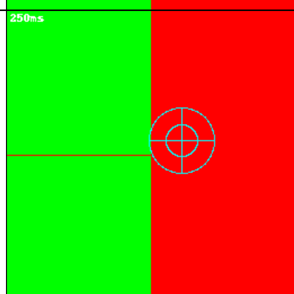
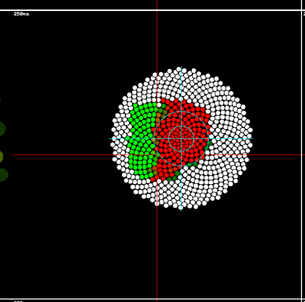
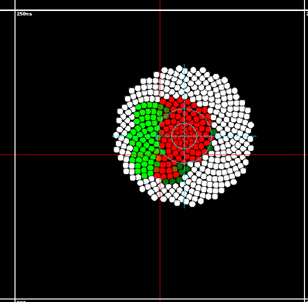
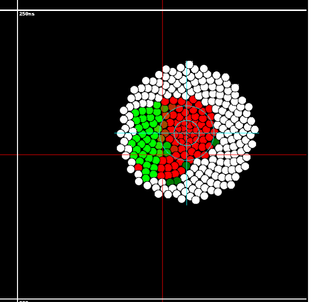
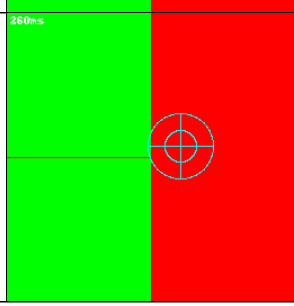
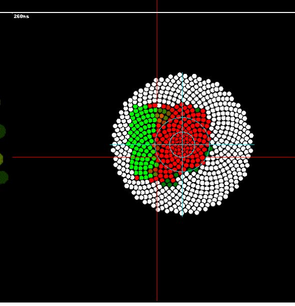
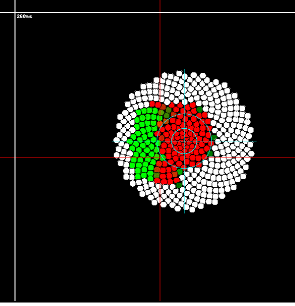
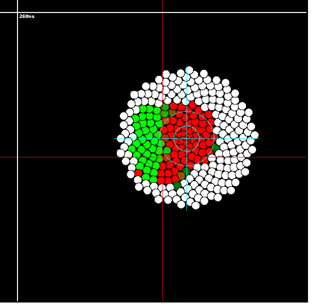
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
24					
25					
26					

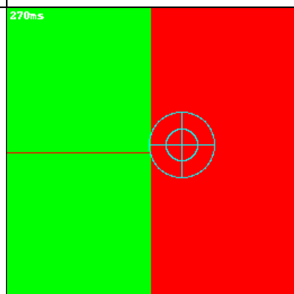
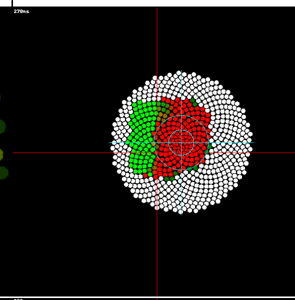
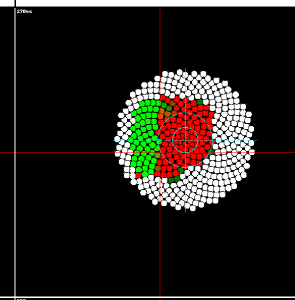
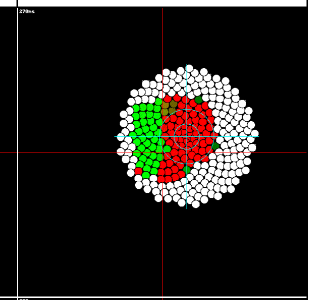
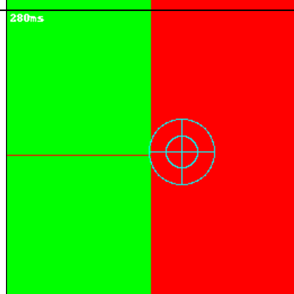
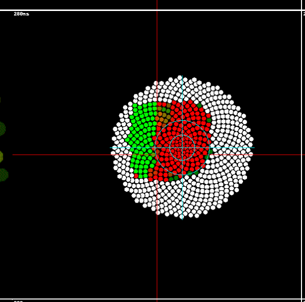
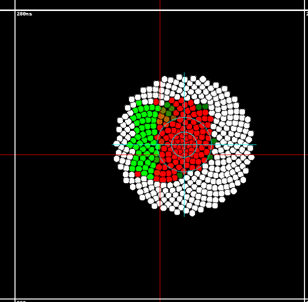
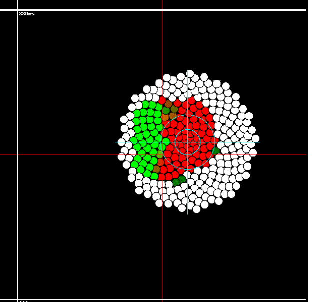
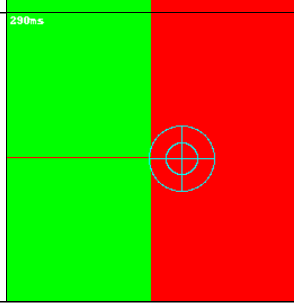
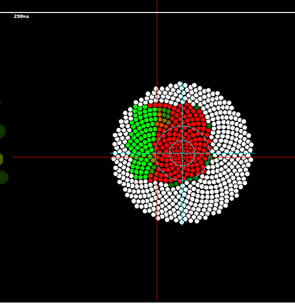
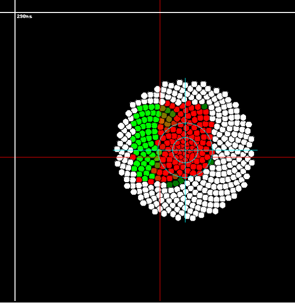
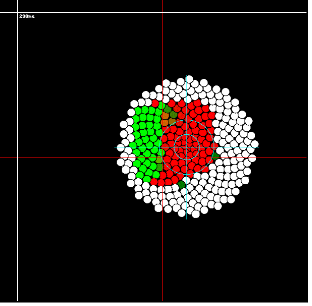
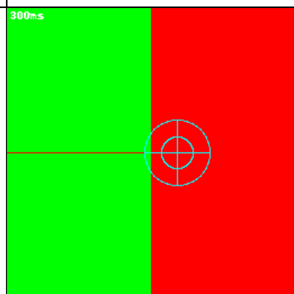
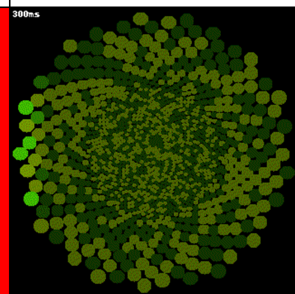
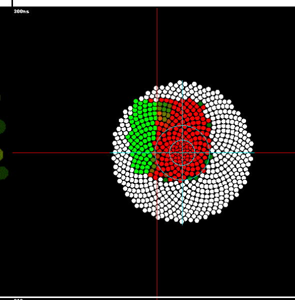
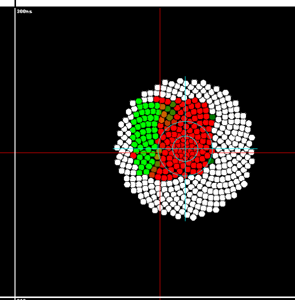
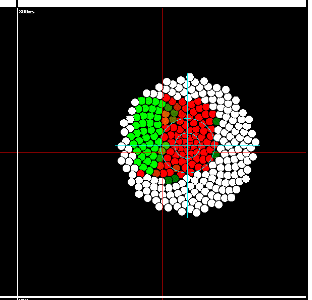
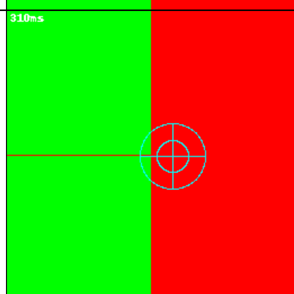
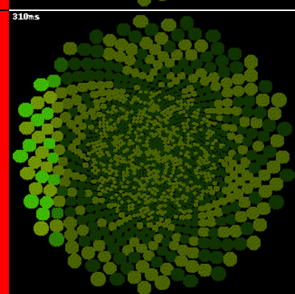
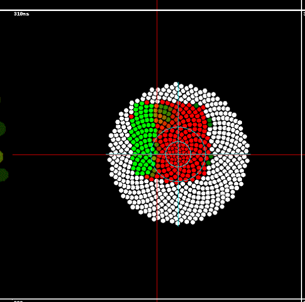
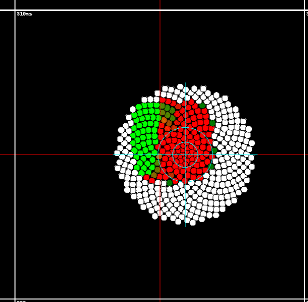
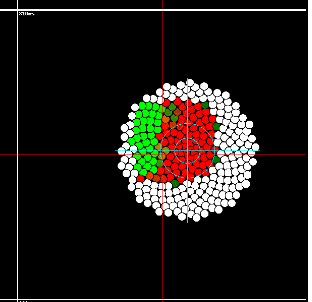
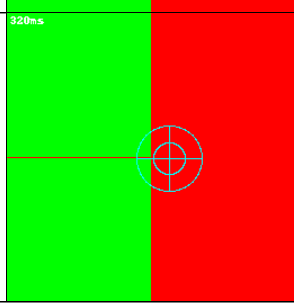
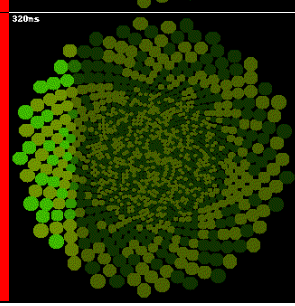
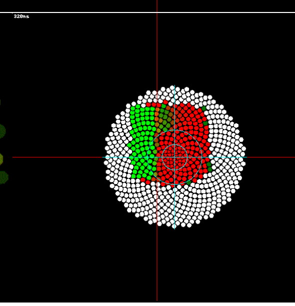
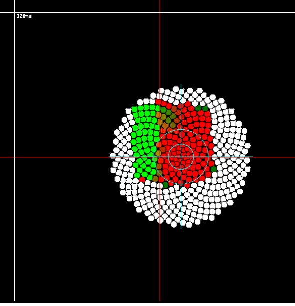
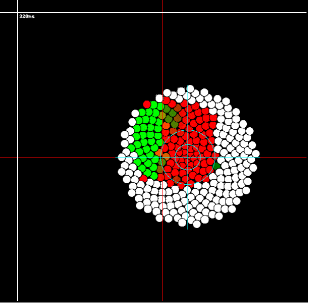
Table 10: Time sequence of filling-out with edge under varying RF sizes					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
27					
28					
29					

Table 10: Time sequence of filling-out with edge under varying RF sizes					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
30					
31					
32					

3.3.5 Test 5 results: Image masking under fast motion

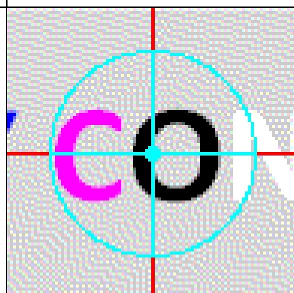
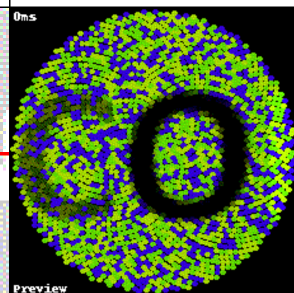
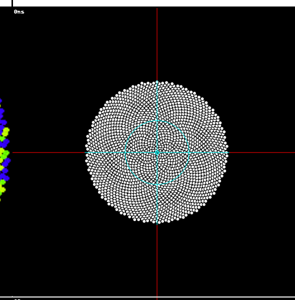
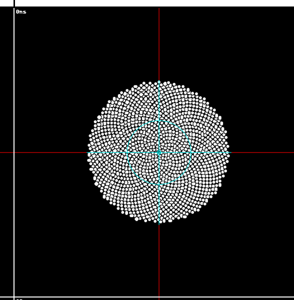
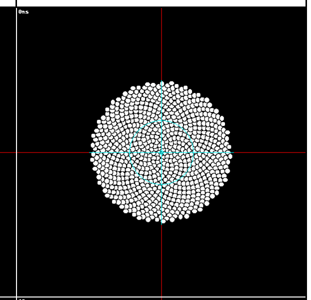
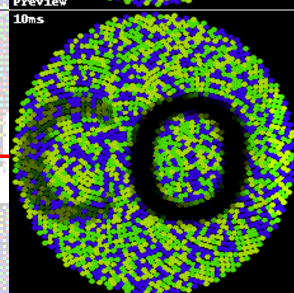
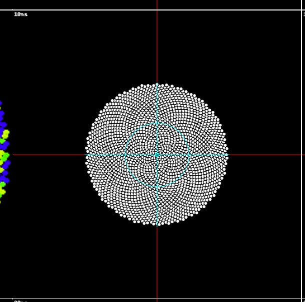
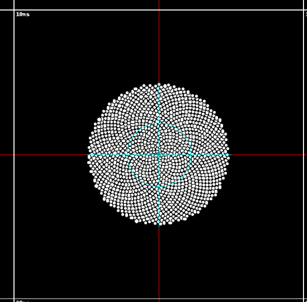
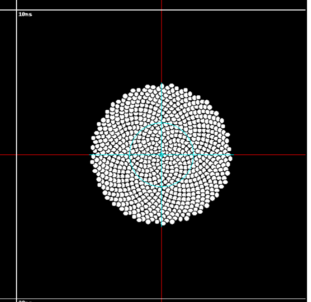
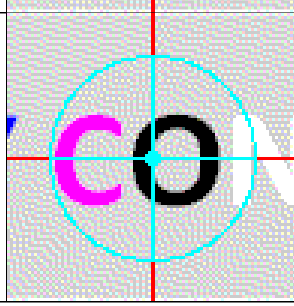
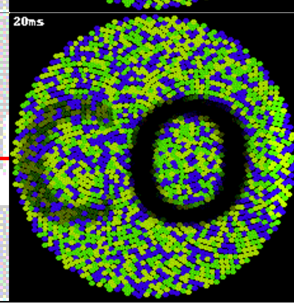
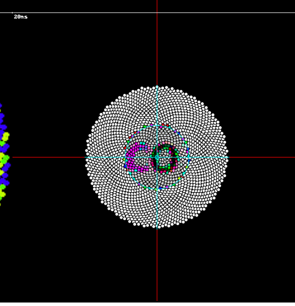
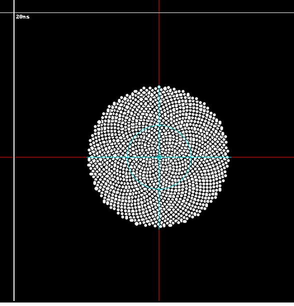
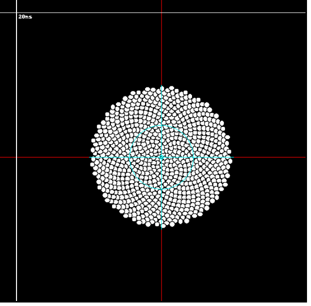
Table 11: Time sequence of filling-out image masking under fast motion					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
0					
1					
2					

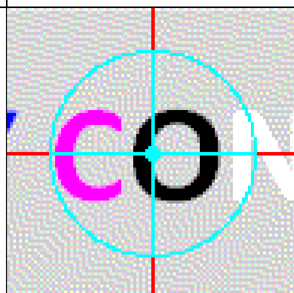
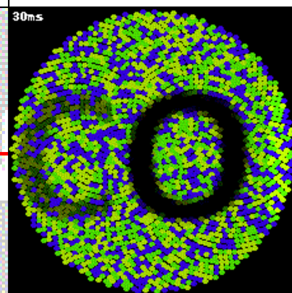
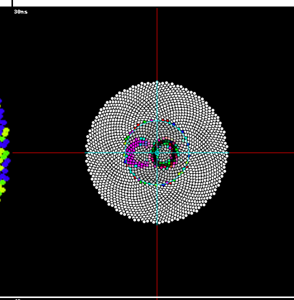
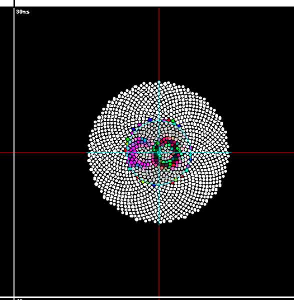
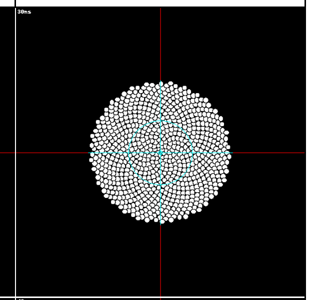
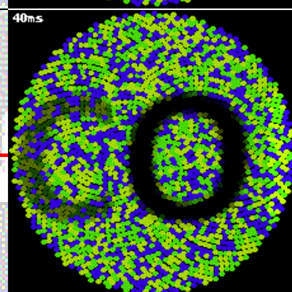
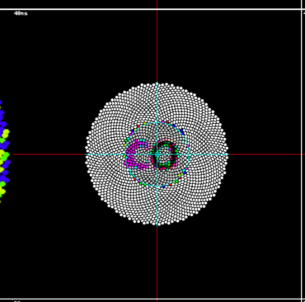
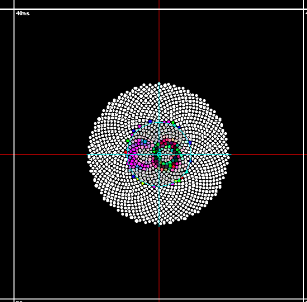
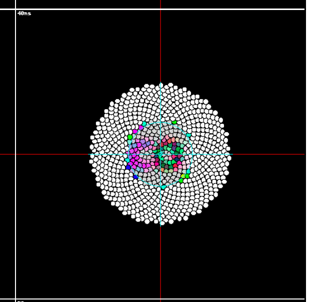
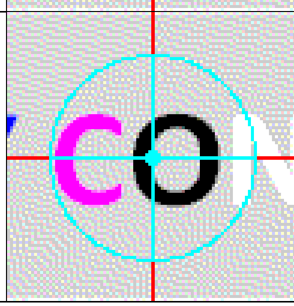
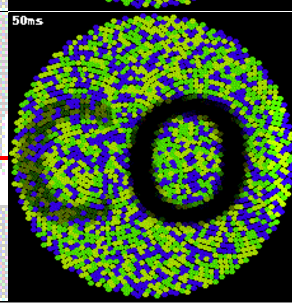
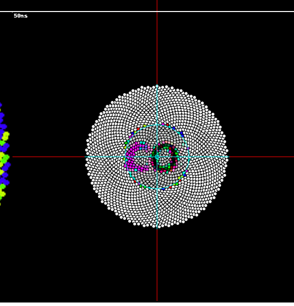
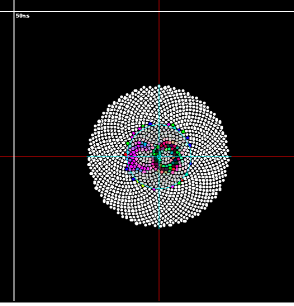
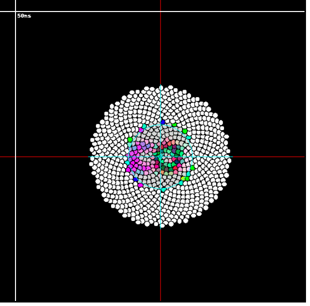
Table 11: Time sequence of filling-out image masking under fast motion					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
3					
4					
5					

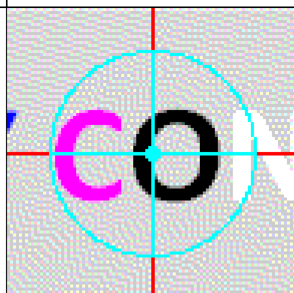
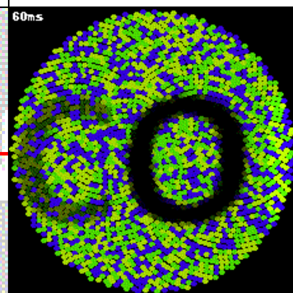
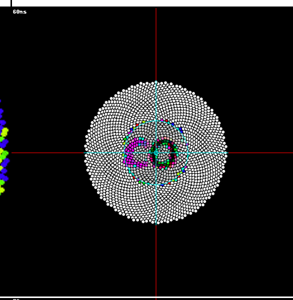
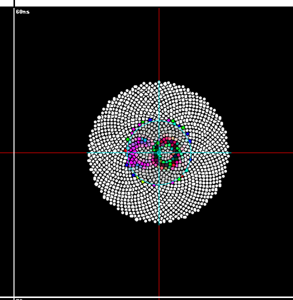
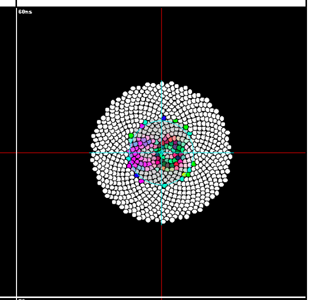
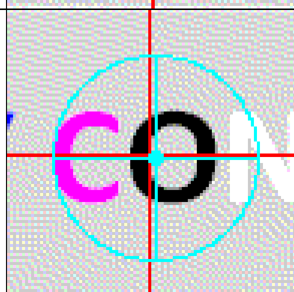
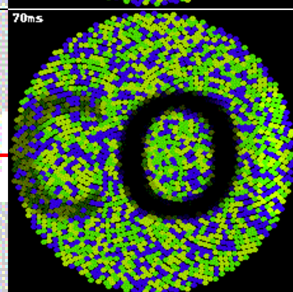
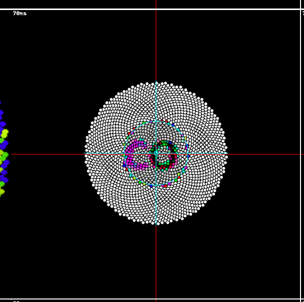
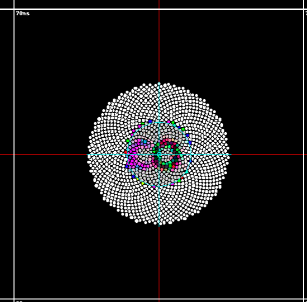
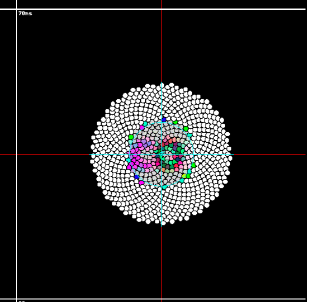
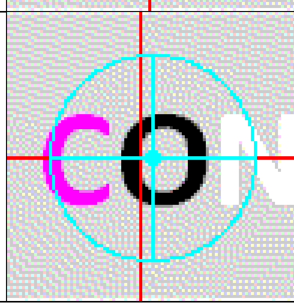
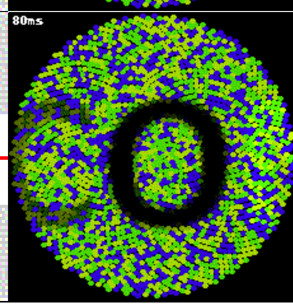
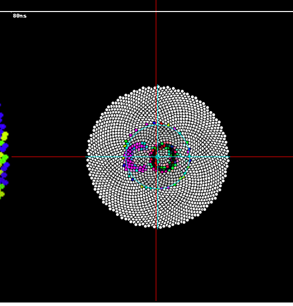
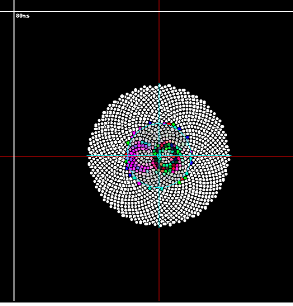
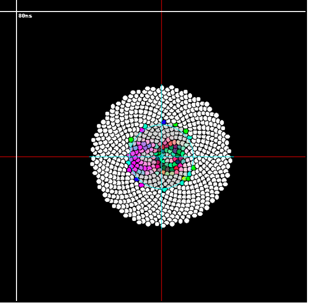
Table 11: Time sequence of filling-out image masking under fast motion					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
6					
7					
8					

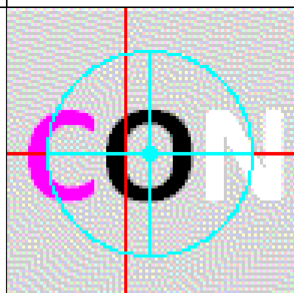
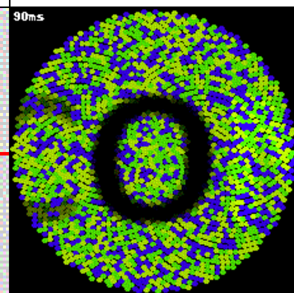
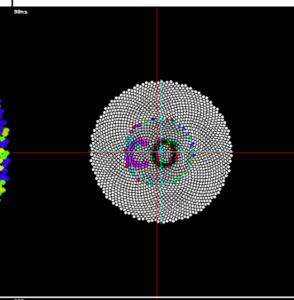
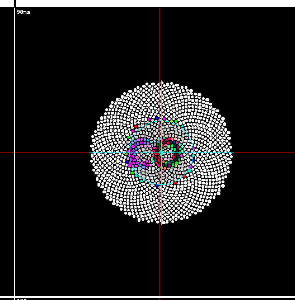
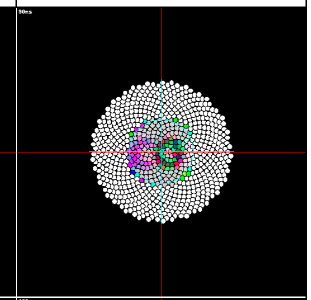
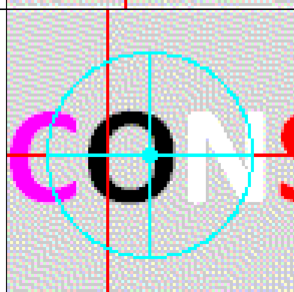
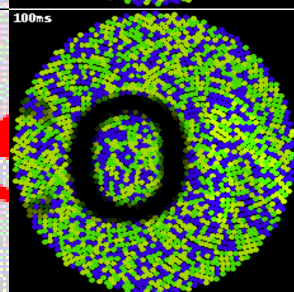
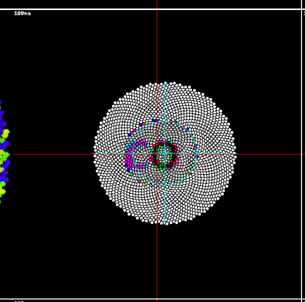
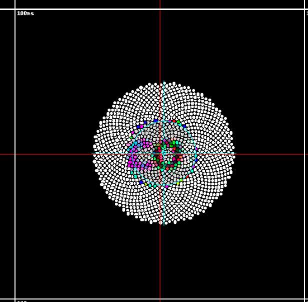
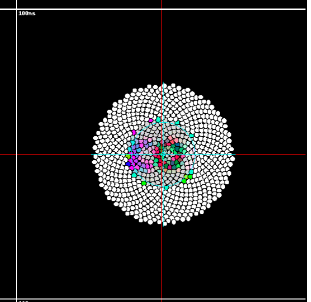
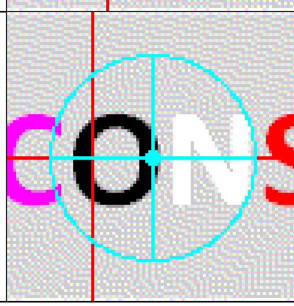
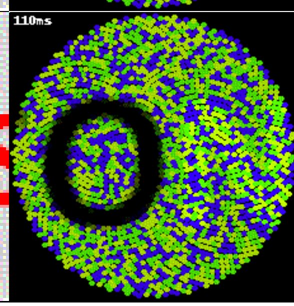
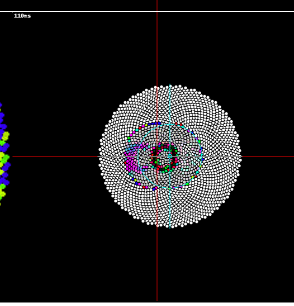
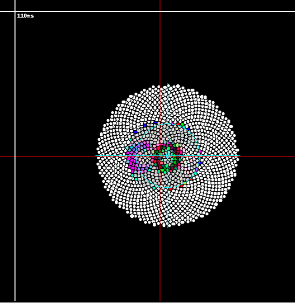
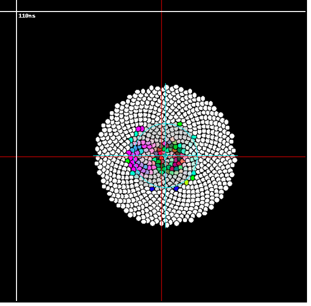
Table 11: Time sequence of filling-out image masking under fast motion					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
9					
10					
11					

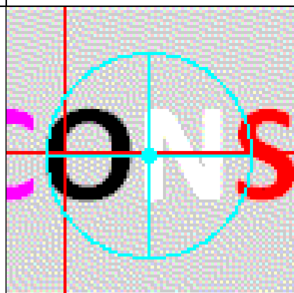
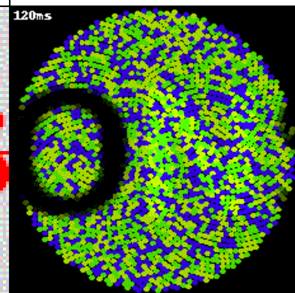
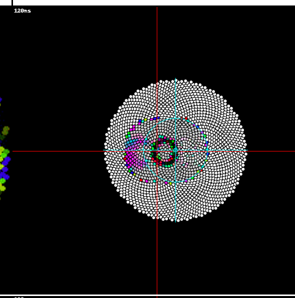
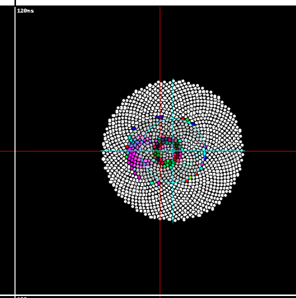
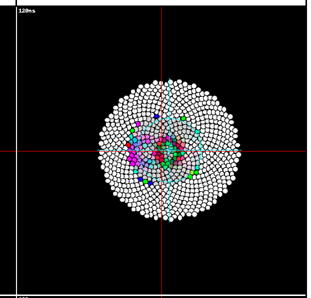
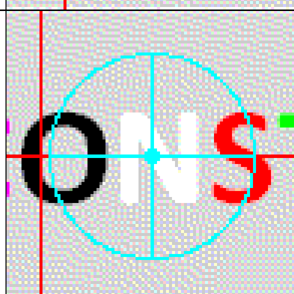
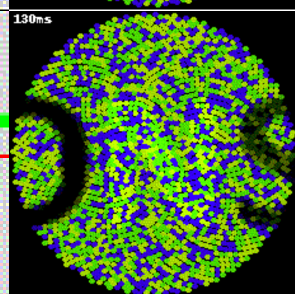
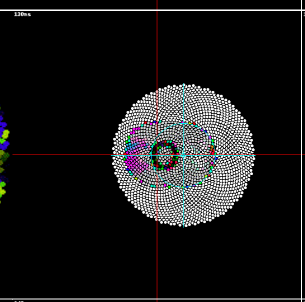
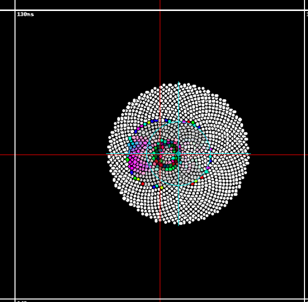
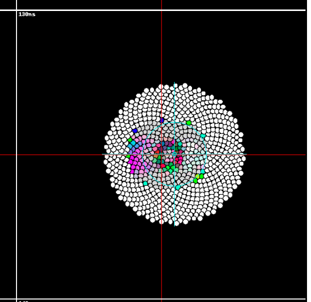
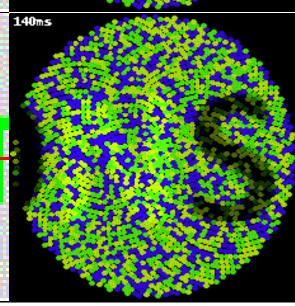
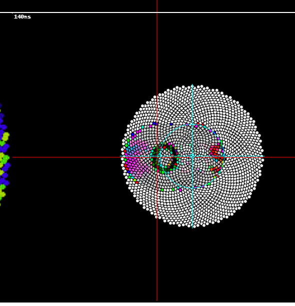
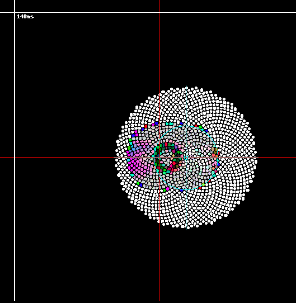
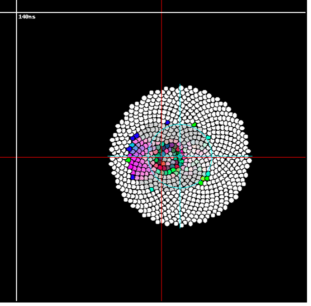
Table 11: Time sequence of filling-out image masking under fast motion					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
12					
13					
14					

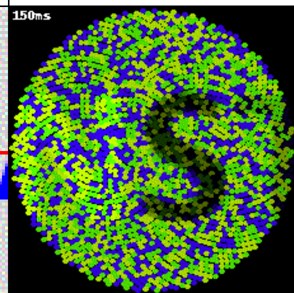
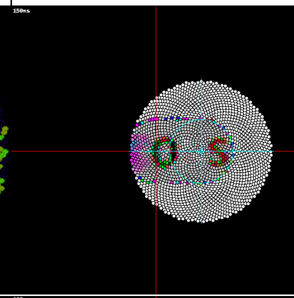
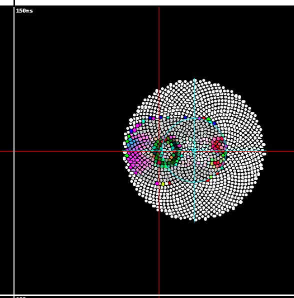
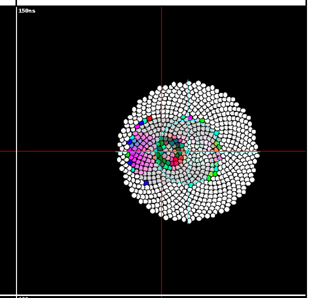
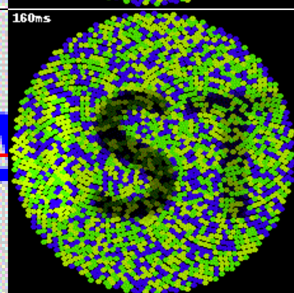
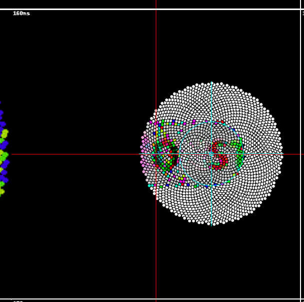
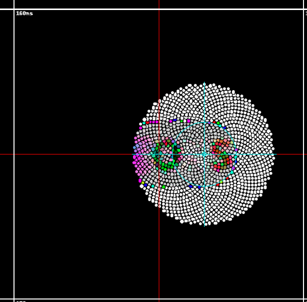
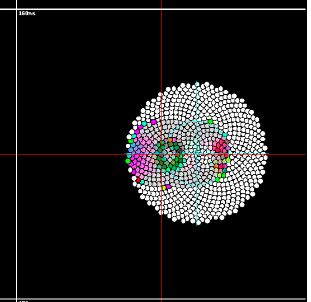
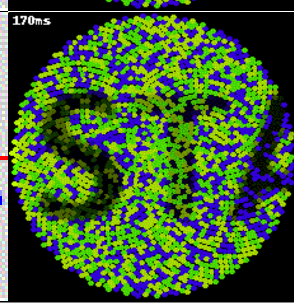
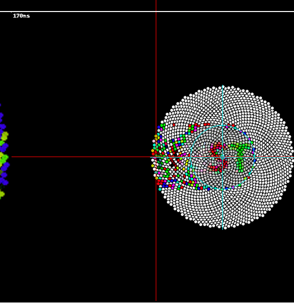
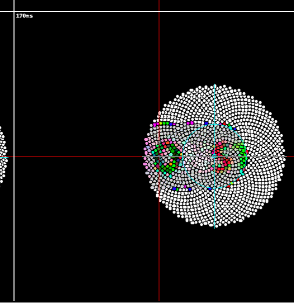
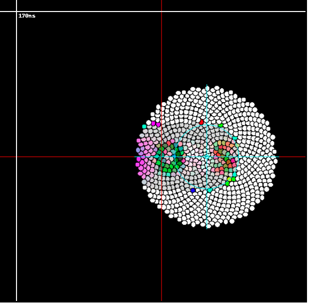
Table 11: Time sequence of filling-out image masking under fast motion					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
15					
16					
17					

Table 11: Time sequence of filling-out image masking under fast motion

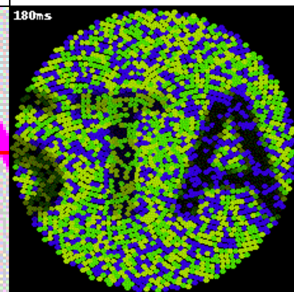
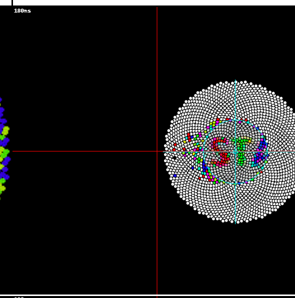
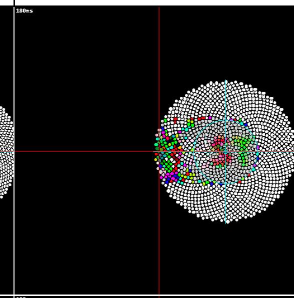
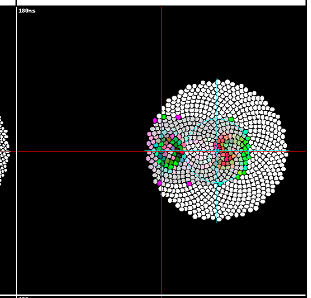
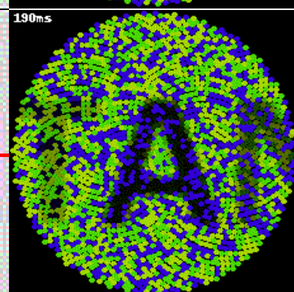
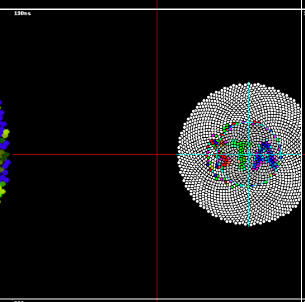
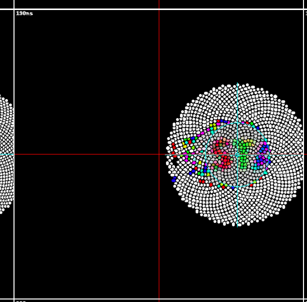
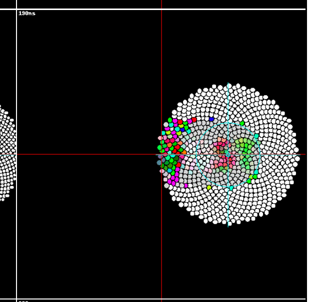
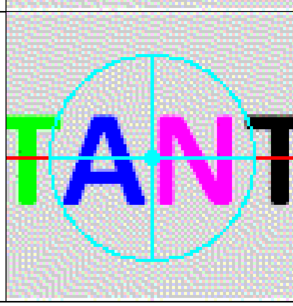
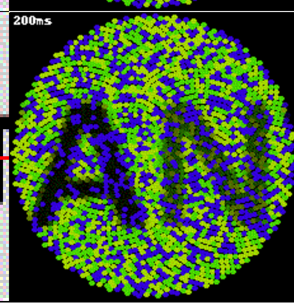
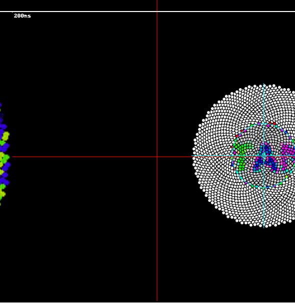
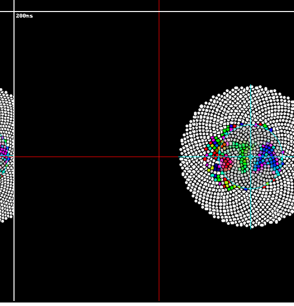
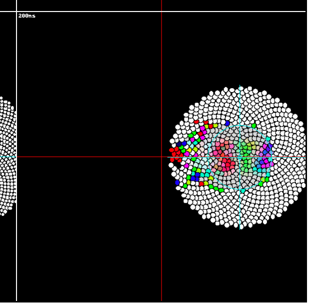
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
18					
19					
20					

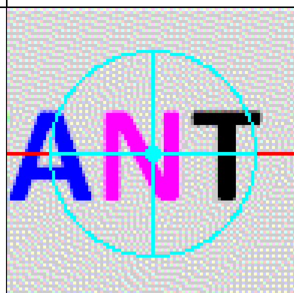
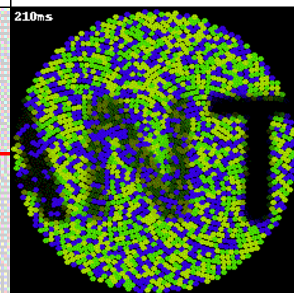
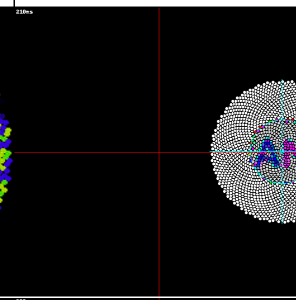
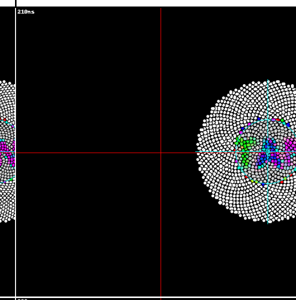
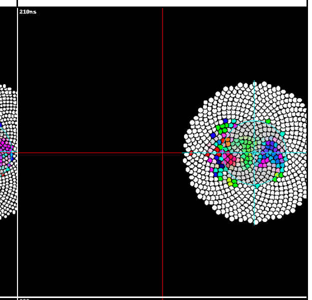
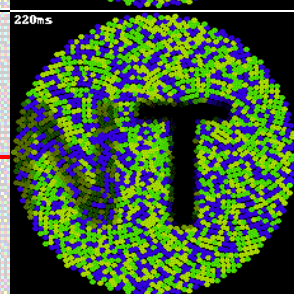
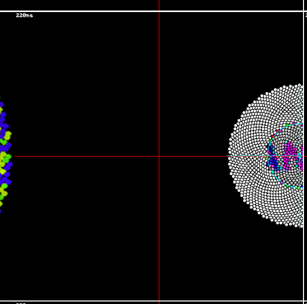
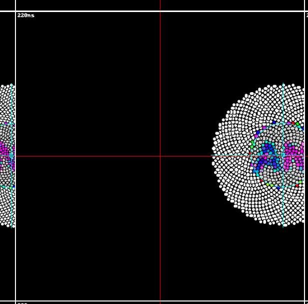
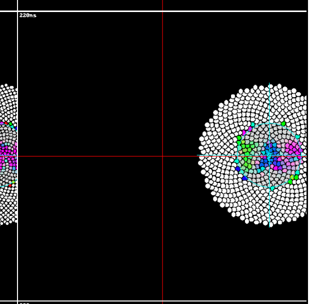
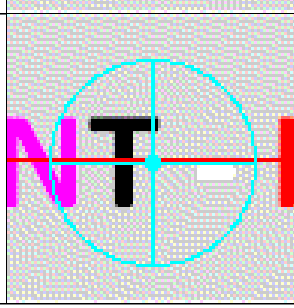
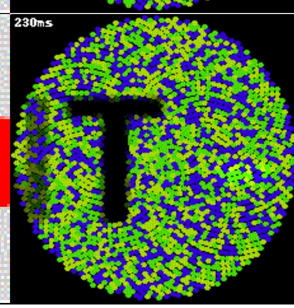
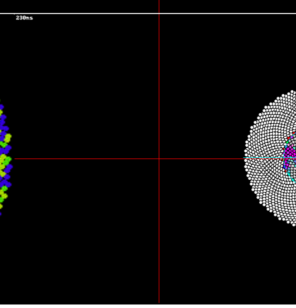
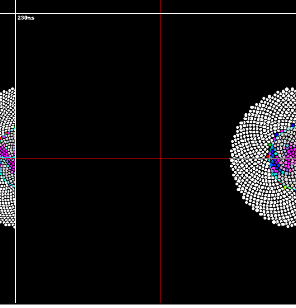
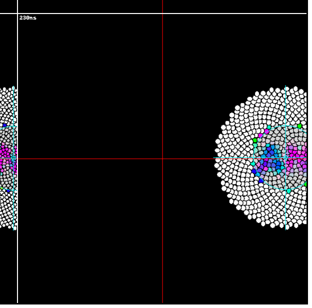
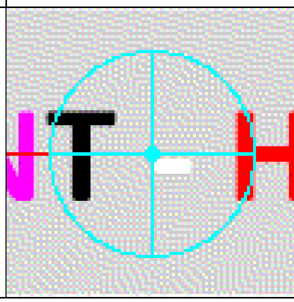
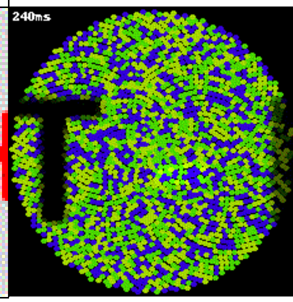
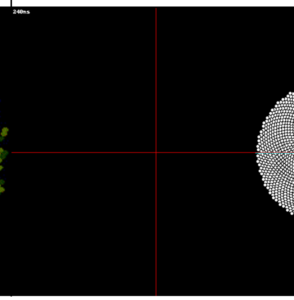
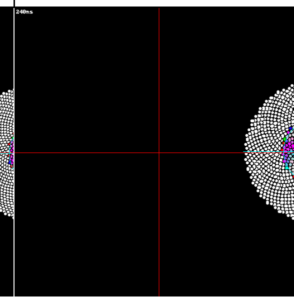
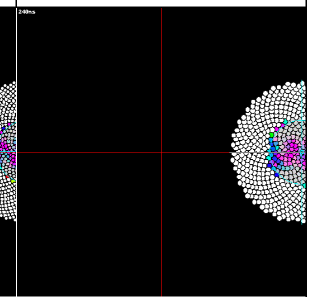
Table 11: Time sequence of filling-out image masking under fast motion					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
21					
22					
23					

Table 11: Time sequence of filling-out image masking under fast motion

Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
24					

3.3.6 Test 6 results: Drawing figures under planned eye movements under paralysis

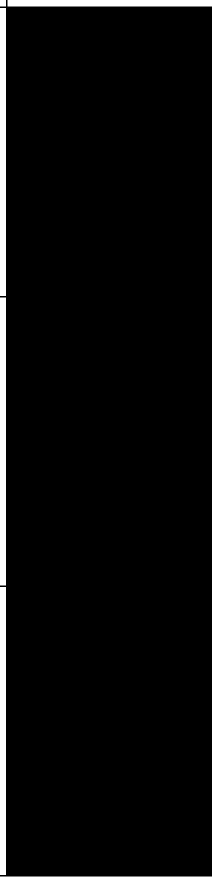
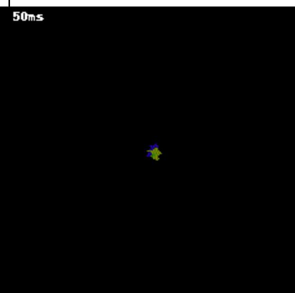
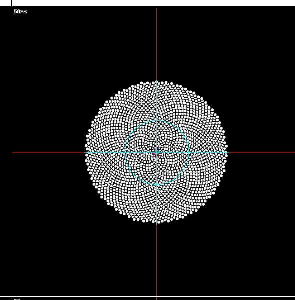
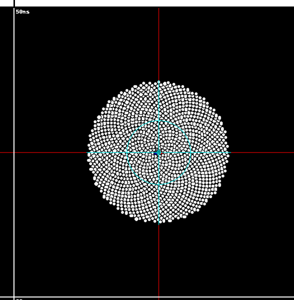
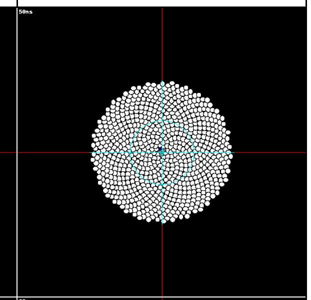
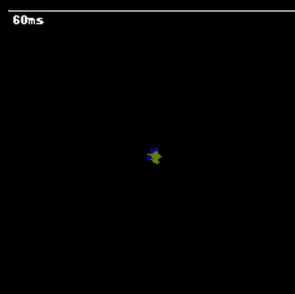
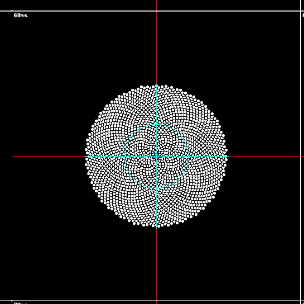
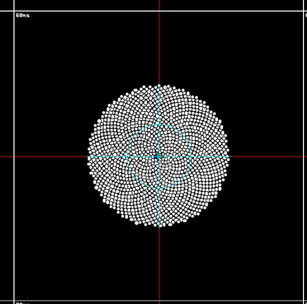
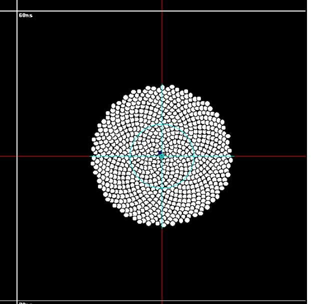
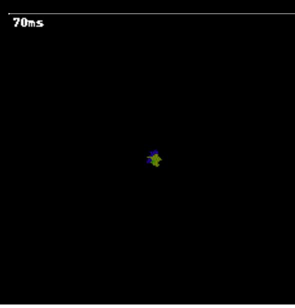
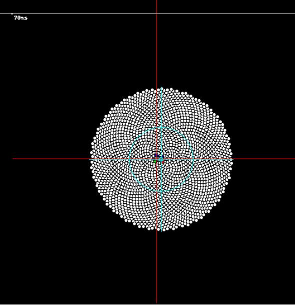
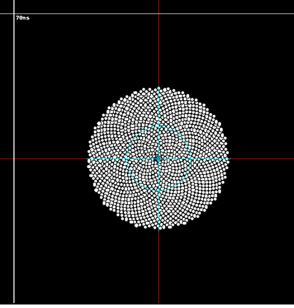
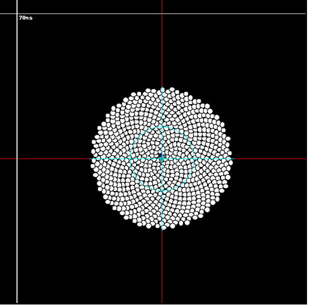
Table 12: Time sequence of filling-out by planned eye movement under paralysis					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
5					
6					
7					

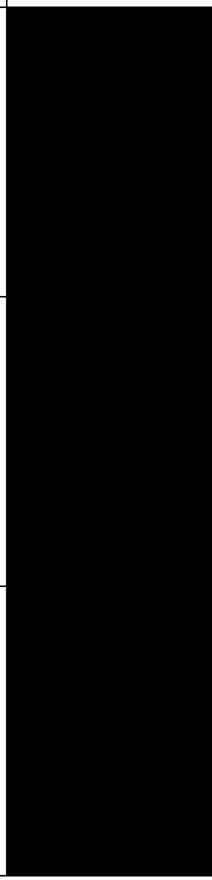
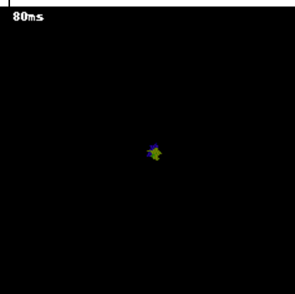
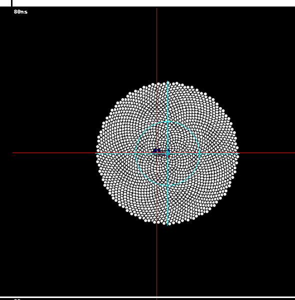
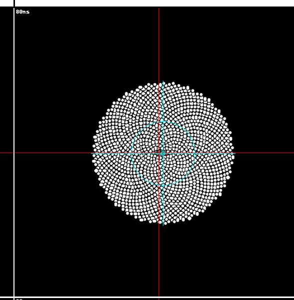
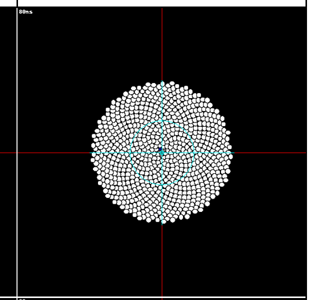
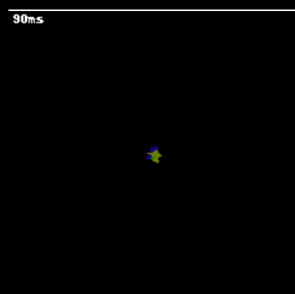
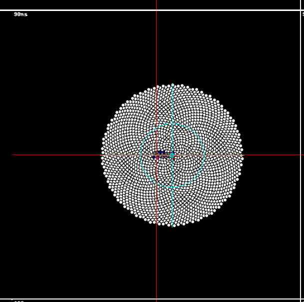
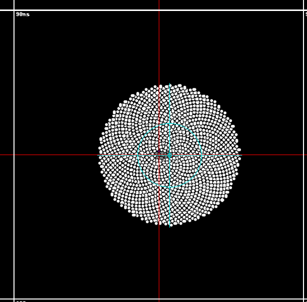
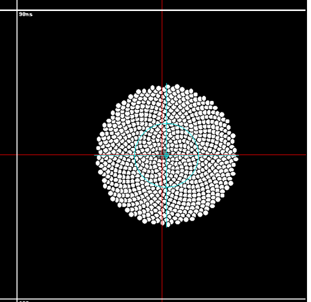
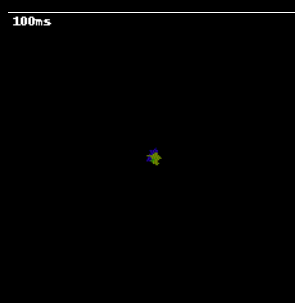
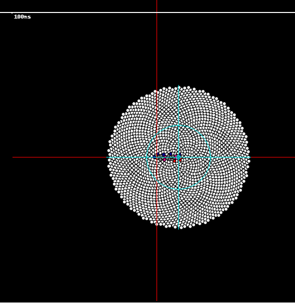
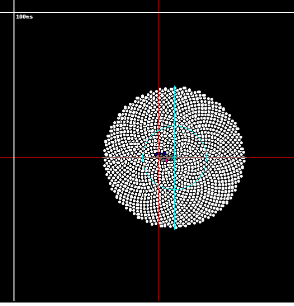
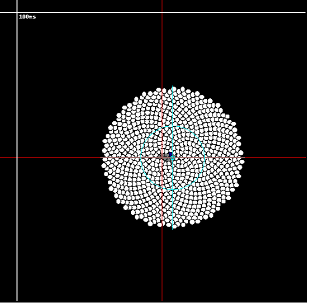
Table 12: Time sequence of filling-out by planned eye movement under paralysis					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
8					
9					
10					

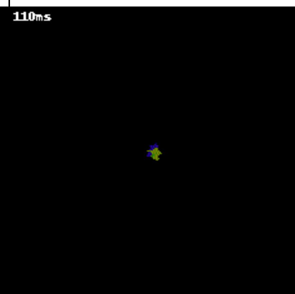
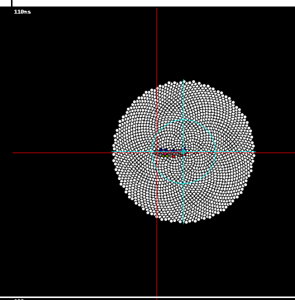
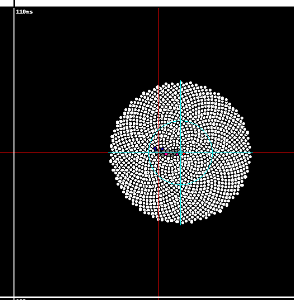
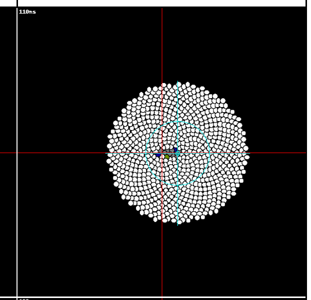
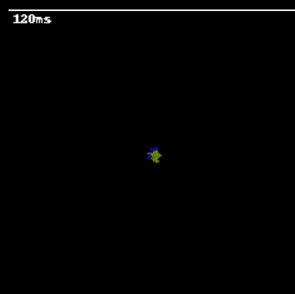
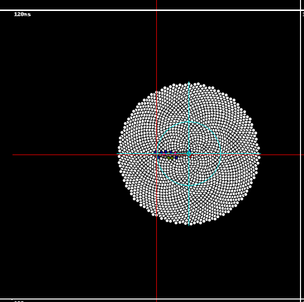
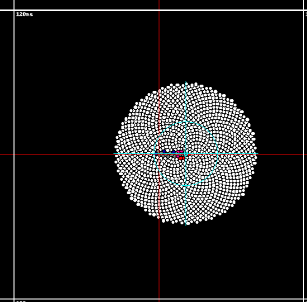
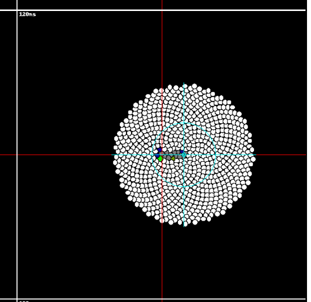
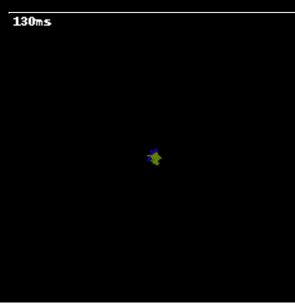
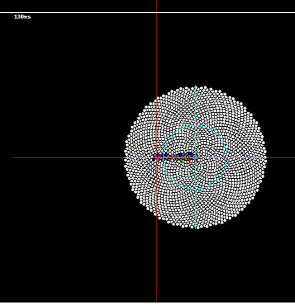
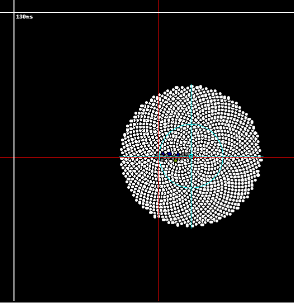
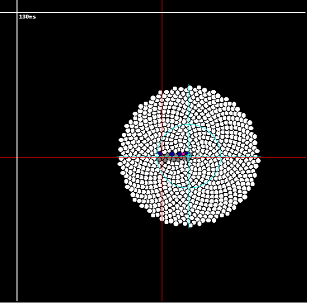
Table 12: Time sequence of filling-out by planned eye movement under paralysis					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
11					
12					
13					

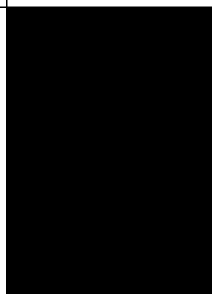
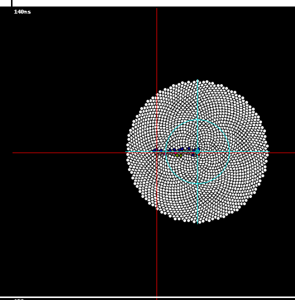
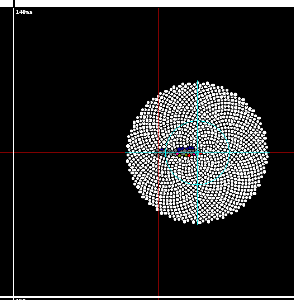
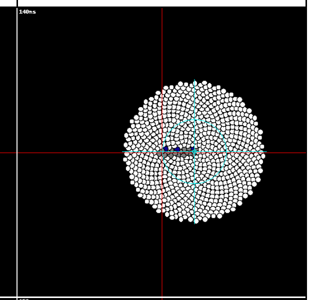
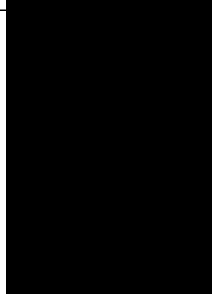
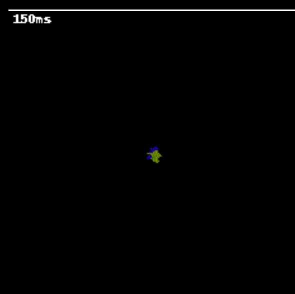
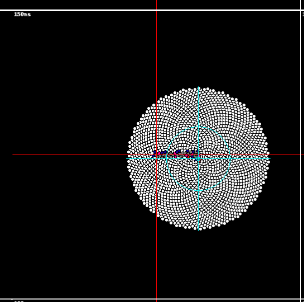
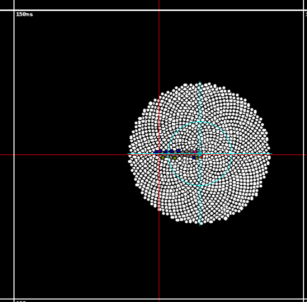
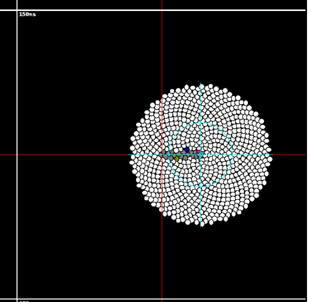
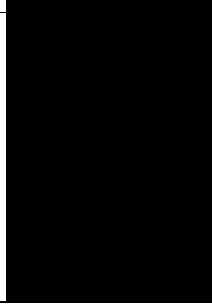
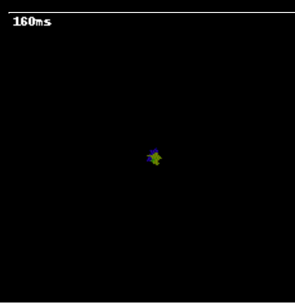
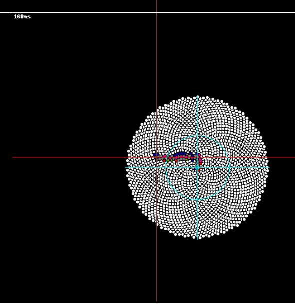
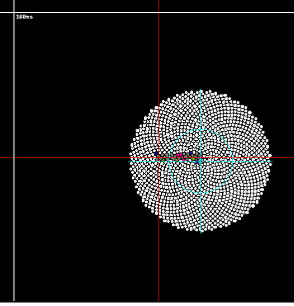
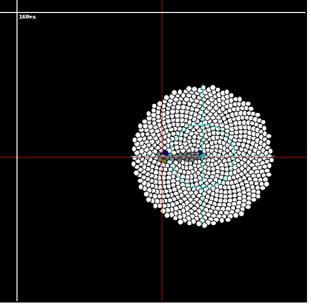
Table 12: Time sequence of filling-out by planned eye movement under paralysis					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
14					
15					
16					

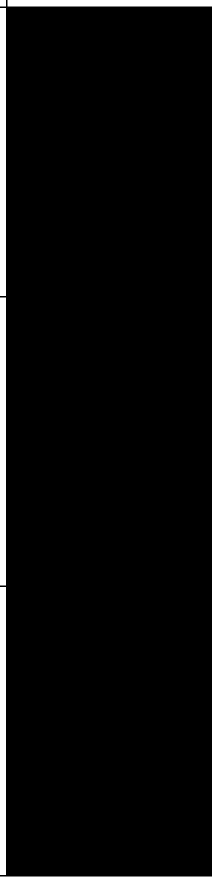
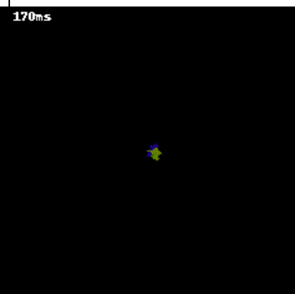
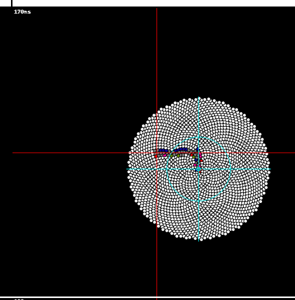
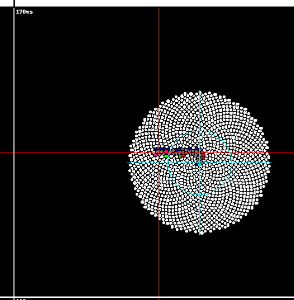
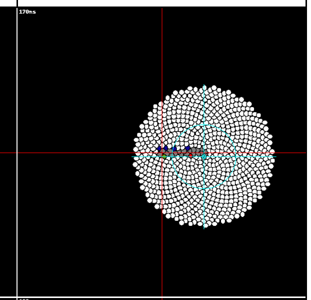
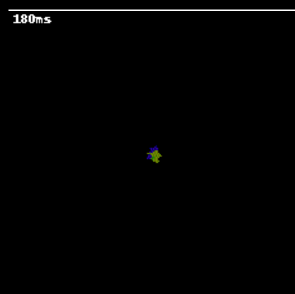
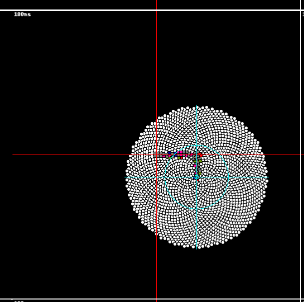
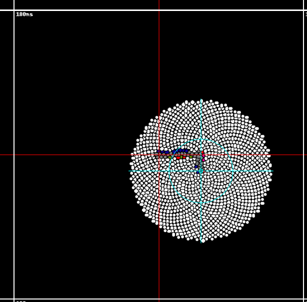
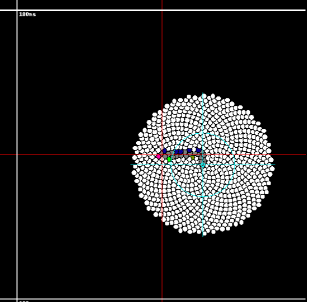
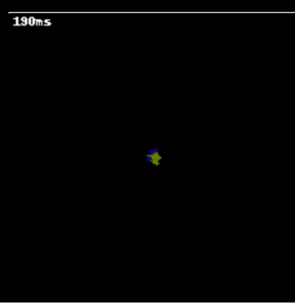
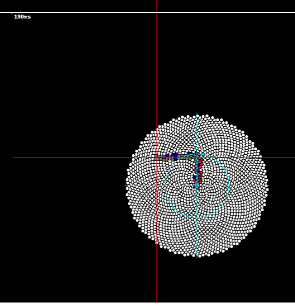
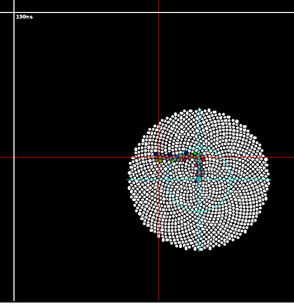
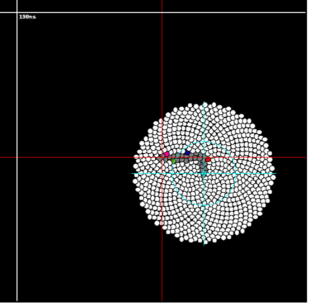
Table 12: Time sequence of filling-out by planned eye movement under paralysis					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
17					
18					
19					

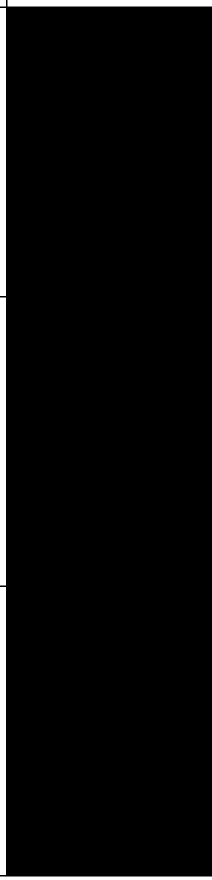
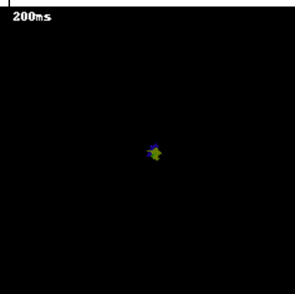
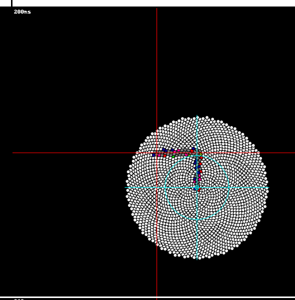
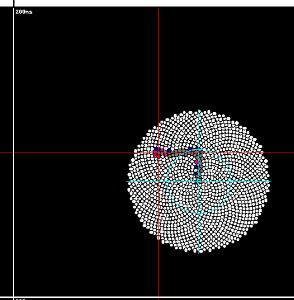
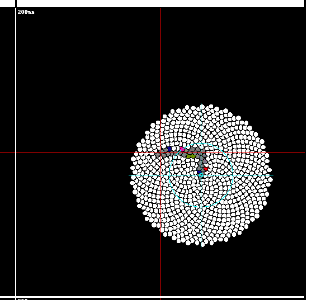
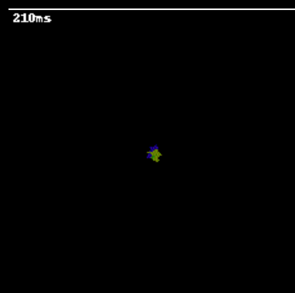
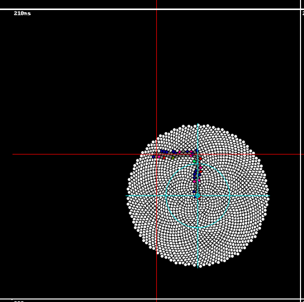
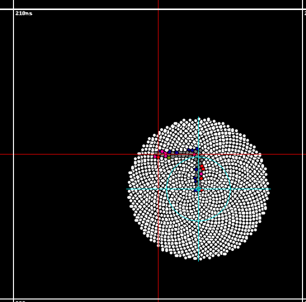
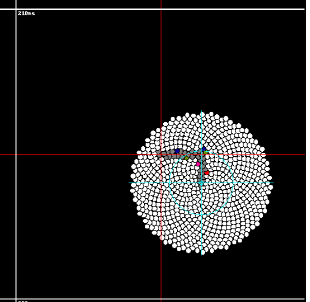
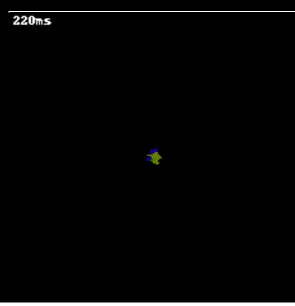
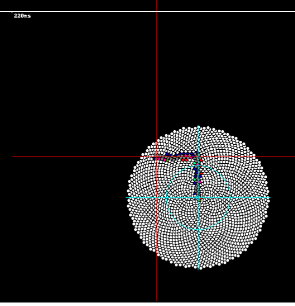
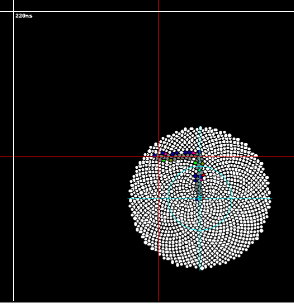
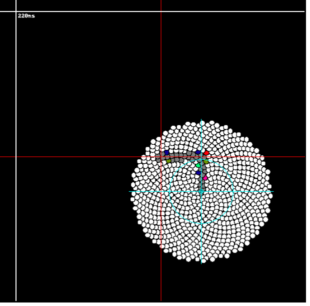
Table 12: Time sequence of filling-out by planned eye movement under paralysis					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
20					
21					
22					

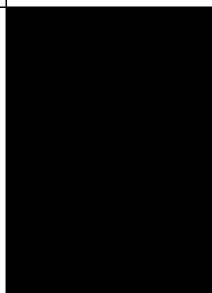
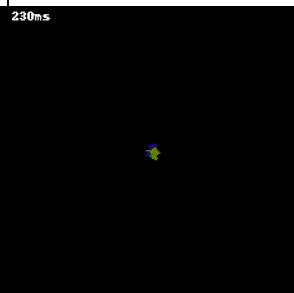
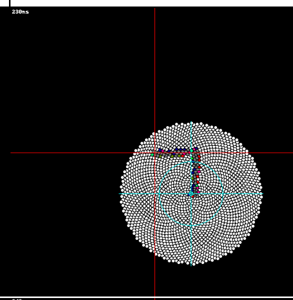
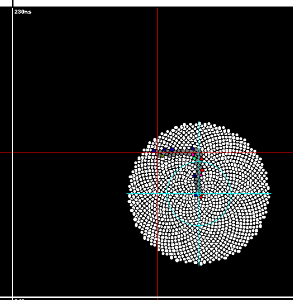
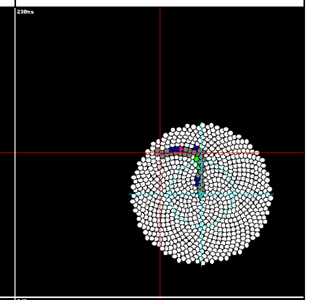
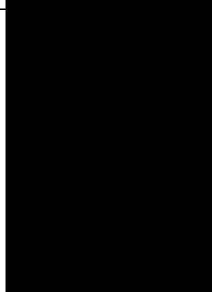
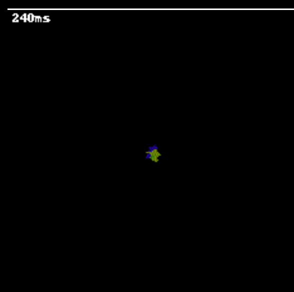
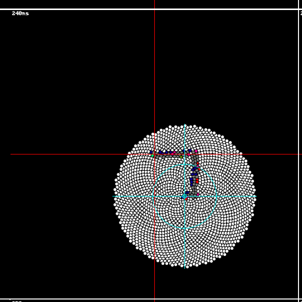
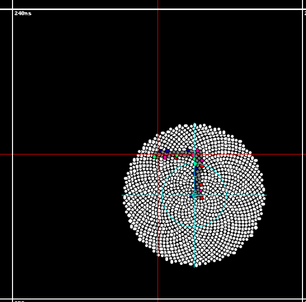
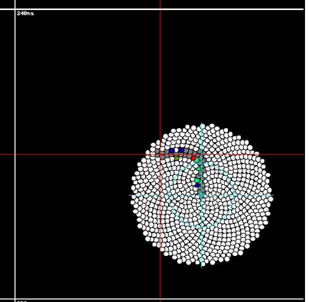
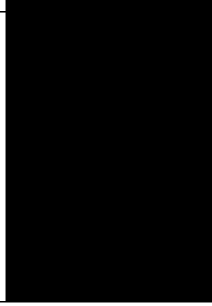
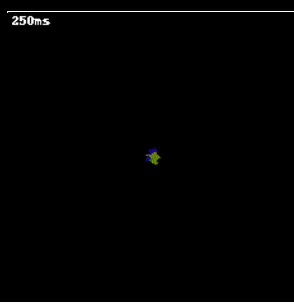
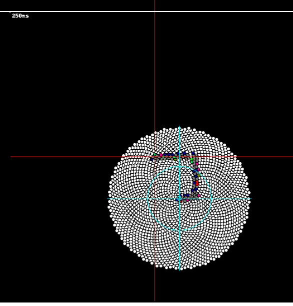
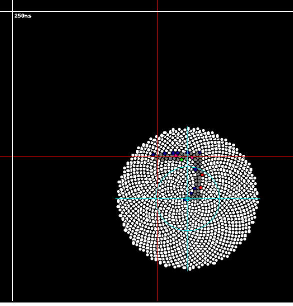
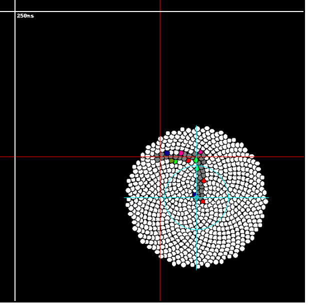
Table 12: Time sequence of filling-out by planned eye movement under paralysis					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
23					
24					
25					

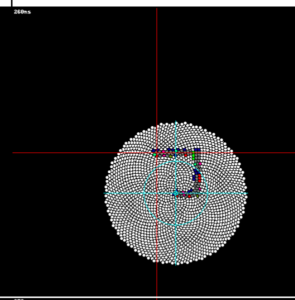
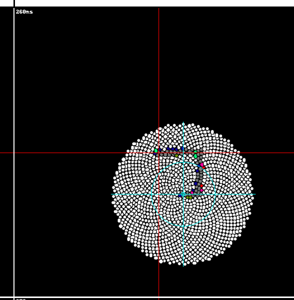
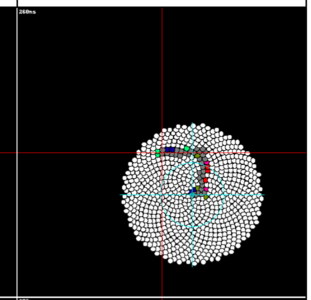
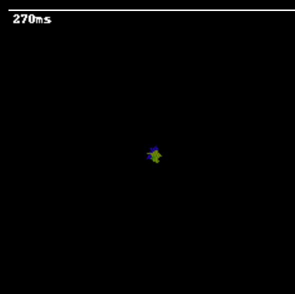
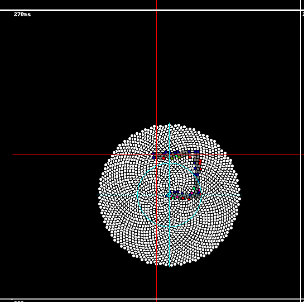
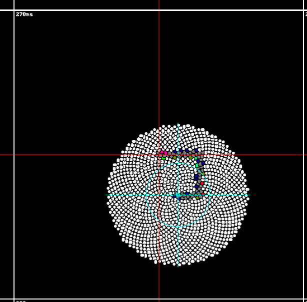
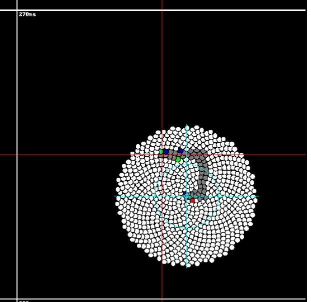
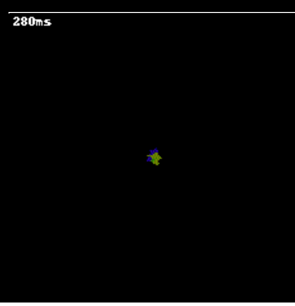
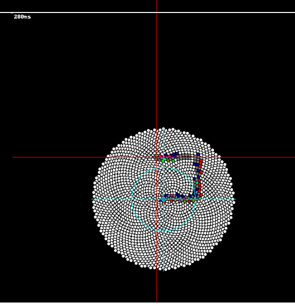
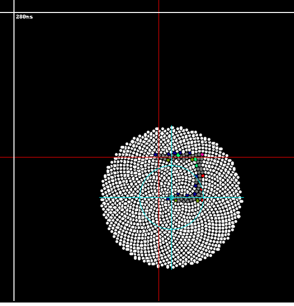
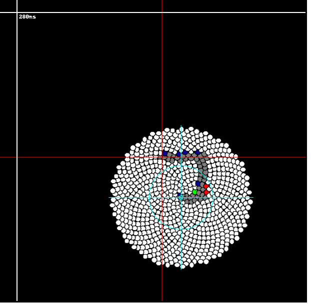
Table 12: Time sequence of filling-out by planned eye movement under paralysis					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
26					
27					
28					

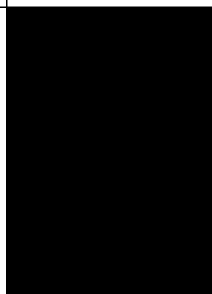
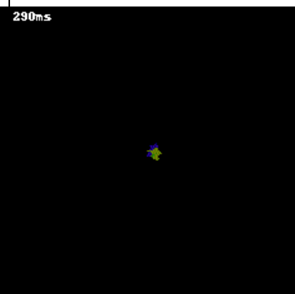
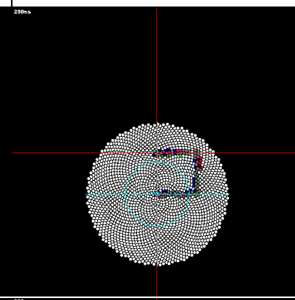
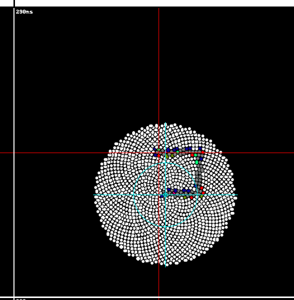
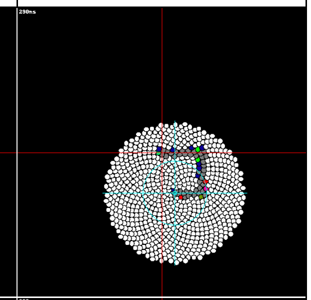
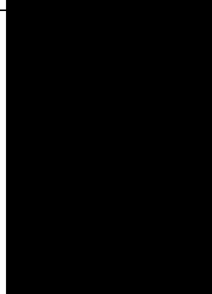
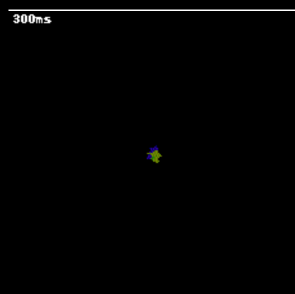
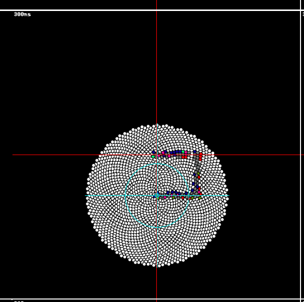
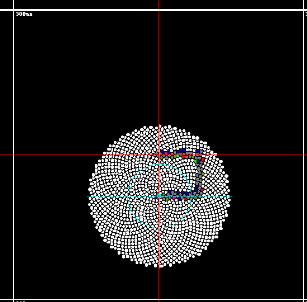
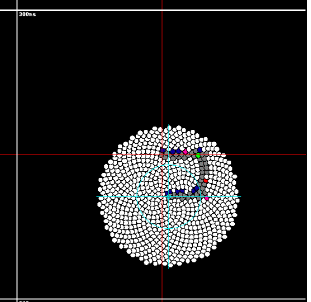
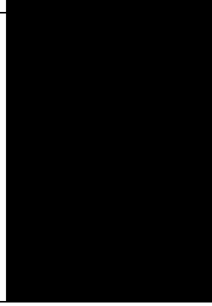
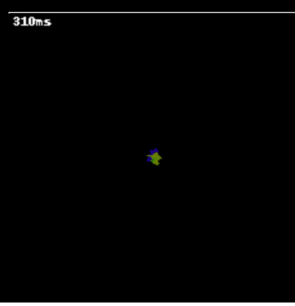
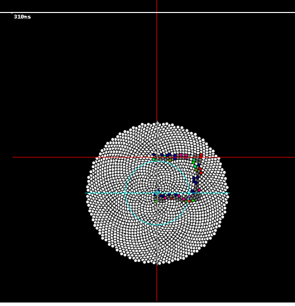
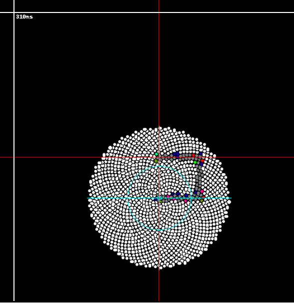
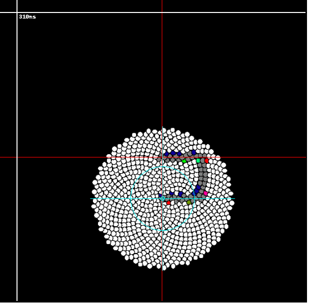
Table 12: Time sequence of filling-out by planned eye movement under paralysis					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
29					
30					
31					

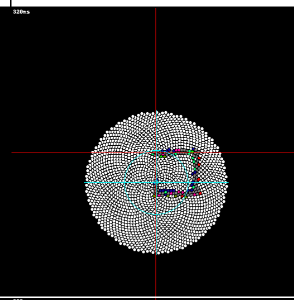
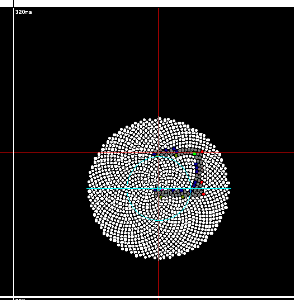
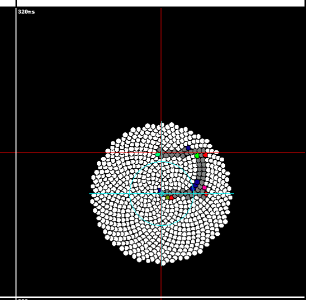
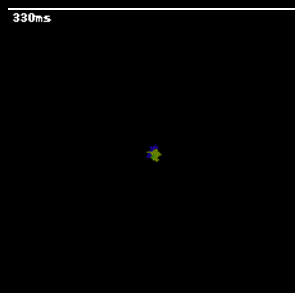
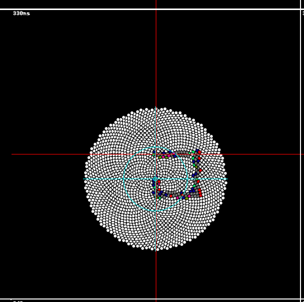
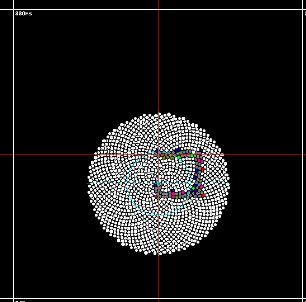
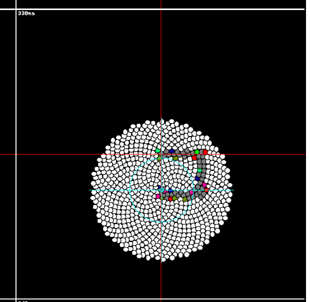
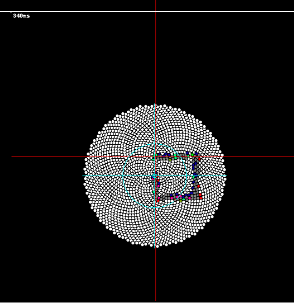
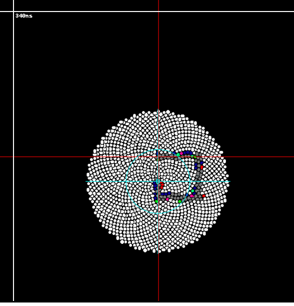
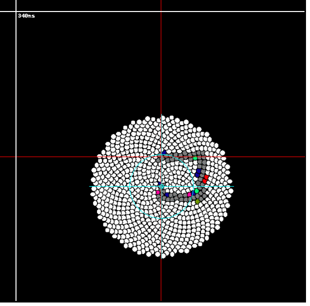
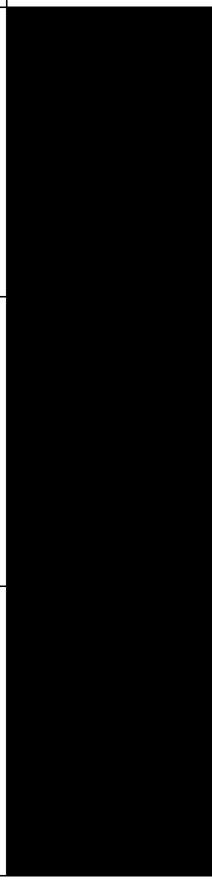
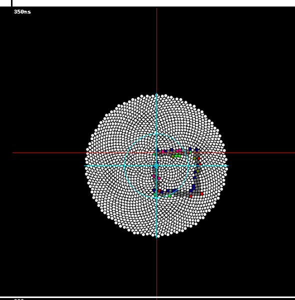
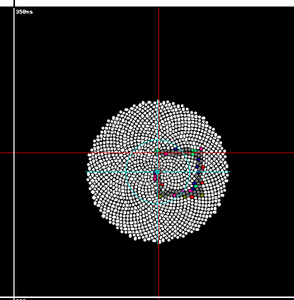
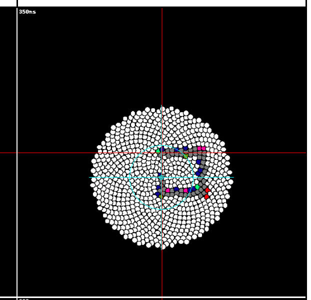
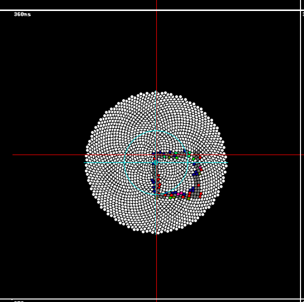
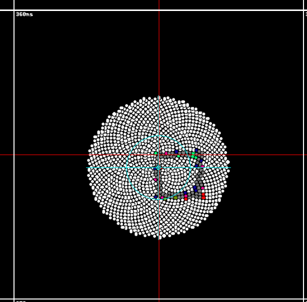
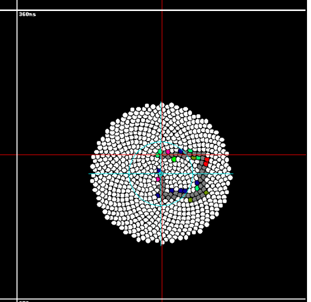
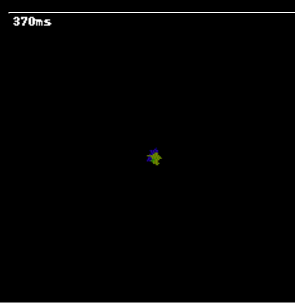
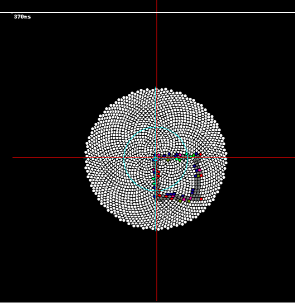
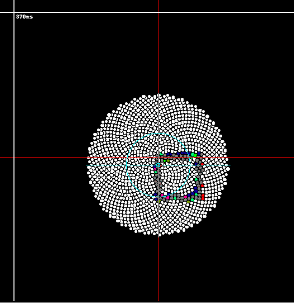
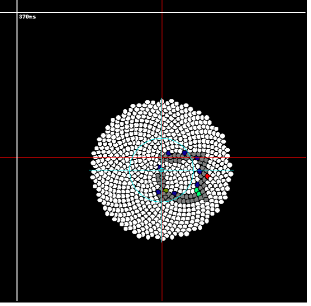
Table 12: Time sequence of filling-out by planned eye movement under paralysis					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
32					
33					
34					

Table 12: Time sequence of filling-out by planned eye movement under paralysis					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
35					
36					
37					

4 Chapter: An emergic model of filling-in after brief stimuli

These supplement the corresponding material in the thesis.

4.1 Subject details

A single virtual subject was used in all four experiments. The *person* is fully characterized by a set of developmental parameters that will be indicated next. The meaning of these developmental parameters can be found in the thesis. Note that development includes a stochastic component so that, for example, while the L:M:S cone ratio may be innately specified, the colour sensitivity type of individual cones is random. Each test had a new incarnation of *person*.

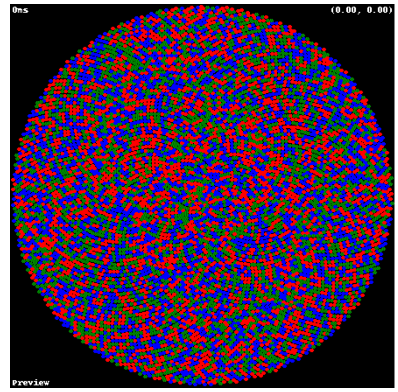


Illustration 10: Photoreceptor mosaic of *person* used in "flash memory" tests 1-4

To focus characterization on memory phenomena, a large homogeneously arranged photoreceptor mosaic was used with equal ratios of red (L), green (M) and blue (S) cones. The size of the cones did not vary. The full set of parameters is shown below.

```
[Person]
note = flash
srt = 10
sex = ai
age = 18
eyecount = 1
ipd = 0
vsize = 17.0
vieweyez = 100
r0conepix = 4
nodalpt = 17
r0coned = 4.0
r0red = 1
r0green = 1
r1coned = 1.0
r1red = 3000
r1green = 3000
r1blue = 3000
blindx = 0.0
blindy = 0.0
blindr = 0.0
blink0d = 6
blink1d = 32
jitmin = 0.1
jitave = 0.7
jitmax = 0.9
p1_0_pixd = 2.5
p1_0_pix = 1800
p1_0_scale = 2
p1_0_fanlat = 5.0
p1_0_fandwn = 2.0
p1_1_pixd = 5.0
p1_1_pix = 500
p1_1_scale = 2
p1_1_fanlat = 2.0
p1_1_fandwn = 2.0
p1_2_pixd = 7.5
p1_2_pix = 250
p1_2_scale = 2
p1_2_fanlat = 1.2
p1_2_fandwn = 1.5
```

4.2 Stimuli details

Four different stimuli were used to validate the robustness of the spatiotemporal filling-in behaviour of the ECM architecture.

4.2.1 Test 1 stimulus: Simple surfaces (Love)

This stimulus is used to test spatiotemporal filling-in behaviour using simple surfaces – the block letters spelling LOVE. The meaning of these parameters is fully described in the thesis. The content of file love.png appears in Illustration 11 minus any overlay.

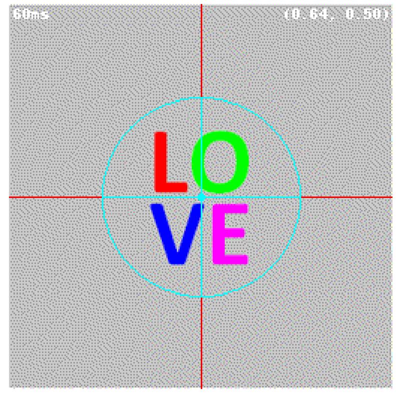


Illustration 11: "Flash memory" view of Love

```
[World]                [Image]                iname = love.png
type = Image           wx = 256               ix = 256
note = Love            wy = 256               iy = 256
srt = 200              wbg = #000000
```

4.2.2 Test 2 stimulus: Natural image (Lena)

This stimulus is used to test spatiotemporal filling-in behaviour using a natural image - a standard image library picture of Lena (Picard, 1995). The meaning of these parameters is fully described in the thesis. The content of file Lena.tiff appears in Illustration 12 minus any overlay.

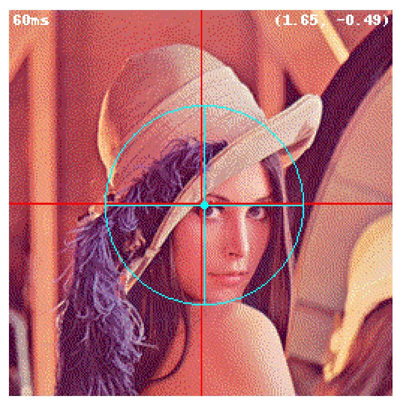


Illustration 12: "Flash memory" view of Lena

```
[World]                [Image]                iname = Lena.tiff
type = Image           wx = 256               ix = 256
note = Lena            wy = 256               iy = 256
srt = 200              wbg = #000000
```

4.2.3 Test 3 stimulus: Dynamic image with surface gradients (Chaser)

This stimulus is used to test spatiotemporal filling-in behaviour in a generic fashion using a dynamic image with surface gradients – the lilac chaser. The stimulus appears in Illustration 13 minus any overlay. The meaning of these parameters is fully described in the thesis.

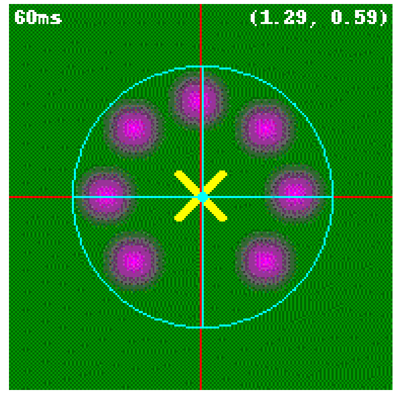


Illustration 13: "Flash memory" view of Chaser

```
[World]
type = Lilac
Chaser
note =
src = 100
[Lilac Chaser]
llcount = 8
spacing = 0.1
pad = 1.0
fg = #ff00ff
bg = #007f00
gamma = 1.0
grdcount = 17
grdwidth = 1
fixfg = #ffff00
fixsize = 0.75
fixwidth = 2
```

4.2.4 Test 4 stimulus: Simple object (Square)

This stimulus is used to test spatiotemporal filling-in behaviour using a simple object – a green square over a blue background. The meaning of these parameters is fully described in the thesis. The content of file square.gif appears in Illustration 14 minus any overlay.

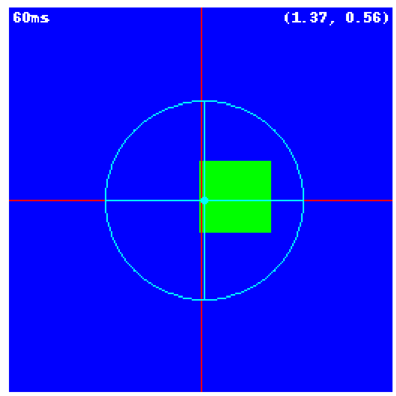


Illustration 14: Test 4 stimulus (Square) with view overlay

```
[World]
type = Image
note = square
srt = 200
[Image]
wx = 256
wy = 256
wbg = #000000
iname = square.gif
ix = 256
iy = 256
```

4.3 Result details

In this section we tabulate a visual frame-by-frame account of results from all experiments. Such a frame-by-frame account allows for the extraction of precise timing information useful for quantitative analysis. It takes 44 pages. All these results are reduced to a single web page of animated images, available at

http://emergic.upwize.com/?page_id=210

The animated account (Leibovitz, 2012a) is preferred as an overview showing behavioural dynamics of filling-in, memory, masking, etc. and makes image stability more salient. It also includes the results in greatest detail – they have been scaled down for print in this supplement, and even smaller in the chapter's *results and discussion* sections.

Each table of results has the following columns. **Time** numerically represents the time tick since the test has started, nominally 10ms/tick. All visual results in that table row are after the tick and computation have finished. **Stimuli** visually represents the stimuli presented to the virtual computer screen, often with retinal overlays. The **Photoreceptor Mosaic** visually represents what the retina senses by looking at the stimuli. **Receptive Fields** at **Level 1**, **Level 2** and **Level 3**, visually represent the three level hierarchy of receptive fields showing their the functional size and placement, not physical size nor placement

4.3.1 Test 1 results: Simple surfaces (Love)

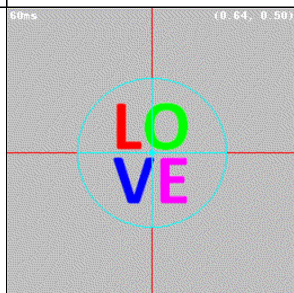
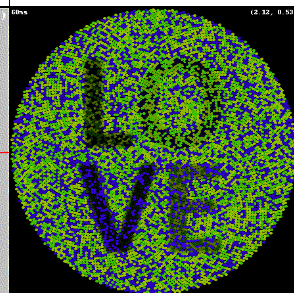
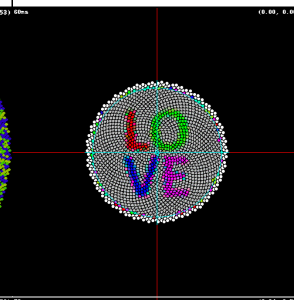
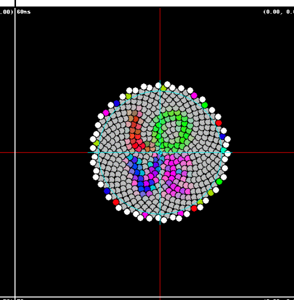
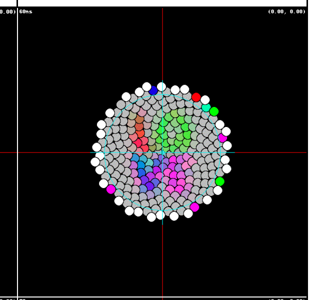
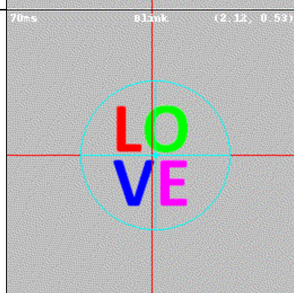
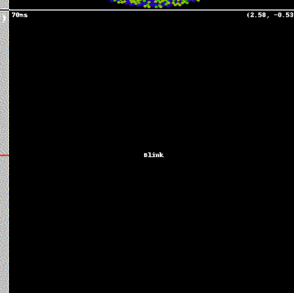
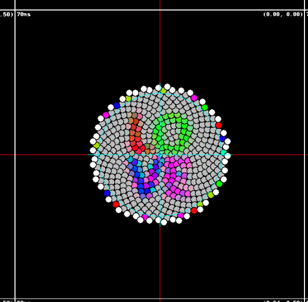
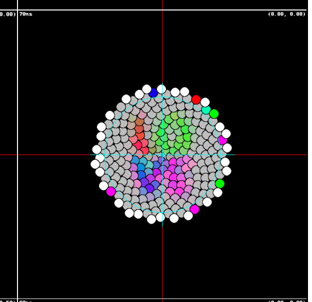
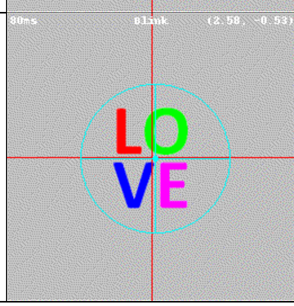
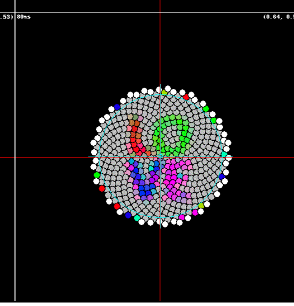
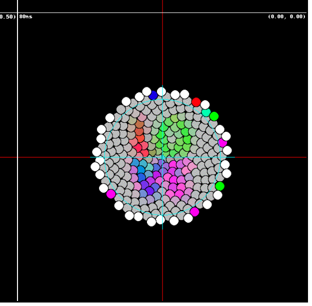
Table 13: Time sequence of active visual memory decay for simple surfaces (Love)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
6					
7					
8					

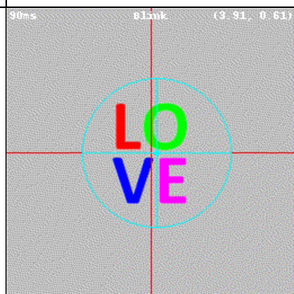
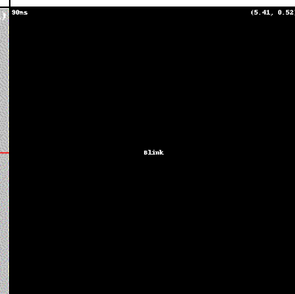
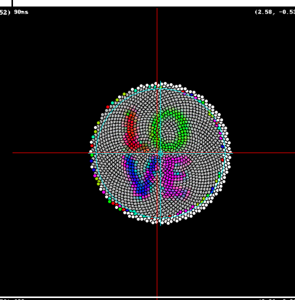
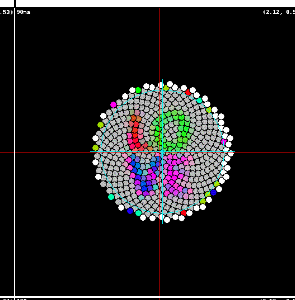
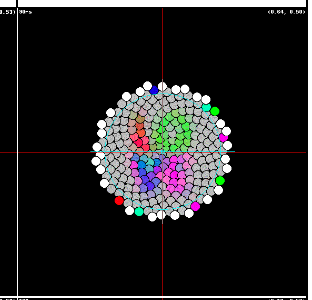
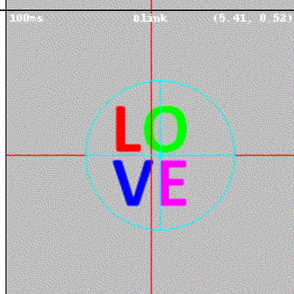
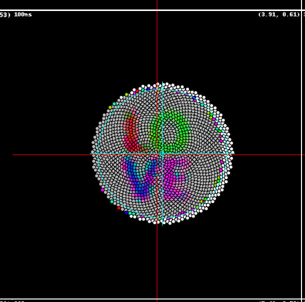
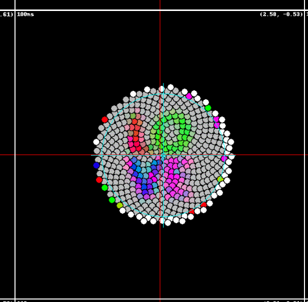
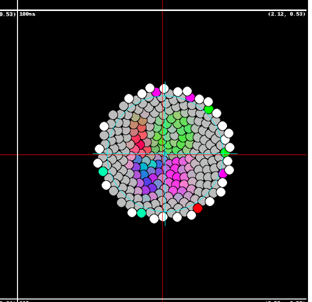
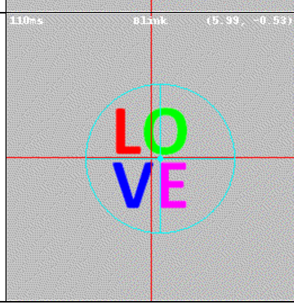
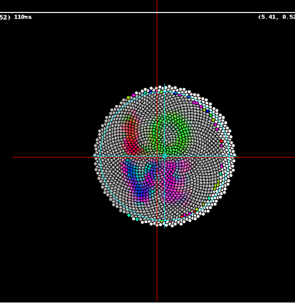
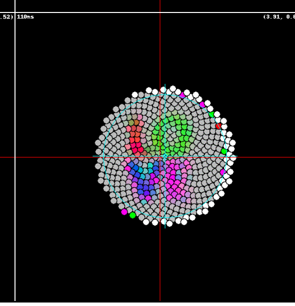
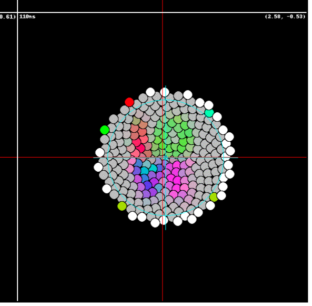
Table 13: Time sequence of active visual memory decay for simple surfaces (Love)					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
9					
10					
11					

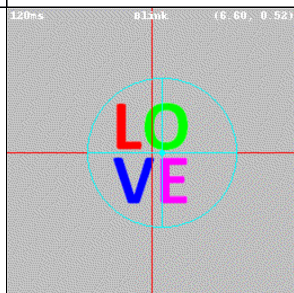
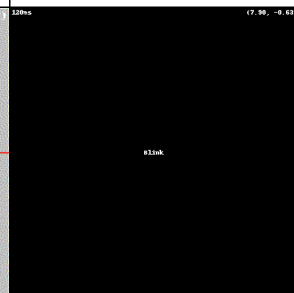
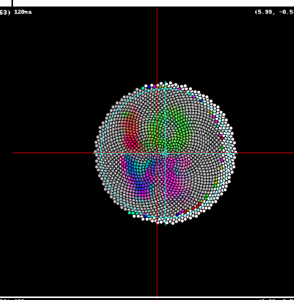
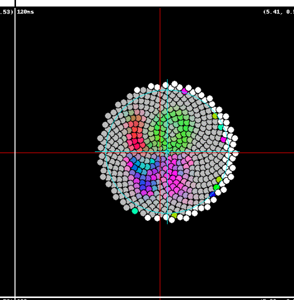
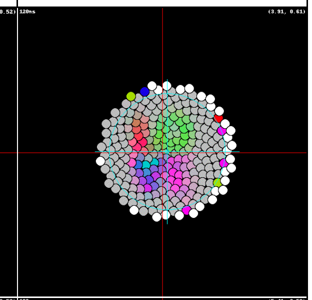
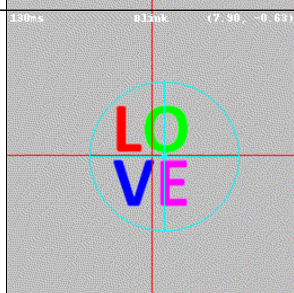
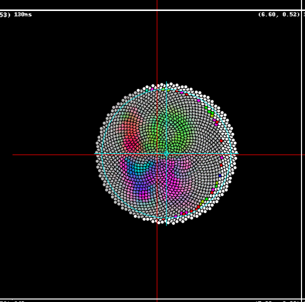
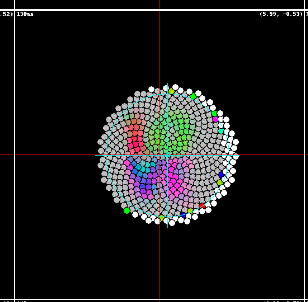
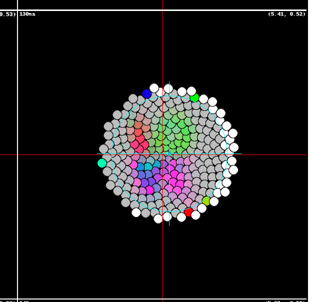
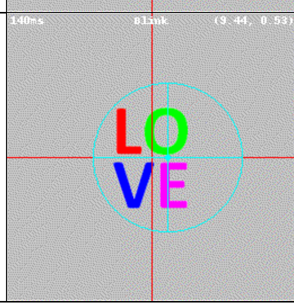
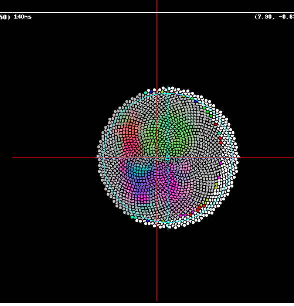
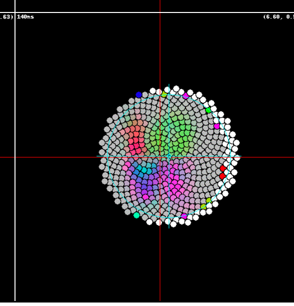
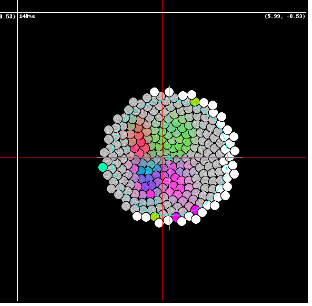
Table 13: Time sequence of active visual memory decay for simple surfaces (Love)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
12					
13					
14					

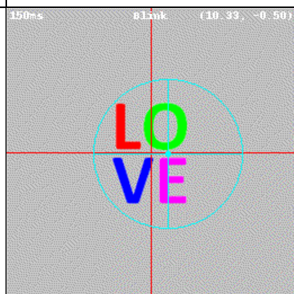
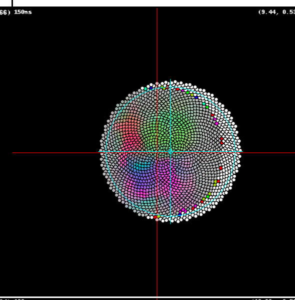
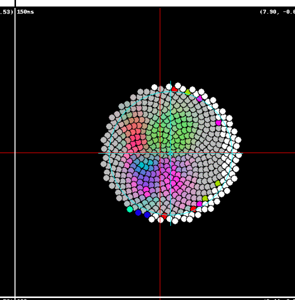
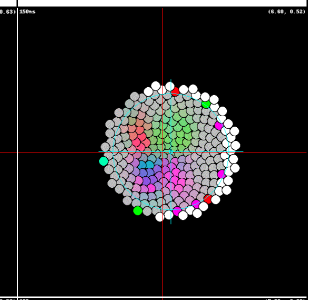
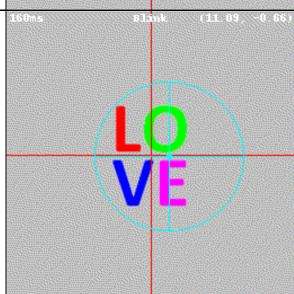
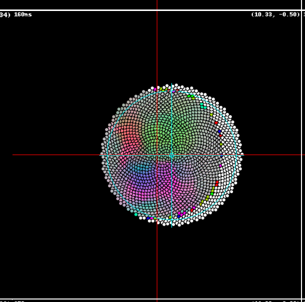
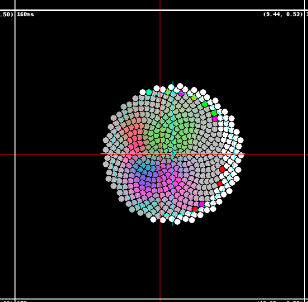
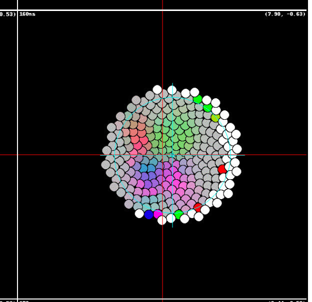
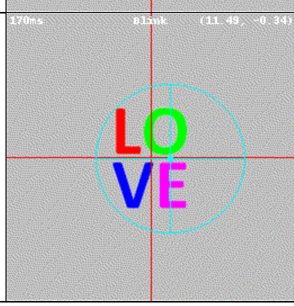
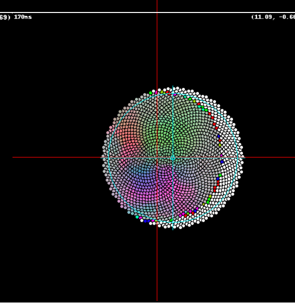
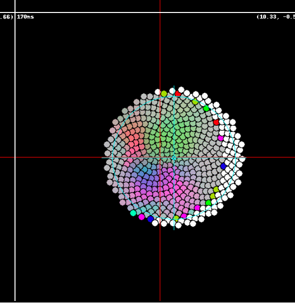
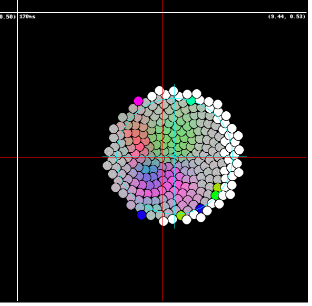
Table 13: Time sequence of active visual memory decay for simple surfaces (Love)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
15					
16					
17					

Table 13: Time sequence of active visual memory decay for simple surfaces (Love)

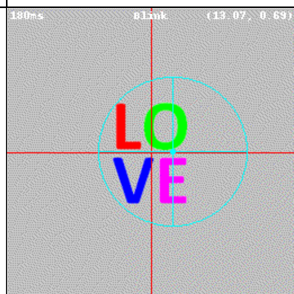
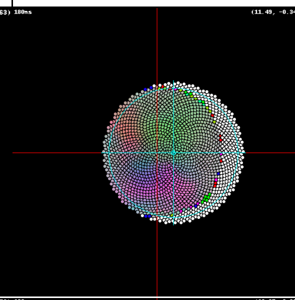
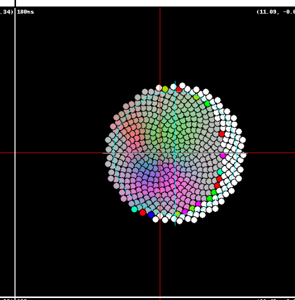
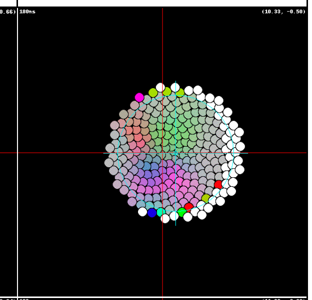
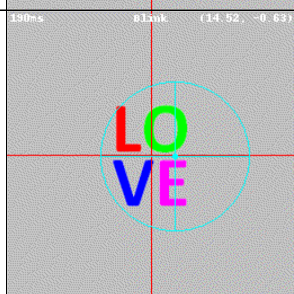
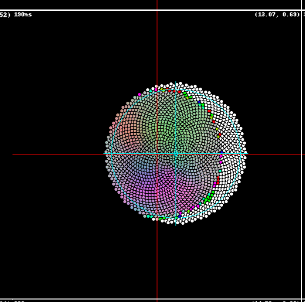
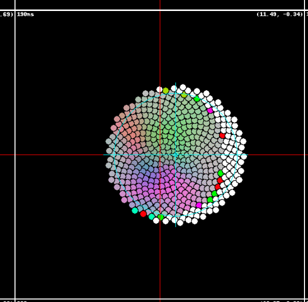
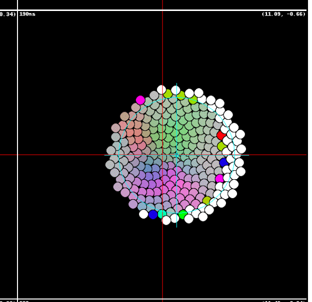
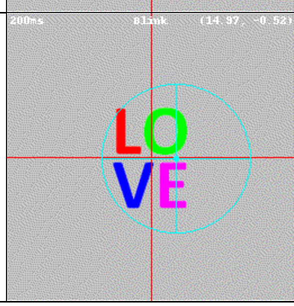
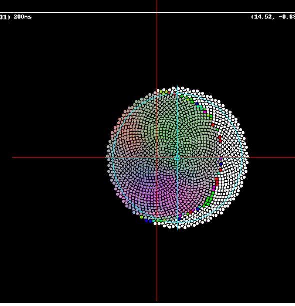
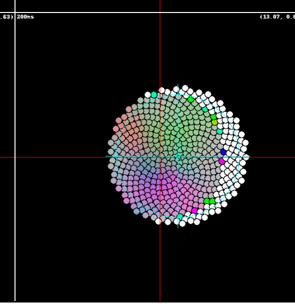
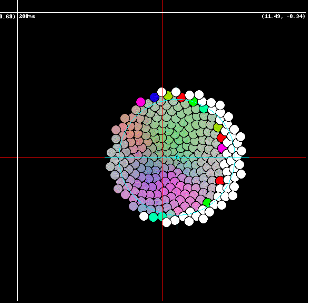
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
18					
19					
20					

Table 13: Time sequence of active visual memory decay for simple surfaces (Love)

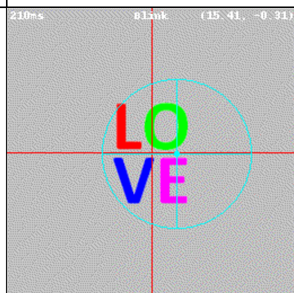
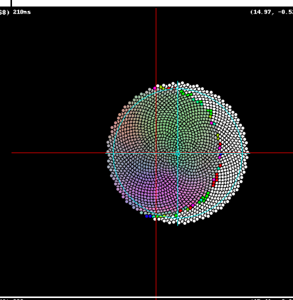
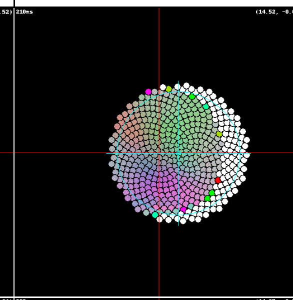
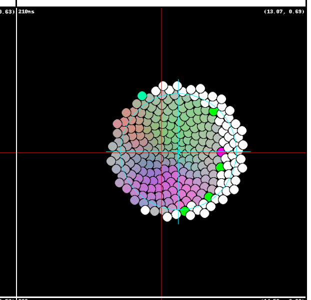
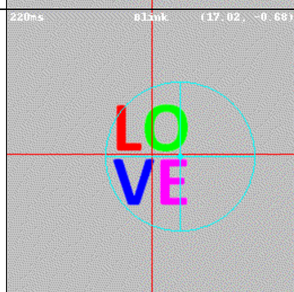
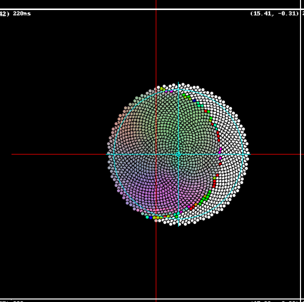
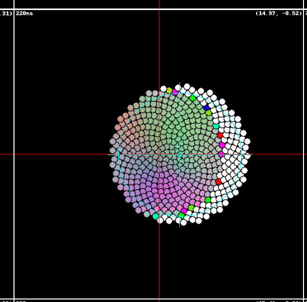
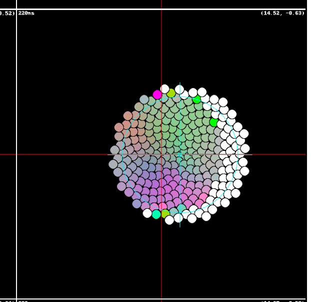
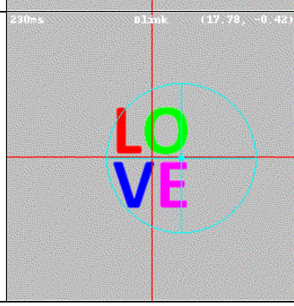
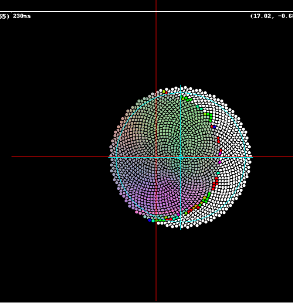
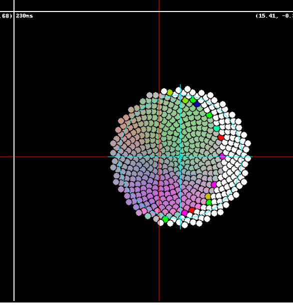
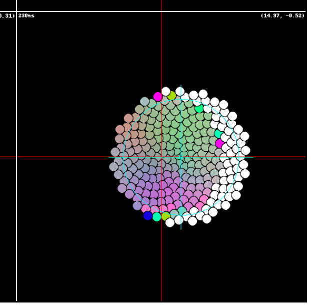
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
21					
22					
23					

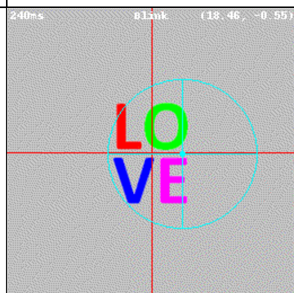
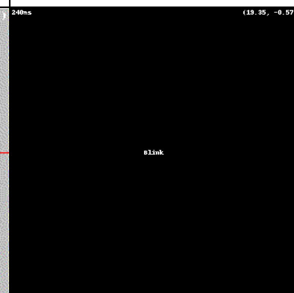
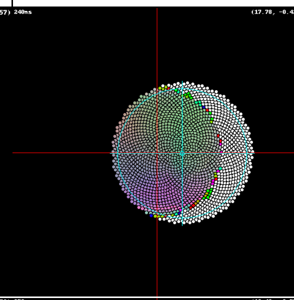
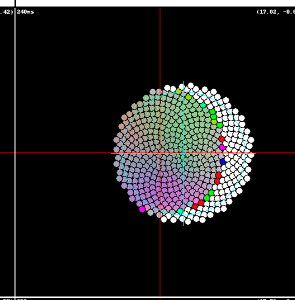
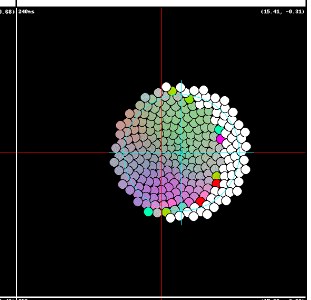
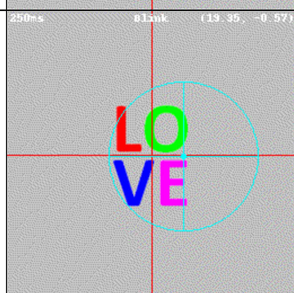
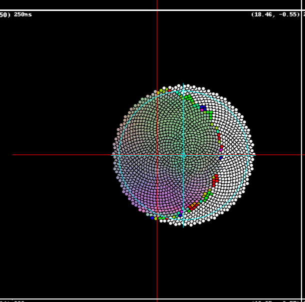
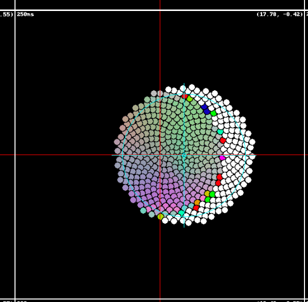
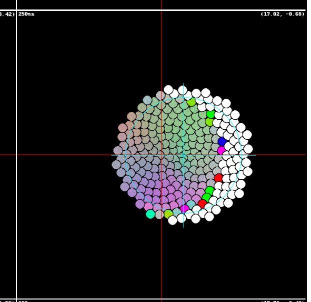
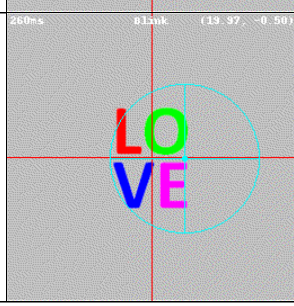
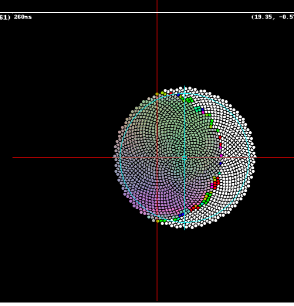
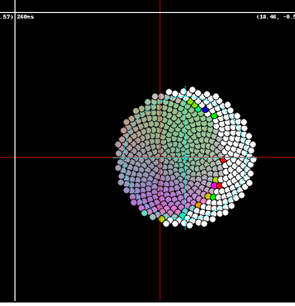
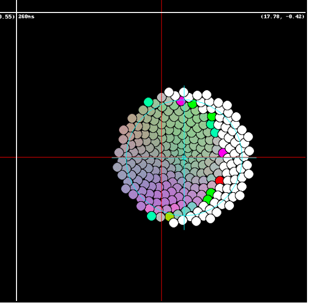
Table 13: Time sequence of active visual memory decay for simple surfaces (Love)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
24					
25					
26					

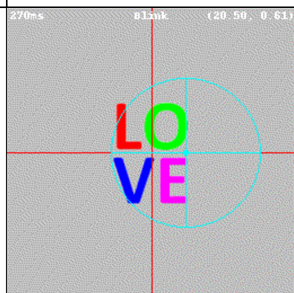
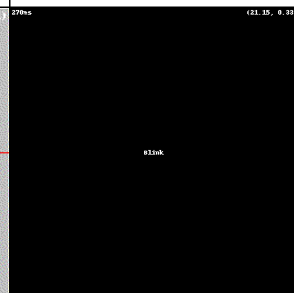
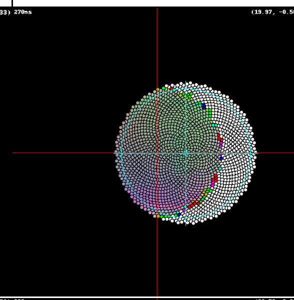
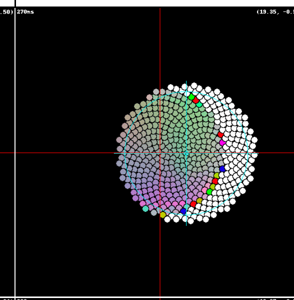
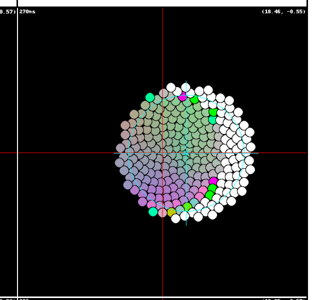
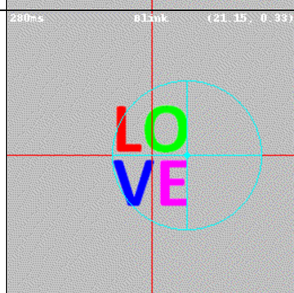
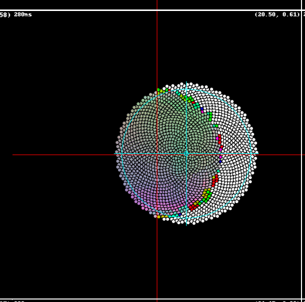
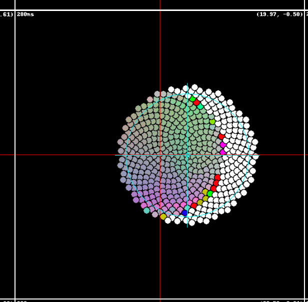
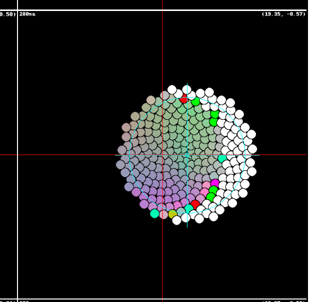
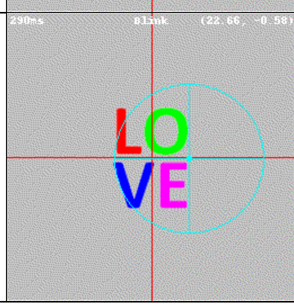
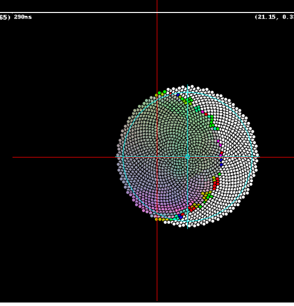
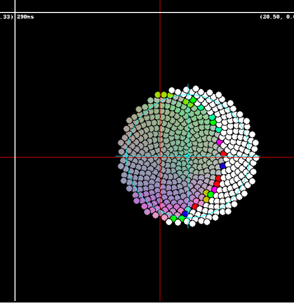
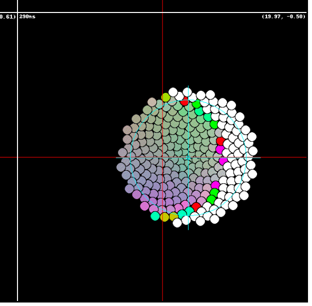
Table 13: Time sequence of active visual memory decay for simple surfaces (Love)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
27					
28					
29					

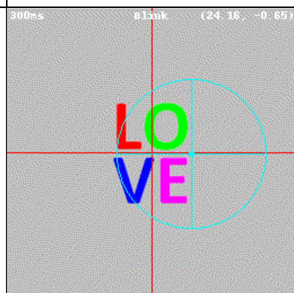
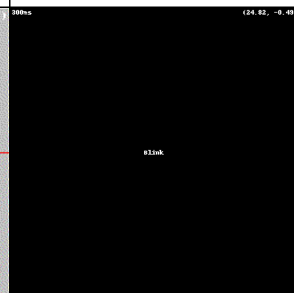
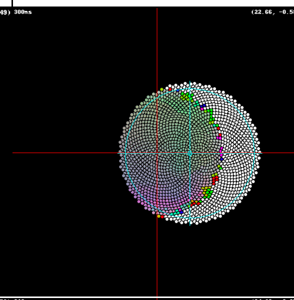
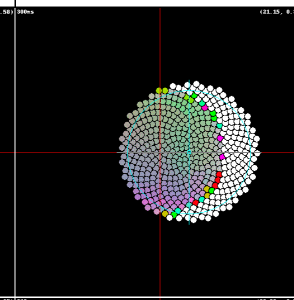
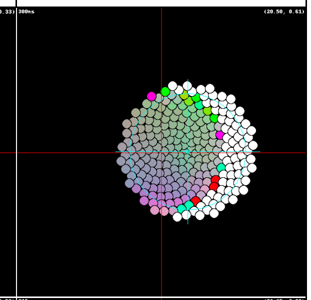
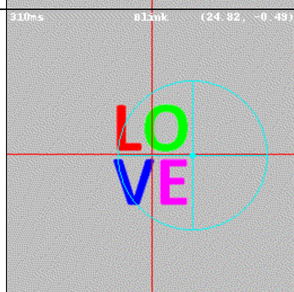
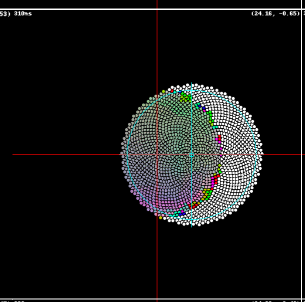
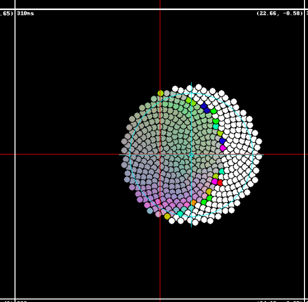
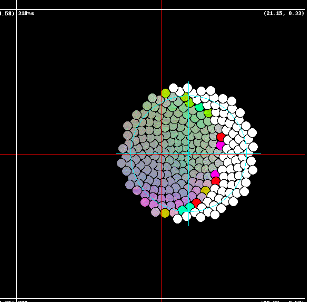
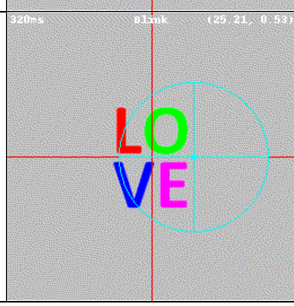
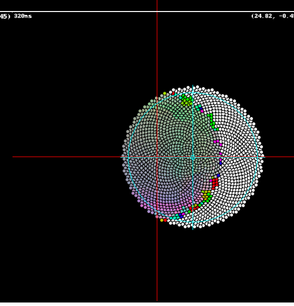
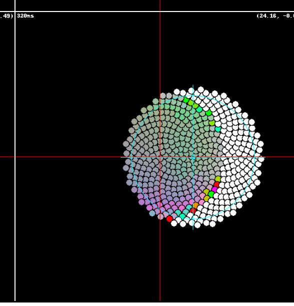
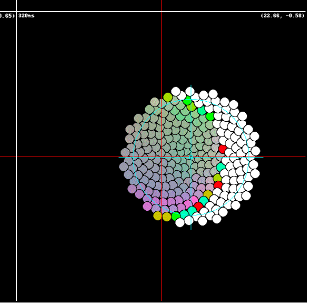
Table 13: Time sequence of active visual memory decay for simple surfaces (Love)					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
30					
31					
32					

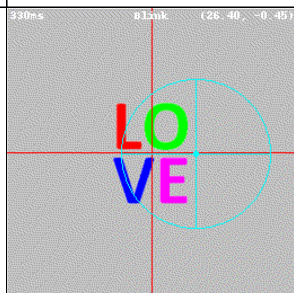
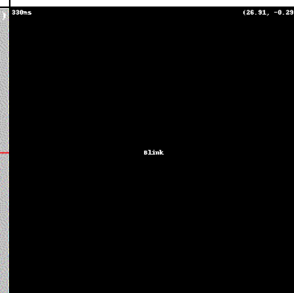
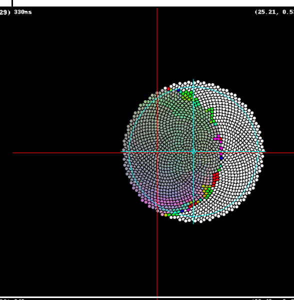
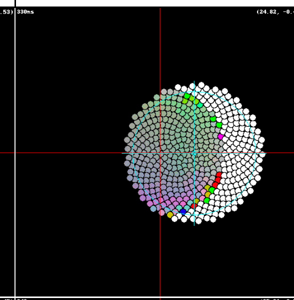
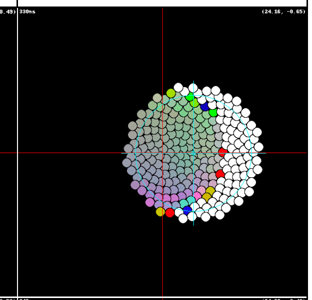
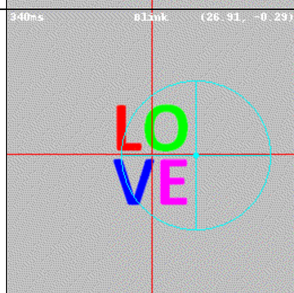
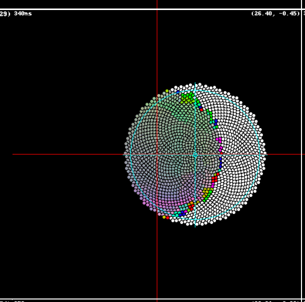
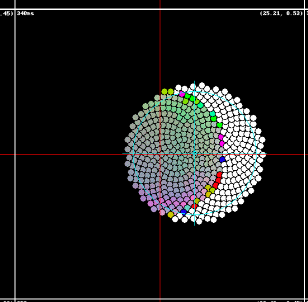
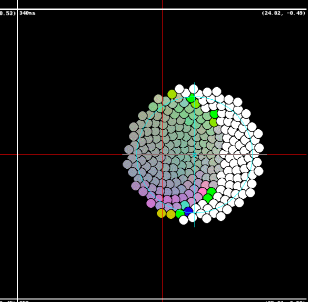
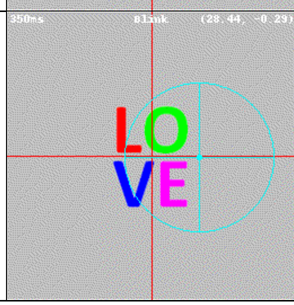
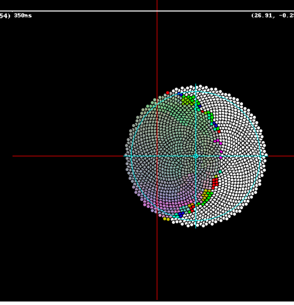
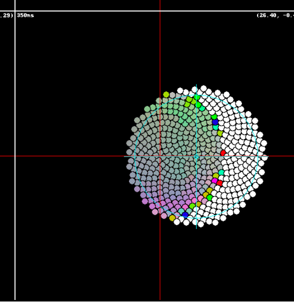
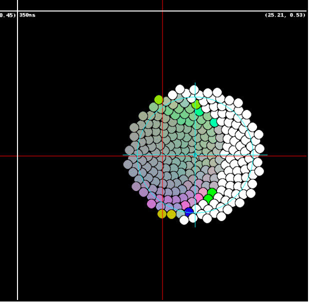
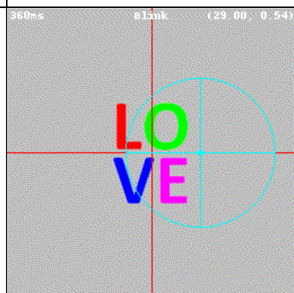
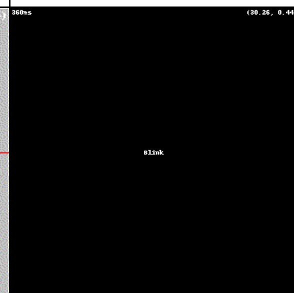
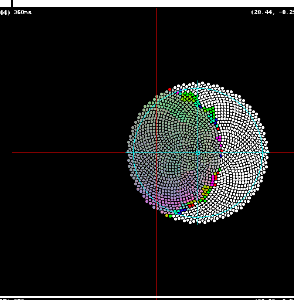
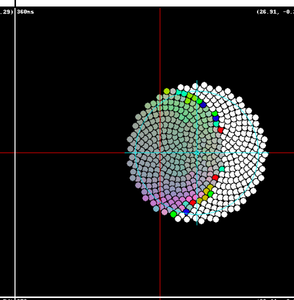
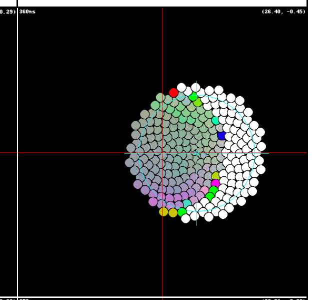
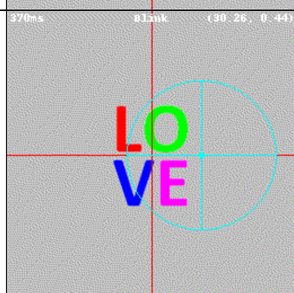
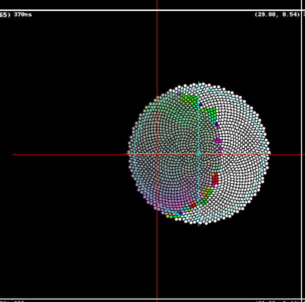
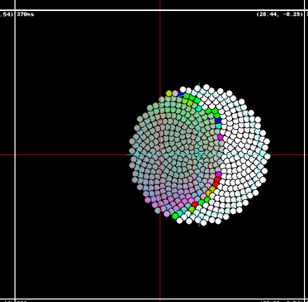
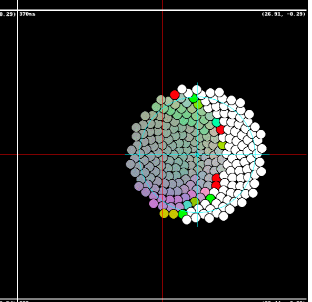
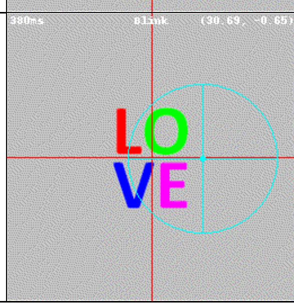
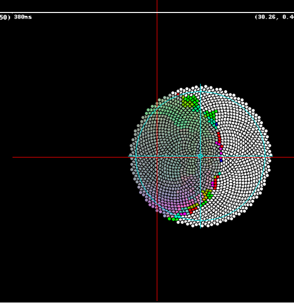
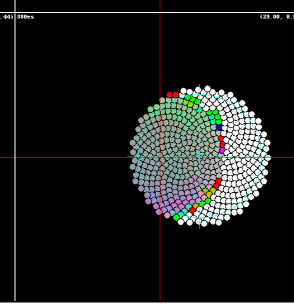
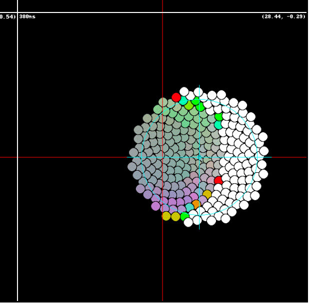
Table 13: Time sequence of active visual memory decay for simple surfaces (Love)					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
33					
34					
35					

Table 13: Time sequence of active visual memory decay for simple surfaces (Love)					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
36					
37					
38					

4.3.2 Test 2 results: Natural image (Lena)

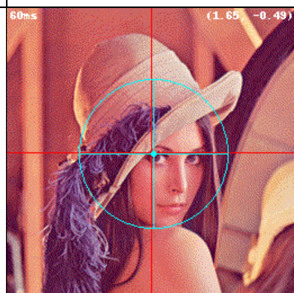
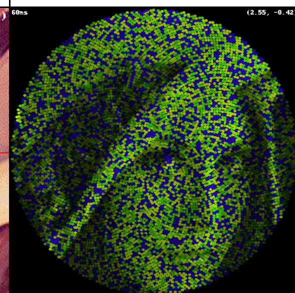
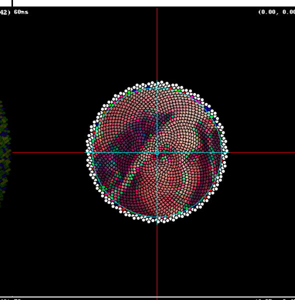
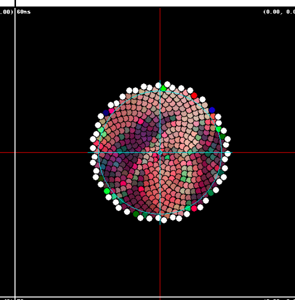
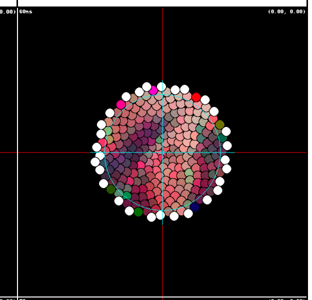
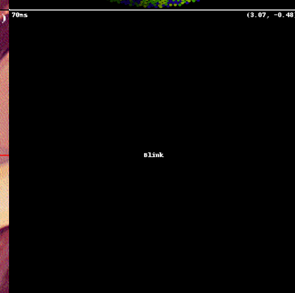
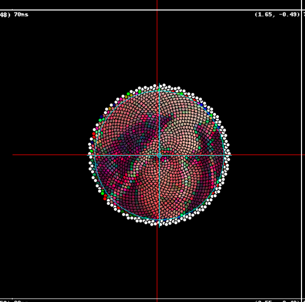
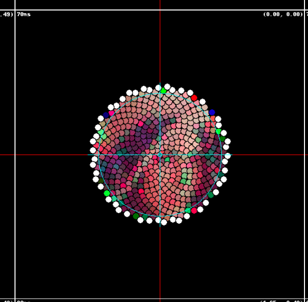
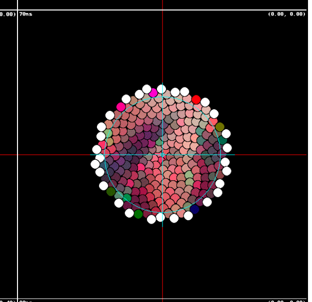
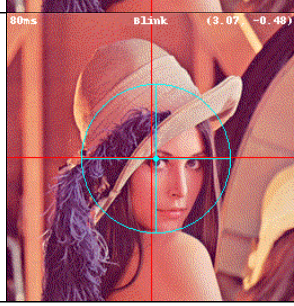
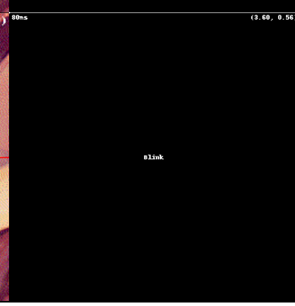
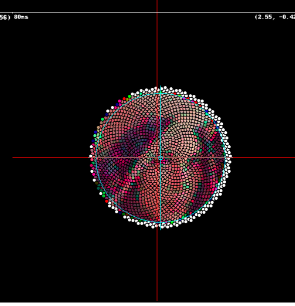
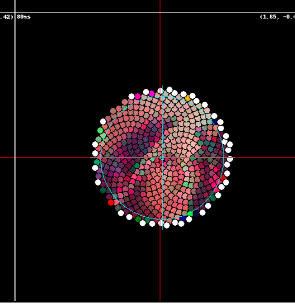
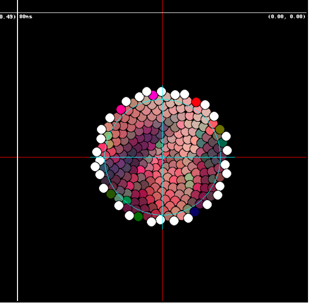
Table 14: Time sequence of active visual memory decay for natural image (Lena)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
6					
7					
8					

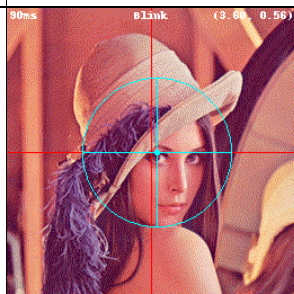
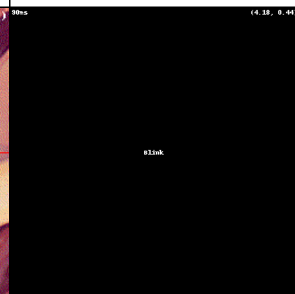
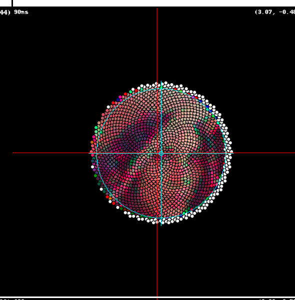
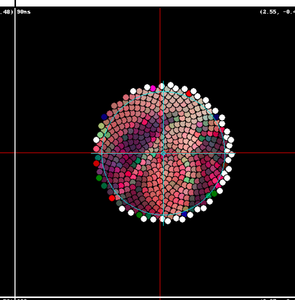
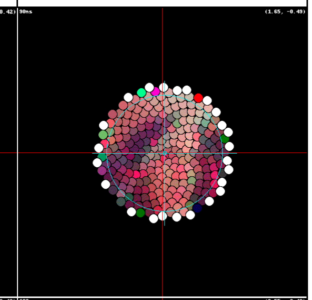
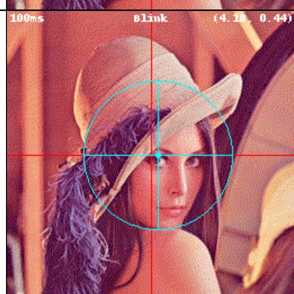
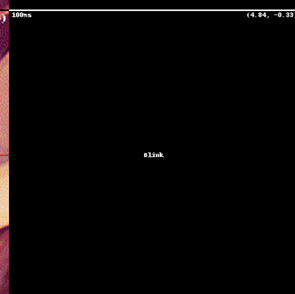
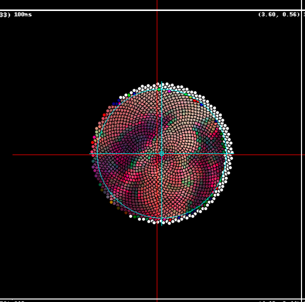
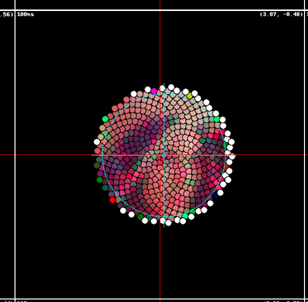
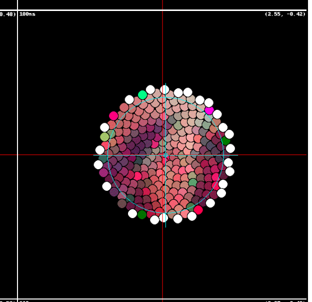
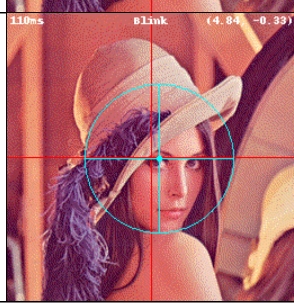
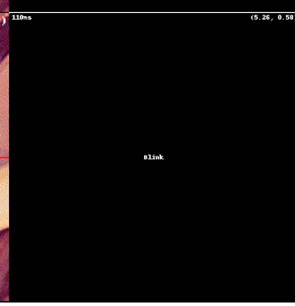
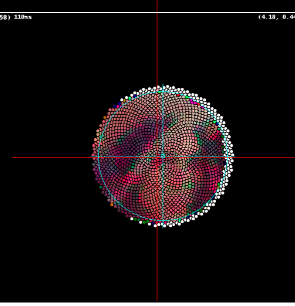
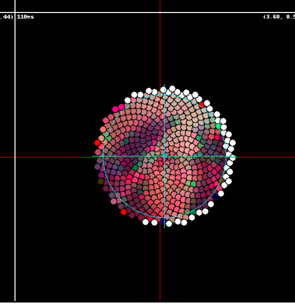
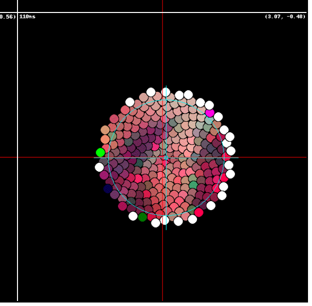
Table 14: Time sequence of active visual memory decay for natural image (Lena)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
9					
10					
11					

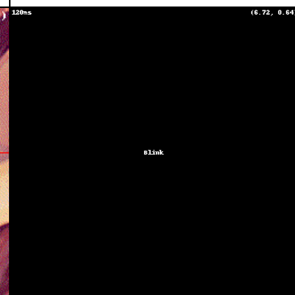
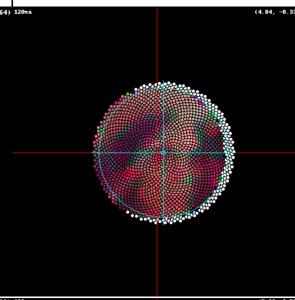
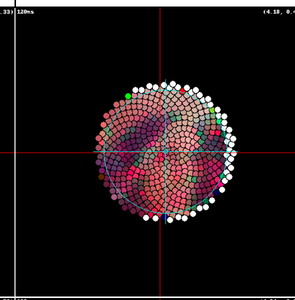
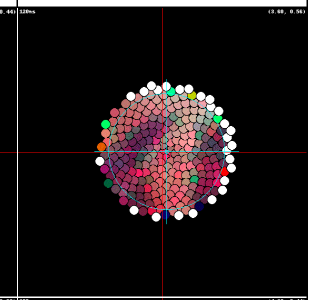
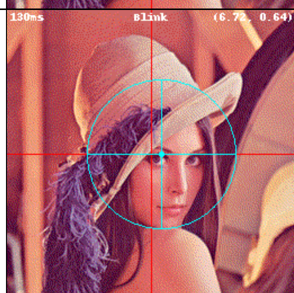
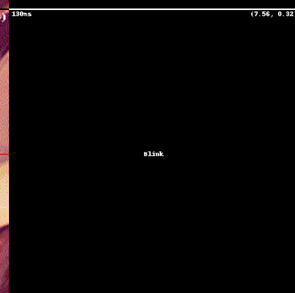
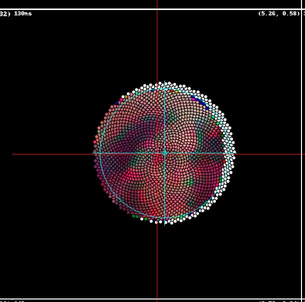
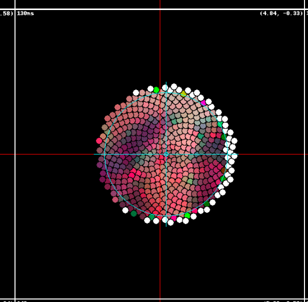
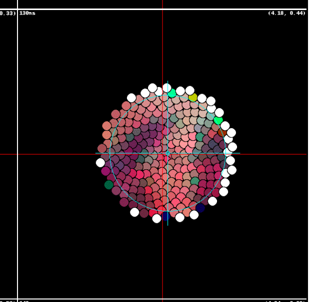
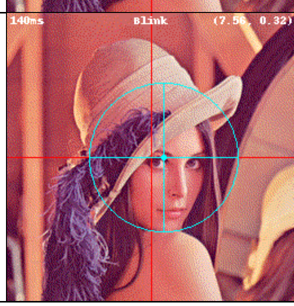
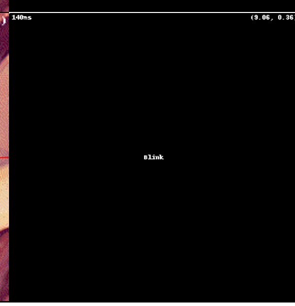
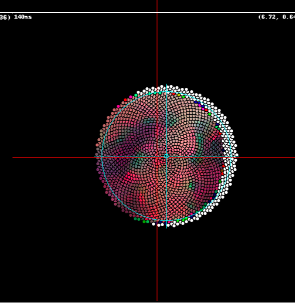
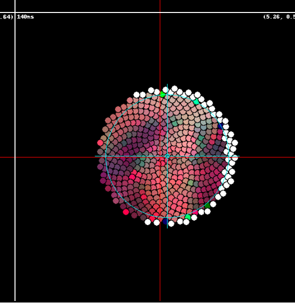
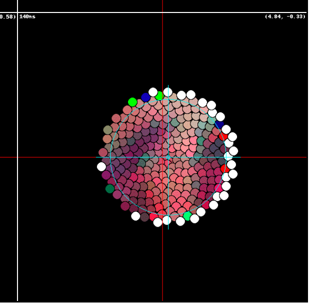
Table 14: Time sequence of active visual memory decay for natural image (Lena)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
12					
13					
14					

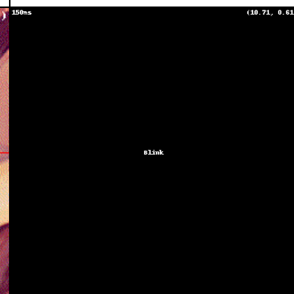
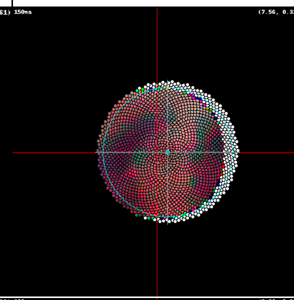
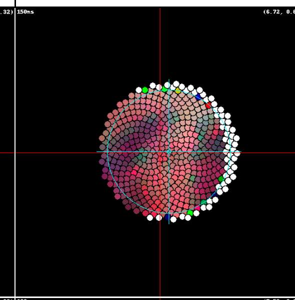
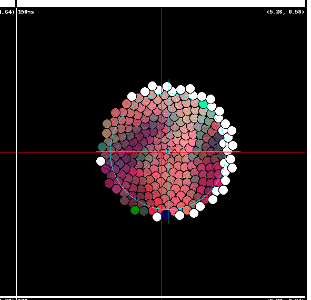
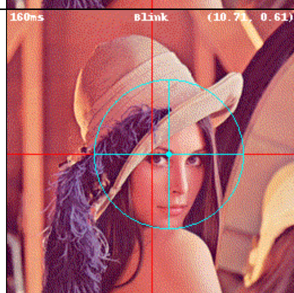
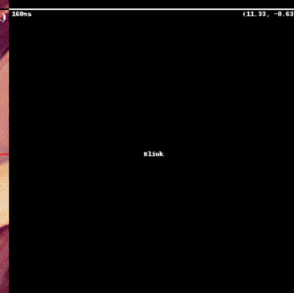
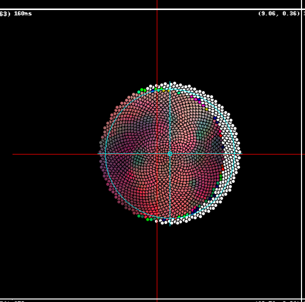
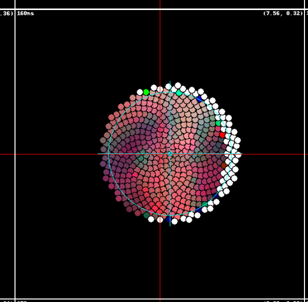
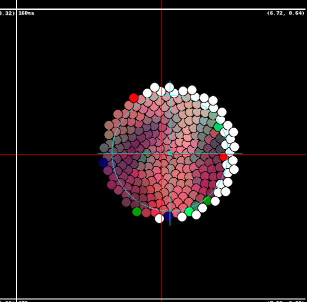
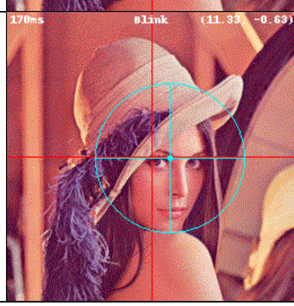
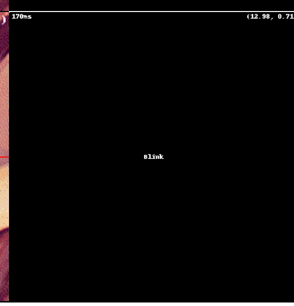
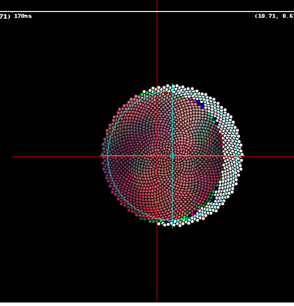
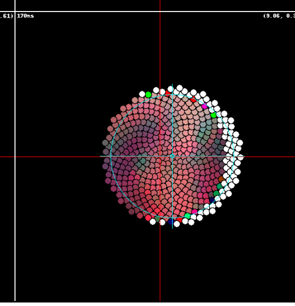
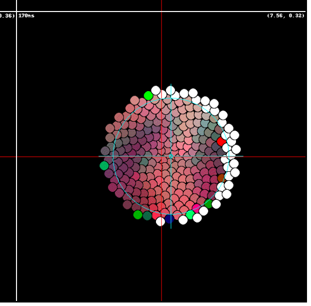
Table 14: Time sequence of active visual memory decay for natural image (Lena)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
15					
16					
17					

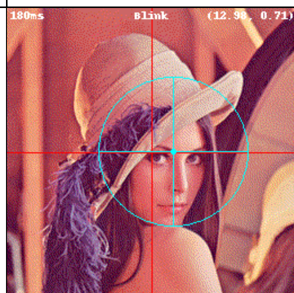
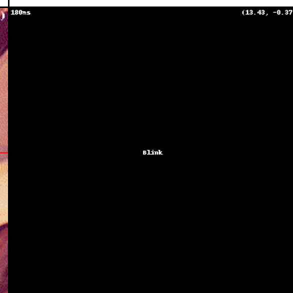
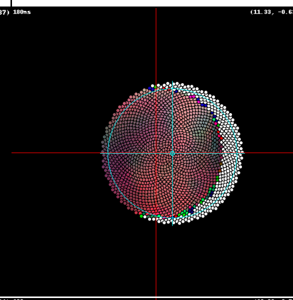
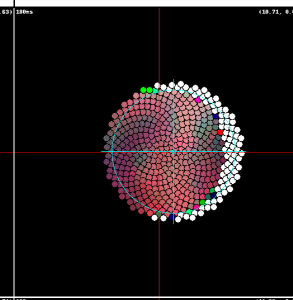
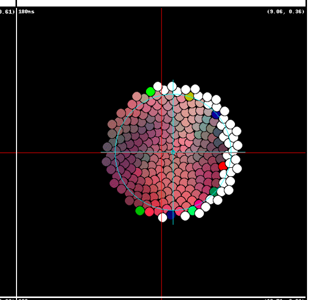
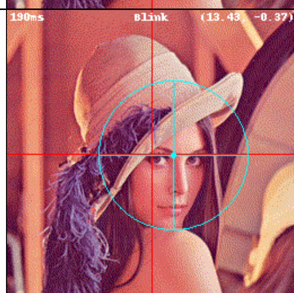
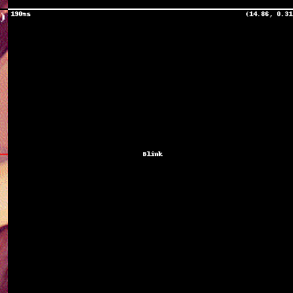
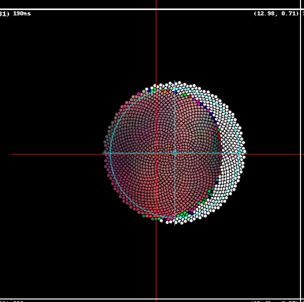
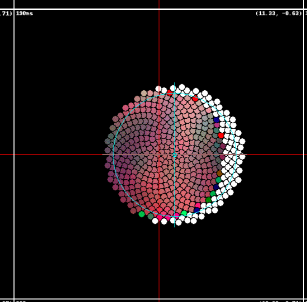
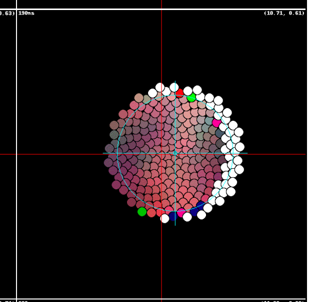
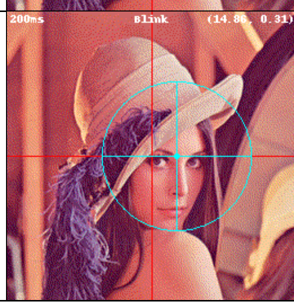
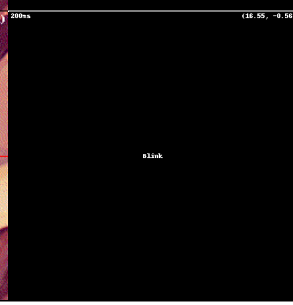
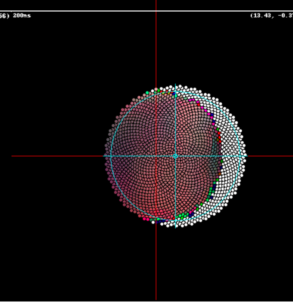
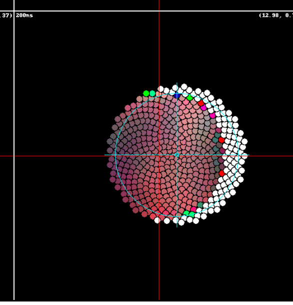
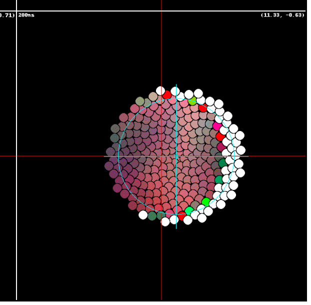
Table 14: Time sequence of active visual memory decay for natural image (Lena)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
18					
19					
20					

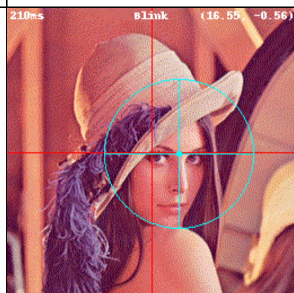
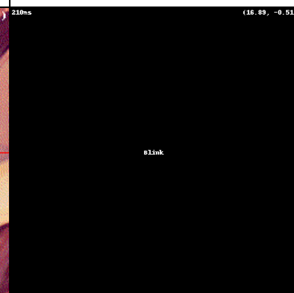
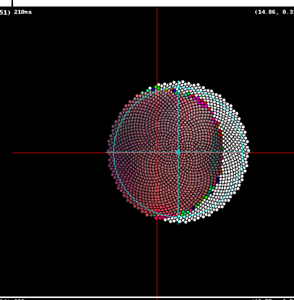
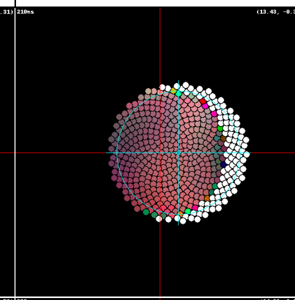
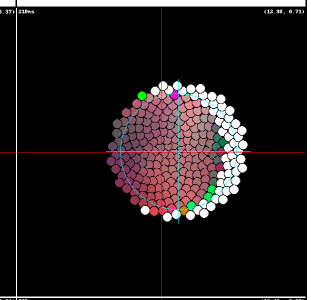
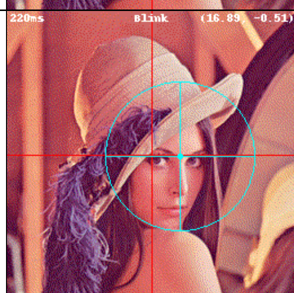
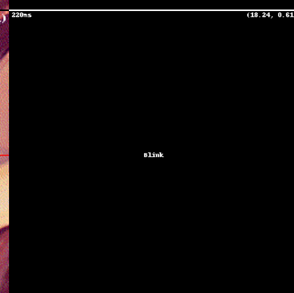
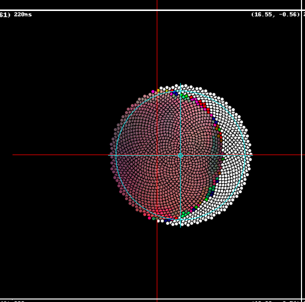
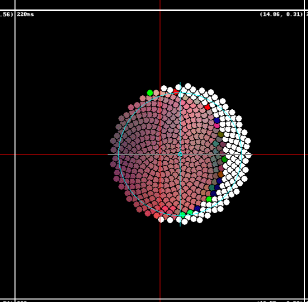
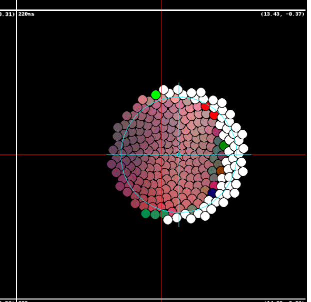
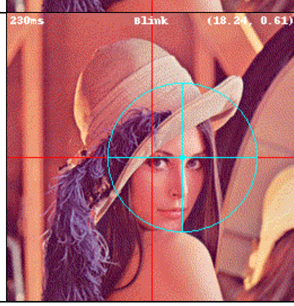
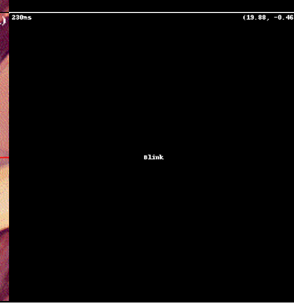
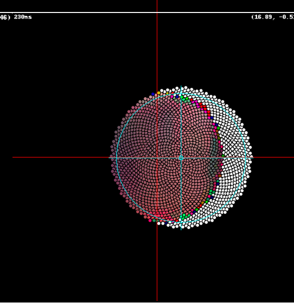
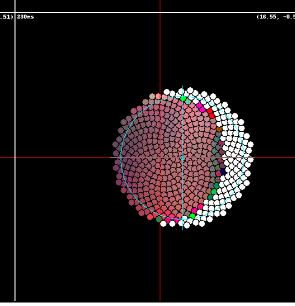
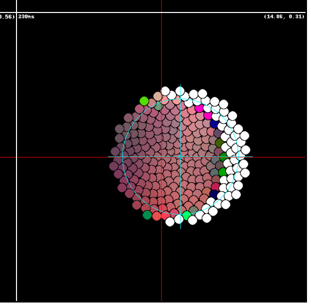
Table 14: Time sequence of active visual memory decay for natural image (Lena)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
21					
22					
23					

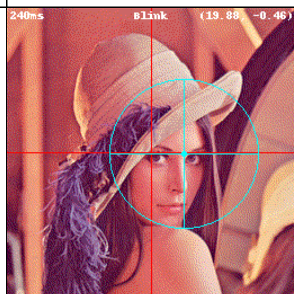
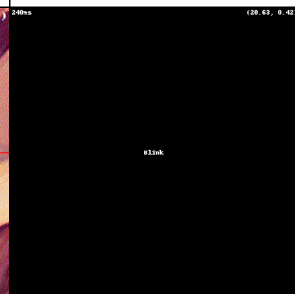
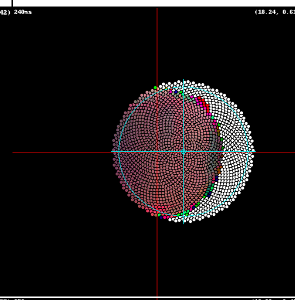
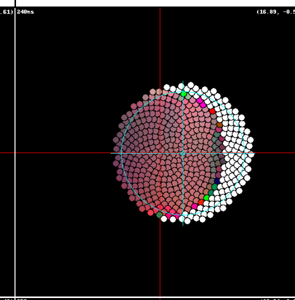
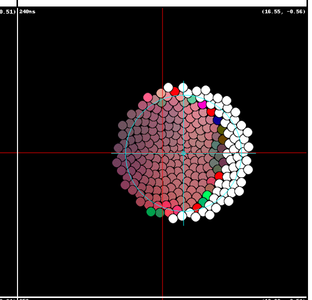
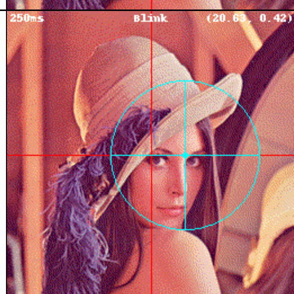
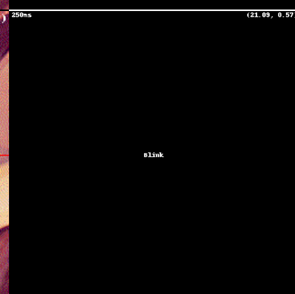
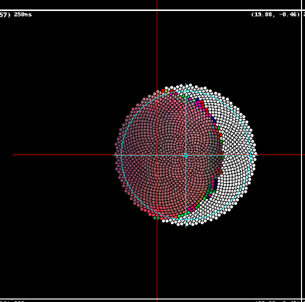
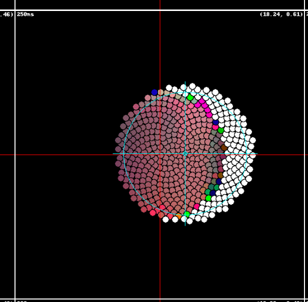
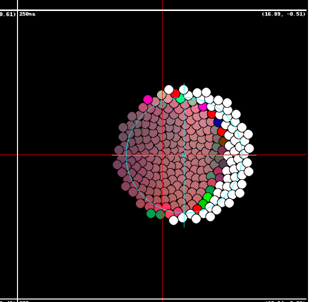
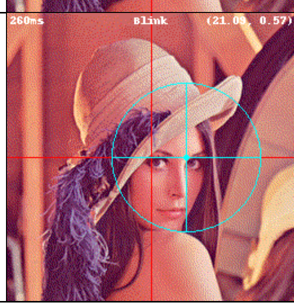
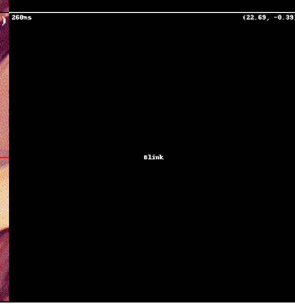
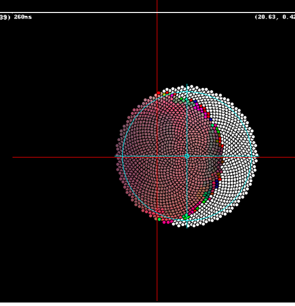
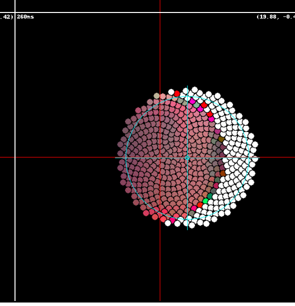
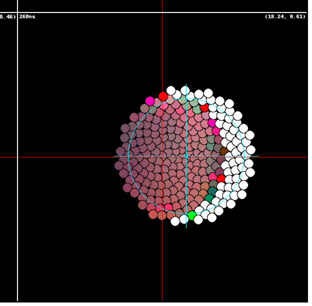
Table 14: Time sequence of active visual memory decay for natural image (Lena)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
24					
25					
26					

Table 14: Time sequence of active visual memory decay for natural image (Lena)

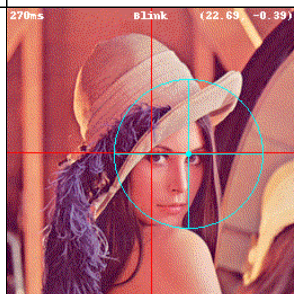
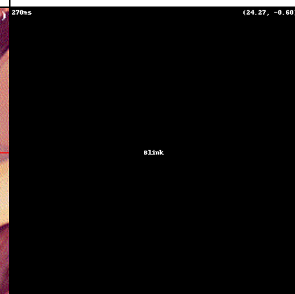
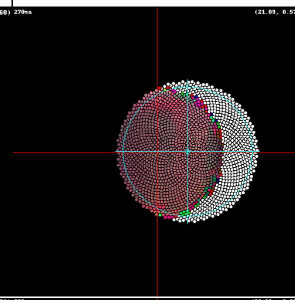
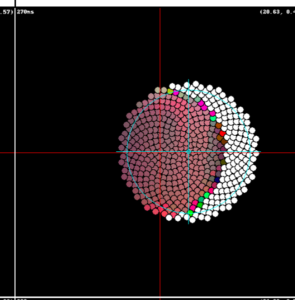
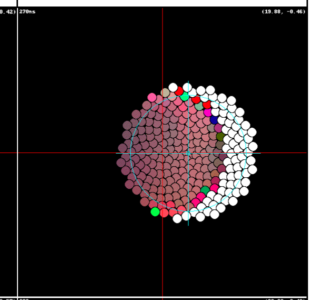
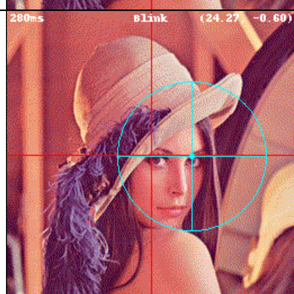
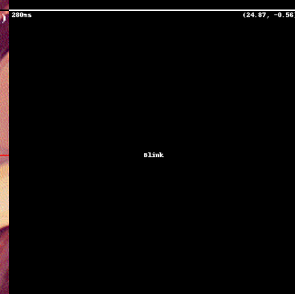
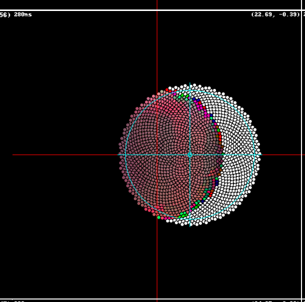
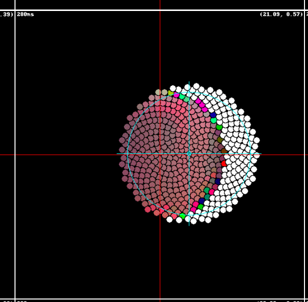
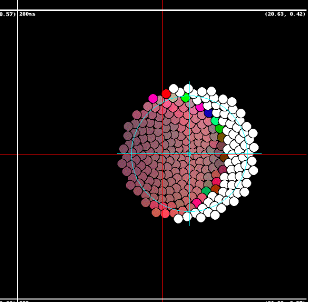
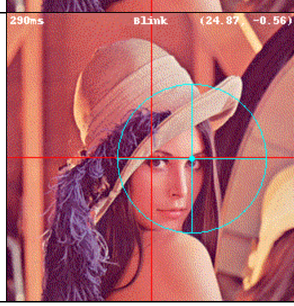
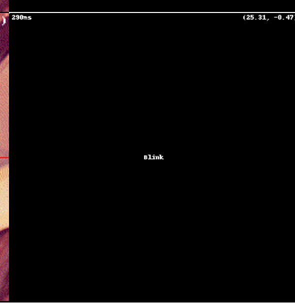
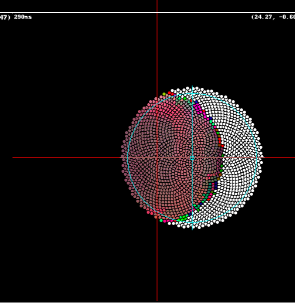
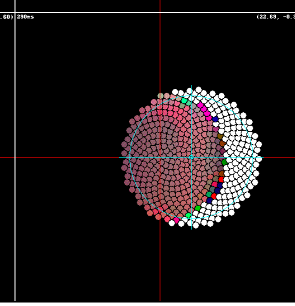
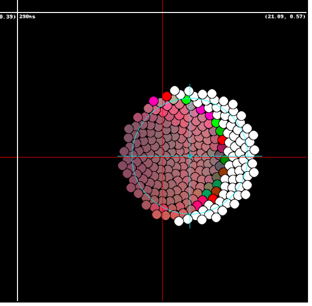
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
27					
28					
29					

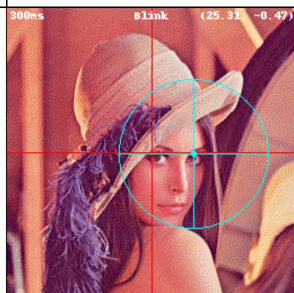
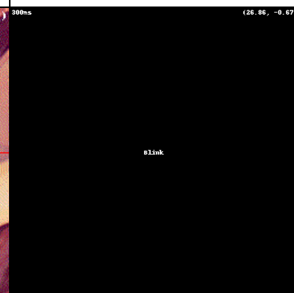
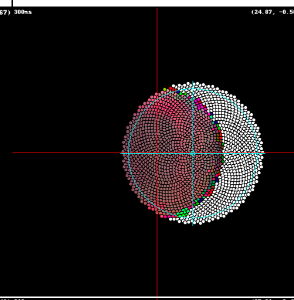
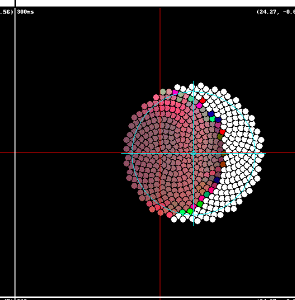
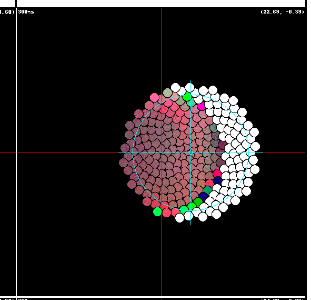
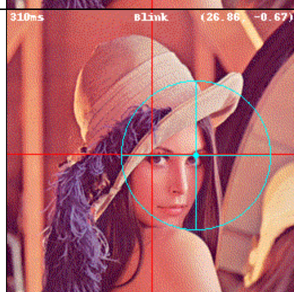
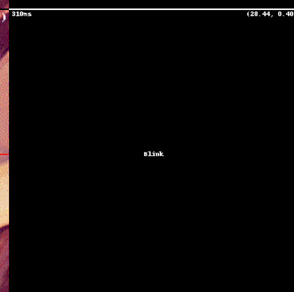
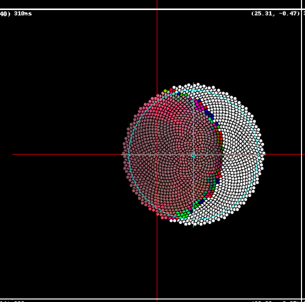
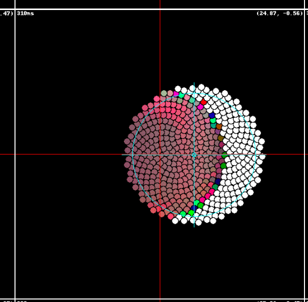
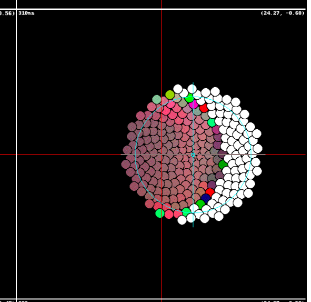
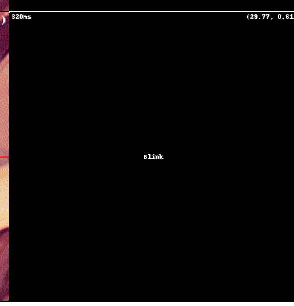
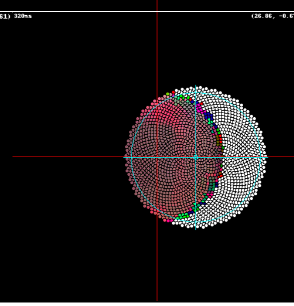
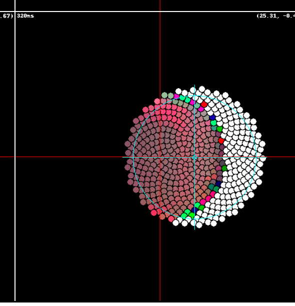
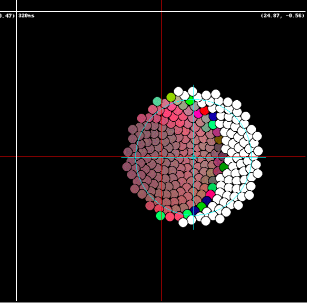
Table 14: Time sequence of active visual memory decay for natural image (Lena)					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
30					
31					
32					

Table 14: Time sequence of active visual memory decay for natural image (Lena)

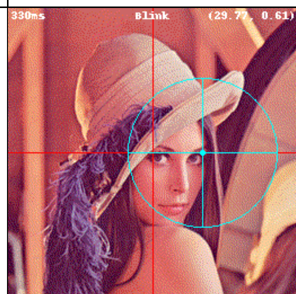
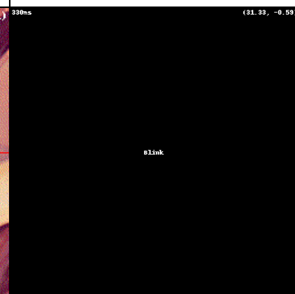
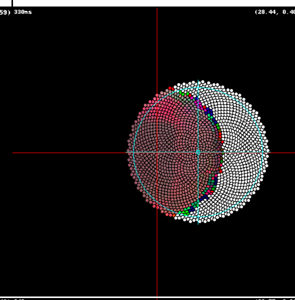
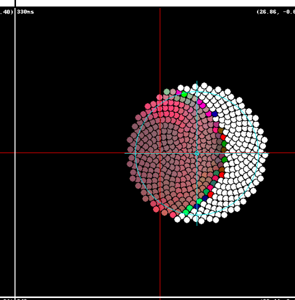
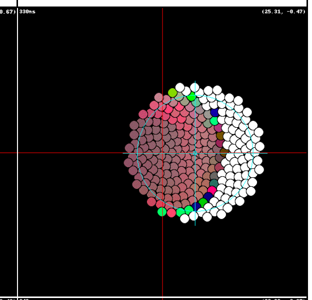
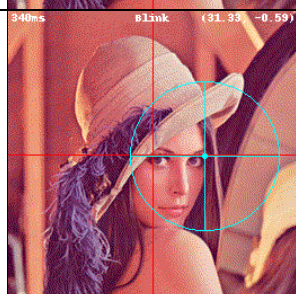
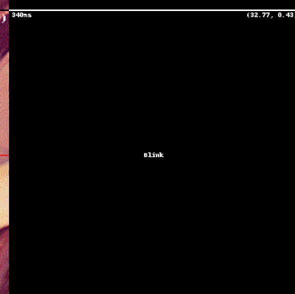
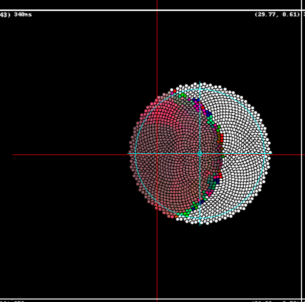
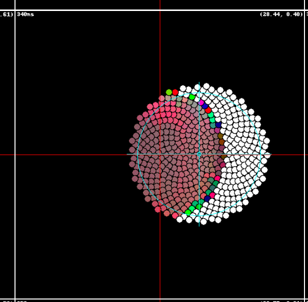
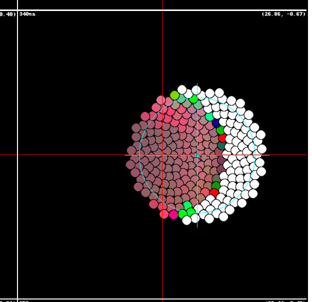
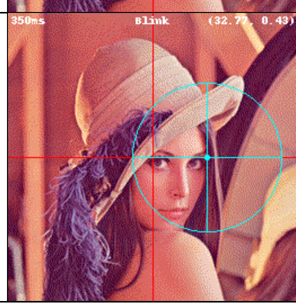
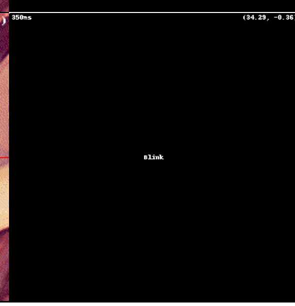
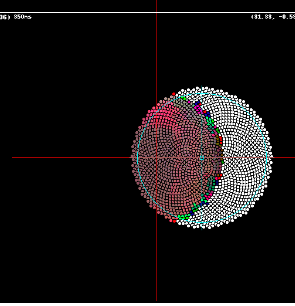
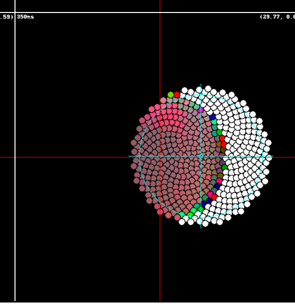
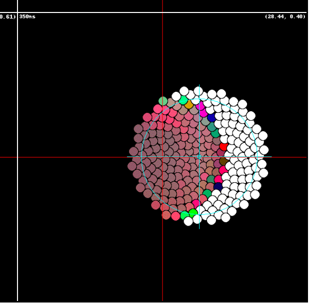
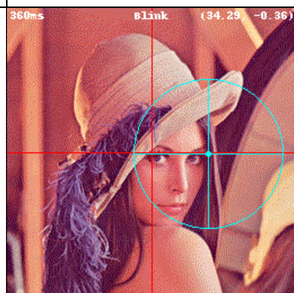
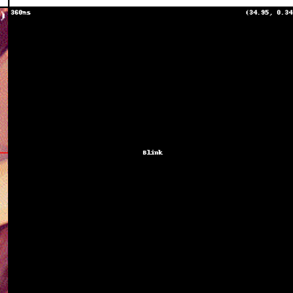
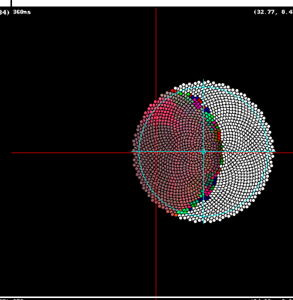
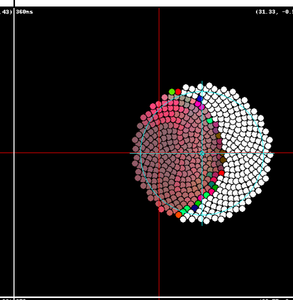
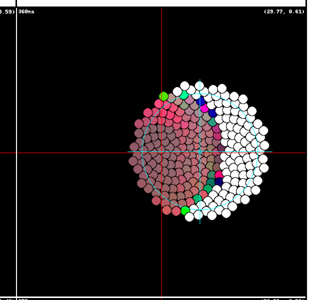
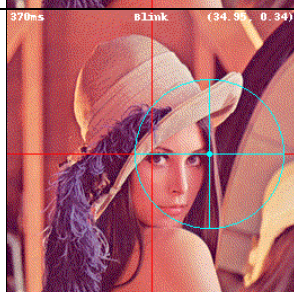
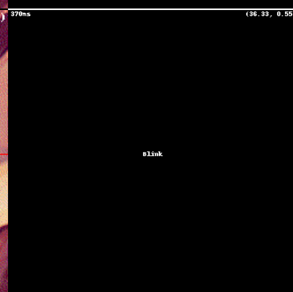
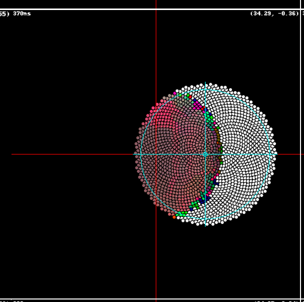
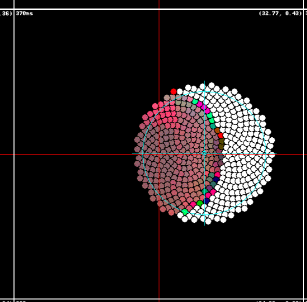
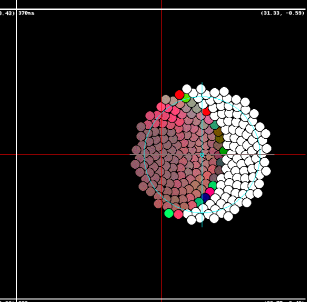
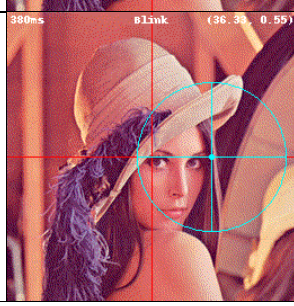
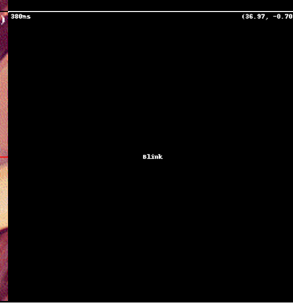
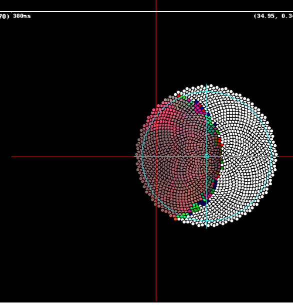
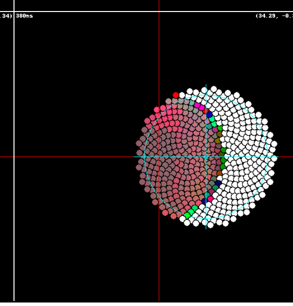
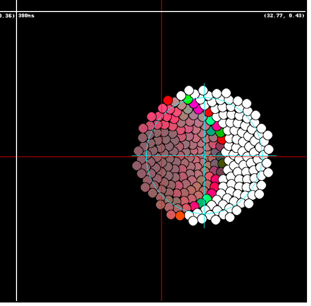
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
33					
34					
35					

Table 14: Time sequence of active visual memory decay for natural image (Lena)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
36					
37					
38					

4.3.3 Test 3 results: Dynamic image with surface gradients (Chaser)

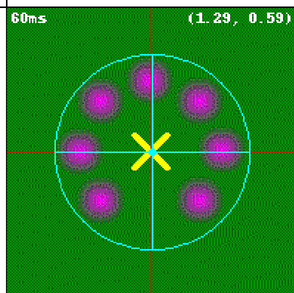
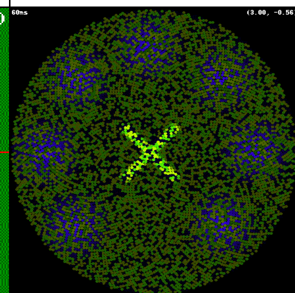
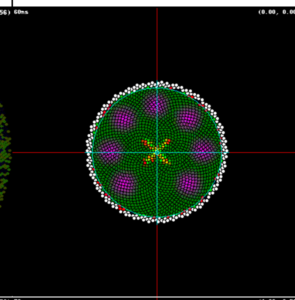
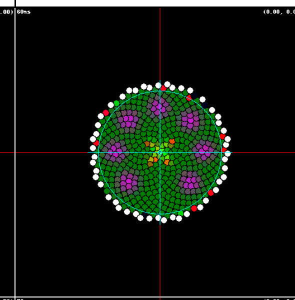
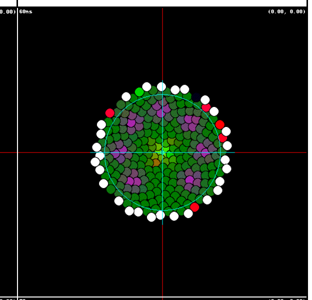
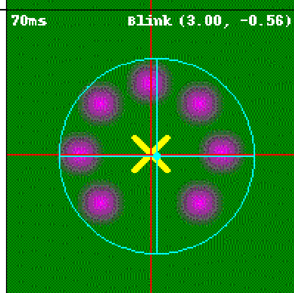
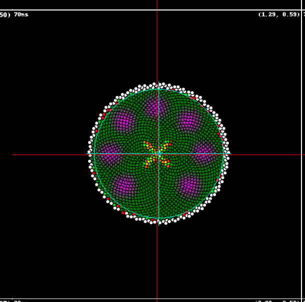
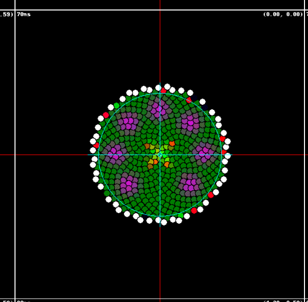
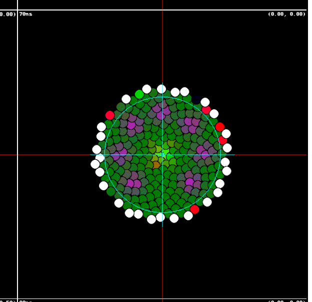
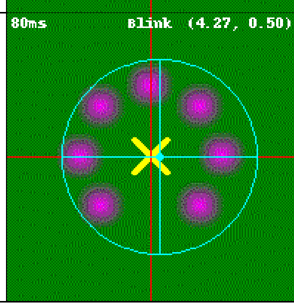
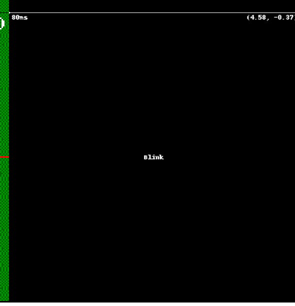
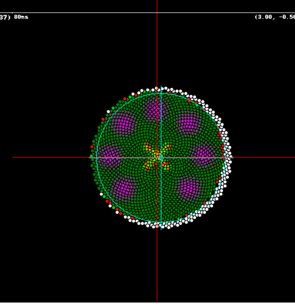
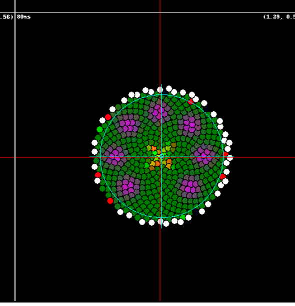
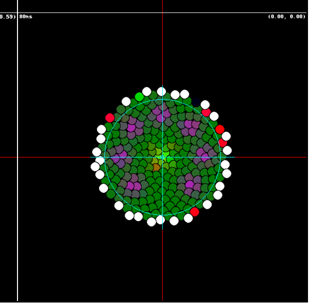
Table 15: Active visual memory decay results over time for dynamic image (Chaser)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
6					
7					
8					

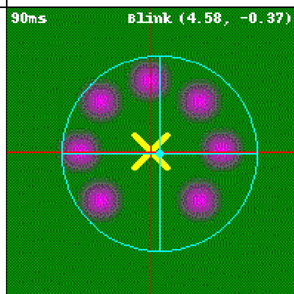
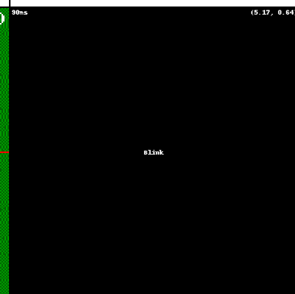
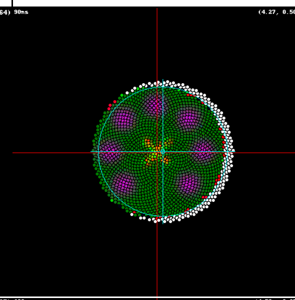
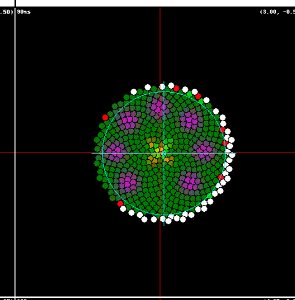
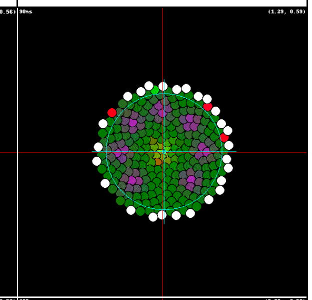
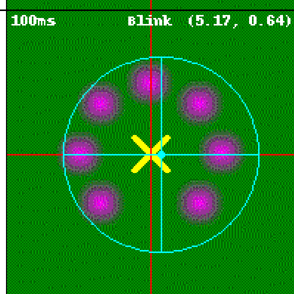
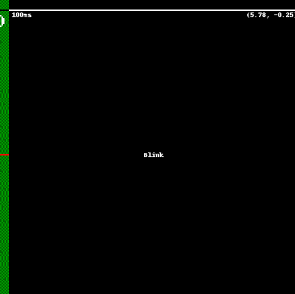
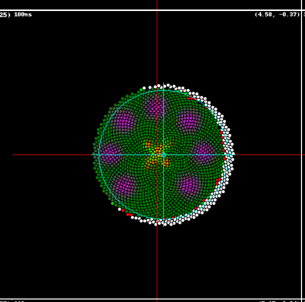
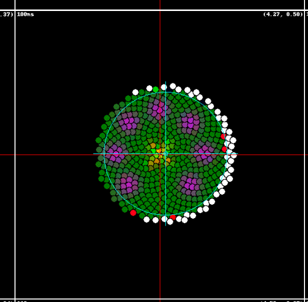
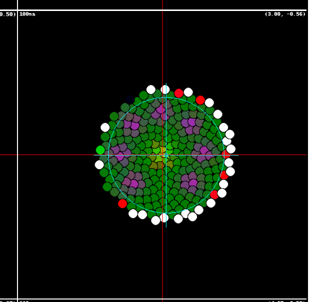
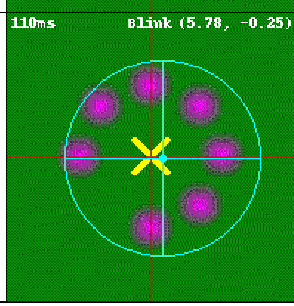
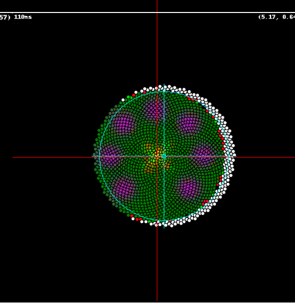
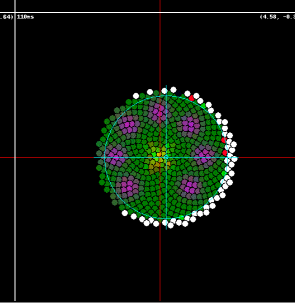
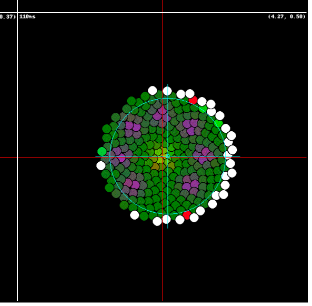
Table 15: Active visual memory decay results over time for dynamic image (Chaser)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
9					
10					
11					

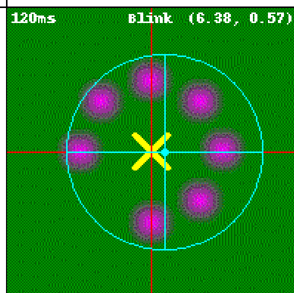
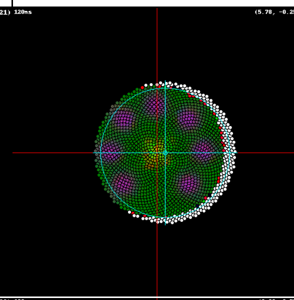
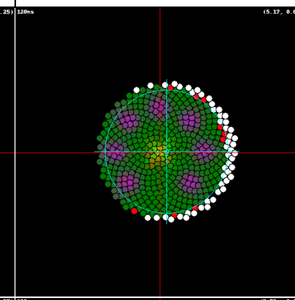
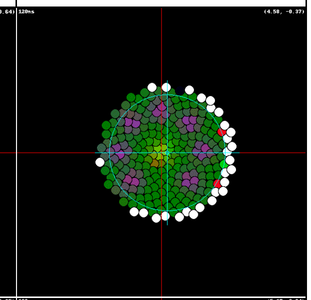
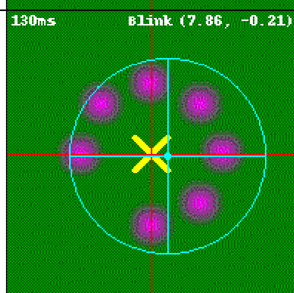
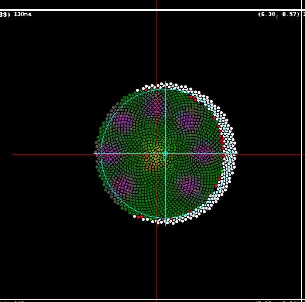
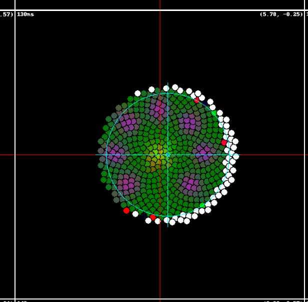
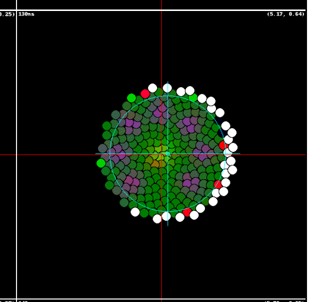
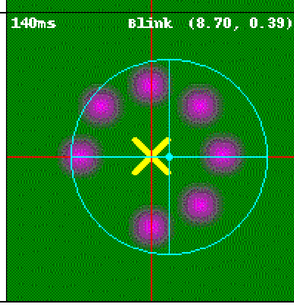
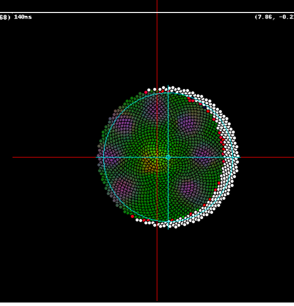
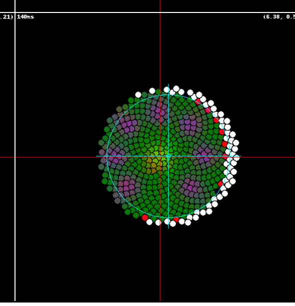
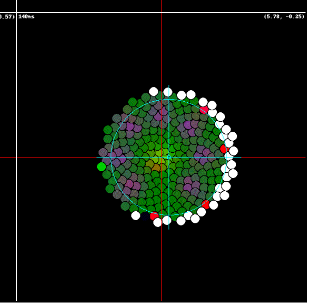
Table 15: Active visual memory decay results over time for dynamic image (Chaser)					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
12					
13					
14					

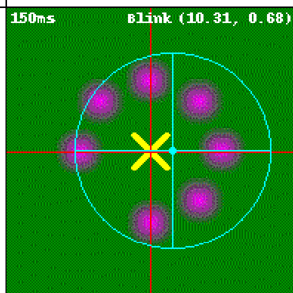
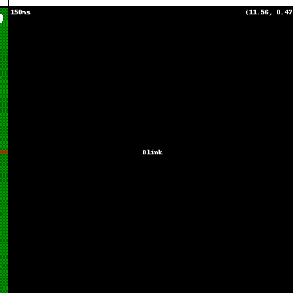
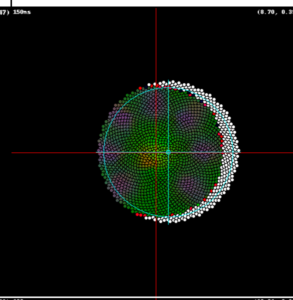
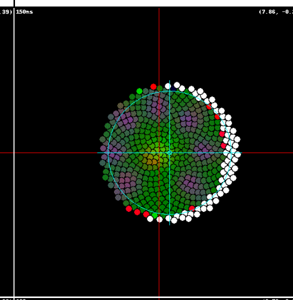
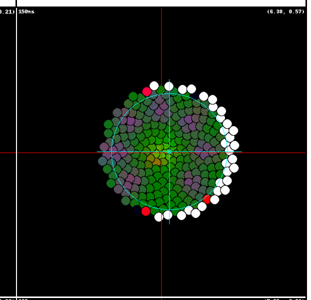
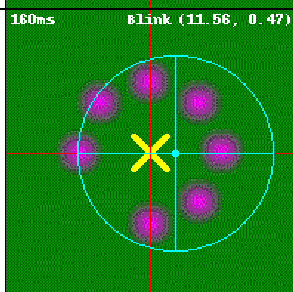
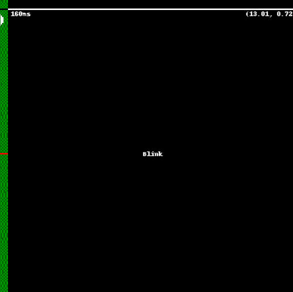
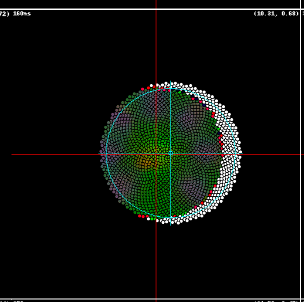
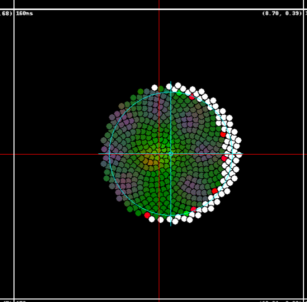
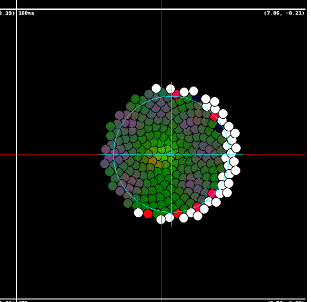
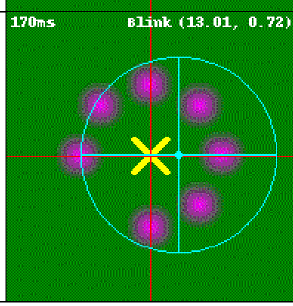
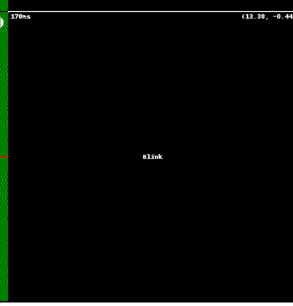
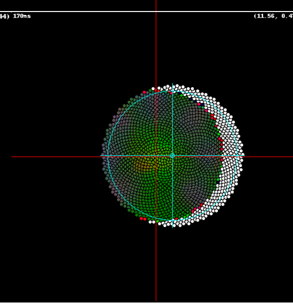
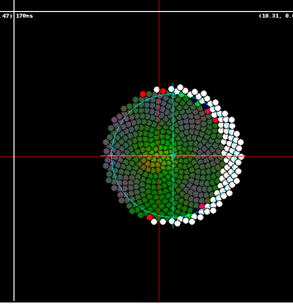
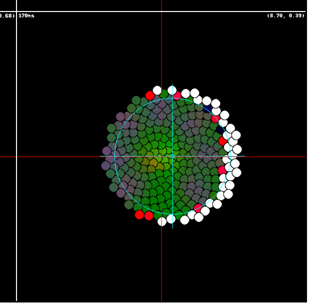
Table 15: Active visual memory decay results over time for dynamic image (Chaser)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
15					
16					
17					

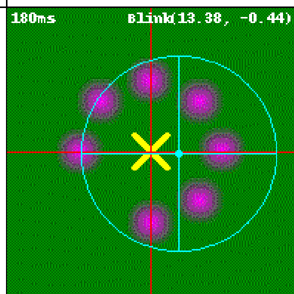
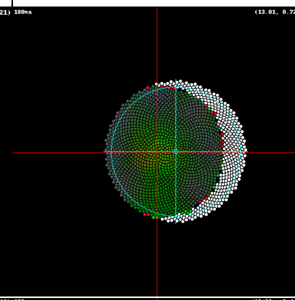
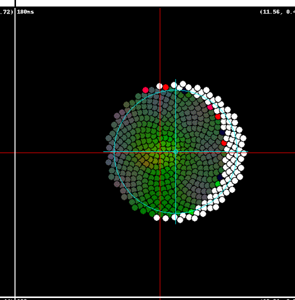
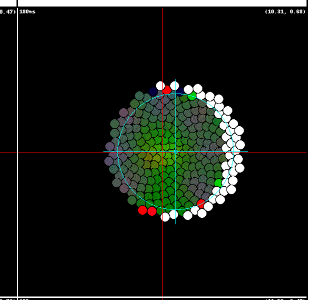
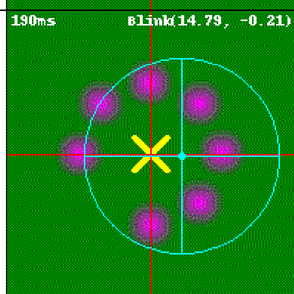
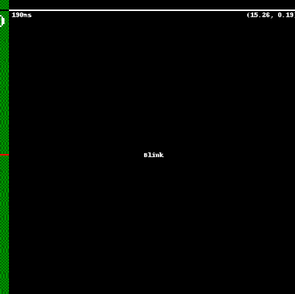
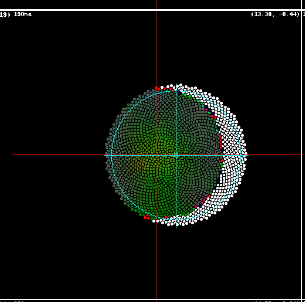
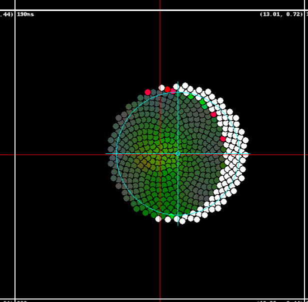
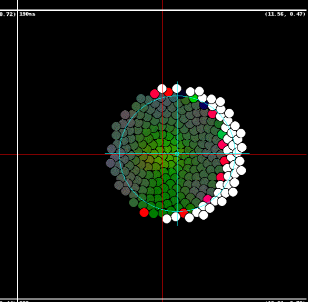
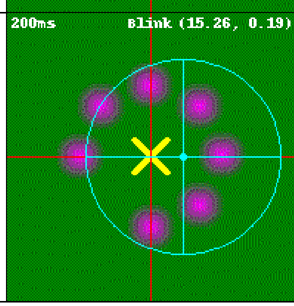
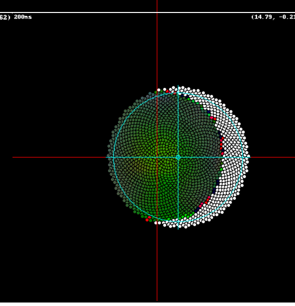
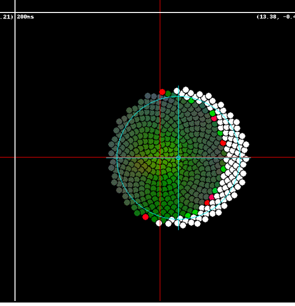
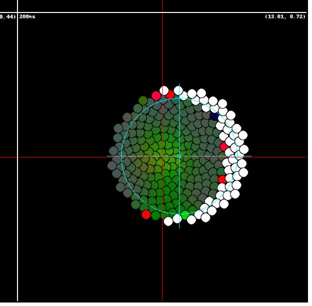
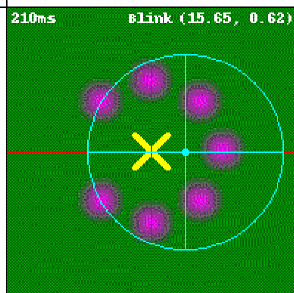
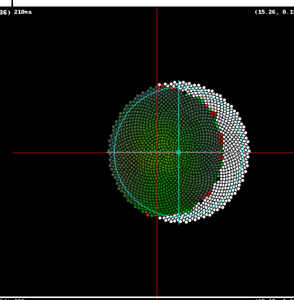
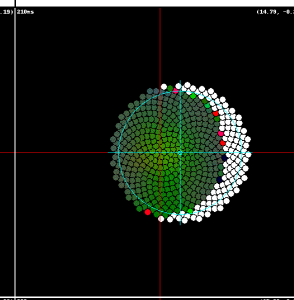
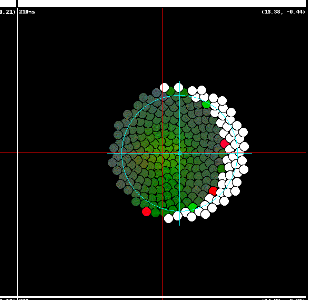
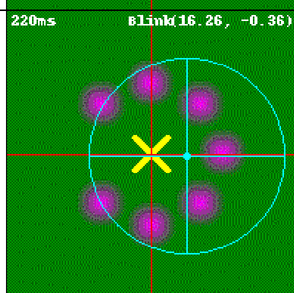
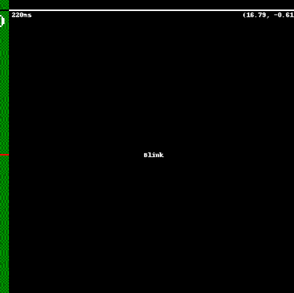
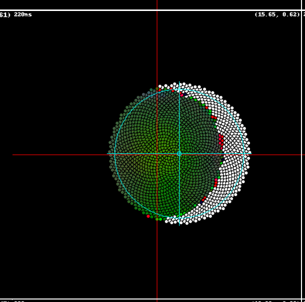
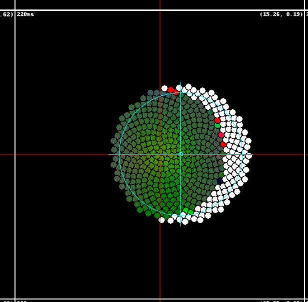
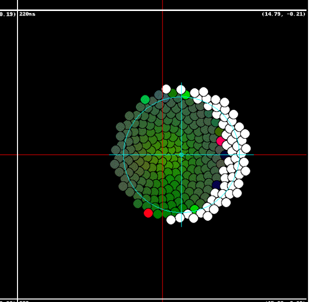
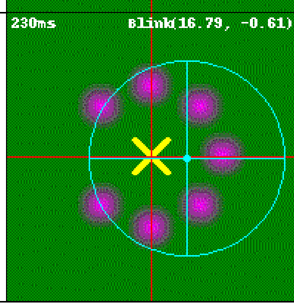
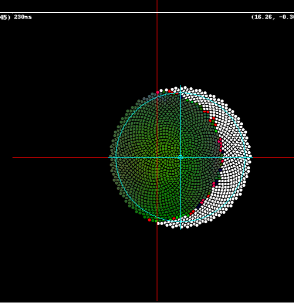
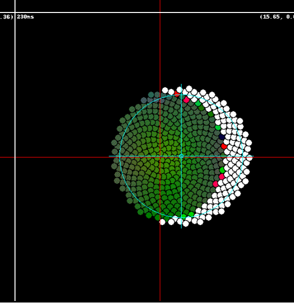
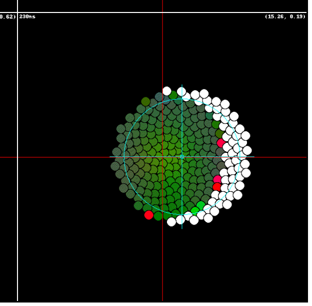
Table 15: Active visual memory decay results over time for dynamic image (Chaser)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
18					
19					
20					

Table 15: Active visual memory decay results over time for dynamic image (Chaser)

Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
21					
22					
23					

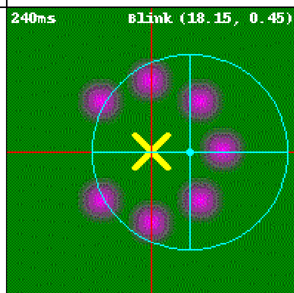
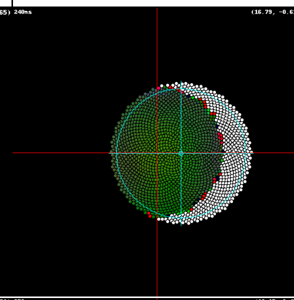
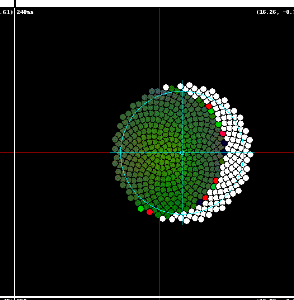
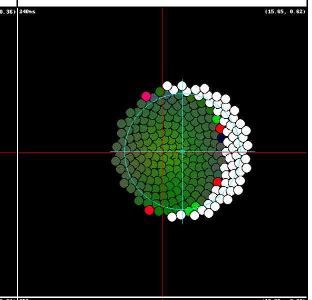
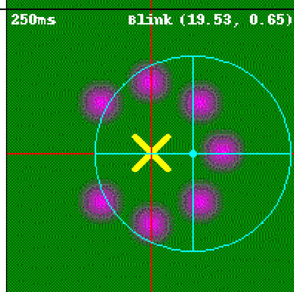
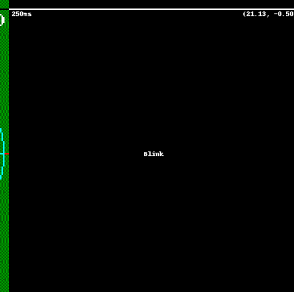
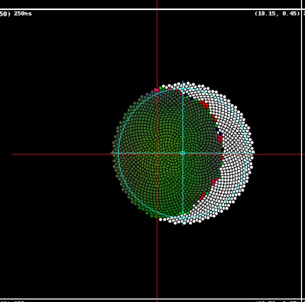
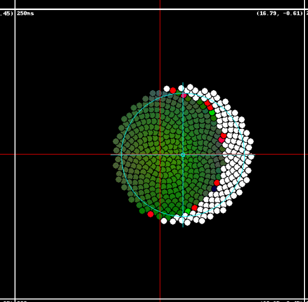
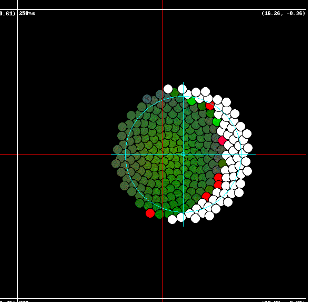
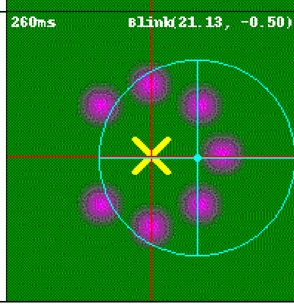
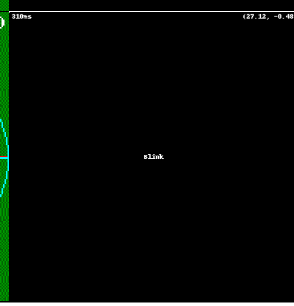
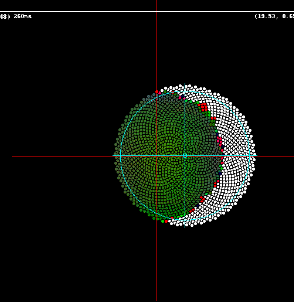
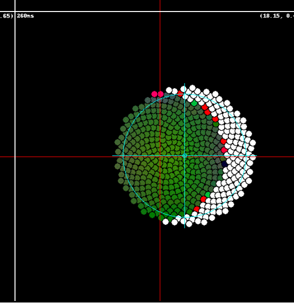
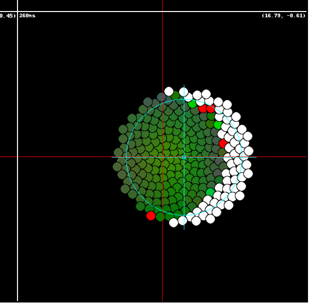
<table>
<tr><th colspan="6">Table 15: Active visual memory decay results over time for dynamic image (Chaser)</th></tr>
<tr><th rowspan="2">Time (ticks)</th><th rowspan="2">Stimuli</th><th rowspan="2">Photoreceptor Mosaic</th><th colspan="3">Receptive Fields</th></tr>
<tr><th>Level 1</th><th>Level 2</th><th>Level 3</th></tr>
<tr><td>24</td><td>
</td><td></td><td></td><td></td><td></td></tr>
<tr><td>25</td><td>
</td><td></td><td></td><td></td><td></td></tr>
<tr><td>26</td><td>
</td><td></td><td></td><td></td><td></td></tr>
</table>

Table 15: Active visual memory decay results over time for dynamic image (Chaser)

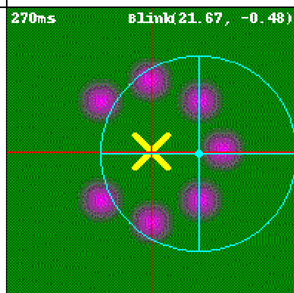
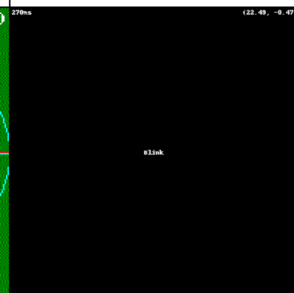
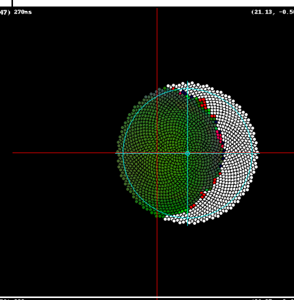
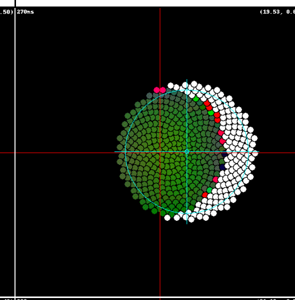
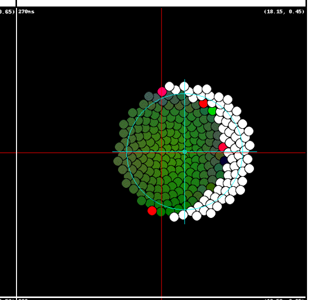
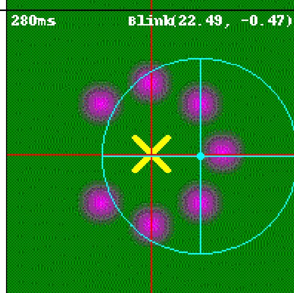
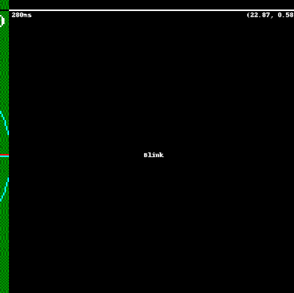
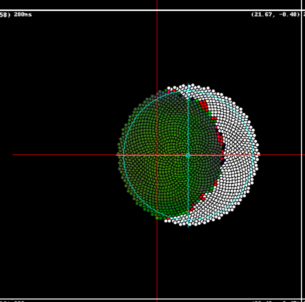
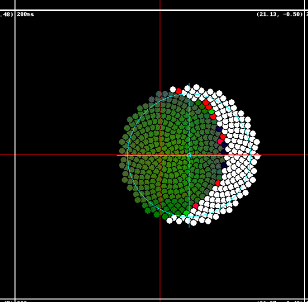
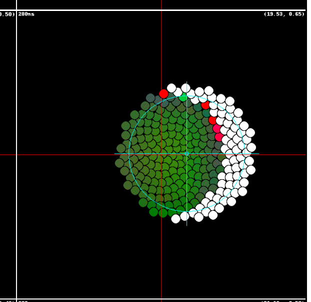
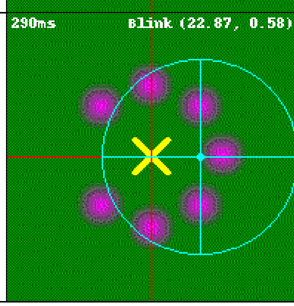
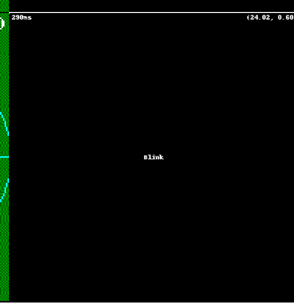
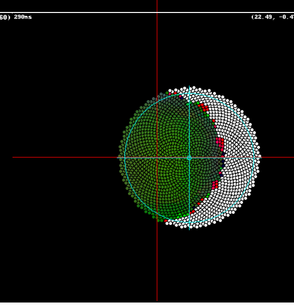
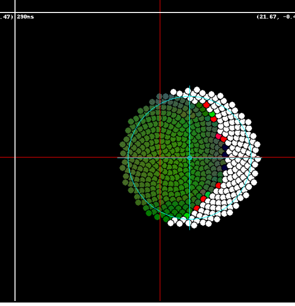
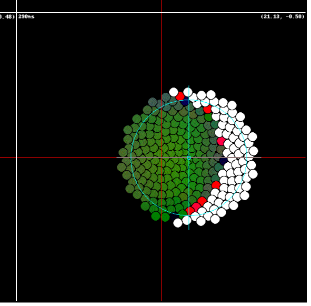
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
27					
28					
29					

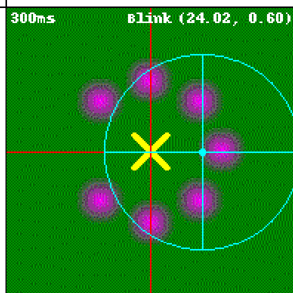
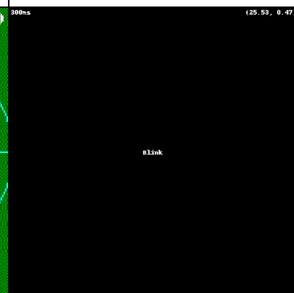
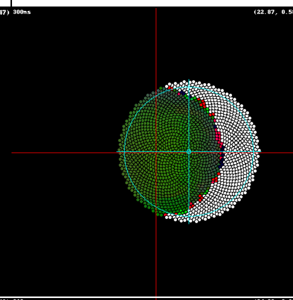
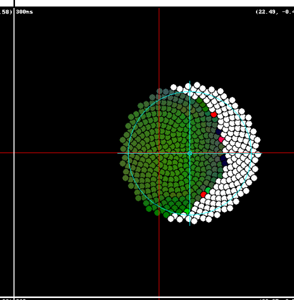
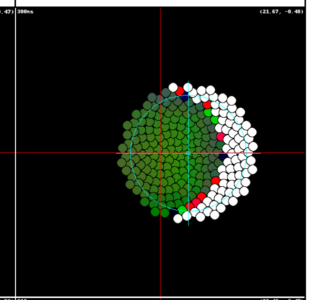
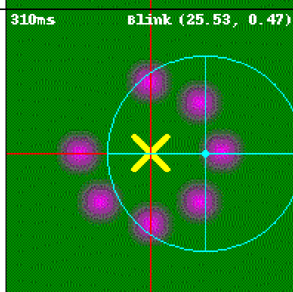
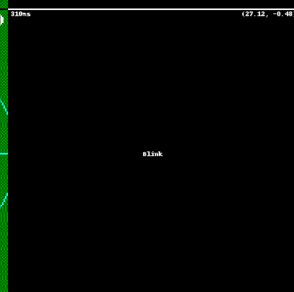
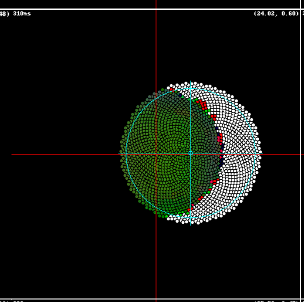
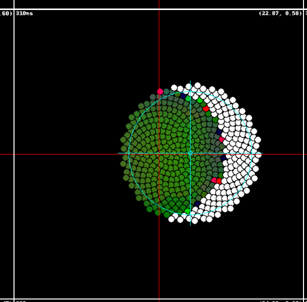
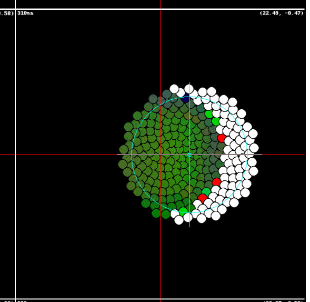
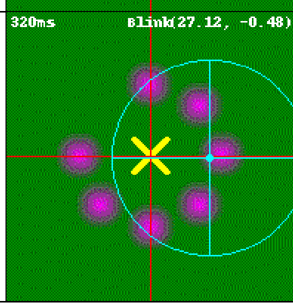
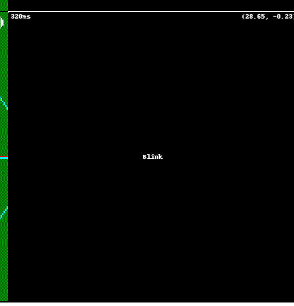
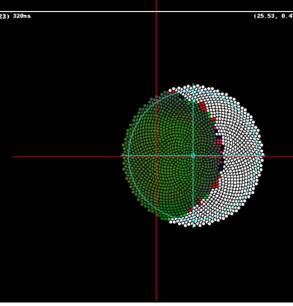
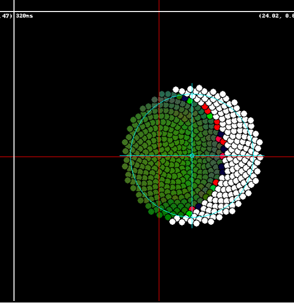
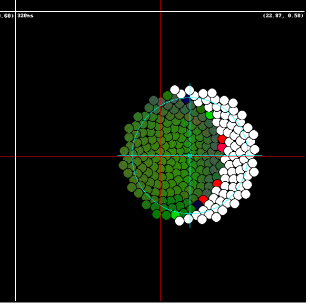
Table 15: Active visual memory decay results over time for dynamic image (Chaser)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
30					
31					
32					

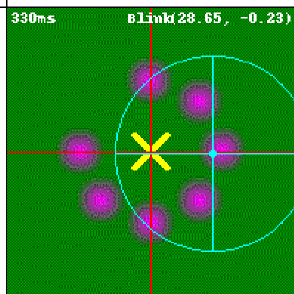
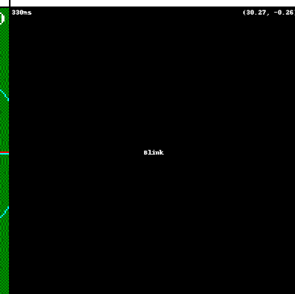
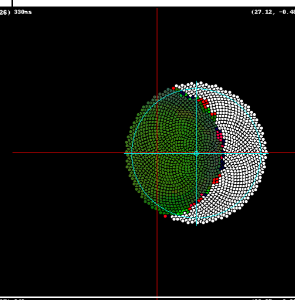
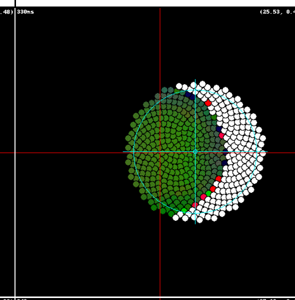
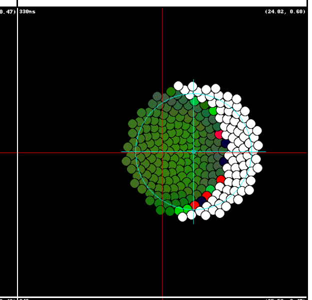
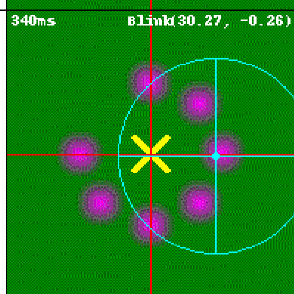
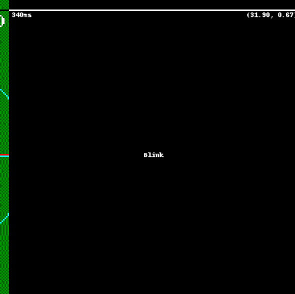
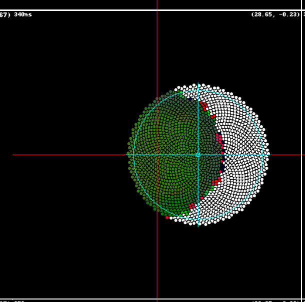
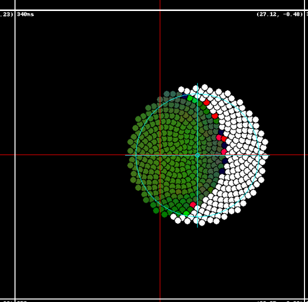
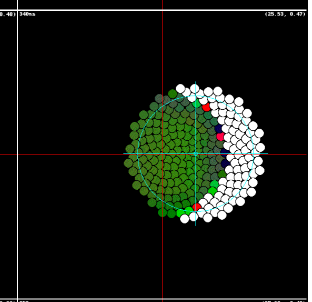
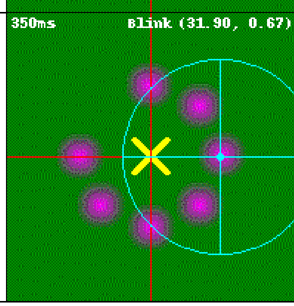
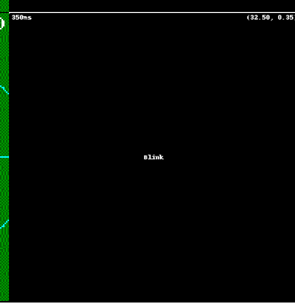
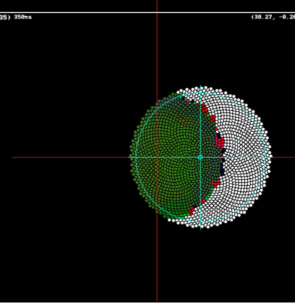
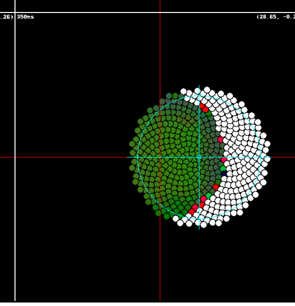
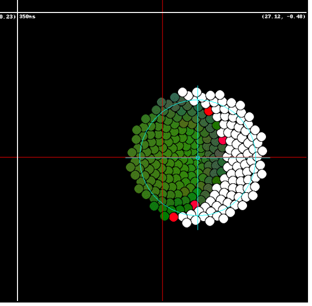
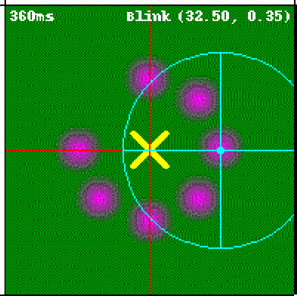
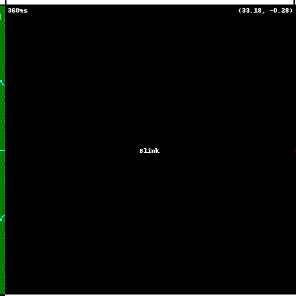
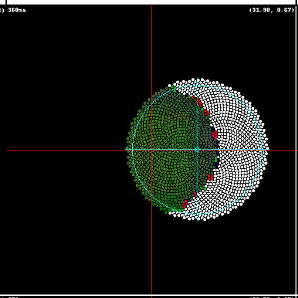
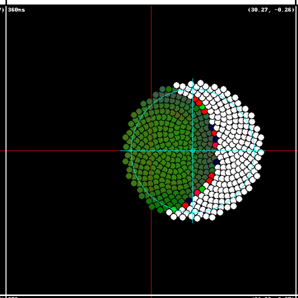
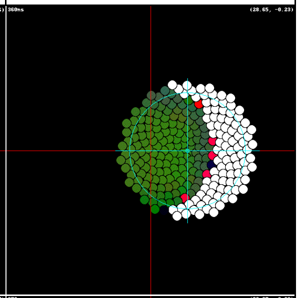
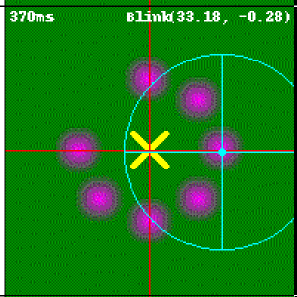
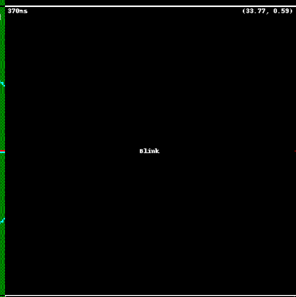
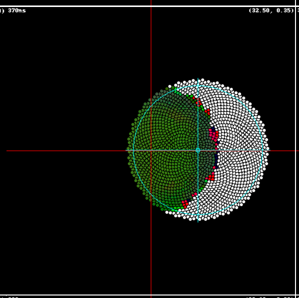
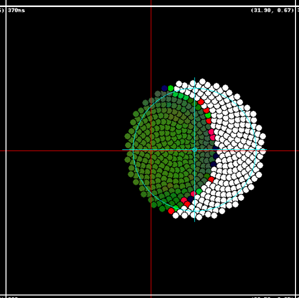
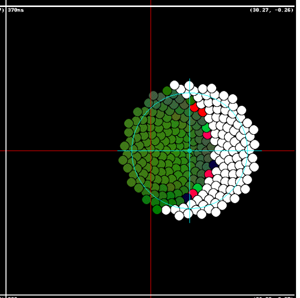
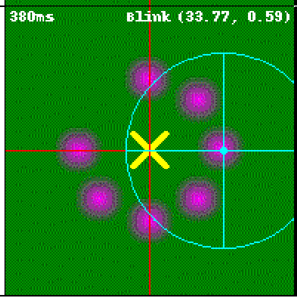
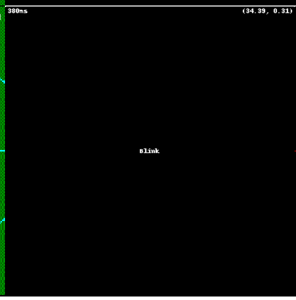
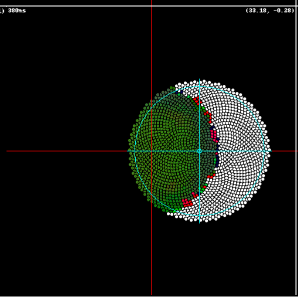
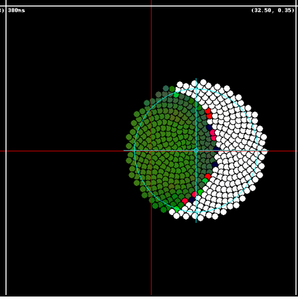
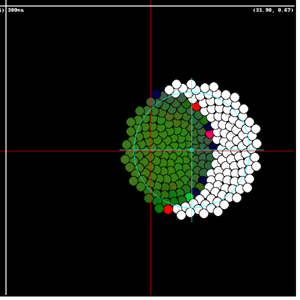
Table 15: Active visual memory decay results over time for dynamic image (Chaser)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
33					
34					
35					

Table 15: Active visual memory decay results over time for dynamic image (Chaser)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
36					
37					
38					

4.3.4 Test 4 results: Simplified object (Square)

Table 16: Time sequence of active visual memory decay for simplified object (Square)

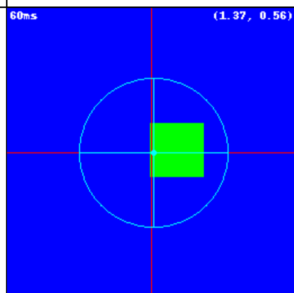
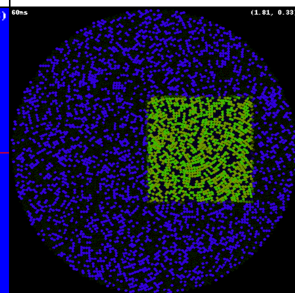
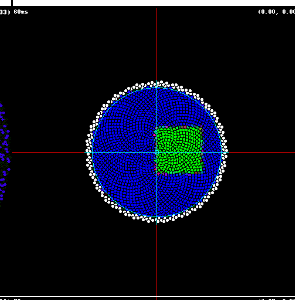
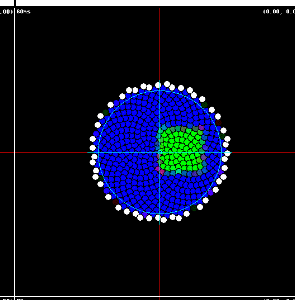
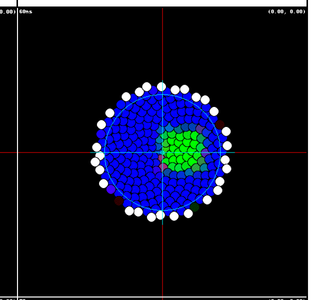
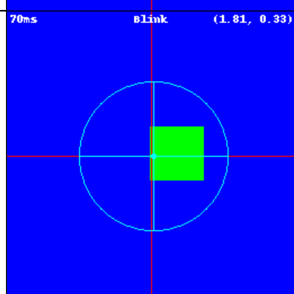
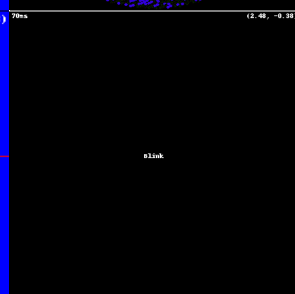
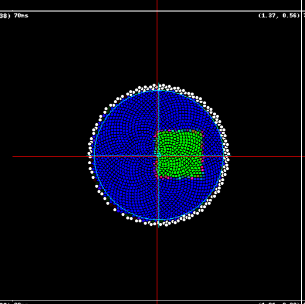
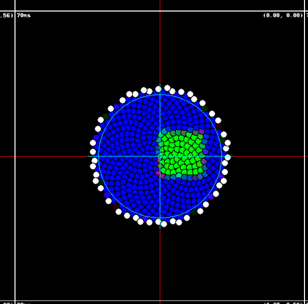
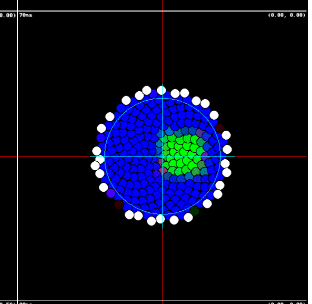
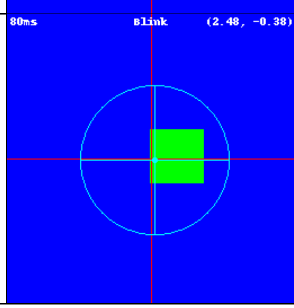
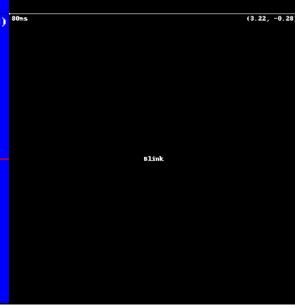
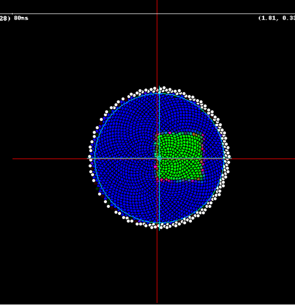
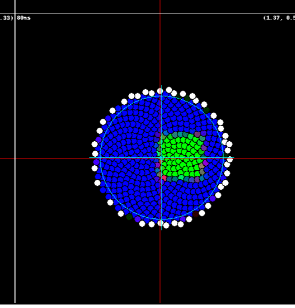
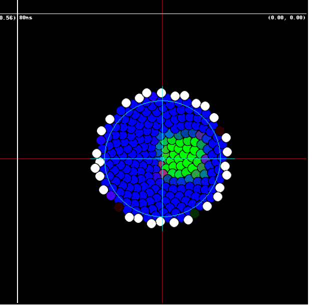
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
6					
7					
8					

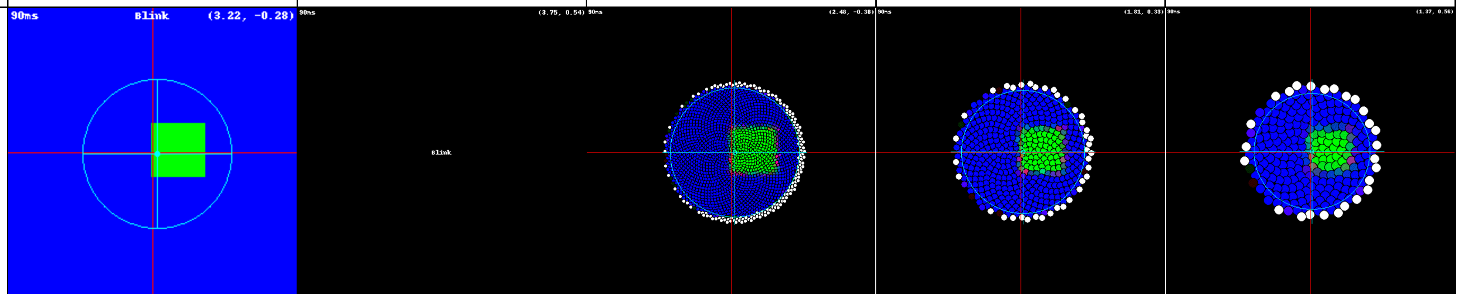
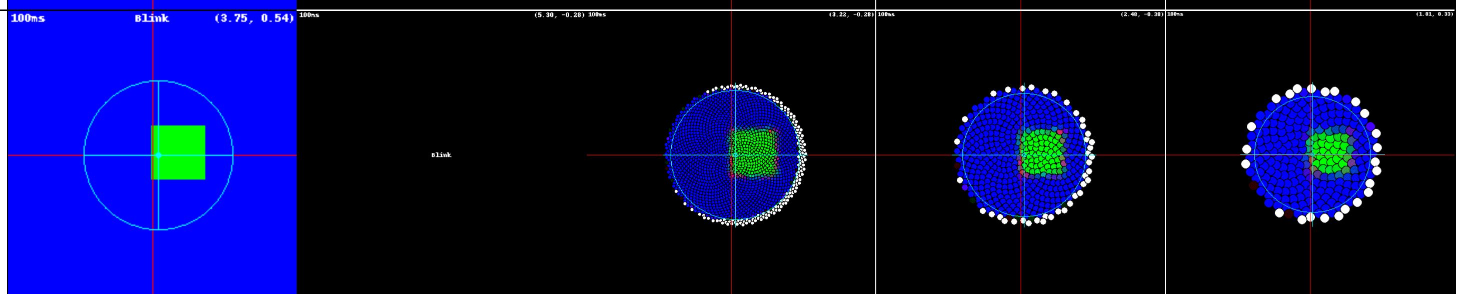
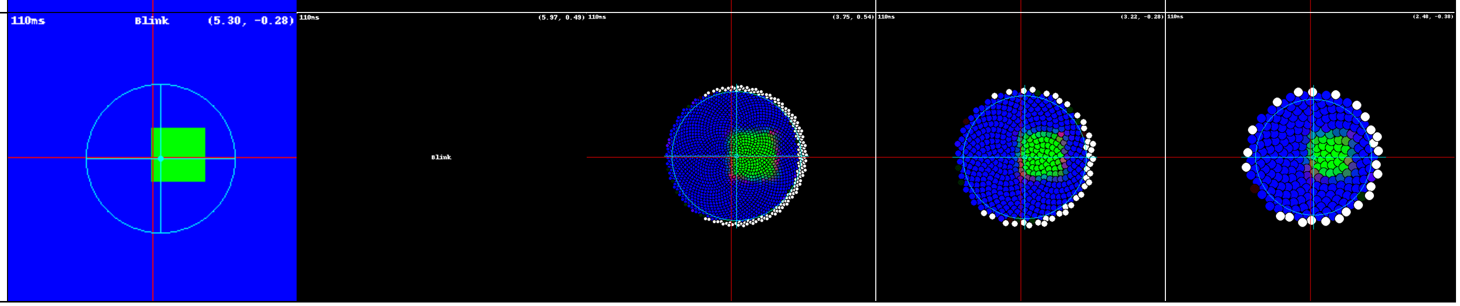
Table 16: Time sequence of active visual memory decay for simplified object (Square)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
9					
10					
11					

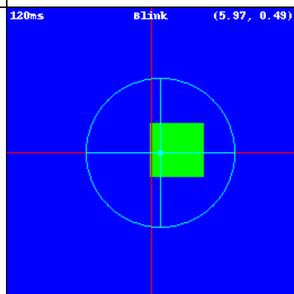
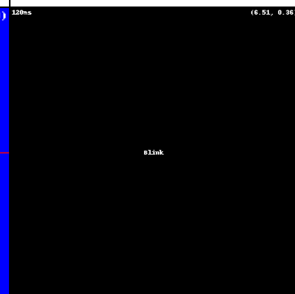
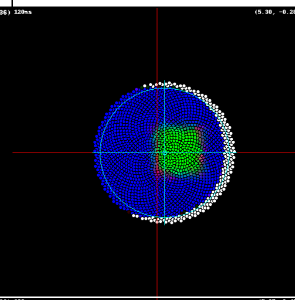
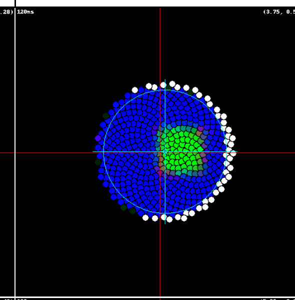
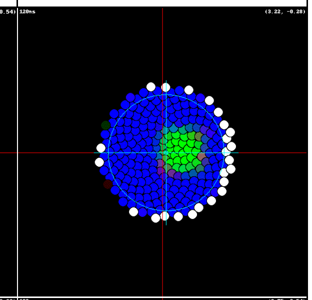
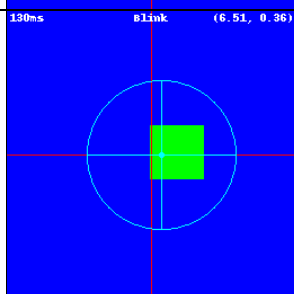
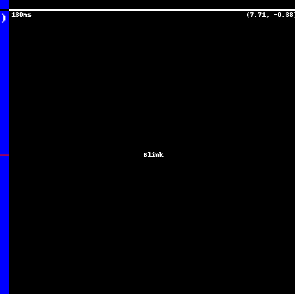
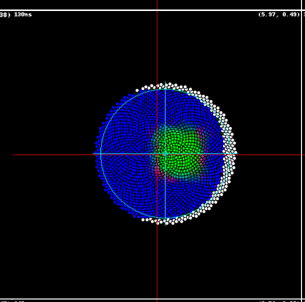
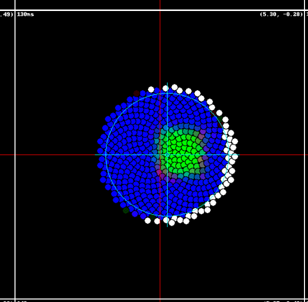
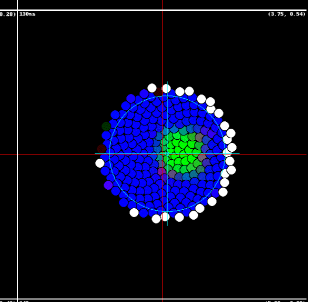
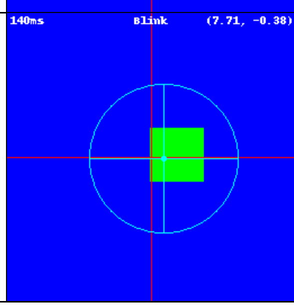
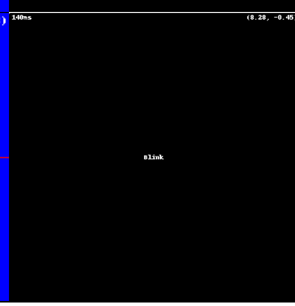
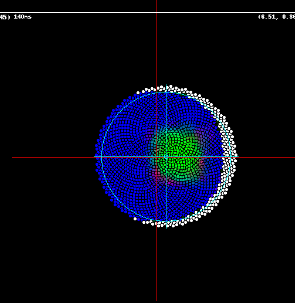
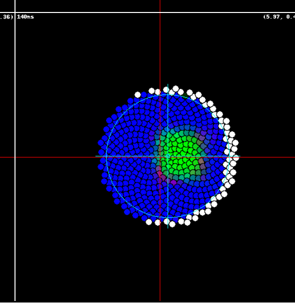
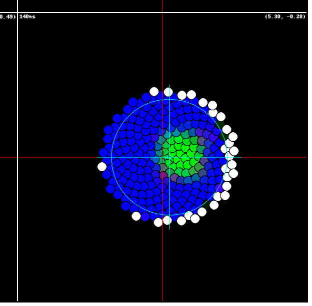
Table 16: Time sequence of active visual memory decay for simplified object (Square)					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
12					
13					
14					

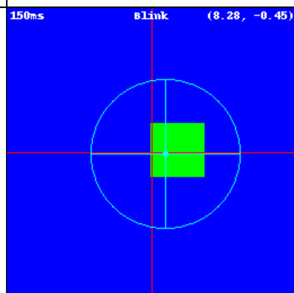
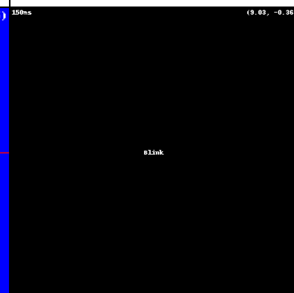
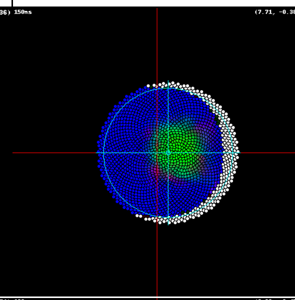
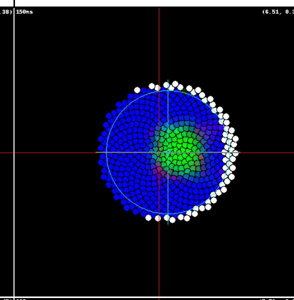
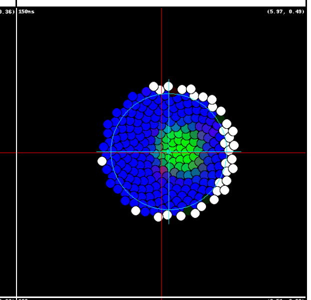
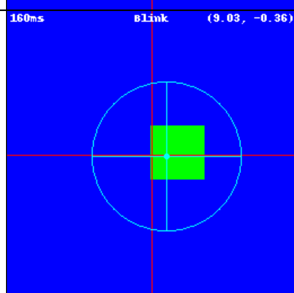
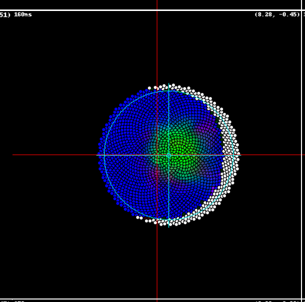
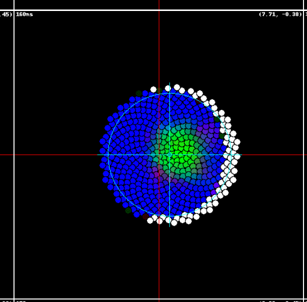
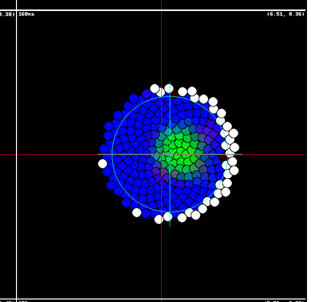
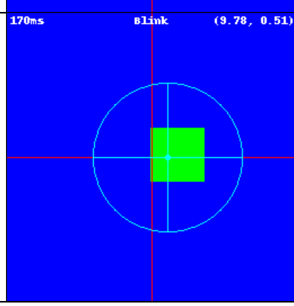
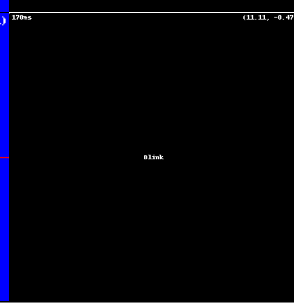
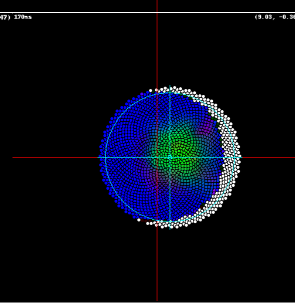
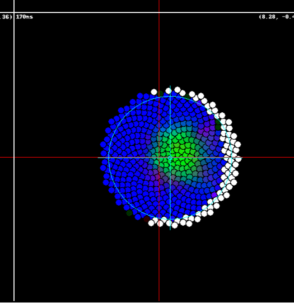
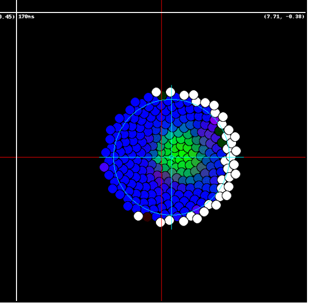
Table 16: Time sequence of active visual memory decay for simplified object (Square)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
15					
16					
17					

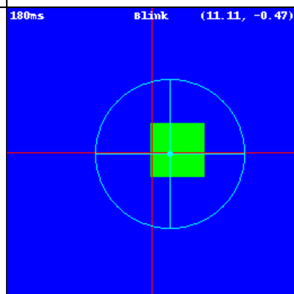
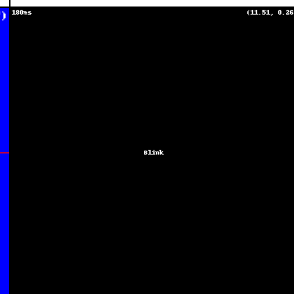
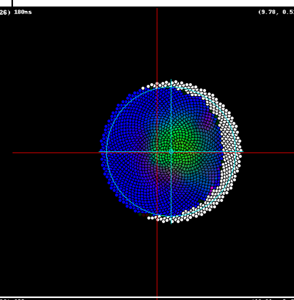
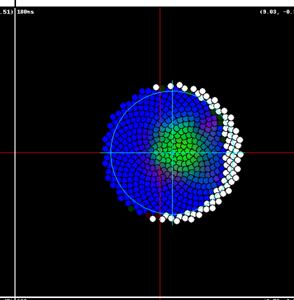
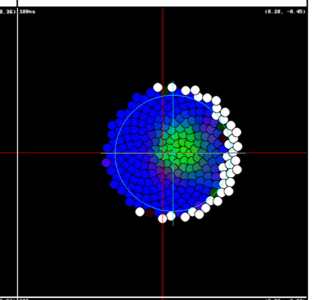
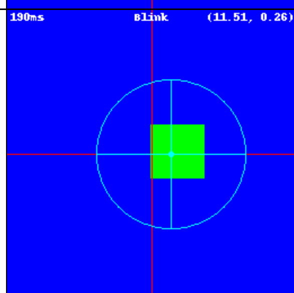
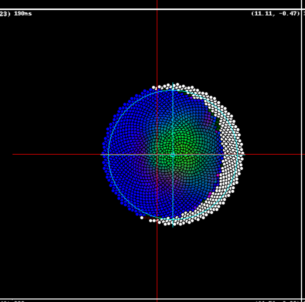
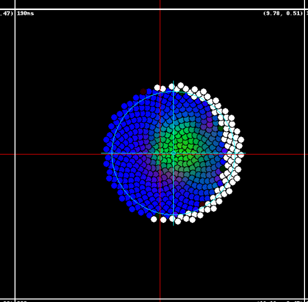
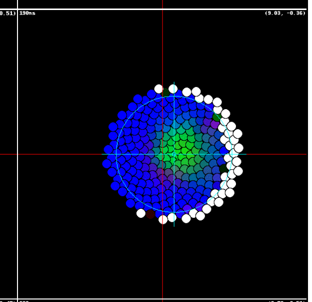
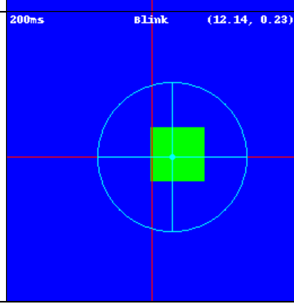
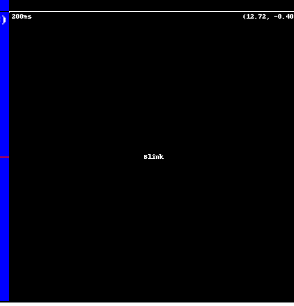
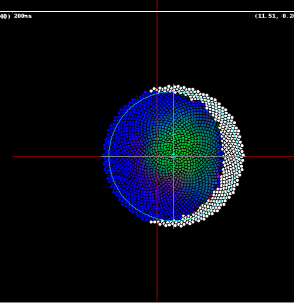
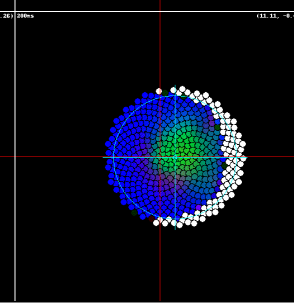
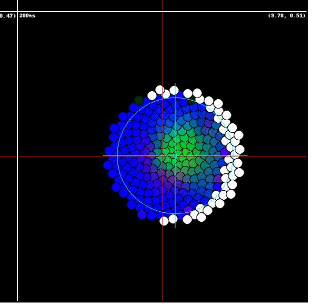
Table 16: Time sequence of active visual memory decay for simplified object (Square)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
18					
19					
20					

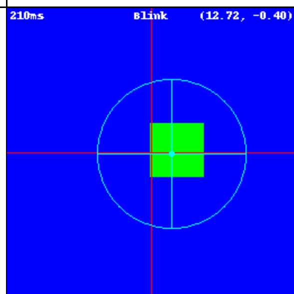
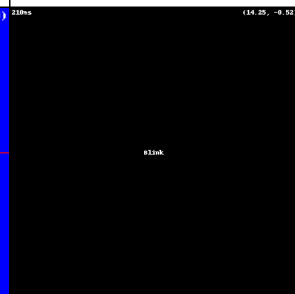
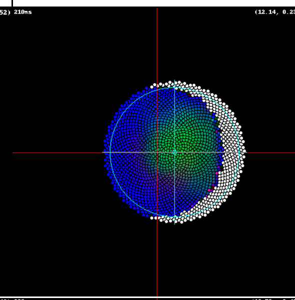
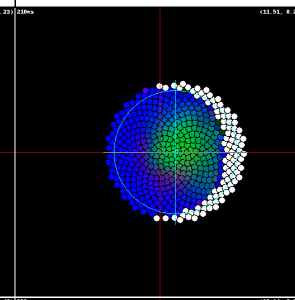
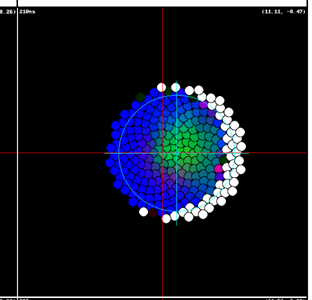
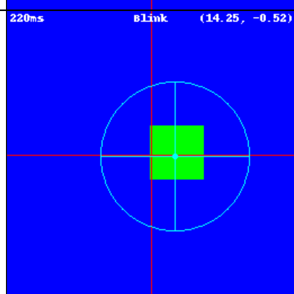
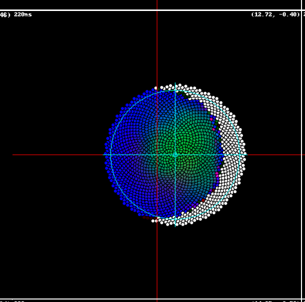
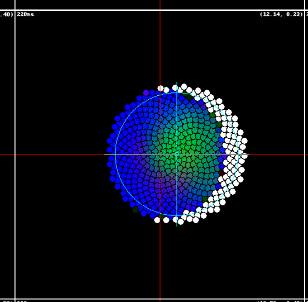
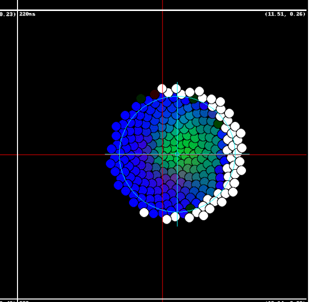
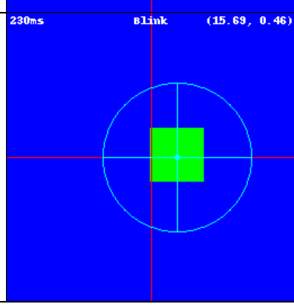
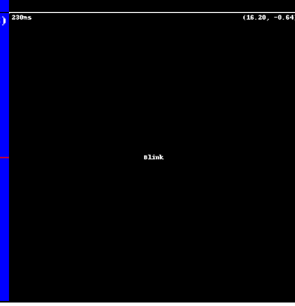
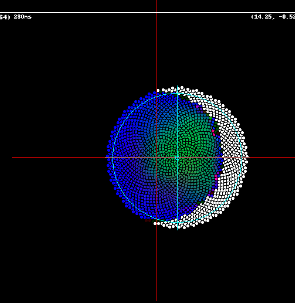
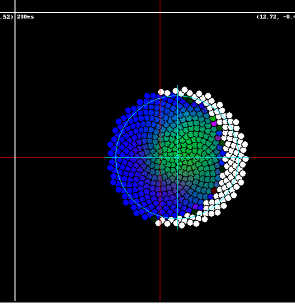
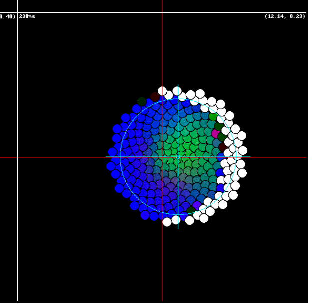
Table 16: Time sequence of active visual memory decay for simplified object (Square)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
21					
22					
23					

Table 16: Time sequence of active visual memory decay for simplified object (Square)

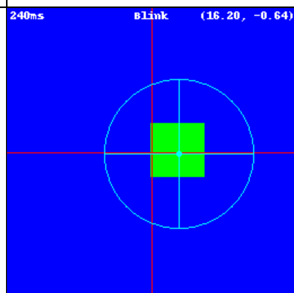
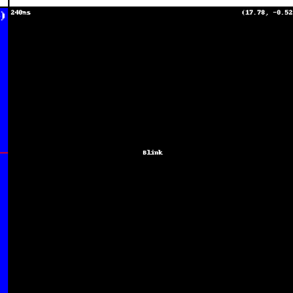
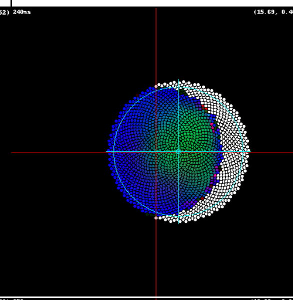
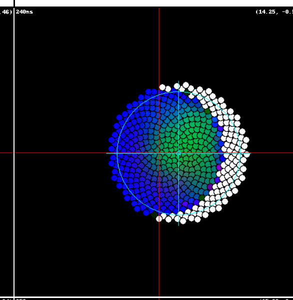
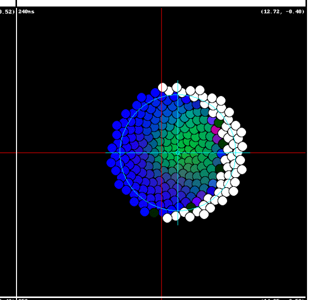
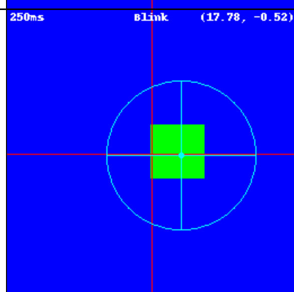
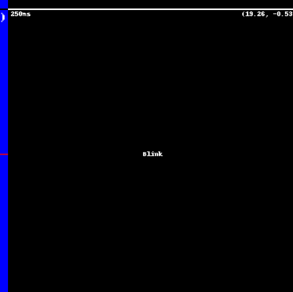
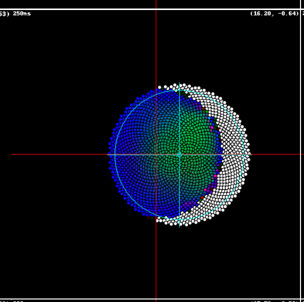
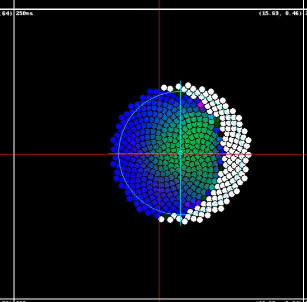
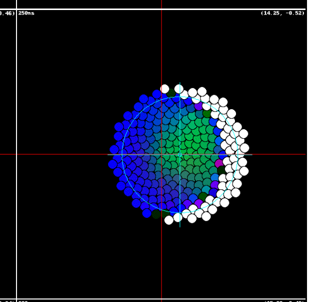
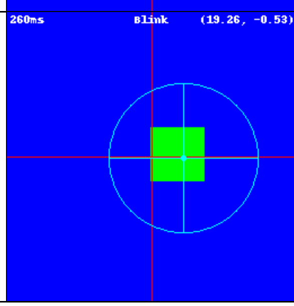
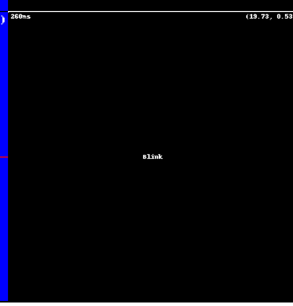
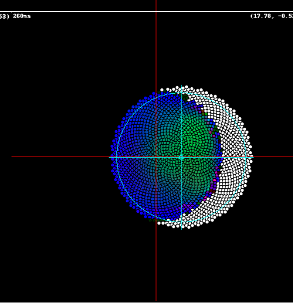
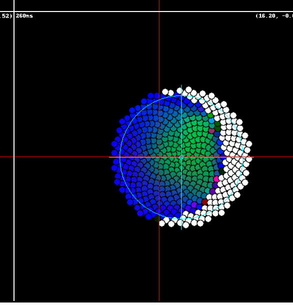
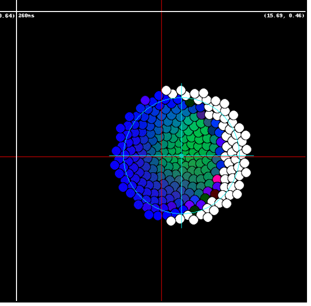
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
24					
25					
26					

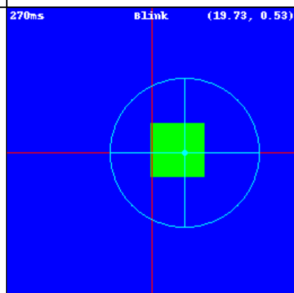
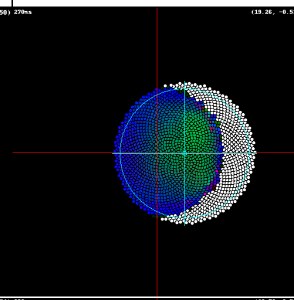
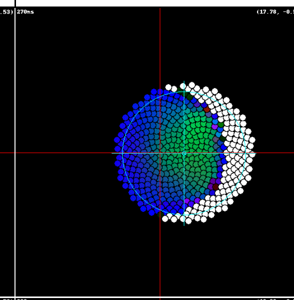
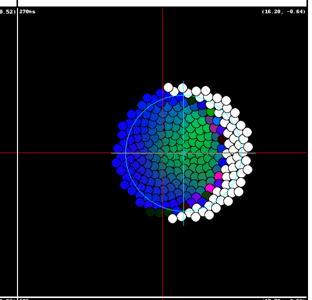
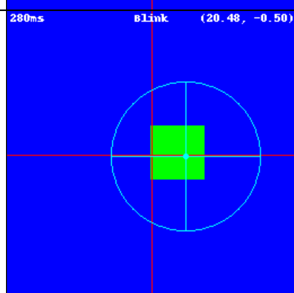
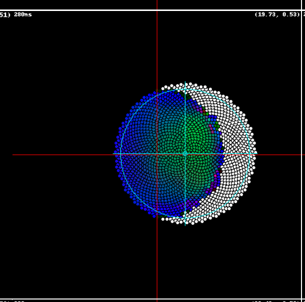
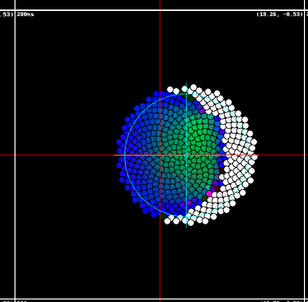
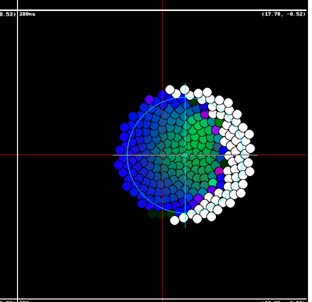
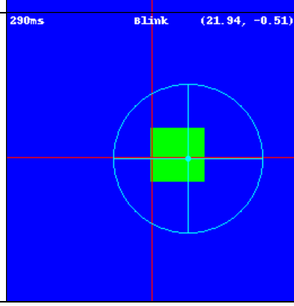
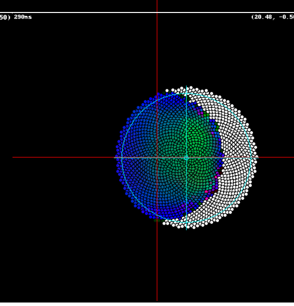
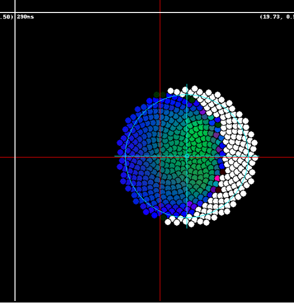
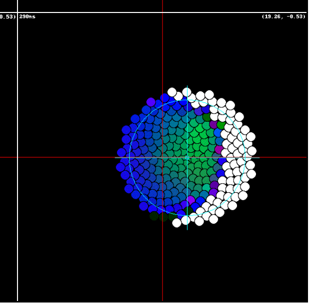
Table 16: Time sequence of active visual memory decay for simplified object (Square)					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
27					
28					
29					

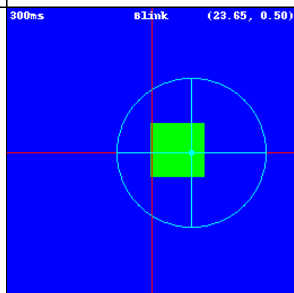
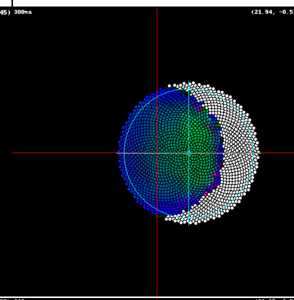
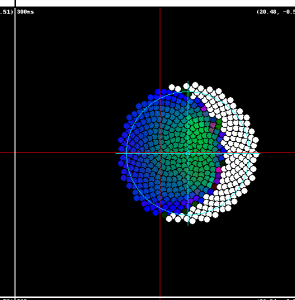
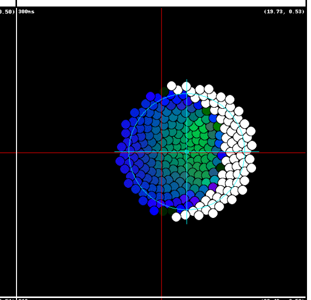
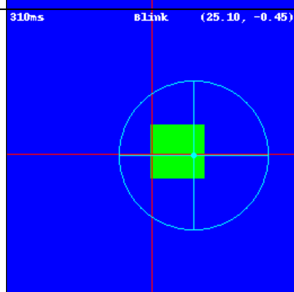
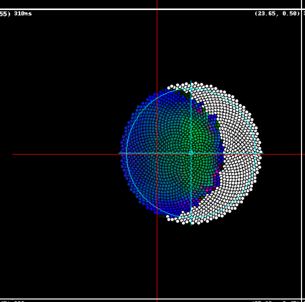
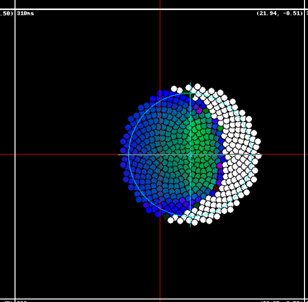
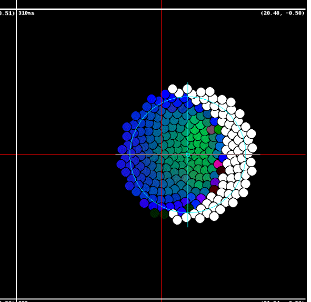
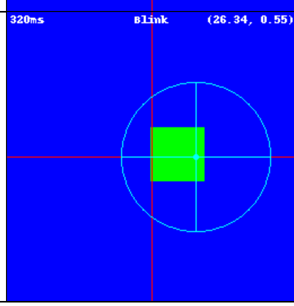
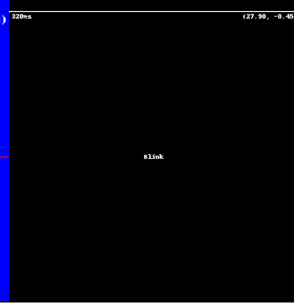
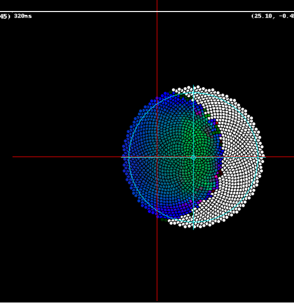
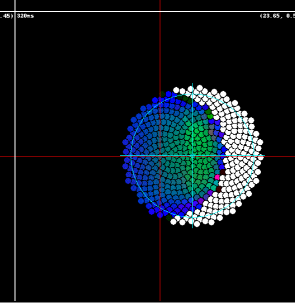
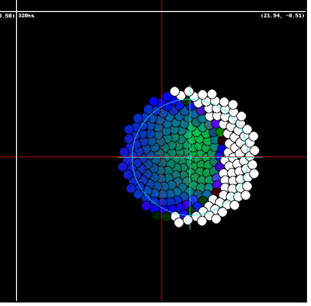
Table 16: Time sequence of active visual memory decay for simplified object (Square)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
30					
31					
32					

Table 16: Time sequence of active visual memory decay for simplified object (Square)

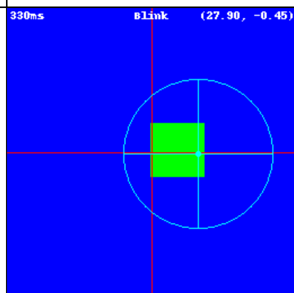
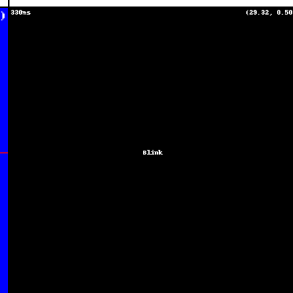
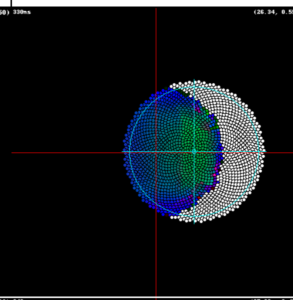
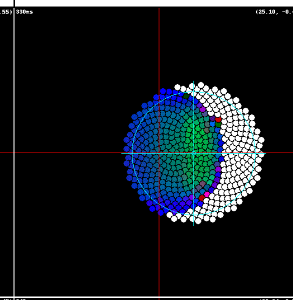
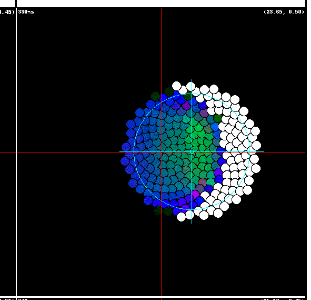
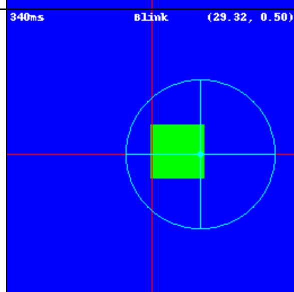
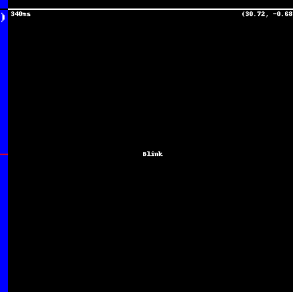
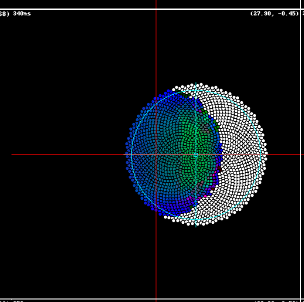
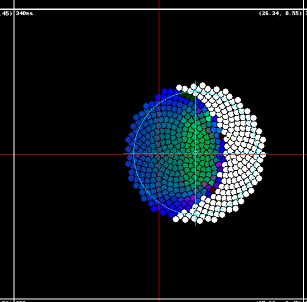
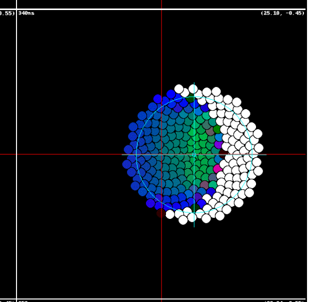
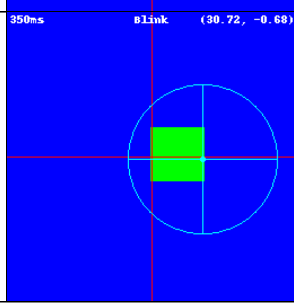
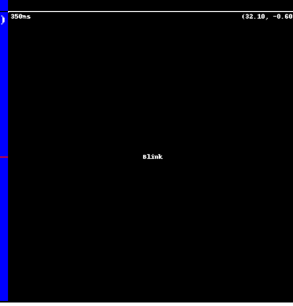
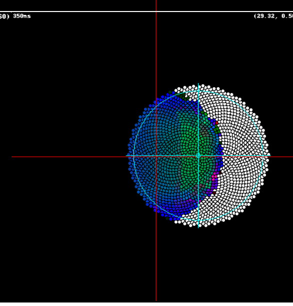
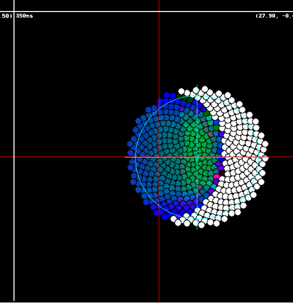
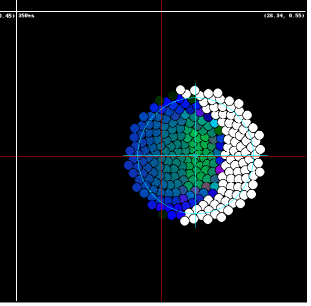
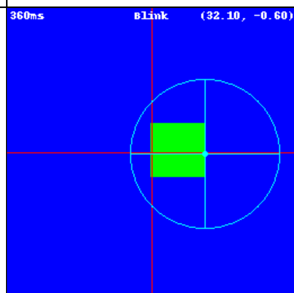
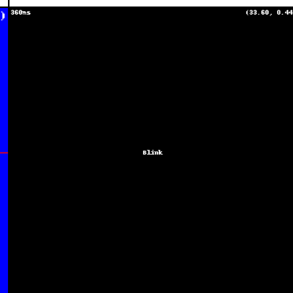
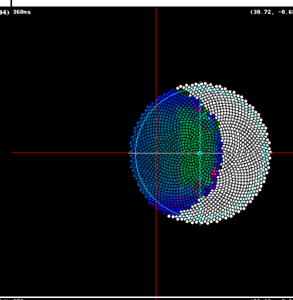
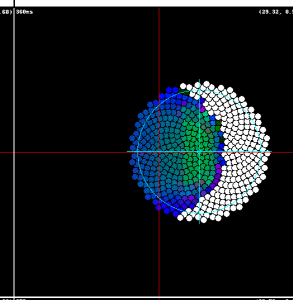
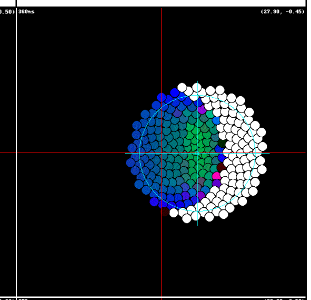
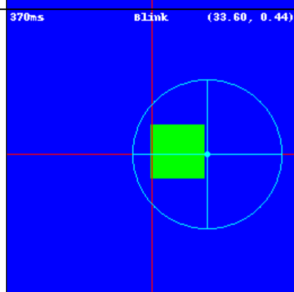
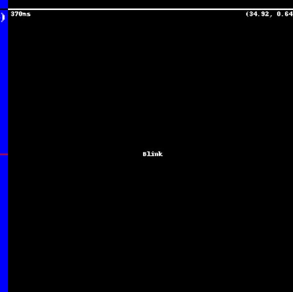
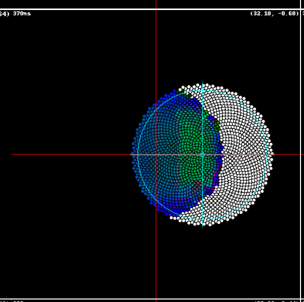
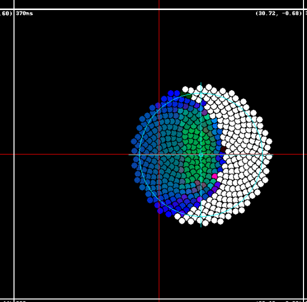
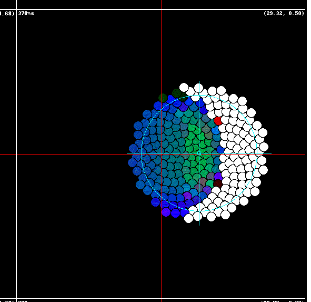
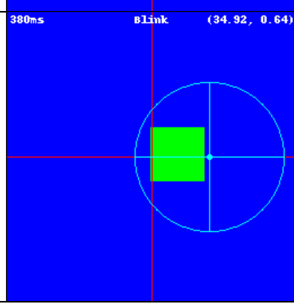
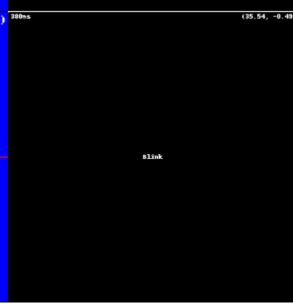
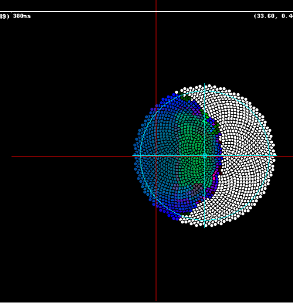
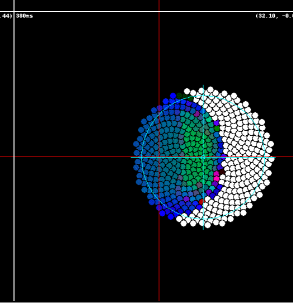
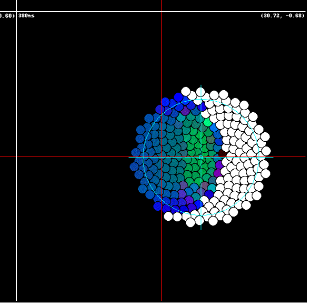
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
33					
34					
35					

Table 16: Time sequence of active visual memory decay for simplified object (Square)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
36					
37					
38					

5 Chapter: An emergic model of filling-in the blind-spot

These supplement the corresponding material in the thesis.

5.1 Subject details

Two virtual subjects were used in these six tests. Each is fully characterized by a set of developmental and behavioural parameters that will be indicated next. The meaning of these parameters can be found in the thesis. Note that development includes a stochastic component so that, for example, while the L:M:S cone ratio may be innately specified, the colour sensitivity type of individual cones is random. To simulate the optical blind spot, a fully grown photoreceptor mosaic is initially developed, but all photoreceptors within a specified region are killed.

5.1.1 Test 1, 2 & 3 subject with dynamic eye

Same as Brief Stimuli subject on page 115, but with an optical blind spot configured as highlighted below. Also sRT changed to 20ms to show it is arbitrary.

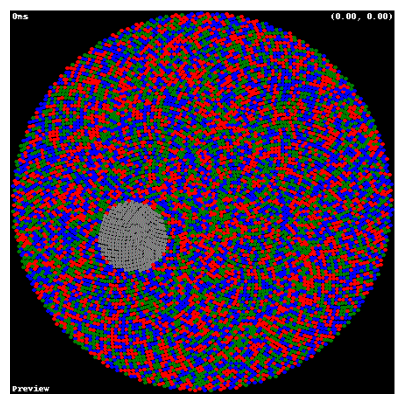


Illustration 15: Photoreceptor mosaic of *person* used in blind spot tests 1-3

```
[Person]
note =
srt = 20
sex = ai
age = 18
eyecount = 1
ipd = 0
vsize = 17.0
vieweyez = 100
r0conepix = 4
nodalpt = 17
r0coned = 4.0
r0red = 1
r0green = 1
r1coned = 1.0
r1red = 3000
r1green = 3000
r1blue = 3000
blindx = -20.0
blindy = -10.0
blindr = 20.0
blink0d = 0
blink1d = 0
jitmin = 0.1
jitave = 0.7
jitmax = 0.9
p1_0_pixd = 2.5
p1_0_pix = 1800
p1_0_scale = 2
p1_0_fanlat = 5.0
p1_0_fandwn = 2.0
p1_1_pixd = 5.0
p1_1_pix = 500
p1_1_scale = 2
p1_1_fanlat = 2.0
p1_1_fandwn = 2.0
p1_2_pixd = 7.5
p1_2_pix = 250
p1_2_scale = 2
p1_2_fanlat = 1.2
p1_2_fandwn = 1.5
```

5.1.2 Test 4, 5, 6 & 7 subject with static eye

This virtual agent (Illustration 16) had its blind spot placed in the center of the eye where the size of higher-level RFs could be carefully controlled.

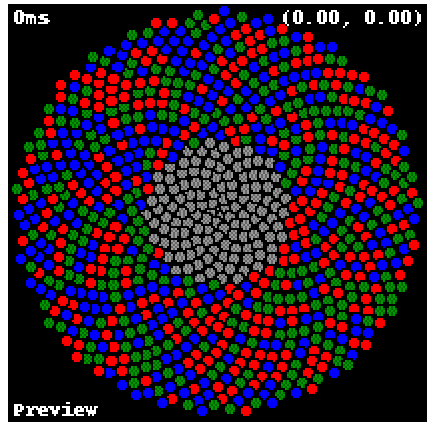


Illustration 16: Photoreceptor mosaic of *person* used in blind spot tests 4-7

```
[Person]
note =
srt = 10
sex = ai
age = 18
eyecount = 1
ipd = 0
vsize = 17.0
vieweyez = 50
r0conepix = 6
nodalpt = 17
r0coned = 10.0
r0red = 1
r0green = 1
r1coned = 1.0
r1red = 300
r1green = 300
r1blue = 300
blindx = 0.0
blindy = 0.0
blindr = 12.0
blink0d = 0
blink1d = 0
jitmin = 0.1
jitave = 0.7
jitmax = 0.9
p1_0_pixd = 2.5
p1_0_pix = 300
p1_0_scale = 1
p1_0_fanlat = 5.0
p1_0_fandwn = 1.0
p1_1_pixd = 5.0
p1_1_pix = 150
p1_1_scale = 1
p1_1_fanlat = 2.0
p1_1_fandwn = 2.0
p1_2_pixd = 10.0
p1_2_pix = 22
p1_2_scale = 1
p1_2_fanlat = 1.2
p1_2_fandwn = 1.5
```

5.1.3 Test 8 subject with final saccade

This virtual subject was similar to the previous one but optimized to fit the ring stimulus. Moreover, its L:M:S cone ratio was made similar to humans as the test results will be compared against human data (Spillmann, Otte, Hamburger, & Magnussen, 2006).

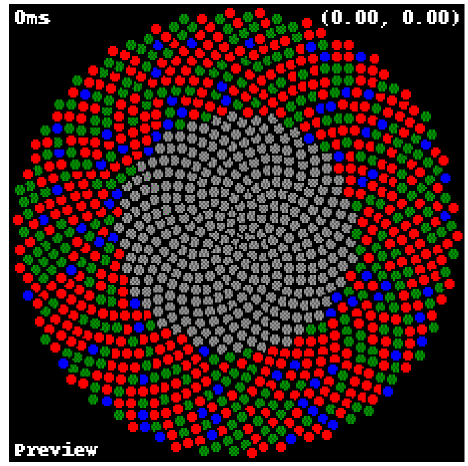


Illustration 17: Photoreceptor mosaic of *person* used in blind spot tests 8

```
[Person]
note =
srt = 10
sex = ai
age = 18
eyecount = 1
ipd = 0
vsize = 17.0
vieweyez = 98
r0conepix = 6
nodalpt = 17
r0coned = 10.0
r0red = 1
r0green = 1
r1coned = 1.0
r1red = 600
r1green = 400
r1blue = 100
blindx = 0.0
blindy = 0.0
blindr = 20.0
blink0d = 0
blink1d = 0
jitmin = 0.1
jitave = 0.7
jitmax = 0.9
p1_0_pixd = 2.5
p1_0_pix = 300
p1_0_scale = 1
p1_0_fanlat = 5.0
p1_0_fandwn = 1.0
p1_1_pixd = 5.0
p1_1_pix = 150
p1_1_scale = 1
p1_1_fanlat = 2.0
p1_1_fandwn = 2.0
p1_2_pixd = 10.0
p1_2_pix = 22
p1_2_scale = 1
p1_2_fanlat = 1.2
p1_2_fandwn = 1.5
```

5.2 Stimuli details

The first three tests characterize filling-in across the *dynamic* optical blind spot due to incessant eye motion using the common Love, Lena and Chaser stimuli. The next three are more traditional *static* blind spot experiments involving a straight line over the blind spot (Test 4), a line moving across the blind spot (Test 5) and a line being inserted into the blind spot (Test 6).

5.2.1 Test 1 stimulus: Simple surfaces (Love)

This stimulus is used to test filling-in behaviour in a generic fashion using simple surfaces – the block letters spelling LOVE. The meaning of these parameters is fully described in the thesis. The content of file blind_love.gif appears in Illustration 18 minus any overlay.

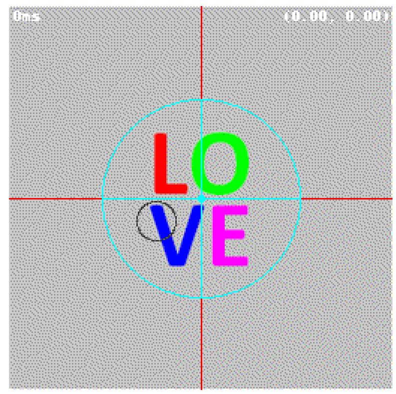


Illustration 18: Blind spot Test 1 stimulus (Love) with overlay

```
[World]
type = Image
note = blind spot
srt = 200
[Image]
wx = 256
wy = 256
wbg = #000000
iname =
blind_love.gif
ix = 256
iy = 256
```

5.2.2 Test 2 stimulus: Natural image (Lena)

This stimulus is used to test filling-in behaviour in a generic fashion using a natural image - a standard image library picture of Lena (Picard, 1995). The meaning of these parameters is fully described in the thesis. The content of file Lena.tiff appears in Illustration 19 minus any overlay.

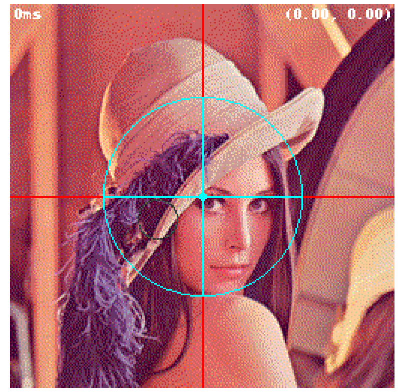


Illustration 19: Blind spot Test 2 stimulus (Lena) with overlay

```
[World]
type = Image
note = blind spot
srt = 200

[Image]
wx = 256
wy = 256
wbg = #000000
iname = Lena.tiff
ix = 256
iy = 256
```

5.2.3 Test 3 stimulus: Dynamic image with surface gradients (Chaser)

This stimulus (as viewed in Illustration 20) is used to test filling-in behaviour in a generic fashion using a dynamic image with surface gradients – the lilac chaser. The meaning of these parameters is fully described in the thesis.

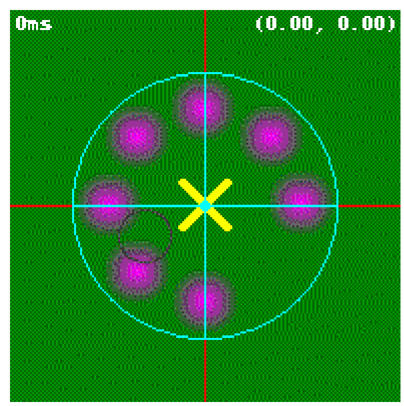


Illustration 20: Blind spot Test 3 stimulus (Chaser) with overlay

```
[World]
type = Lilac Chaser
note = blind spot
srt = 100
[Lilac Chaser]
llcount = 8
spacing = 0.1
pad = 1.0
fg = #ff00ff
bg = #007f00
gamma = 1.0
grdcount = 17
grdwidth = 1
fixfg = #ffff00
fixsize = 0.75
fixwidth = 2
```

5.2.4 Test 4 stimulus: Line static

The blind spot was positioned over a horizontal line and was kept static barring any jitter. The screen capture 'eye' provided the view as shown in Illustration 21 with overlay.

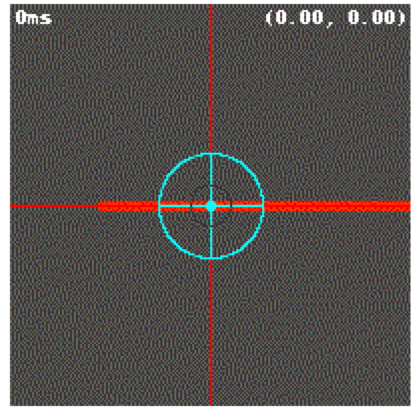


Illustration 21: Blind spot Test 4 stimulus (LineStatic) with overlay

```
[World]
type = Screen
note = blind spot
srt = 50
[Screen]
wsize = 0
wx = 256
wy = 256
wscale = 1.0
scrx = 63
scry = 700
scrw = 200
scrh = 200
movx = 0
movy = 0
```

5.2.5 Test 5 stimulus: Line across

The blind spot was positioned just under horizontal line and was kept static barring any jitter. The screen capture 'eye' provided the view as shown in Illustration 22 with overlay. It effectively caused the line to move downwards across the blind spot.

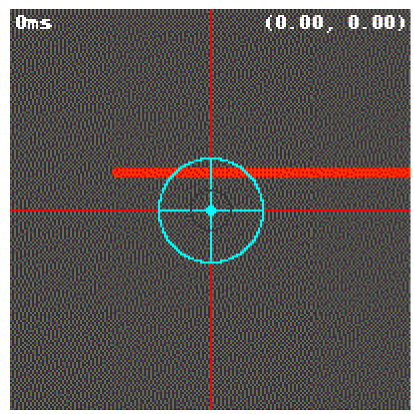


Illustration 22: Blind spot Test 5 stimulus (LineAcross) with overlay

```
[World]
type = Screen
note = blind spot
srt = 50
[Screen]
wsize = 0
wx = 256
wy = 256
wscale = 1.0
scrx = 63
scry = 700
scrw = 200
scrh = 200
movx = 0
movy = -1
```

5.2.6 Test 6 stimulus: Line in

The blind spot was positioned just to the left of a horizontal line and was kept static barring any jitter. The screen capture 'eye' provided the view as shown in Illustration 23 with overlay. It effectively caused the line to move leftwards into the blind spot.

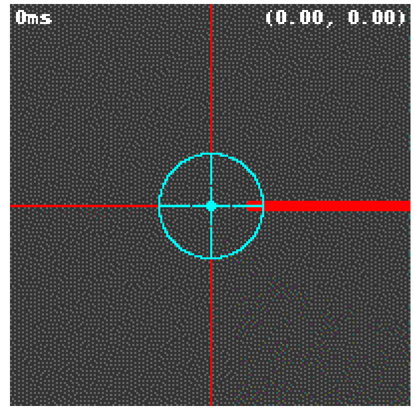


Illustration 23: Blind spot Test 6 stimulus (LineIn) with overlay

```
[World]
type = Screen
note = blind spot
srt = 50
[Screen]
wsize = 0
wx = 256
wy = 256
wscale = 1.0
scrx = 63
scry = 700
scrw = 200
scrh = 200
movx = 1
movy = 0
```

5.2.7 Test 7 stimulus: Line static with background masked

With the equivalent stimulus of Test 4, but with the person not viewing any world, the code was instrumented to inject the horizontal red bar (3.6' height) onto the photoreceptors instead. Effectively, the dark background was masked so as not to interfere with the line in the fixational layer.

5.2.8 Test 8 stimulus: ring around the blind spot

This stimulus forms a ring around the blind spot to be filled-in, and then the eye will saccade. It is intended to reproduce the effects of (Spillmann et al., 2006), so the ring was adapted to the perfect circularity of our virtual blind spot.

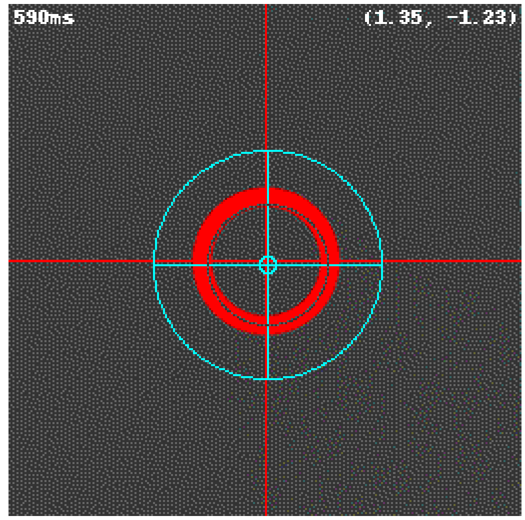


Illustration 24: Blind spot Test 8 stimulus (Ring) with overlay

5.3 Result details

In this section we tabulate a visual frame-by-frame account of results from all experiments. Such a frame-by-frame account allows for the extraction of precise timing information useful for quantitative analysis. It takes [] pages. All these results are reduced to a single web page of animated images, available at

http://emergic.upwize.com/?page_id=377

The animated account (Leibovitz, 2012a) is preferred as an overview showing behavioural dynamics of filling-in, memory, masking, etc. and makes image stability more salient. It also includes the results in greatest detail – they have been scaled down for print in this supplement, and even smaller in the chapter's *results and discussion* sections.

Each table of results has the following columns. **Time** numerically represents the time tick since the test has started, nominally 10ms/tick. All visual results in that table row are after the tick and computation have finished. **Stimuli** visually represents the stimuli presented to the virtual computer screen, often with retinal overlays. The **Photoreceptor Mosaic** visually represents what the retina senses by looking at the stimuli. **Receptive Fields** at **Level 1**, **Level 2** and **Level 3**, visually represent the three level hierarchy of receptive fields showing their the functional size and placement, not physical size nor placement

5.3.1 Test 1 results: Simple surfaces (Love)

Table 17: Time sequence of blind spot moving over simple surfaces (Love)

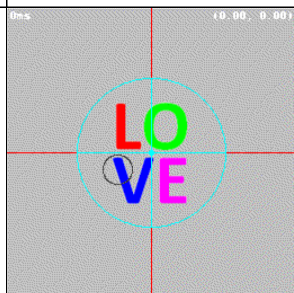
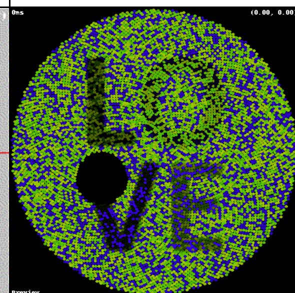
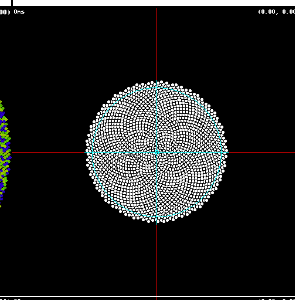
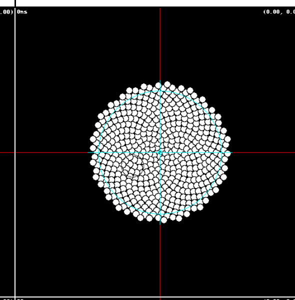
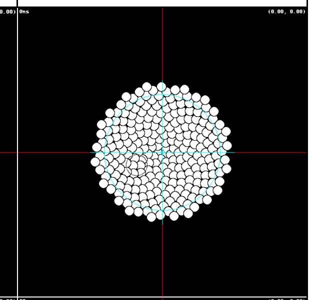
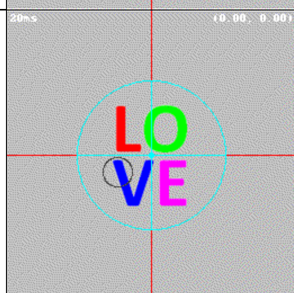
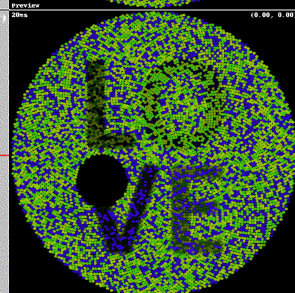
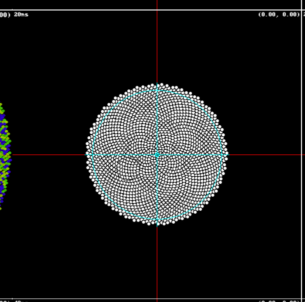
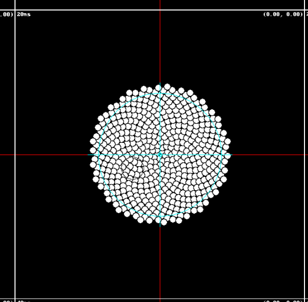
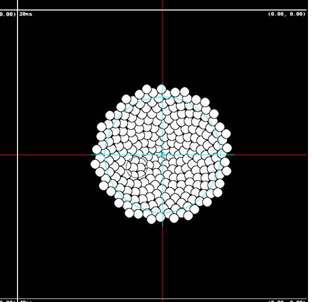
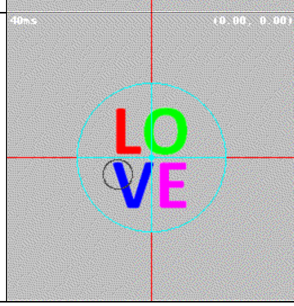
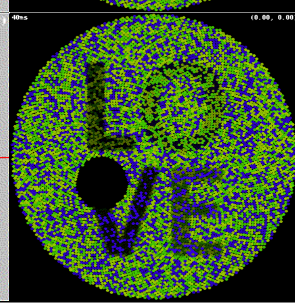
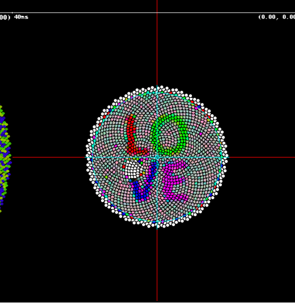
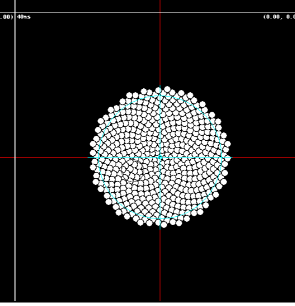
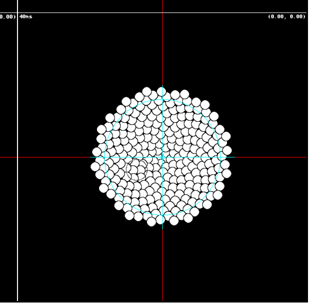
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
0					
1					
2					

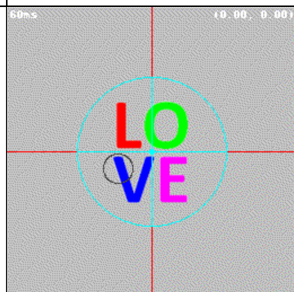
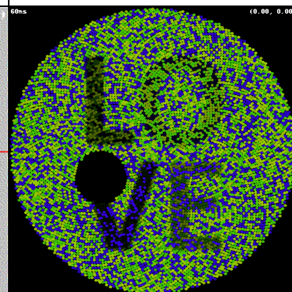
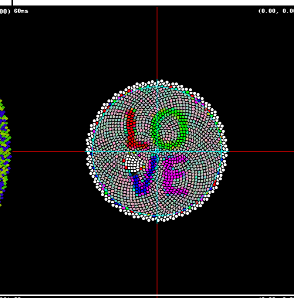
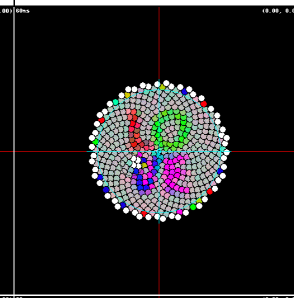
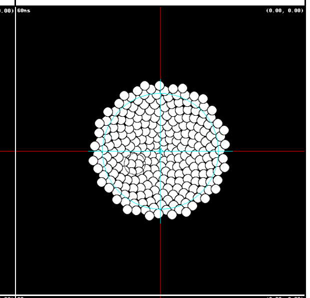
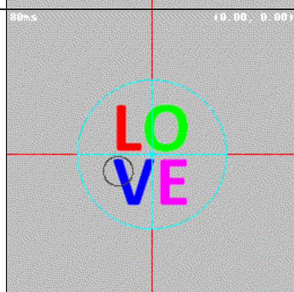
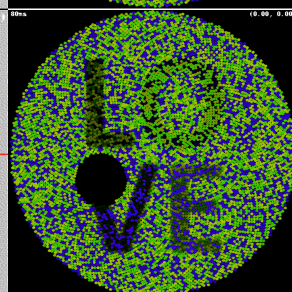
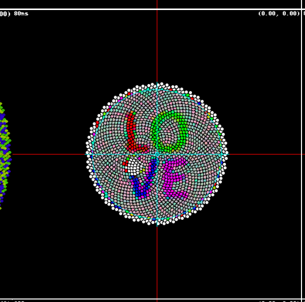
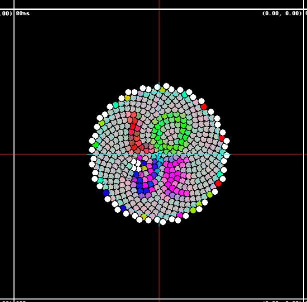
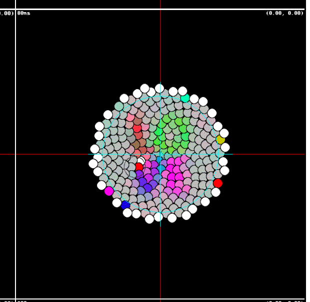
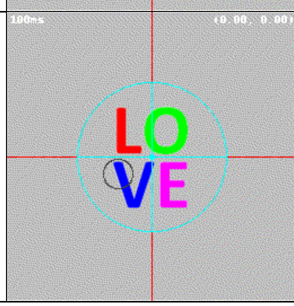
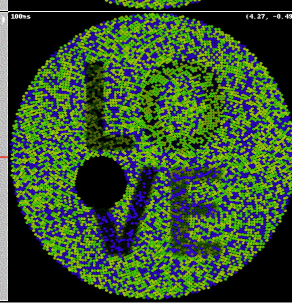
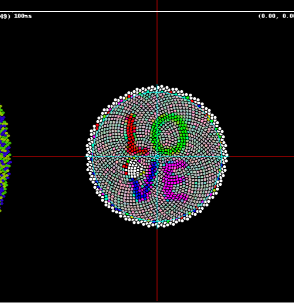
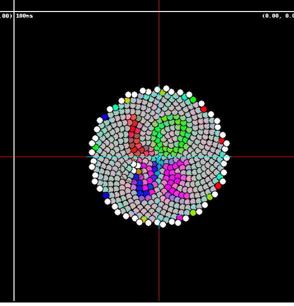
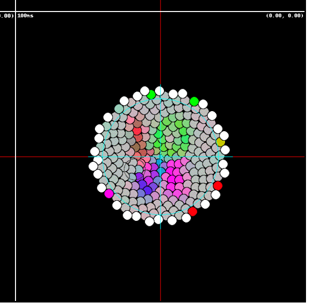
Table 17: Time sequence of blind spot moving over simple surfaces (Love)					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
3					
4					
5					

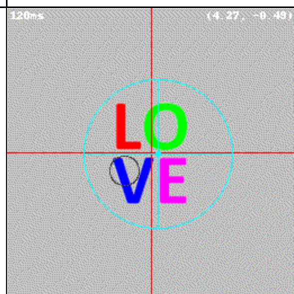
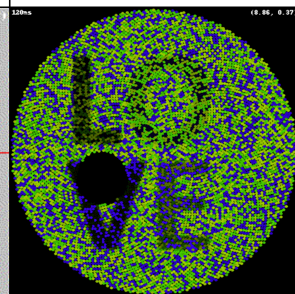
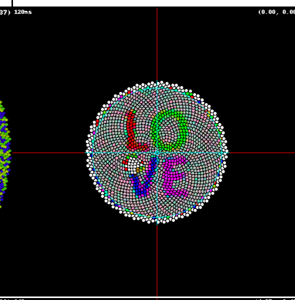
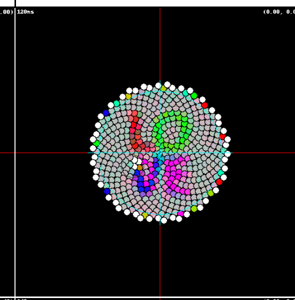
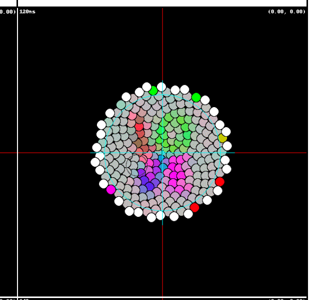
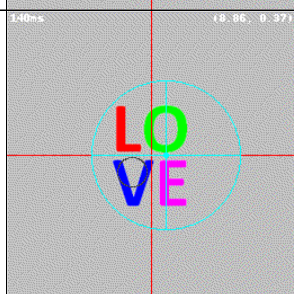
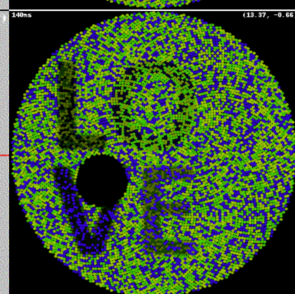
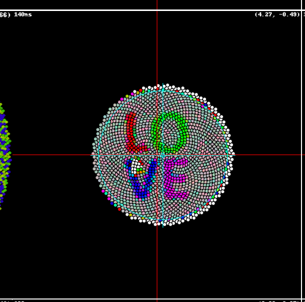
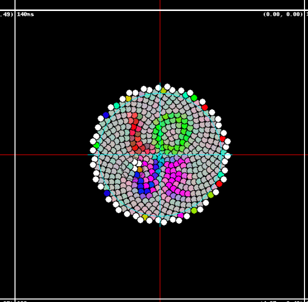
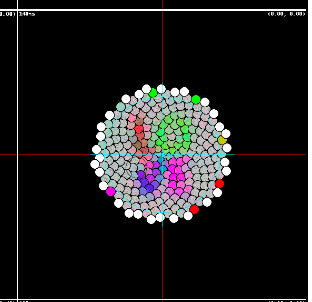
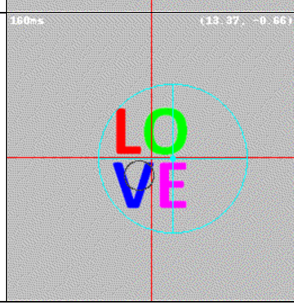
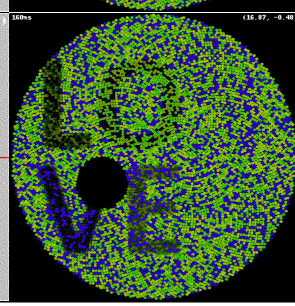
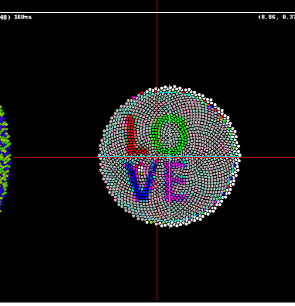
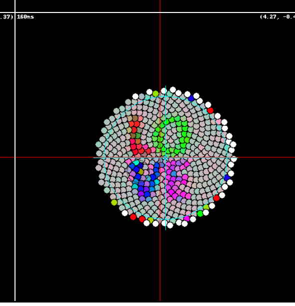
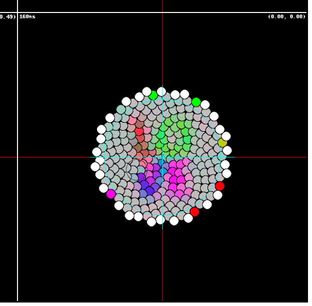
Table 17: Time sequence of blind spot moving over simple surfaces (Love)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
6					
7					
8					

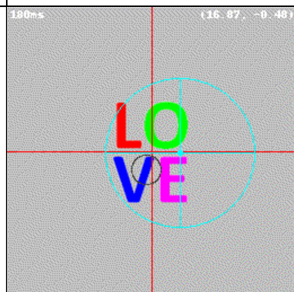
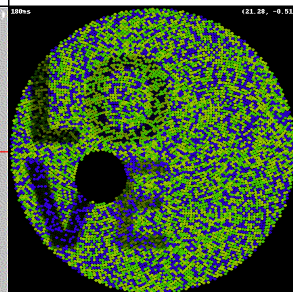
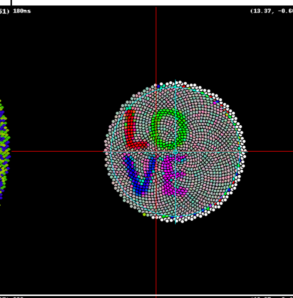
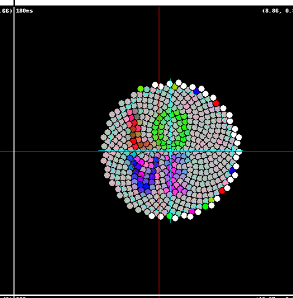
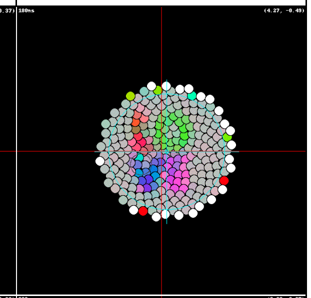
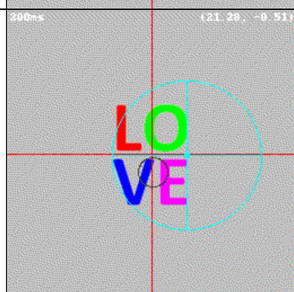
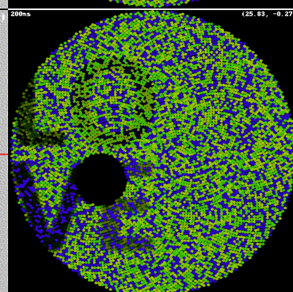
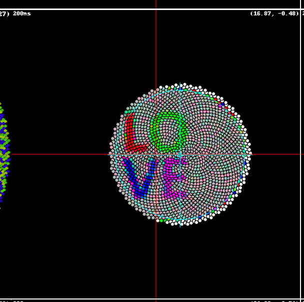
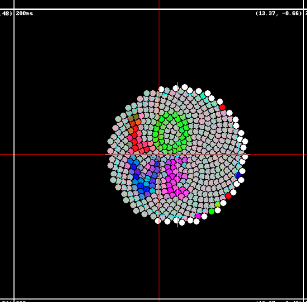
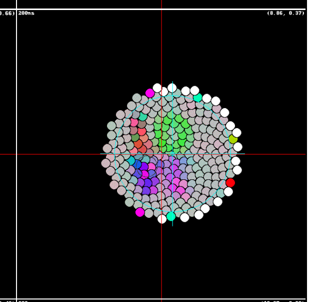
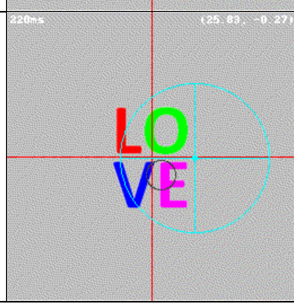
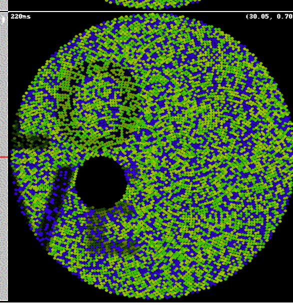
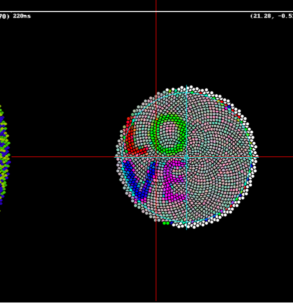
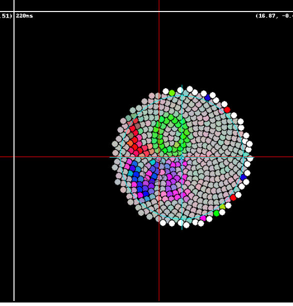
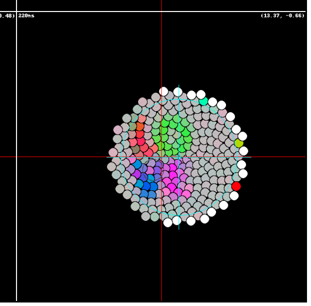
Table 17: Time sequence of blind spot moving over simple surfaces (Love)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
9					
10					
11					

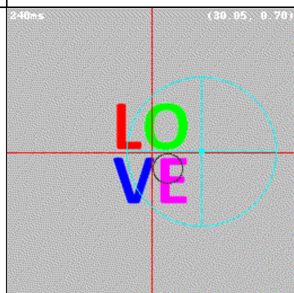
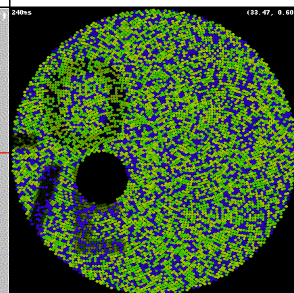
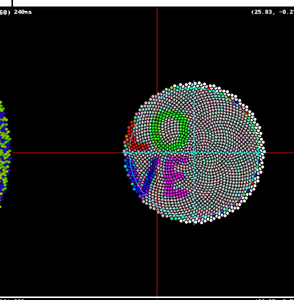
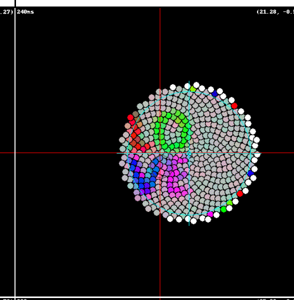
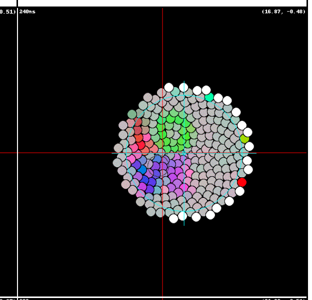
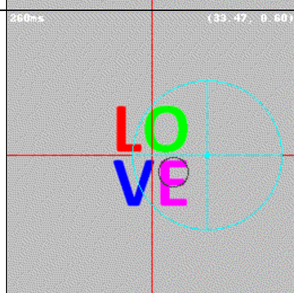
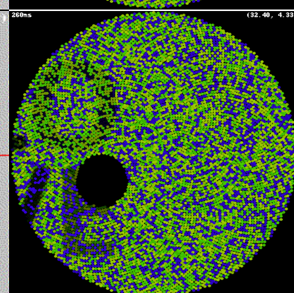
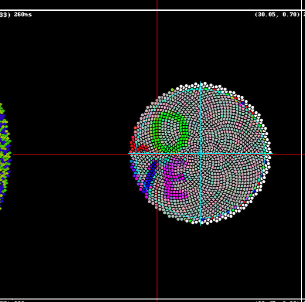
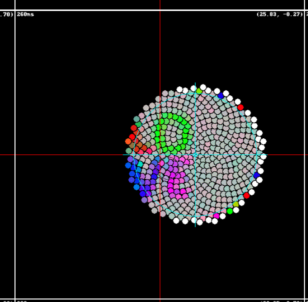
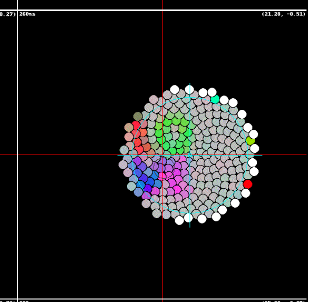
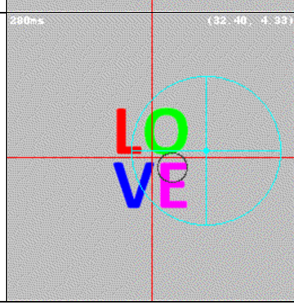
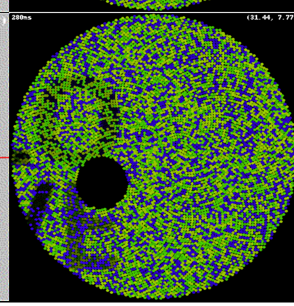
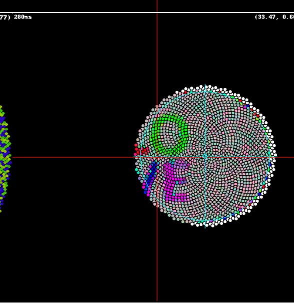
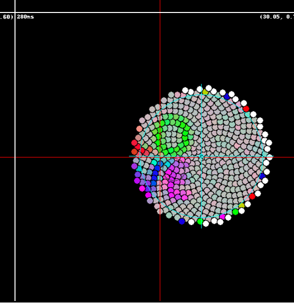
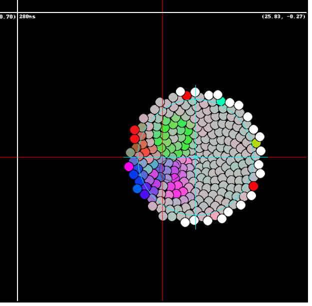
Table 17: Time sequence of blind spot moving over simple surfaces (Love)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
12					
13					
14					

Table 17: Time sequence of blind spot moving over simple surfaces (Love)

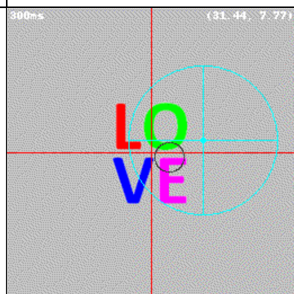
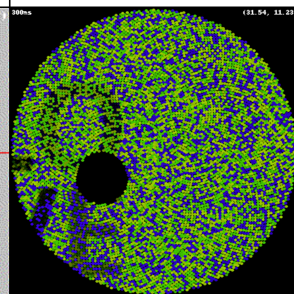
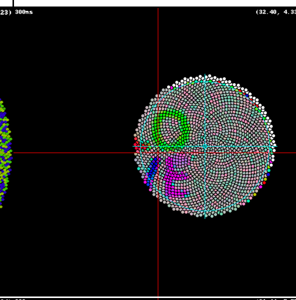
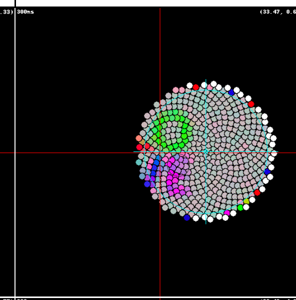
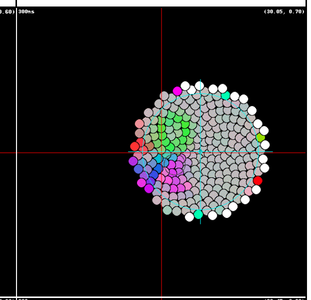
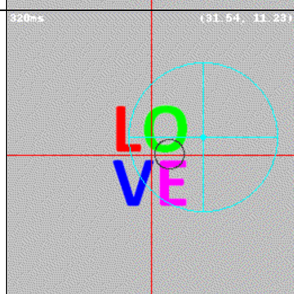
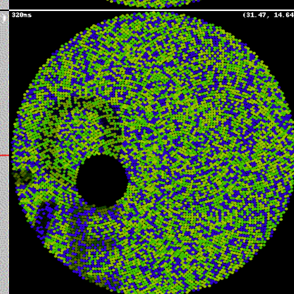
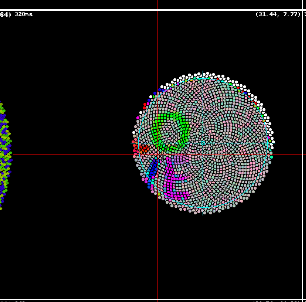
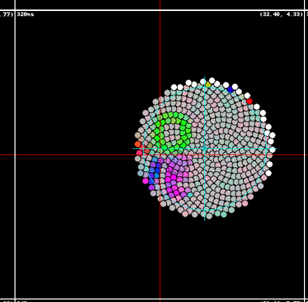
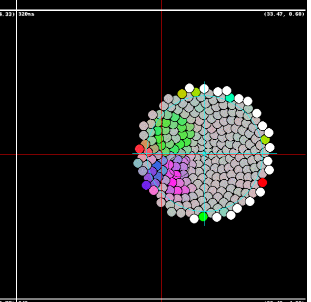
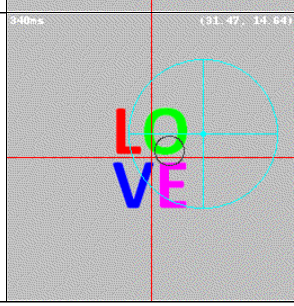
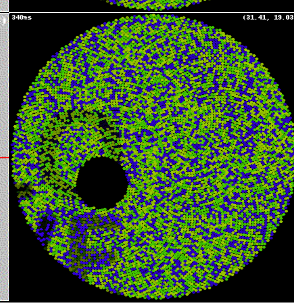
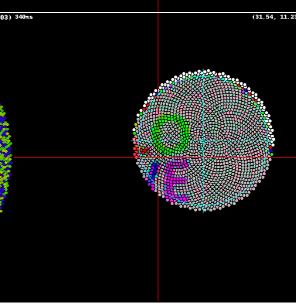
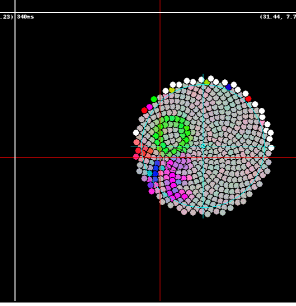
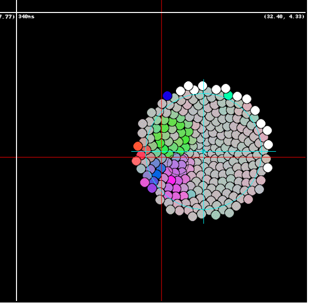
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
15					
16					
17					

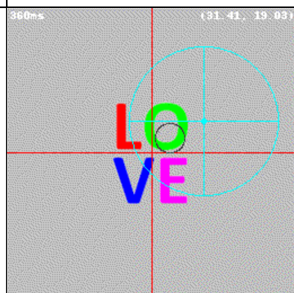
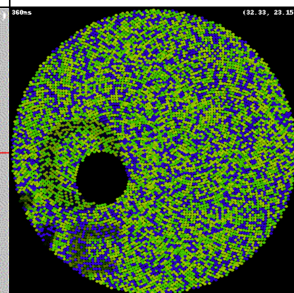
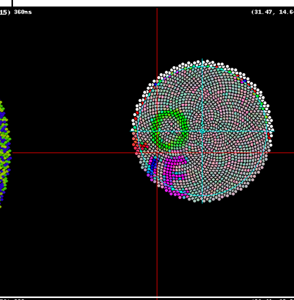
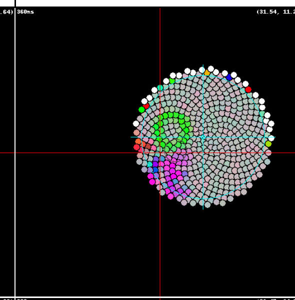
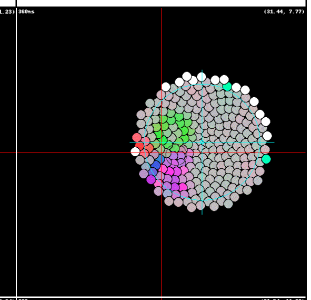
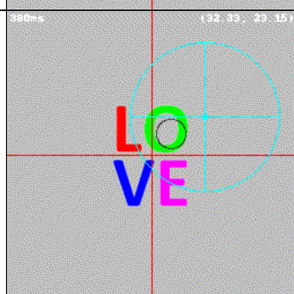
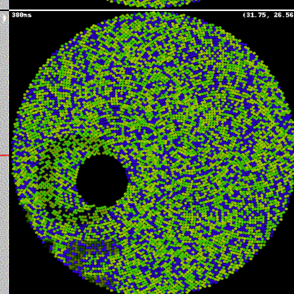
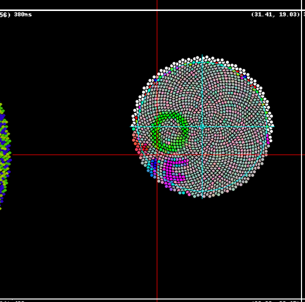
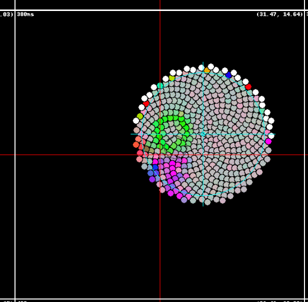
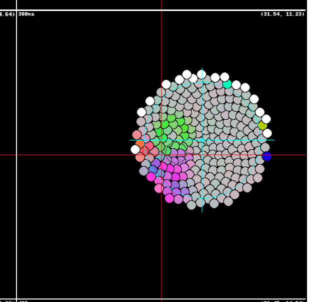
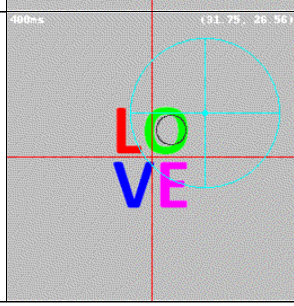
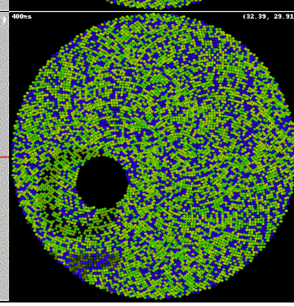
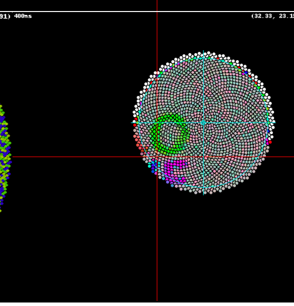
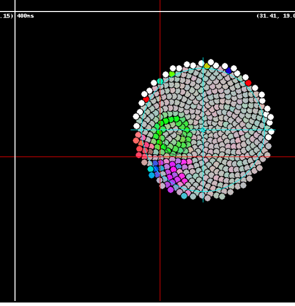
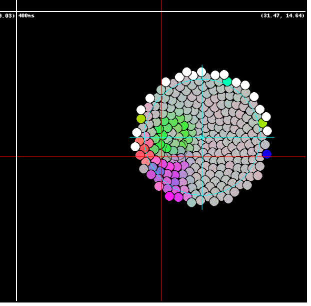
Table 17: Time sequence of blind spot moving over simple surfaces (Love)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
18					
19					
20					

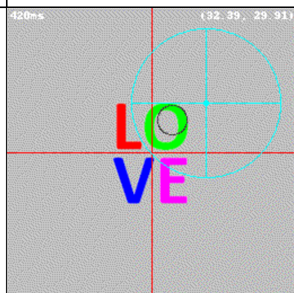
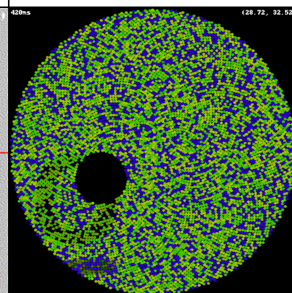
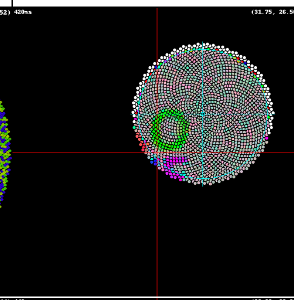
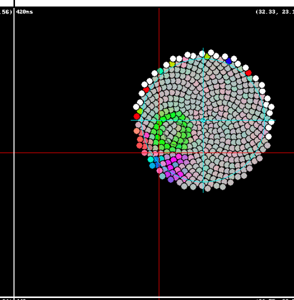
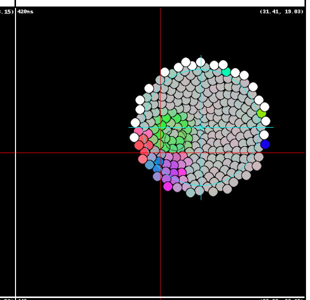
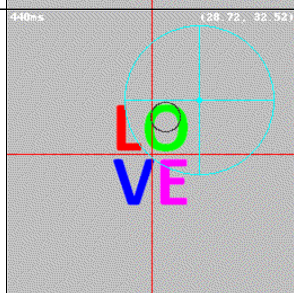
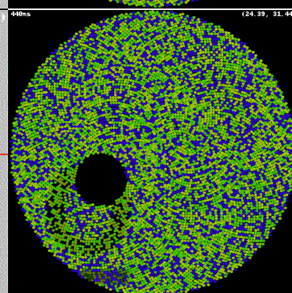
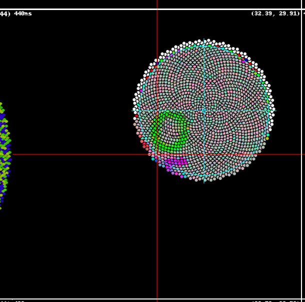
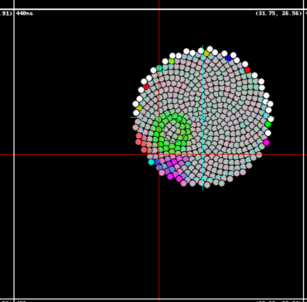
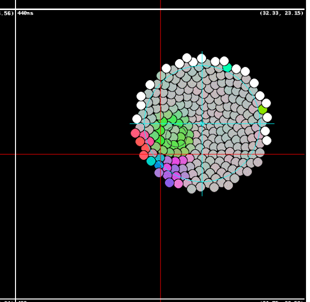
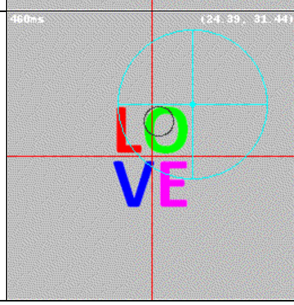
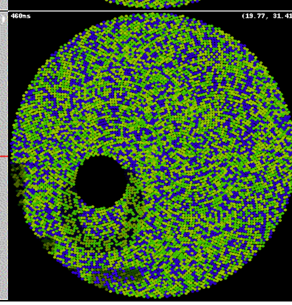
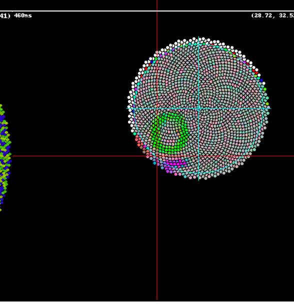
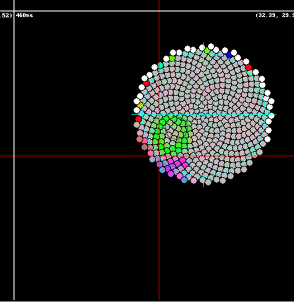
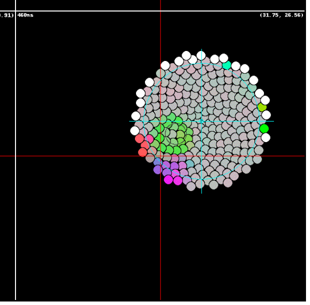
Table 17: Time sequence of blind spot moving over simple surfaces (Love)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
21					
22					
23					

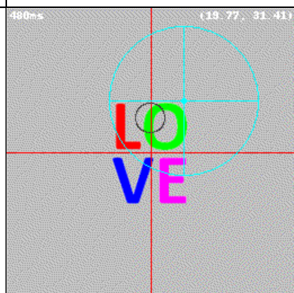
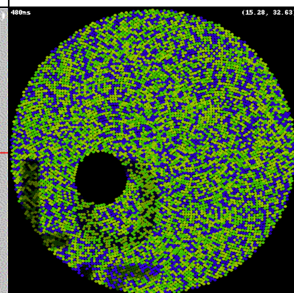
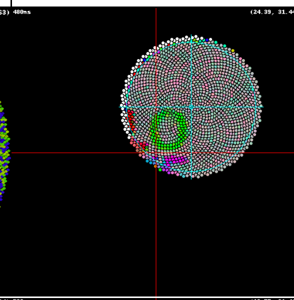
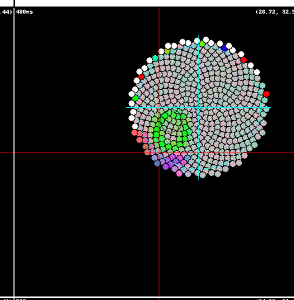
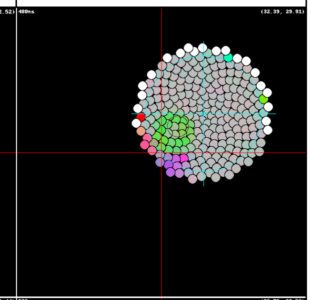
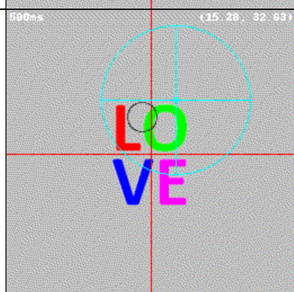
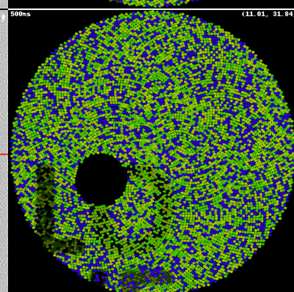
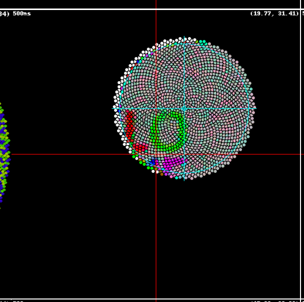
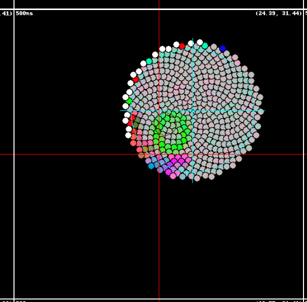
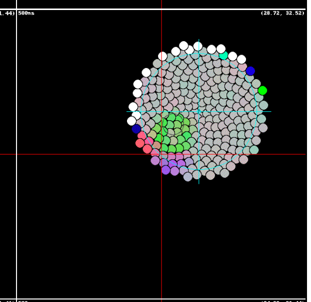
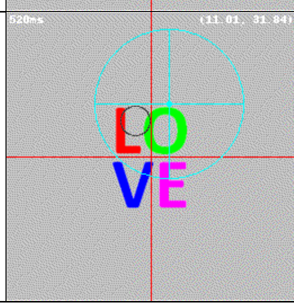
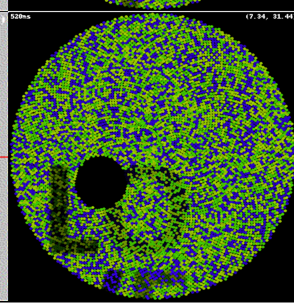
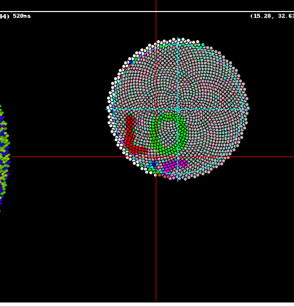
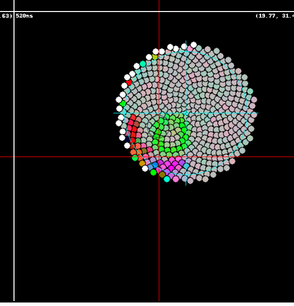
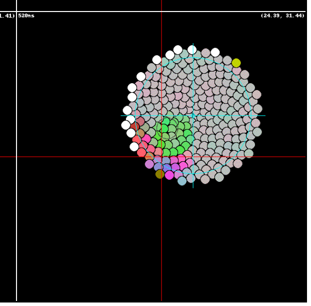
Table 17: Time sequence of blind spot moving over simple surfaces (Love)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
24					
25					
26					

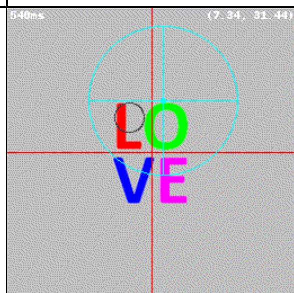
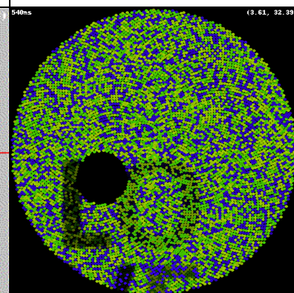
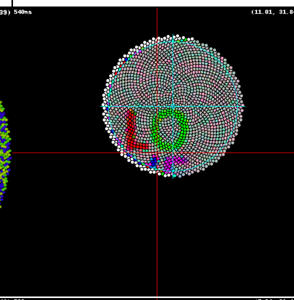
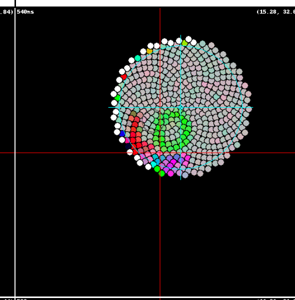
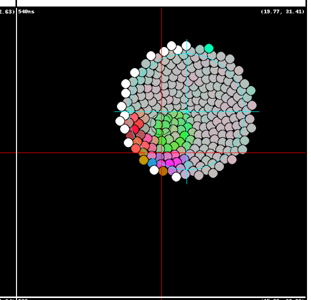
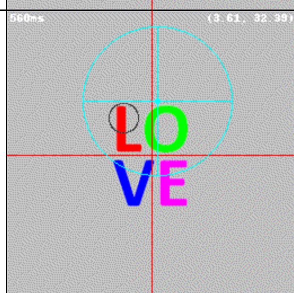
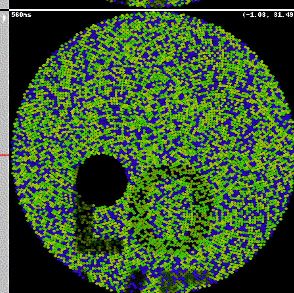
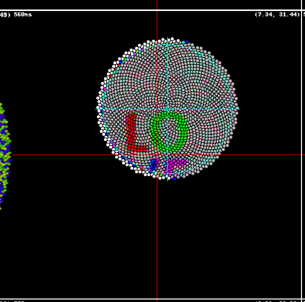
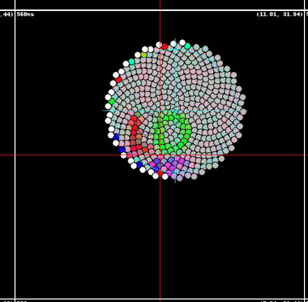
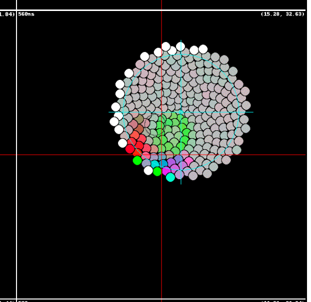
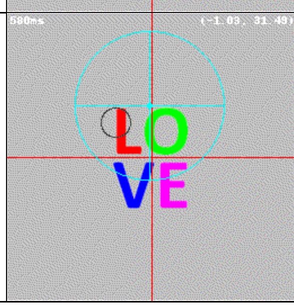
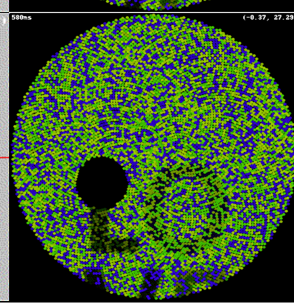
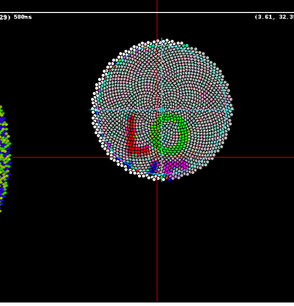
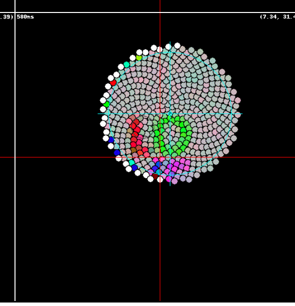
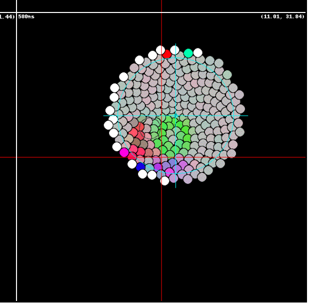
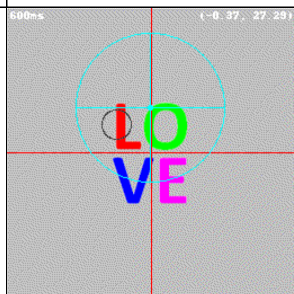
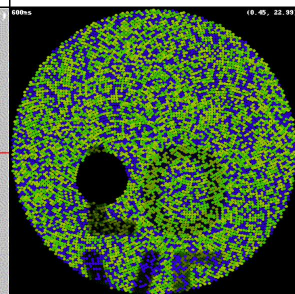
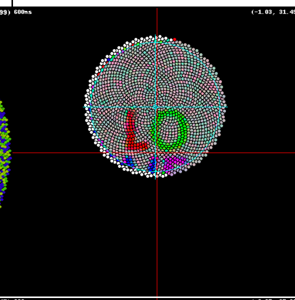
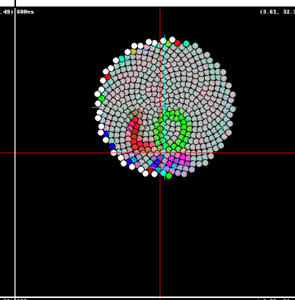
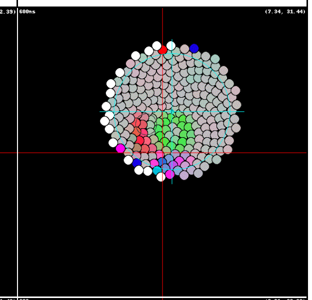
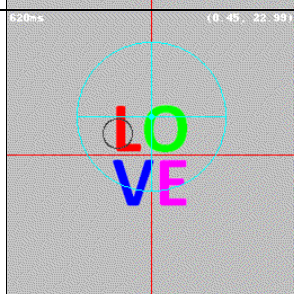
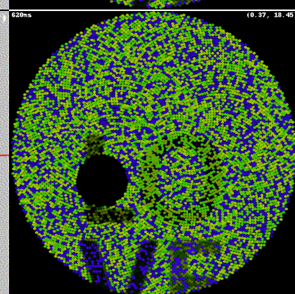
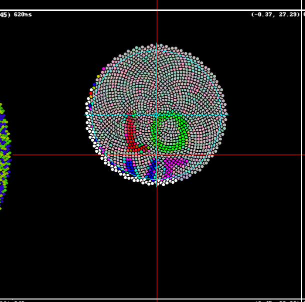
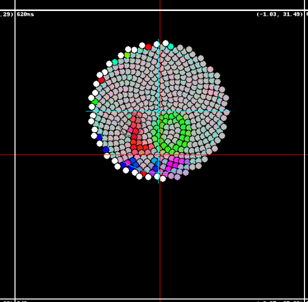
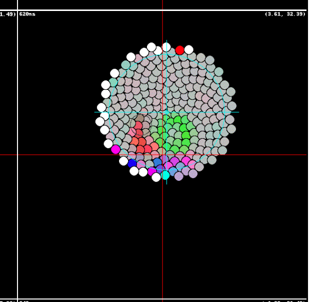
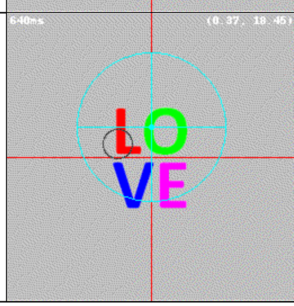
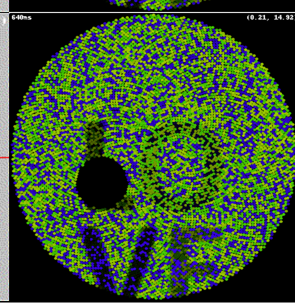
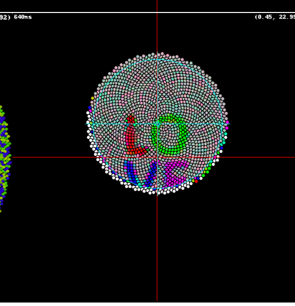
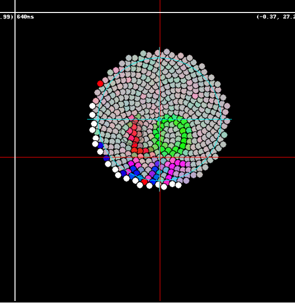
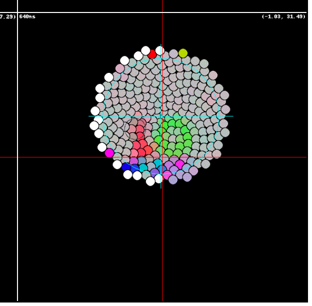
Table 17: Time sequence of blind spot moving over simple surfaces (Love)					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
27					
28					
29					

Table 17: Time sequence of blind spot moving over simple surfaces (Love)					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
30					
31					
32					

5.3.2 Test 2 results: Natural image (Lena)

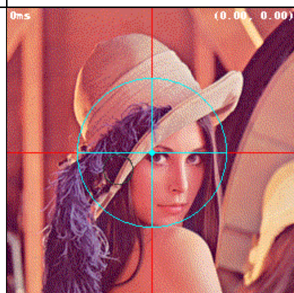
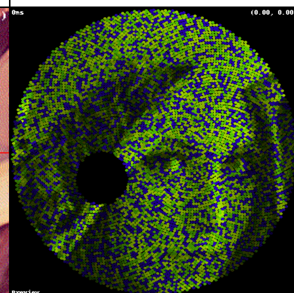
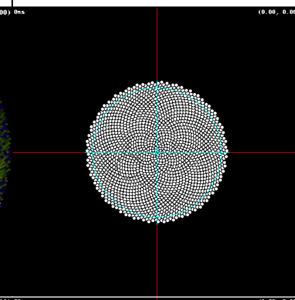
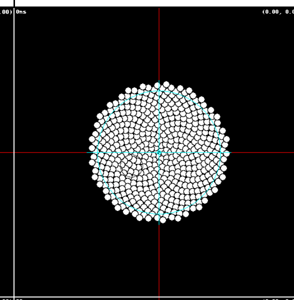
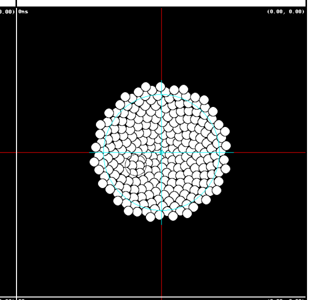
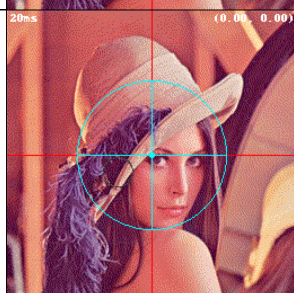
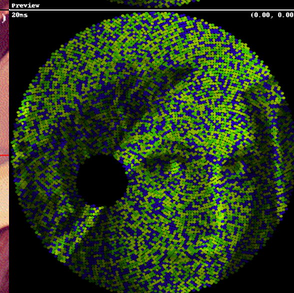
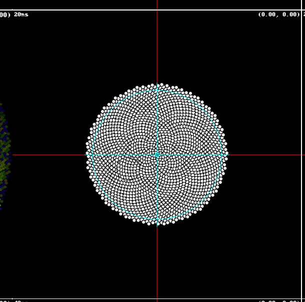
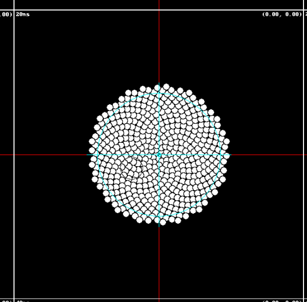
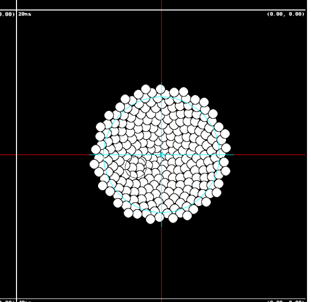
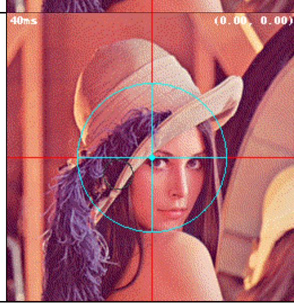
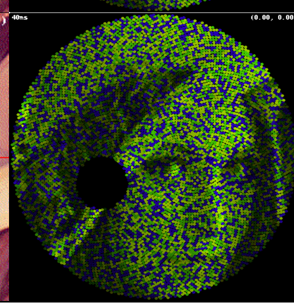
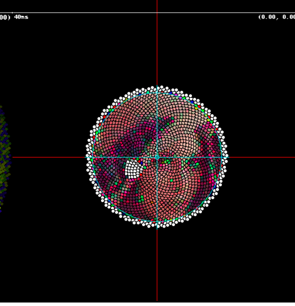
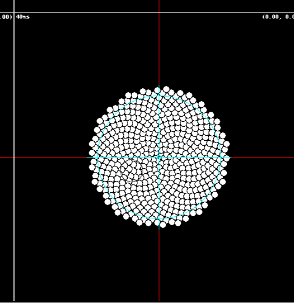
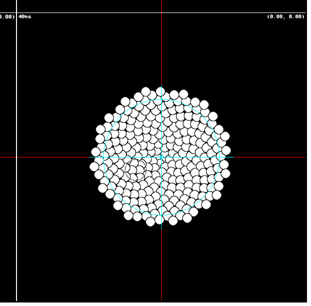
Table 18: Time sequence of blind spot moving over natural image (Lena)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
0					
1					
2					

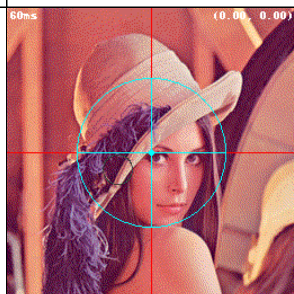
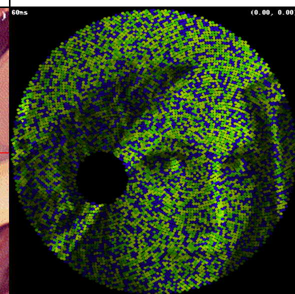
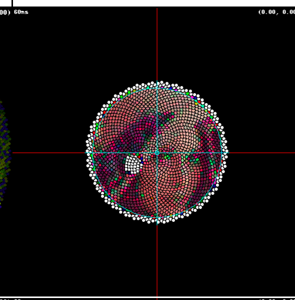
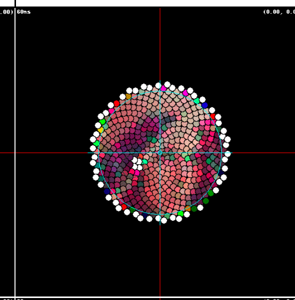
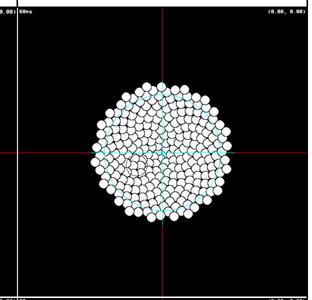
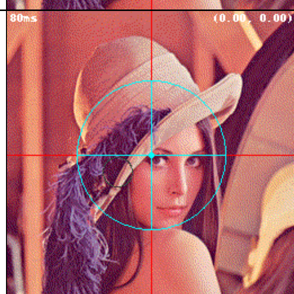
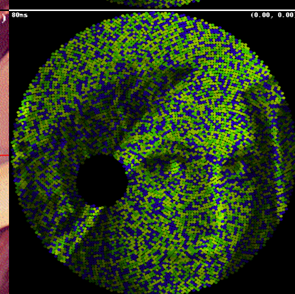
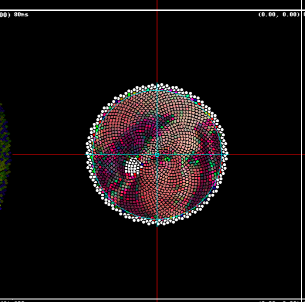
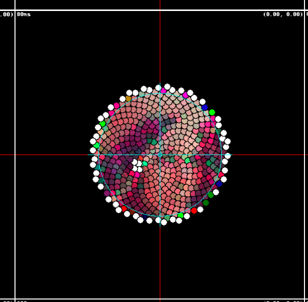
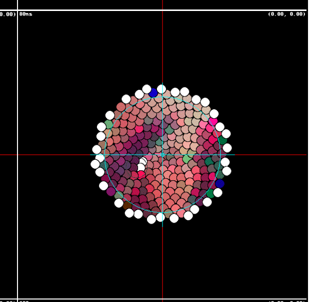
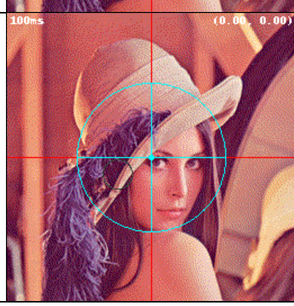
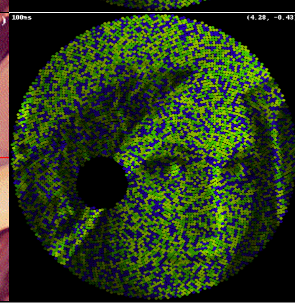
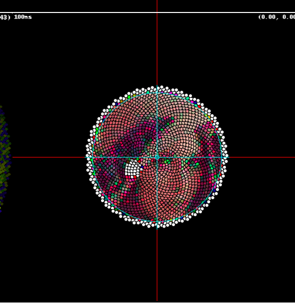
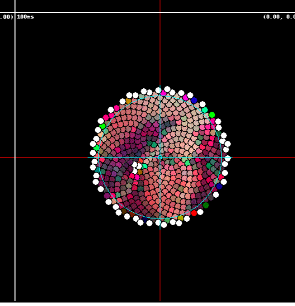
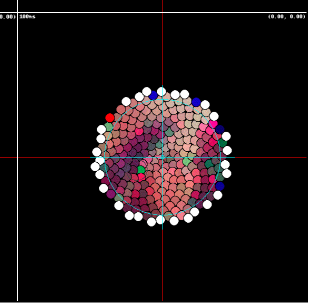
Table 18: Time sequence of blind spot moving over natural image (Lena)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
3					
4					
5					

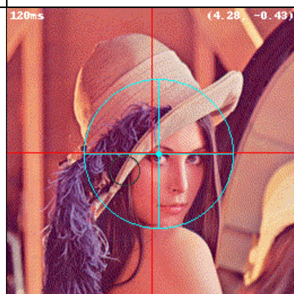
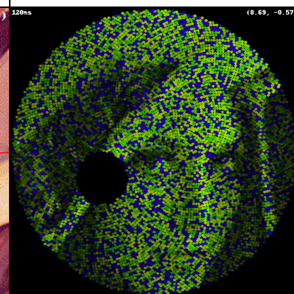
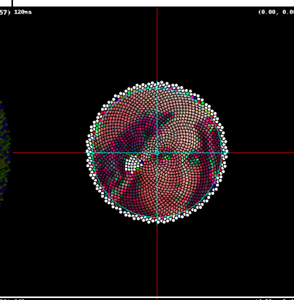
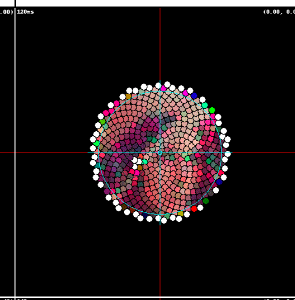
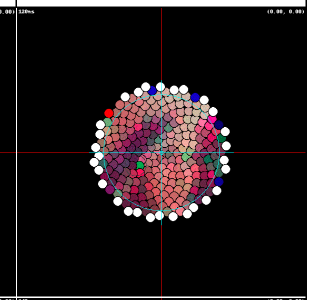
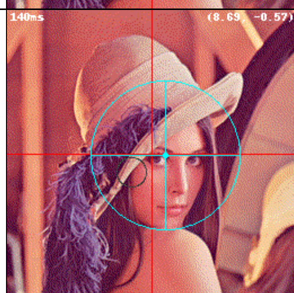
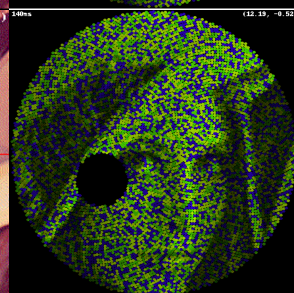
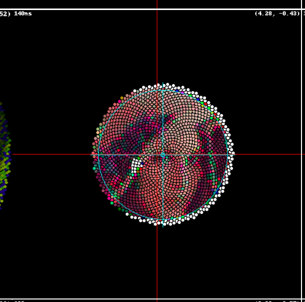
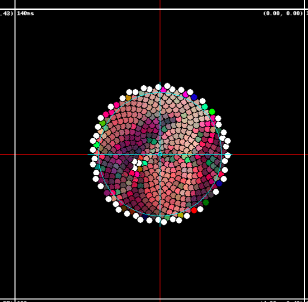
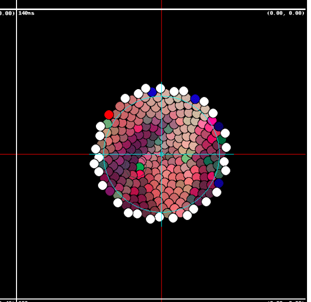
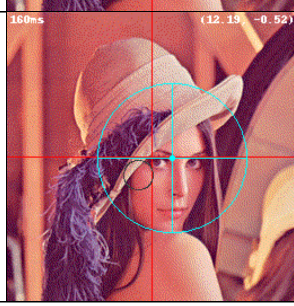
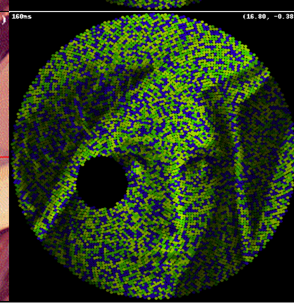
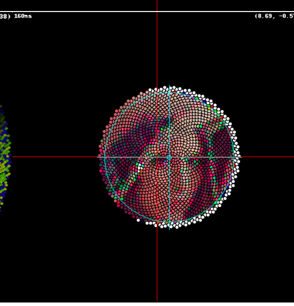
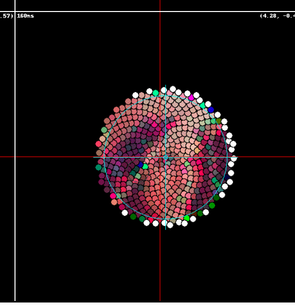
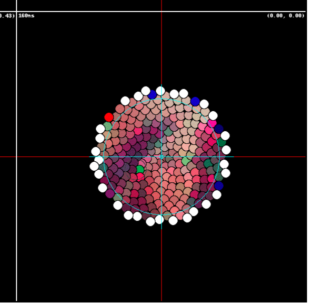
Table 18: Time sequence of blind spot moving over natural image (Lena)					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
6					
7					
8					

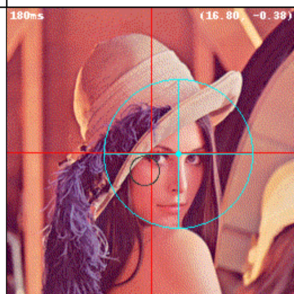
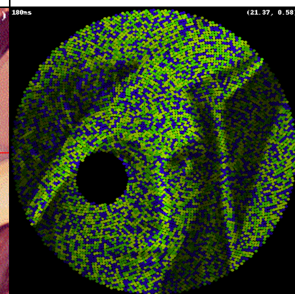
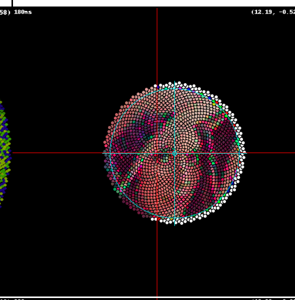
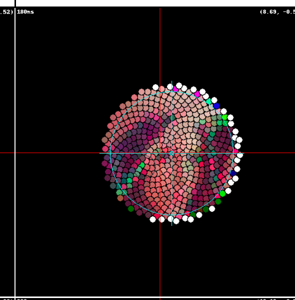
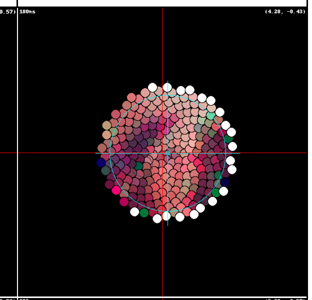
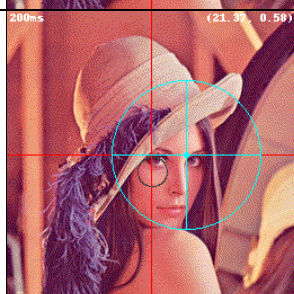
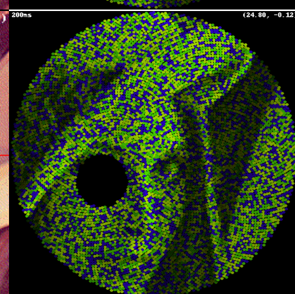
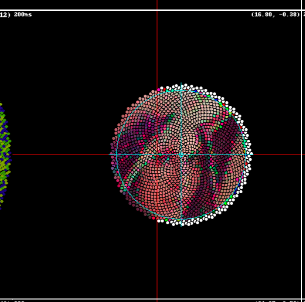
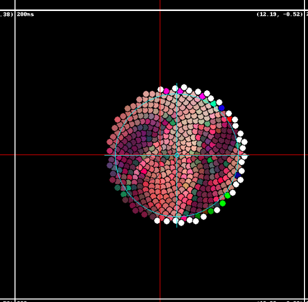
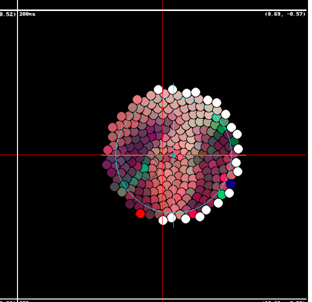
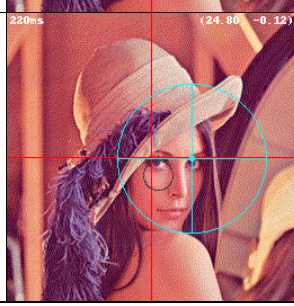
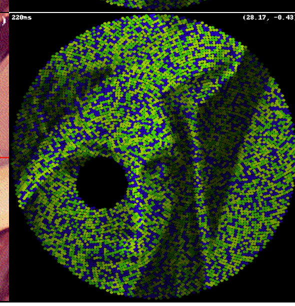
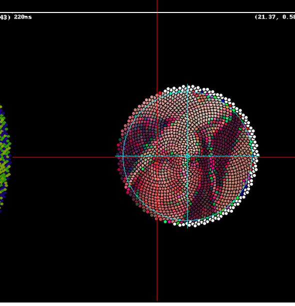
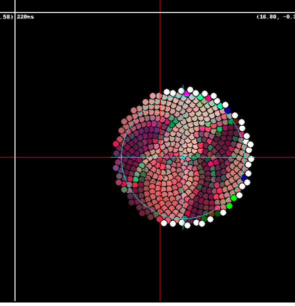
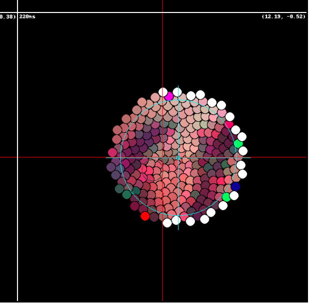
Table 18: Time sequence of blind spot moving over natural image (Lena)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
9					
10					
11					

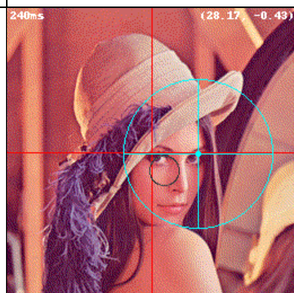
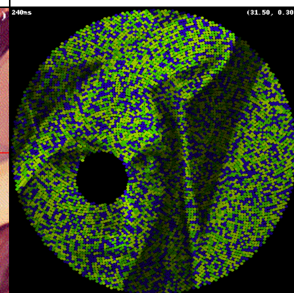
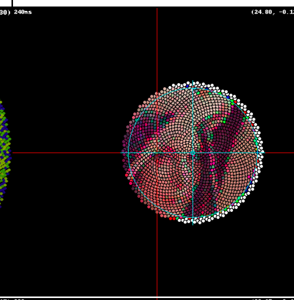
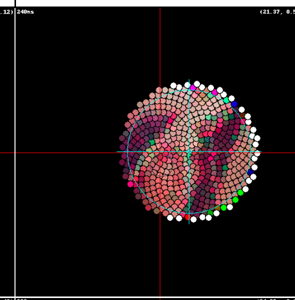
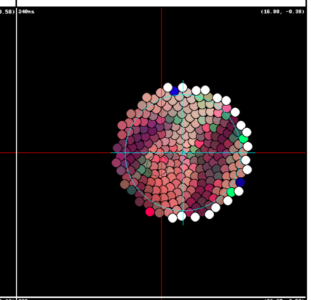
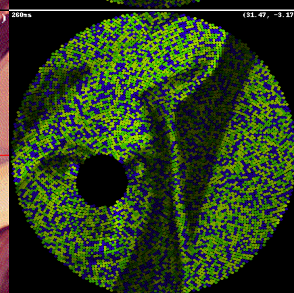
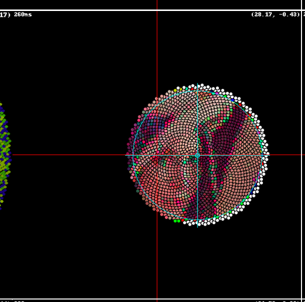
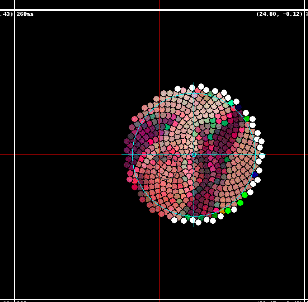
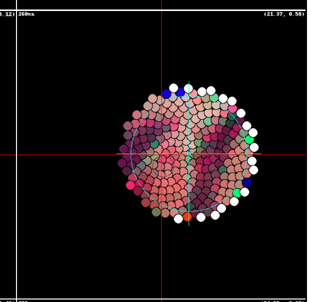
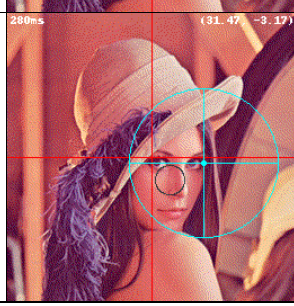
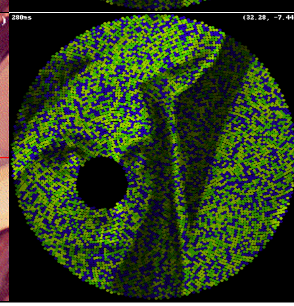
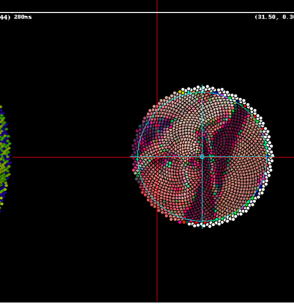
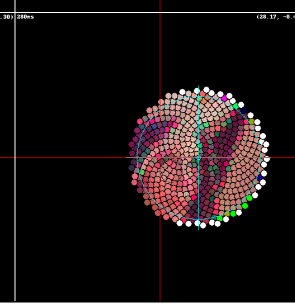
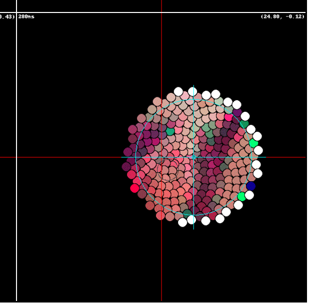
Table 18: Time sequence of blind spot moving over natural image (Lena)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
12					
13					
14					

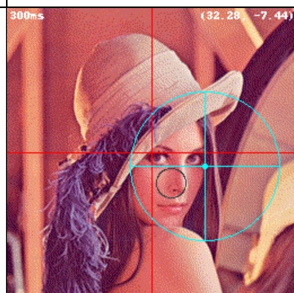
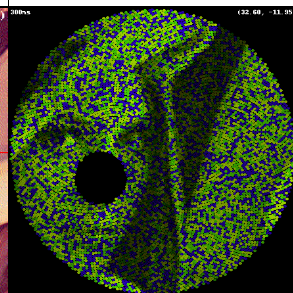
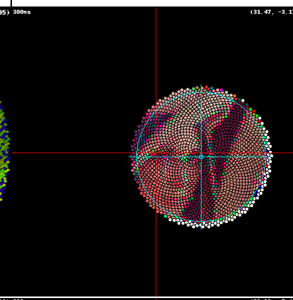
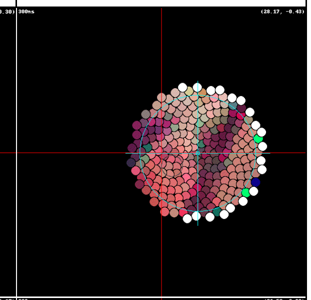
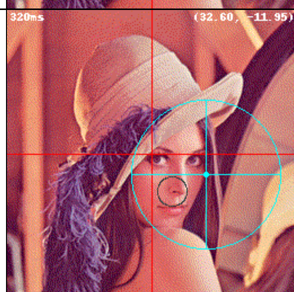
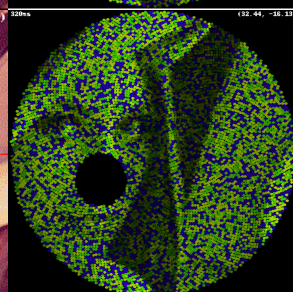
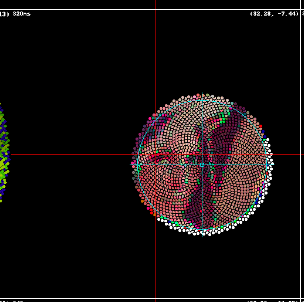
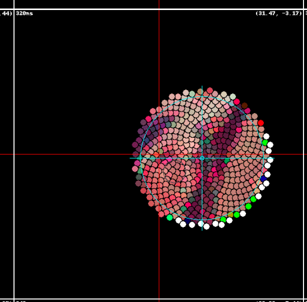
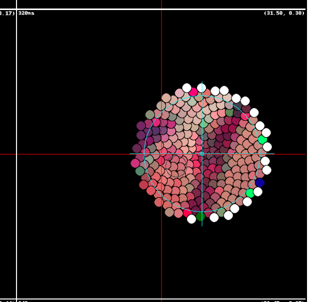
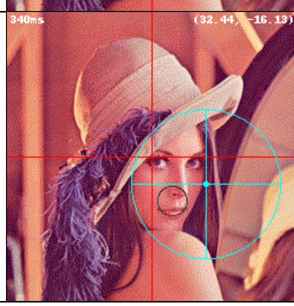
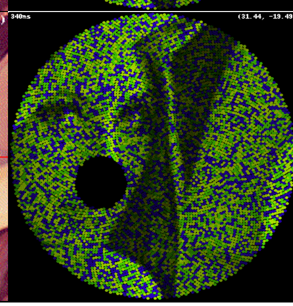
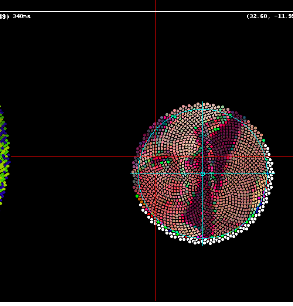
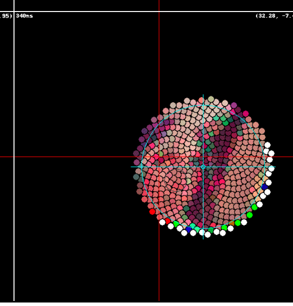
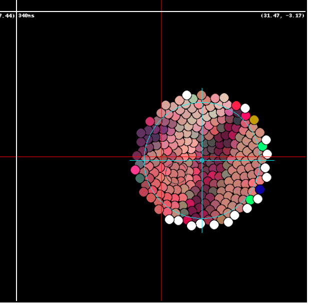
Table 18: Time sequence of blind spot moving over natural image (Lena)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
15					
16					
17					

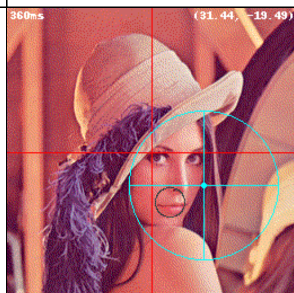
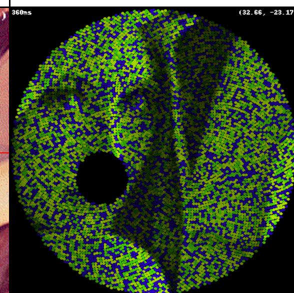
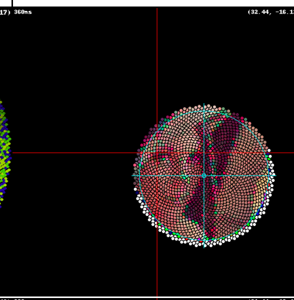
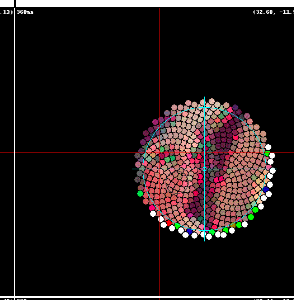
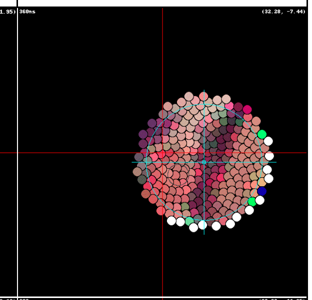
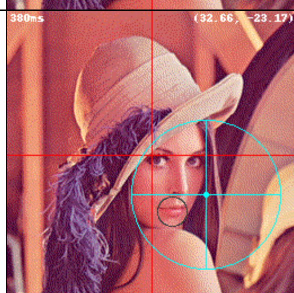
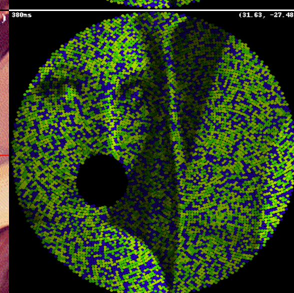
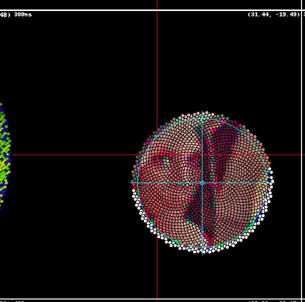
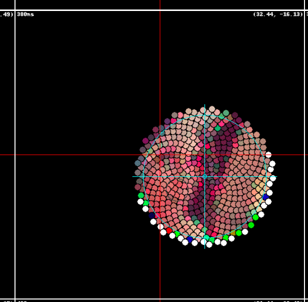
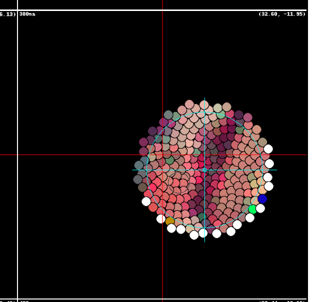
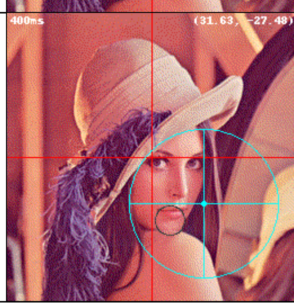
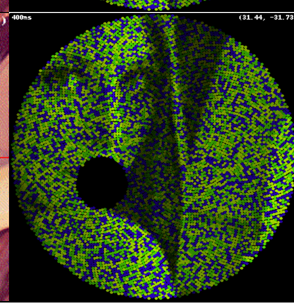
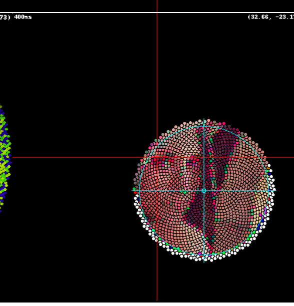
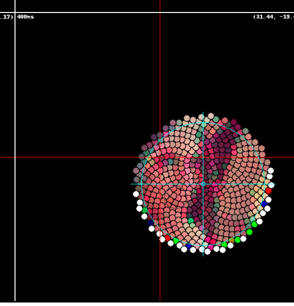
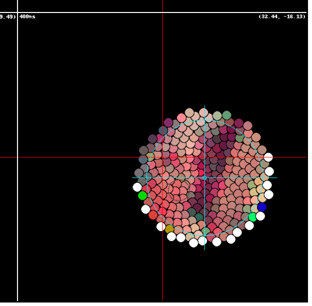
Table 18: Time sequence of blind spot moving over natural image (Lena)					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
18					
19					
20					

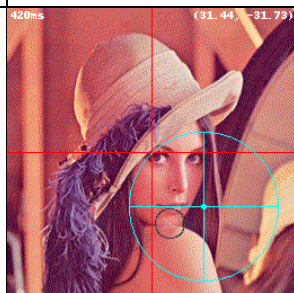
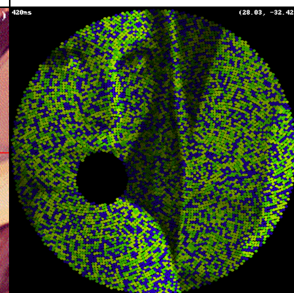
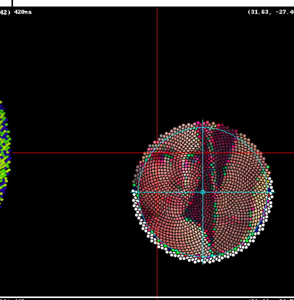
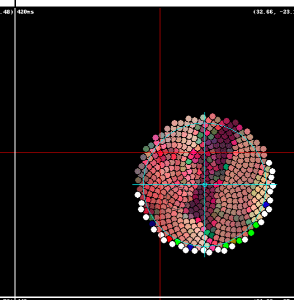
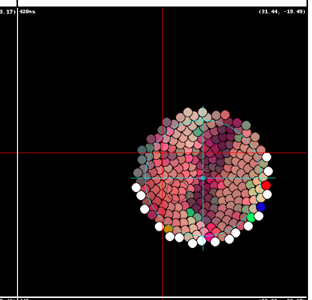
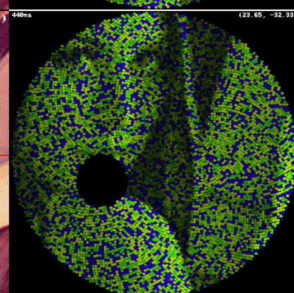
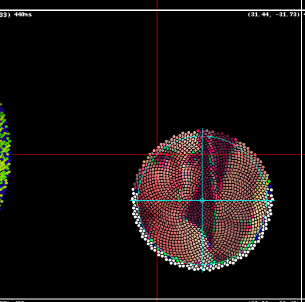
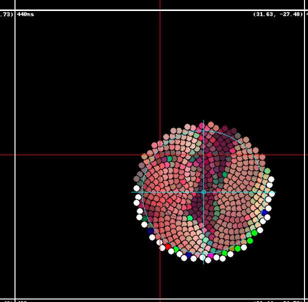
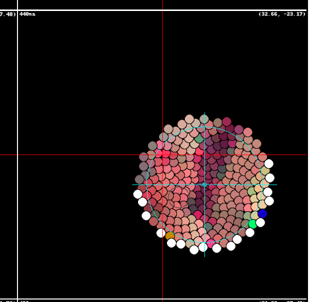
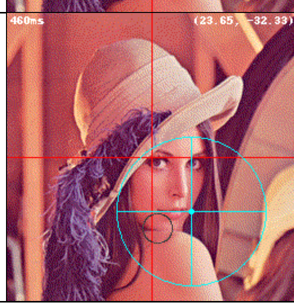
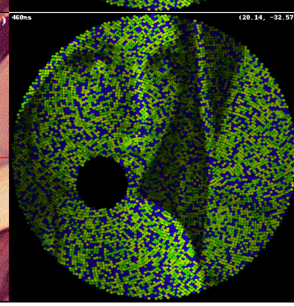
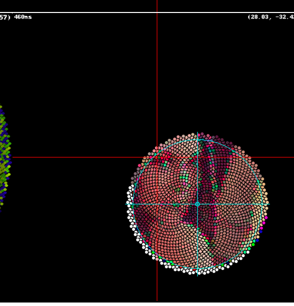
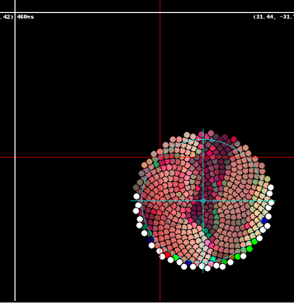
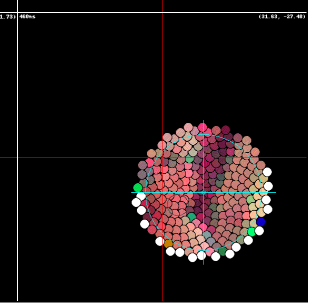
Table 18: Time sequence of blind spot moving over natural image (Lena)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
21					
22					
23					

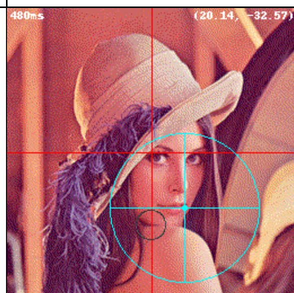
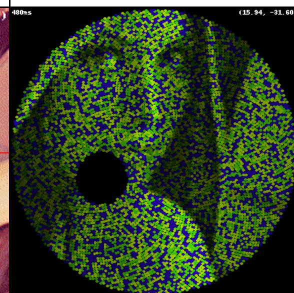
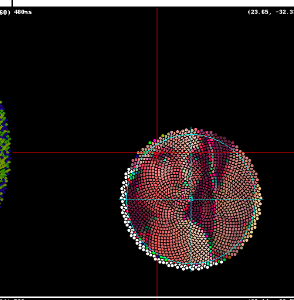
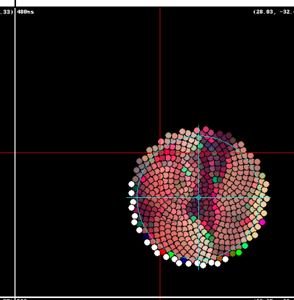
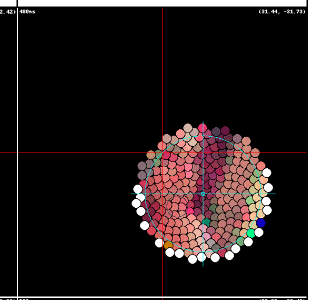
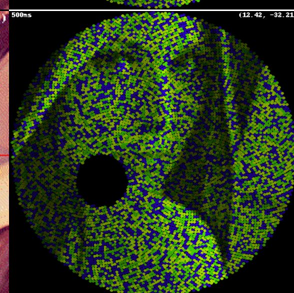
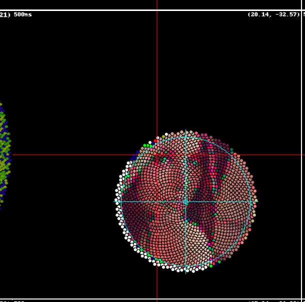
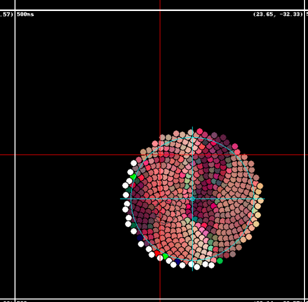
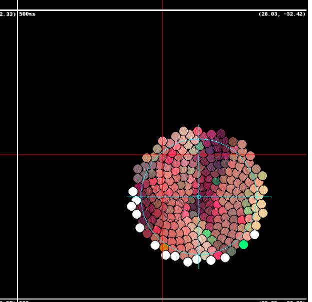
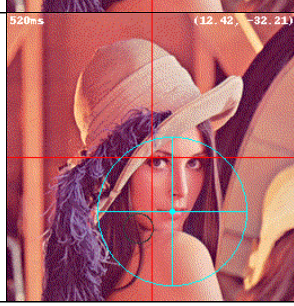
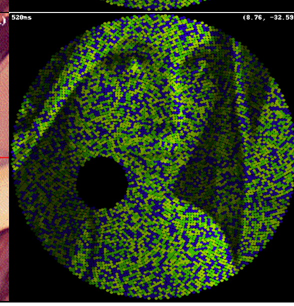
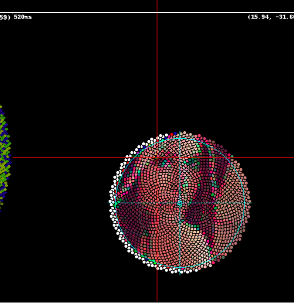
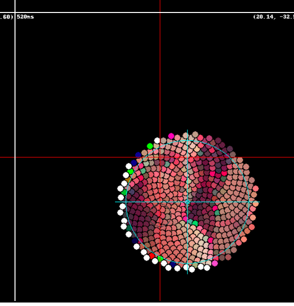
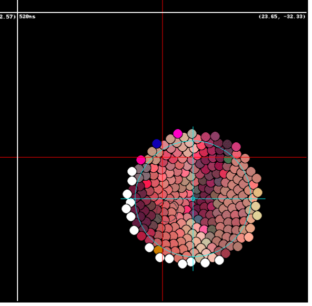
Table 18: Time sequence of blind spot moving over natural image (Lena)					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
24					
25					
26					

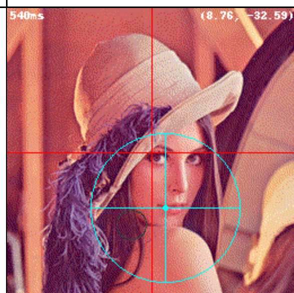
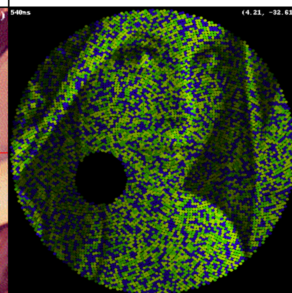
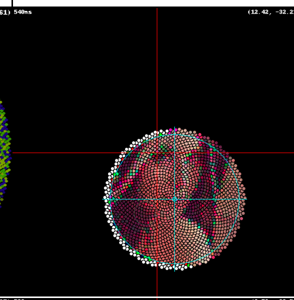
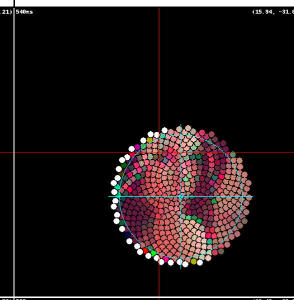
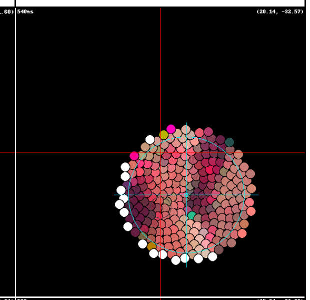
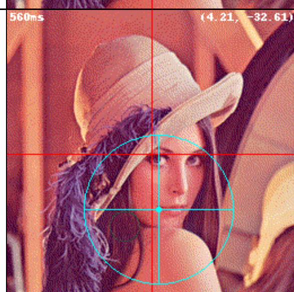
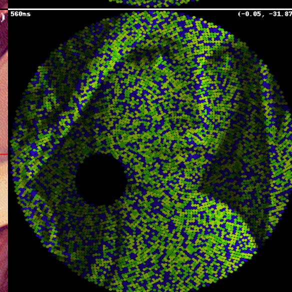
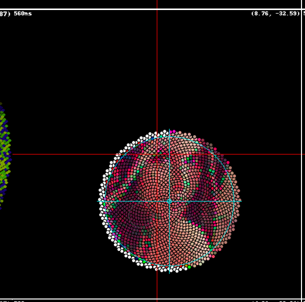
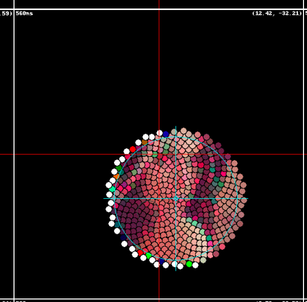
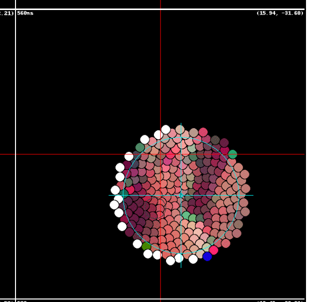
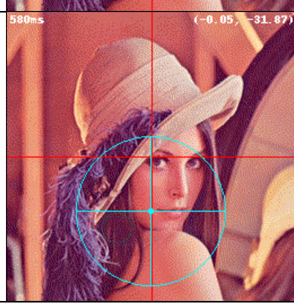
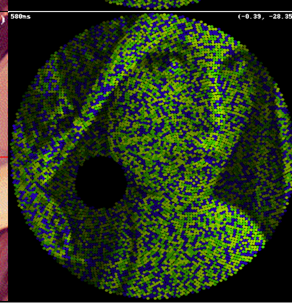
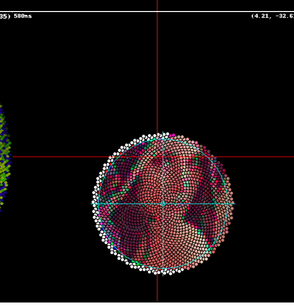
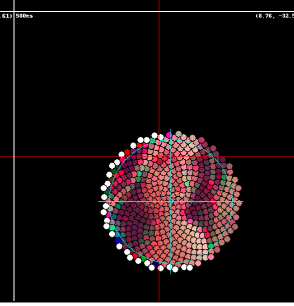
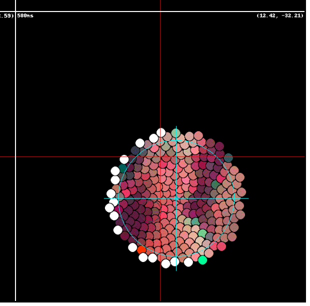
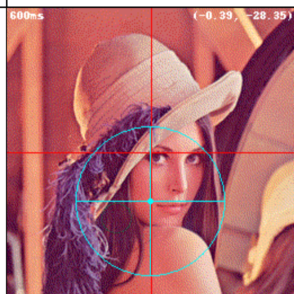
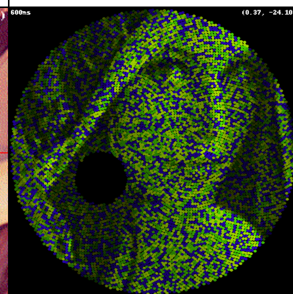
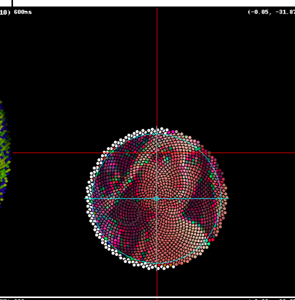
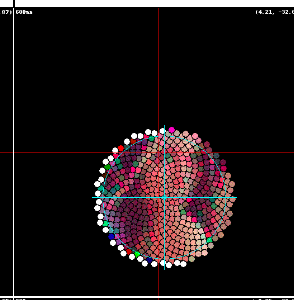
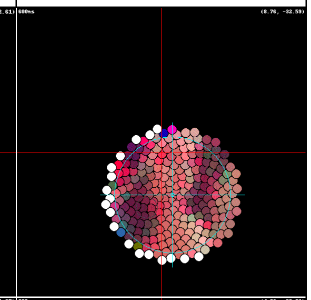
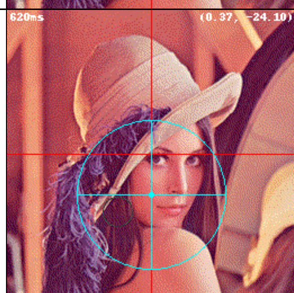
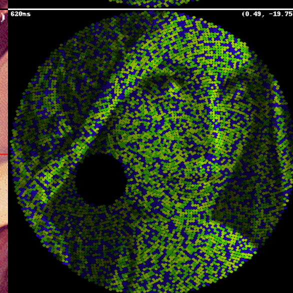
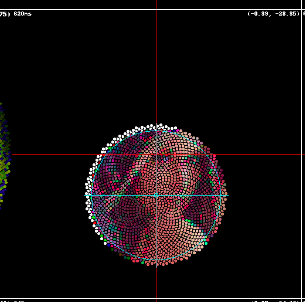
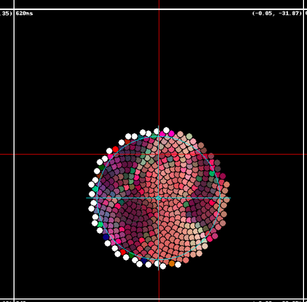
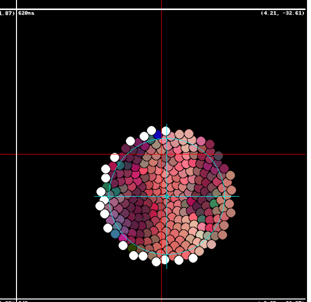
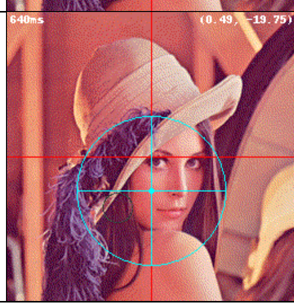
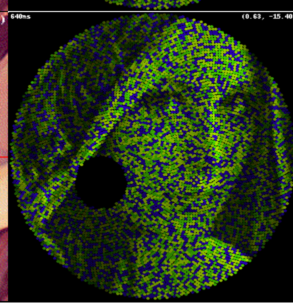
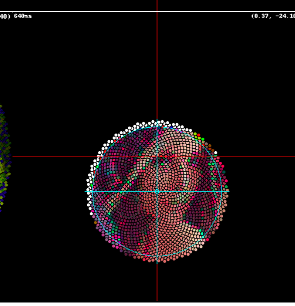
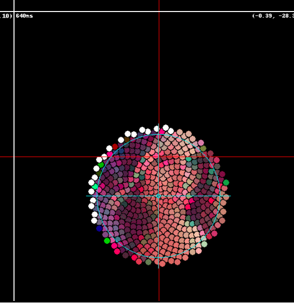
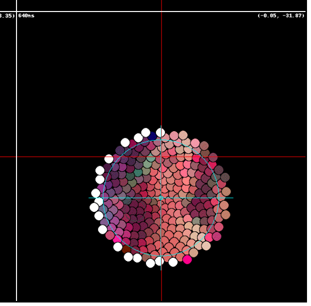
Table 18: Time sequence of blind spot moving over natural image (Lena)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
27					
28					
29					

Table 18: Time sequence of blind spot moving over natural image (Lena)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
30					
31					
32					

5.3.3 Test 3 results: Dynamic image (Chaser)

Table 19: Time sequence of blind spot moving over dynamic image (Chaser)

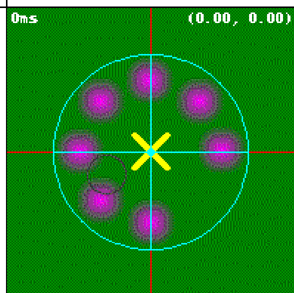
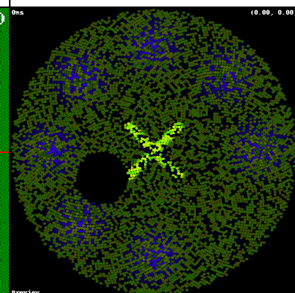
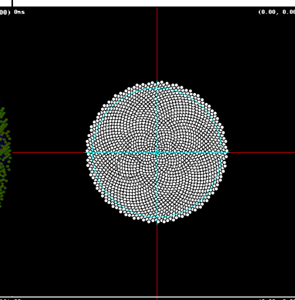
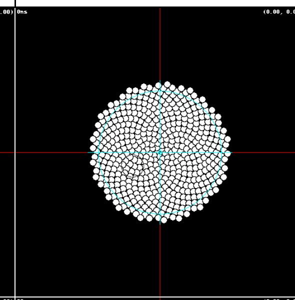
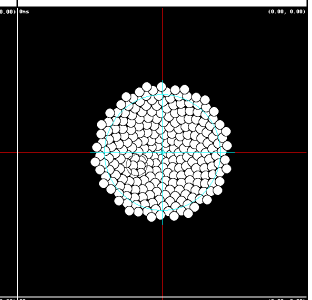
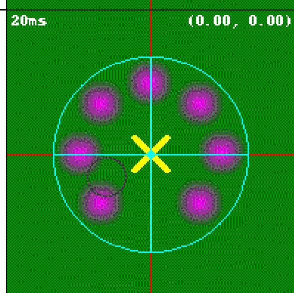
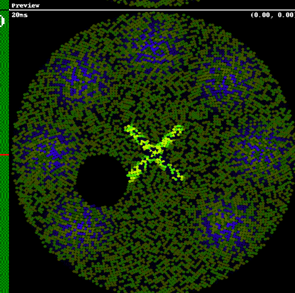
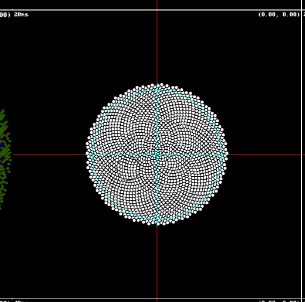
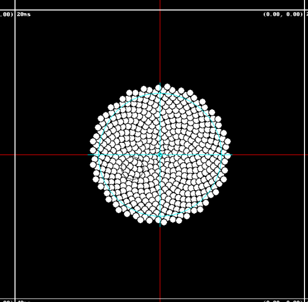
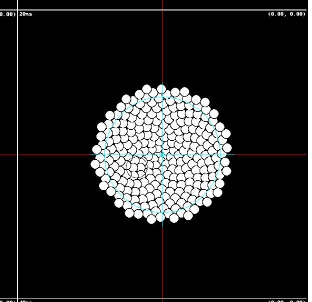
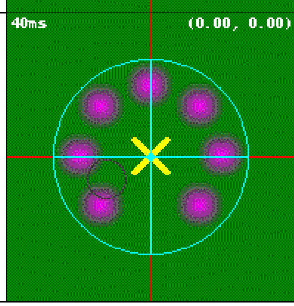
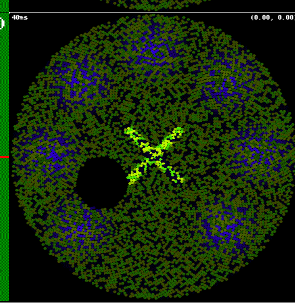
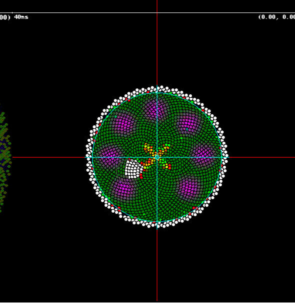
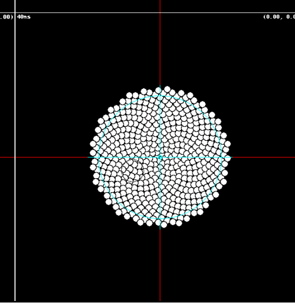
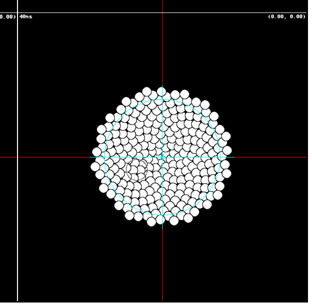
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields Level 1	Receptive Fields Level 2	Receptive Fields Level 3
0					
1					
2					

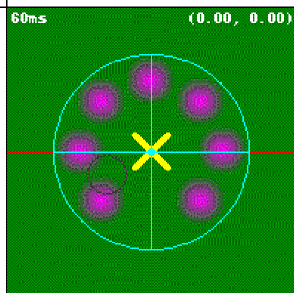
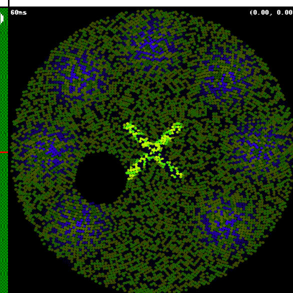
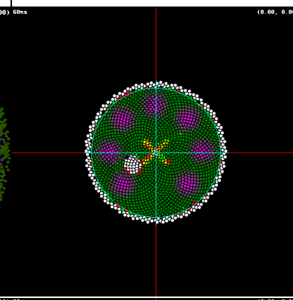
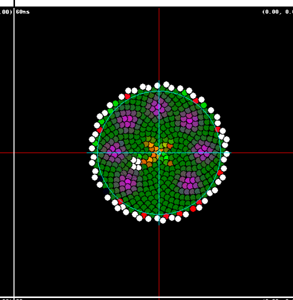
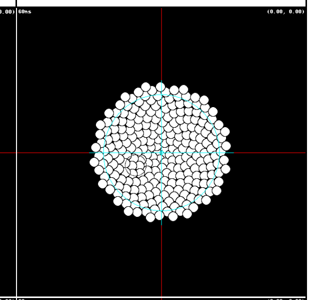
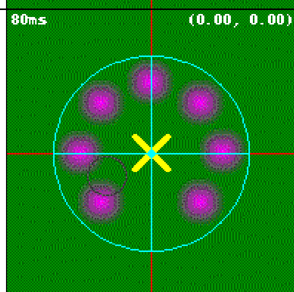
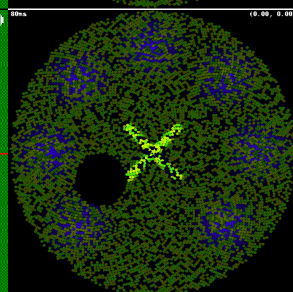
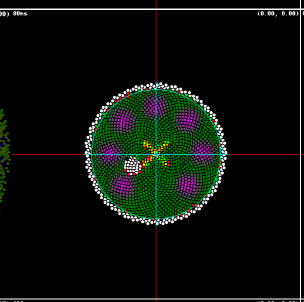
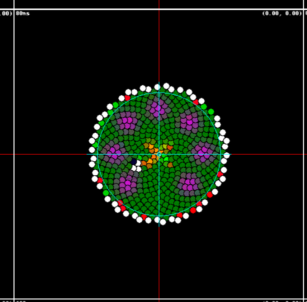
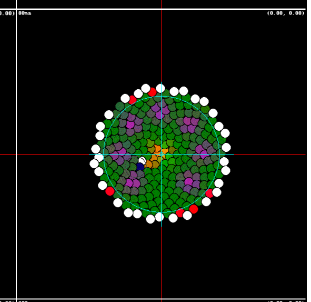
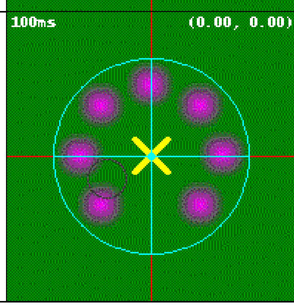
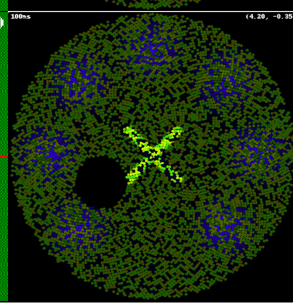
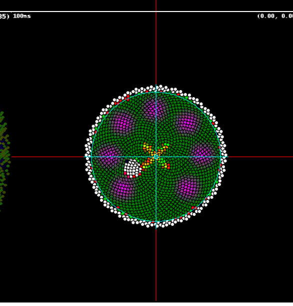
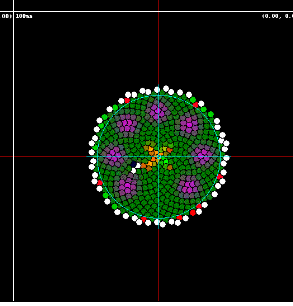
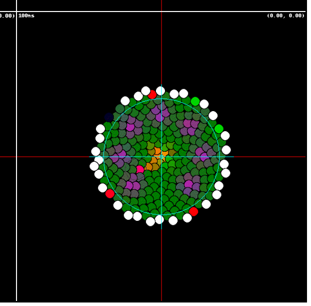
Table 19: Time sequence of blind spot moving over dynamic image (Chaser)					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
3					
4					
5					

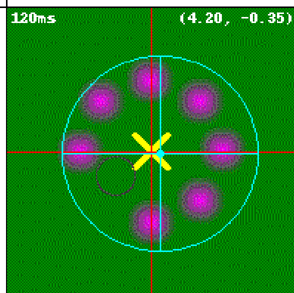
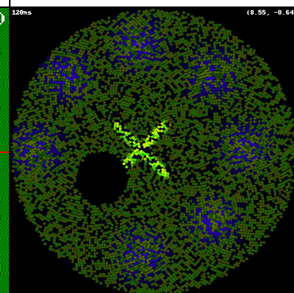
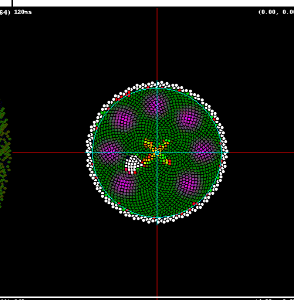
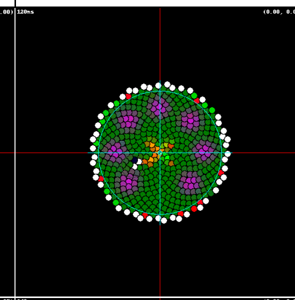
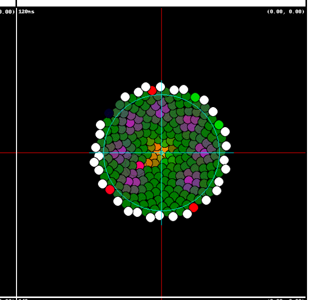
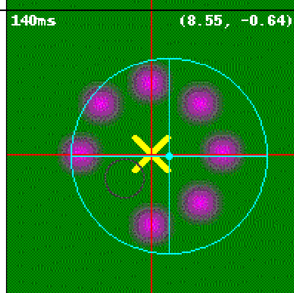
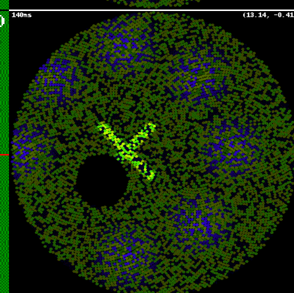
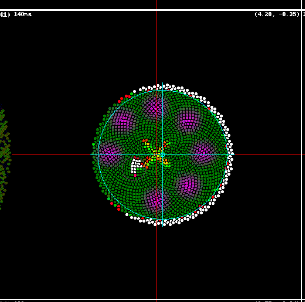
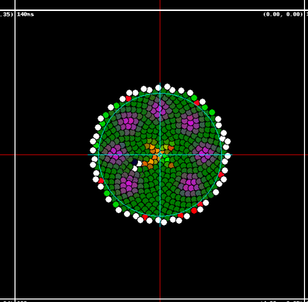
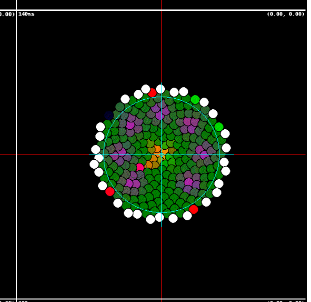
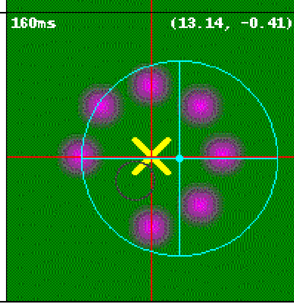
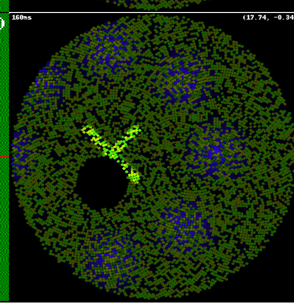
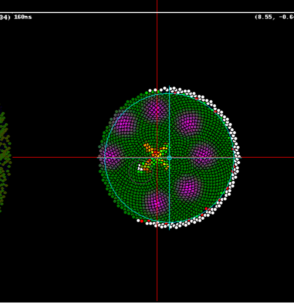
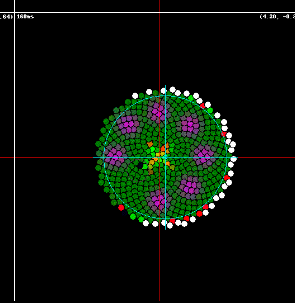
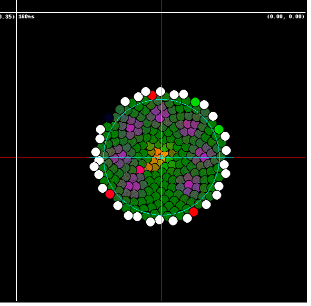
Table 19: Time sequence of blind spot moving over dynamic image (Chaser)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
6					
7					
8					

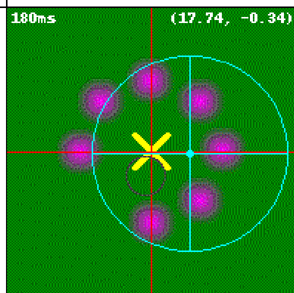
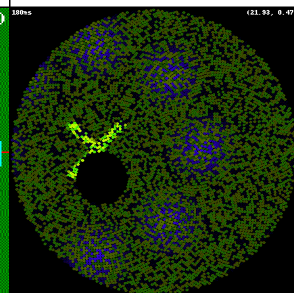
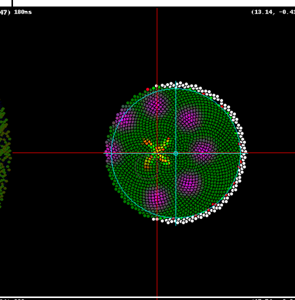
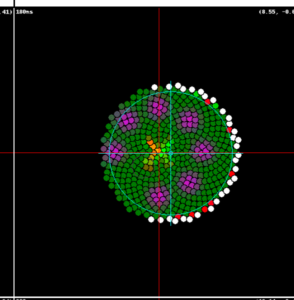
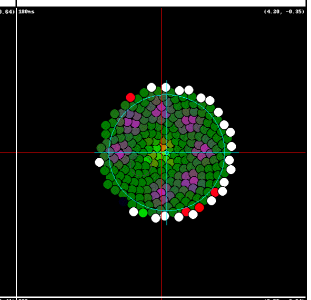
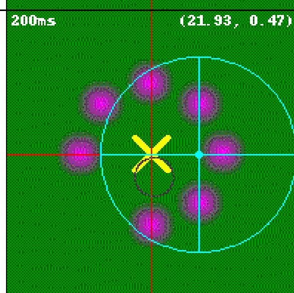
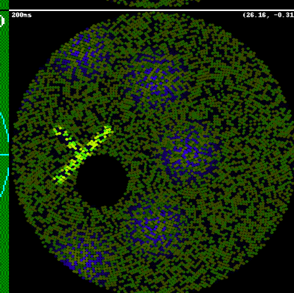
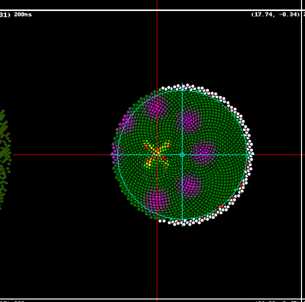
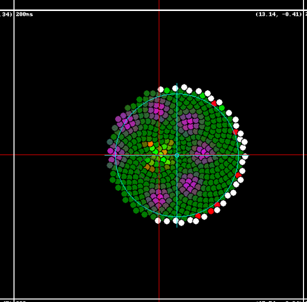
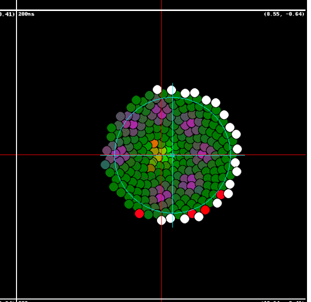
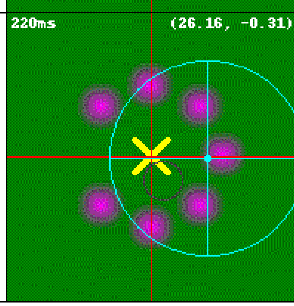
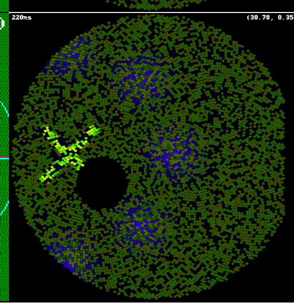
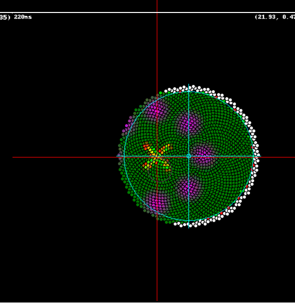
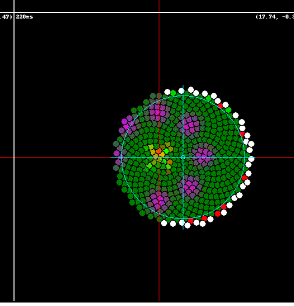
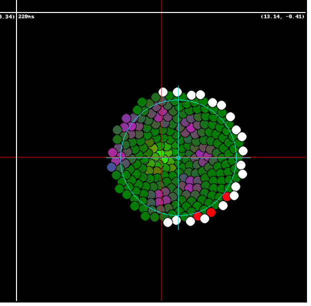
Table 19: Time sequence of blind spot moving over dynamic image (Chaser)					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
9					
10					
11					

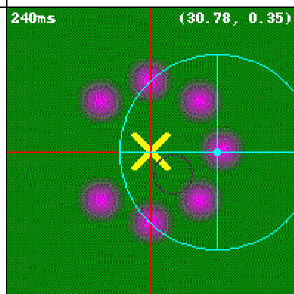
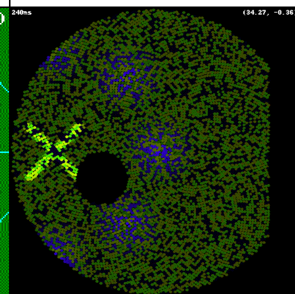
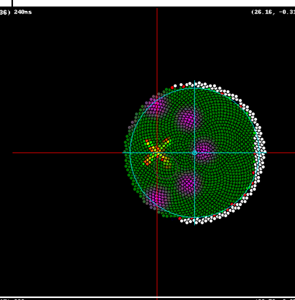
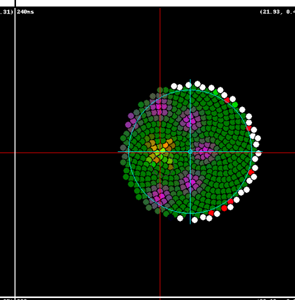
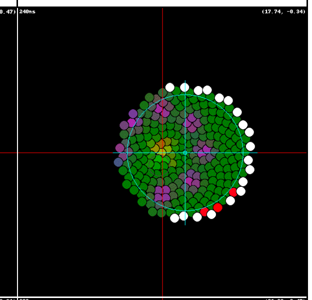
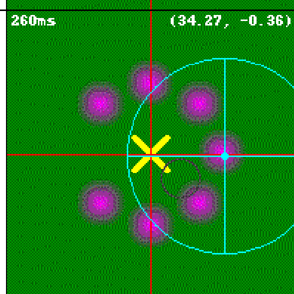
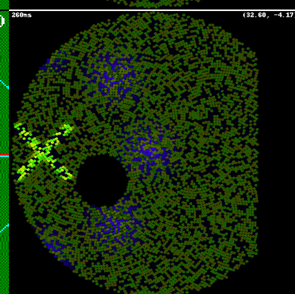
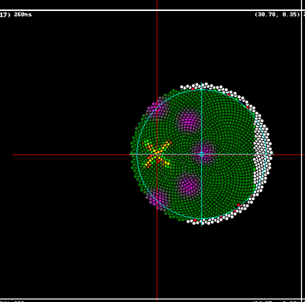
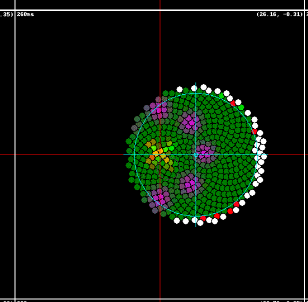
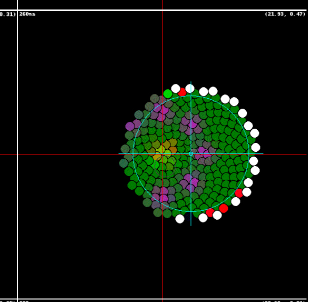
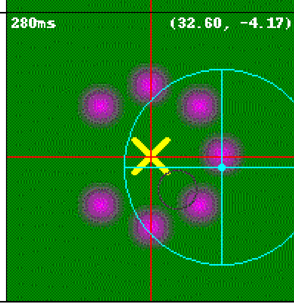
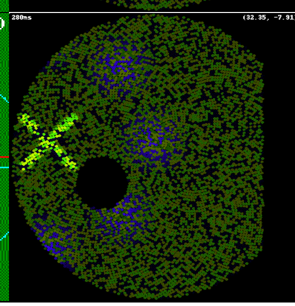
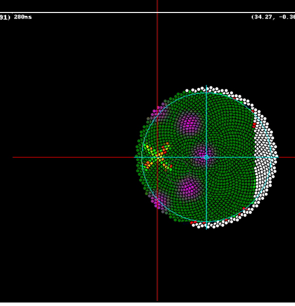
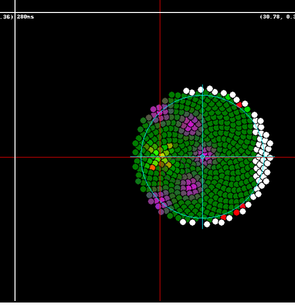
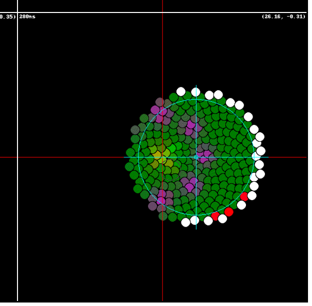
Table 19: Time sequence of blind spot moving over dynamic image (Chaser)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
12					
13					
14					

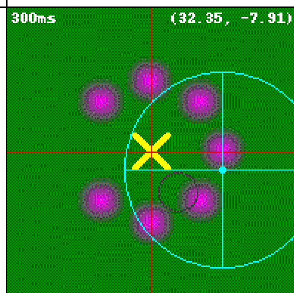
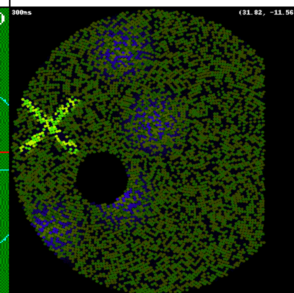
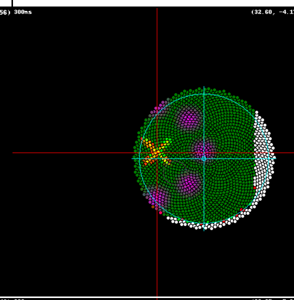
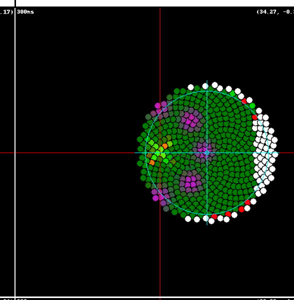
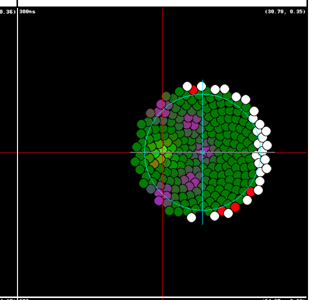
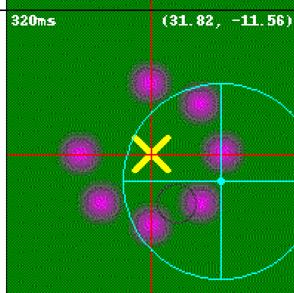
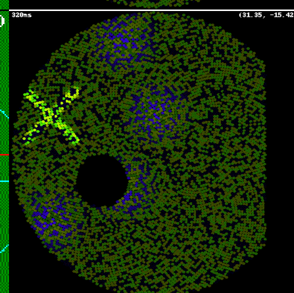
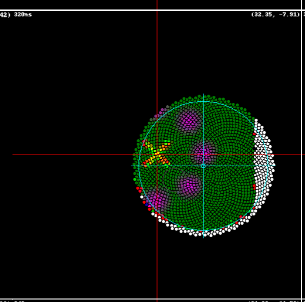
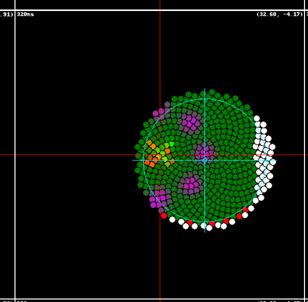
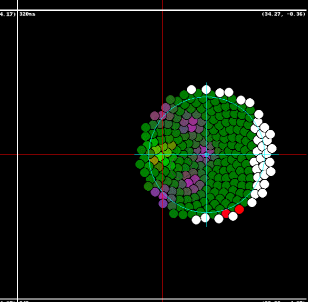
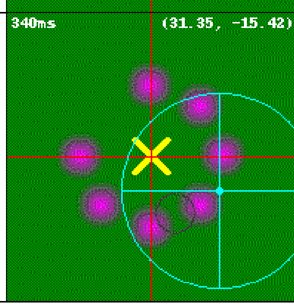
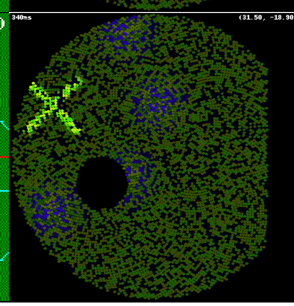
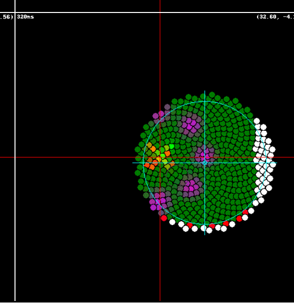
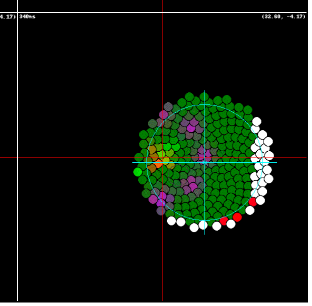
Table 19: Time sequence of blind spot moving over dynamic image (Chaser)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
15					
16					
17					

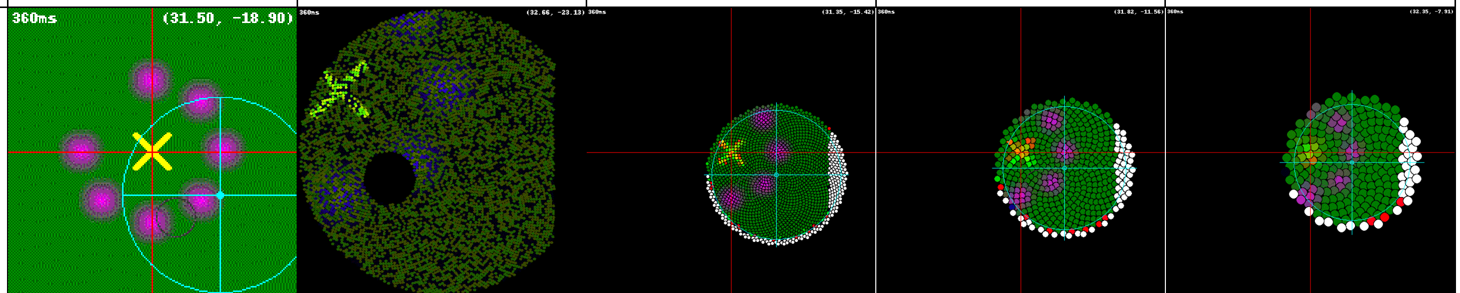
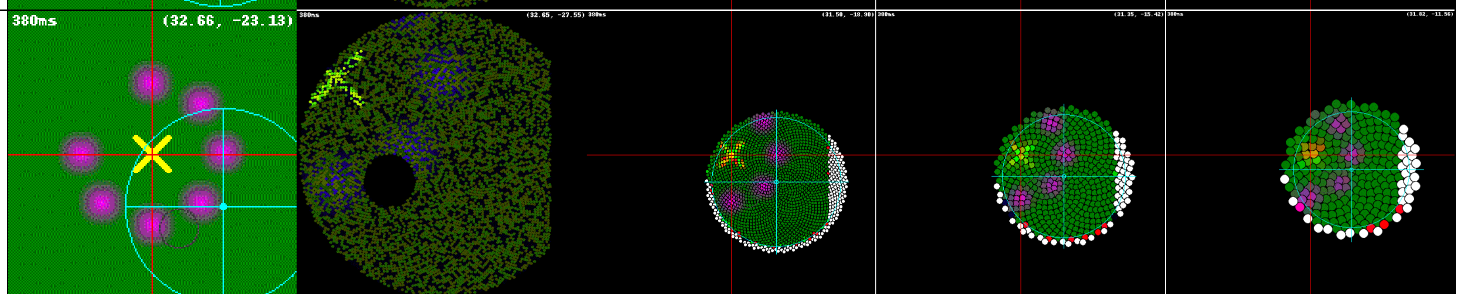
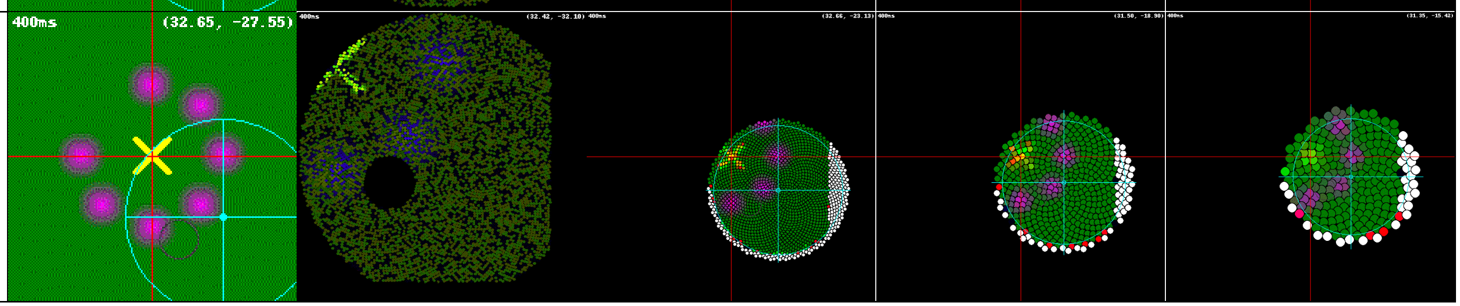
Table 19: Time sequence of blind spot moving over dynamic image (Chaser)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
18					
19					
20					

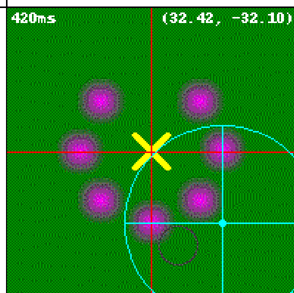
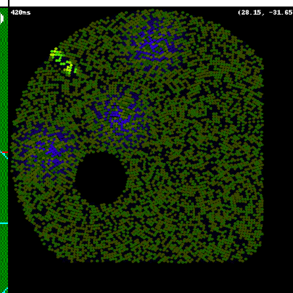
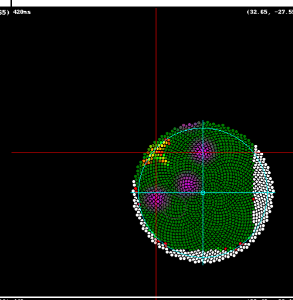
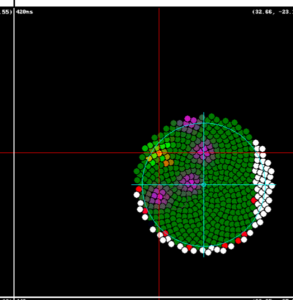
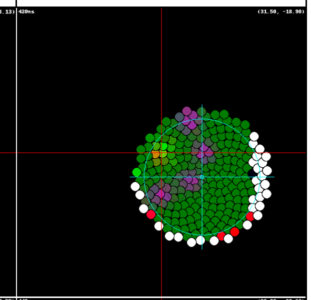
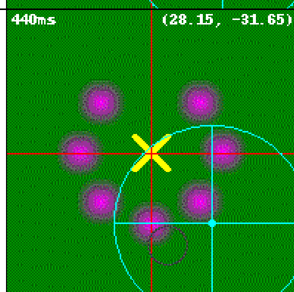
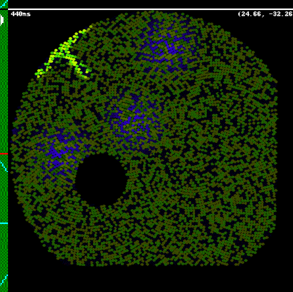
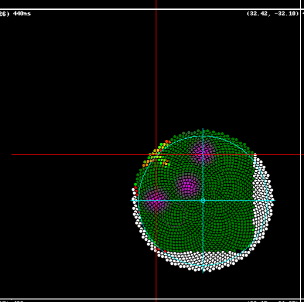
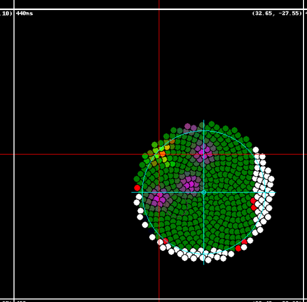
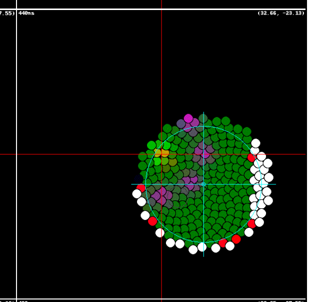
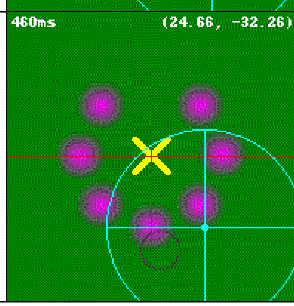
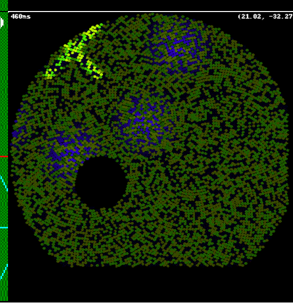
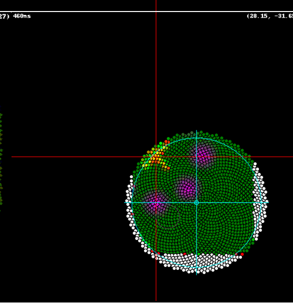
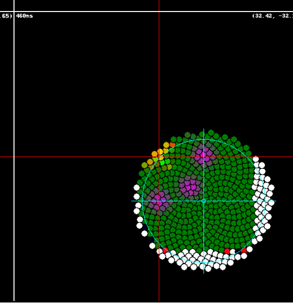
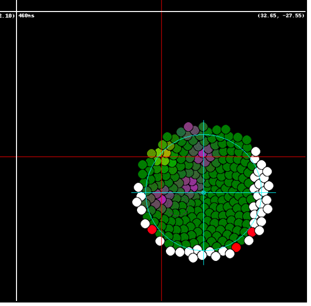
Table 19: Time sequence of blind spot moving over dynamic image (Chaser)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
21					
22					
23					

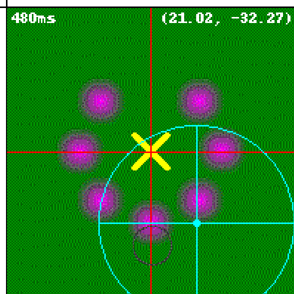
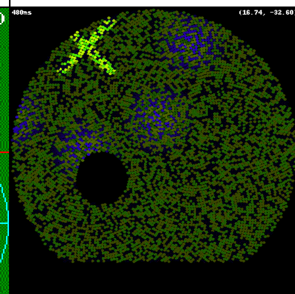
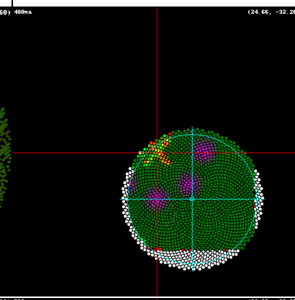
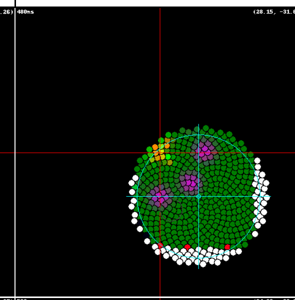
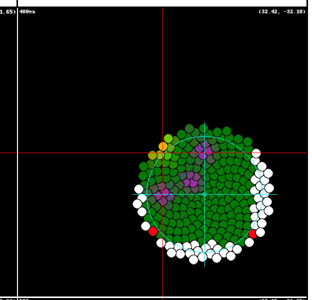
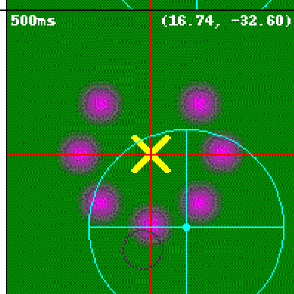
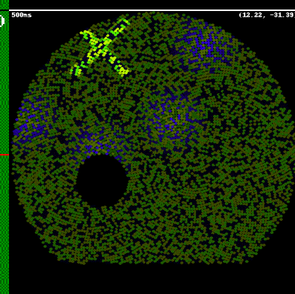
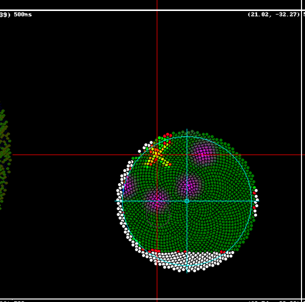
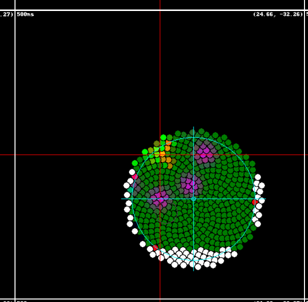
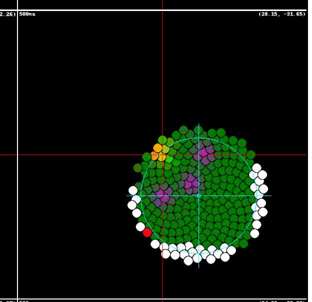
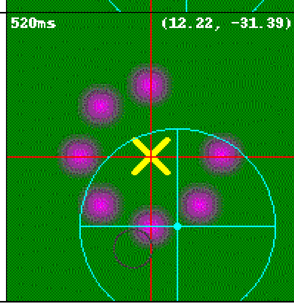
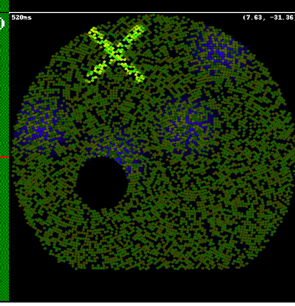
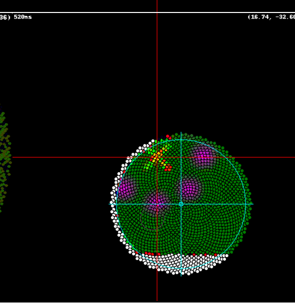
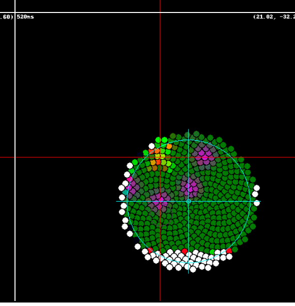
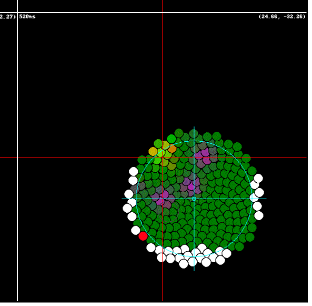
Table 19: Time sequence of blind spot moving over dynamic image (Chaser)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
24					
25					
26					

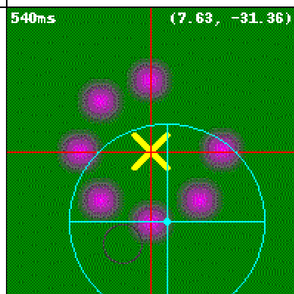
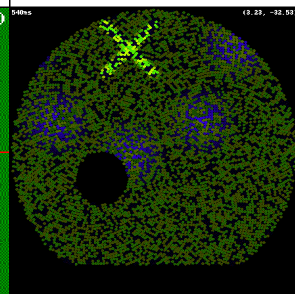
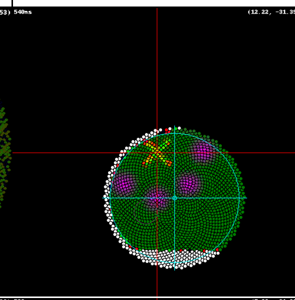
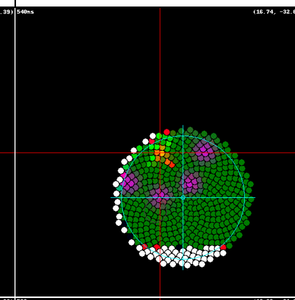
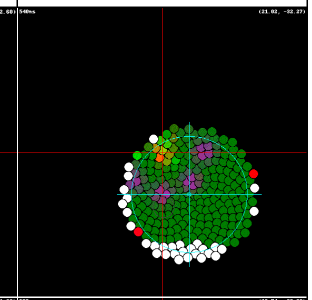
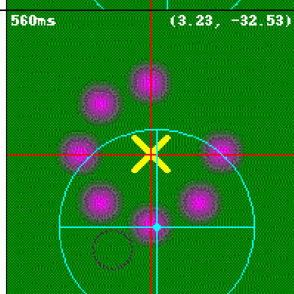
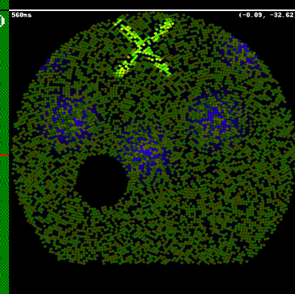
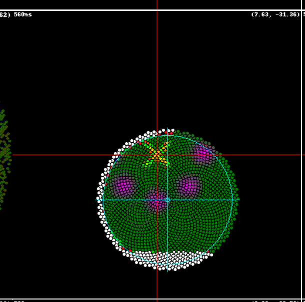
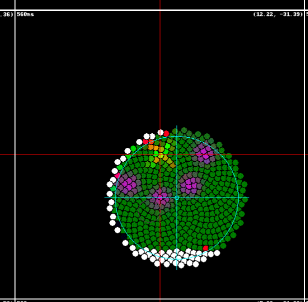
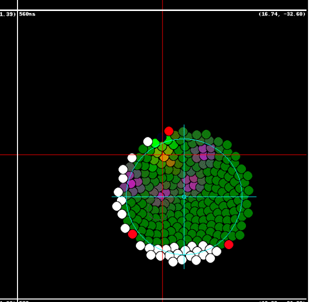
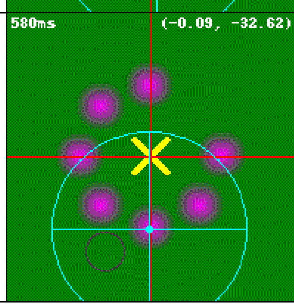
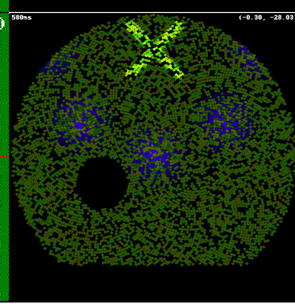
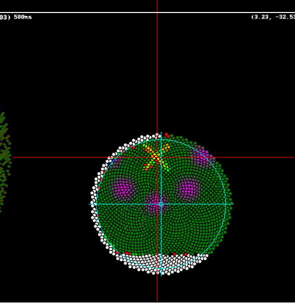
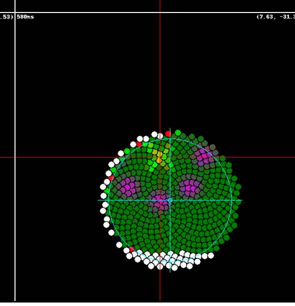
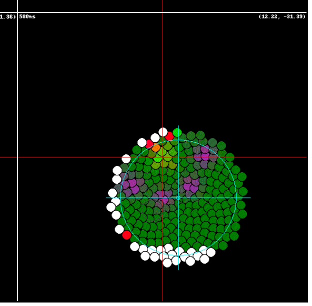
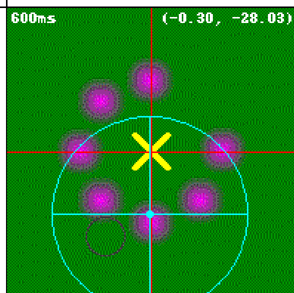
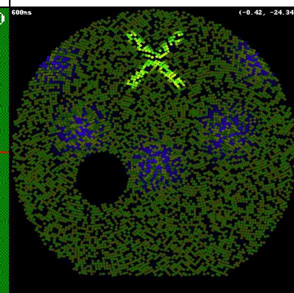
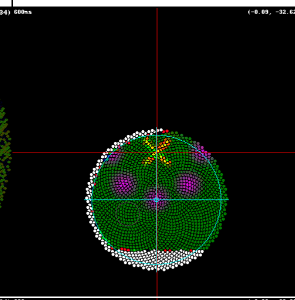
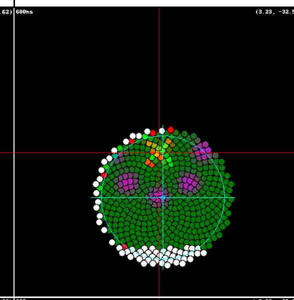
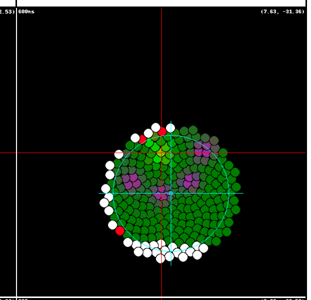
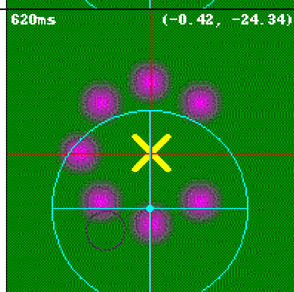
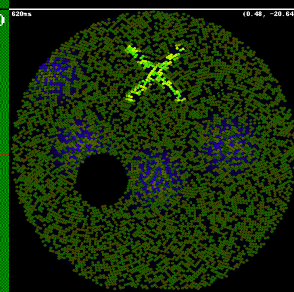
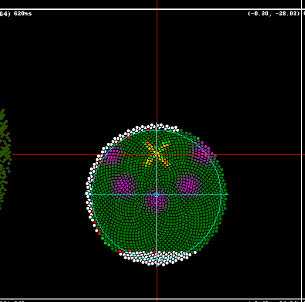
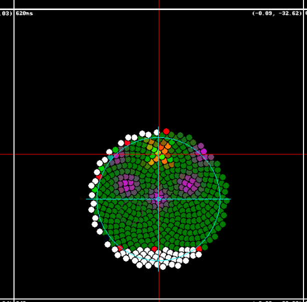
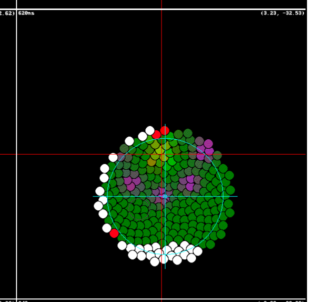
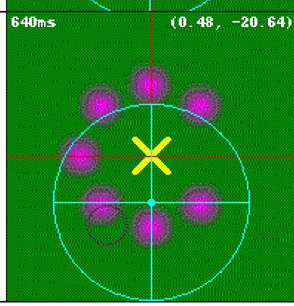
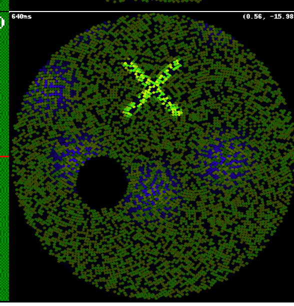
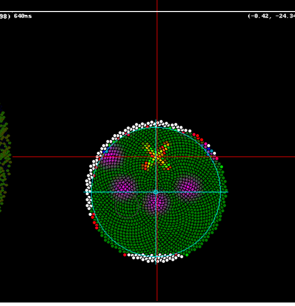
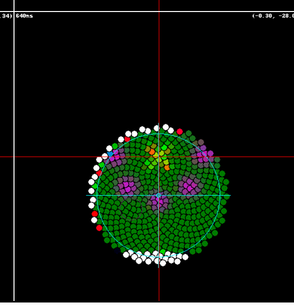
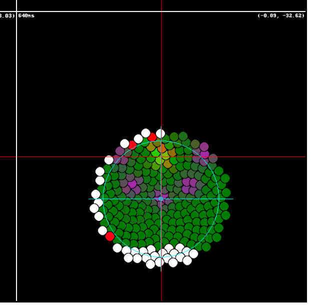
Table 19: Time sequence of blind spot moving over dynamic image (Chaser)					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
27					
28					
29					

Table 19: Time sequence of blind spot moving over dynamic image (Chaser)					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
30					
31					
32					

5.3.4 Test 4 results: Line static

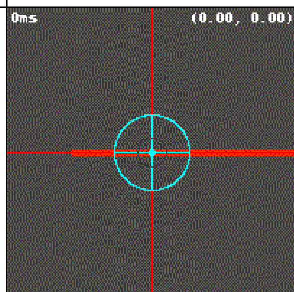
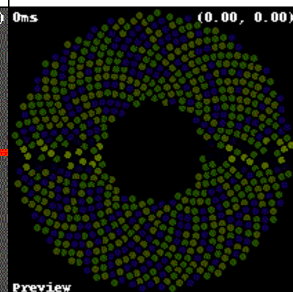
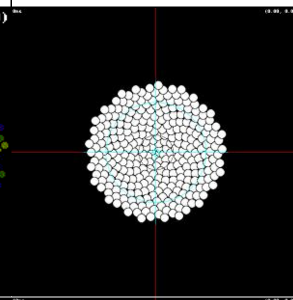
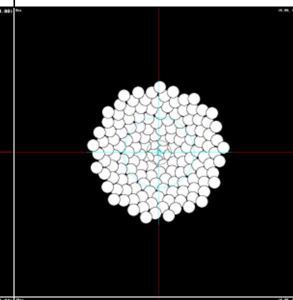
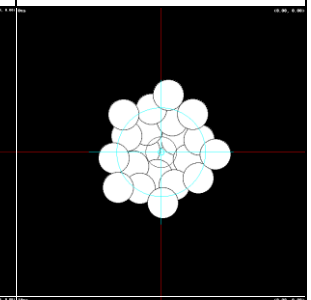
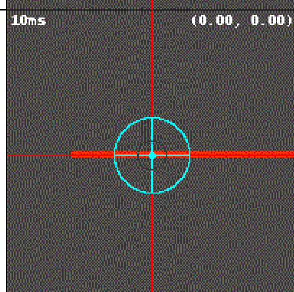
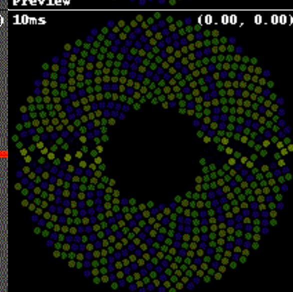
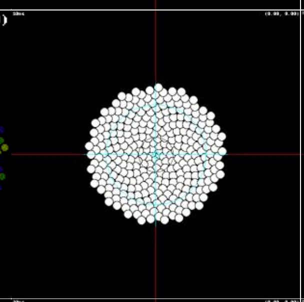
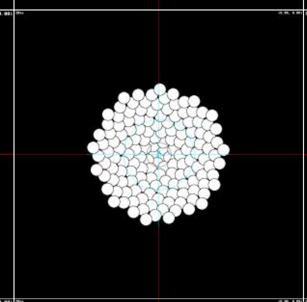
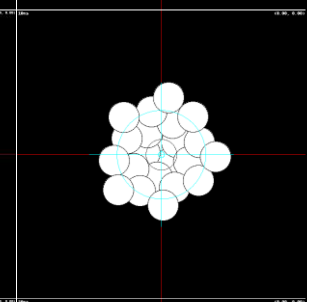
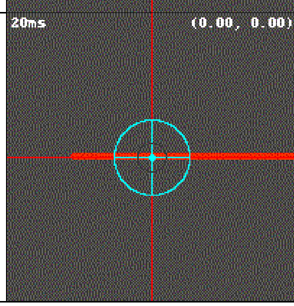
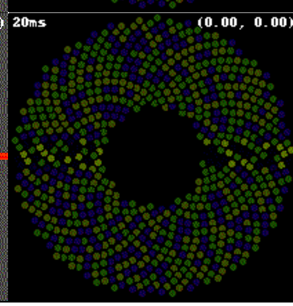
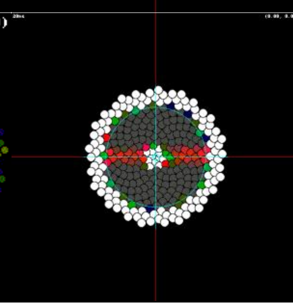
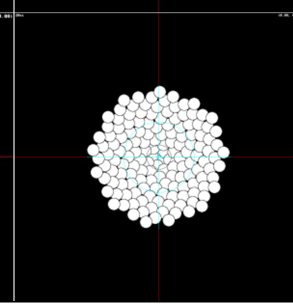
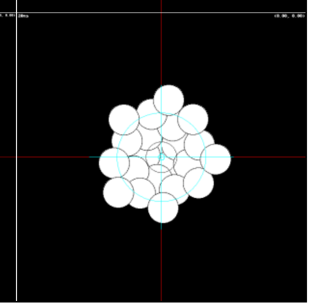
Table 20: Time sequence of static line filling-in over blind spot					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
0					
1					
2					

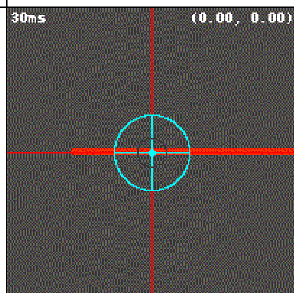
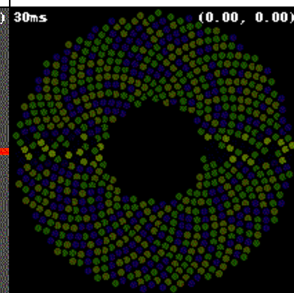
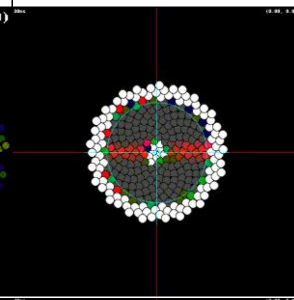
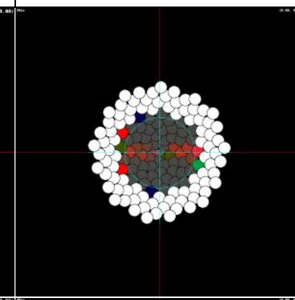
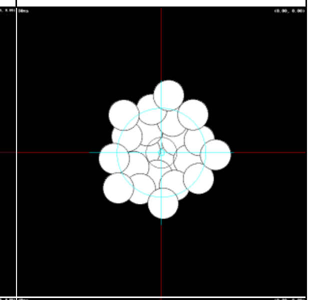
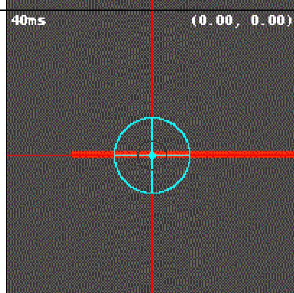
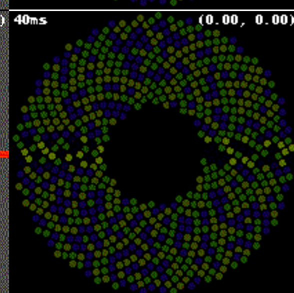
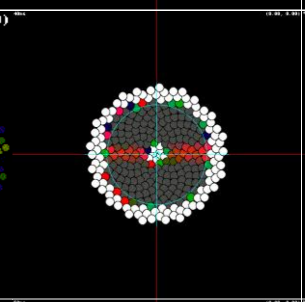
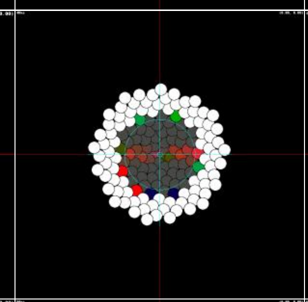
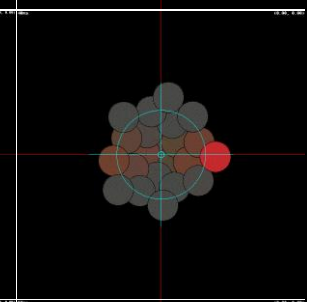
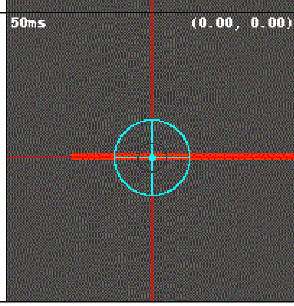
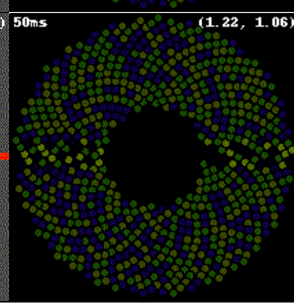
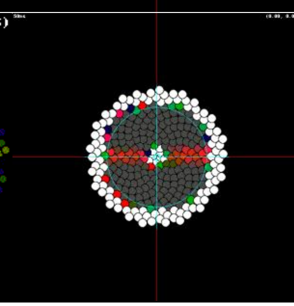
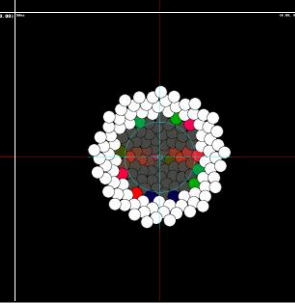
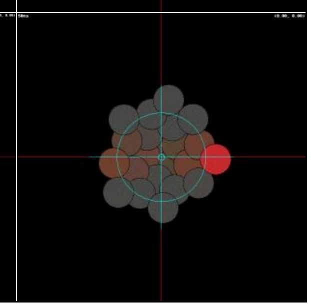
Table 20: Time sequence of static line filling-in over blind spot					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
3					
4					
5					

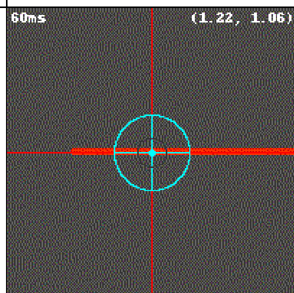
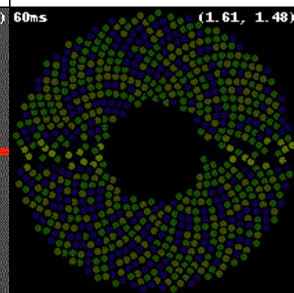
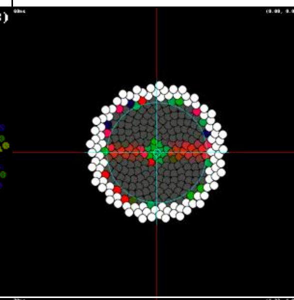
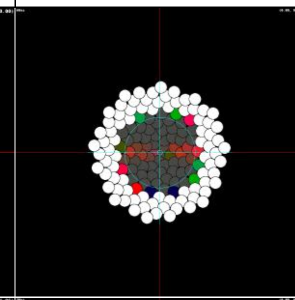
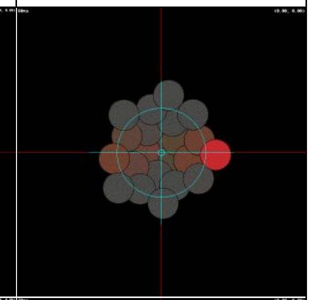
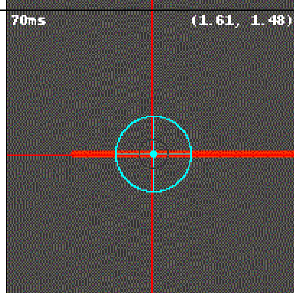
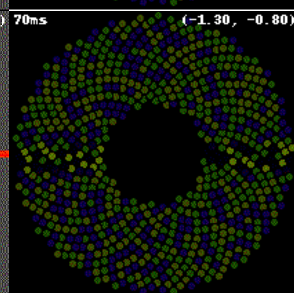
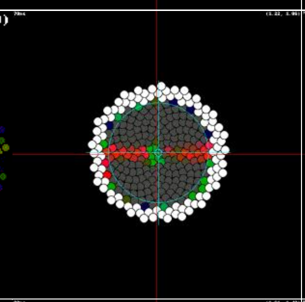
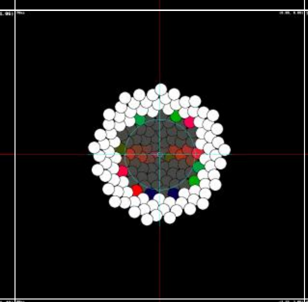
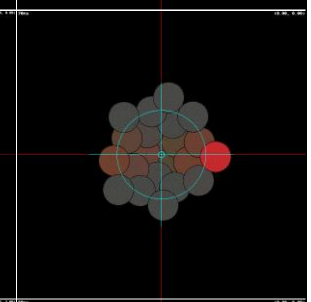
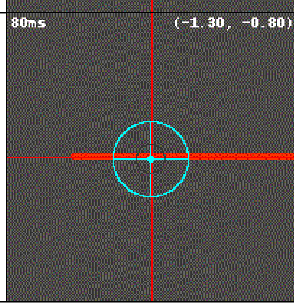
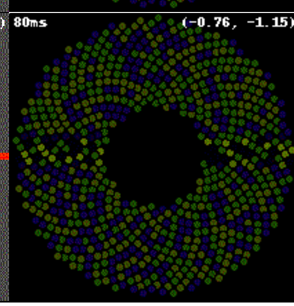
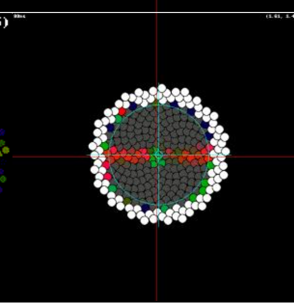
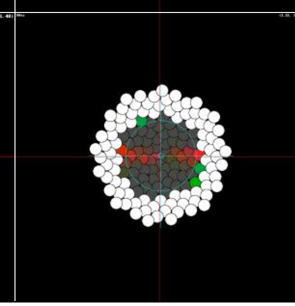
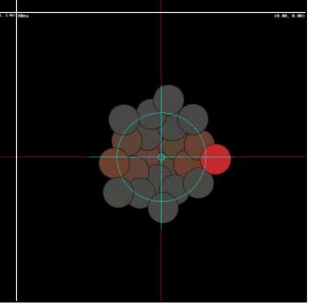
Table 20: Time sequence of static line filling-in over blind spot					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
6					
7					
8					

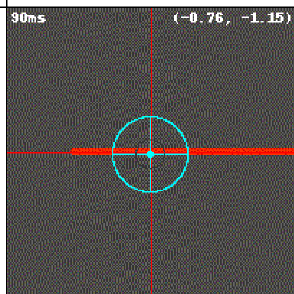
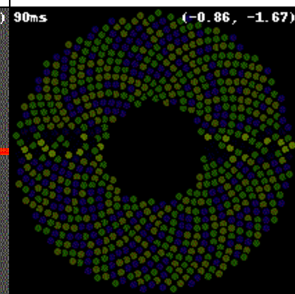
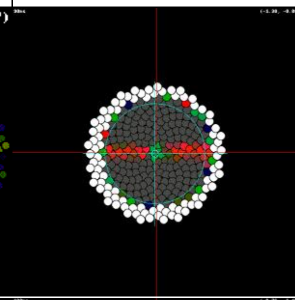
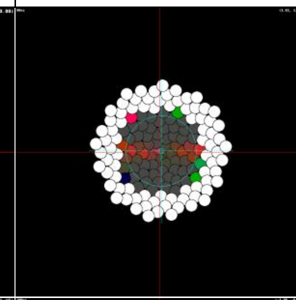
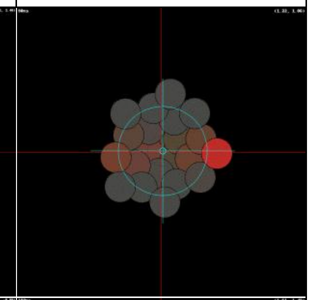
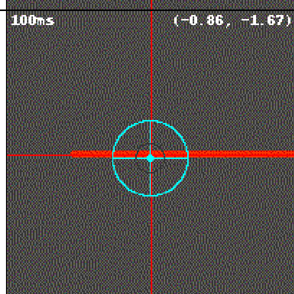
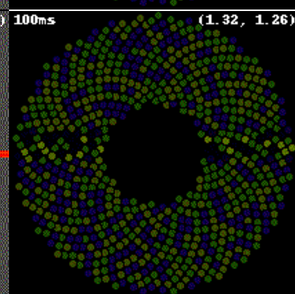
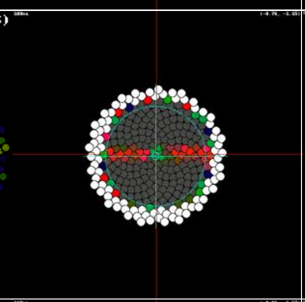
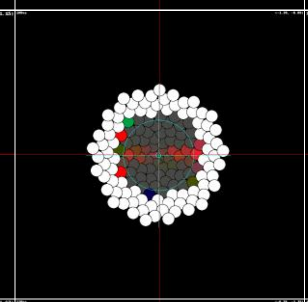
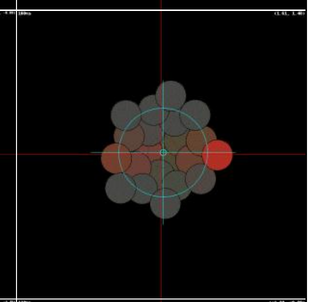
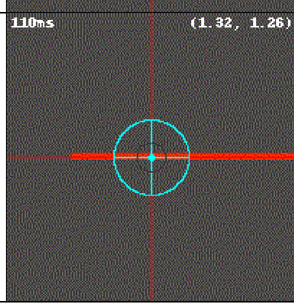
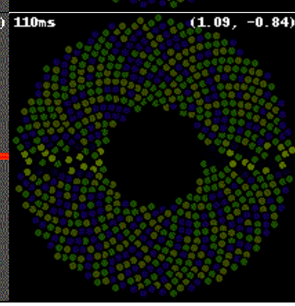
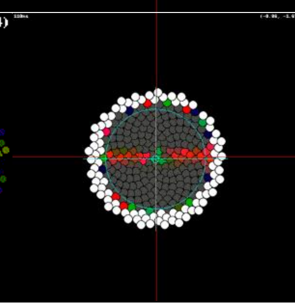
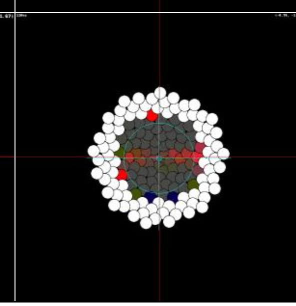
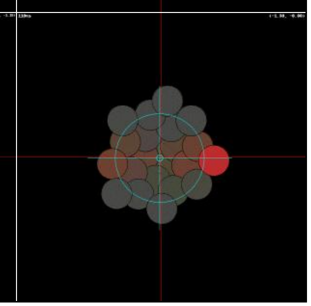
Table 20: Time sequence of static line filling-in over blind spot					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
9					
10					
11					

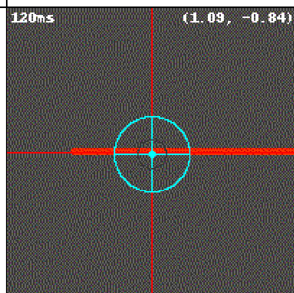
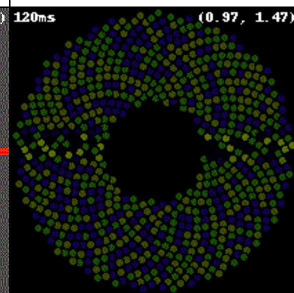
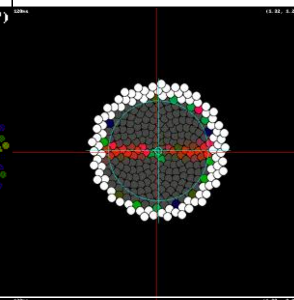
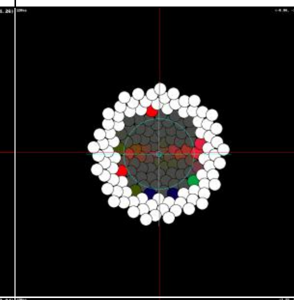
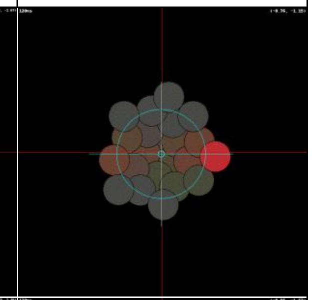
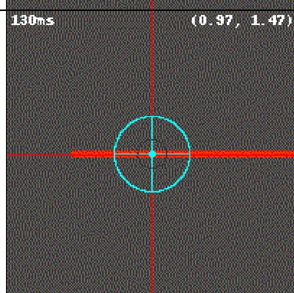
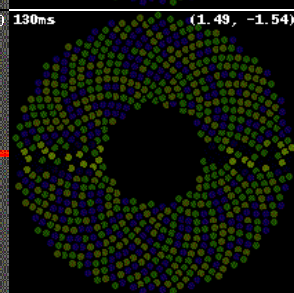
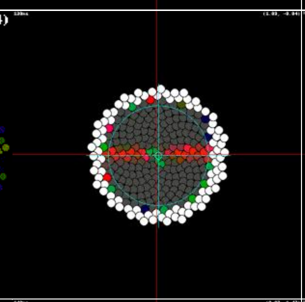
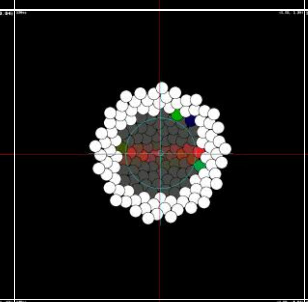
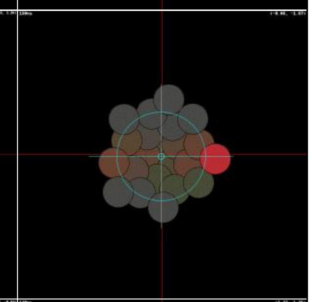
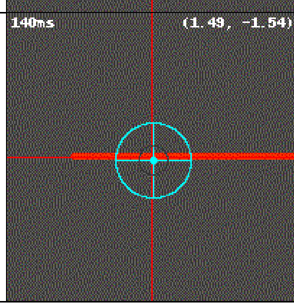
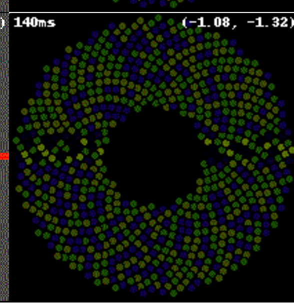
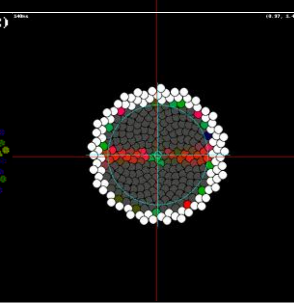
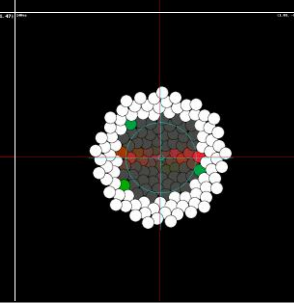
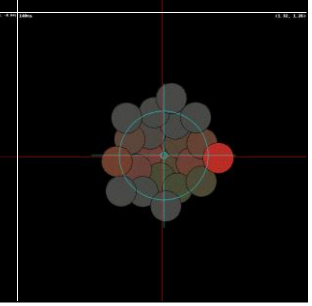
Table 20: Time sequence of static line filling-in over blind spot					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
12					
13					
14					

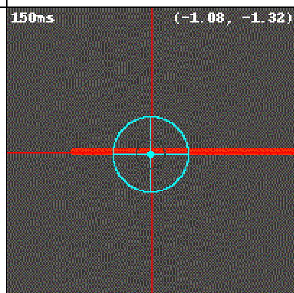
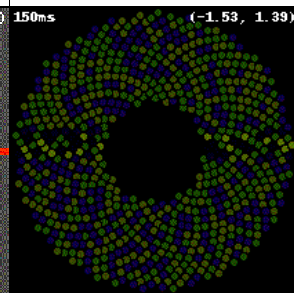
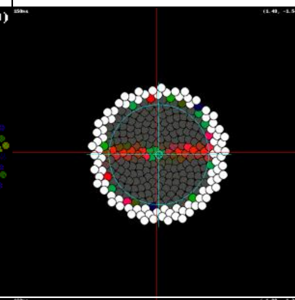
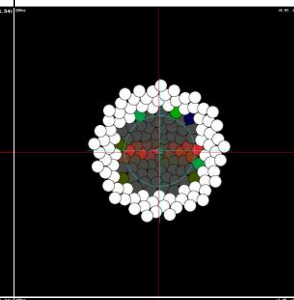
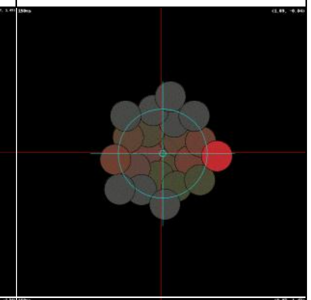
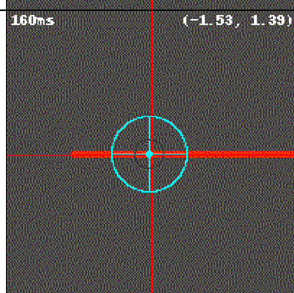
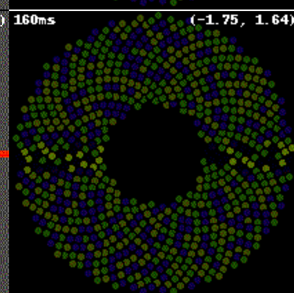
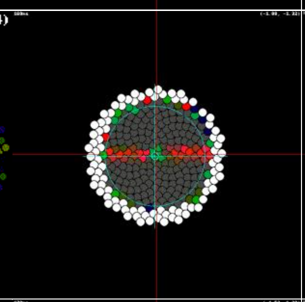
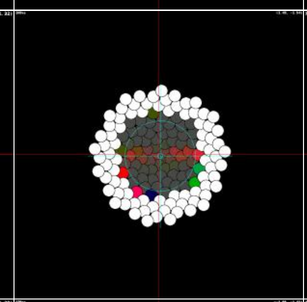
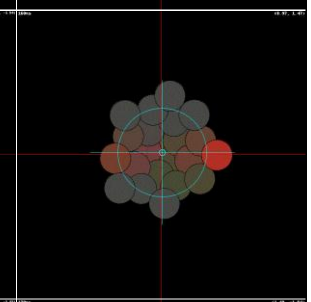
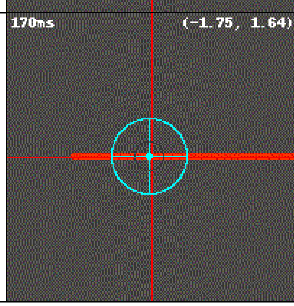
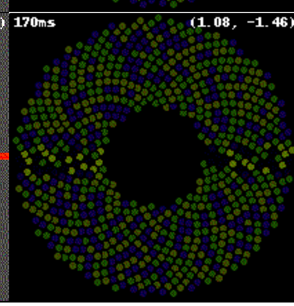
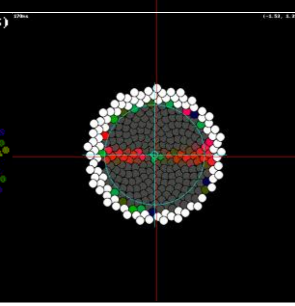
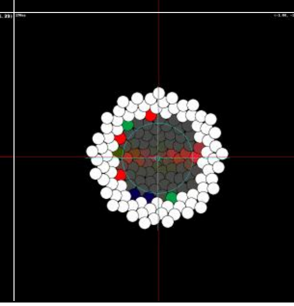
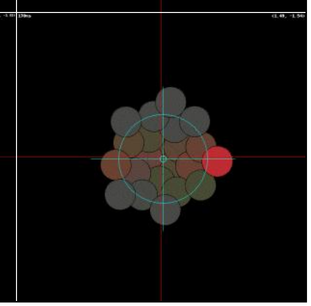
Table 20: Time sequence of static line filling-in over blind spot					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
15					
16					
17					

Table 20: Time sequence of static line filling-in over blind spot

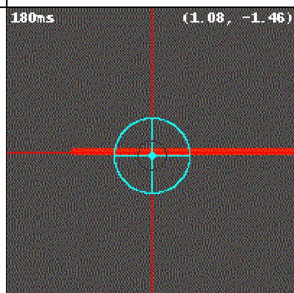
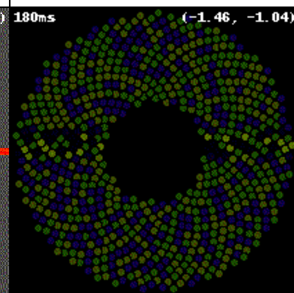
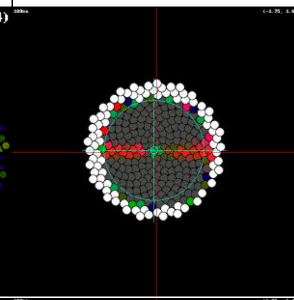
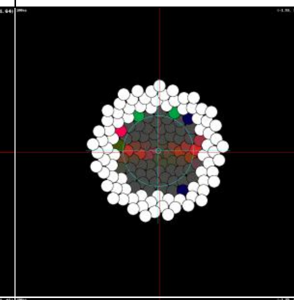
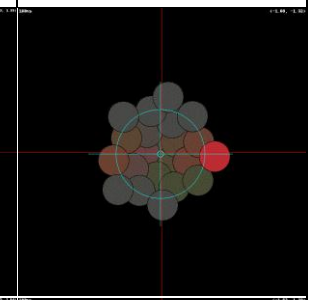
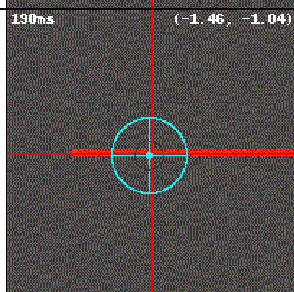
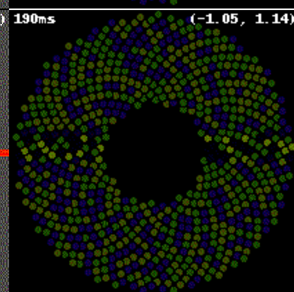
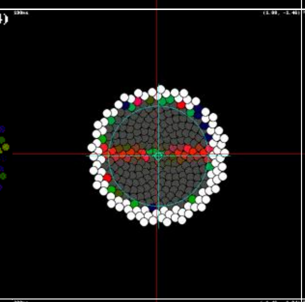
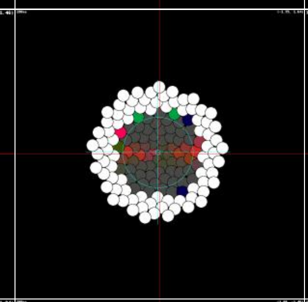
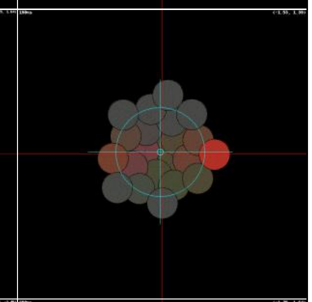
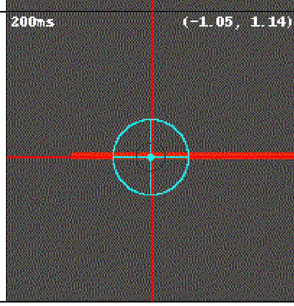
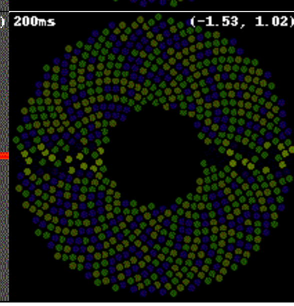
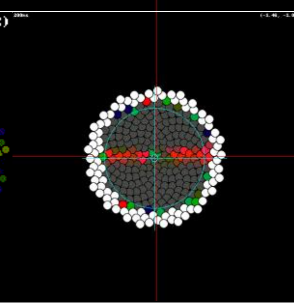
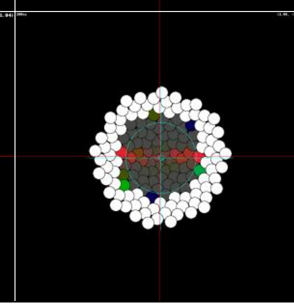
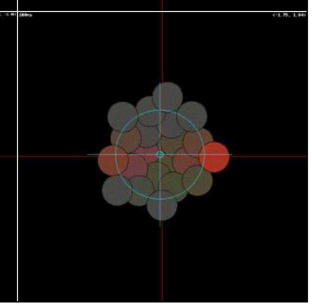
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields Level 1	Receptive Fields Level 2	Receptive Fields Level 3
18					
19					
20					

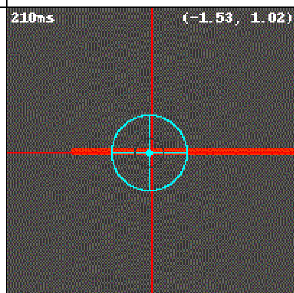
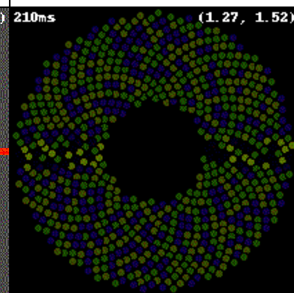
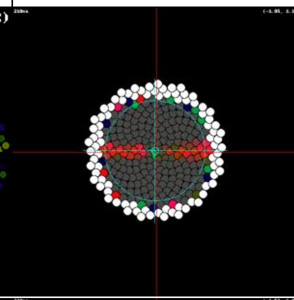
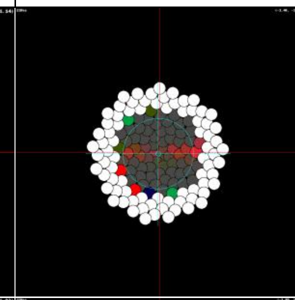
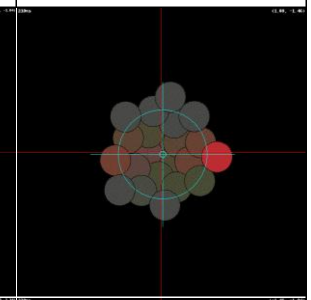
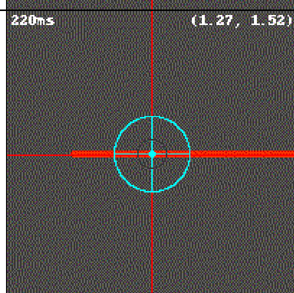
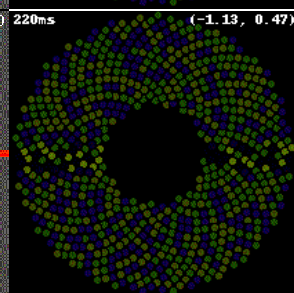
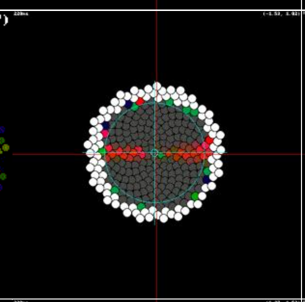
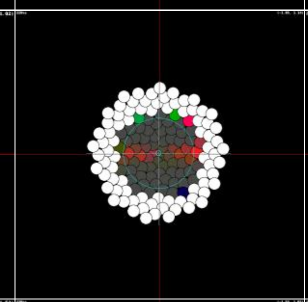
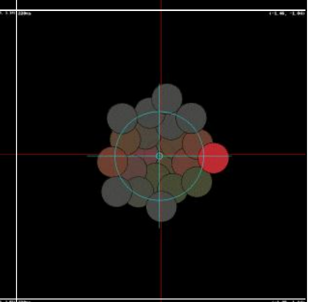
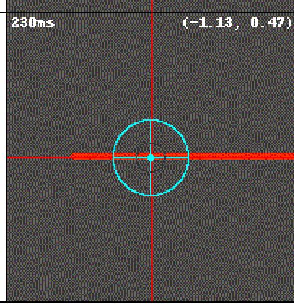
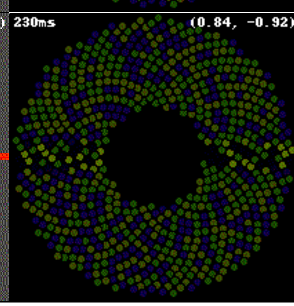
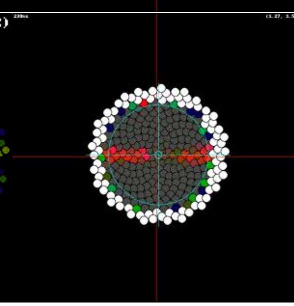
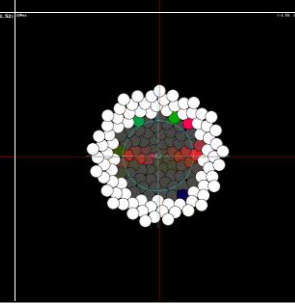
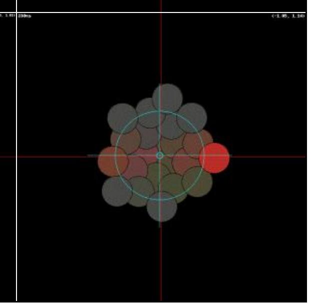
Table 20: Time sequence of static line filling-in over blind spot					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
21					
22					
23					

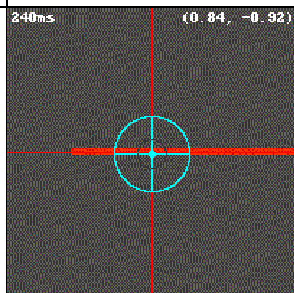
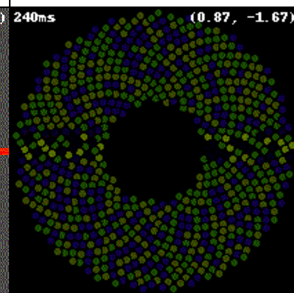
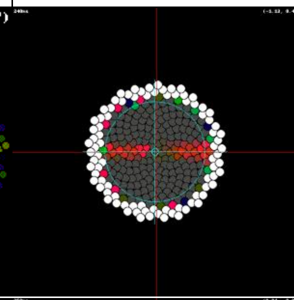
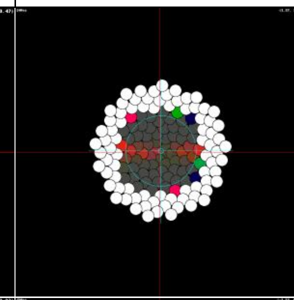
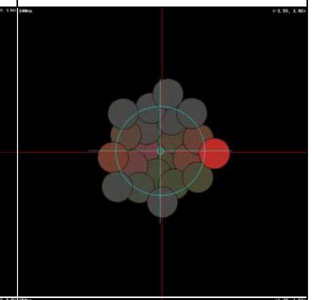
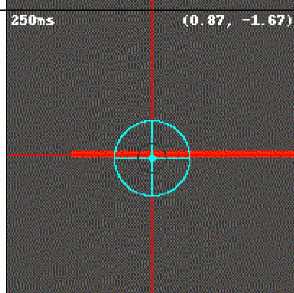
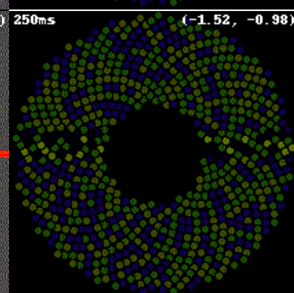
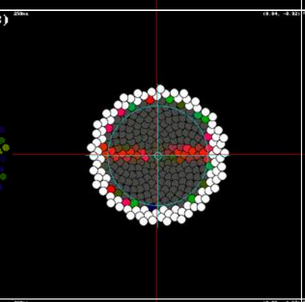
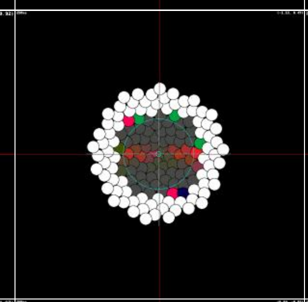
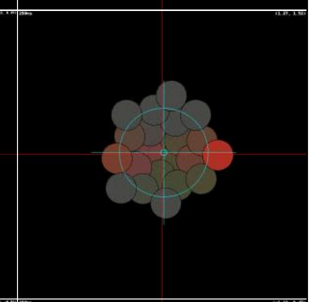
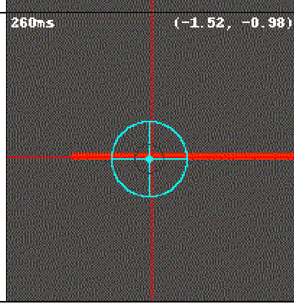
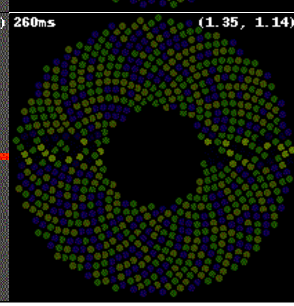
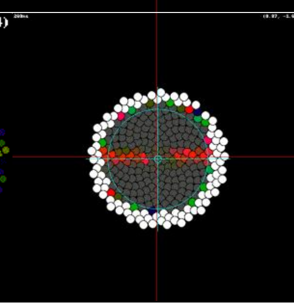
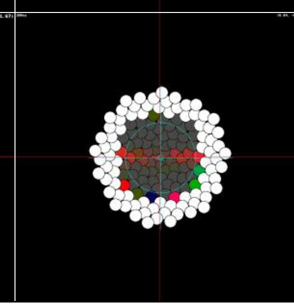
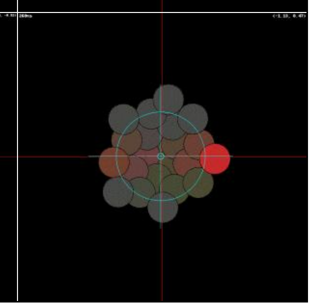
Table 20: Time sequence of static line filling-in over blind spot					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
24					
25					
26					

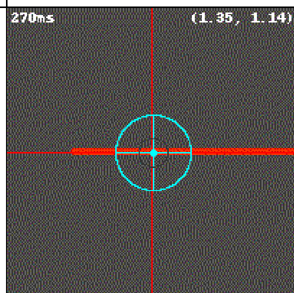
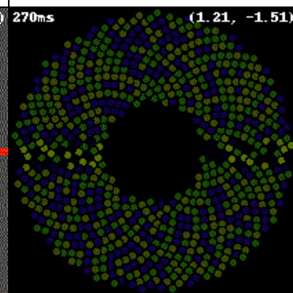
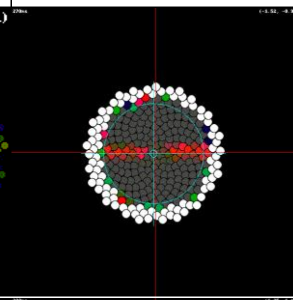
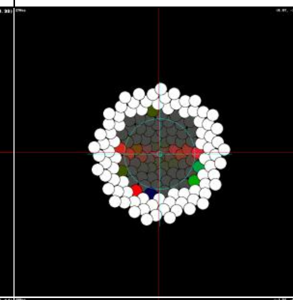
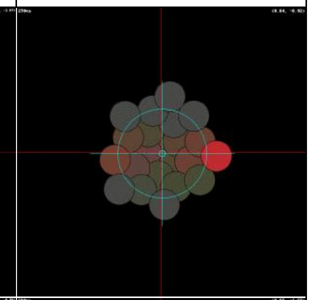
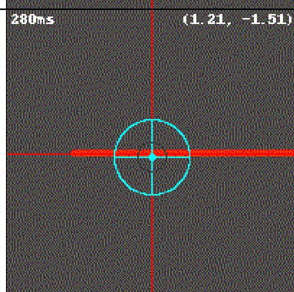
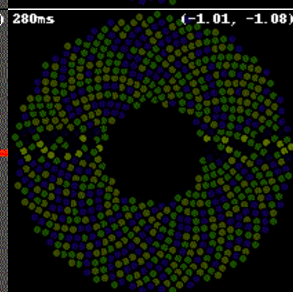
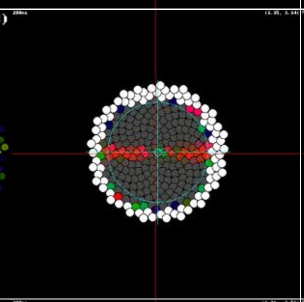
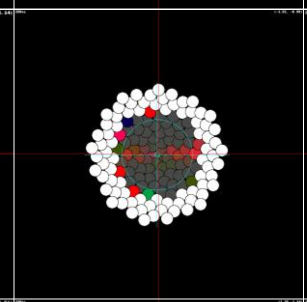
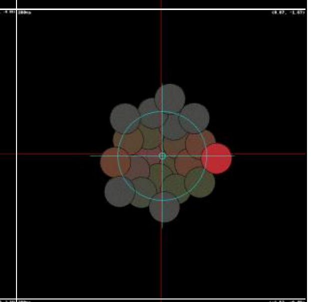
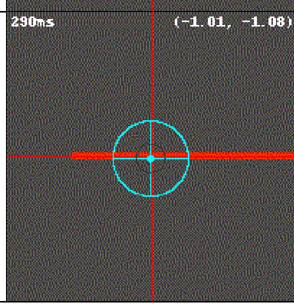
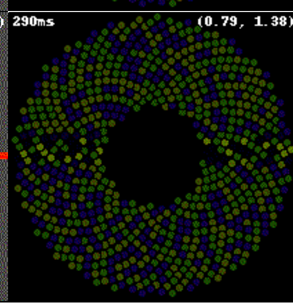
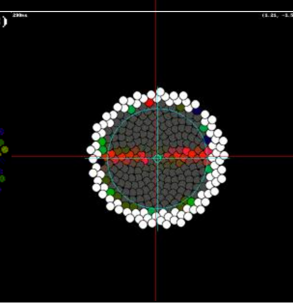
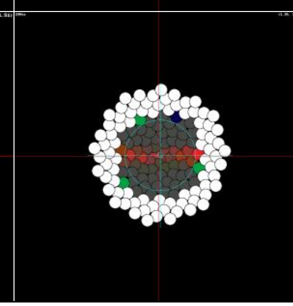
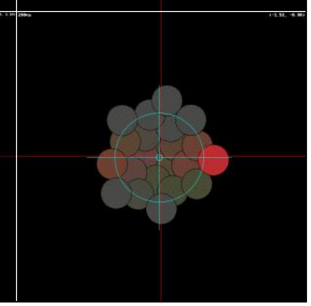
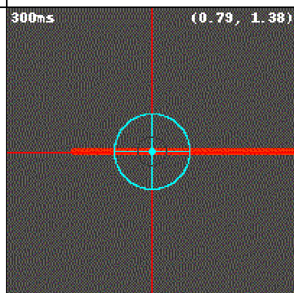
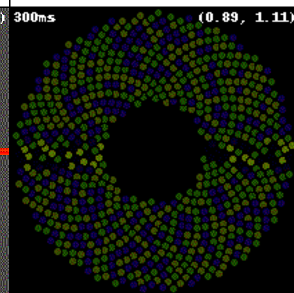
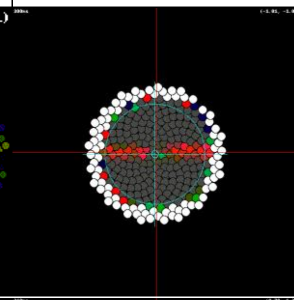
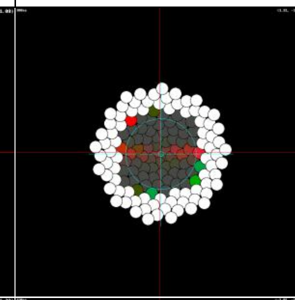
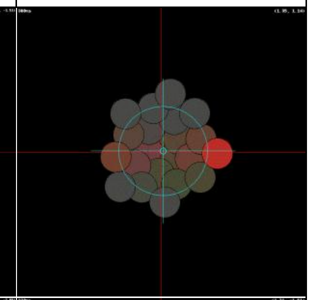
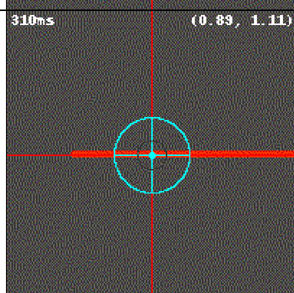
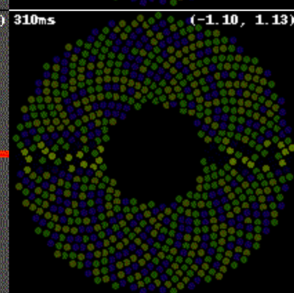
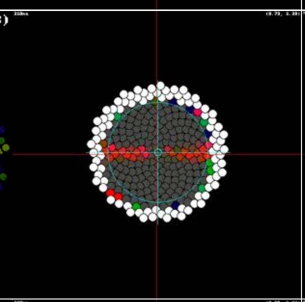
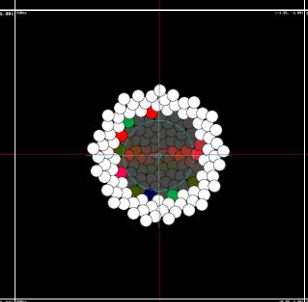
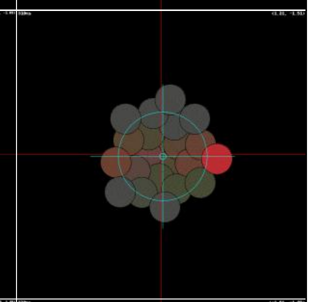
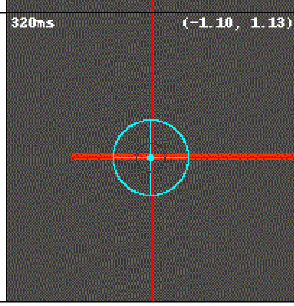
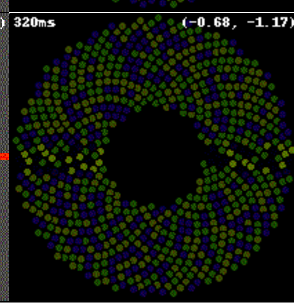
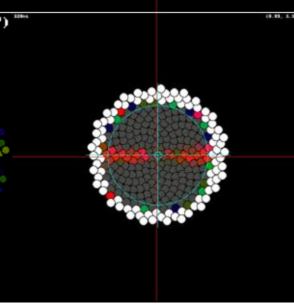
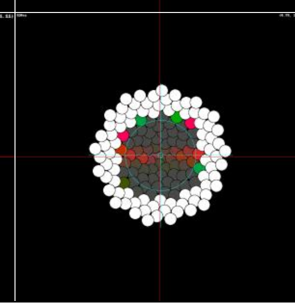
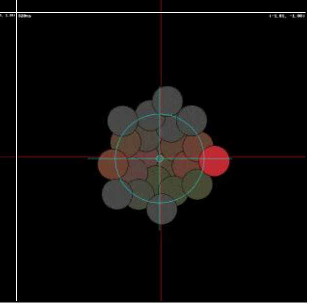
Table 20: Time sequence of static line filling-in over blind spot					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
27					
28					
29					

Table 20: Time sequence of static line filling-in over blind spot					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
30					
31					
32					

5.3.5 Test 5 results: Line across

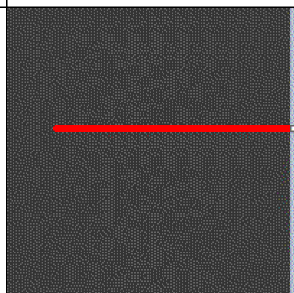
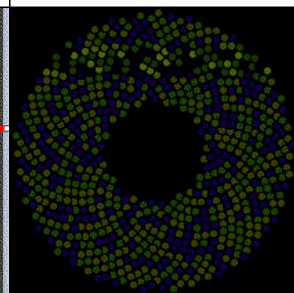
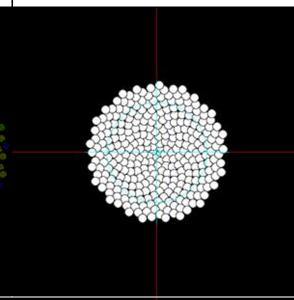
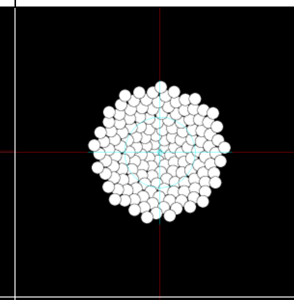
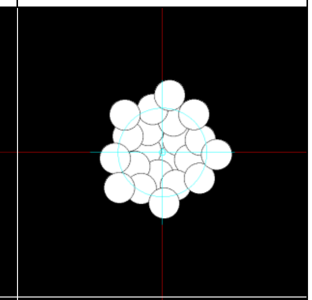
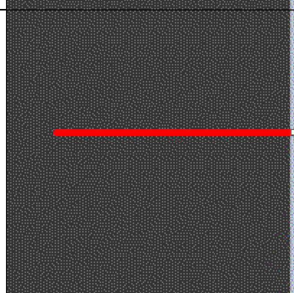
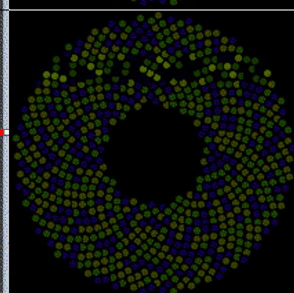
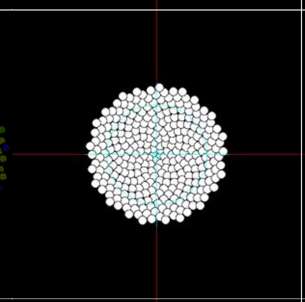
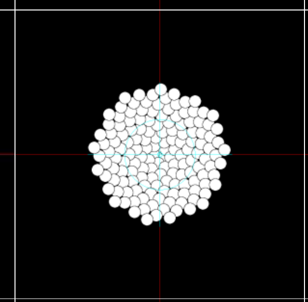
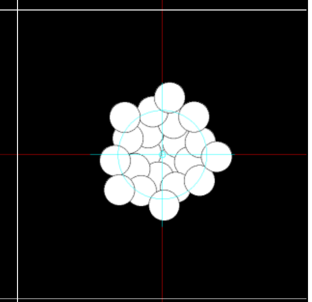
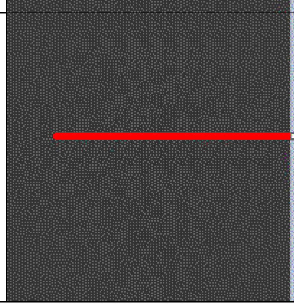
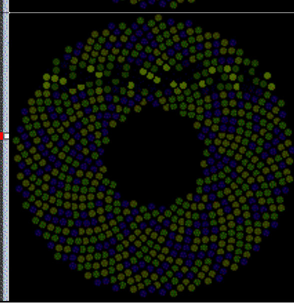
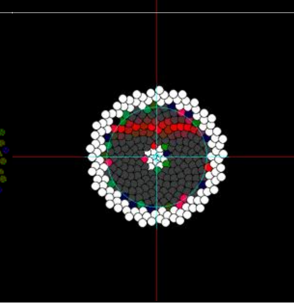
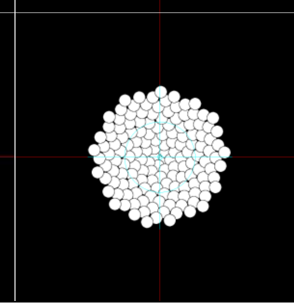
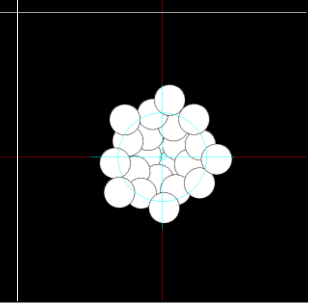
Table 21: Time sequence of line moving across blind spot while filling-in					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
0					
1					
2					

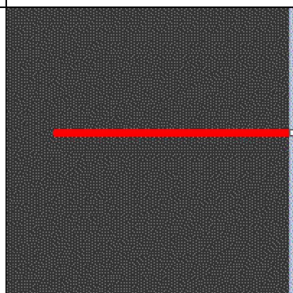
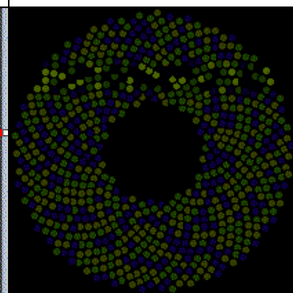
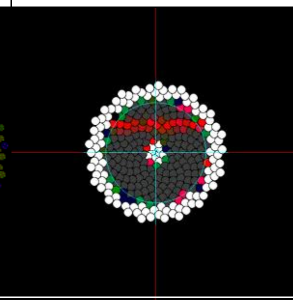
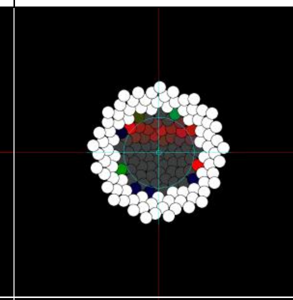
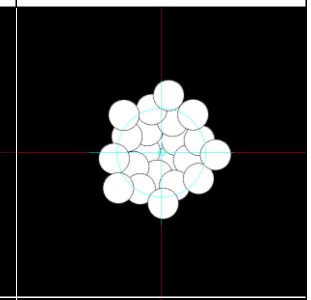
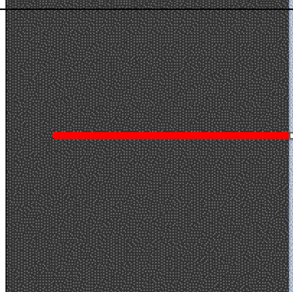
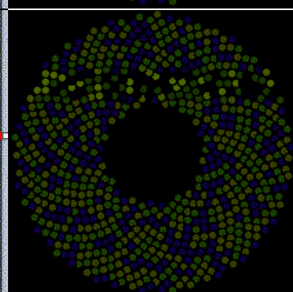
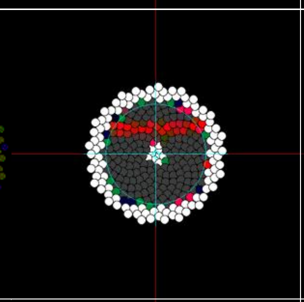
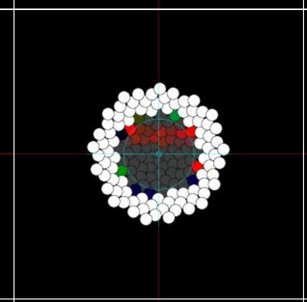
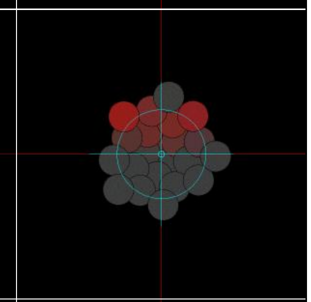
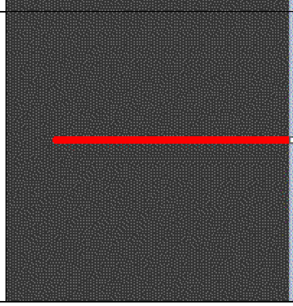
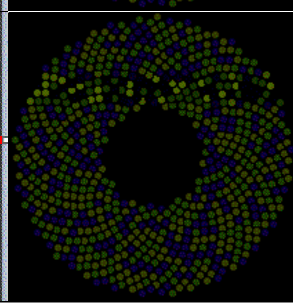
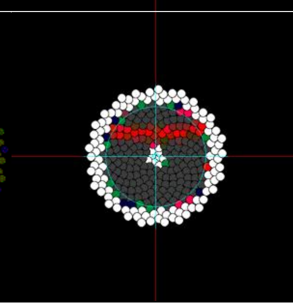
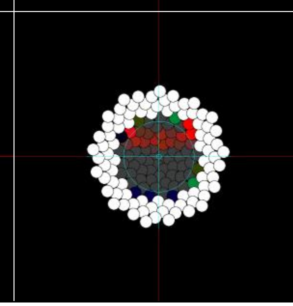
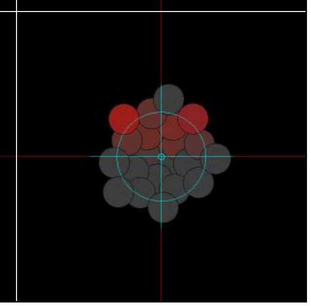
Table 21: Time sequence of line moving across blind spot while filling-in					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
3					
4					
5					

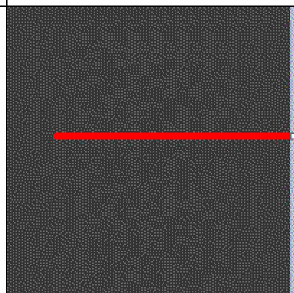
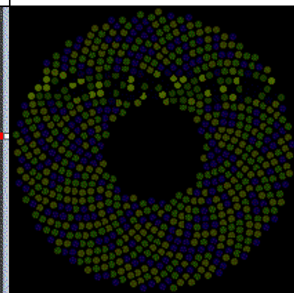
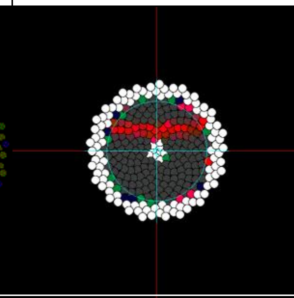
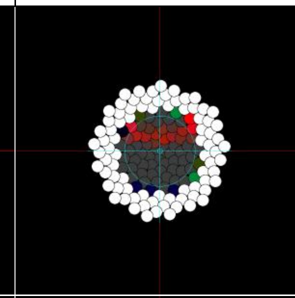
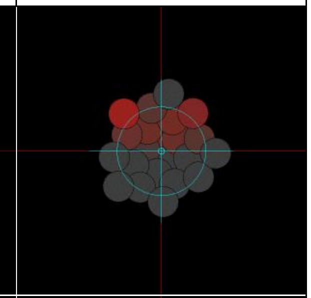
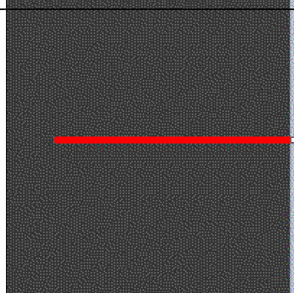
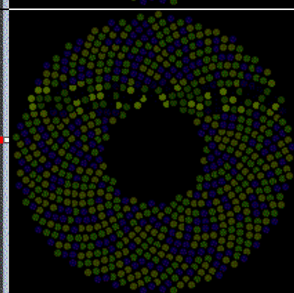
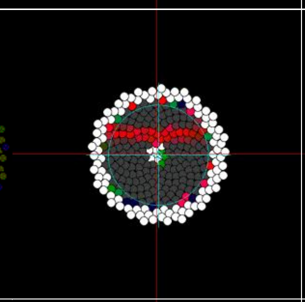
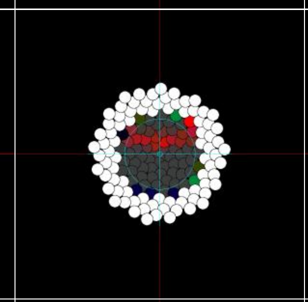
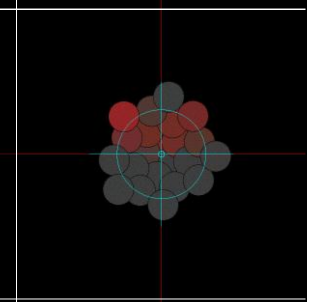
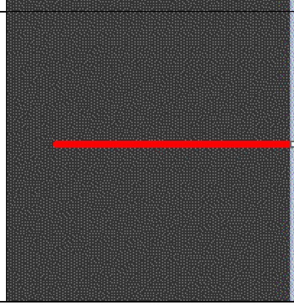
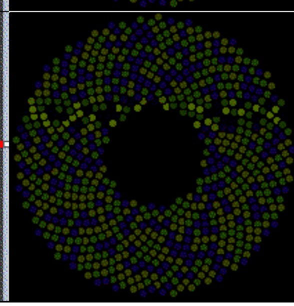
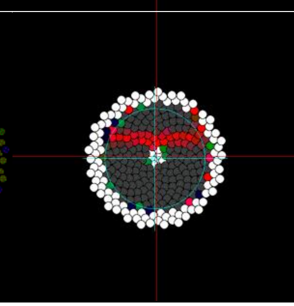
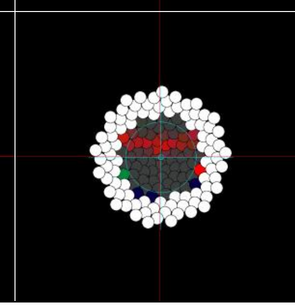
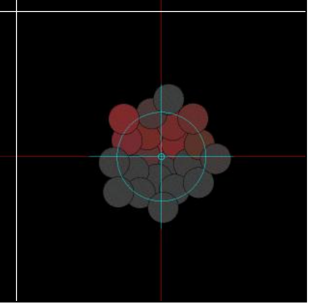
Table 21: Time sequence of line moving across blind spot while filling-in					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
6					
7					
8					

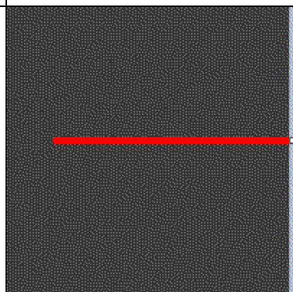
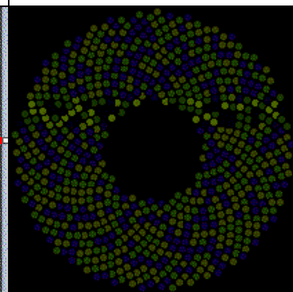
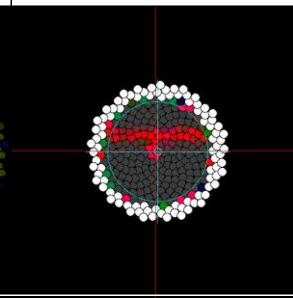
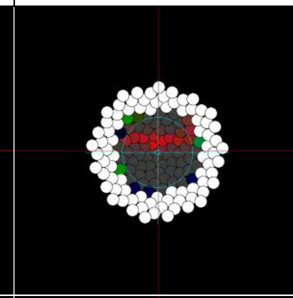
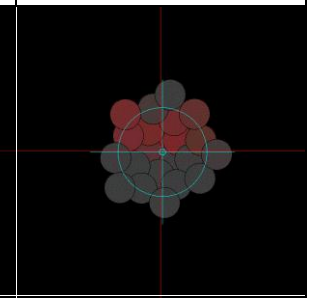
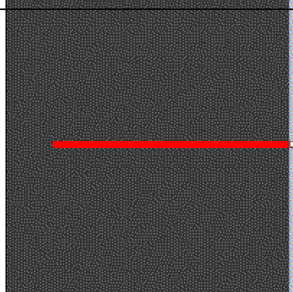
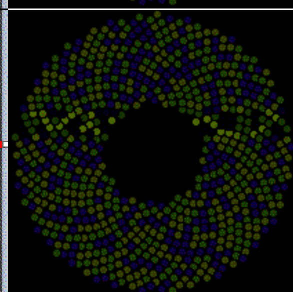
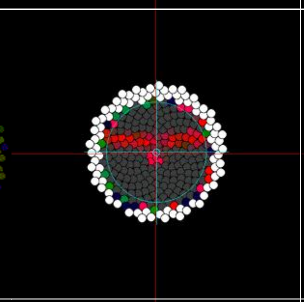
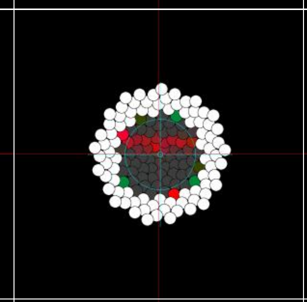
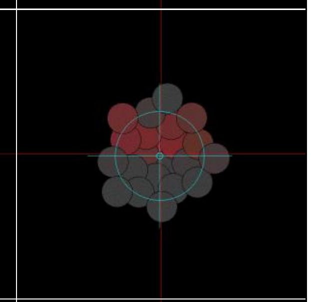
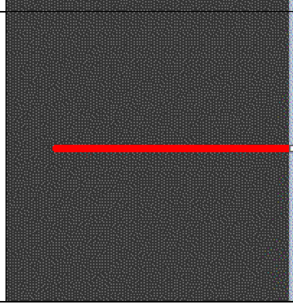
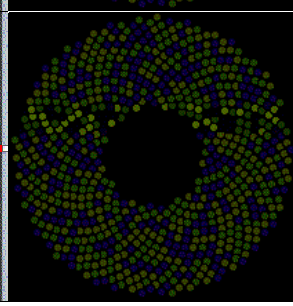
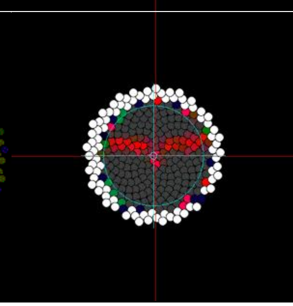
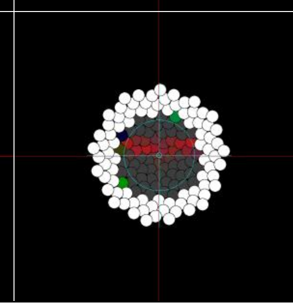
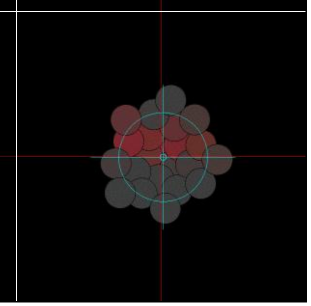
Table 21: Time sequence of line moving across blind spot while filling-in					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
9					
10					
11					

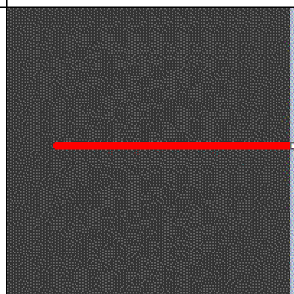
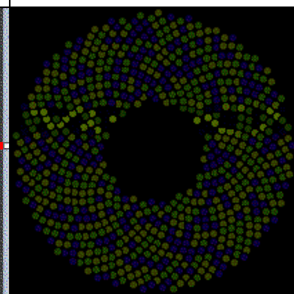
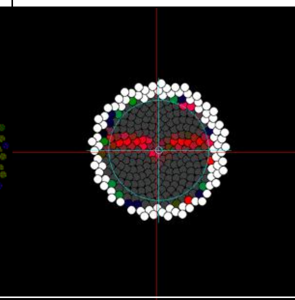
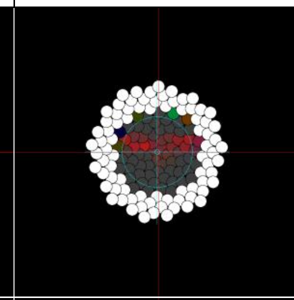
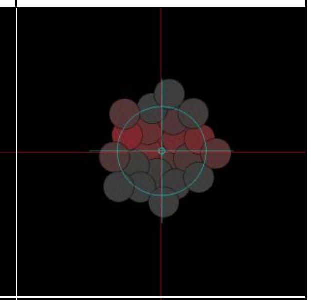
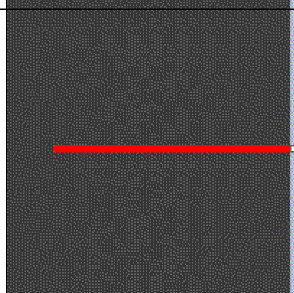
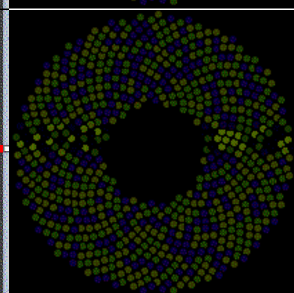
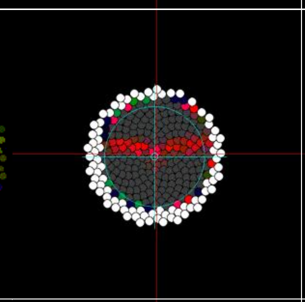
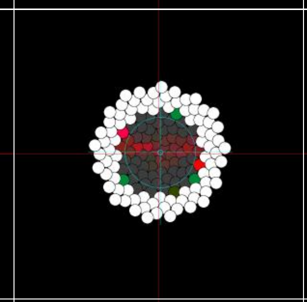
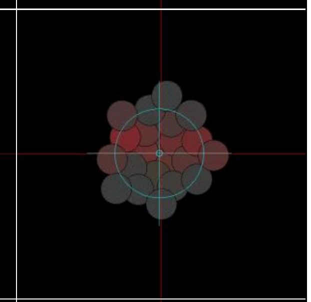
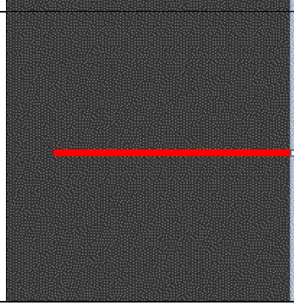
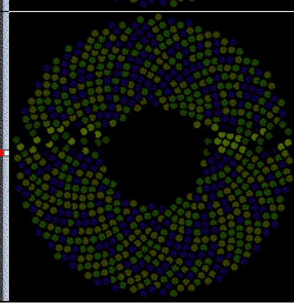
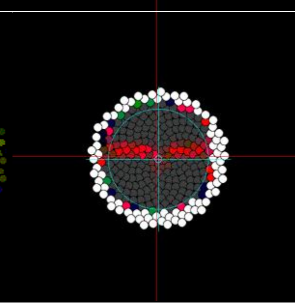
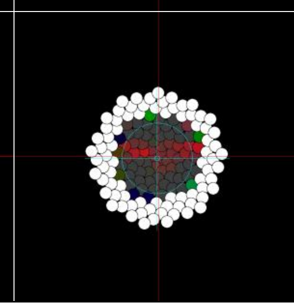
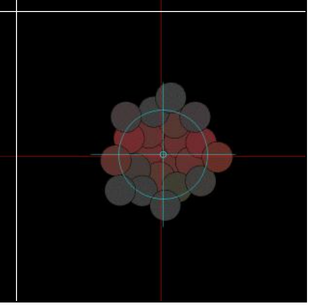
Table 21: Time sequence of line moving across blind spot while filling-in					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
12					
13					
14					

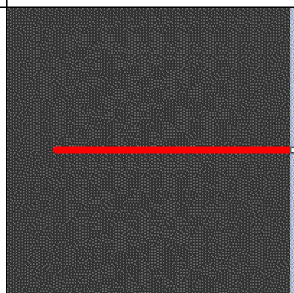
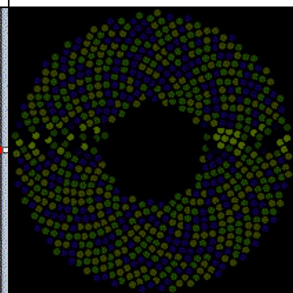
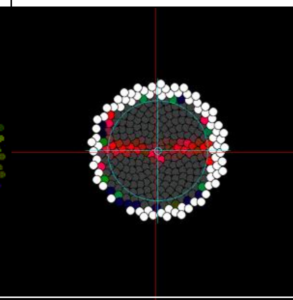
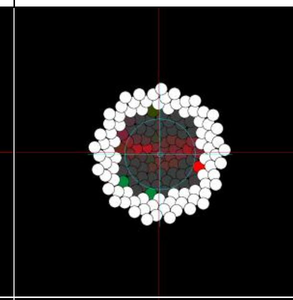
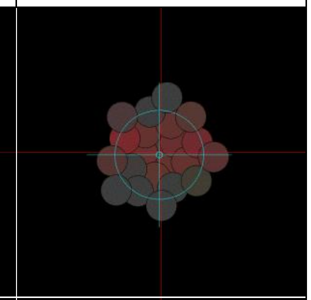
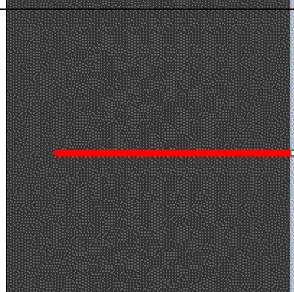
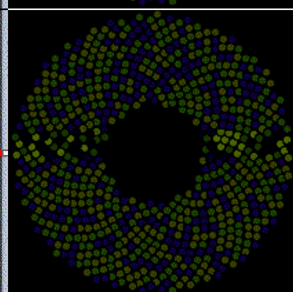
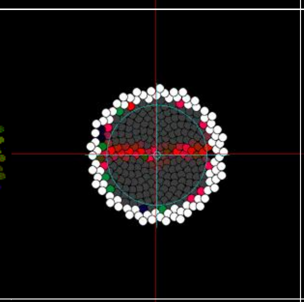
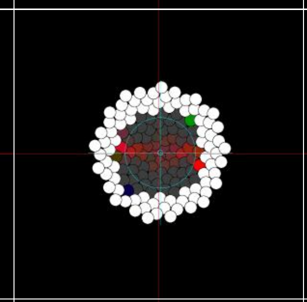
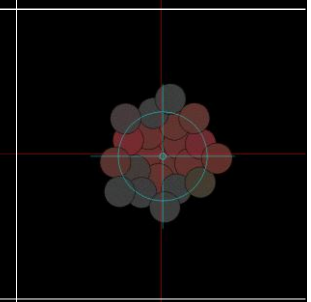
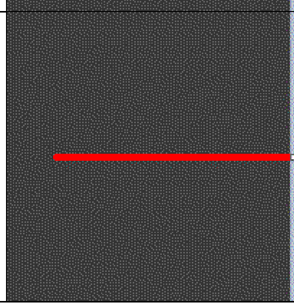
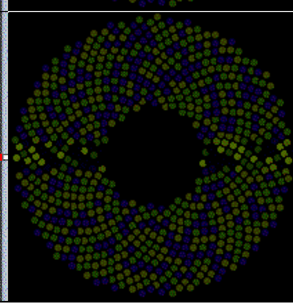
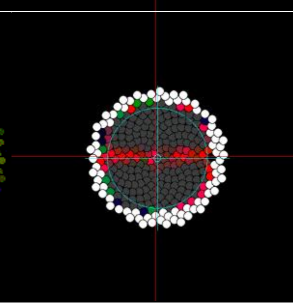
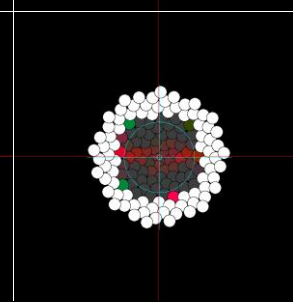
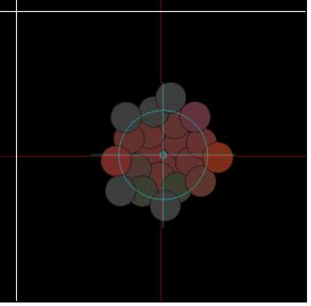
Table 21: Time sequence of line moving across blind spot while filling-in					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
15					
16					
17					

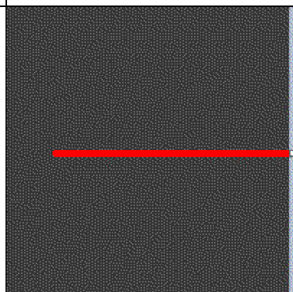
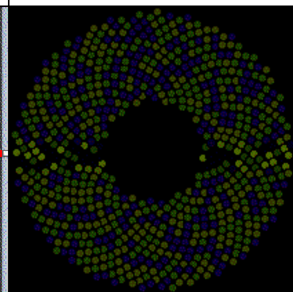
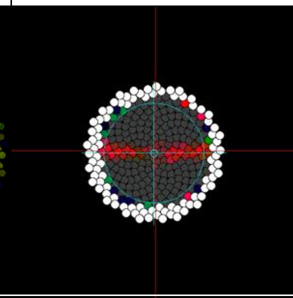
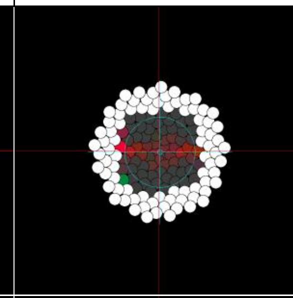
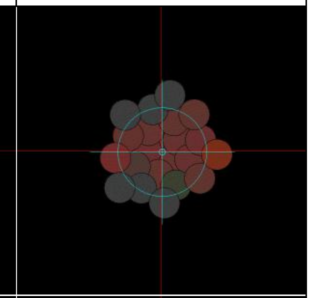
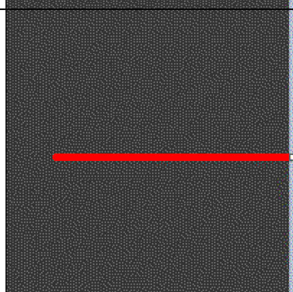
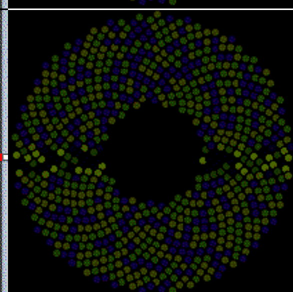
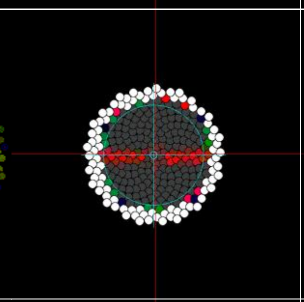
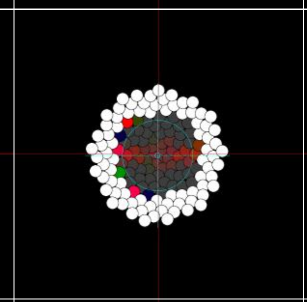
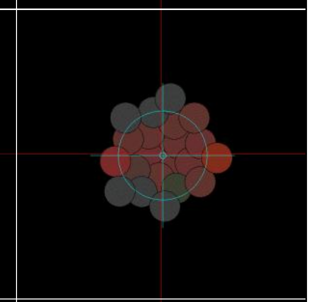
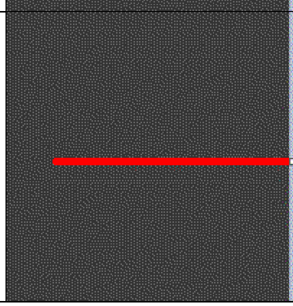
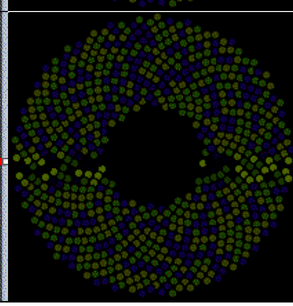
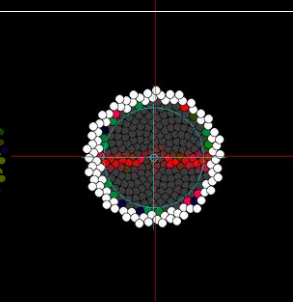
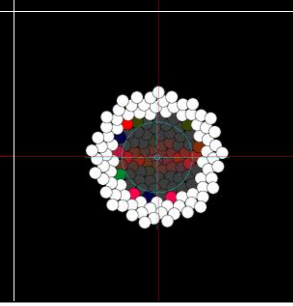
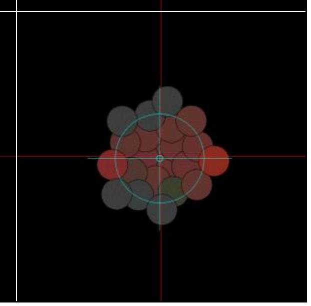
Table 21: Time sequence of line moving across blind spot while filling-in					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
18					
19					
20					

Table 21: Time sequence of line moving across blind spot while filling-in

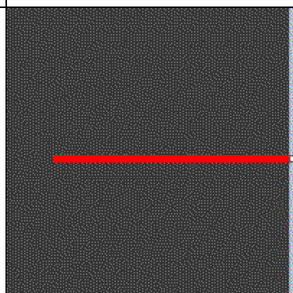
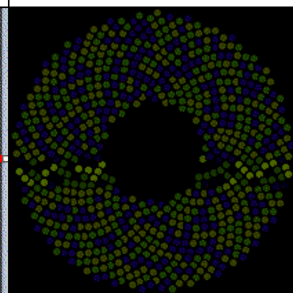
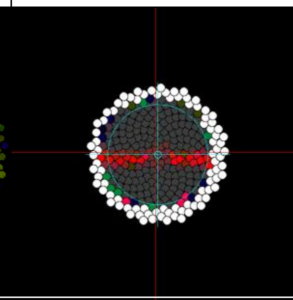
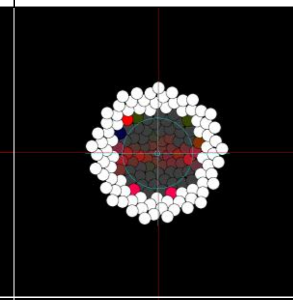
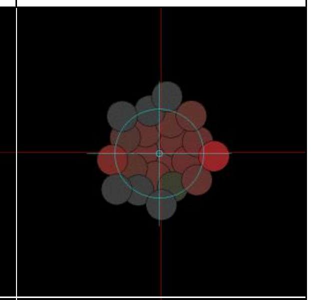
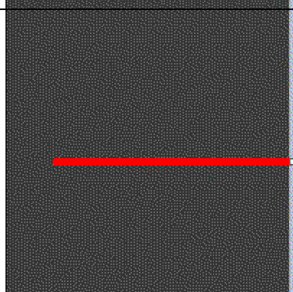
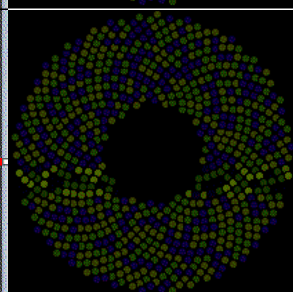
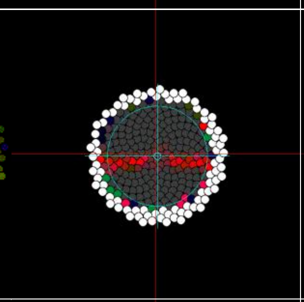
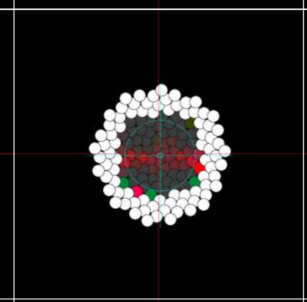
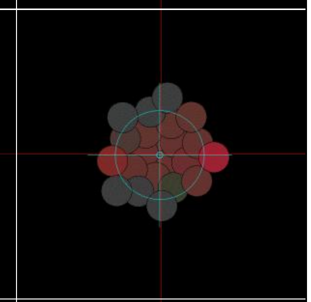
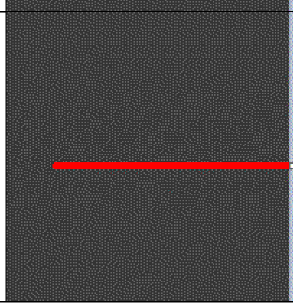
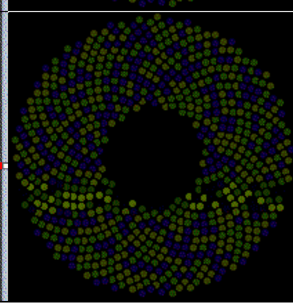
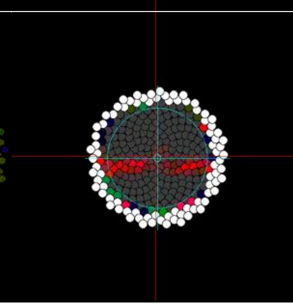
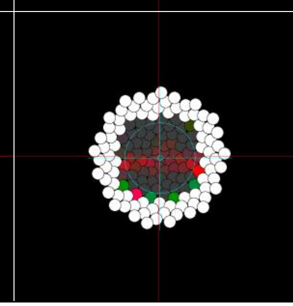
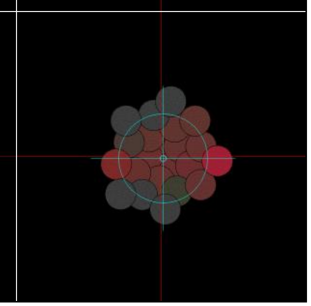
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
21					
22					
23					

Table 21: Time sequence of line moving across blind spot while filling-in

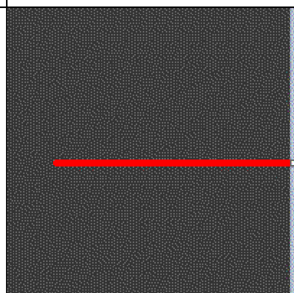
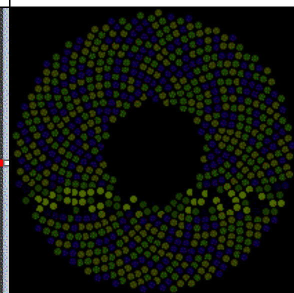
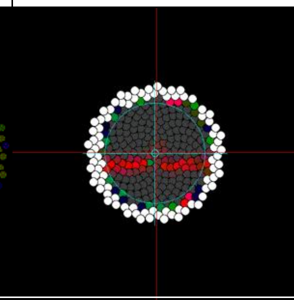
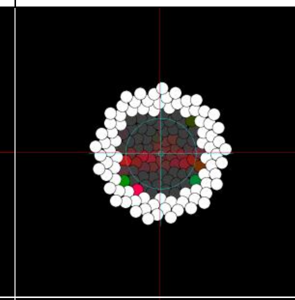
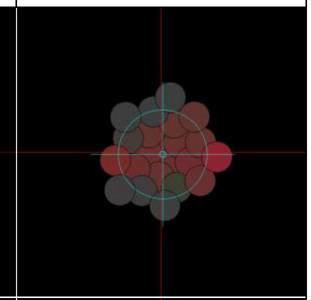
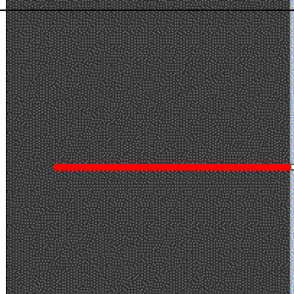
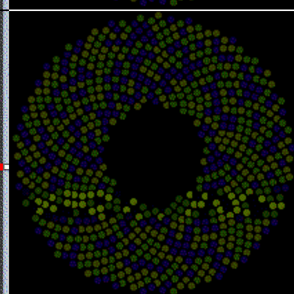
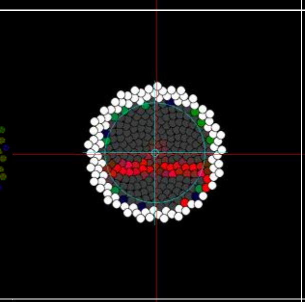
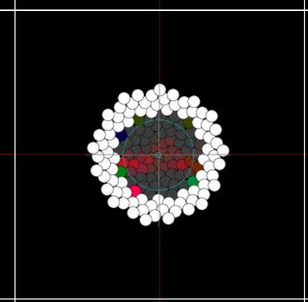
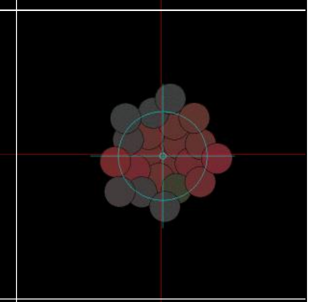
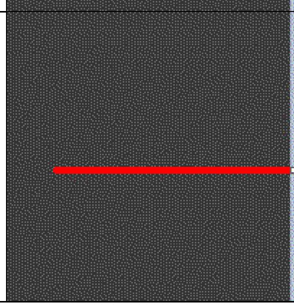
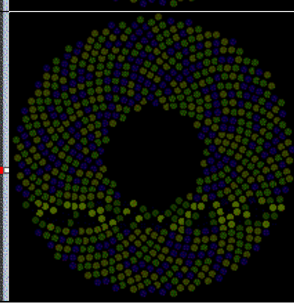
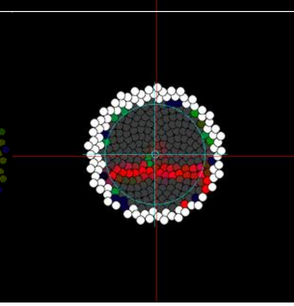
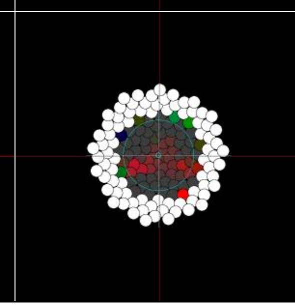
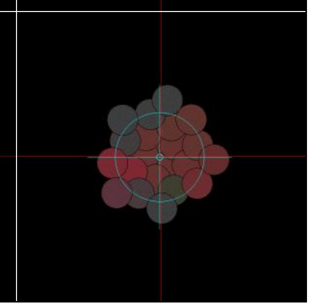
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
24					
25					
26					

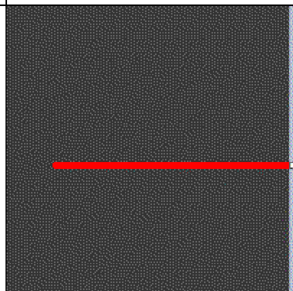
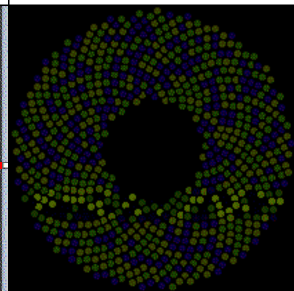
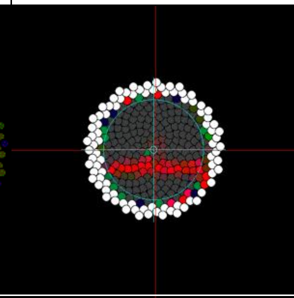
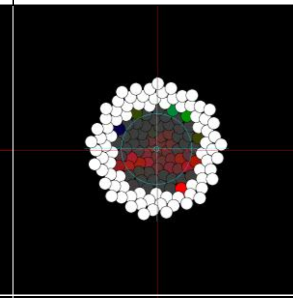
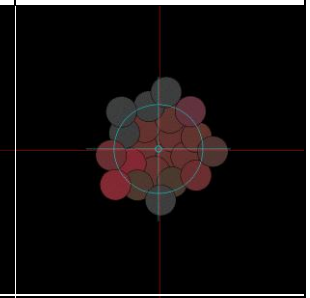
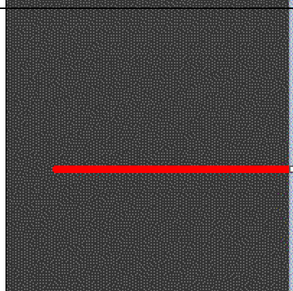
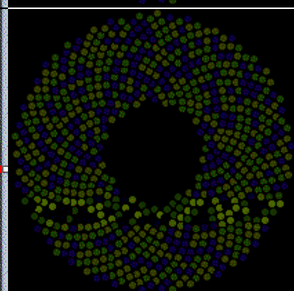
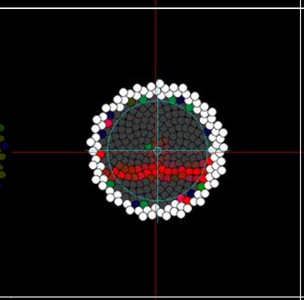
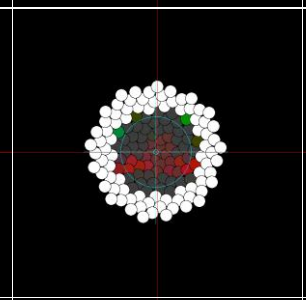
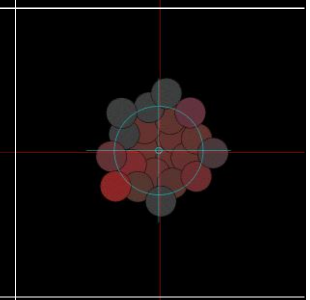
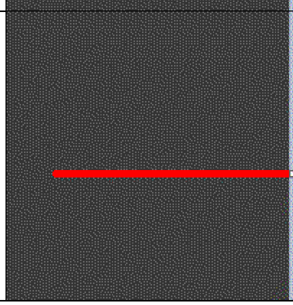
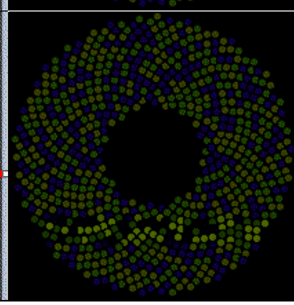
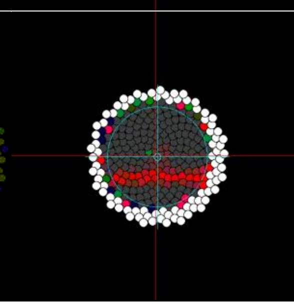
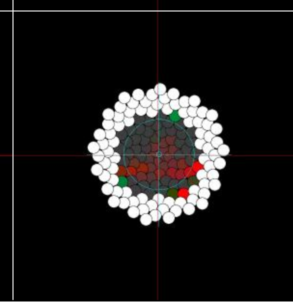
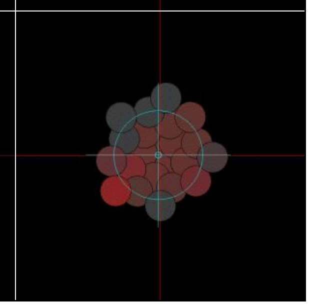
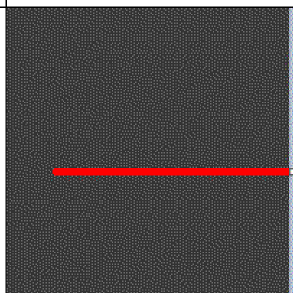
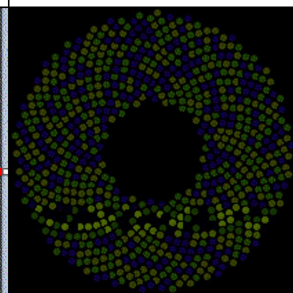
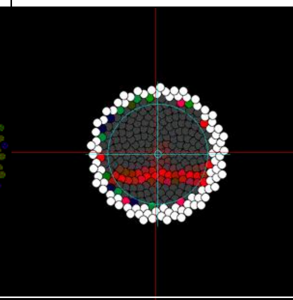
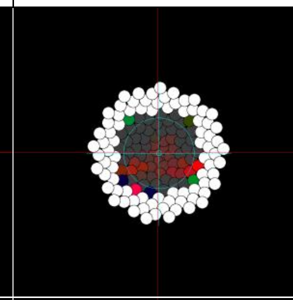
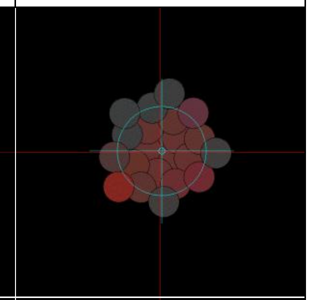
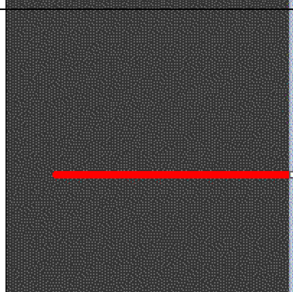
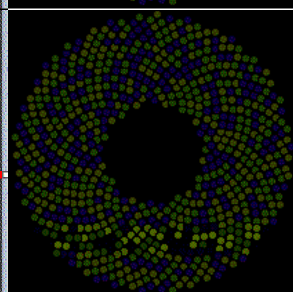
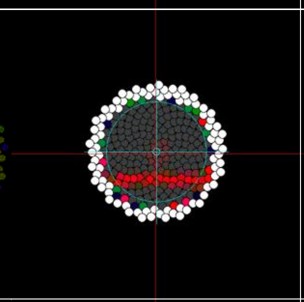
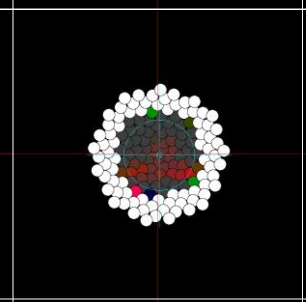
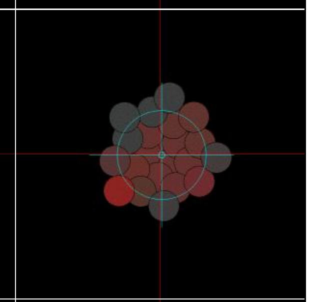
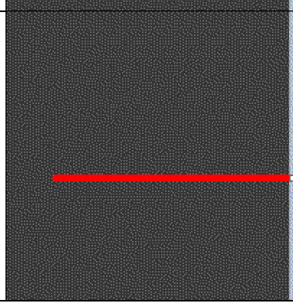
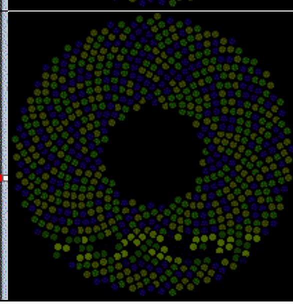
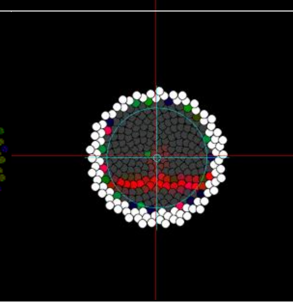
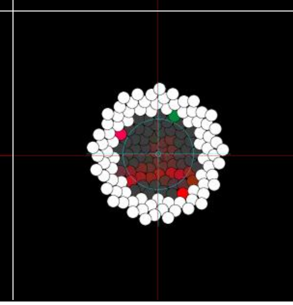
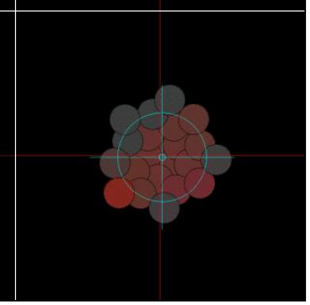
Table 21: Time sequence of line moving across blind spot while filling-in					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
27					
28					
29					

Table 21: Time sequence of line moving across blind spot while filling-in					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
30					
31					
32					

5.3.6 Test 6 results: Line in

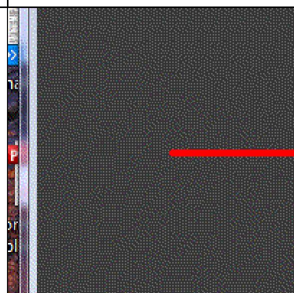
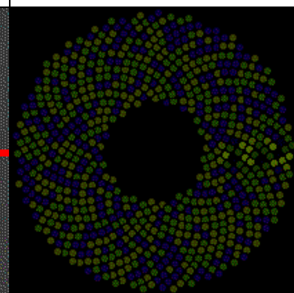
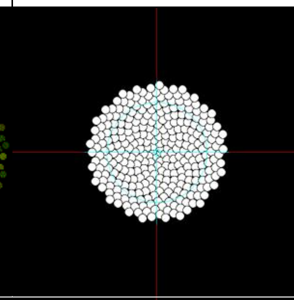
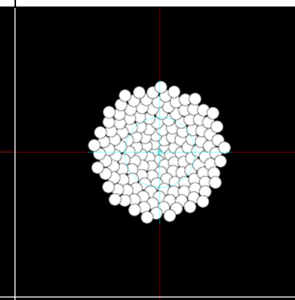
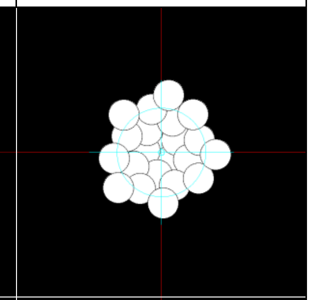
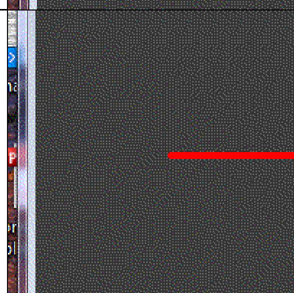
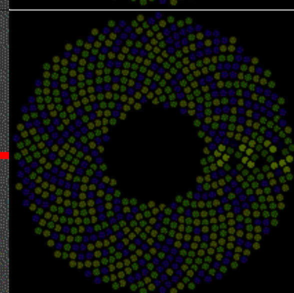
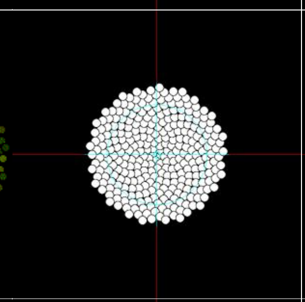
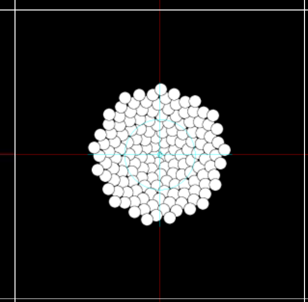
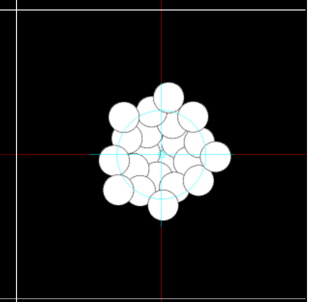
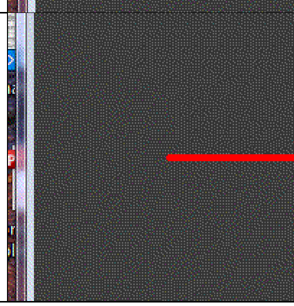
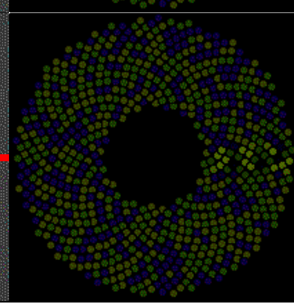
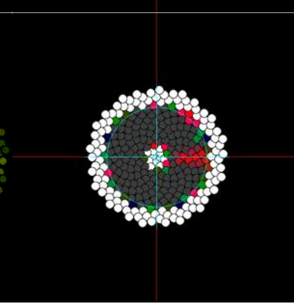
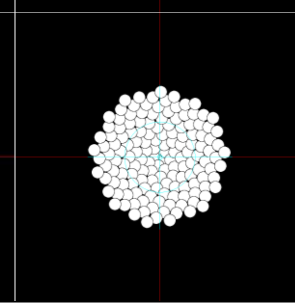
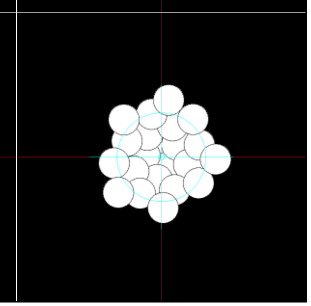
Table 22: Time sequence of line moving into blind spot then being filled-in					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
0					
1					
2					

Table 22: Time sequence of line moving into blind spot then being filled-in

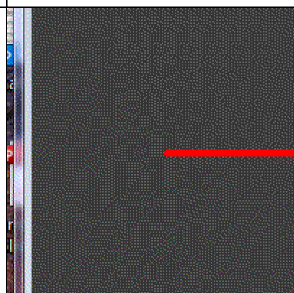
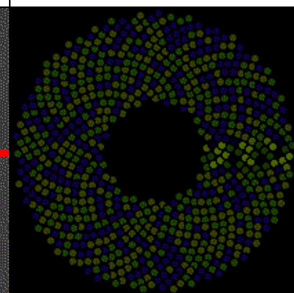
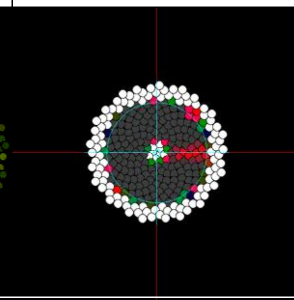
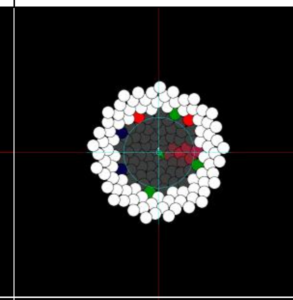
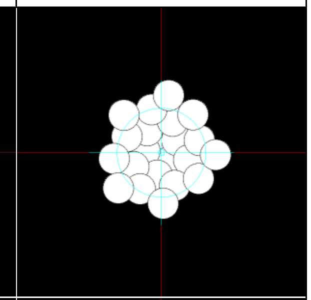
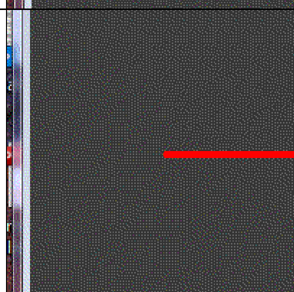
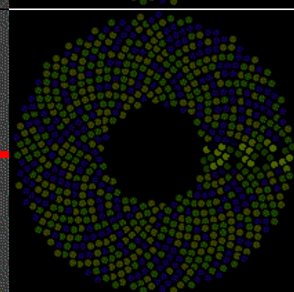
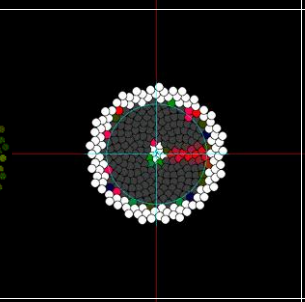
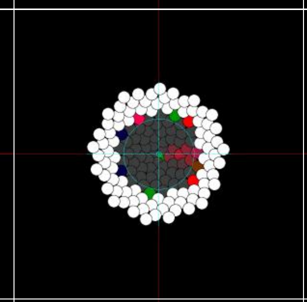
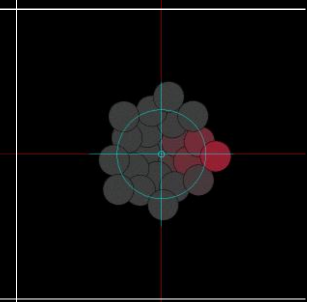
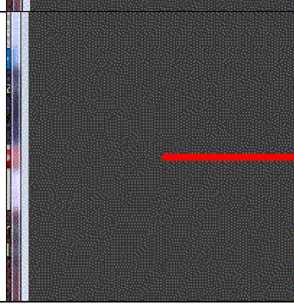
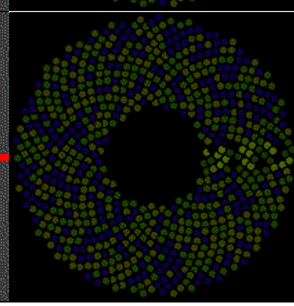
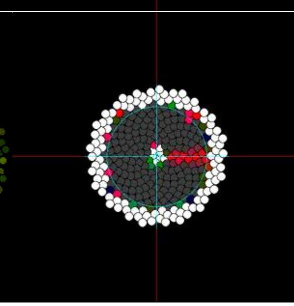
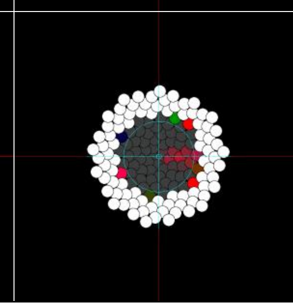
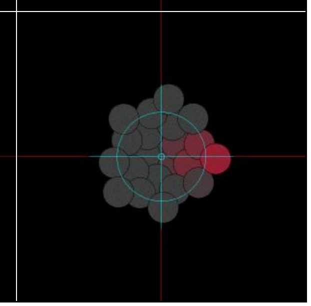
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
3					
4					
5					

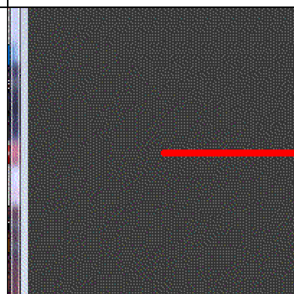
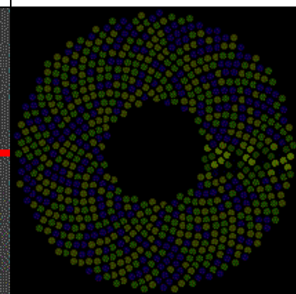
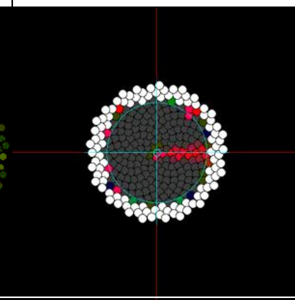
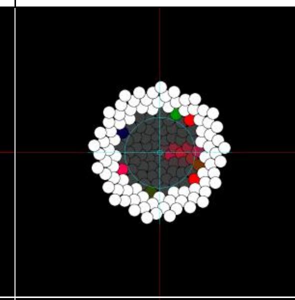
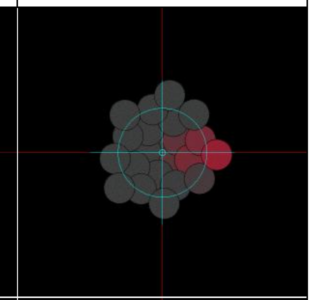
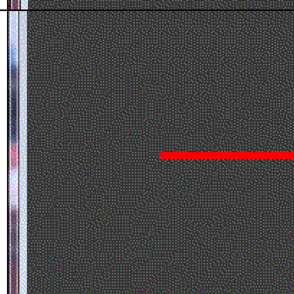
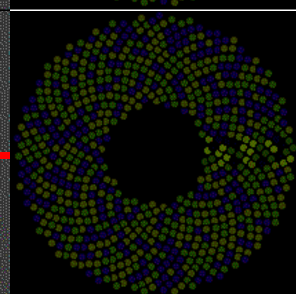
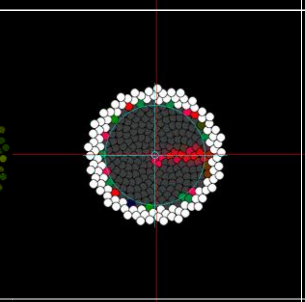
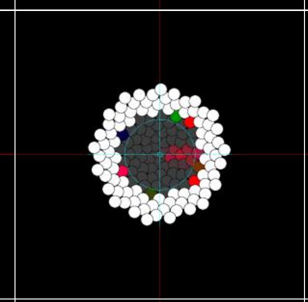
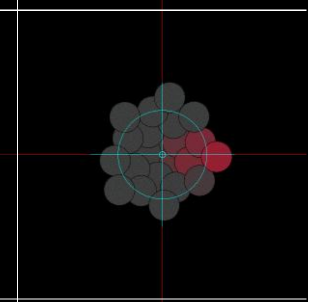
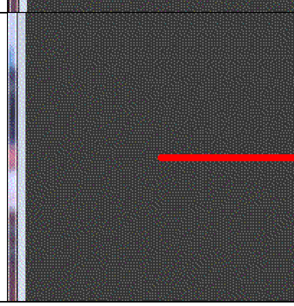
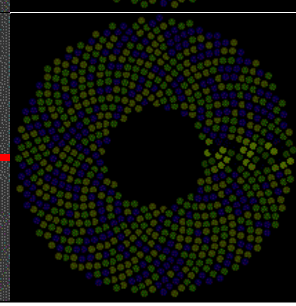
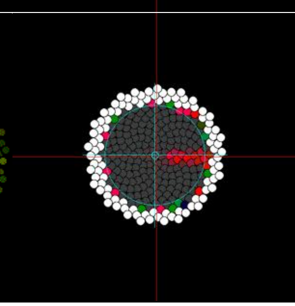
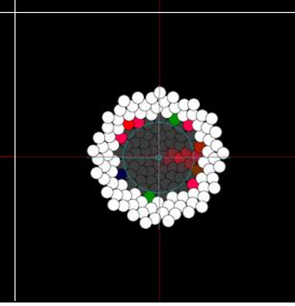
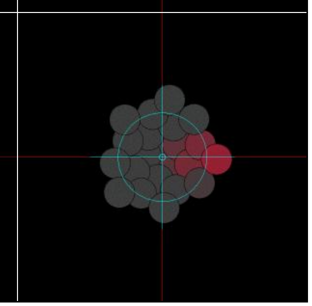
Table 22: Time sequence of line moving into blind spot then being filled-in					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
6					
7					
8					

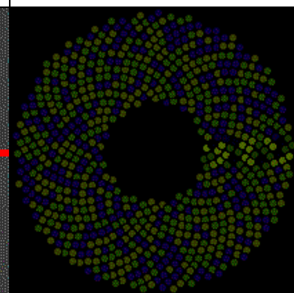
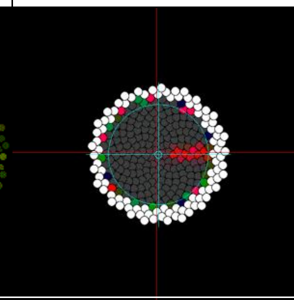
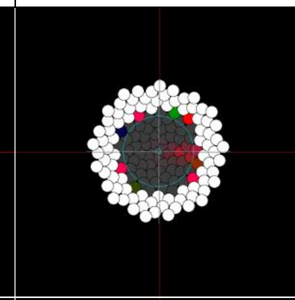
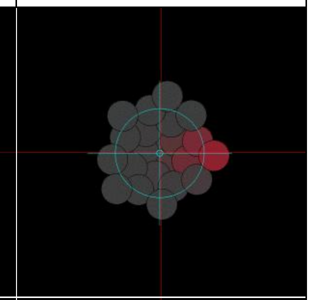
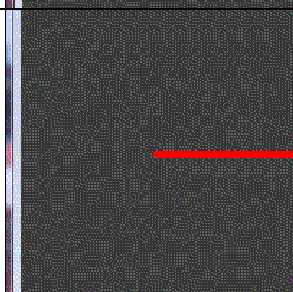
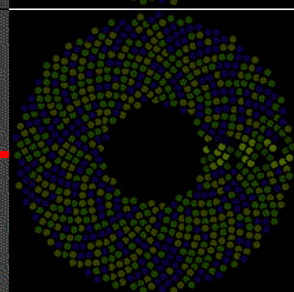
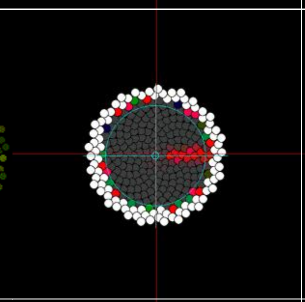
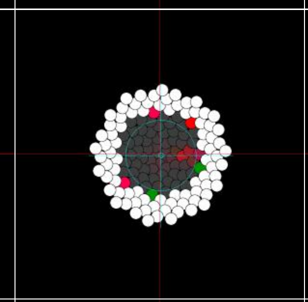
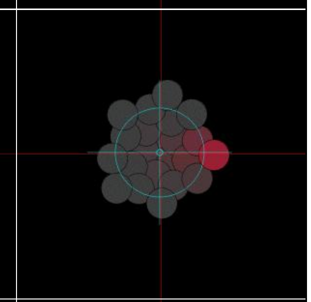
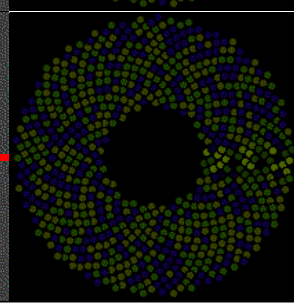
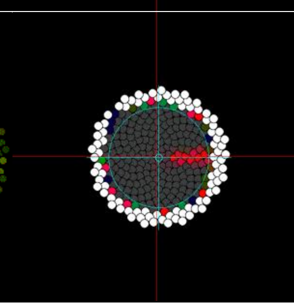
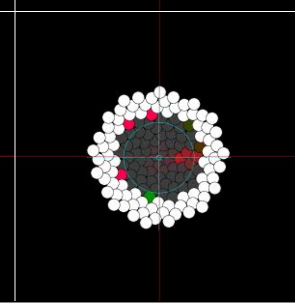
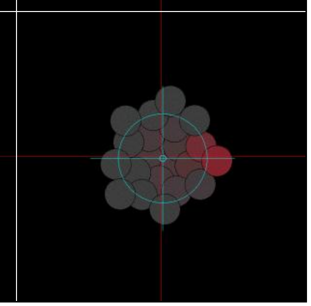
Table 22: Time sequence of line moving into blind spot then being filled-in					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
9					
10					
11					

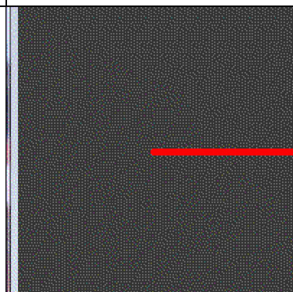
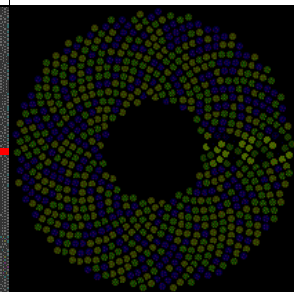
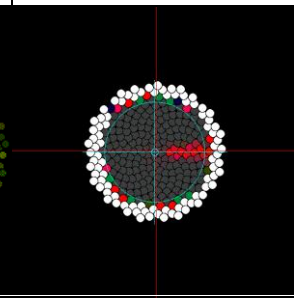
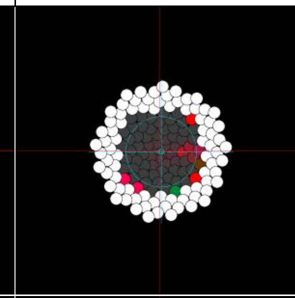
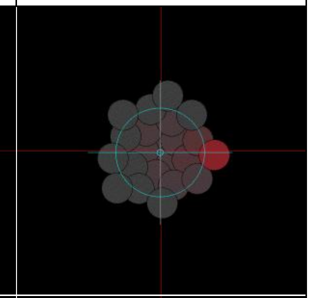
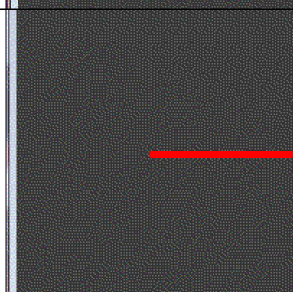
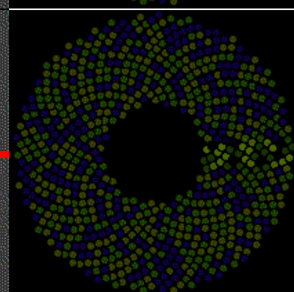
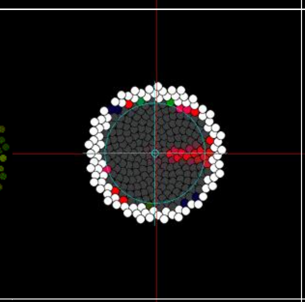
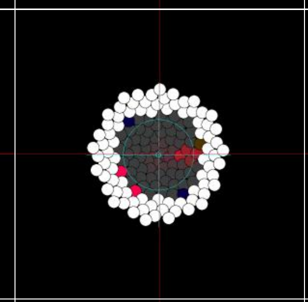
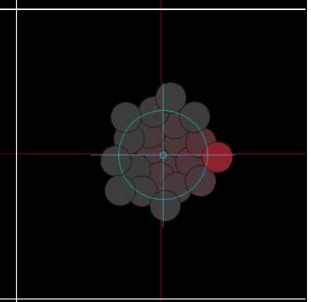
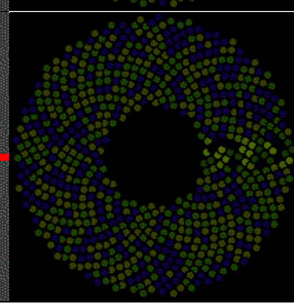
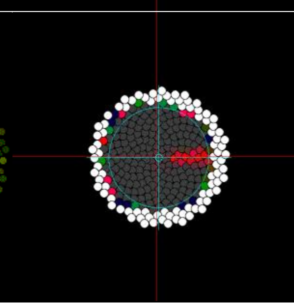
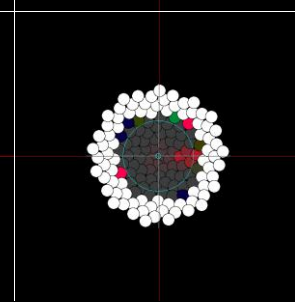
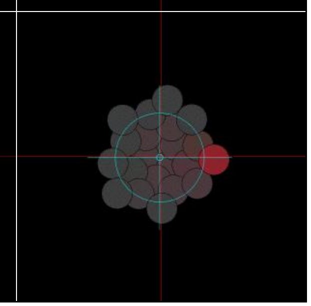
Table 22: Time sequence of line moving into blind spot then being filled-in					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
12					
13					
14					

Table 22: Time sequence of line moving into blind spot then being filled-in

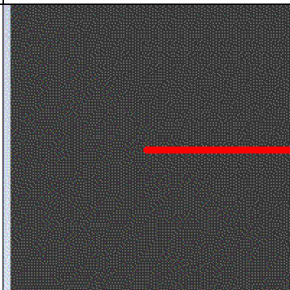
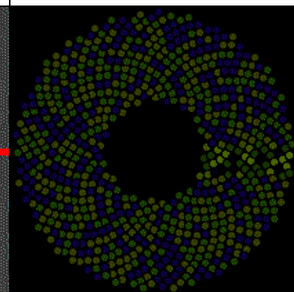
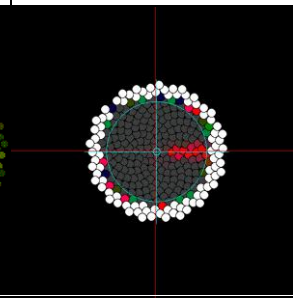
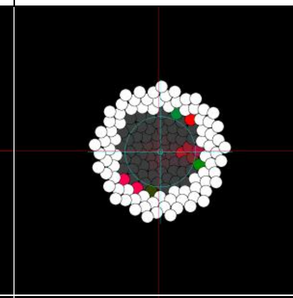
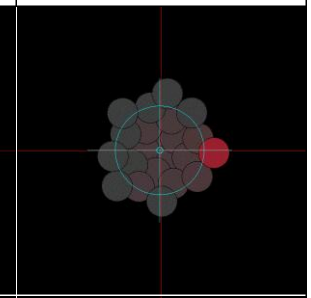
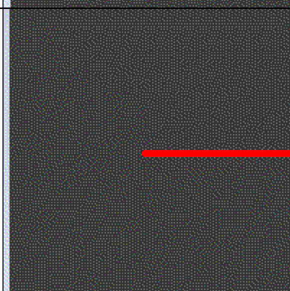
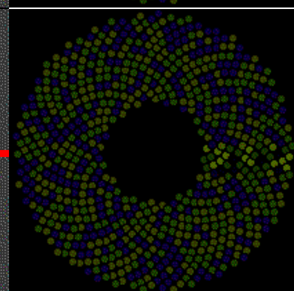
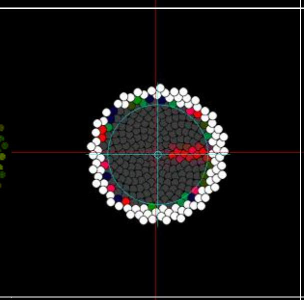
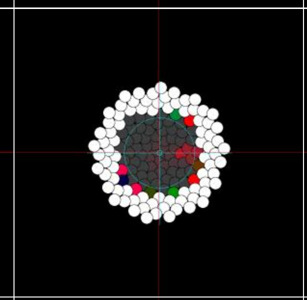
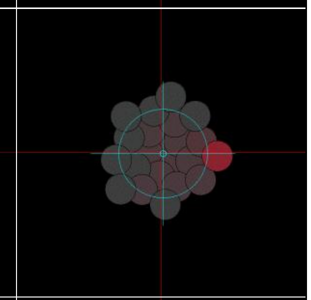
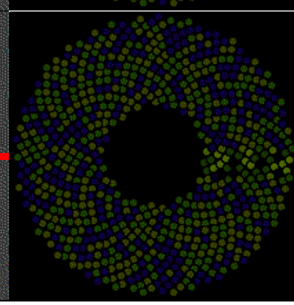
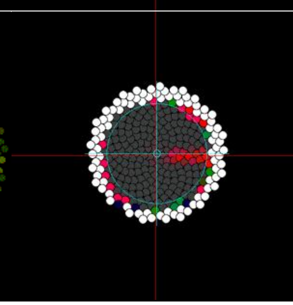
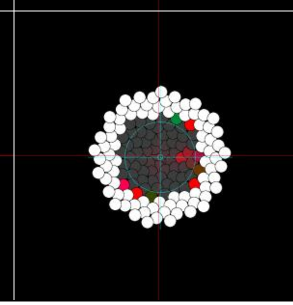
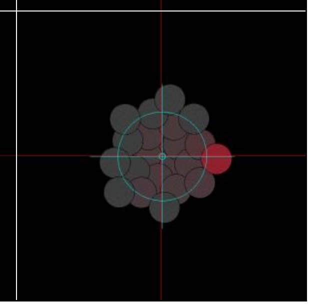
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
15					
16					
17					

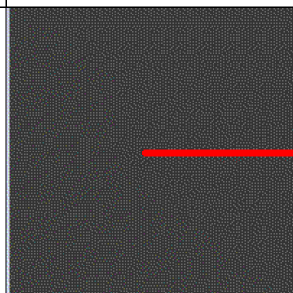
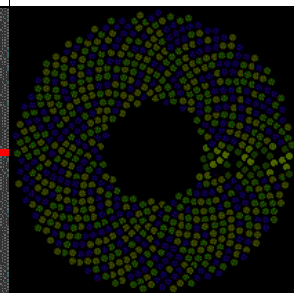
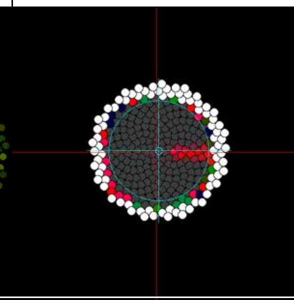
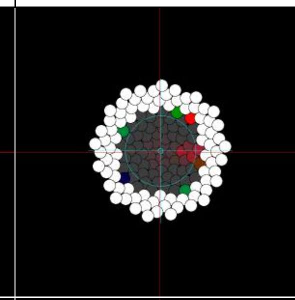
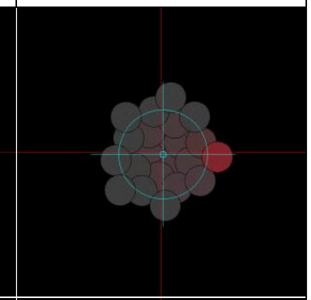
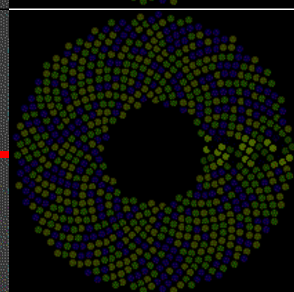
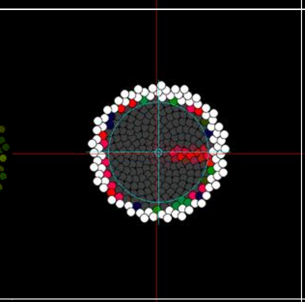
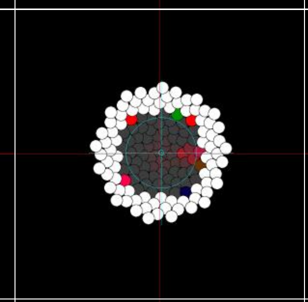
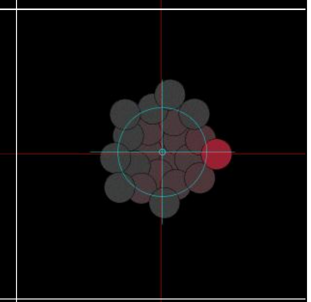
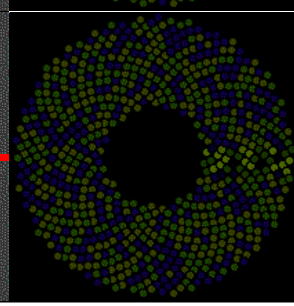
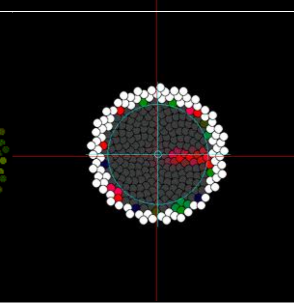
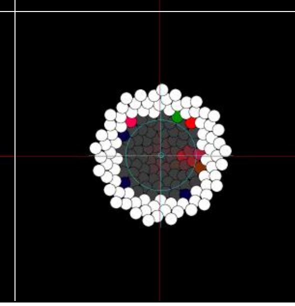
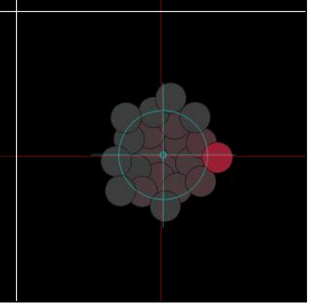
Table 22: Time sequence of line moving into blind spot then being filled-in					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
18					
19					
20					

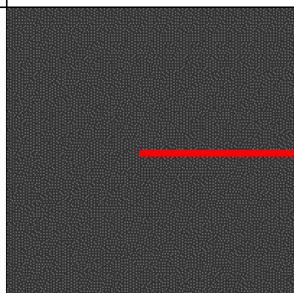
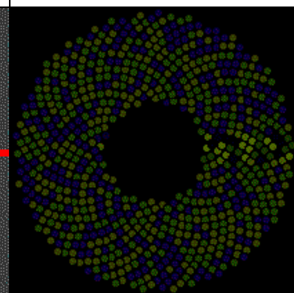
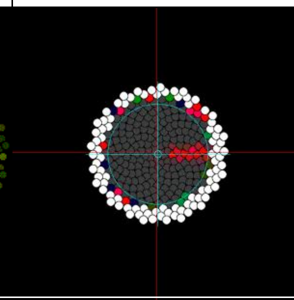
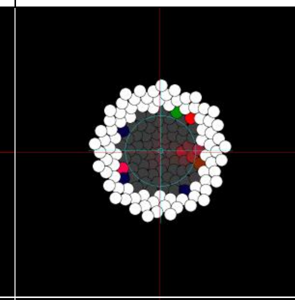
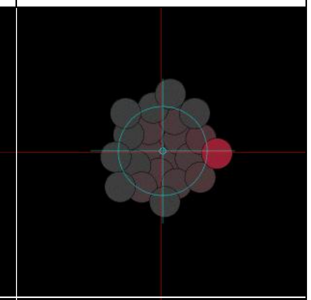
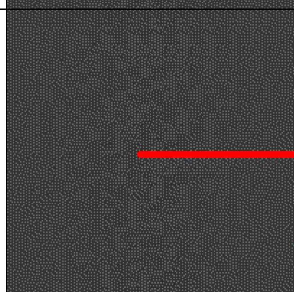
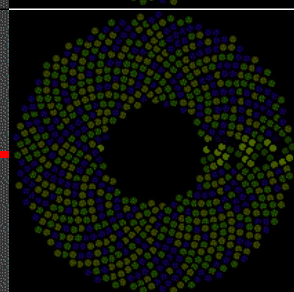
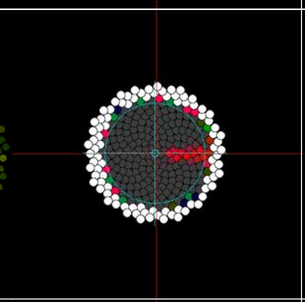
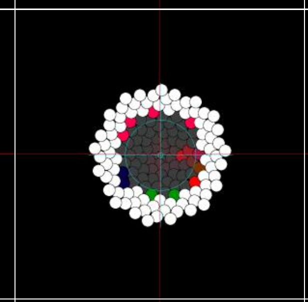
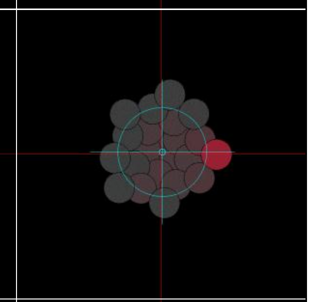
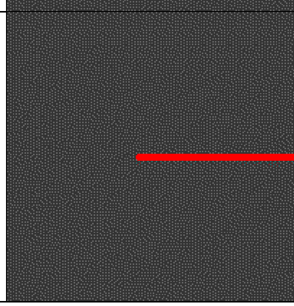
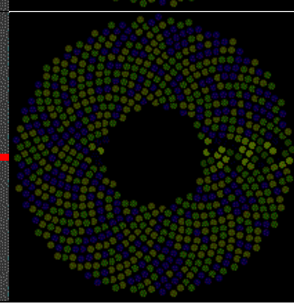
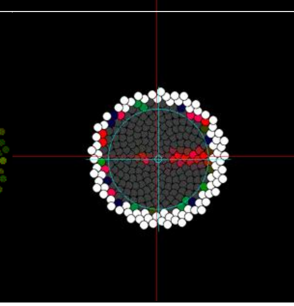
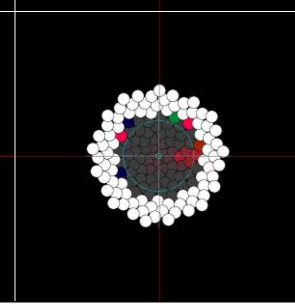
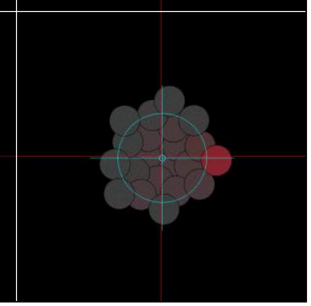
Table 22: Time sequence of line moving into blind spot then being filled-in					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
21					
22					
23					

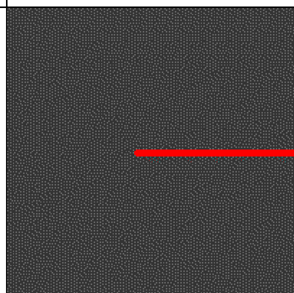
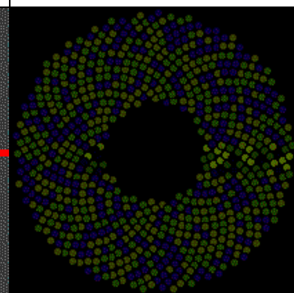
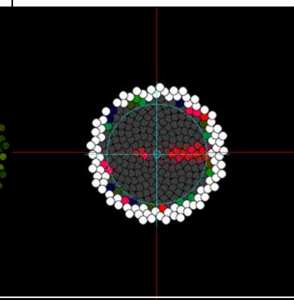
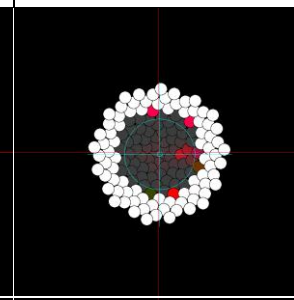
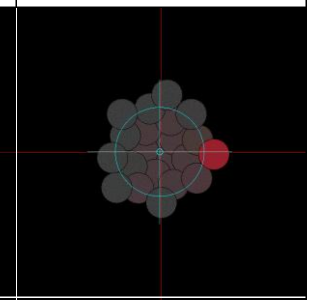
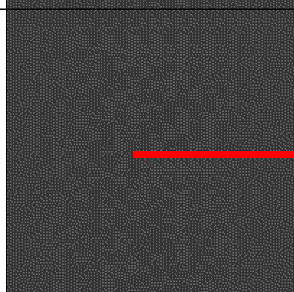
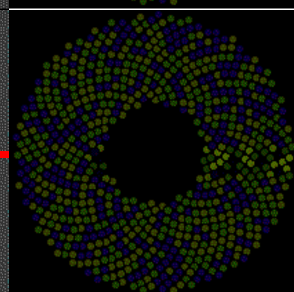
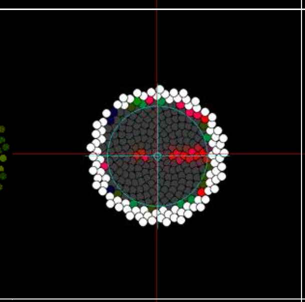
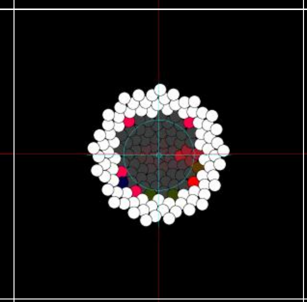
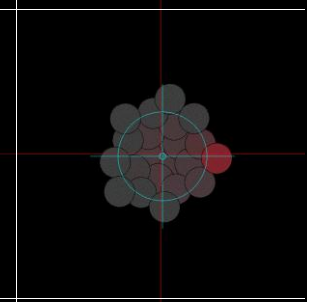
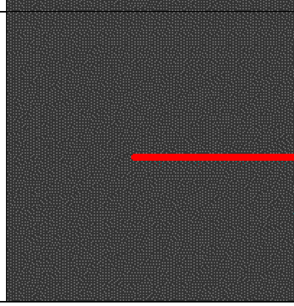
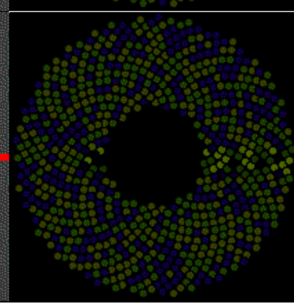
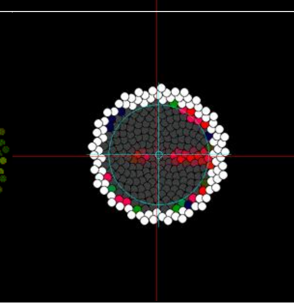
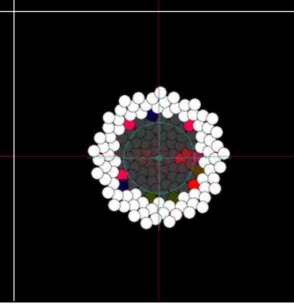
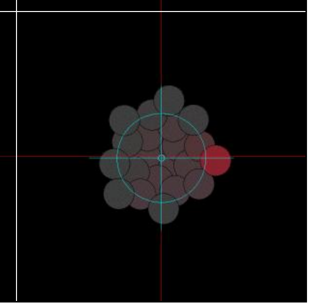
Table 22: Time sequence of line moving into blind spot then being filled-in					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
24					
25					
26					

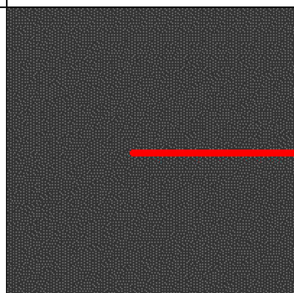
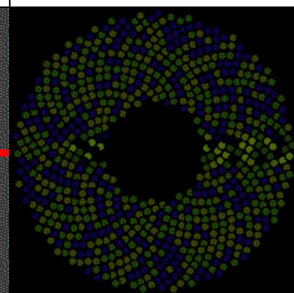
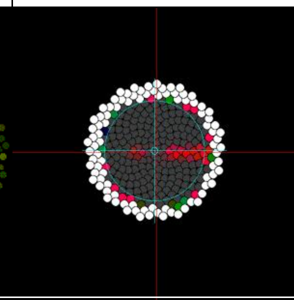
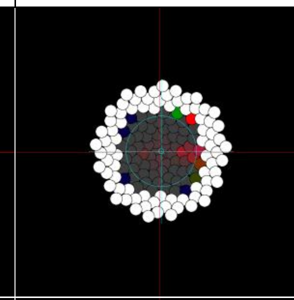
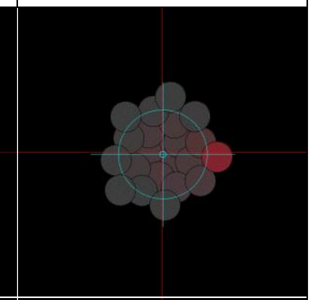
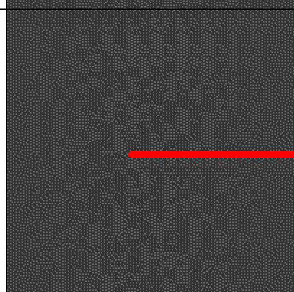
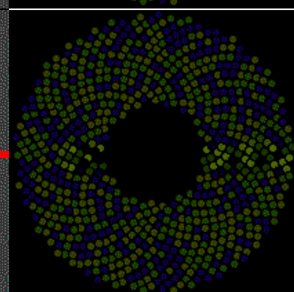
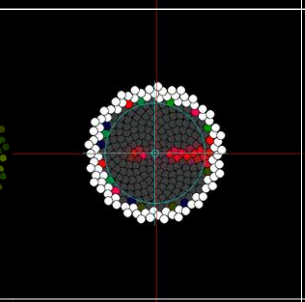
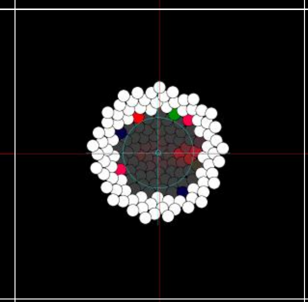
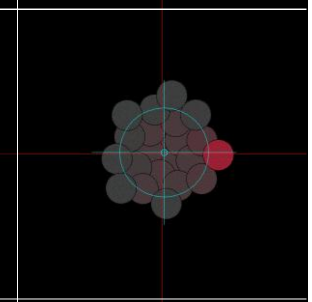
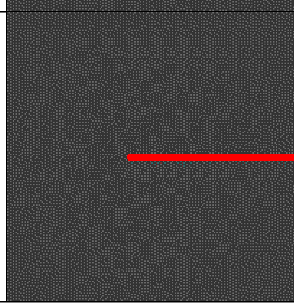
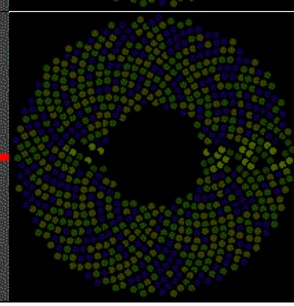
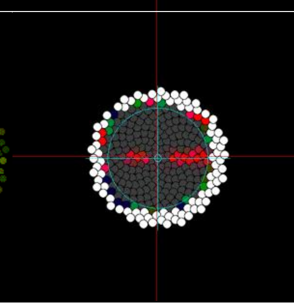
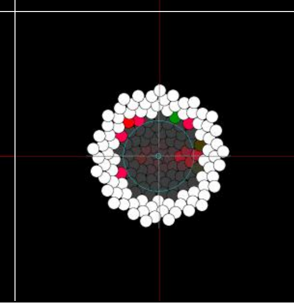
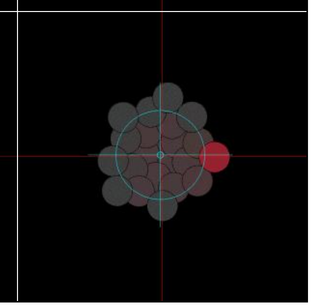
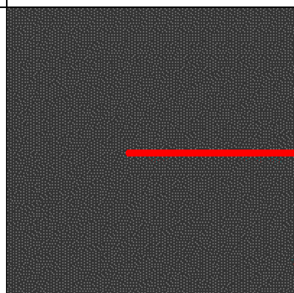
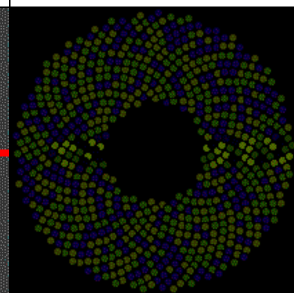
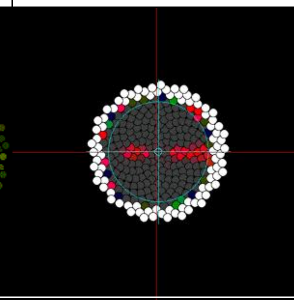
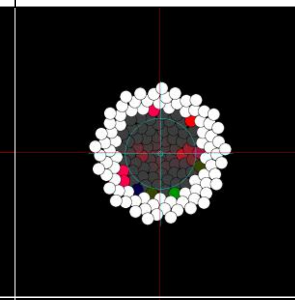
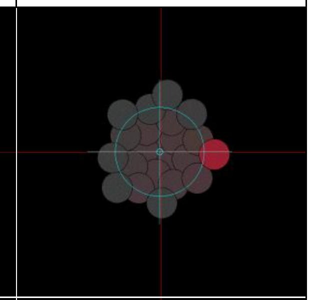
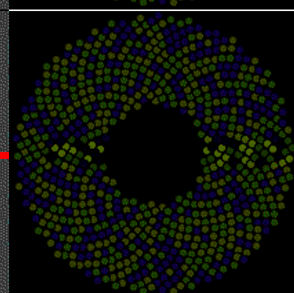
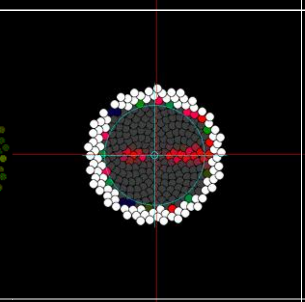
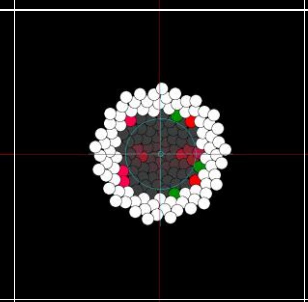
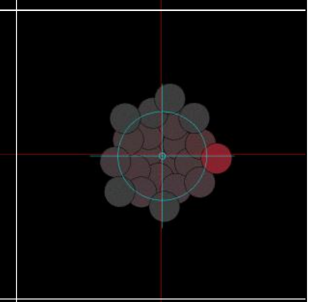
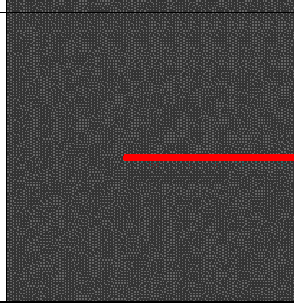
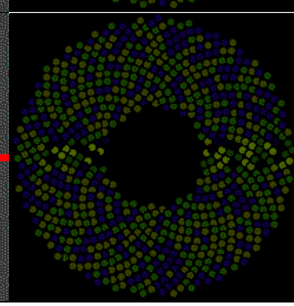
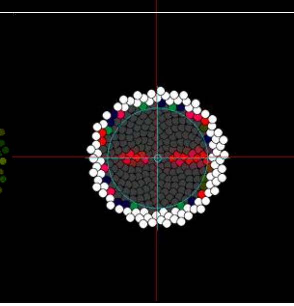
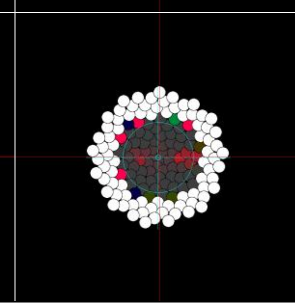
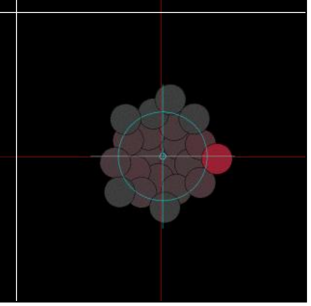
Table 22: Time sequence of line moving into blind spot then being filled-in					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
27					
28					
29					

Table 22: Time sequence of line moving into blind spot then being filled-in					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
30					
31					
32					

5.3.7 Test 7 results: Line static with background masked

Table 23: Time sequence of static line over blind spot with background masked

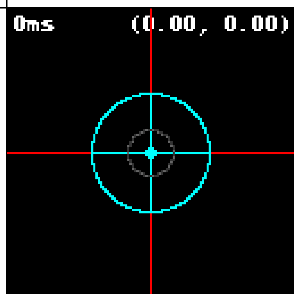
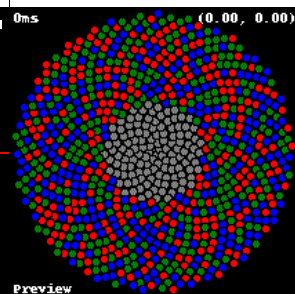
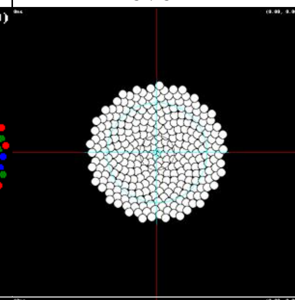
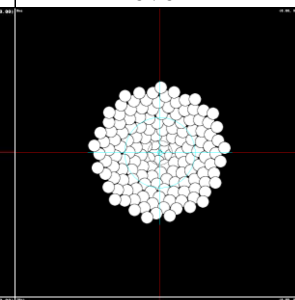
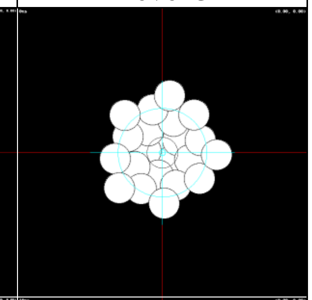
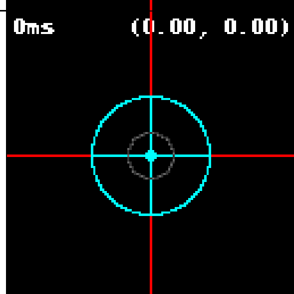
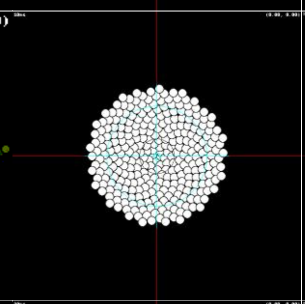
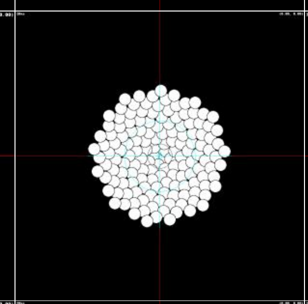
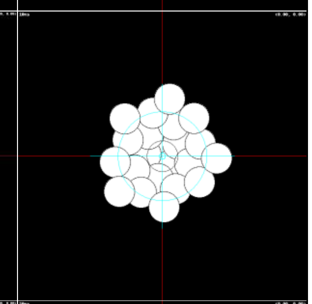
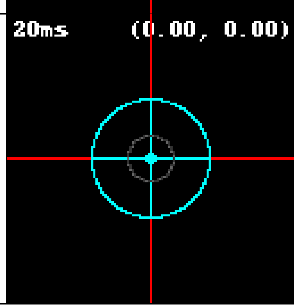
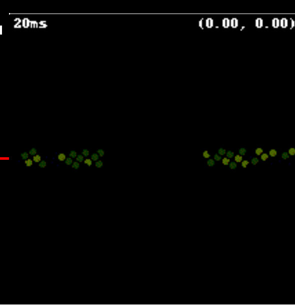
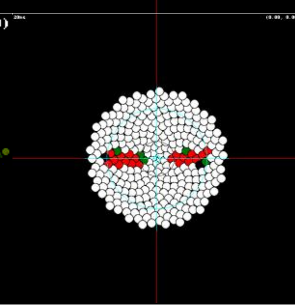
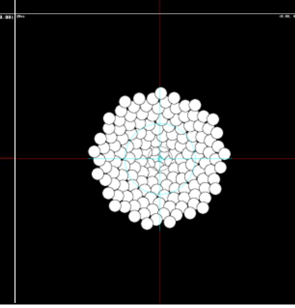
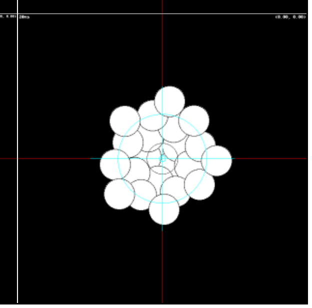
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
0					
1					
2					

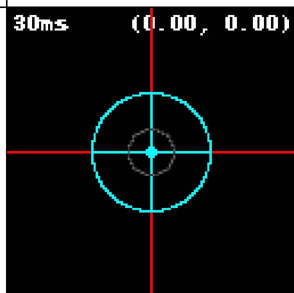
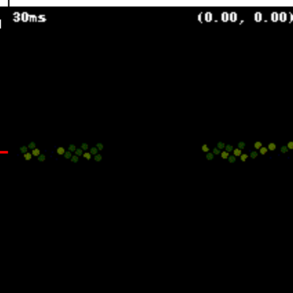
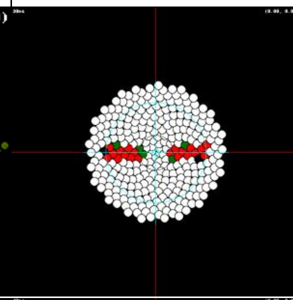
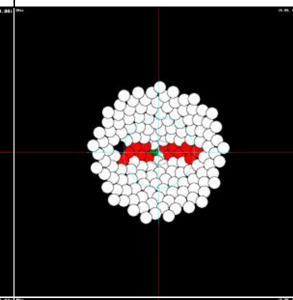
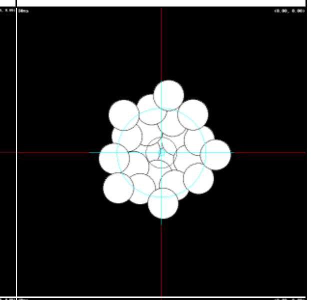
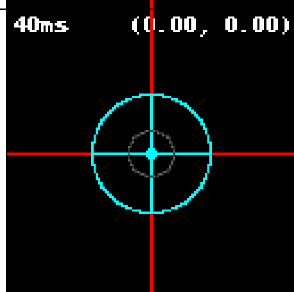
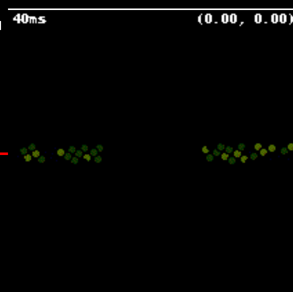
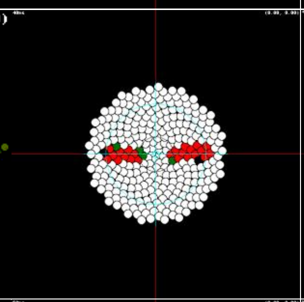
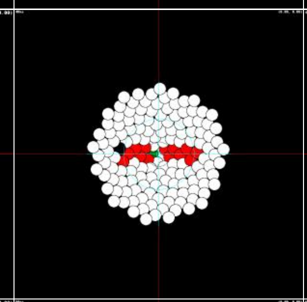
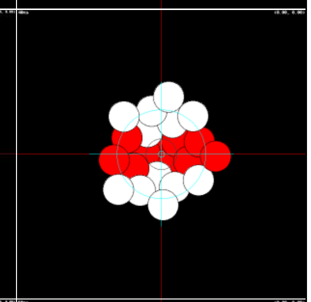
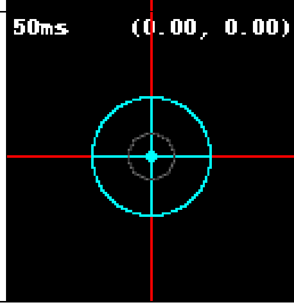
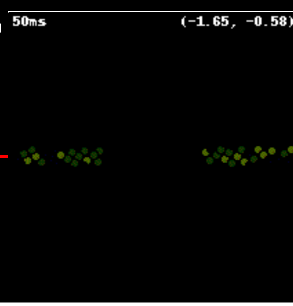
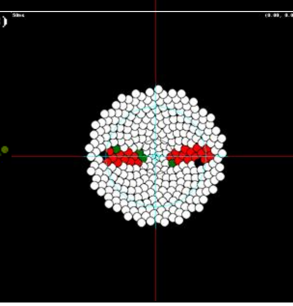
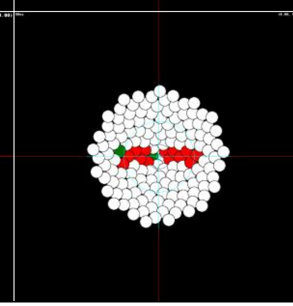
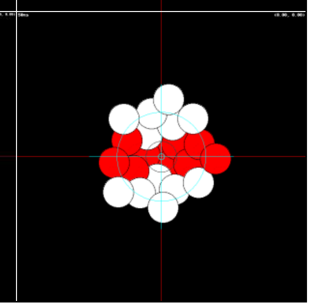
Table 23: Time sequence of static line over blind spot with background masked					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
3					
4					
5					

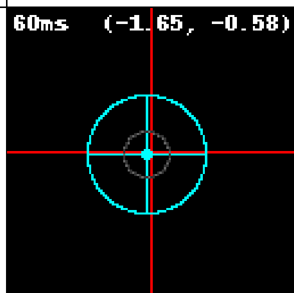
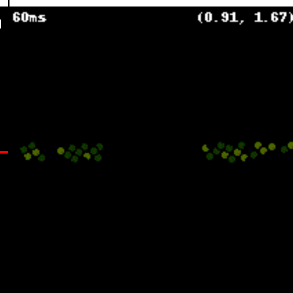
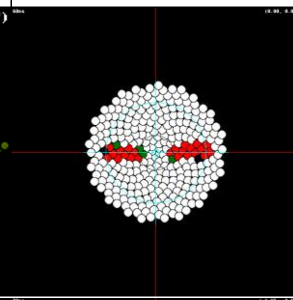
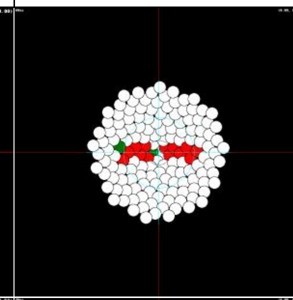
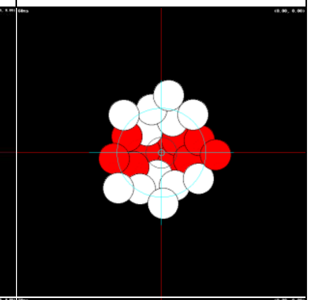
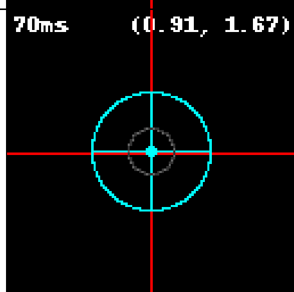
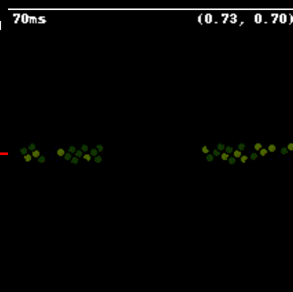
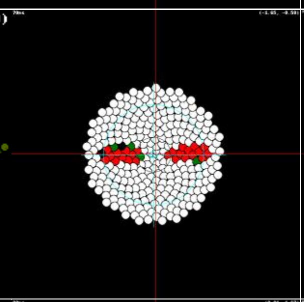
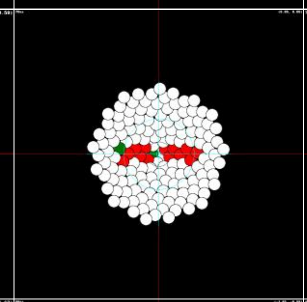
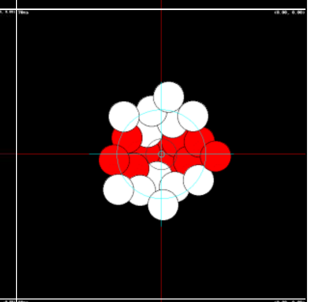
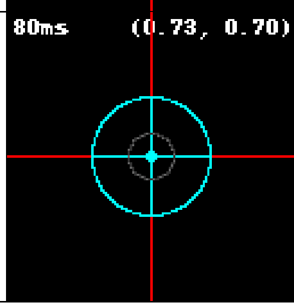
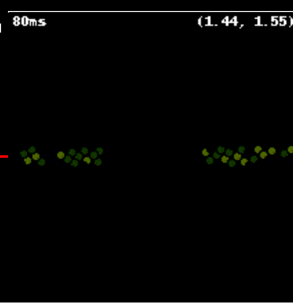
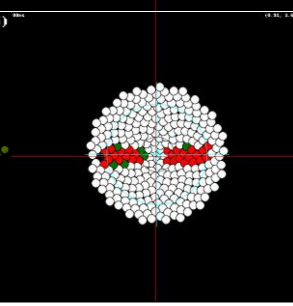
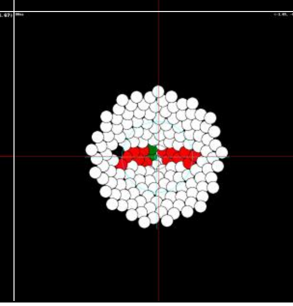
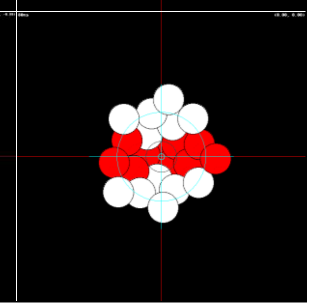
Table 23: Time sequence of static line over blind spot with background masked					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
6					
7					
8					

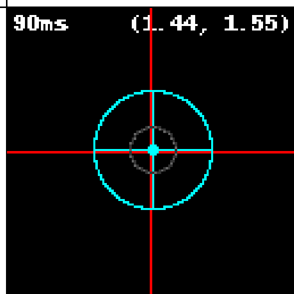
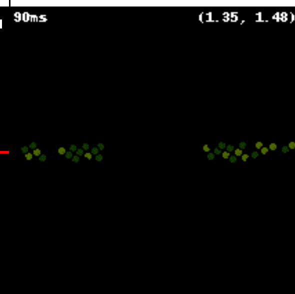
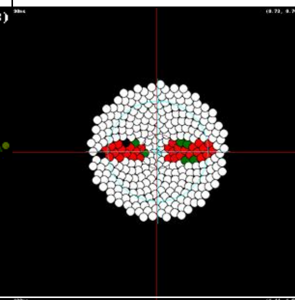
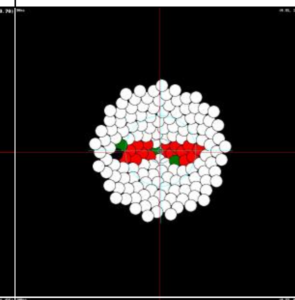
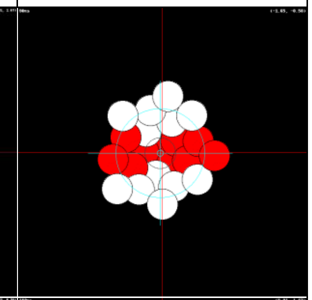
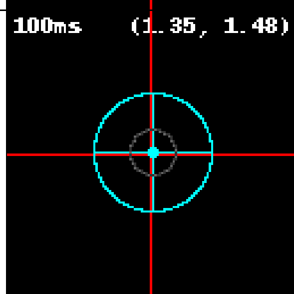
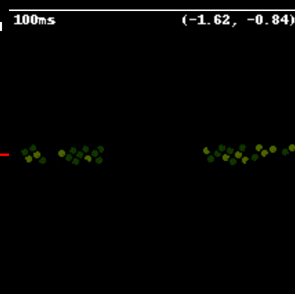
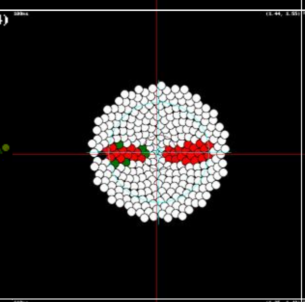
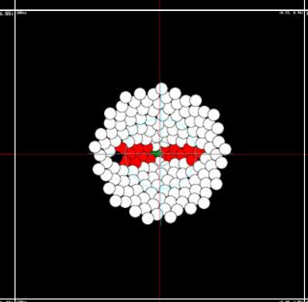
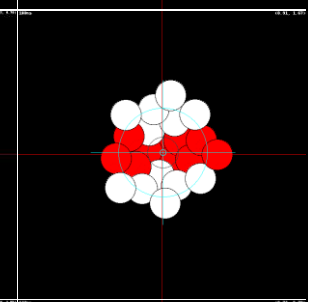
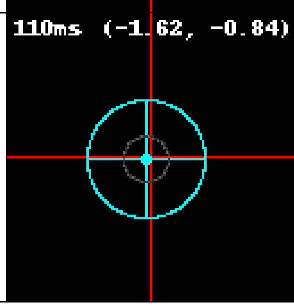
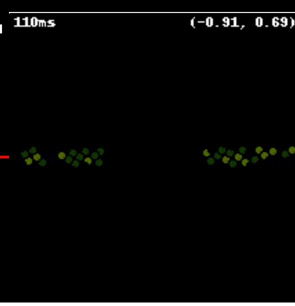
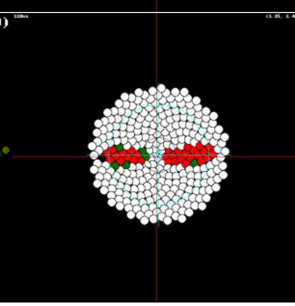
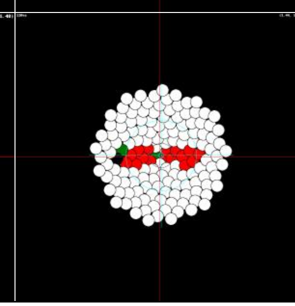
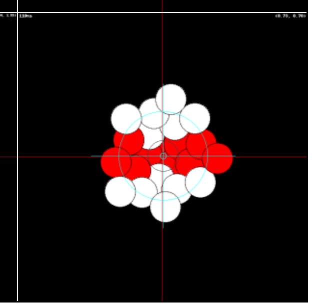
Table 23: Time sequence of static line over blind spot with background masked					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
9					
10					
11					

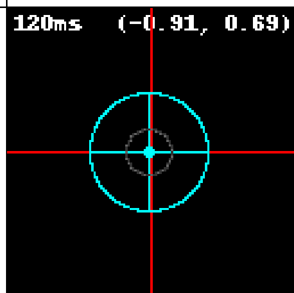
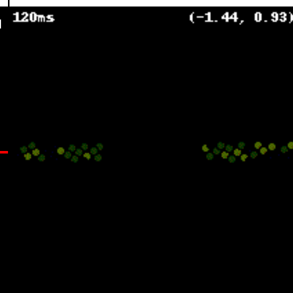
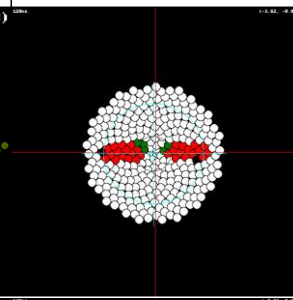
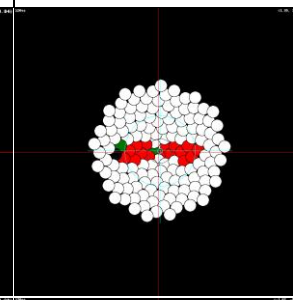
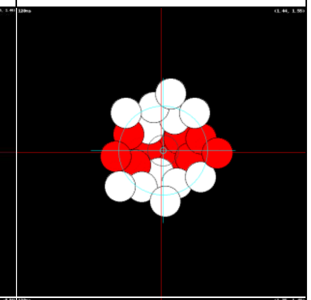
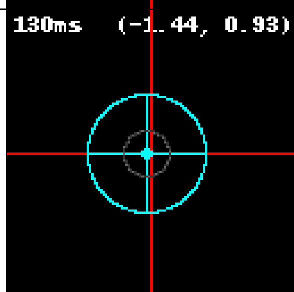
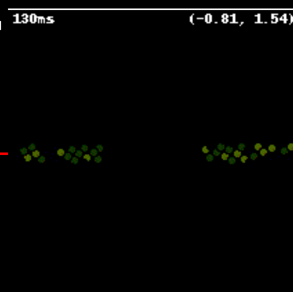
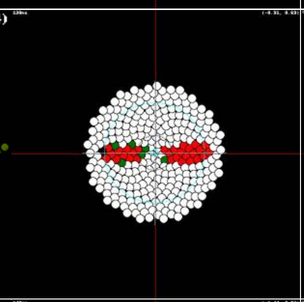
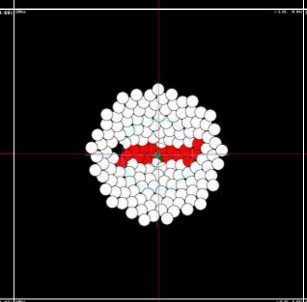
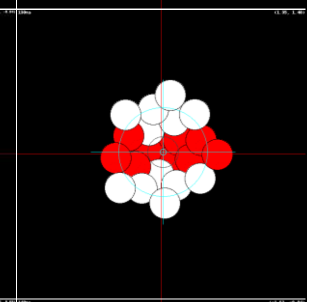
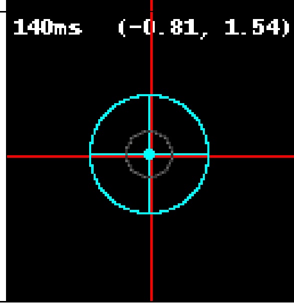
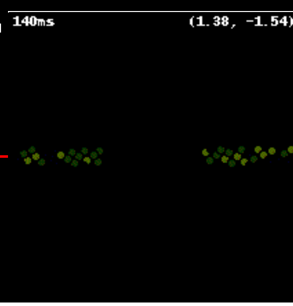
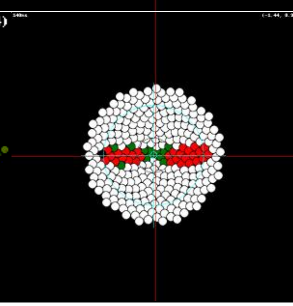
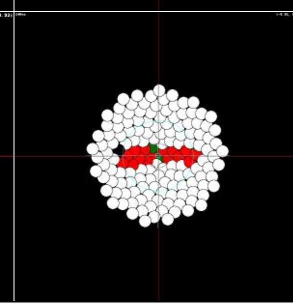
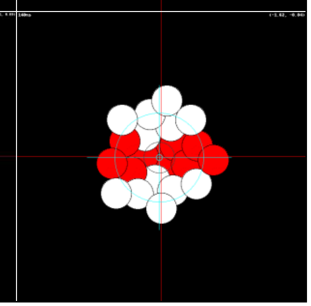
Table 23: Time sequence of static line over blind spot with background masked					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
12					
13					
14					

Table 23: Time sequence of static line over blind spot with background masked

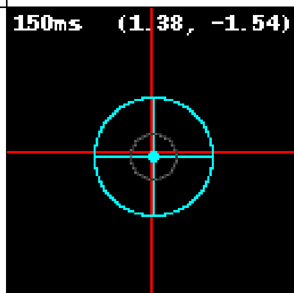
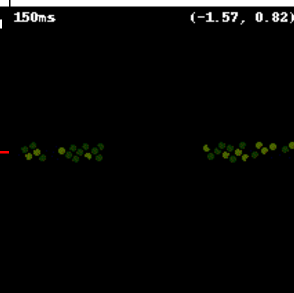
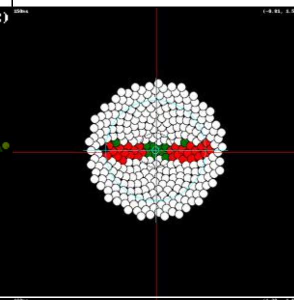
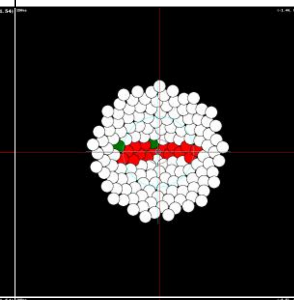
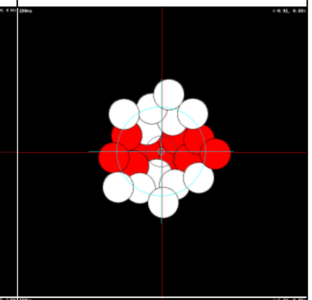
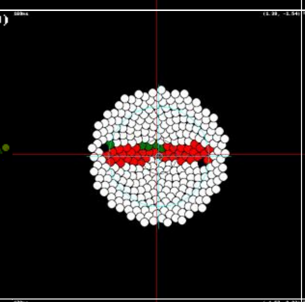
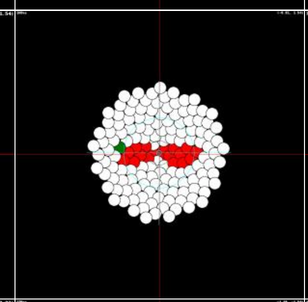
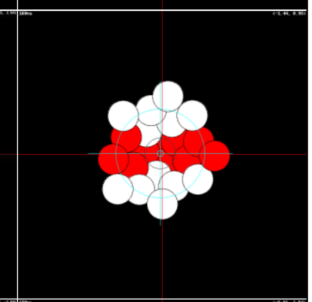
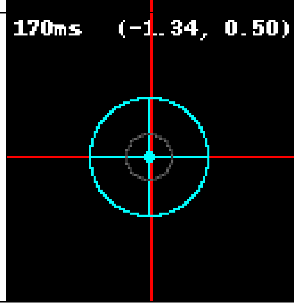
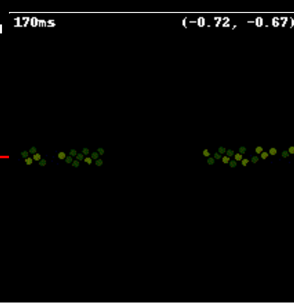
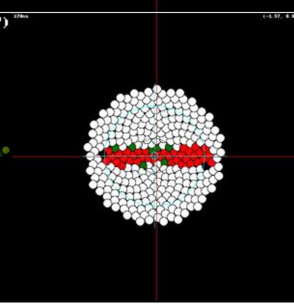
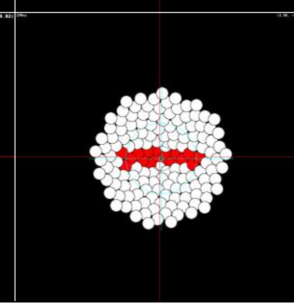
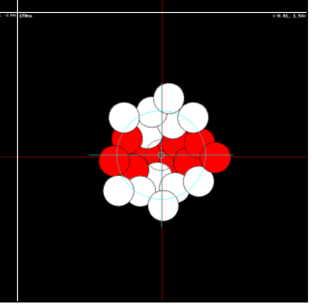
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
15					
16					
17					

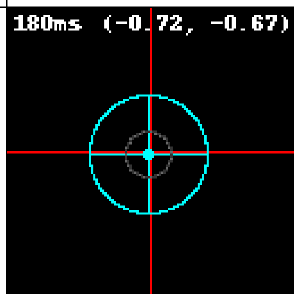
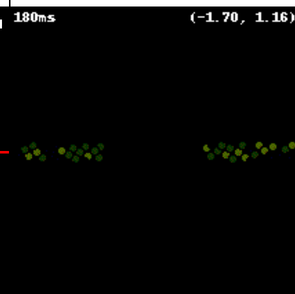
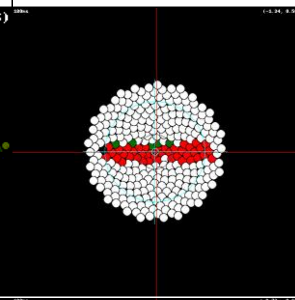
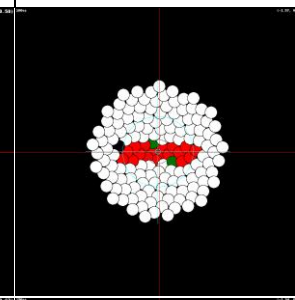
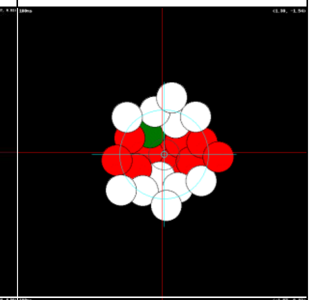
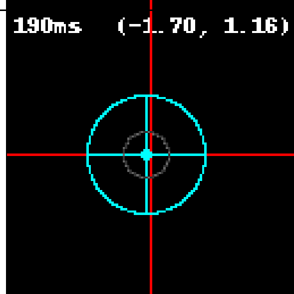
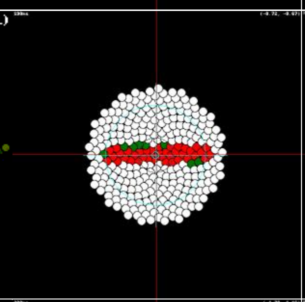
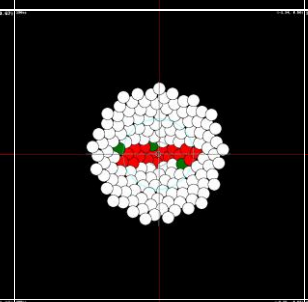
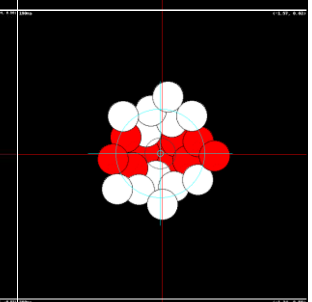
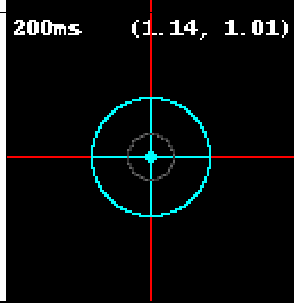
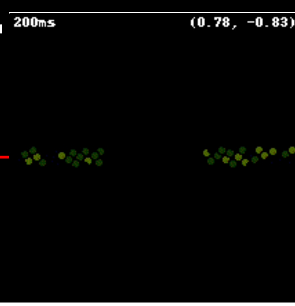
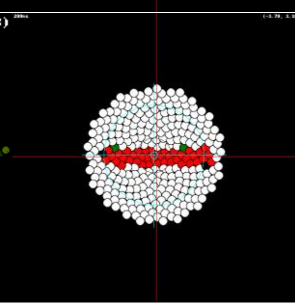
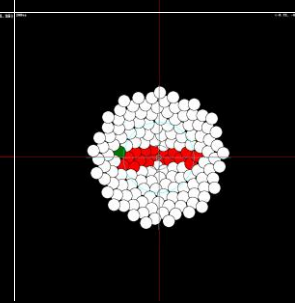
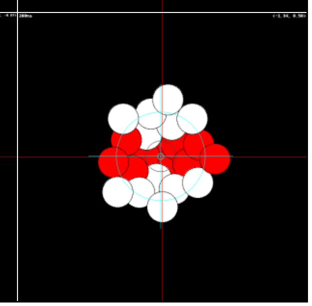
Table 23: Time sequence of static line over blind spot with background masked					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
18					
19					
20					

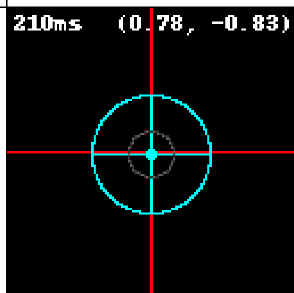
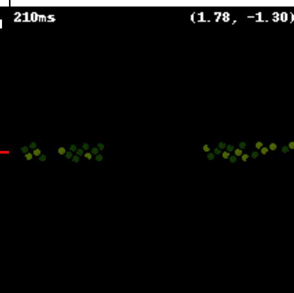
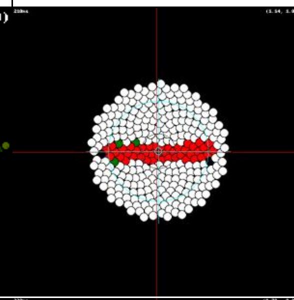
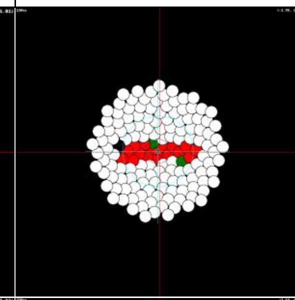
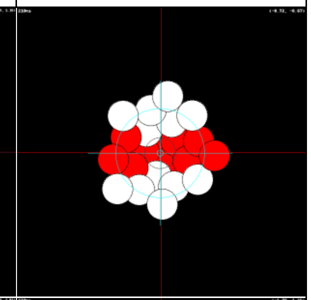
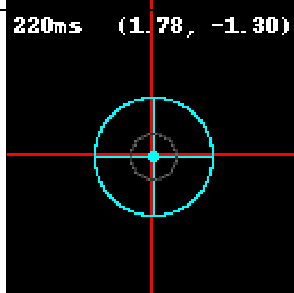
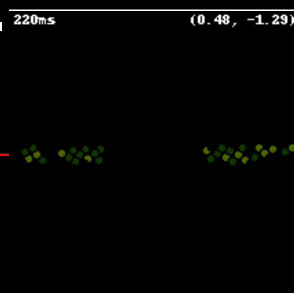
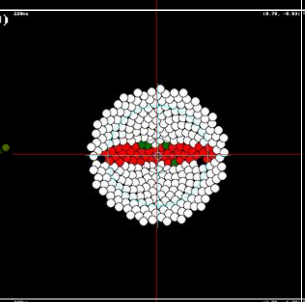
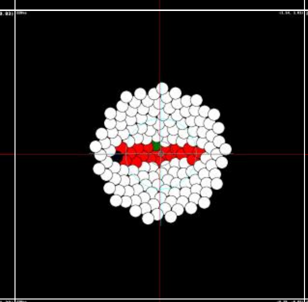
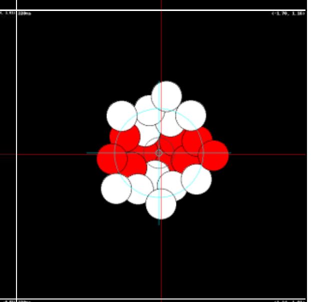
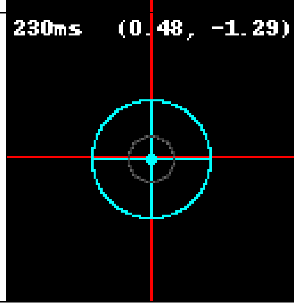
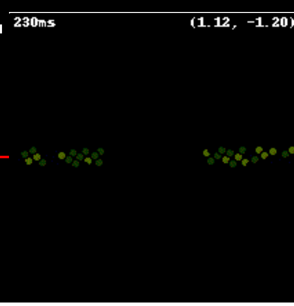
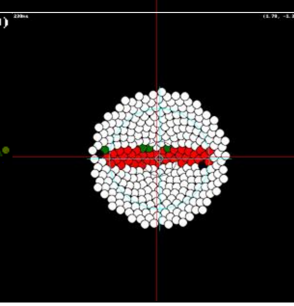
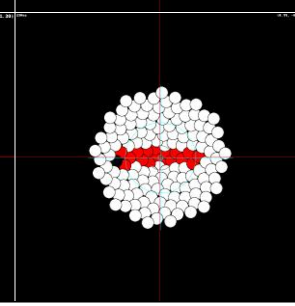
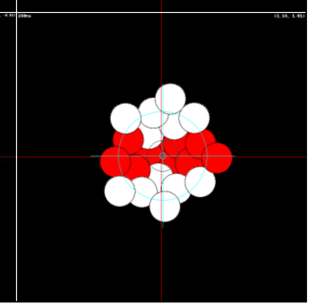
Table 23: Time sequence of static line over blind spot with background masked					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
21					
22					
23					

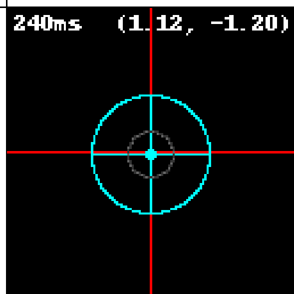
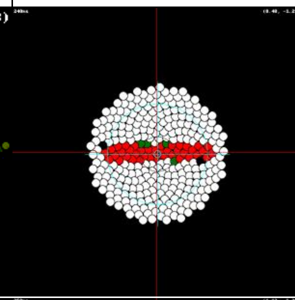
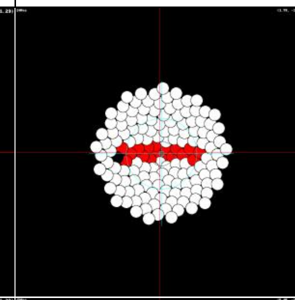
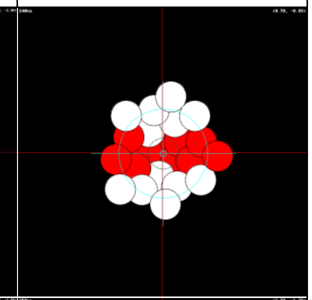
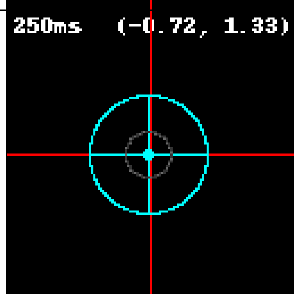
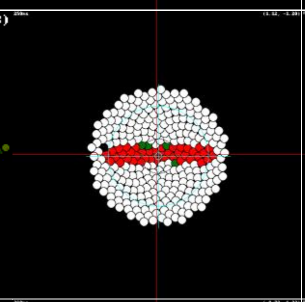
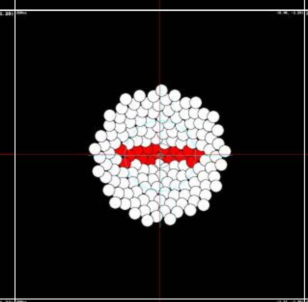
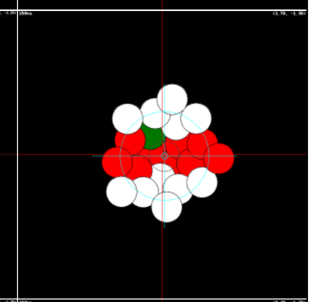
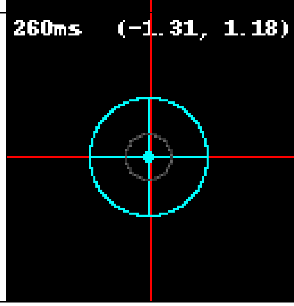
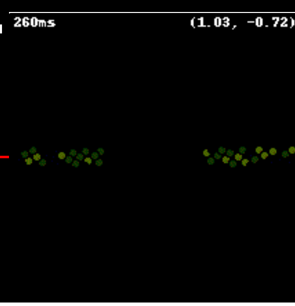
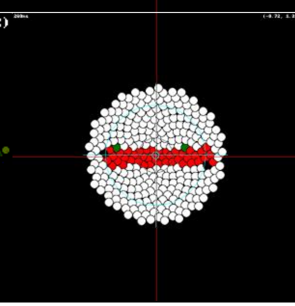
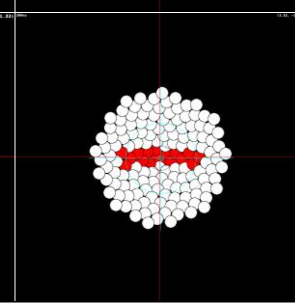
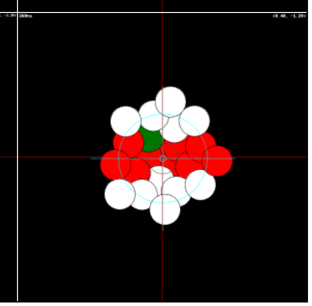
Table 23: Time sequence of static line over blind spot with background masked					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
24					
25					
26					

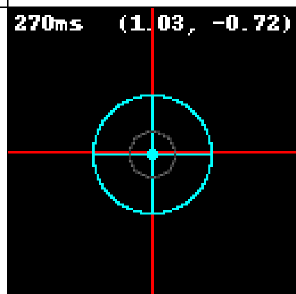
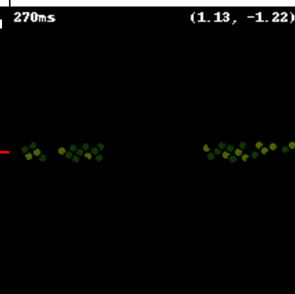
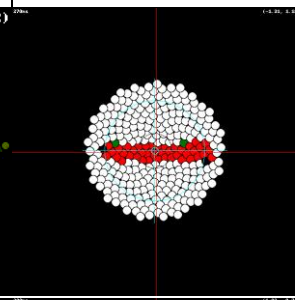
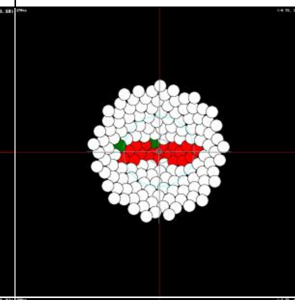
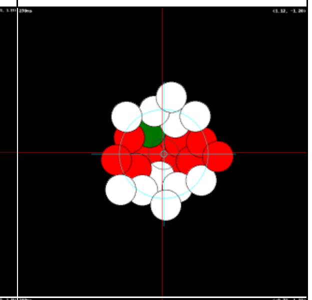
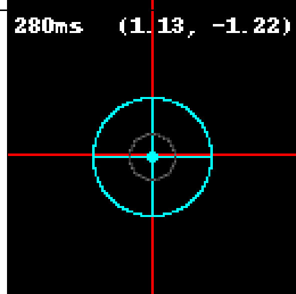
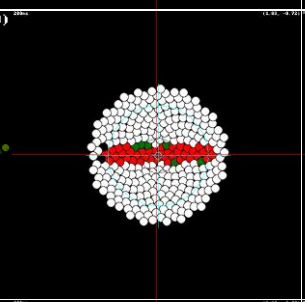
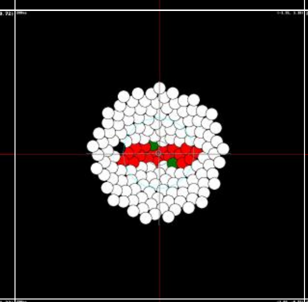
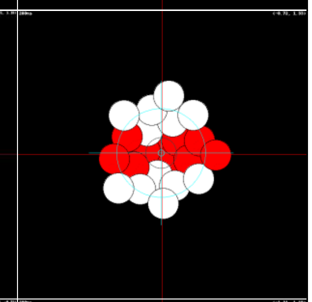
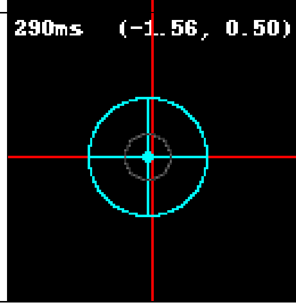
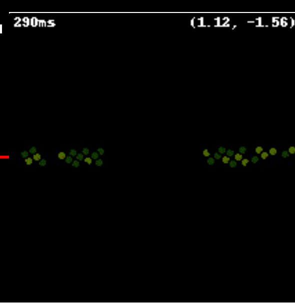
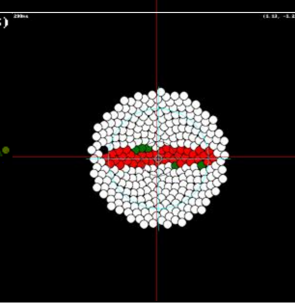
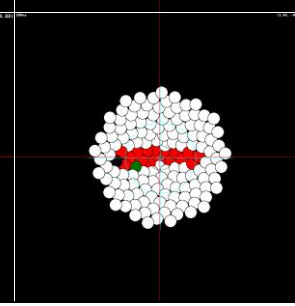
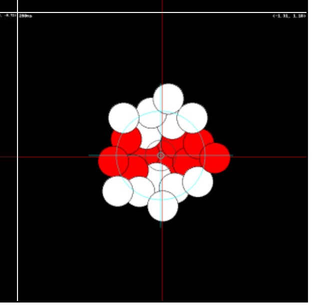
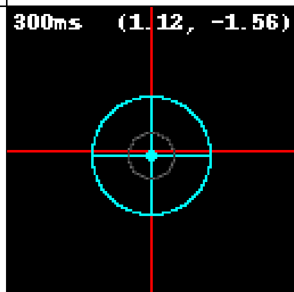
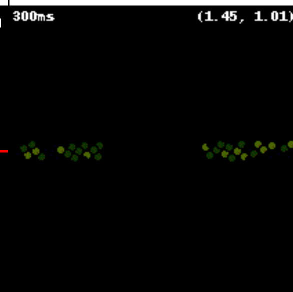
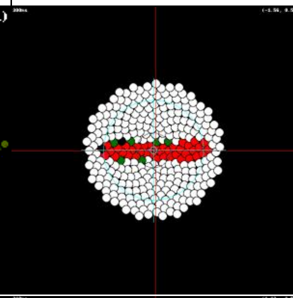
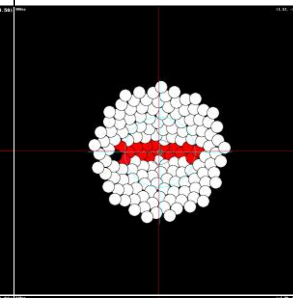
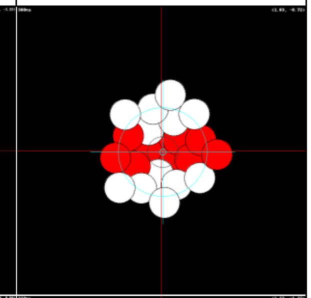
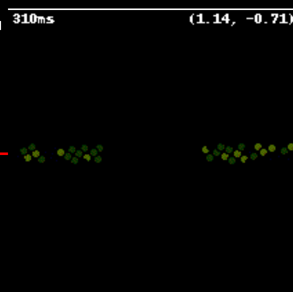
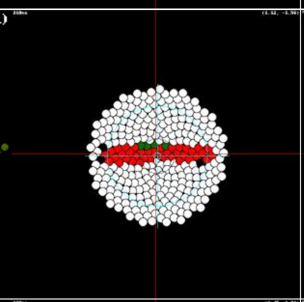
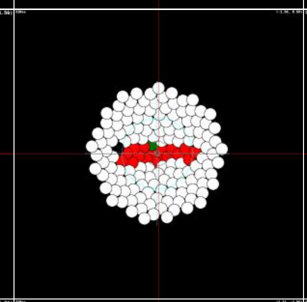
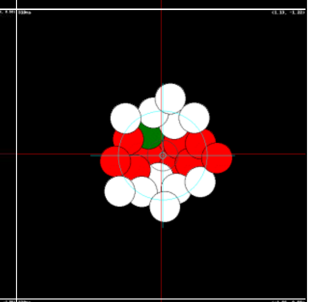
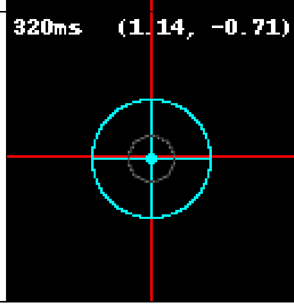
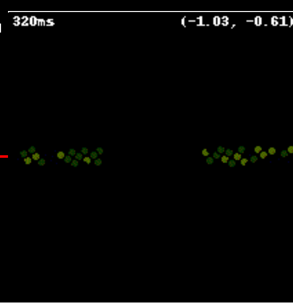
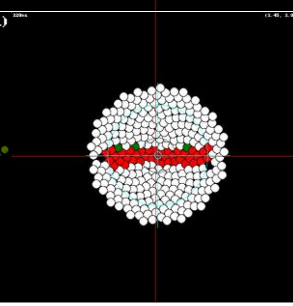
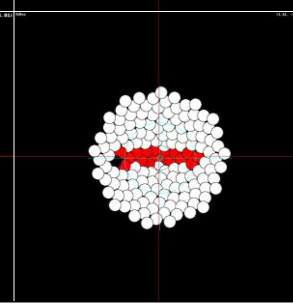
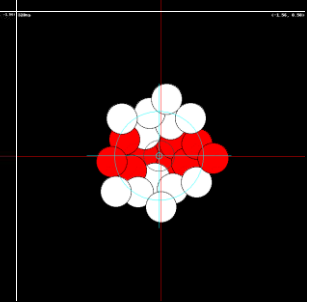
Table 23: Time sequence of static line over blind spot with background masked					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
27					
28					
29					

Table 23: Time sequence of static line over blind spot with background masked					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
30					
31					
32					

5.3.8 Test 8 results: Filling-in ring then saccade

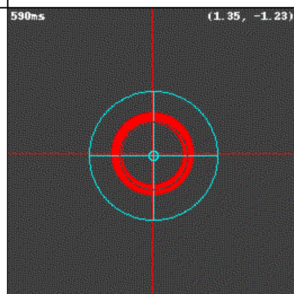
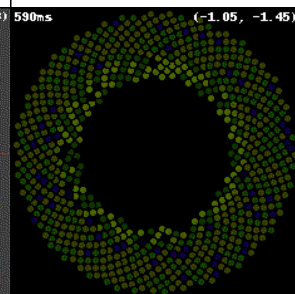
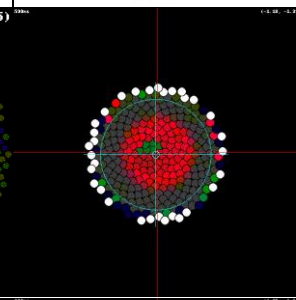
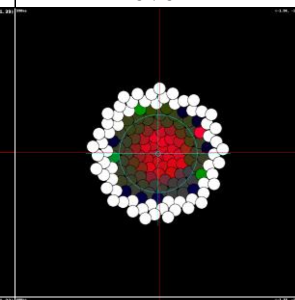
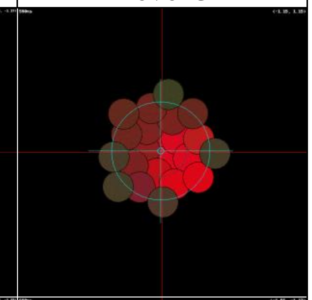
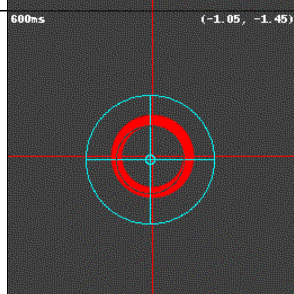
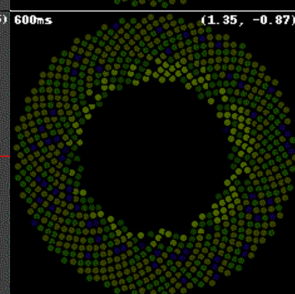
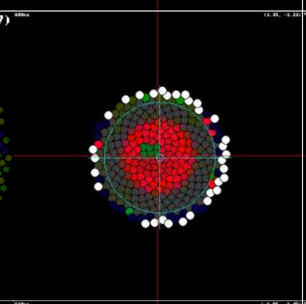
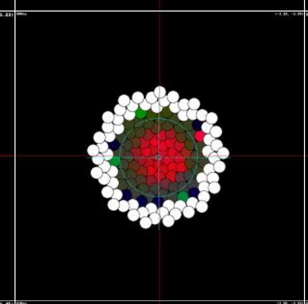
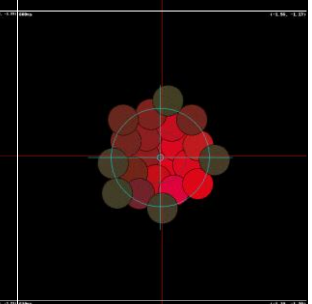
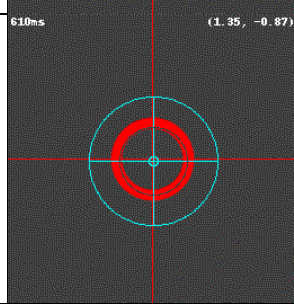
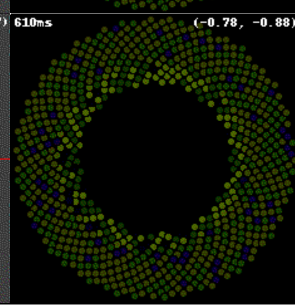
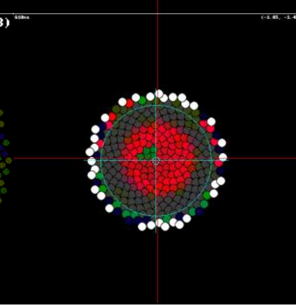
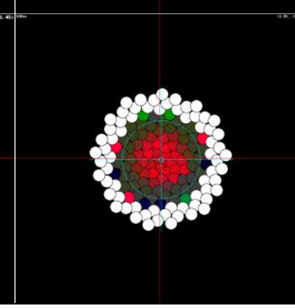
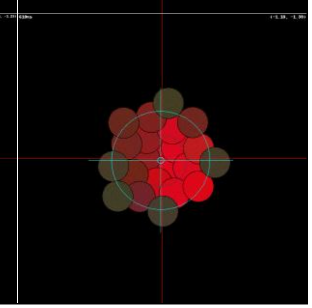
Table 24: Time sequence of filling-in blind spot with ring then saccade					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
59					
60					
61					

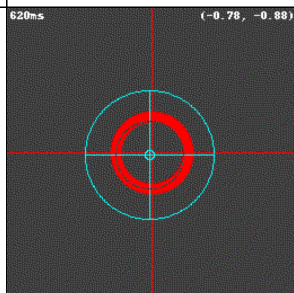
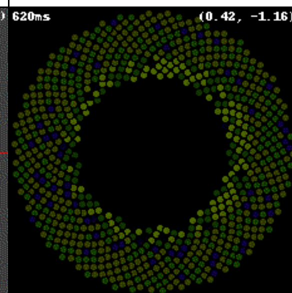
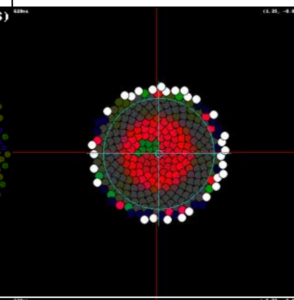
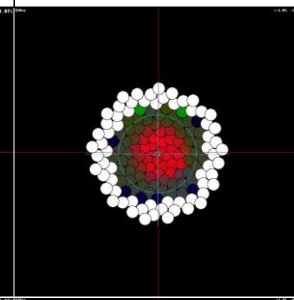
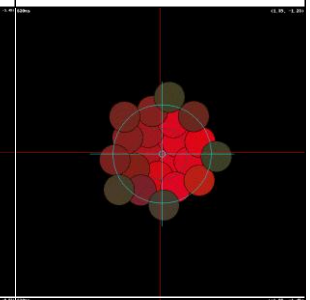
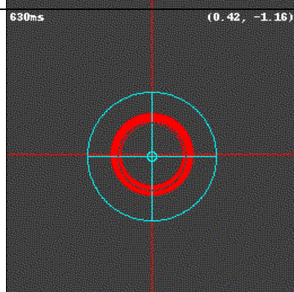
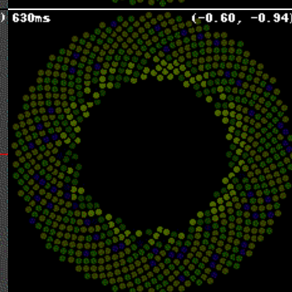
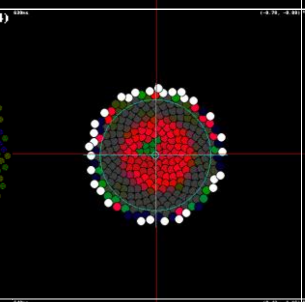
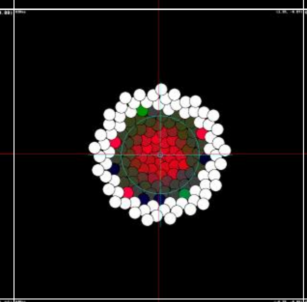
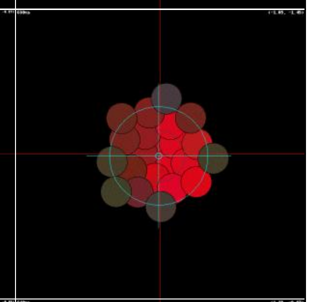
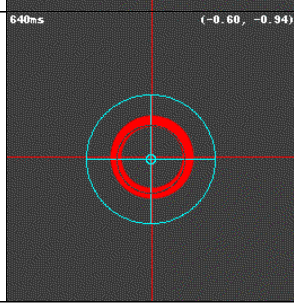
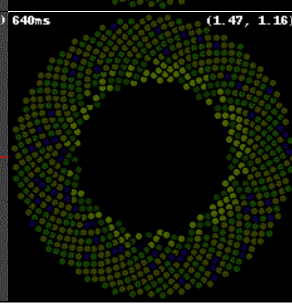
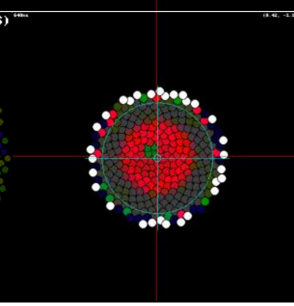
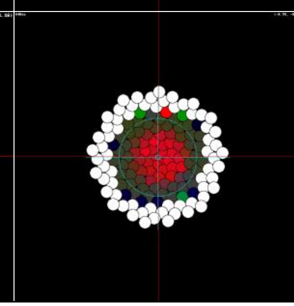
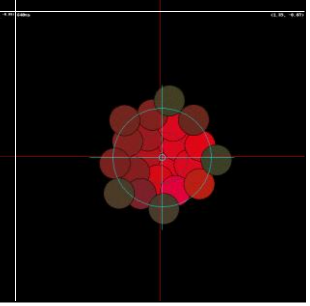
Table 24: Time sequence of filling-in blind spot with ring then saccade					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
62					
63					
64					

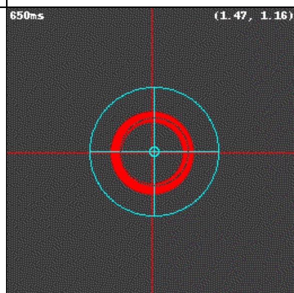
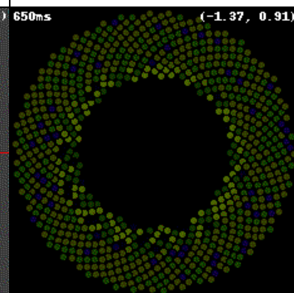
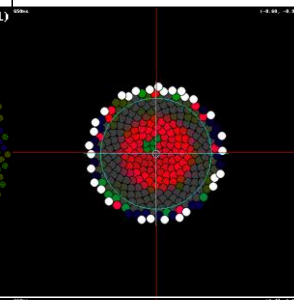
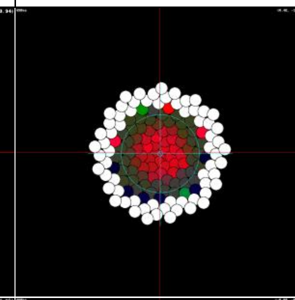
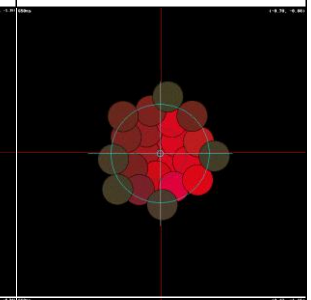
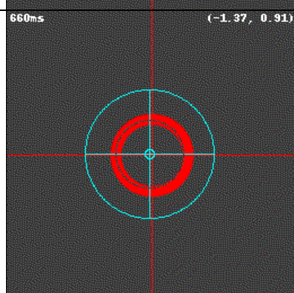
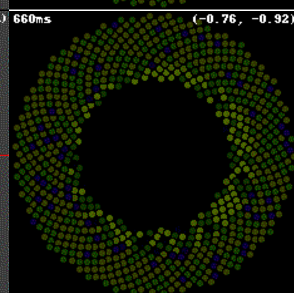
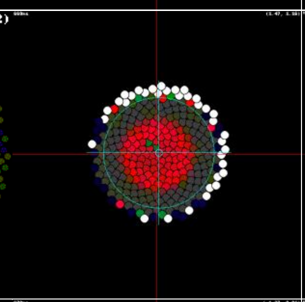
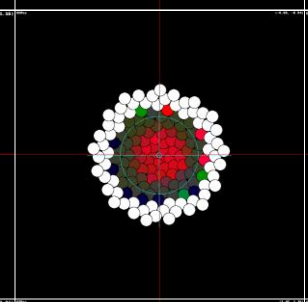
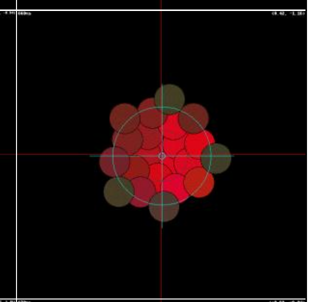
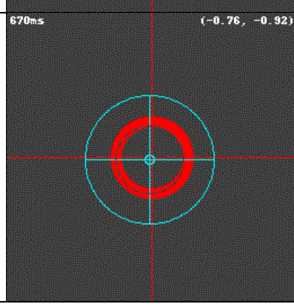
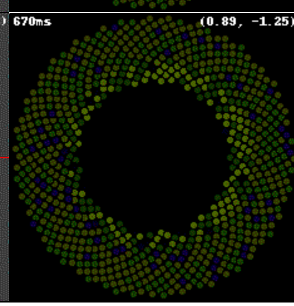
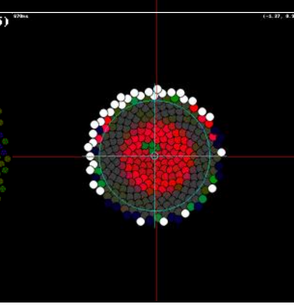
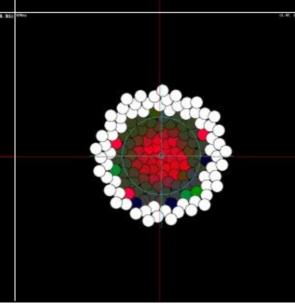
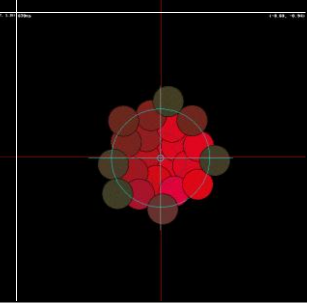
Table 24: Time sequence of filling-in blind spot with ring then saccade					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
65					
66					
67					

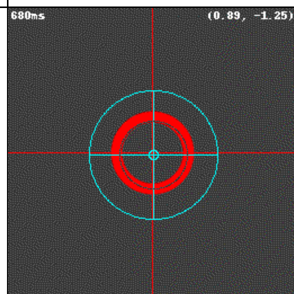
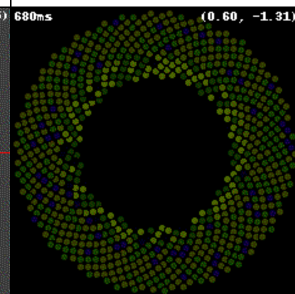
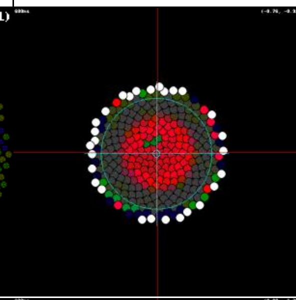
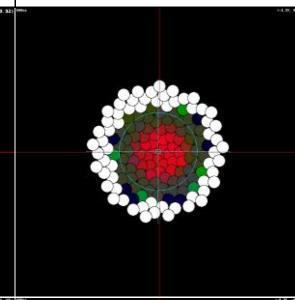
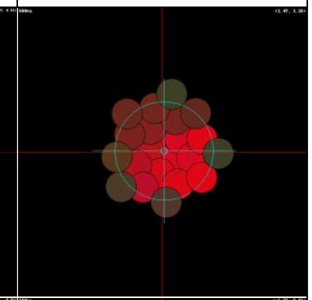
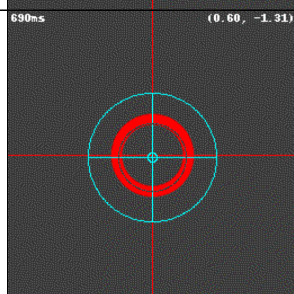
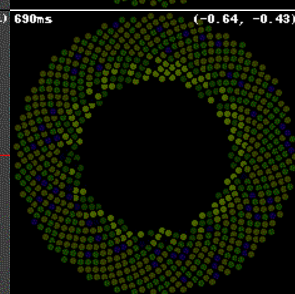
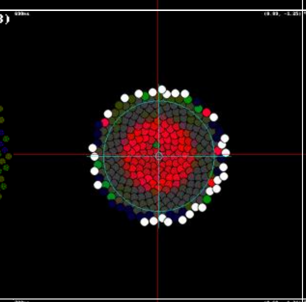
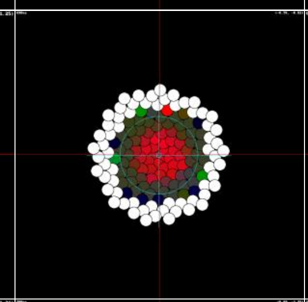
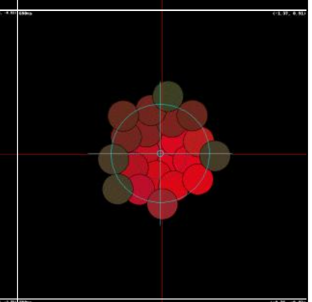
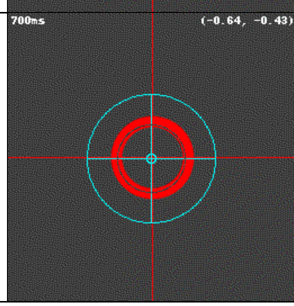
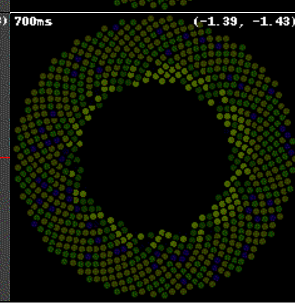
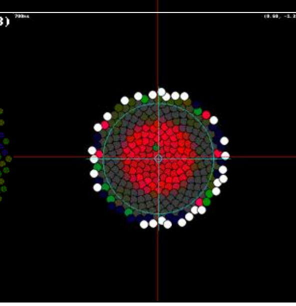
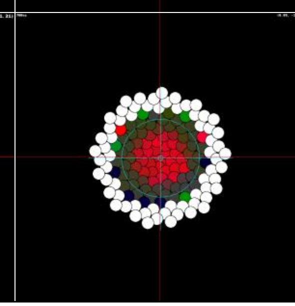
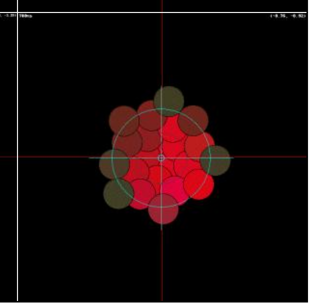
Table 24: Time sequence of filling-in blind spot with ring then saccade					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
68					
69					
70					

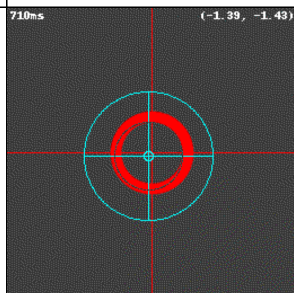
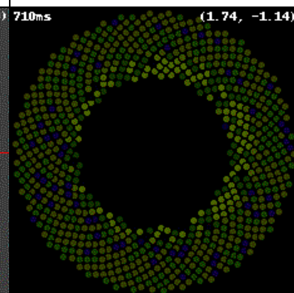
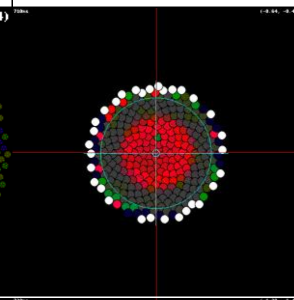
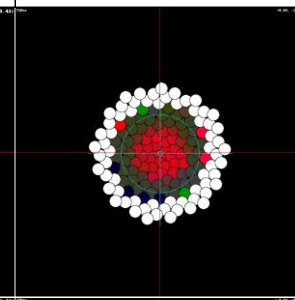
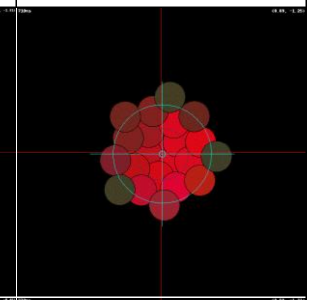
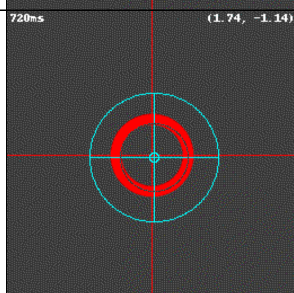
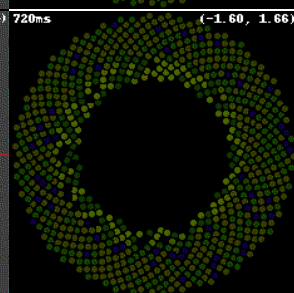
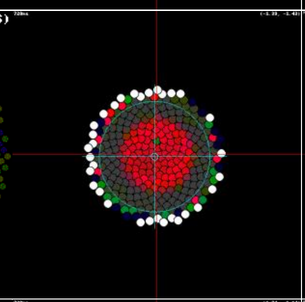
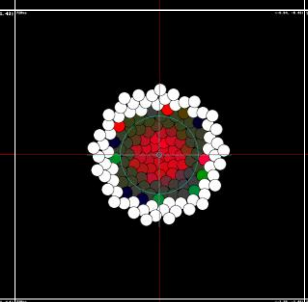
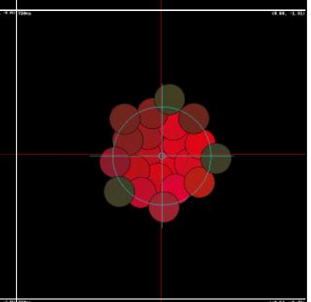
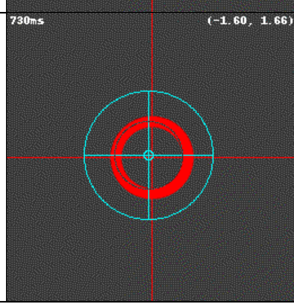
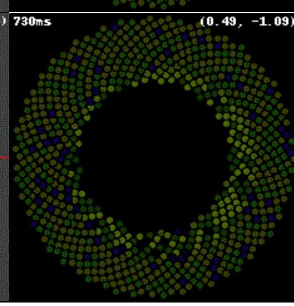
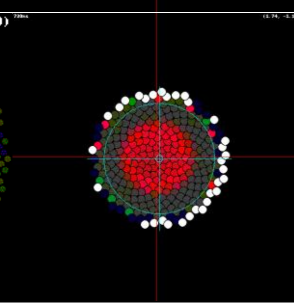
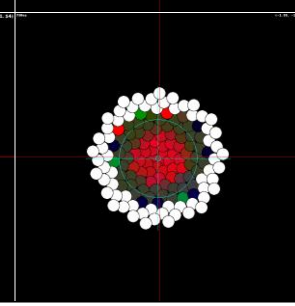
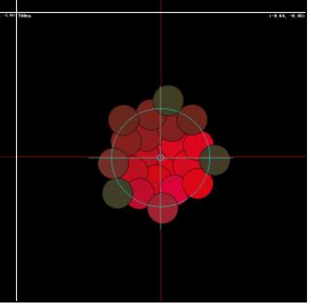
Table 24: Time sequence of filling-in blind spot with ring then saccade					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
71					
72					
73					

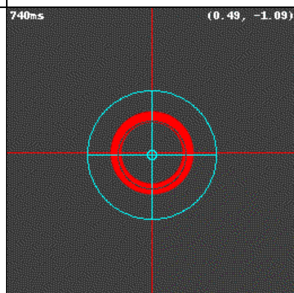
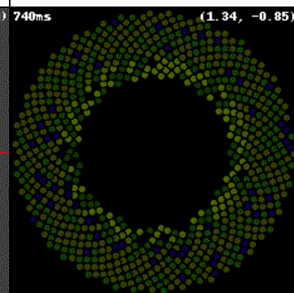
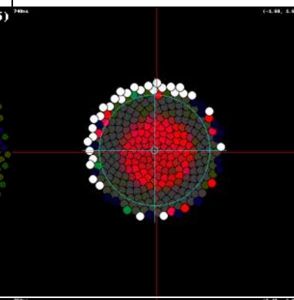
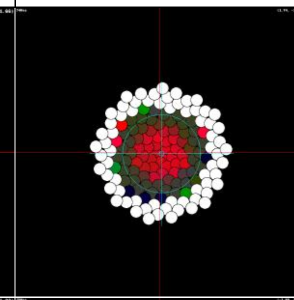
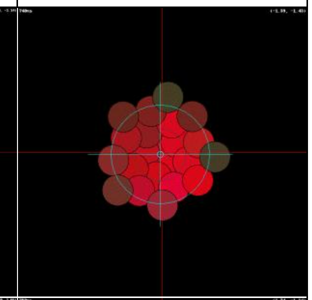
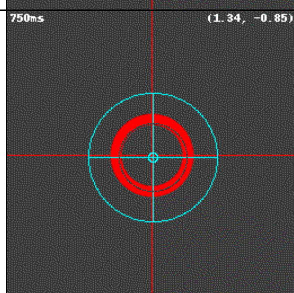
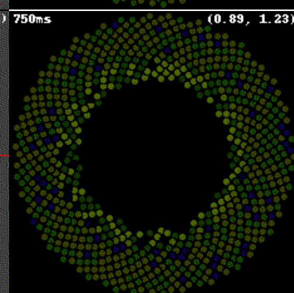
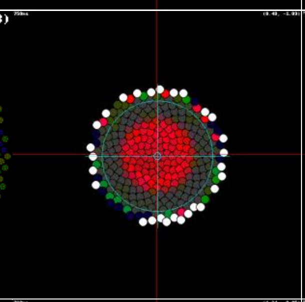
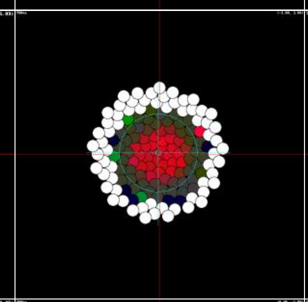
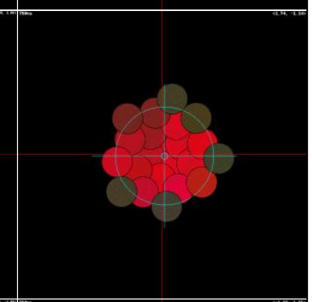
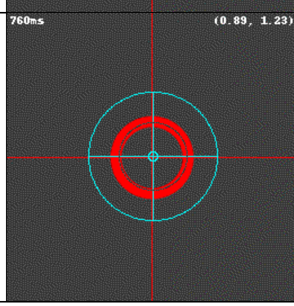
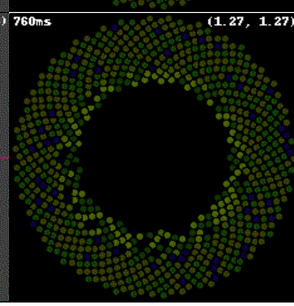
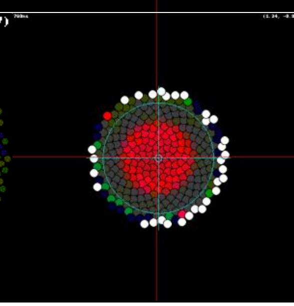
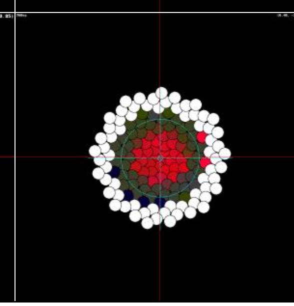
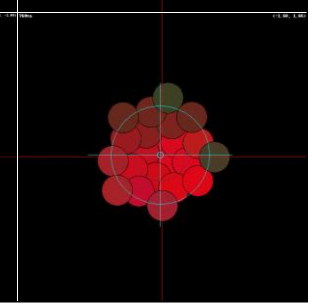
Table 24: Time sequence of filling-in blind spot with ring then saccade					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
74					
75					
76					

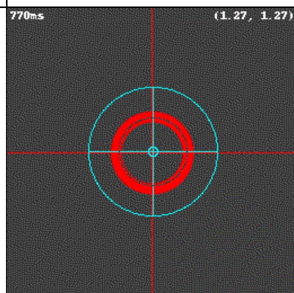
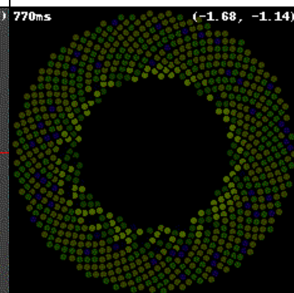
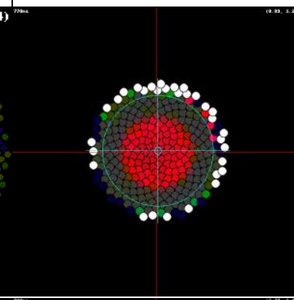
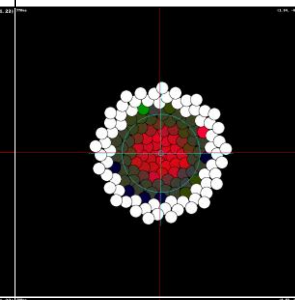
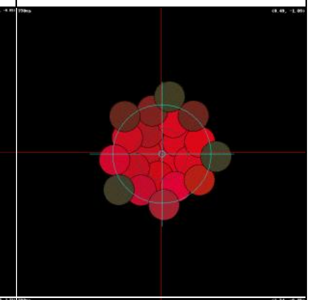
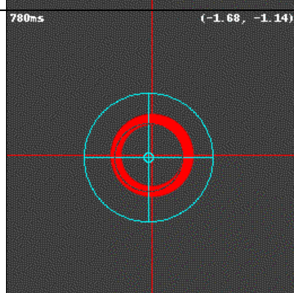
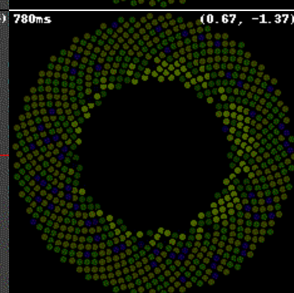
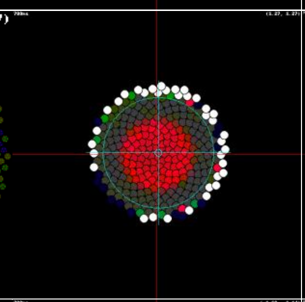
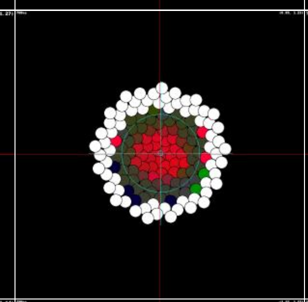
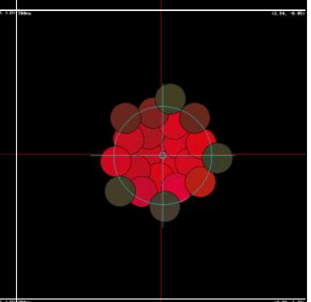
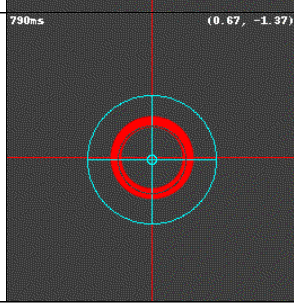
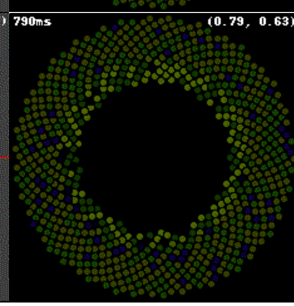
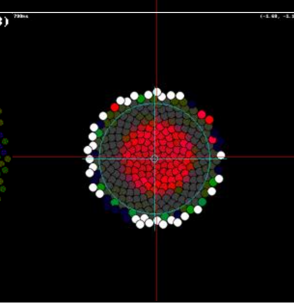
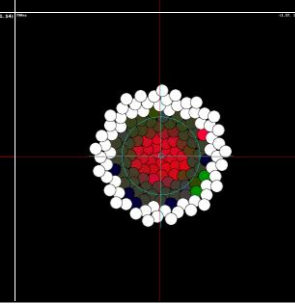
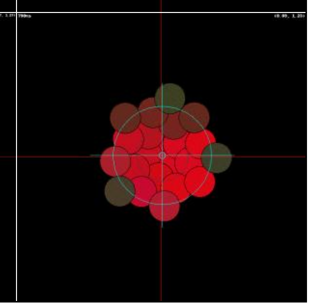
Table 24: Time sequence of filling-in blind spot with ring then saccade					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
77					
78					
79					

Table 24: Time sequence of filling-in blind spot with ring then saccade

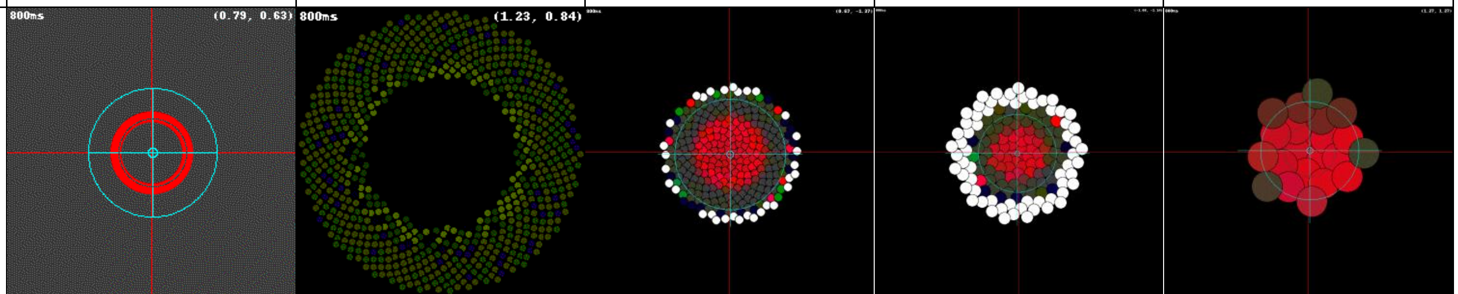
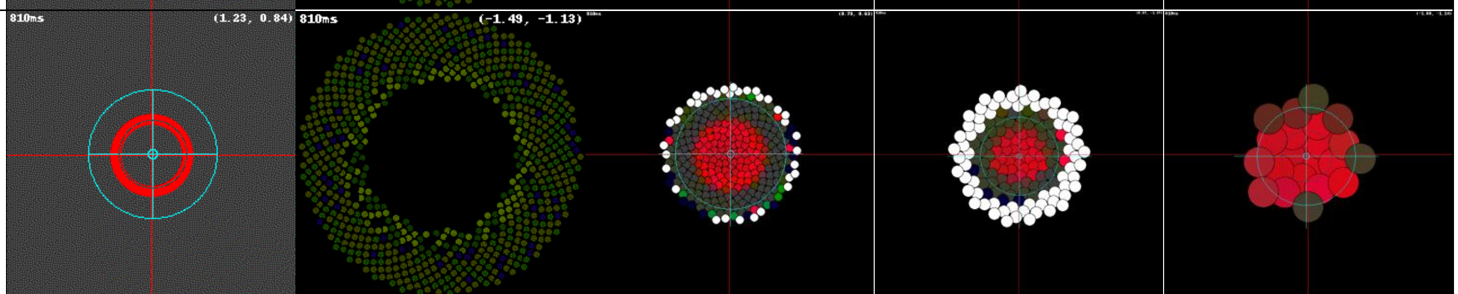
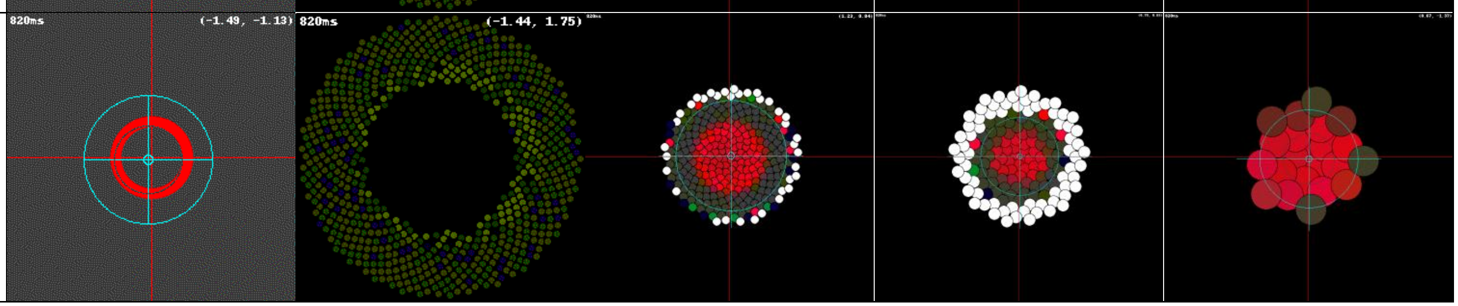
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
80					
81					
82					

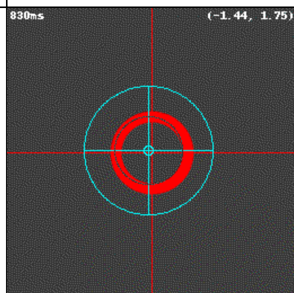
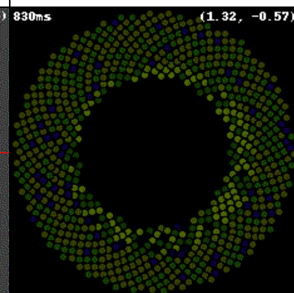
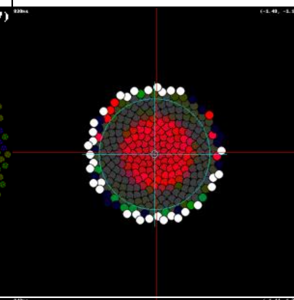
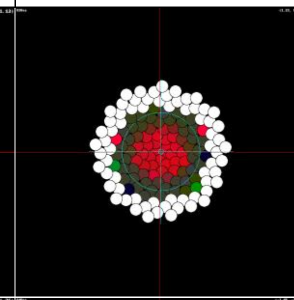
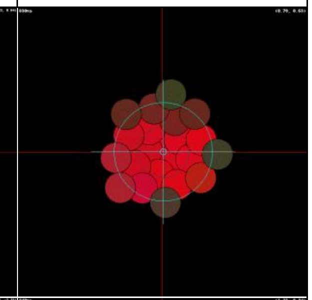
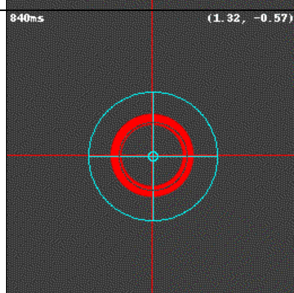
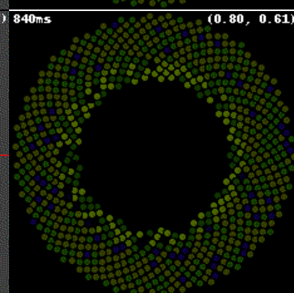
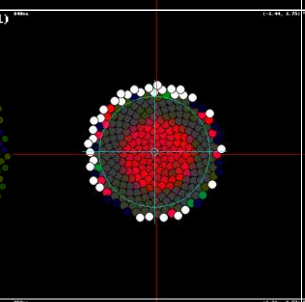
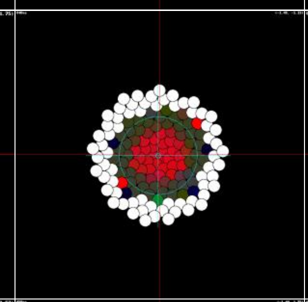
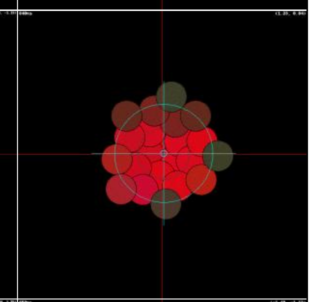
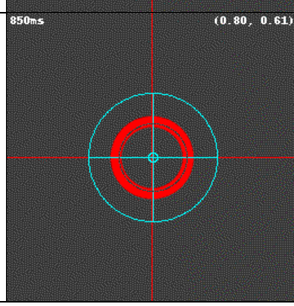
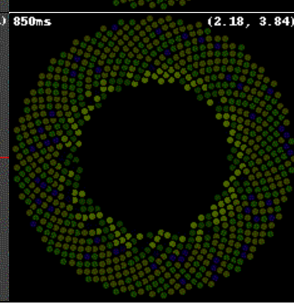
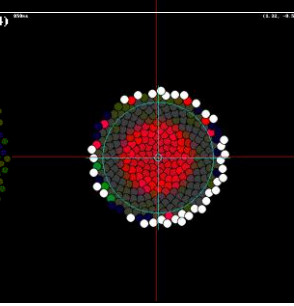
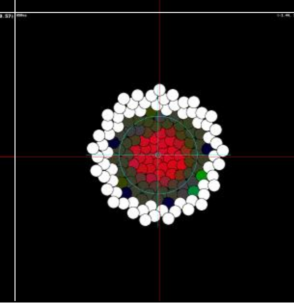
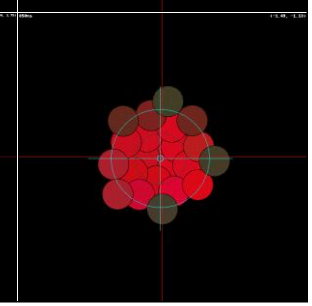
Table 24: Time sequence of filling-in blind spot with ring then saccade					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
83					
84					
85					

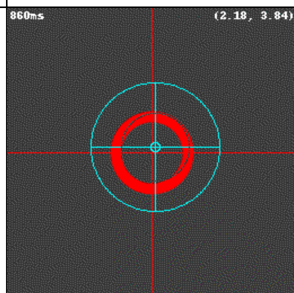
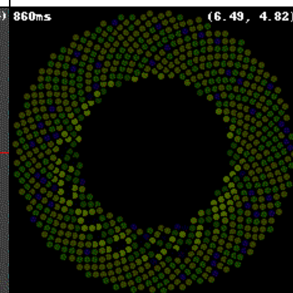
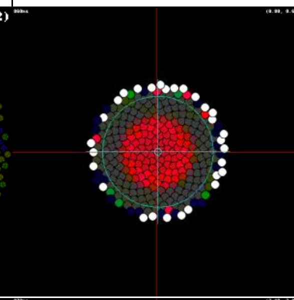
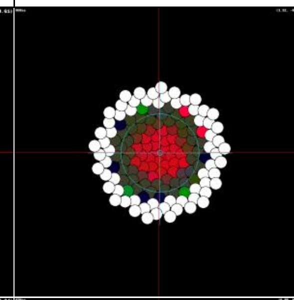
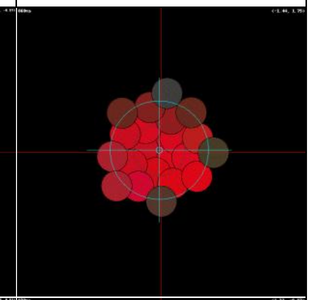
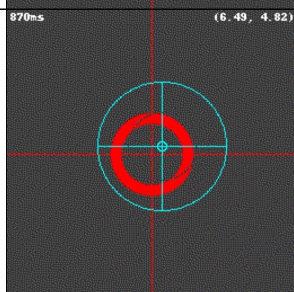
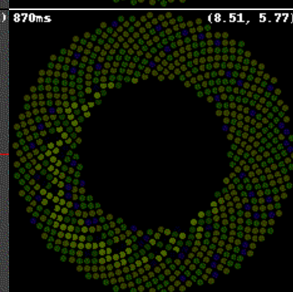
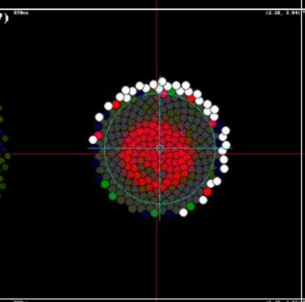
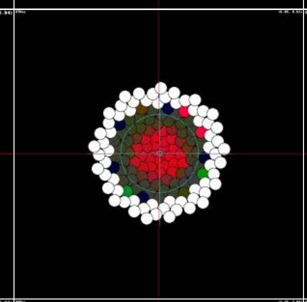
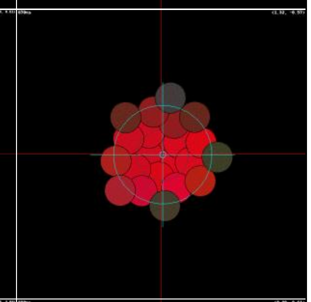
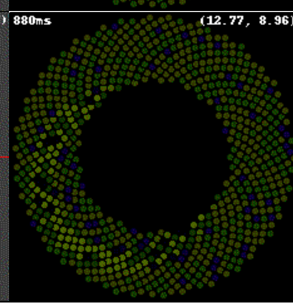
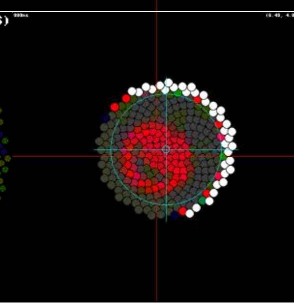
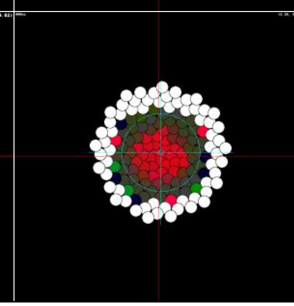
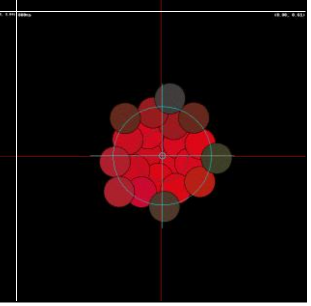
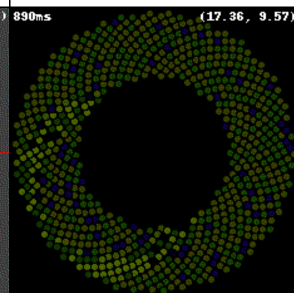
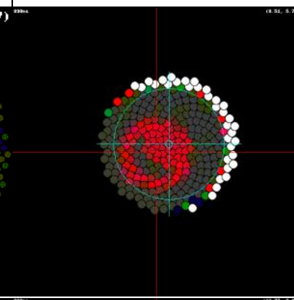
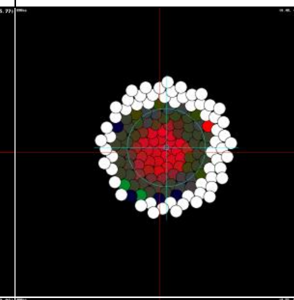
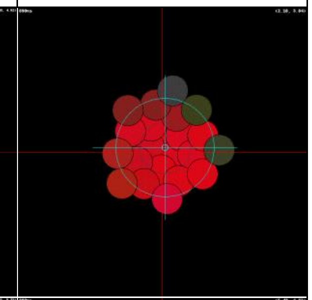
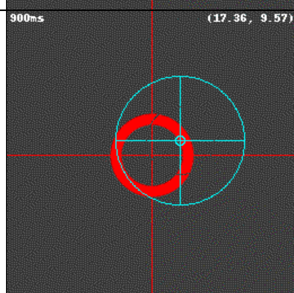
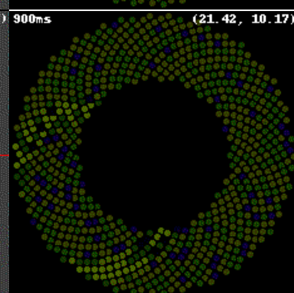
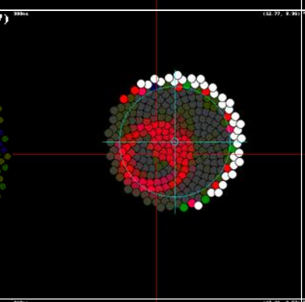
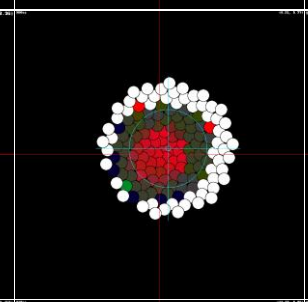
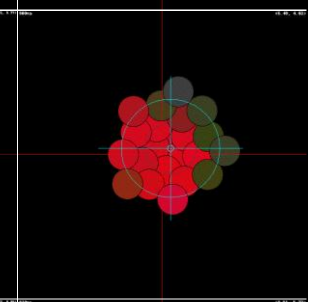
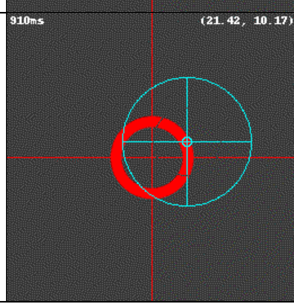
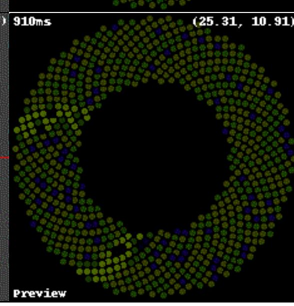
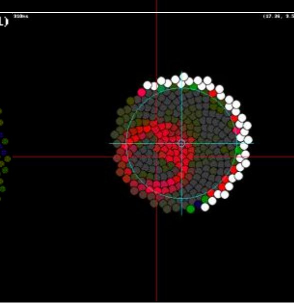
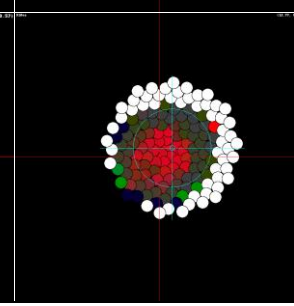
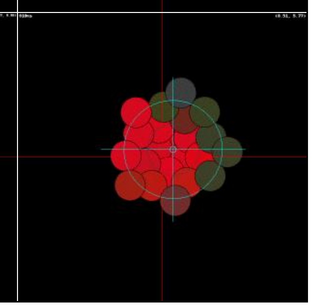
Table 24: Time sequence of filling-in blind spot with ring then saccade					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
86					
87					
88					

Table 24: Time sequence of filling-in blind spot with ring then saccade					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
89					
90					
91					

Appendices

Appendix A: An emergic model of filling-in for anorthoscopic perception

These supplement the corresponding material in the thesis.

A.1 Subject details

A single virtual subject was used in all four experiments. The *person* is fully characterized by a set of developmental parameters that will be indicated next. The meaning of these developmental parameters can be found in the thesis. Note that development includes a stochastic component so that, for example, while the L:M:S cone ratio may be innately specified, the colour sensitivity type of individual cones is random. Each test had a new incarnation of *person*.

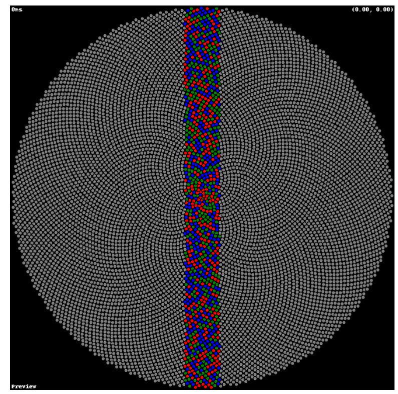


Illustration 25: Photoreceptor mosaic of *person* used in experiments 1-4.
Suppressed photoreceptors are shown in grey to mimic anorthoscopic perception.

To focus characterization on the filling-in for anorthoscopic perception phenomena, a large homogeneously arranged photoreceptor mosaic was used with equal ratios of red (L), green (M) and blue (S) cones. The size of the cones did not vary.

The software was further instrumented to supress all the developed photoreceptors except for a central 8′ wide strip. The full set of parameters is shown below, but the lateral fan-out parameters are highlighted as these support the anorthoscopic phenomenon.

```
[Person]
note = slit
srt = 10
sex = ai
age = 18
eyecount = 1
ipd = 0
vsize = 17.0
vieweyez = 100
r0conepix = 4
nodalpt = 17
r0coned = 4.0
r0red = 1
r0green = 1
```

```
r1coned = 1.0
r1red = 3000
r1green = 3000
r1blue = 3000
blindx = 0.0
blindy = 0.0
blindr = 0.0
blink0d = 0
blink1d = 0
jitmin = 0.1
jitave = 0.7
jitmax = 0.9
p1_0_pixd = 2.5
p1_0_pix = 1800
```

```
p1_0_scale = 2
p1_0_fanlat = 5.0
p1_0_fandwn = 2.0
p1_1_pixd = 5.0
p1_1_pix = 500
p1_1_scale = 2
p1_1_fanlat = 2.0
p1_1_fandwn = 2.0
p1_2_pixd = 7.5
p1_2_pix = 250
p1_2_scale = 2
p1_2_fanlat = 1.2
p1_2_fandwn = 1.5
```

A.2 Stimuli details

Four different stimuli were used to validate the robustness of the anorthoscopic filling-in behaviour of the ECM architecture.

A.2.1 Test 1 stimulus: Simple surfaces (Love)

This stimulus is used to test anorthoscopic filling-in behaviour using simple surfaces – the block letters spelling LOVE. The meaning of these parameters is fully described in the thesis. The content of file love.png appears in Illustration 26 minus any overlay.

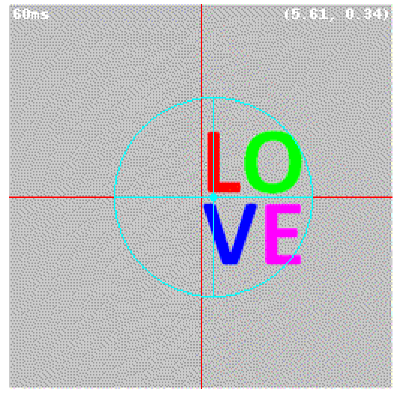


Illustration 26: Test 1 stimulus (Love) with view overlay

```
[World]
type = Image
note = Love
srt = 200
```

```
[Image]
wx = 256
wy = 256
wbg = #000000
```

```
iname = love.png
ix = 256
iy = 256
```

A.2.2 Test 2 stimulus: Natural image (Lena)

This stimulus is used to test anorthoscopic filling-in behaviour using a natural image - a standard image library picture of Lena (Picard, 1995). The meaning of these parameters is fully described in the thesis. The content of file Lena.tiff appears in Illustration 27 minus any overlay.

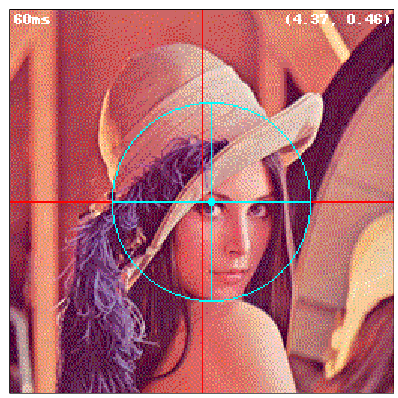


Illustration 27: Test 2 stimulus (Lena) with view overlay

```
[World]
type = Image
note = Lena
srt = 200
```

```
[Image]
wx = 256
wy = 256
wbg = #000000
```

```
iname = Lena.tiff
ix = 256
iy = 256
```

A.2.3 Test 3 stimulus: Dynamic image with surface gradients (Chaser)

This stimulus is used to test anorthoscopic filling-in behaviour in a generic fashion using a dynamic image with surface gradients – the lilac chaser. The meaning of these parameters is fully described in the thesis. The virtual agent was monitored for 32 ticks (320ms), so this chaser with 8 lilacs needed to move the lilac gap every 40ms to complete an entire circuit of motion.

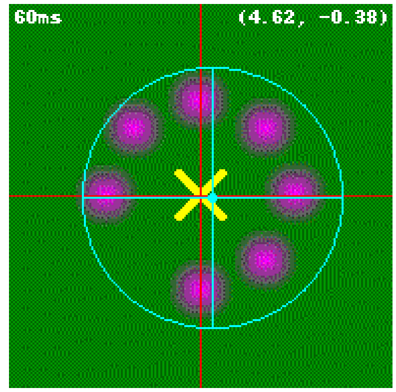


Illustration 28: Test 3 stimulus (Chaser) with view overlay

```
[World]
type = Lilac
Chaser
note =
srt = 40
[Lilac Chaser]
llcount = 8
spacing = 0.1
pad = 1.0
fg = #ff00ff
bg = #007f00
gamma = 1.0
grdcount = 17
grdwidth = 1
fixfg = #ffff00
fixsize = 0.75
fixwidth = 2
```

A.2.4 Test 4 stimulus: Simple object (Square)

This stimulus is used to test anorthoscopic filling-in behaviour using a simple object – a green square over a blue background. The meaning of these parameters is fully described in the thesis. The content of file square.gif appears in Illustration 29 minus any overlay.

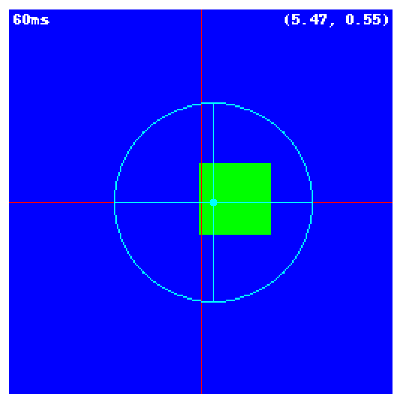


Illustration 29: Test 4 stimulus (Square) with view overlay

```
[World]
type = Image
note = square
srt = 200
[Image]
wx = 256
wy = 256
wbg = #000000
iname = square.gif
ix = 256
iy = 256
```

The purpose of this stimulus is to eventually compare it to its black and white counterpart in (Francis & Grossberg, 1996). However, that must await the next chapter.

A.3 Result details

In this section we tabulate a visual frame-by-frame account of results from all experiments. Such a frame-by-frame account allows for the extraction of precise timing information useful for quantitative analysis. It takes 44 pages. All these results are reduced to a single web page of animated images, available at

http://emergic.upwize.com/?page_id=434

The animated account (Leibovitz, 2012a) is preferred as an overview showing behavioural dynamics of filling-in, memory, etc. and makes image stability more salient. It also includes the results in greatest detail – they have been scaled down for print in this supplement, and even smaller in the chapter's *results and discussion* sections.

Each table of results has the following columns. **Time** numerically represents the time tick since the test has started, nominally 10ms/tick. All visual results in that table row are after the tick and computation have finished. **Stimuli** visually represents the stimuli presented to the virtual computer screen, often with retinal overlays. The **Photoreceptor Mosaic** visually represents what the retina senses by looking at the stimuli. **Receptive Fields** at **Level 1**, **Level 2** and **Level 3**, visually represent the three level hierarchy of receptive fields showing their the functional size and placement, not physical size nor placement

A.3.1 Test 1 results: Simple surfaces (Love)

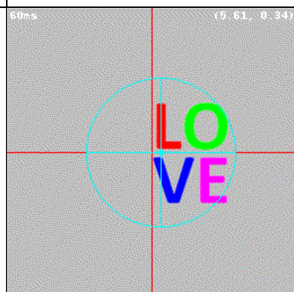
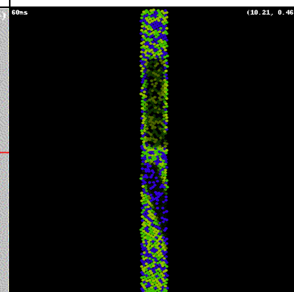
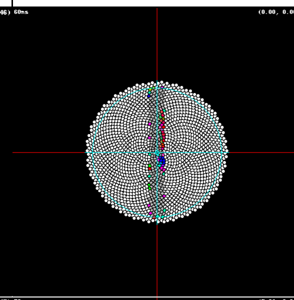
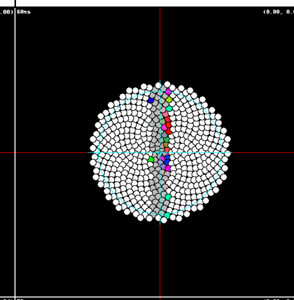
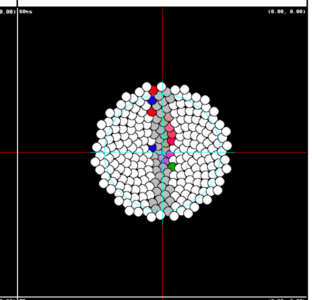
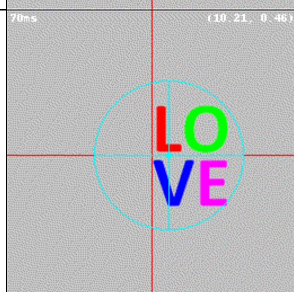
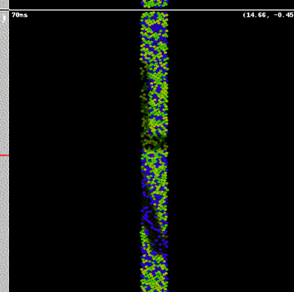
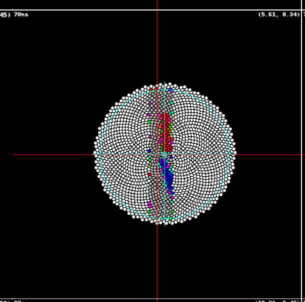
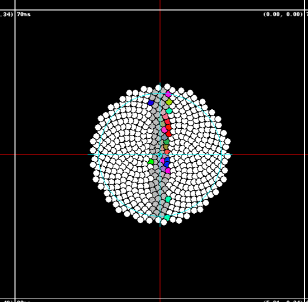
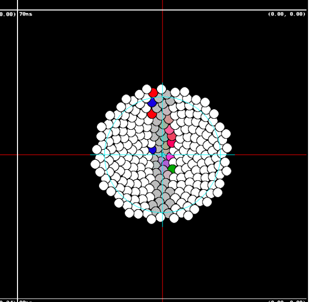
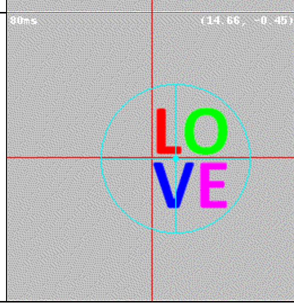
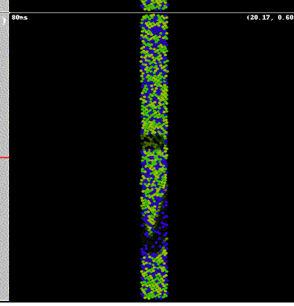
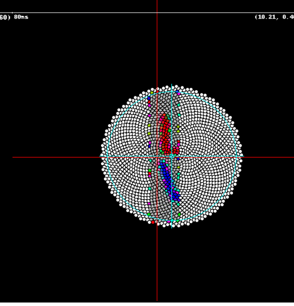
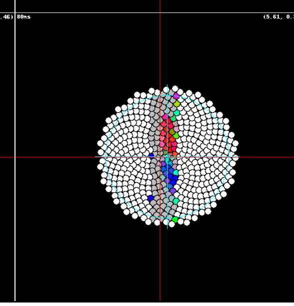
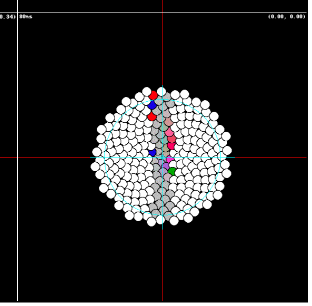
Table 25: Time sequence of narrow slit filling-in over simple surface (Love)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
6					
7					
8					

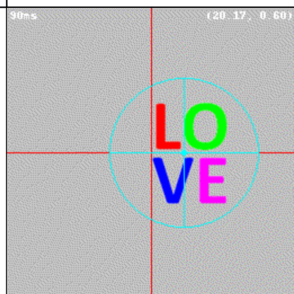
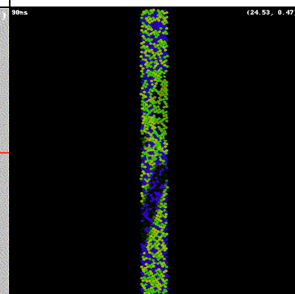
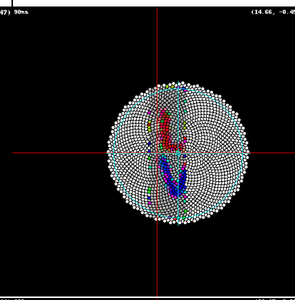
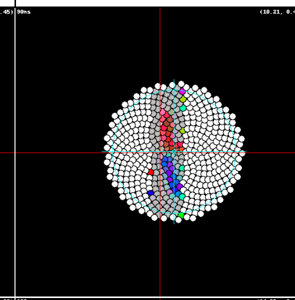
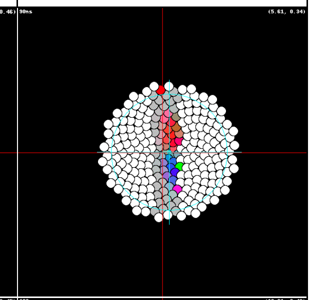
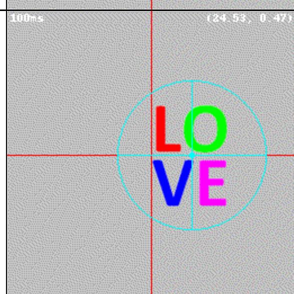
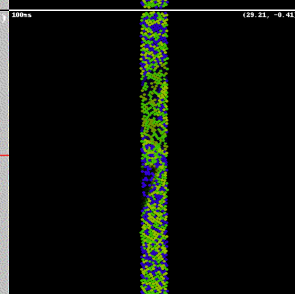
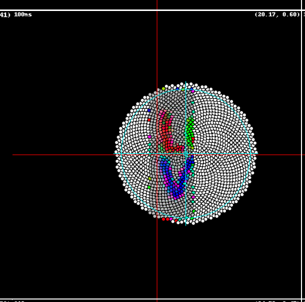
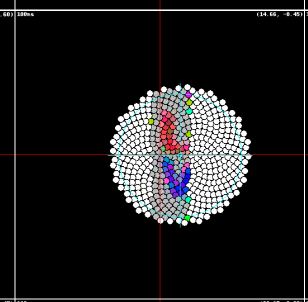
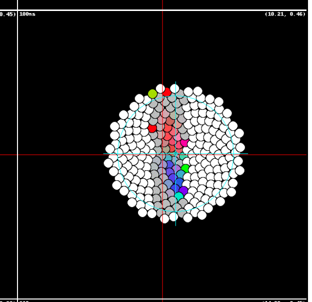
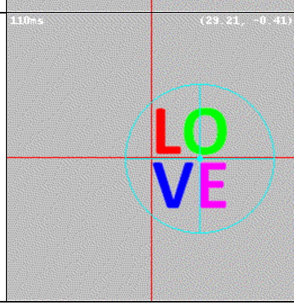
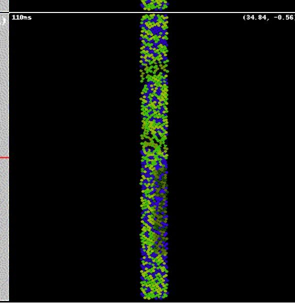
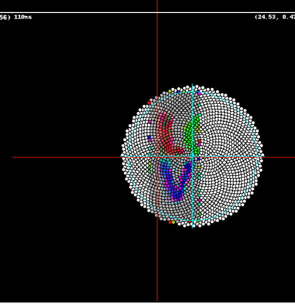
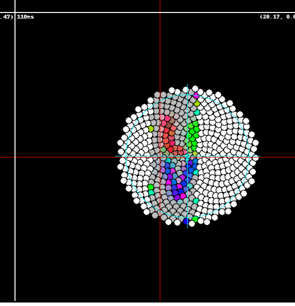
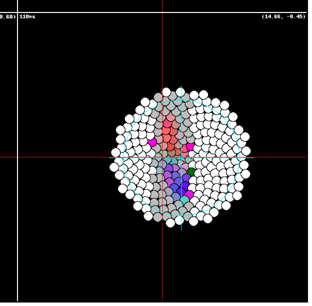
Table 25: Time sequence of narrow slit filling-in over simple surface (Love)					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
9					
10					
11					

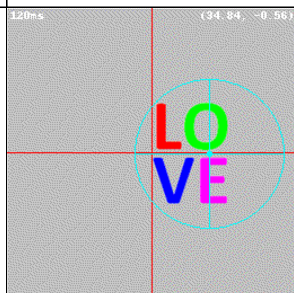
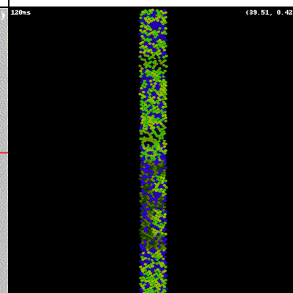
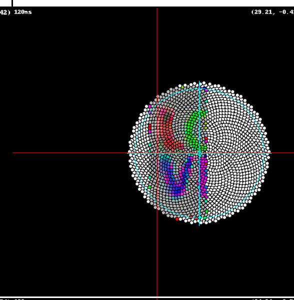
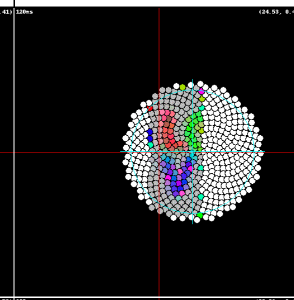
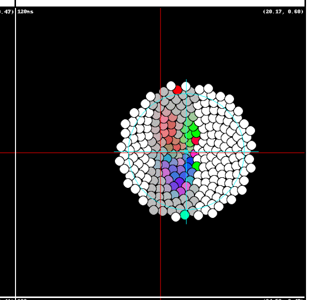
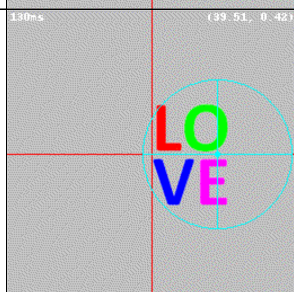
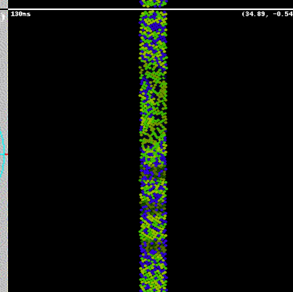
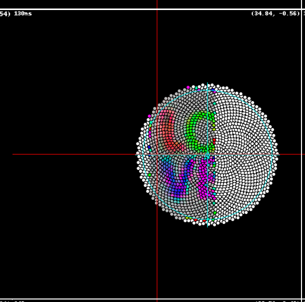
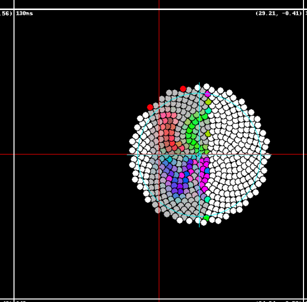
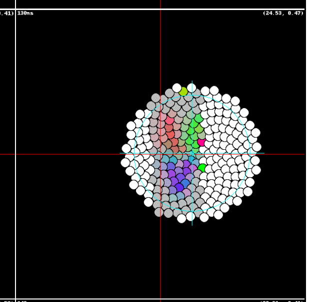
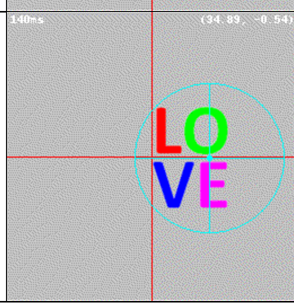
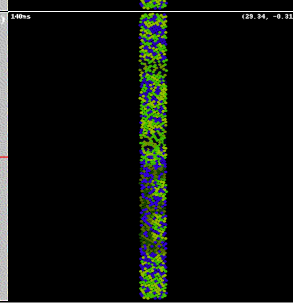
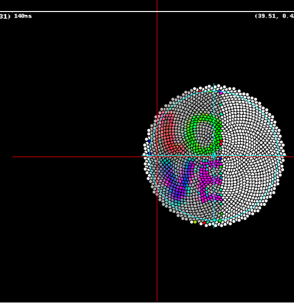
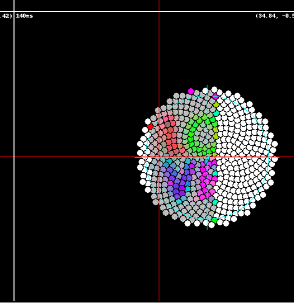
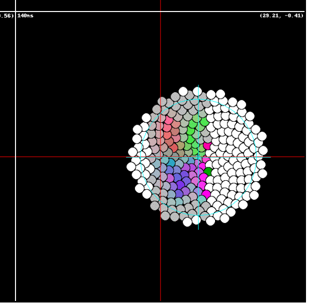
Table 25: Time sequence of narrow slit filling-in over simple surface (Love)					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
12					
13					
14					

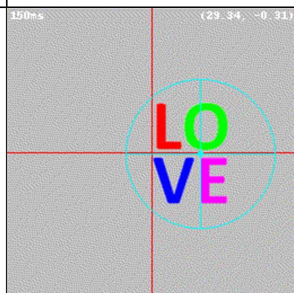
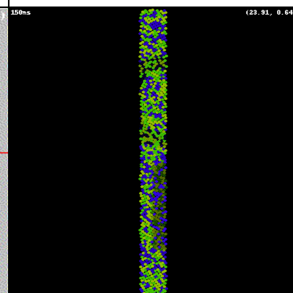
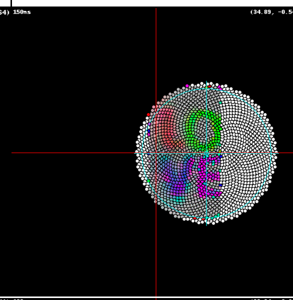
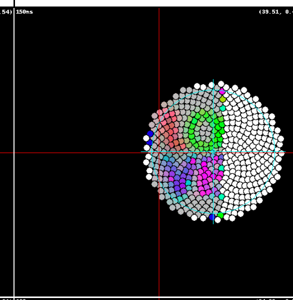
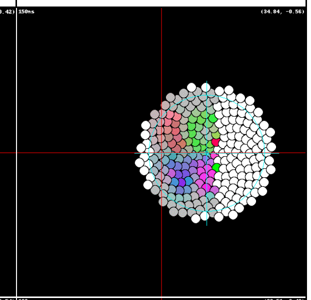
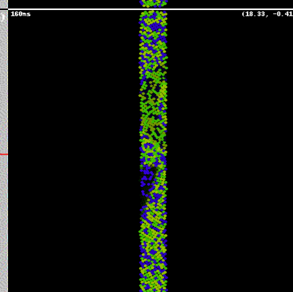
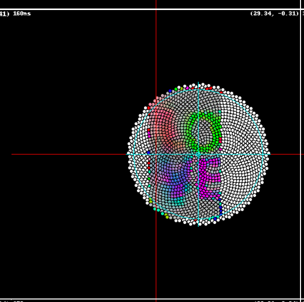
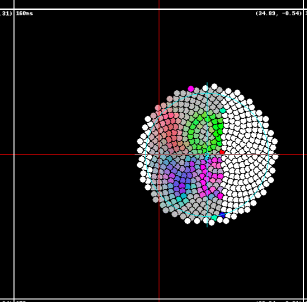
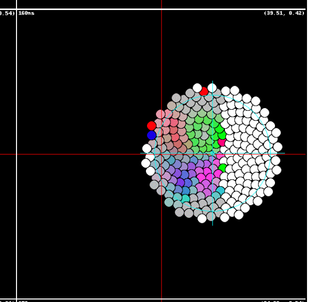
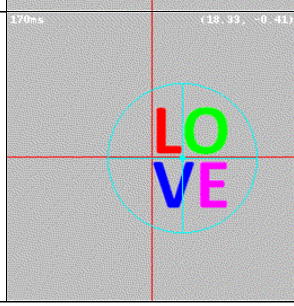
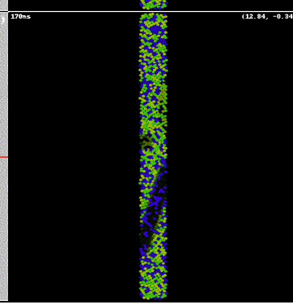
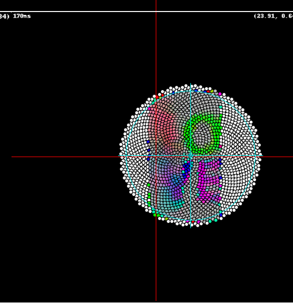
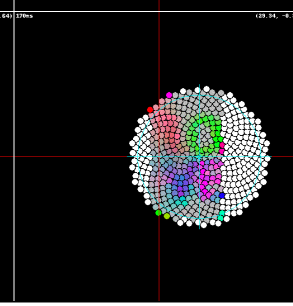
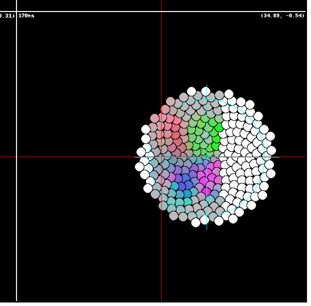
Table 25: Time sequence of narrow slit filling-in over simple surface (Love)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
15					
16					
17					

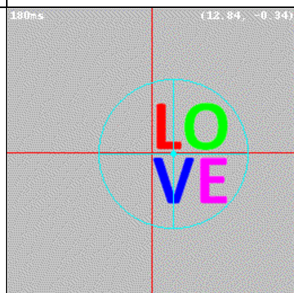
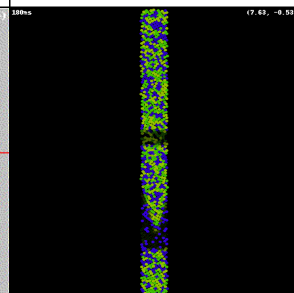
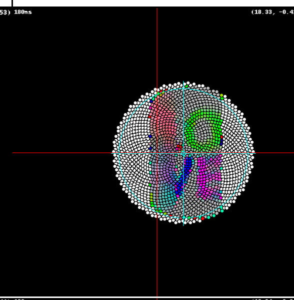
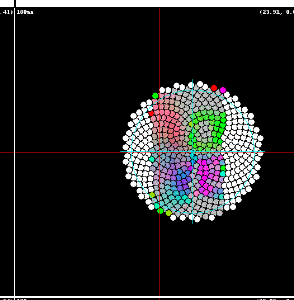
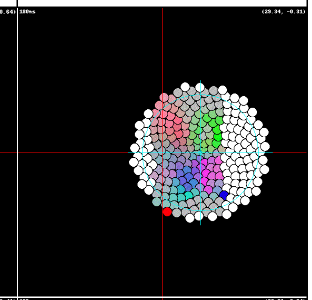
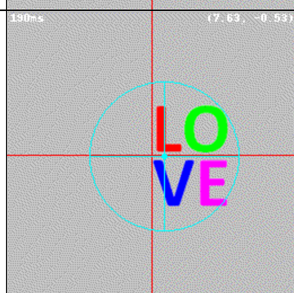
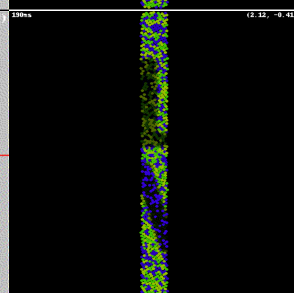
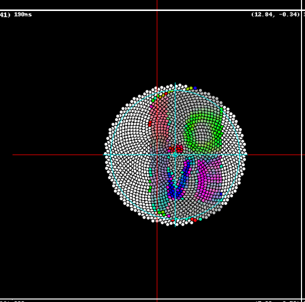
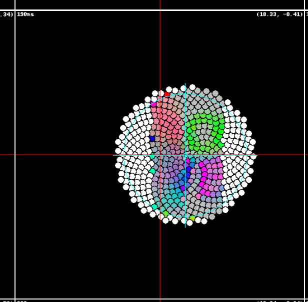
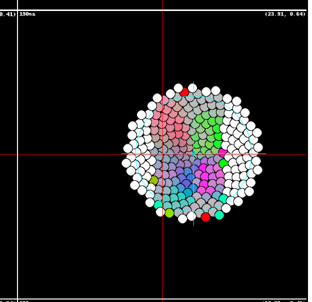
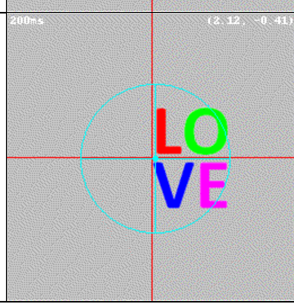
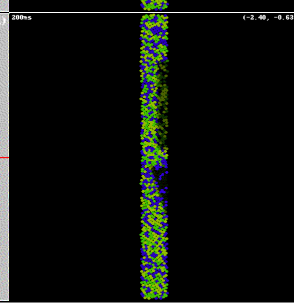
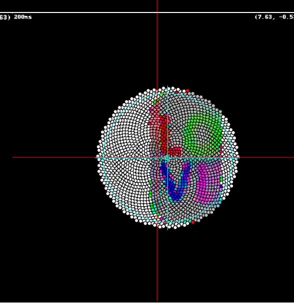
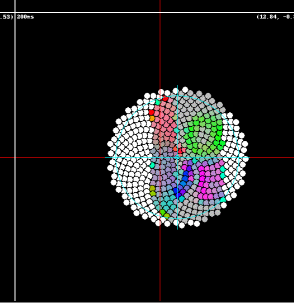
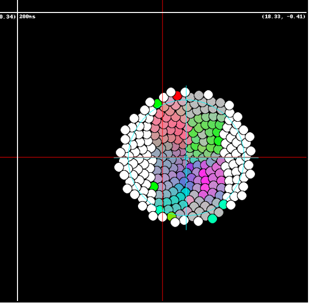
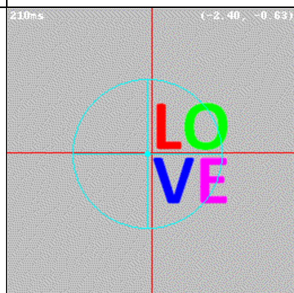
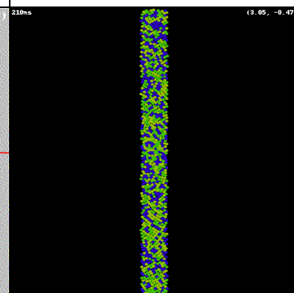
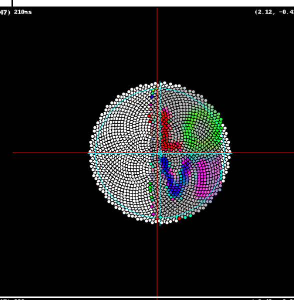
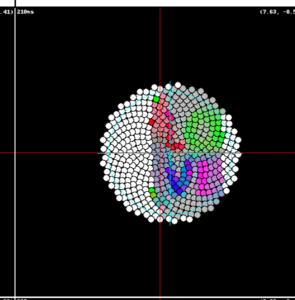
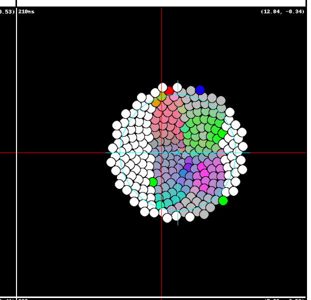
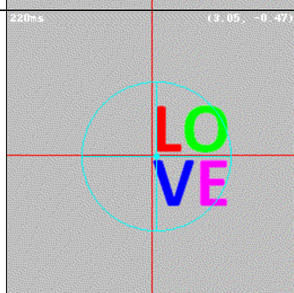
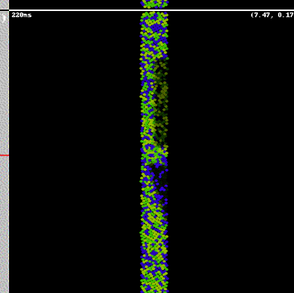
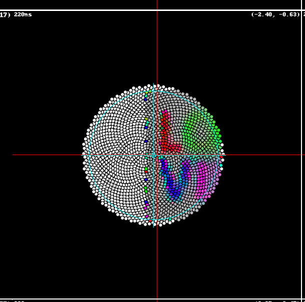
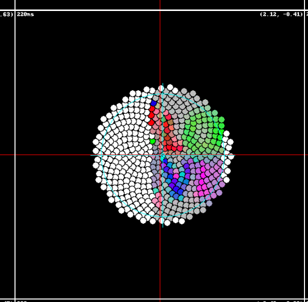
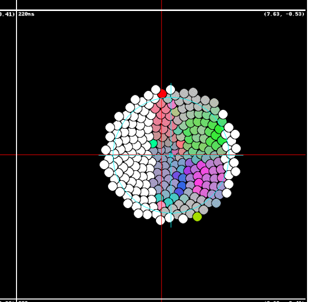
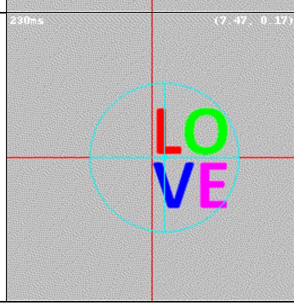
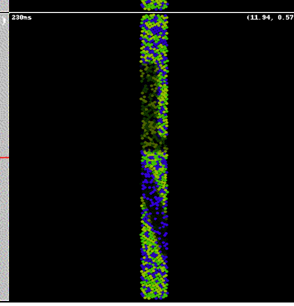
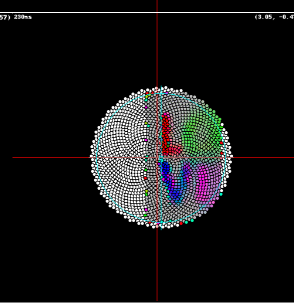
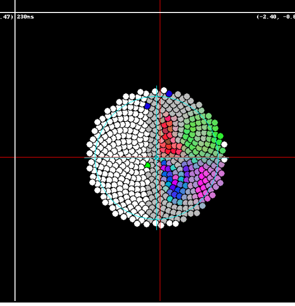
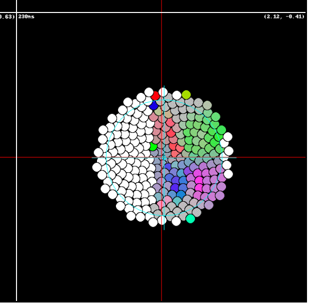
Table 25: Time sequence of narrow slit filling-in over simple surface (Love)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
18					
19					
20					

Table 25: Time sequence of narrow slit filling-in over simple surface (Love)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
21					
22					
23					

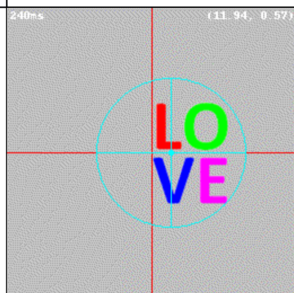
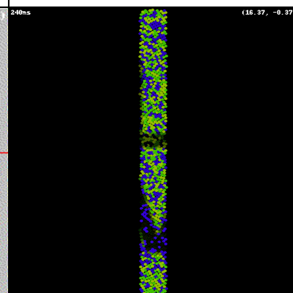
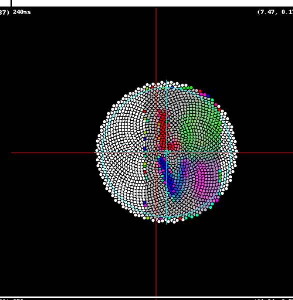
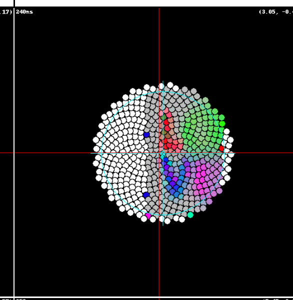
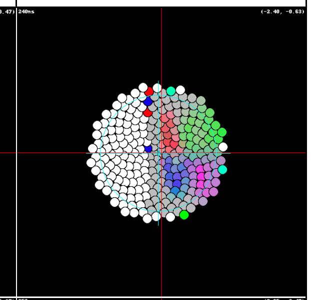
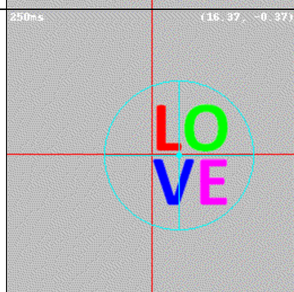
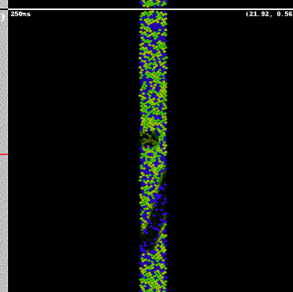
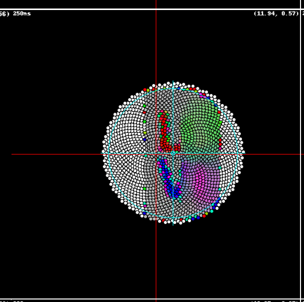
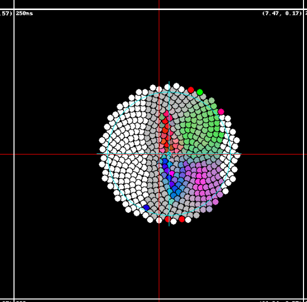
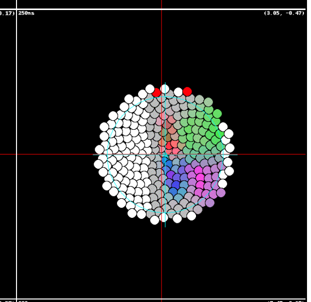
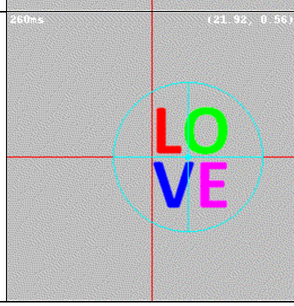
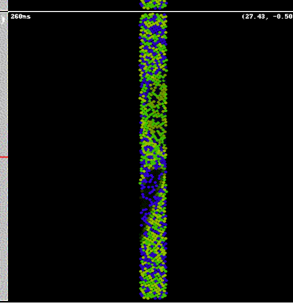
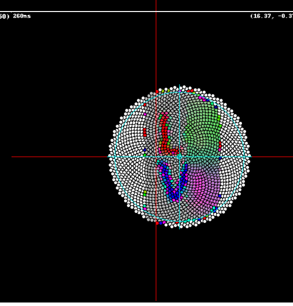
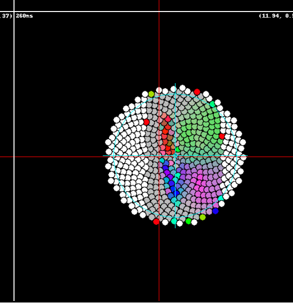
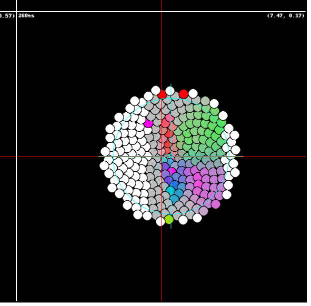
<table>
<tr><th colspan="6">Table 25: Time sequence of narrow slit filling-in over simple surface (Love)</th></tr>
<tr><th rowspan="2">Time (ticks)</th><th rowspan="2">Stimuli</th><th rowspan="2">Photoreceptor Mosaic</th><th colspan="3">Receptive Fields</th></tr>
<tr><th>Level 1</th><th>Level 2</th><th>Level 3</th></tr>
<tr><td>24</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>25</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>26</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

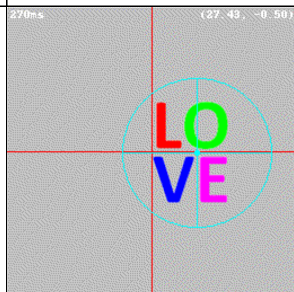
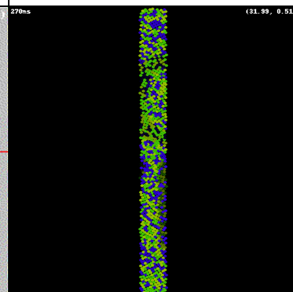
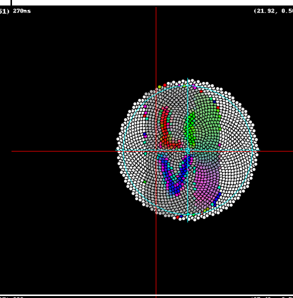
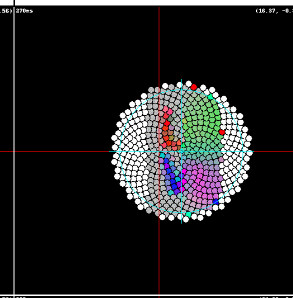
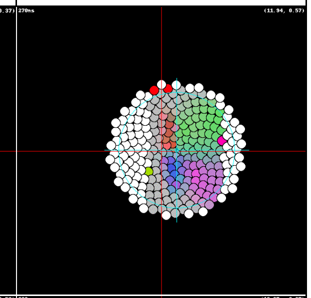
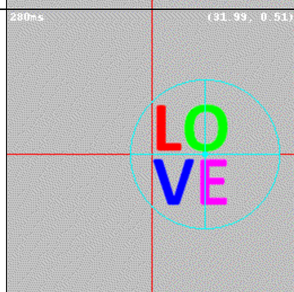
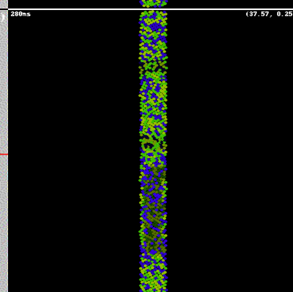
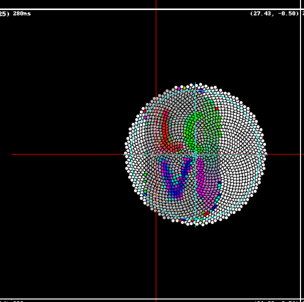
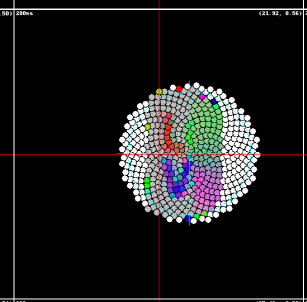
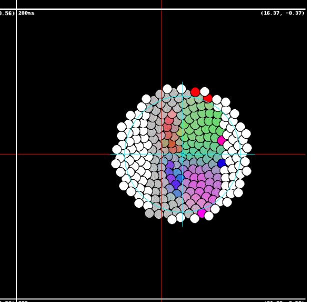
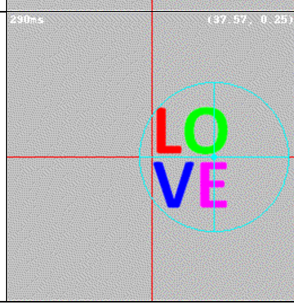
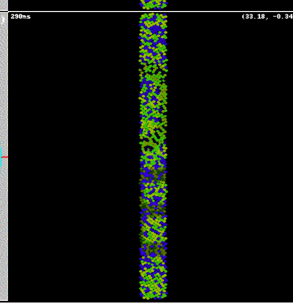
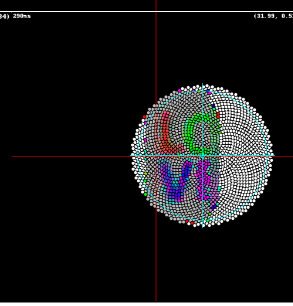
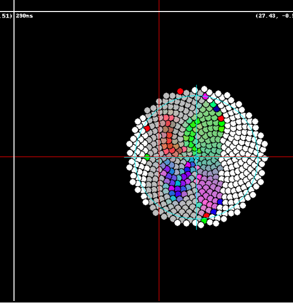
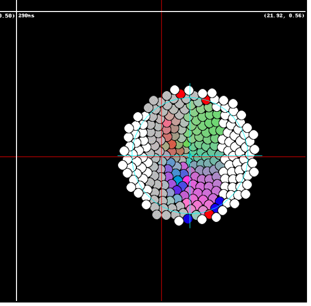
Table 25: Time sequence of narrow slit filling-in over simple surface (Love)					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
27					
28					
29					

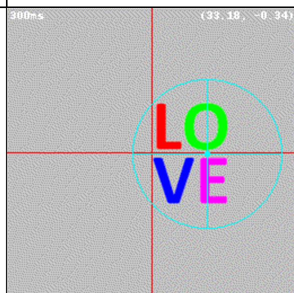
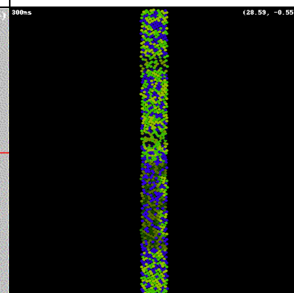
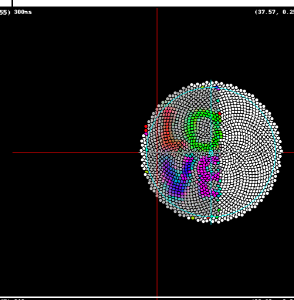
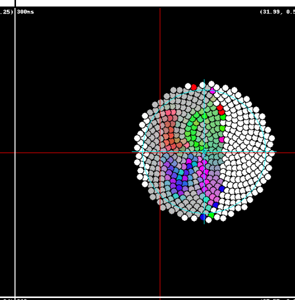
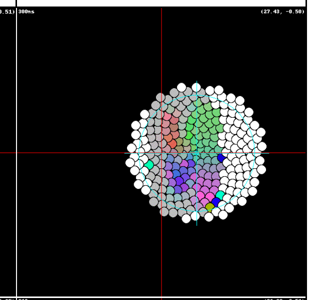
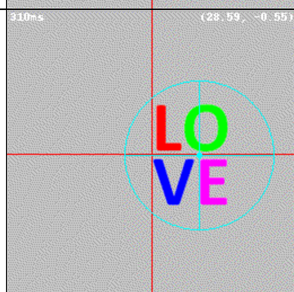
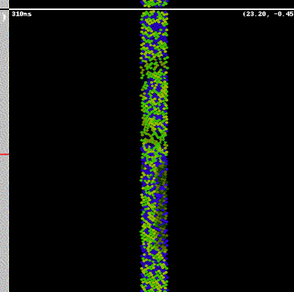
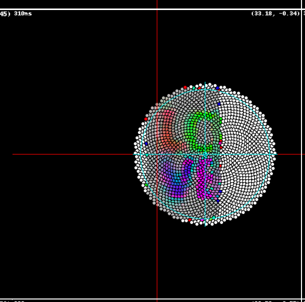
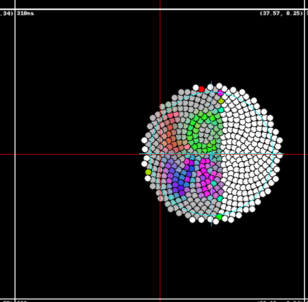
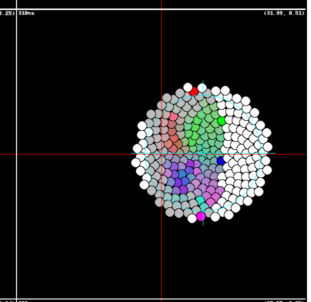
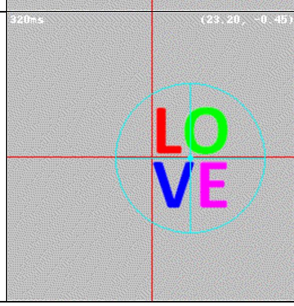
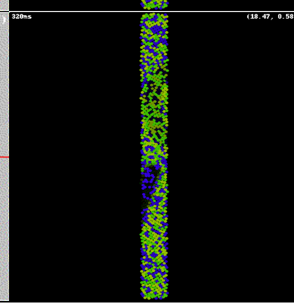
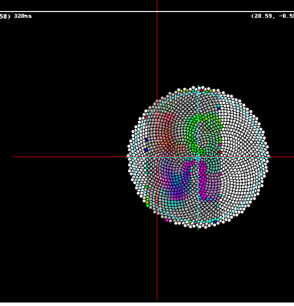
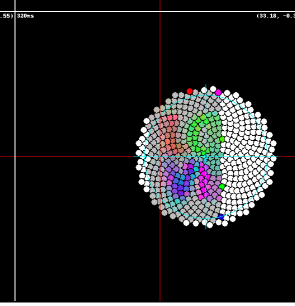
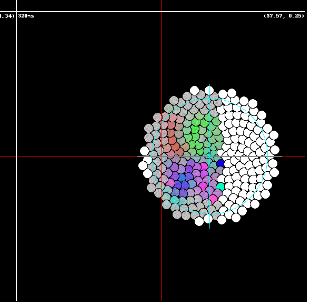
Table 25: Time sequence of narrow slit filling-in over simple surface (Love)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
30					
31					
32					

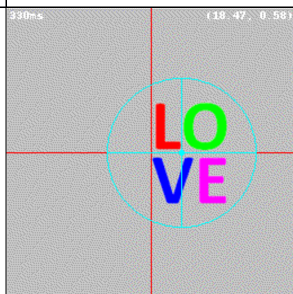
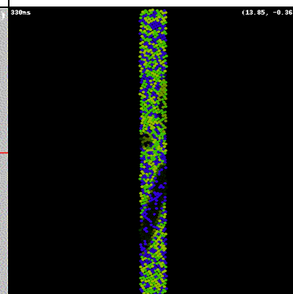
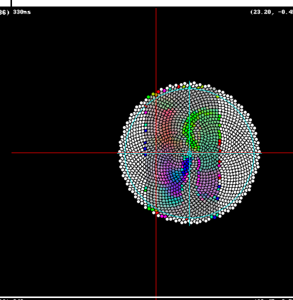
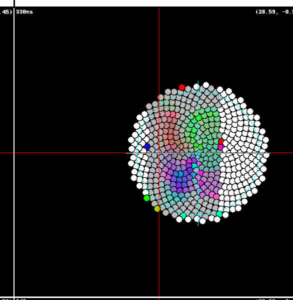
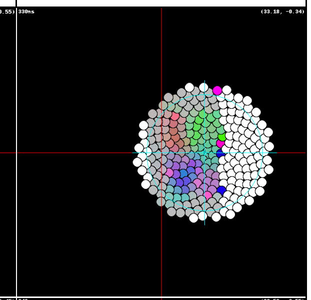
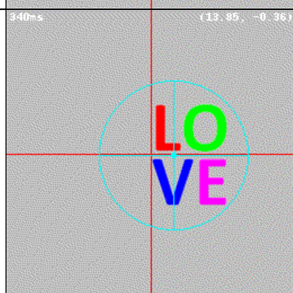
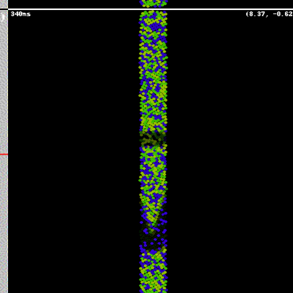
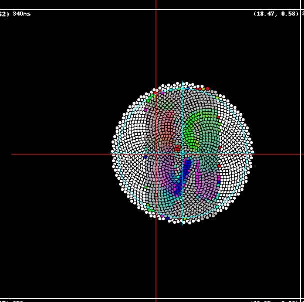
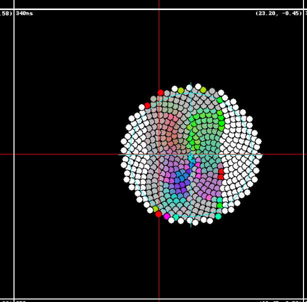
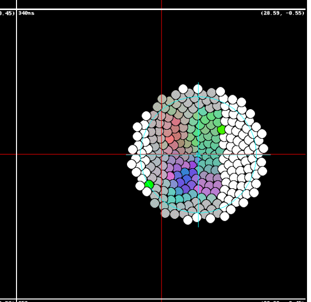
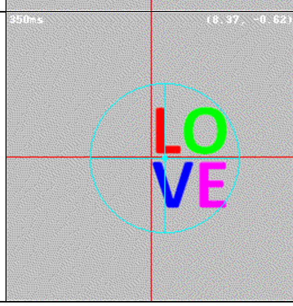
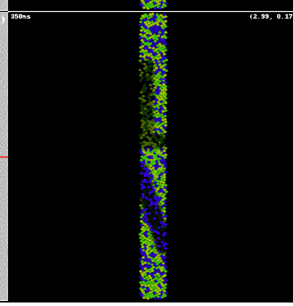
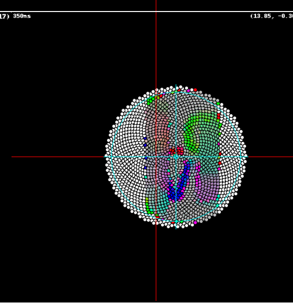
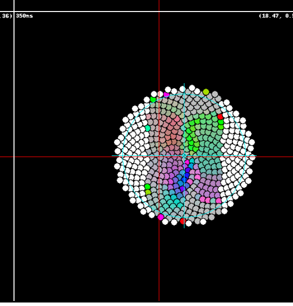
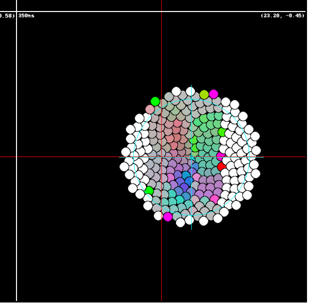
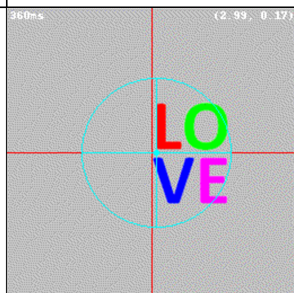
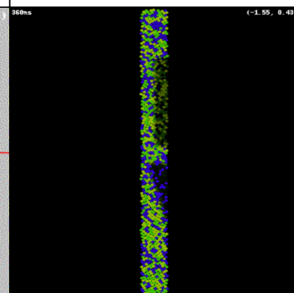
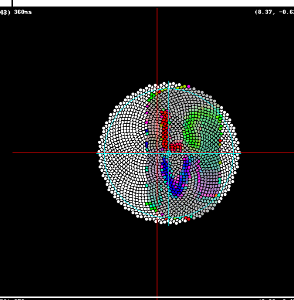
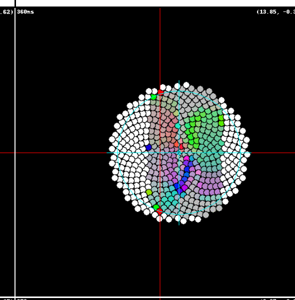
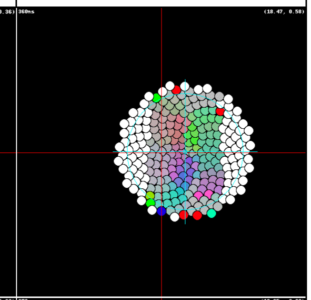
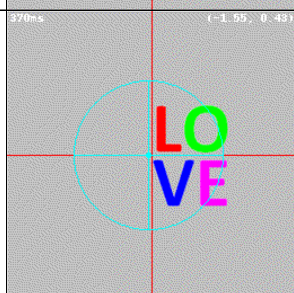
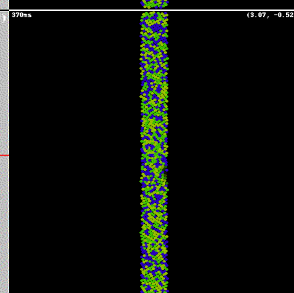
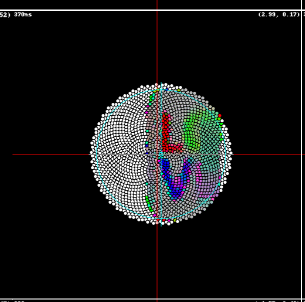
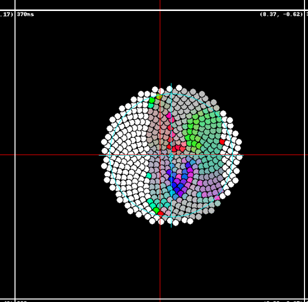
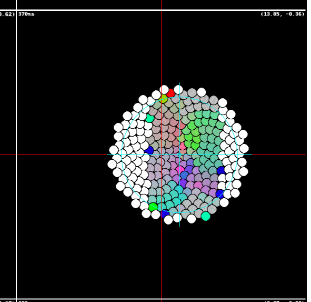
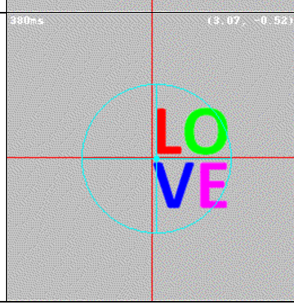
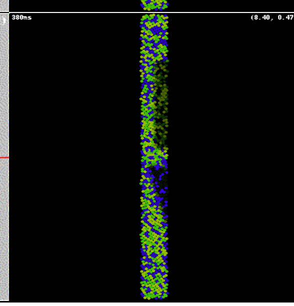
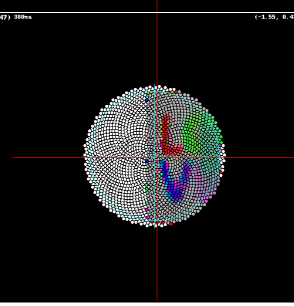
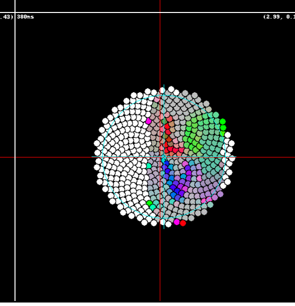
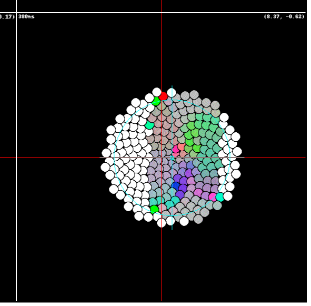
Table 25: Time sequence of narrow slit filling-in over simple surface (Love)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
33					
34					
35					

Table 25: Time sequence of narrow slit filling-in over simple surface (Love)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
36					
37					
38					

A.3.2 Test 2 results: Natural image (Lena)

Table 26: Time sequence of narrow slit filling-in over natural image (Lena)

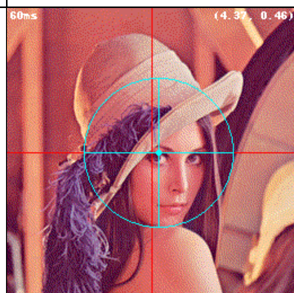
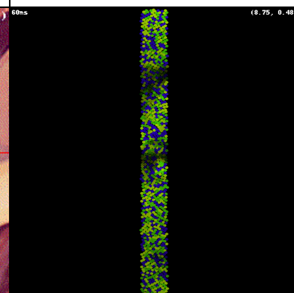
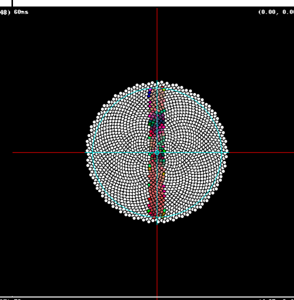
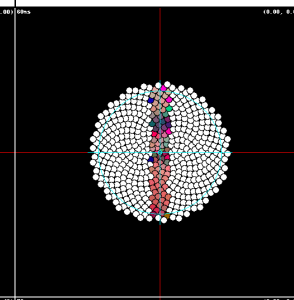
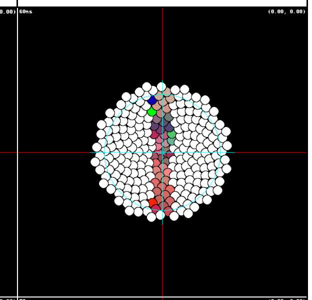
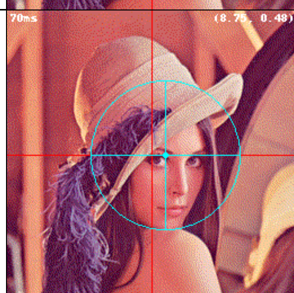
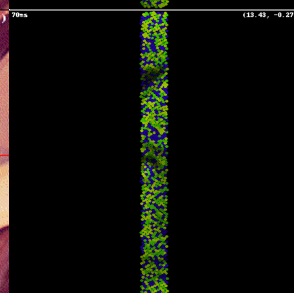
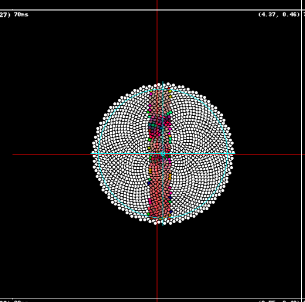
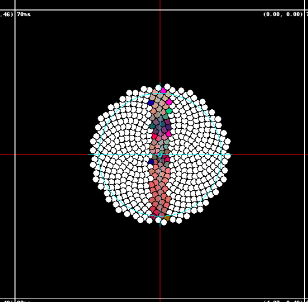
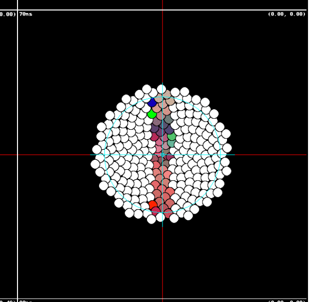
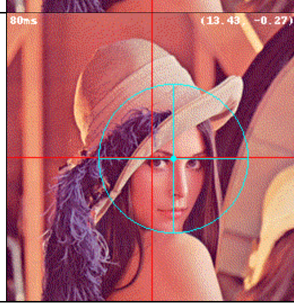
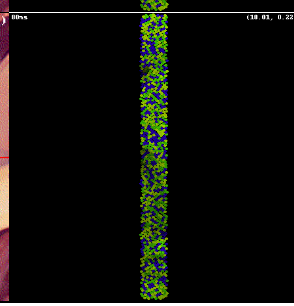
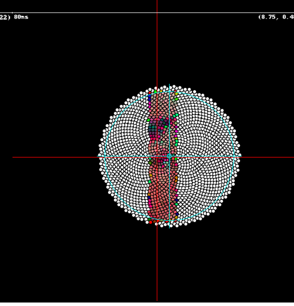
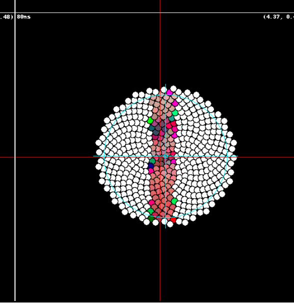
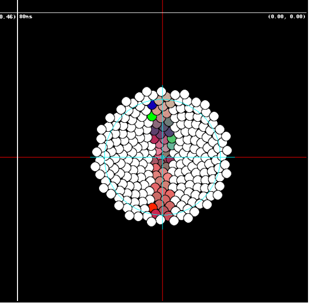
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
6					
7					
8					

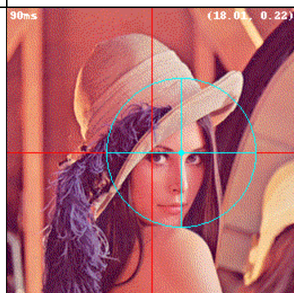
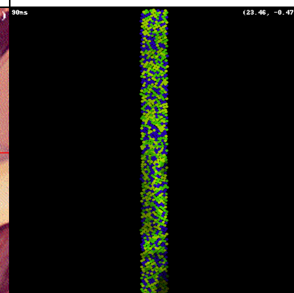
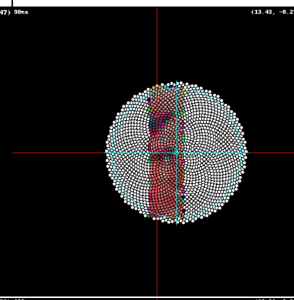
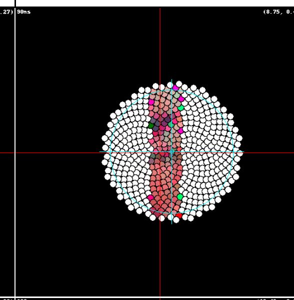
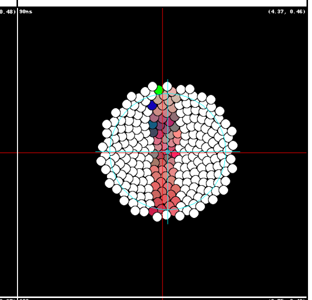
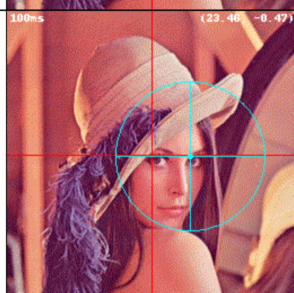
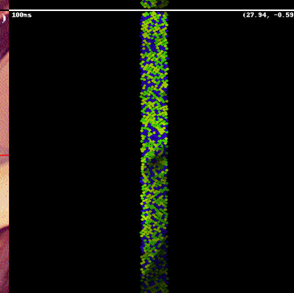
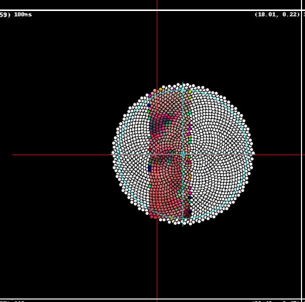
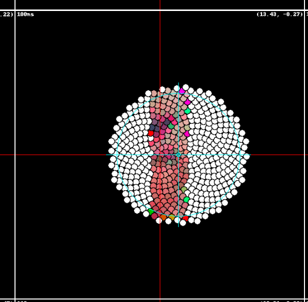
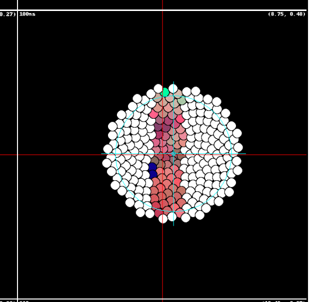
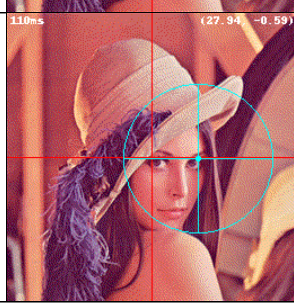
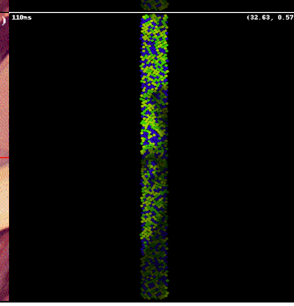
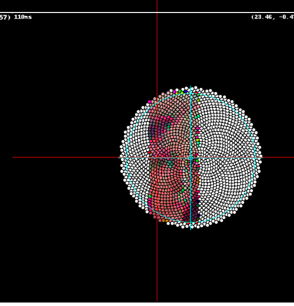
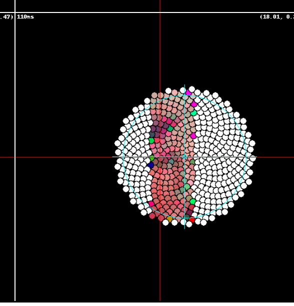
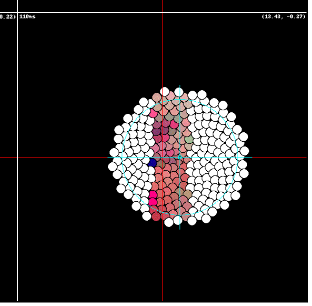
Table 26: Time sequence of narrow slit filling-in over natural image (Lena)					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
9					
10					
11					

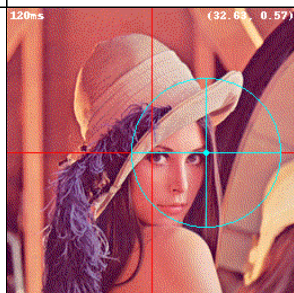
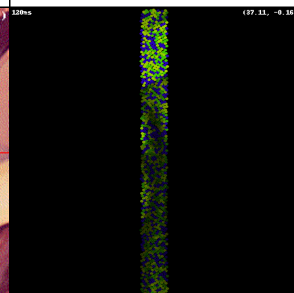
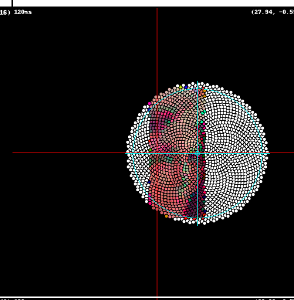
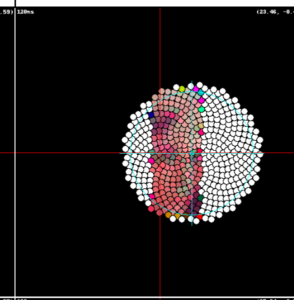
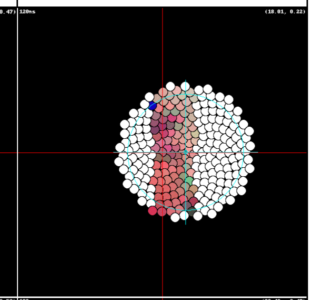
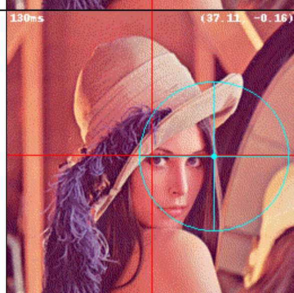
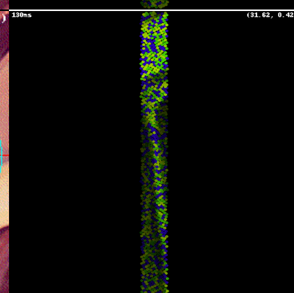
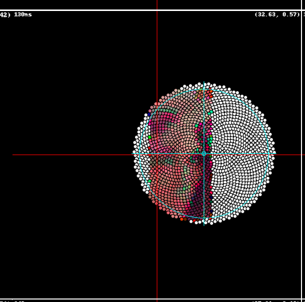
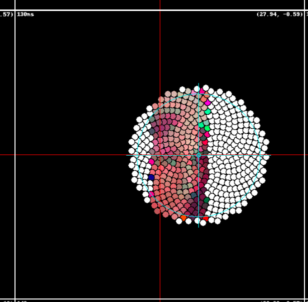
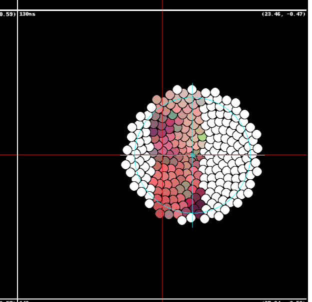
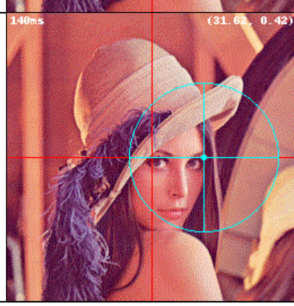
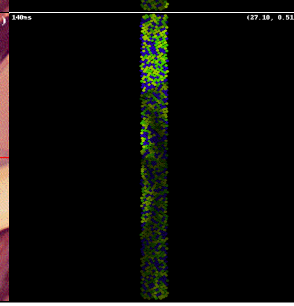
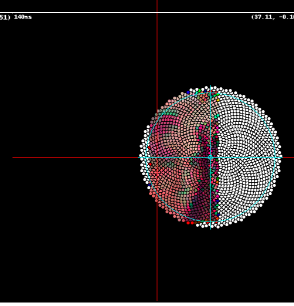
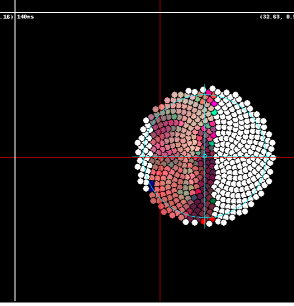
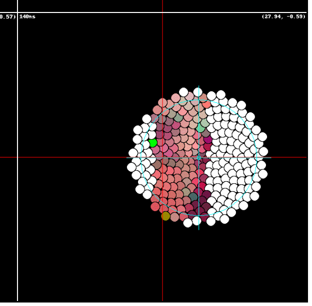
Table 26: Time sequence of narrow slit filling-in over natural image (Lena)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
12					
13					
14					

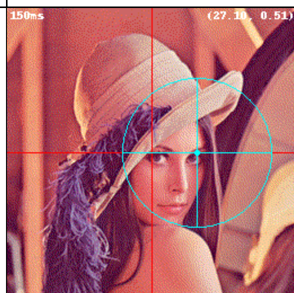
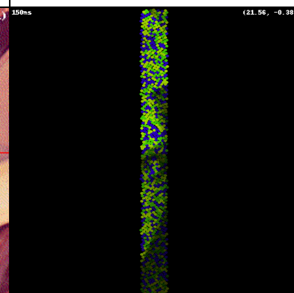
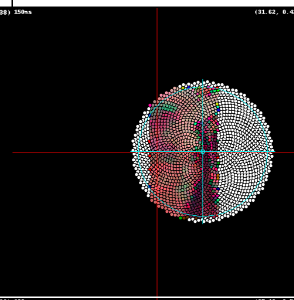
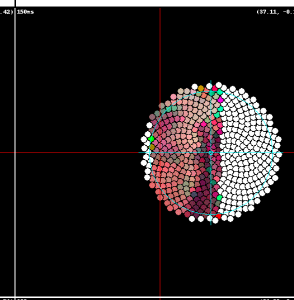
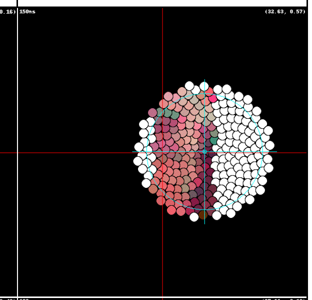
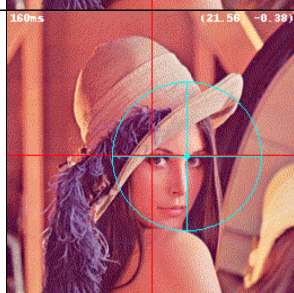
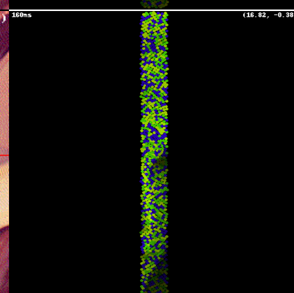
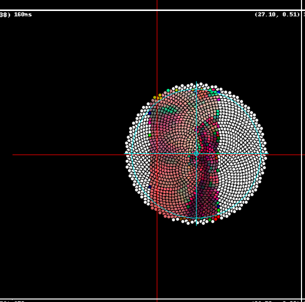
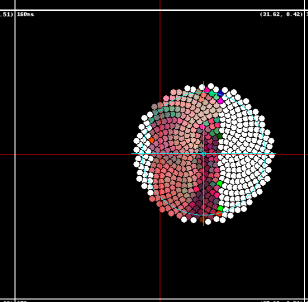
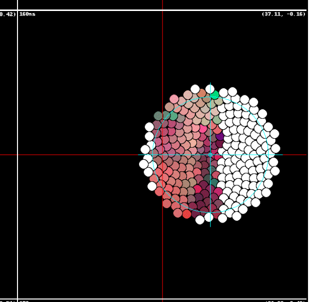
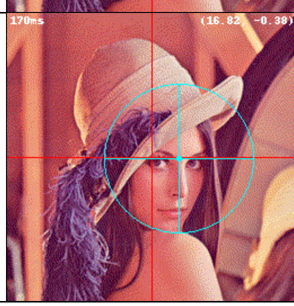
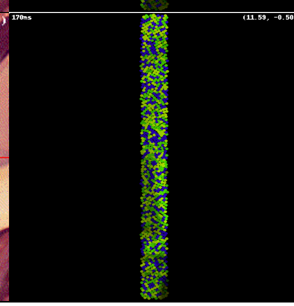
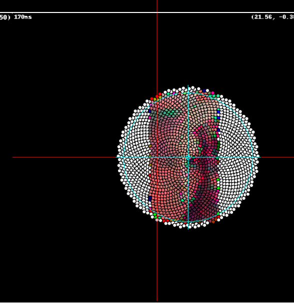
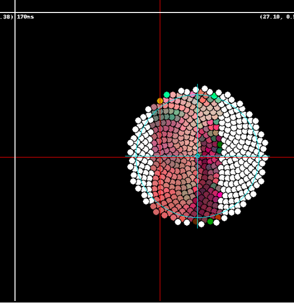
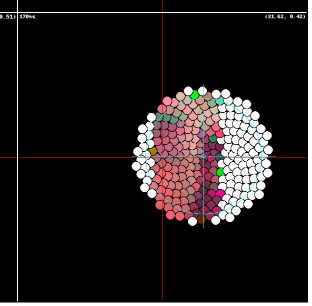
Table 26: Time sequence of narrow slit filling-in over natural image (Lena)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
15					
16					
17					

Table 26: Time sequence of narrow slit filling-in over natural image (Lena)

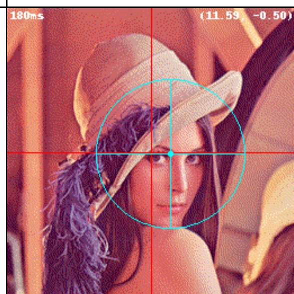
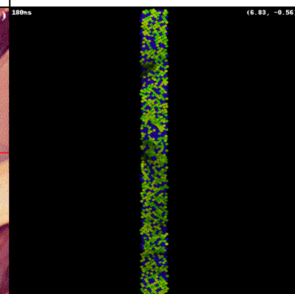
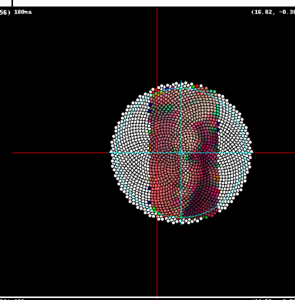
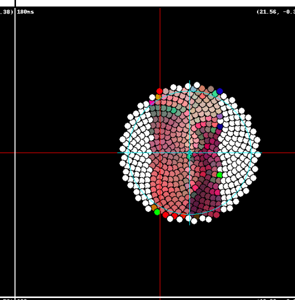
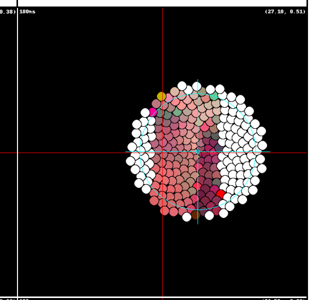
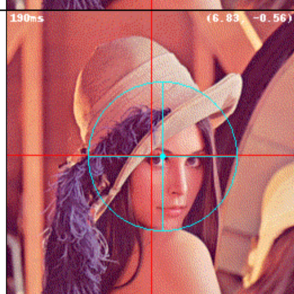
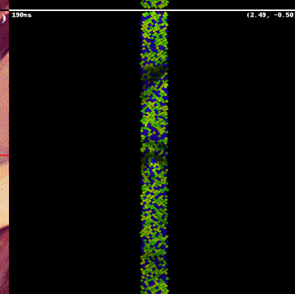
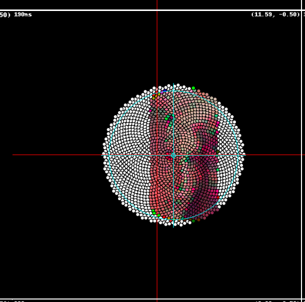
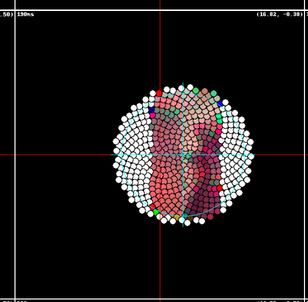
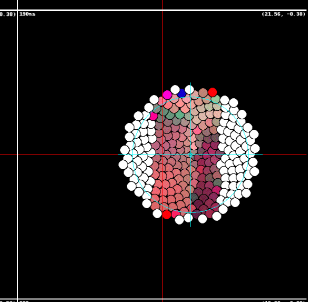
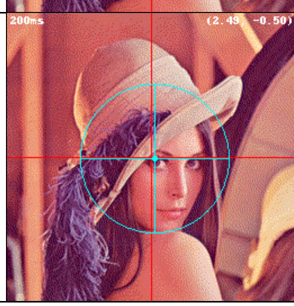
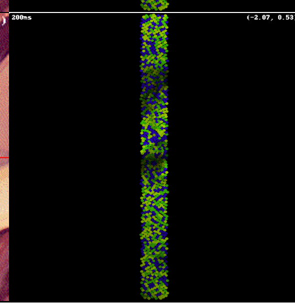
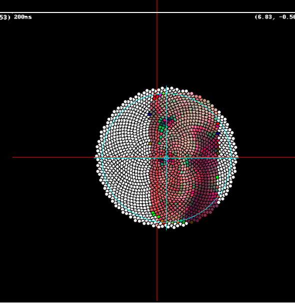
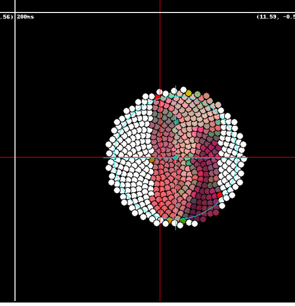
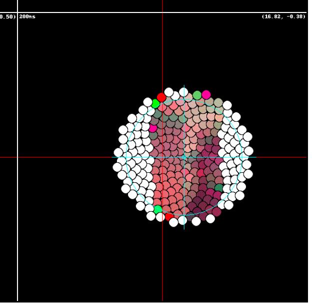
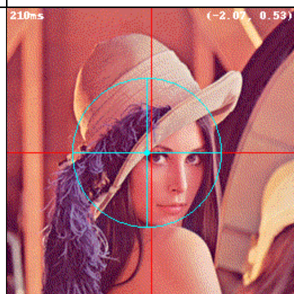
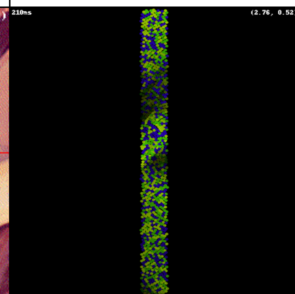
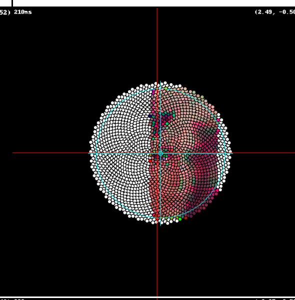
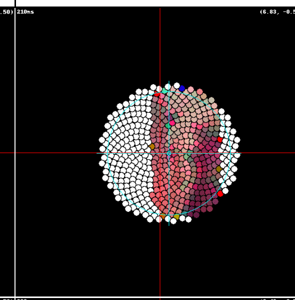
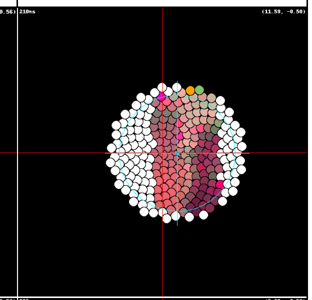
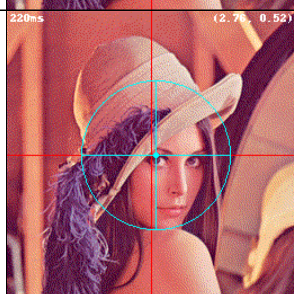
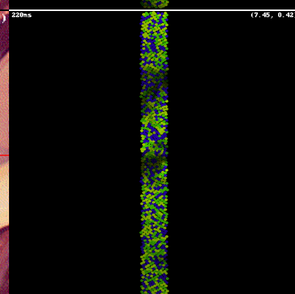
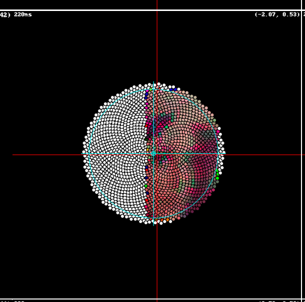
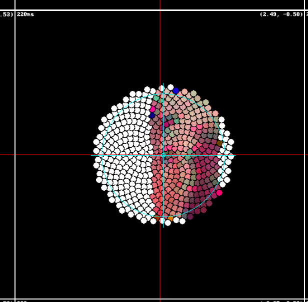
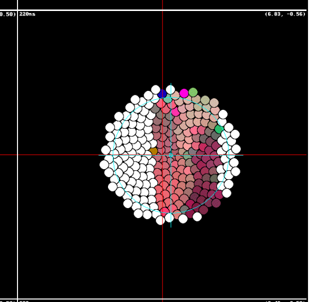
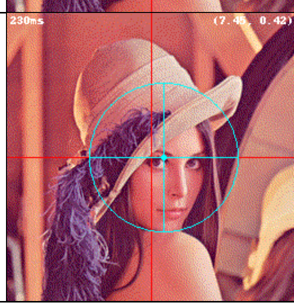
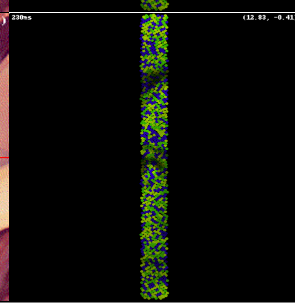
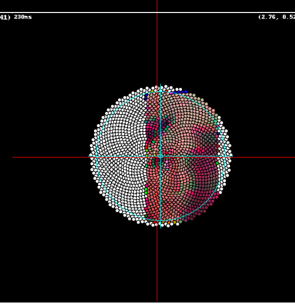
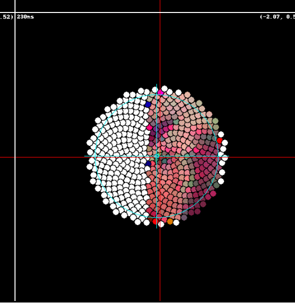
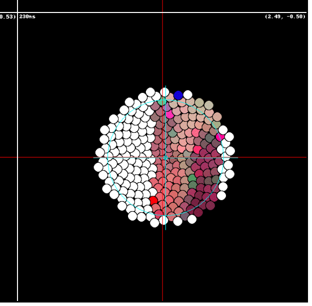
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
18					
19					
20					

Table 26: Time sequence of narrow slit filling-in over natural image (Lena)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
21					
22					
23					

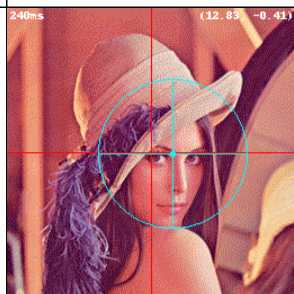
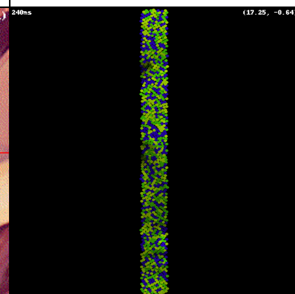
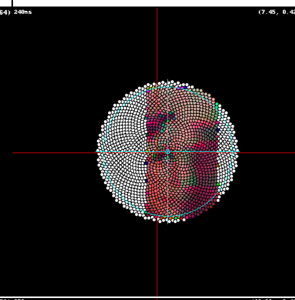
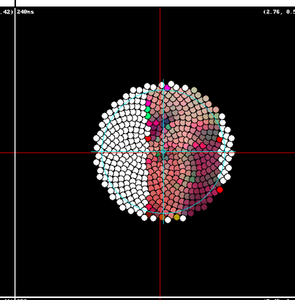
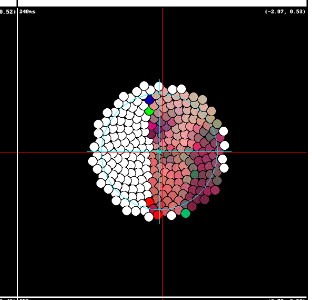
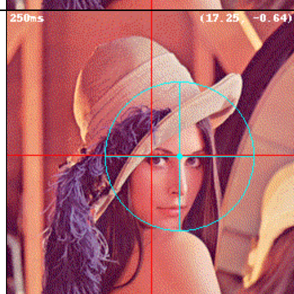
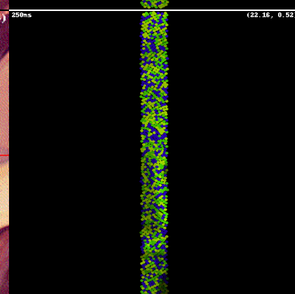
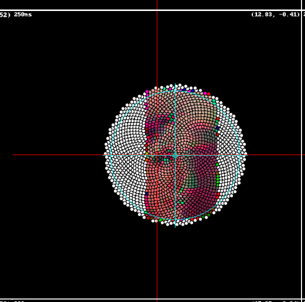
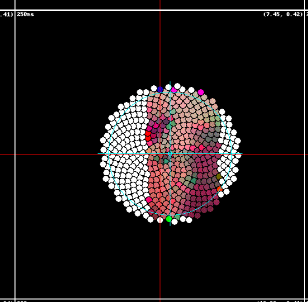
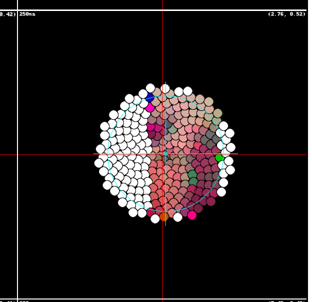
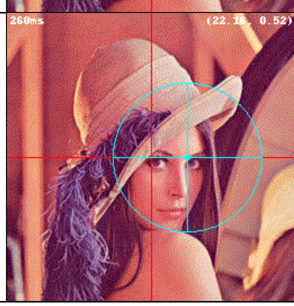
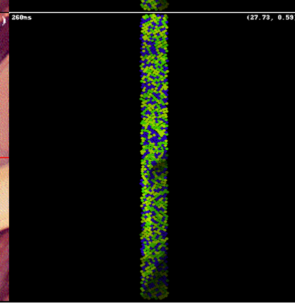
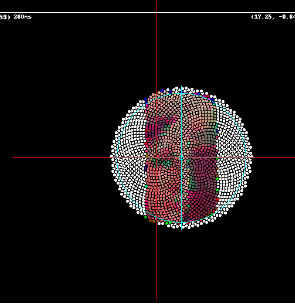
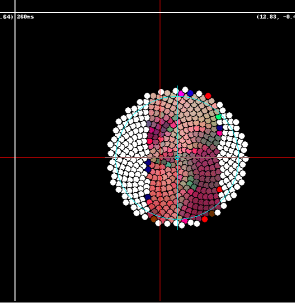
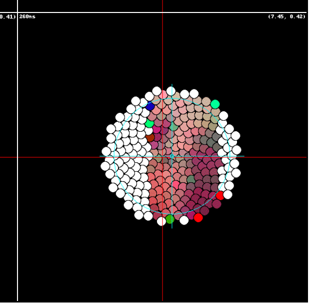
<table>
<tr><th colspan="6">Table 26: Time sequence of narrow slit filling-in over natural image (Lena)</th></tr>
<tr><th rowspan="2">Time (ticks)</th><th rowspan="2">Stimuli</th><th rowspan="2">Photoreceptor Mosaic</th><th colspan="3">Receptive Fields</th></tr>
<tr><th>Level 1</th><th>Level 2</th><th>Level 3</th></tr>
<tr><td>24</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>25</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>26</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

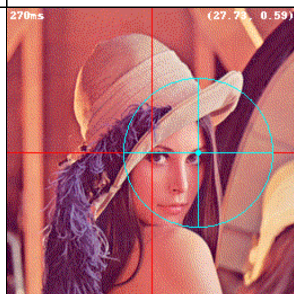
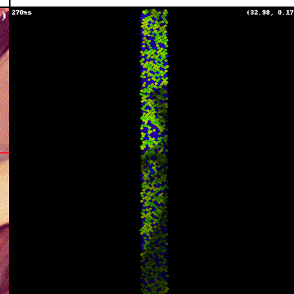
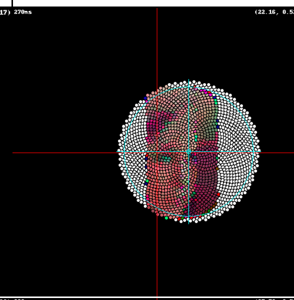
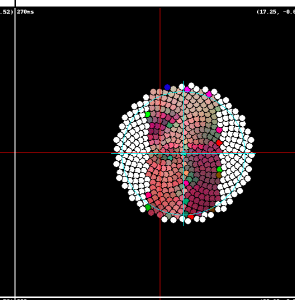
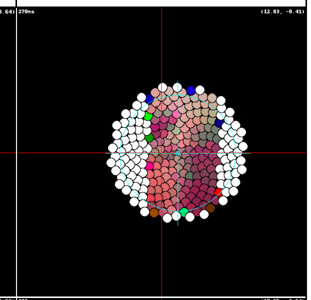
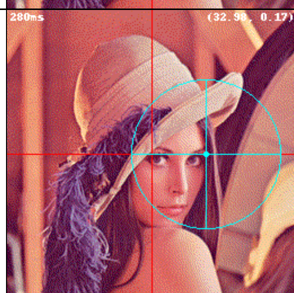
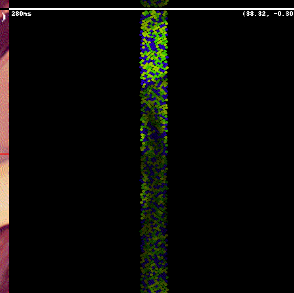
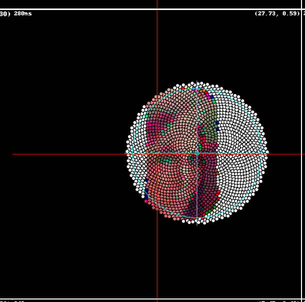
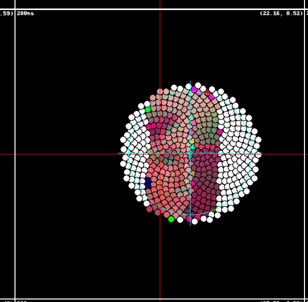
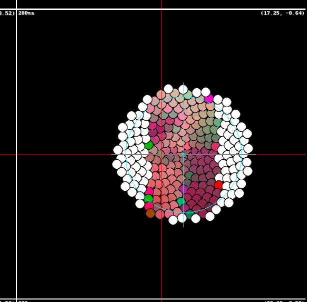
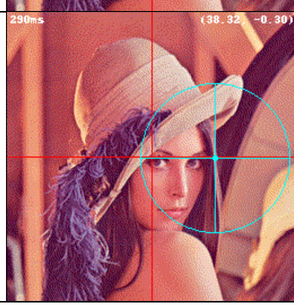
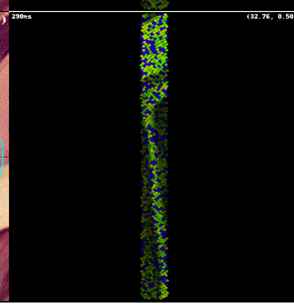
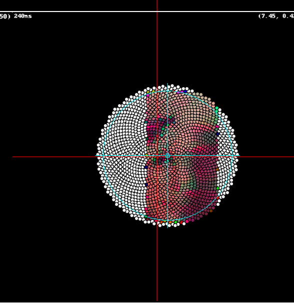
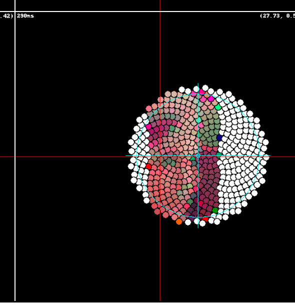
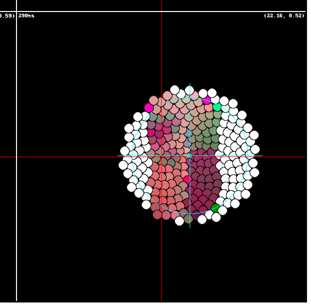
Table 26: Time sequence of narrow slit filling-in over natural image (Lena)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
27					
28					
29					

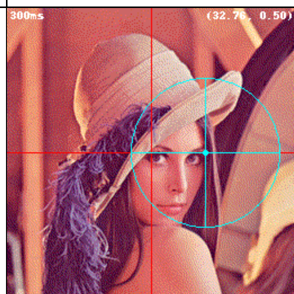
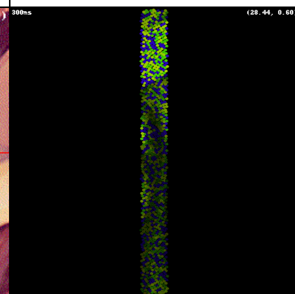
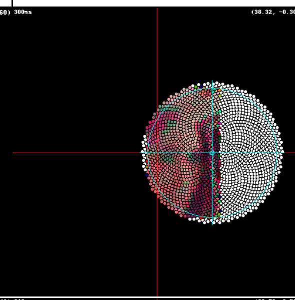
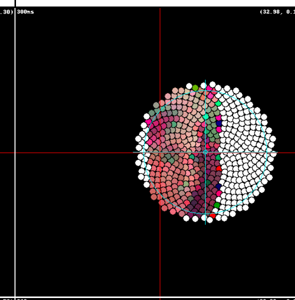
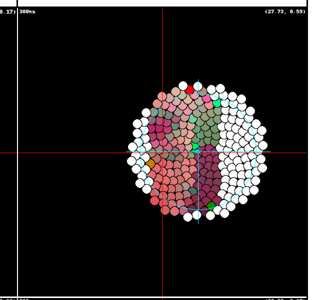
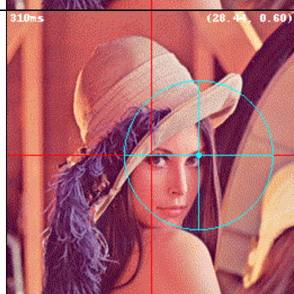
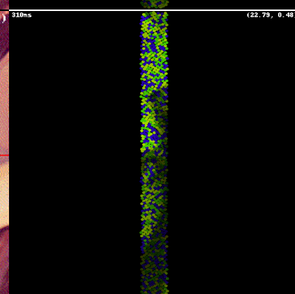
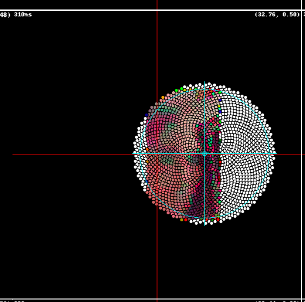
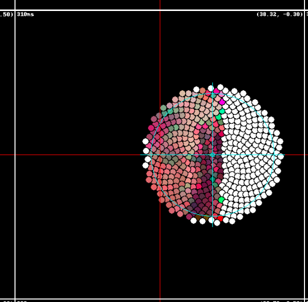
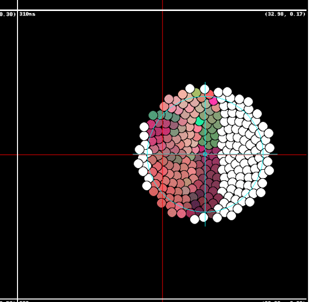
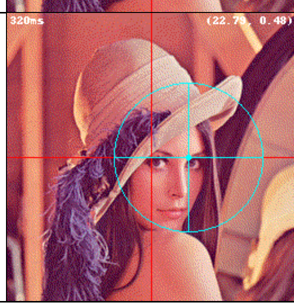
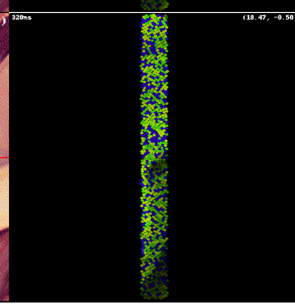
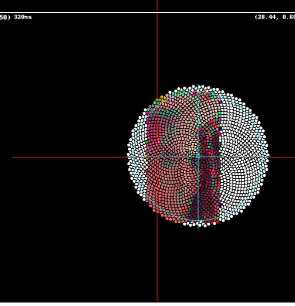
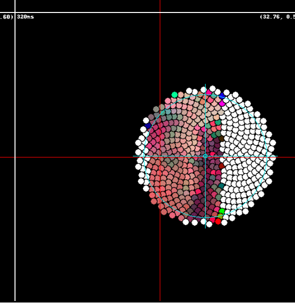
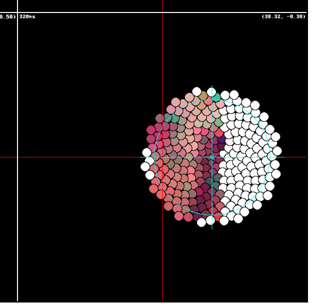
Table 26: Time sequence of narrow slit filling-in over natural image (Lena)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
30					
31					
32					

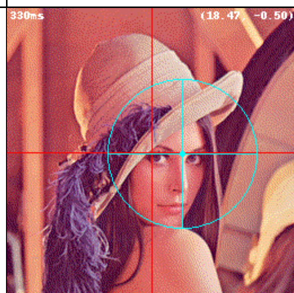
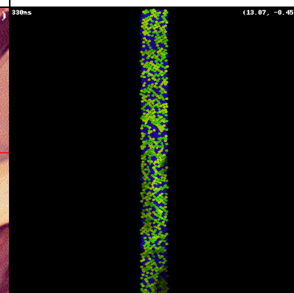
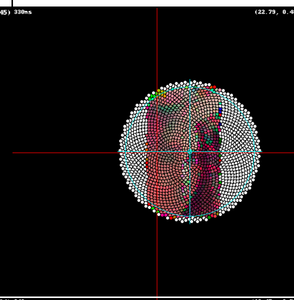
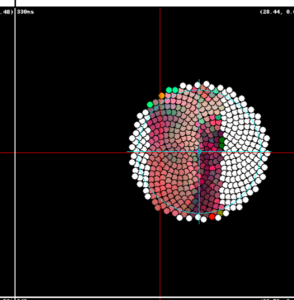
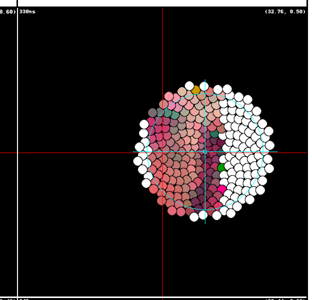
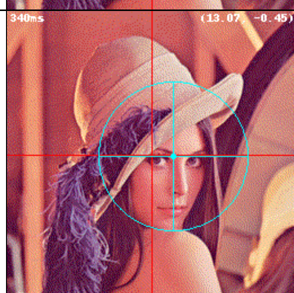
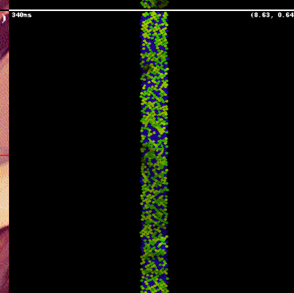
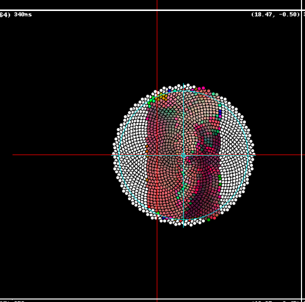
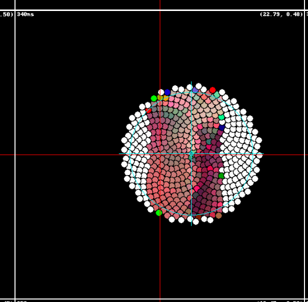
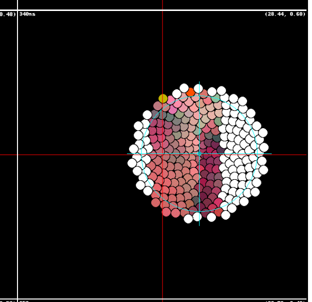
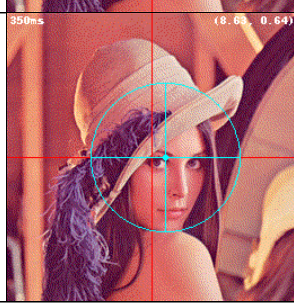
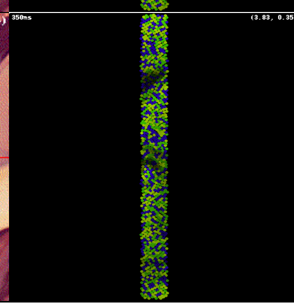
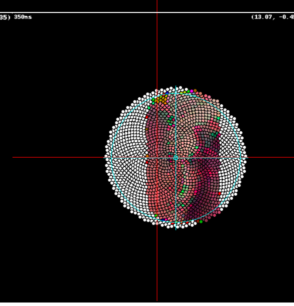
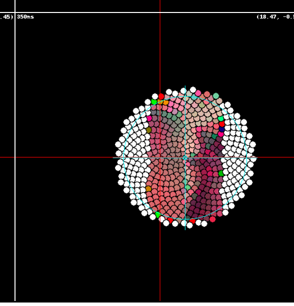
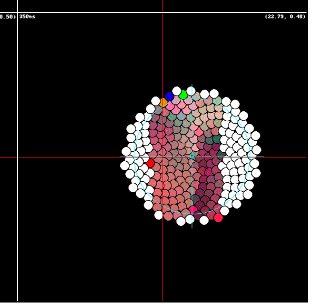
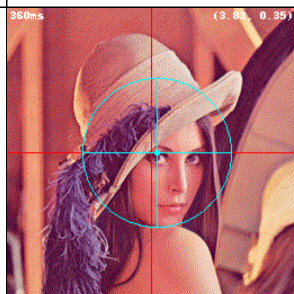
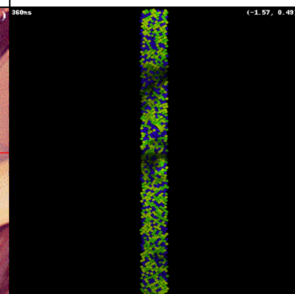
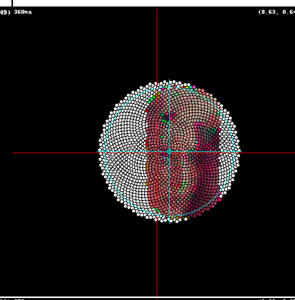
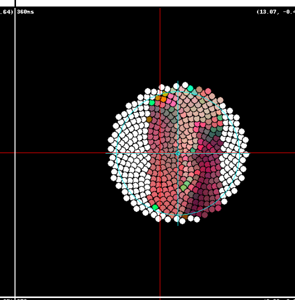
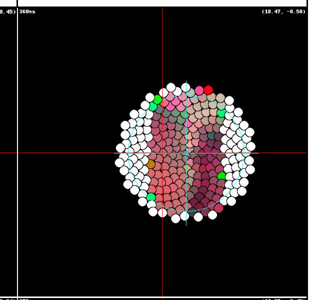
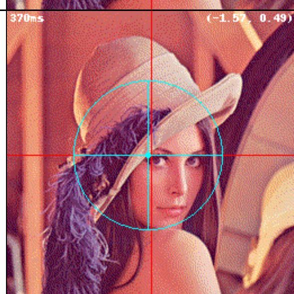
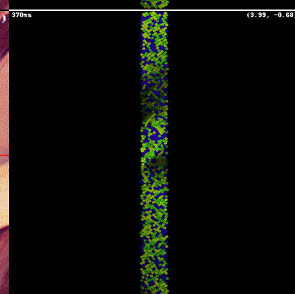
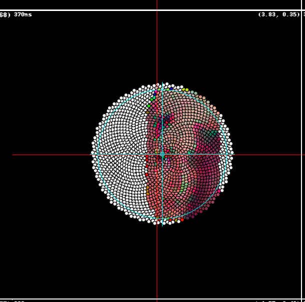
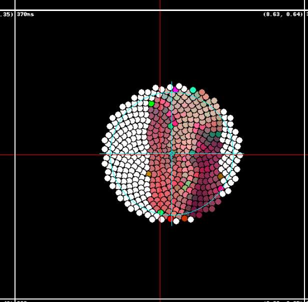
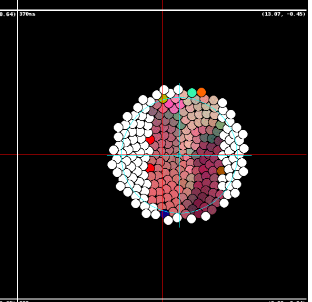
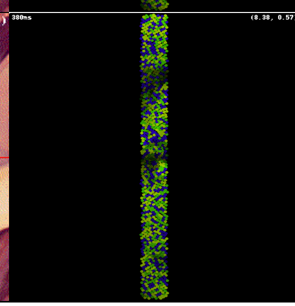
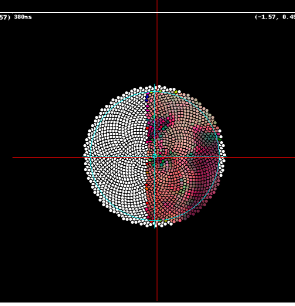
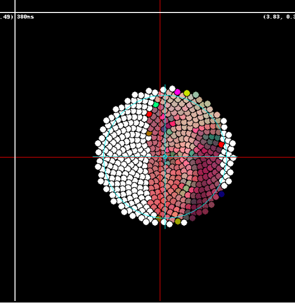
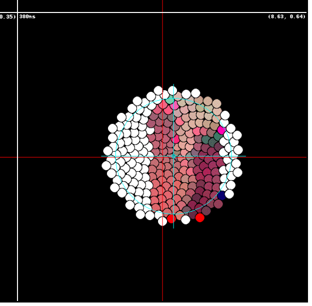
Table 26: Time sequence of narrow slit filling-in over natural image (Lena)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
33					
34					
35					

Table 26: Time sequence of narrow slit filling-in over natural image (Lena)

Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
36					
37					
38					

A.3.3 Test 3 results: Dynamic image with surface gradients (Chaser)

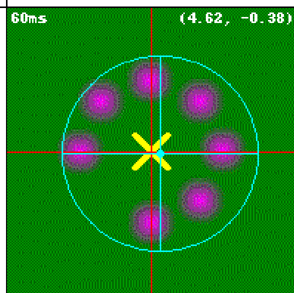
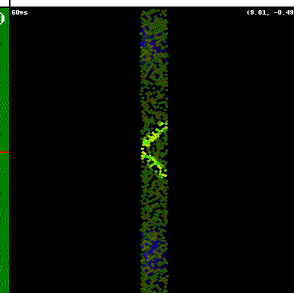
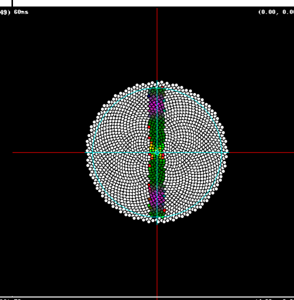
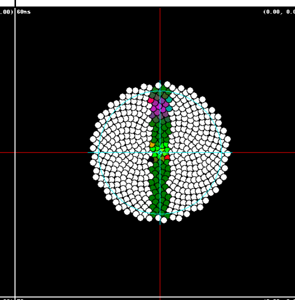
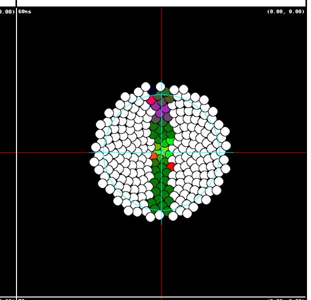
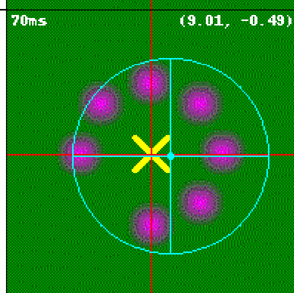
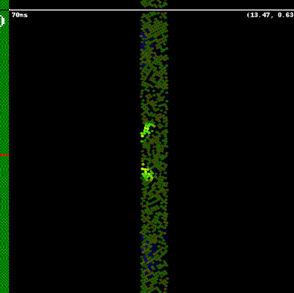
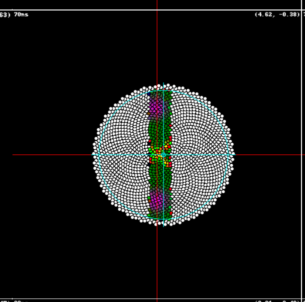
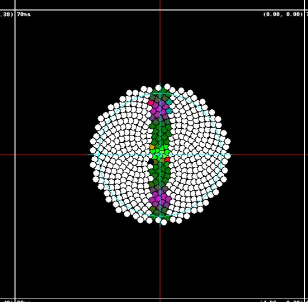
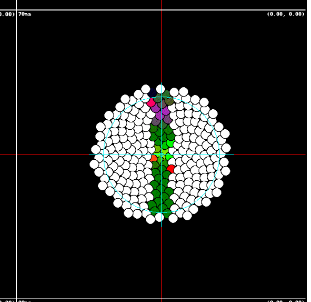
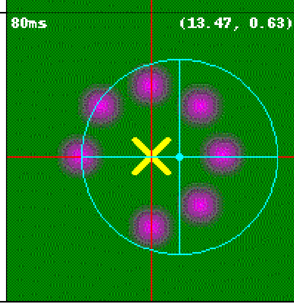
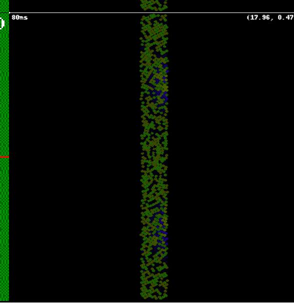
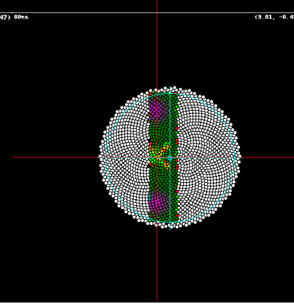
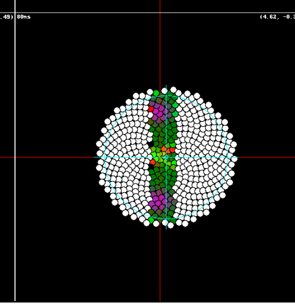
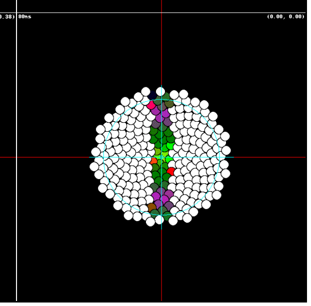
Table 27: Time sequence of narrow slit filling-in over dynamic image with surface gradients (Chaser)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
6					
7					
8					

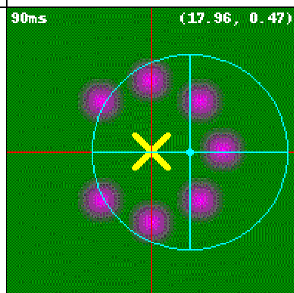
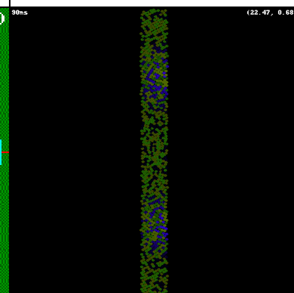
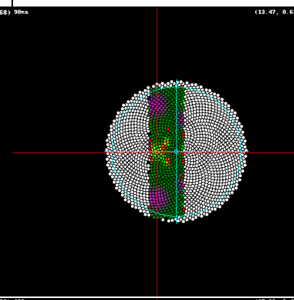
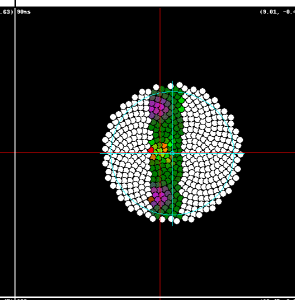
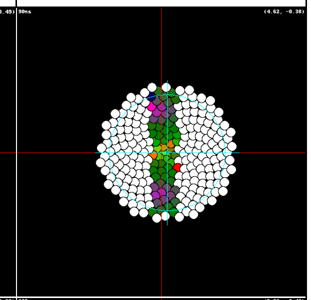
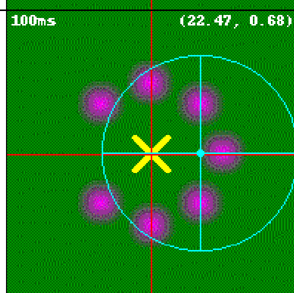
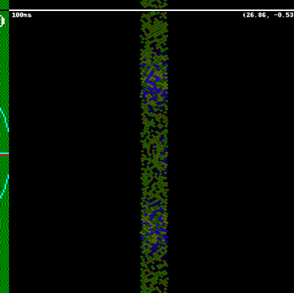
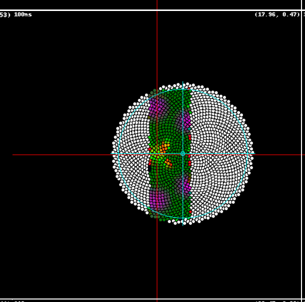
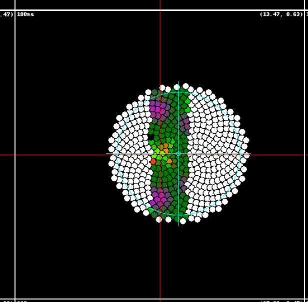
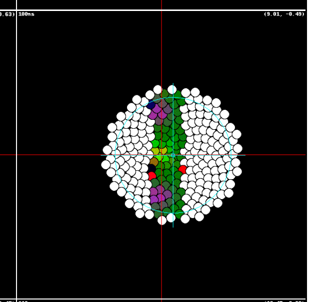
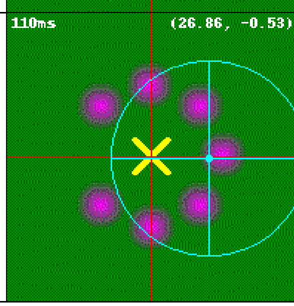
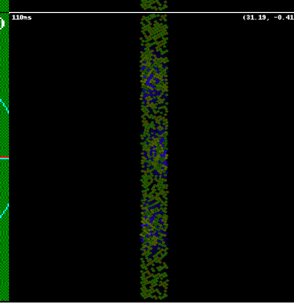
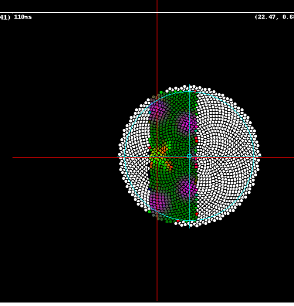
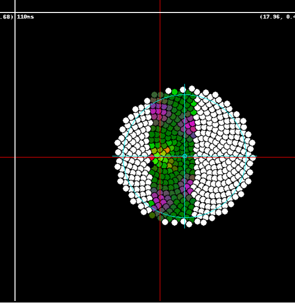
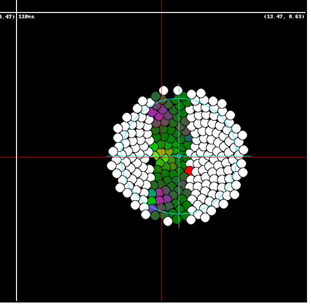
Table 27: Time sequence of narrow slit filling-in over dynamic image with surface gradients (Chaser)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
9					
10					
11					

Table 27: Time sequence of narrow slit filling-in over dynamic image with surface gradients (Chaser)

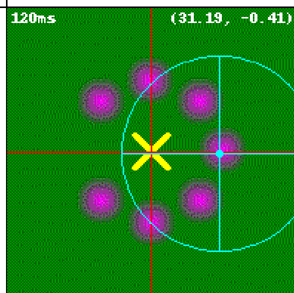
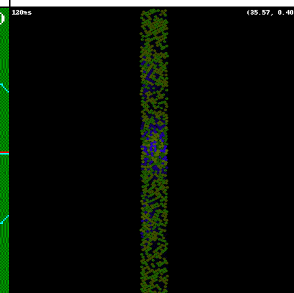
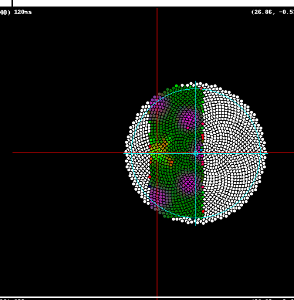
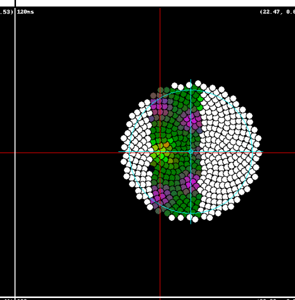
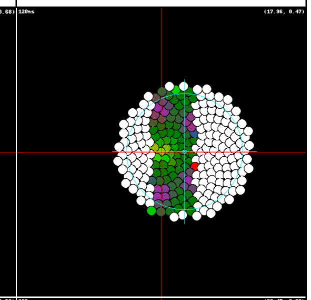
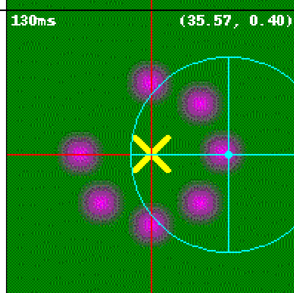
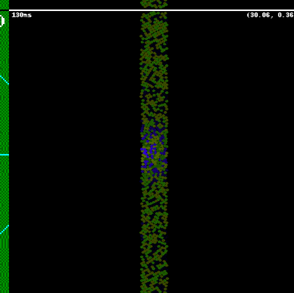
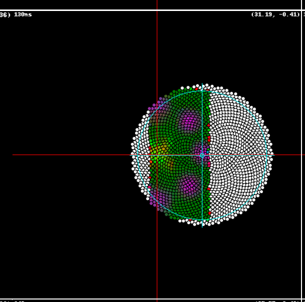
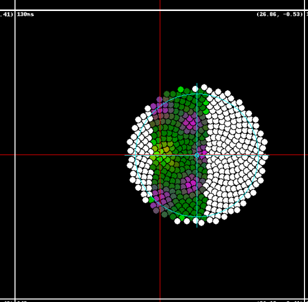
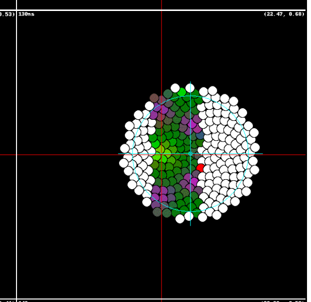
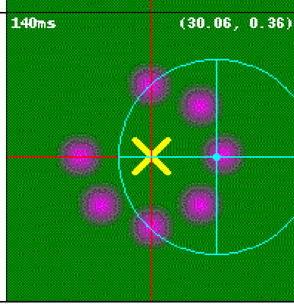
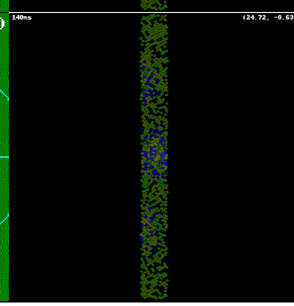
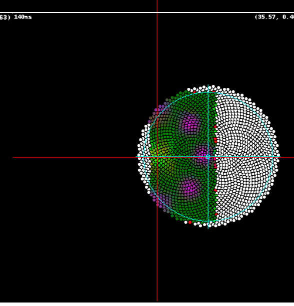
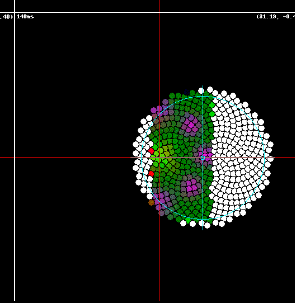
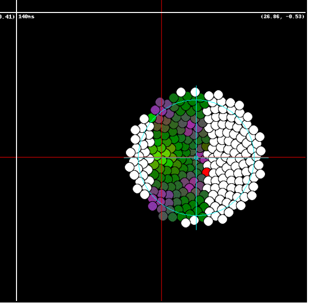
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
12					
13					
14					

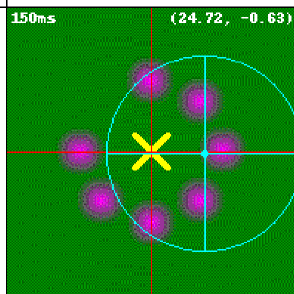
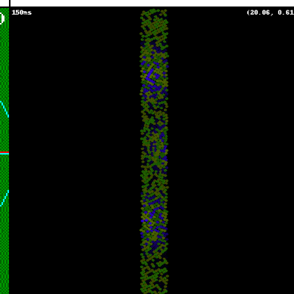
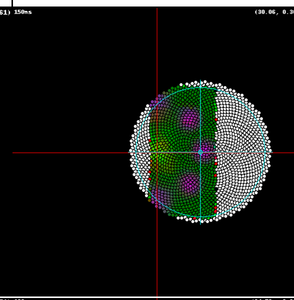
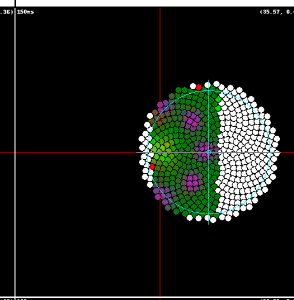
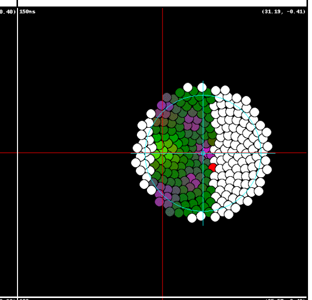
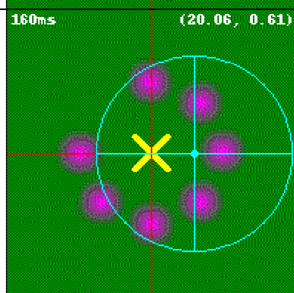
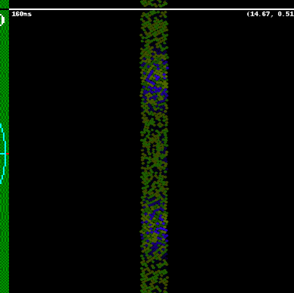
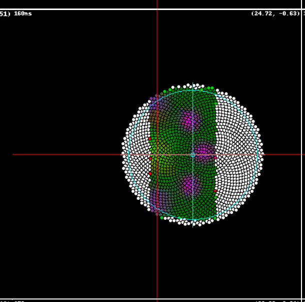
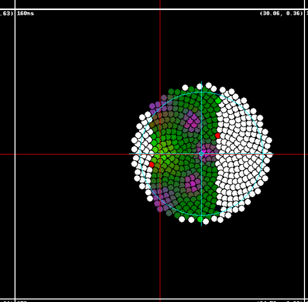
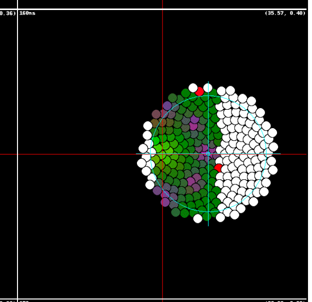
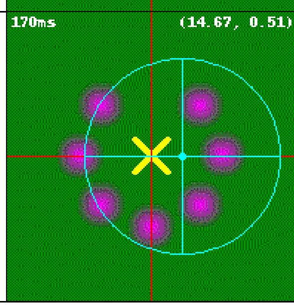
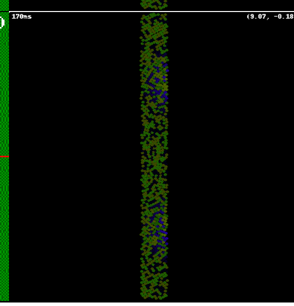
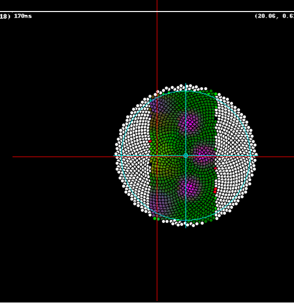
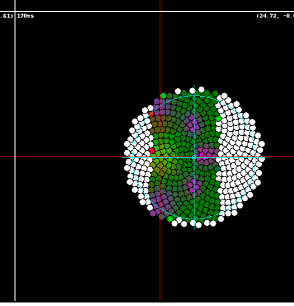
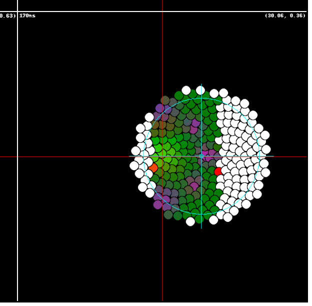
Table 27: Time sequence of narrow slit filling-in over dynamic image with surface gradients (Chaser)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields Level 1	Receptive Fields Level 2	Receptive Fields Level 3
15					
16					
17					

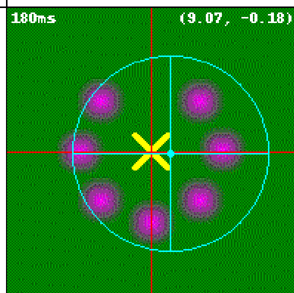
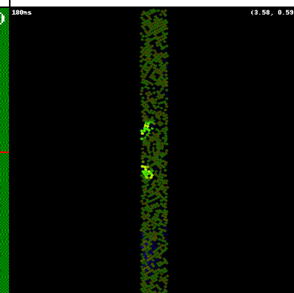
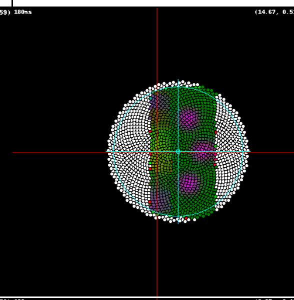
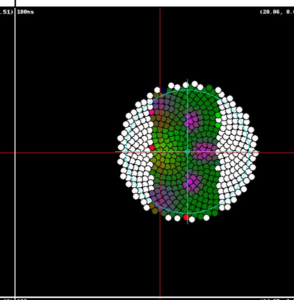
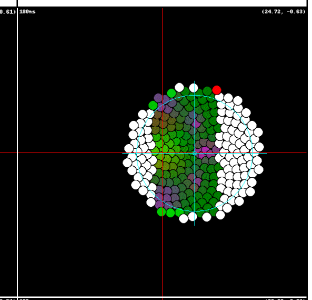
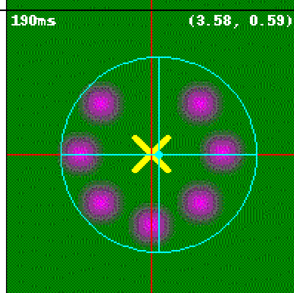
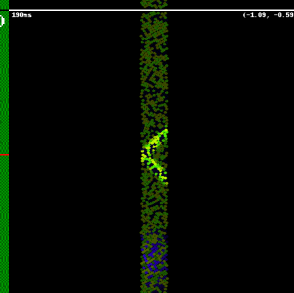
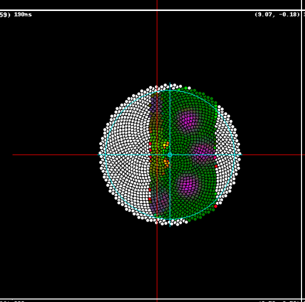
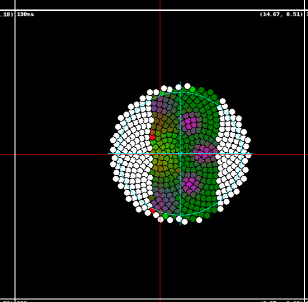
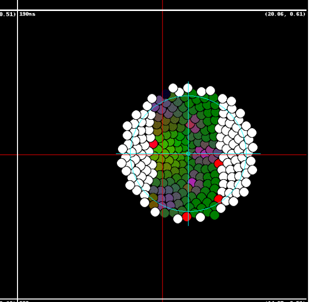
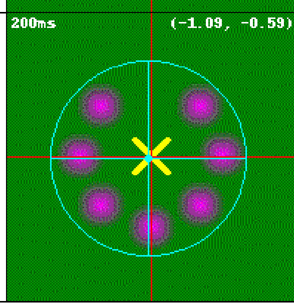
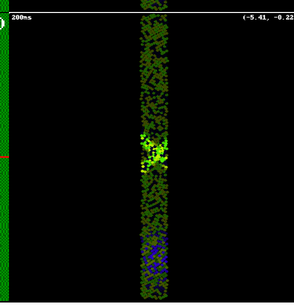
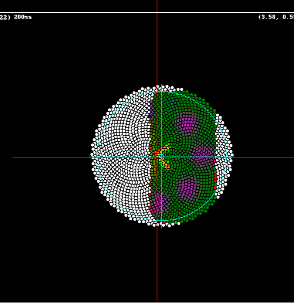
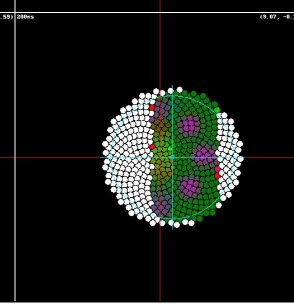
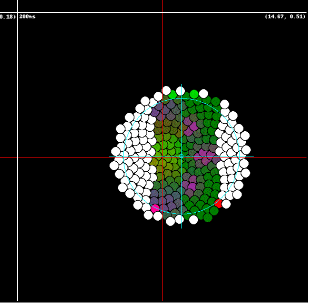
Table 27: Time sequence of narrow slit filling-in over dynamic image with surface gradients (Chaser)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
18					
19					
20					

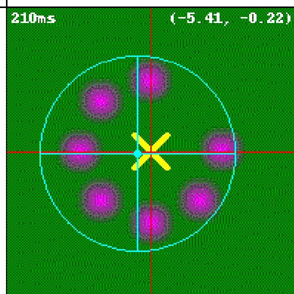
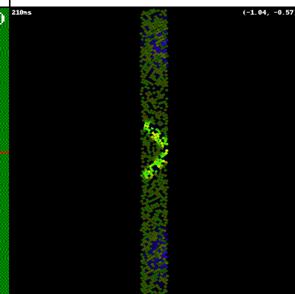
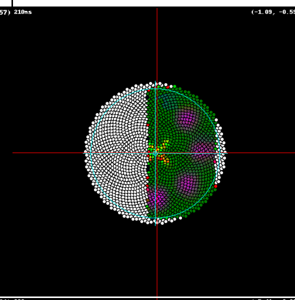
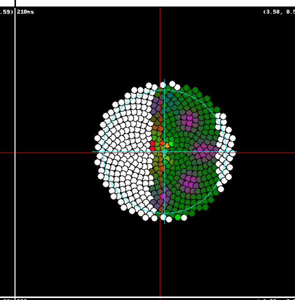
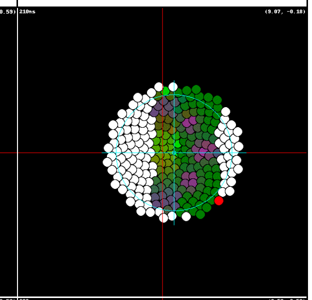
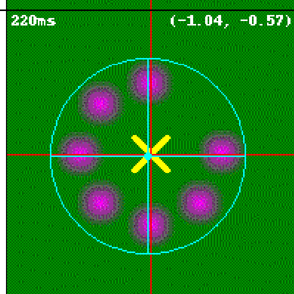
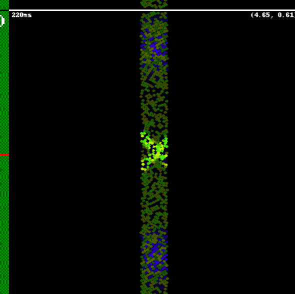
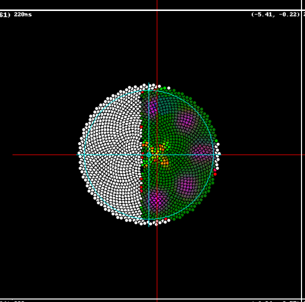
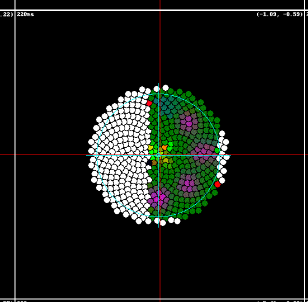
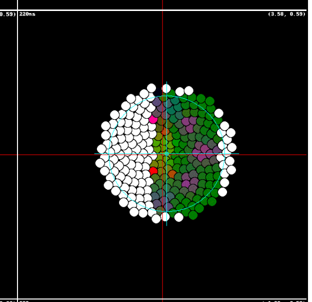
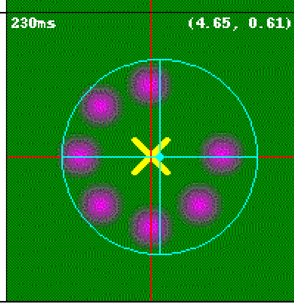
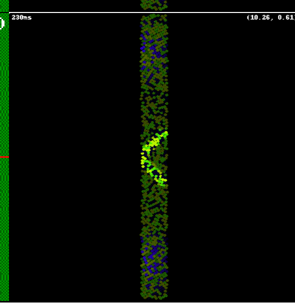
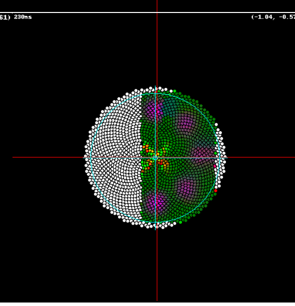
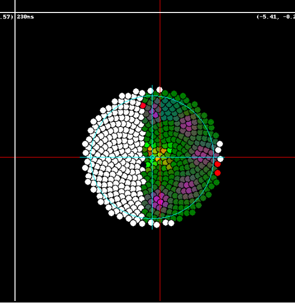
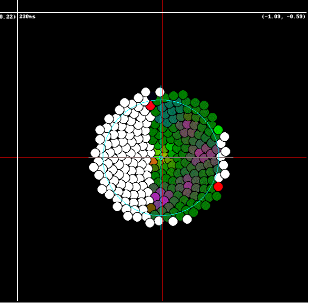
Table 27: Time sequence of narrow slit filling-in over dynamic image with surface gradients (Chaser)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
21					
22					
23					

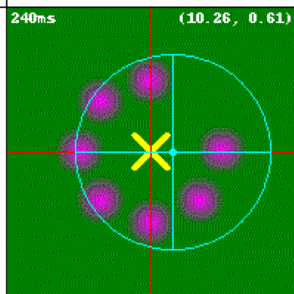
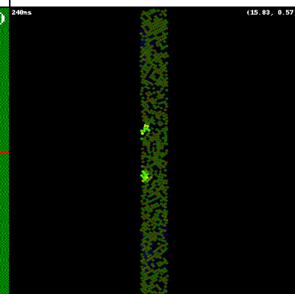
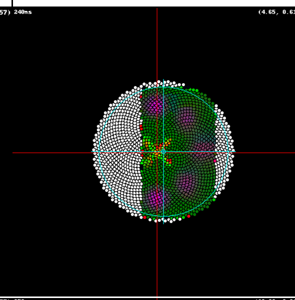
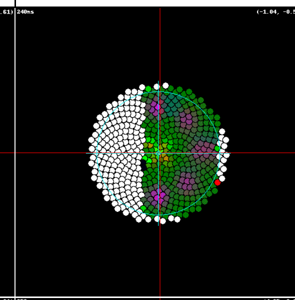
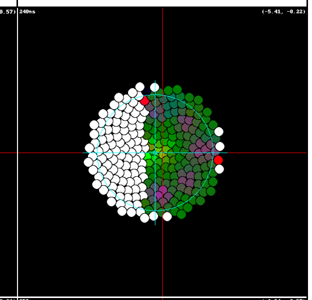
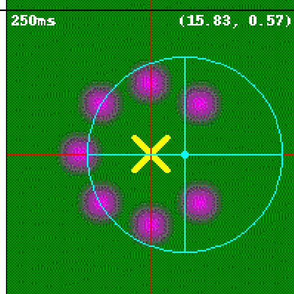
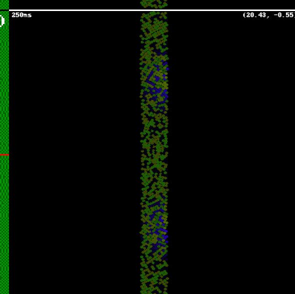
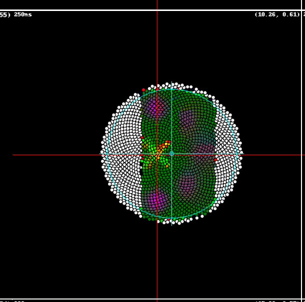
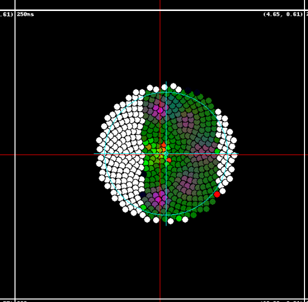
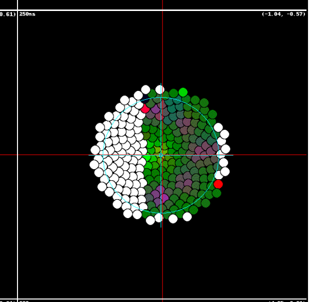
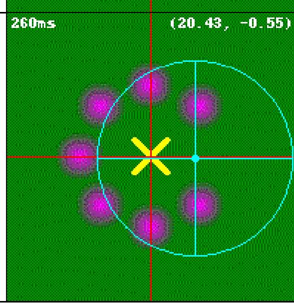
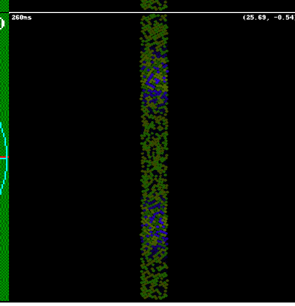
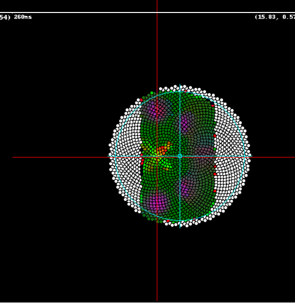
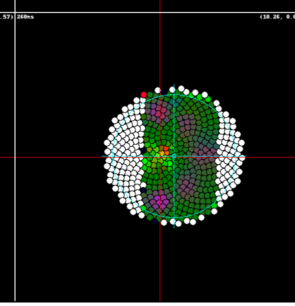
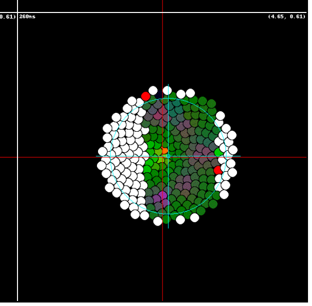
Table 27: Time sequence of narrow slit filling-in over dynamic image with surface gradients (Chaser)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
24					
25					
26					

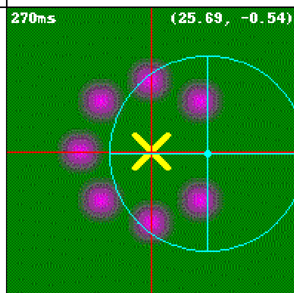
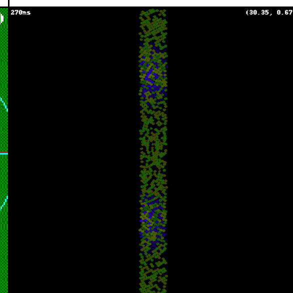
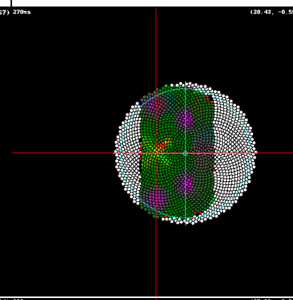
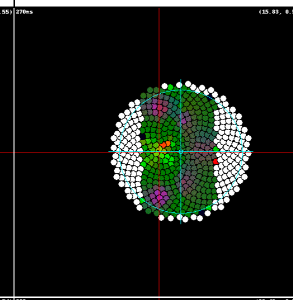
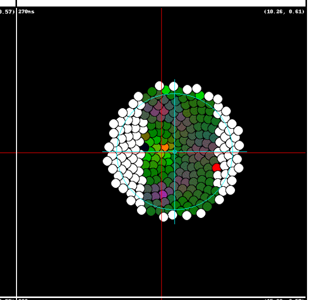
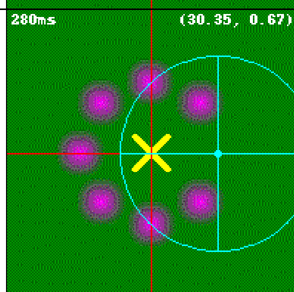
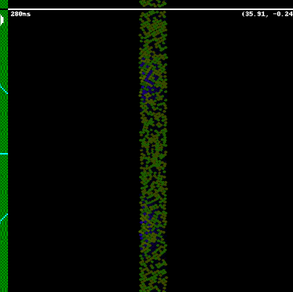
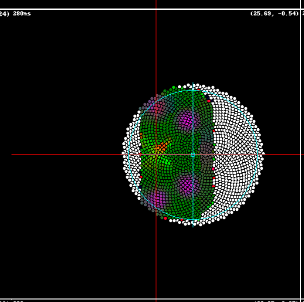
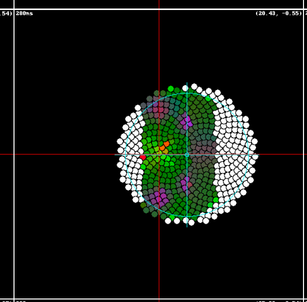
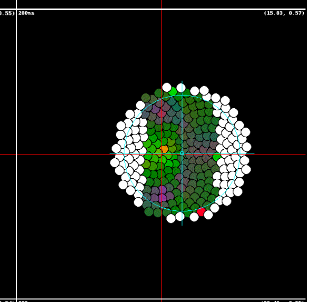
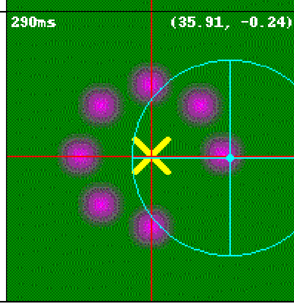
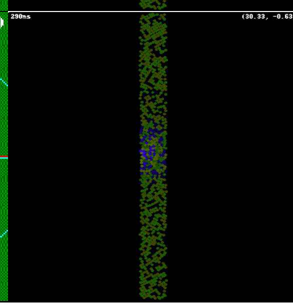
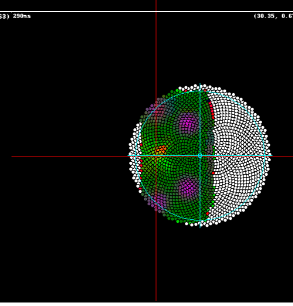
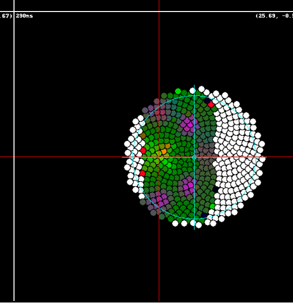
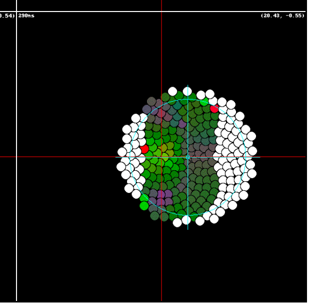
Table 27: Time sequence of narrow slit filling-in over dynamic image with surface gradients (Chaser)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
27					
28					
29					

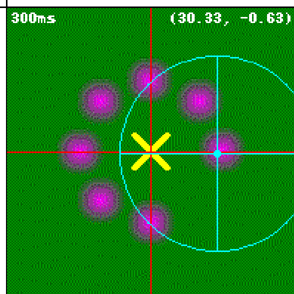
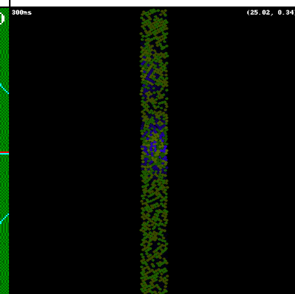
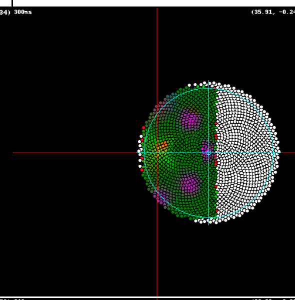
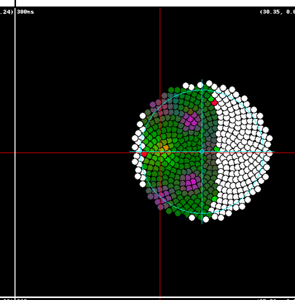
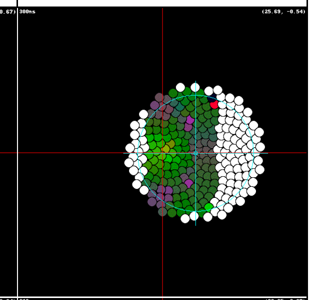
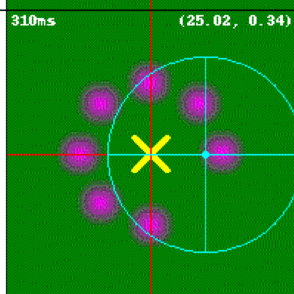
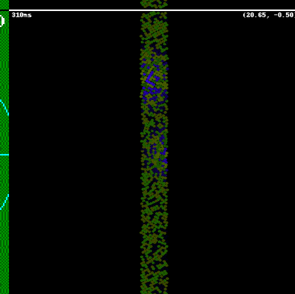
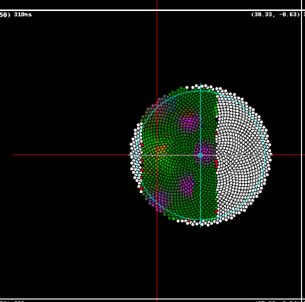
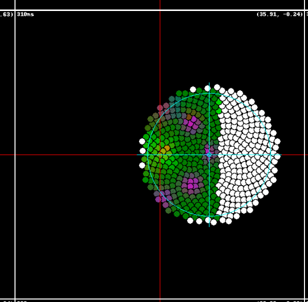
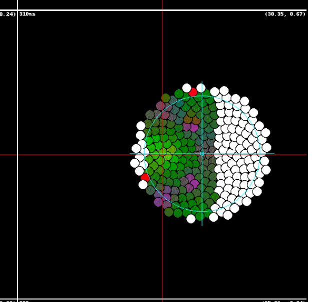
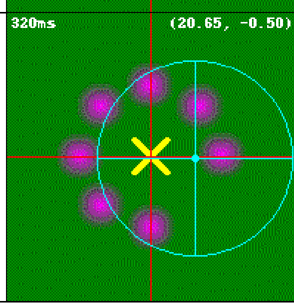
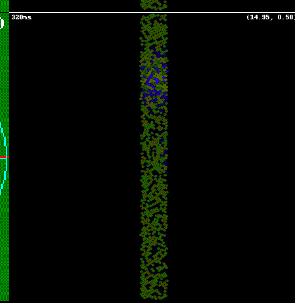
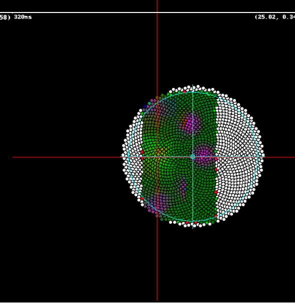
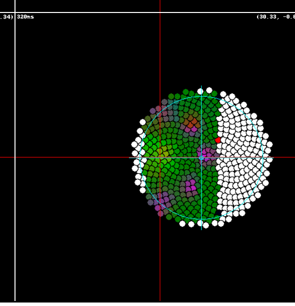
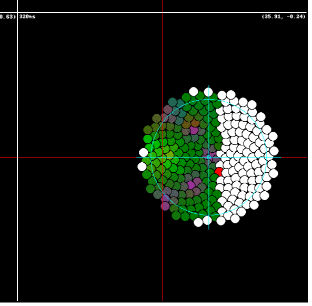
Table 27: Time sequence of narrow slit filling-in over dynamic image with surface gradients (Chaser)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
30					
31					
32					

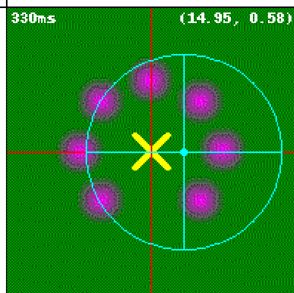
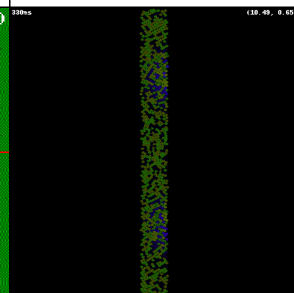
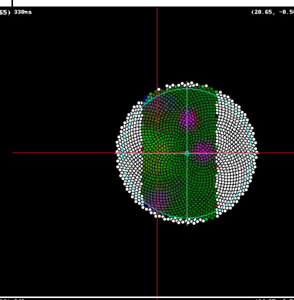
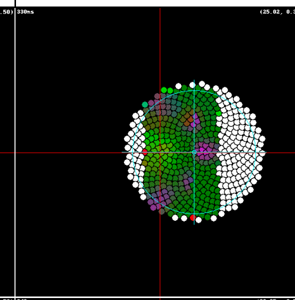
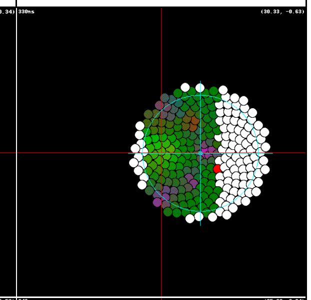
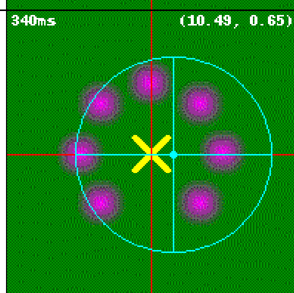
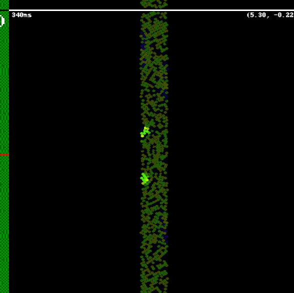
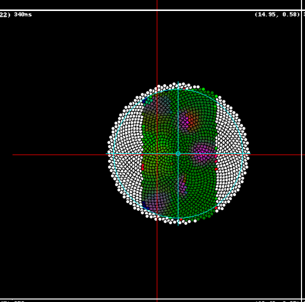
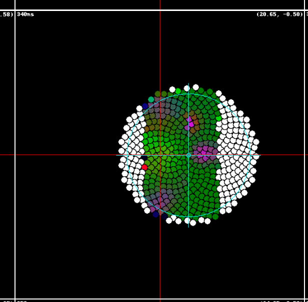
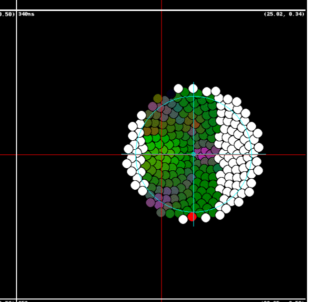
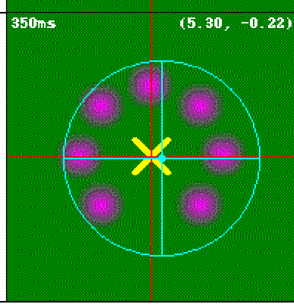
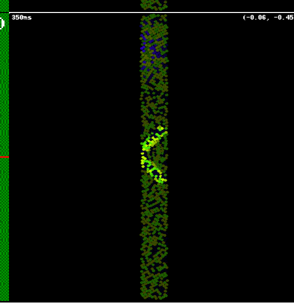
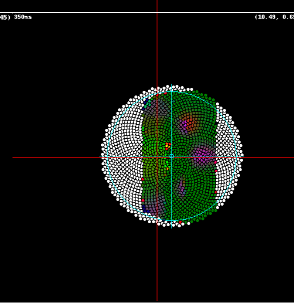
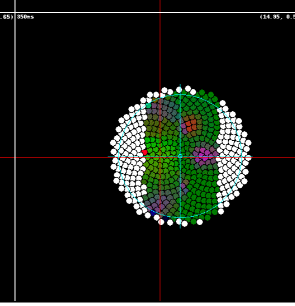
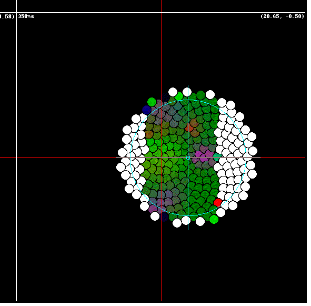
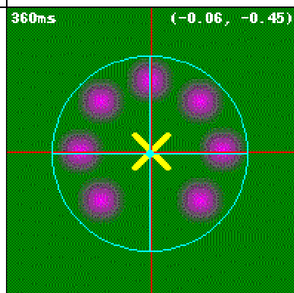
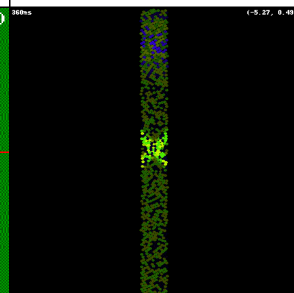
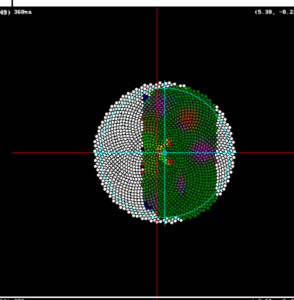
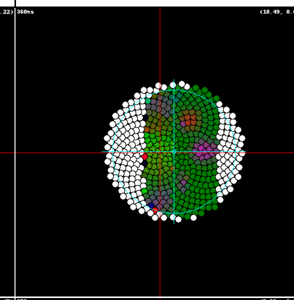
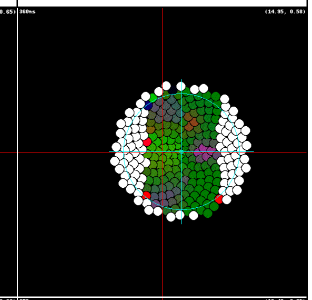
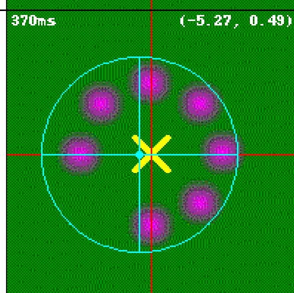
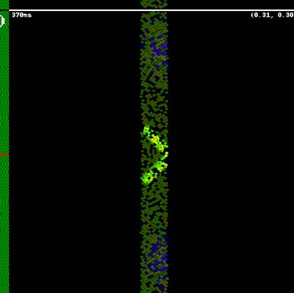
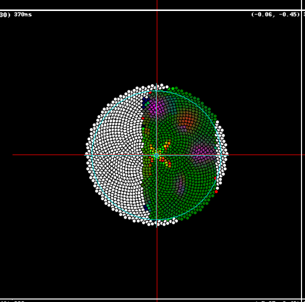
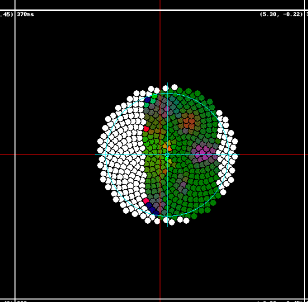
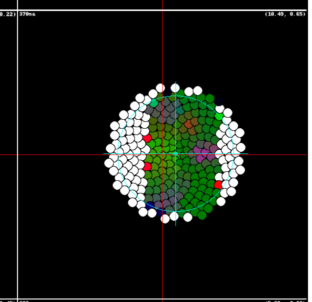
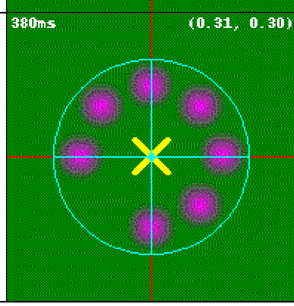
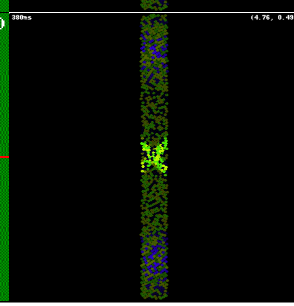
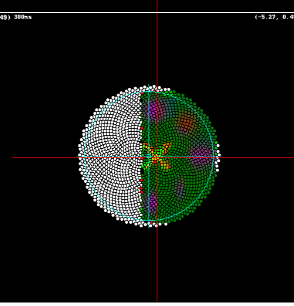
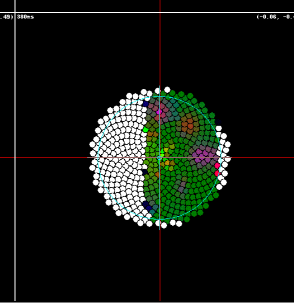
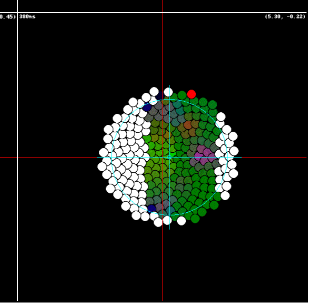
Table 27: Time sequence of narrow slit filling-in over dynamic image with surface gradients (Chaser)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
33					
34					
35					

Table 27: Time sequence of narrow slit filling-in over dynamic image with surface gradients (Chaser)					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
36					
37					
38					

A.3.4 Test 4 results: Simple object (Square)

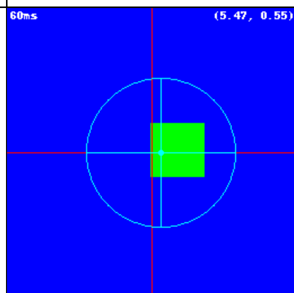
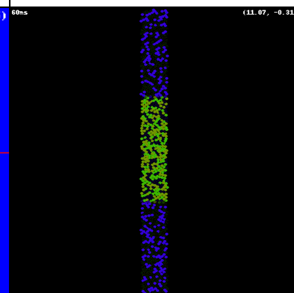
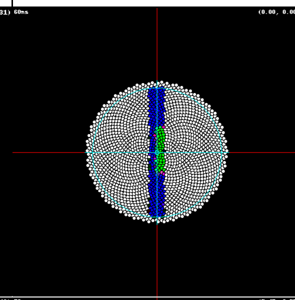
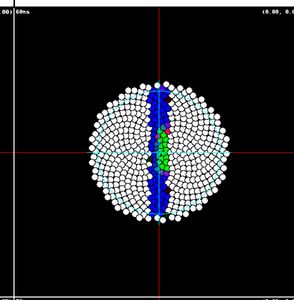
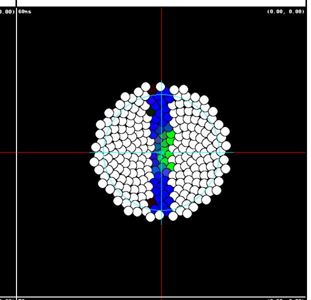
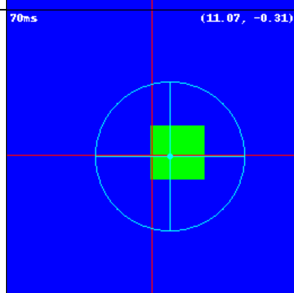
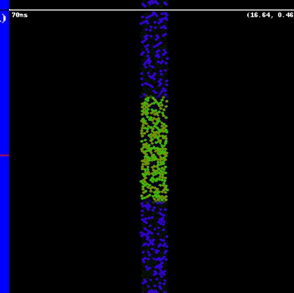
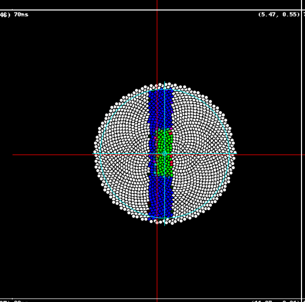
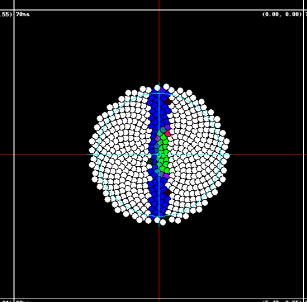
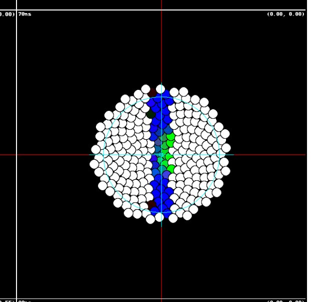
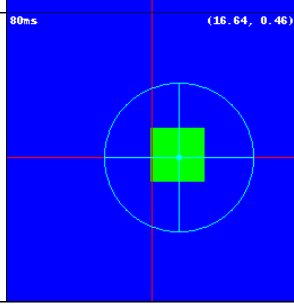
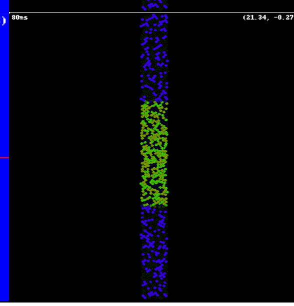
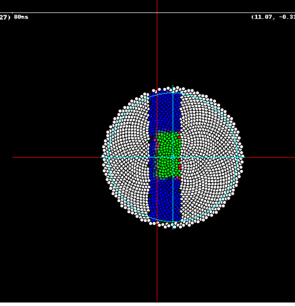
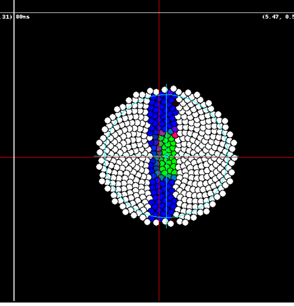
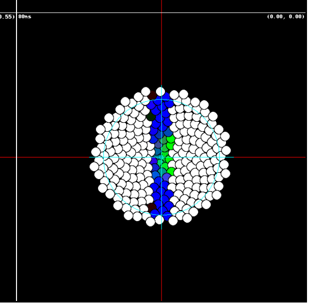
Table 28: Time sequence of narrow slit filling-in over simple object (Square)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
6					
7					
8					

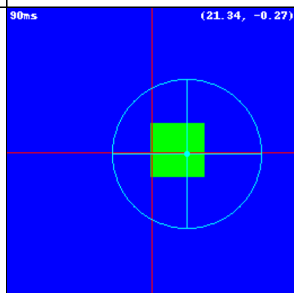
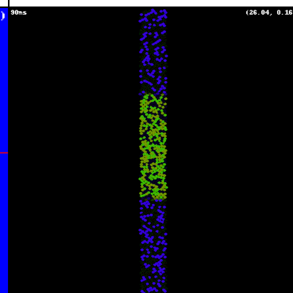
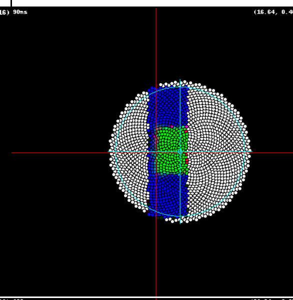
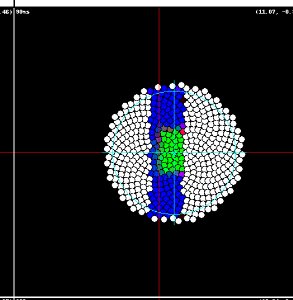
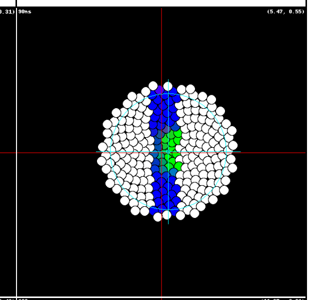
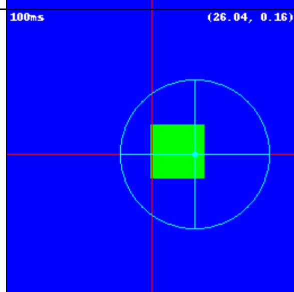
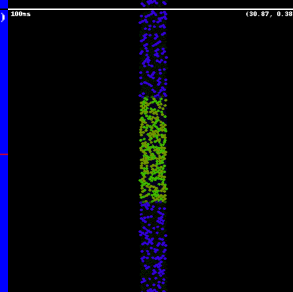
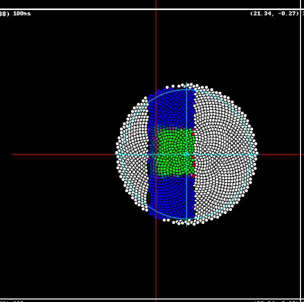
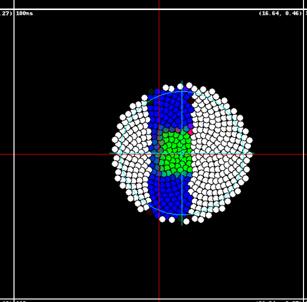
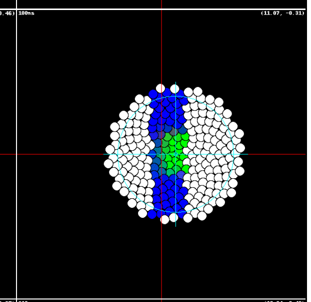
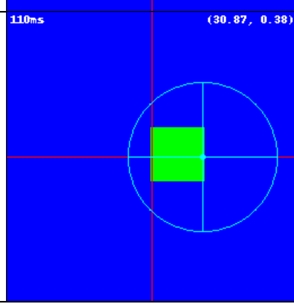
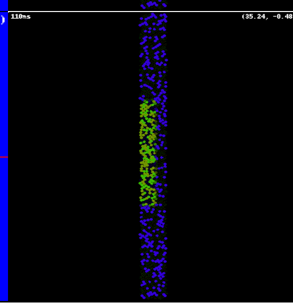
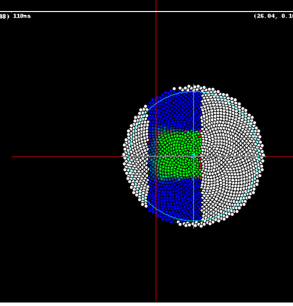
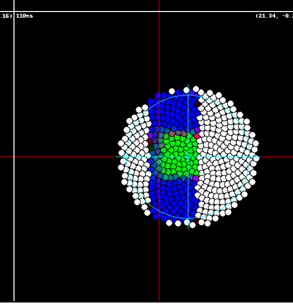
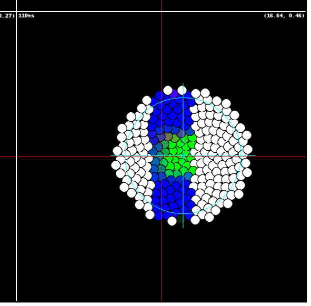
Table 28: Time sequence of narrow slit filling-in over simple object (Square)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
9					
10					
11					

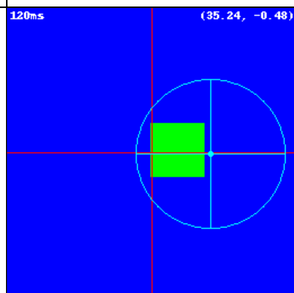
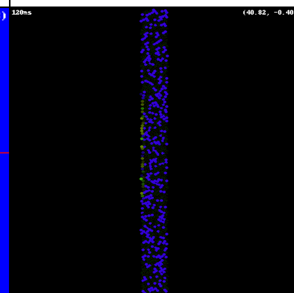
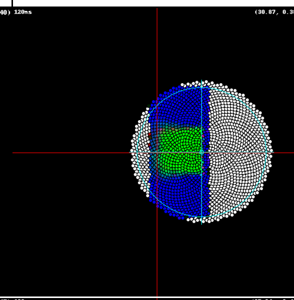
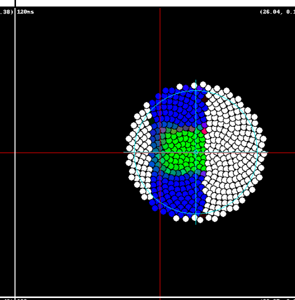
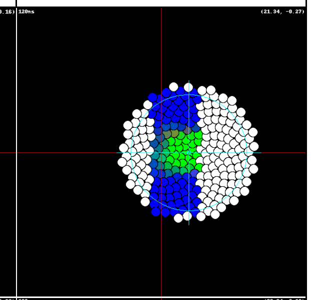
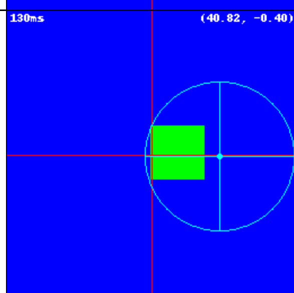
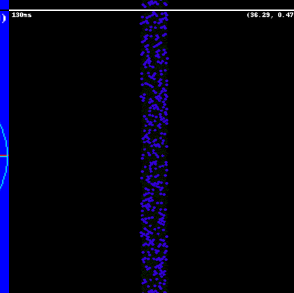
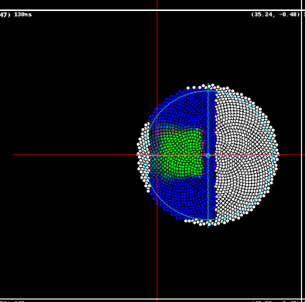
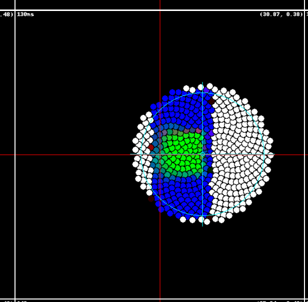
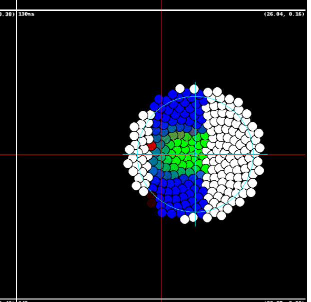
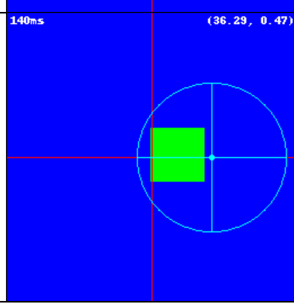
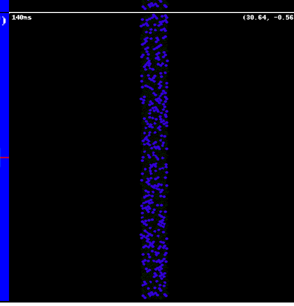
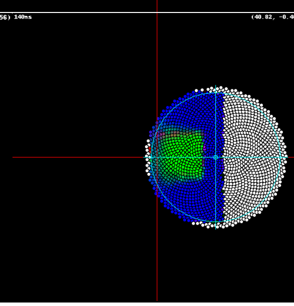
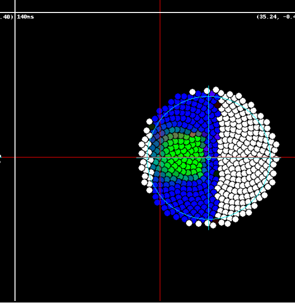
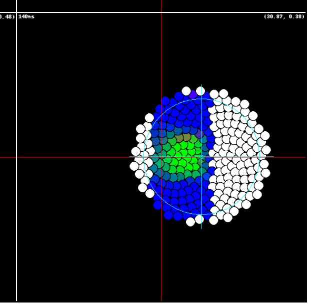
Table 28: Time sequence of narrow slit filling-in over simple object (Square)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
12					
13					
14					

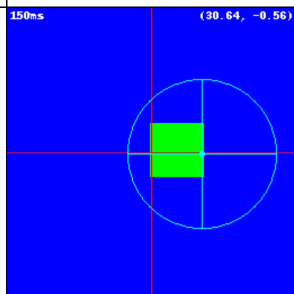
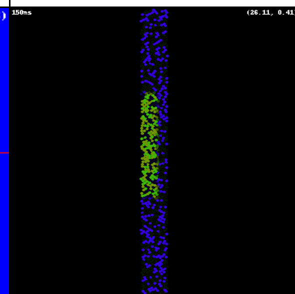
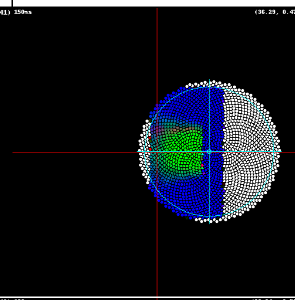
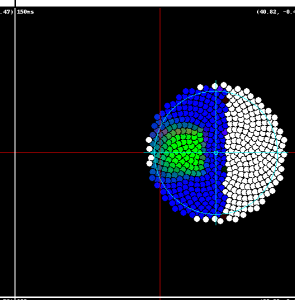
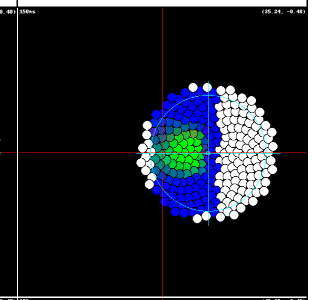
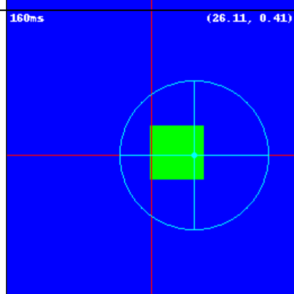
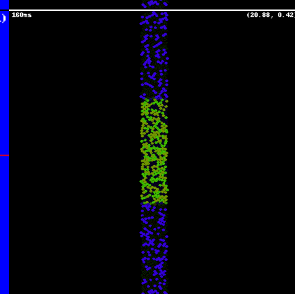
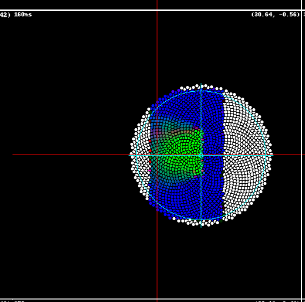
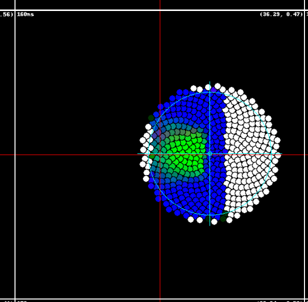
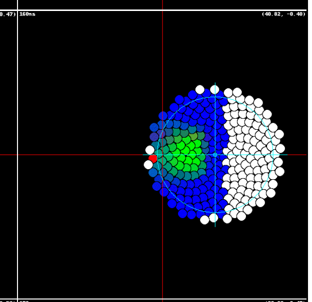
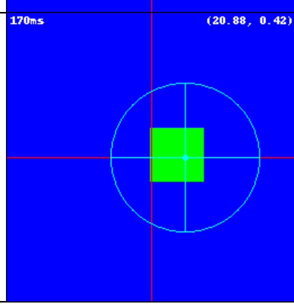
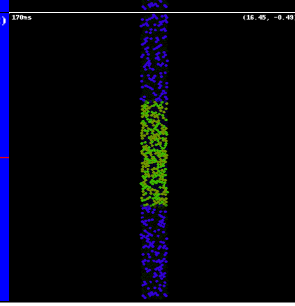
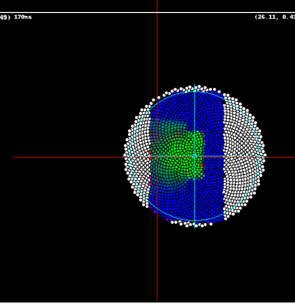
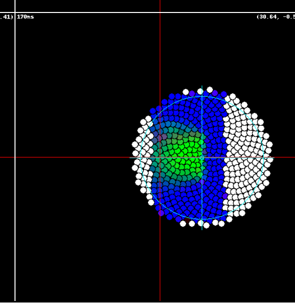
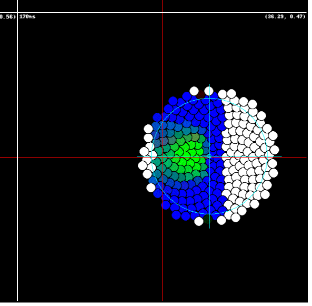
Table 28: Time sequence of narrow slit filling-in over simple object (Square)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
15					
16					
17					

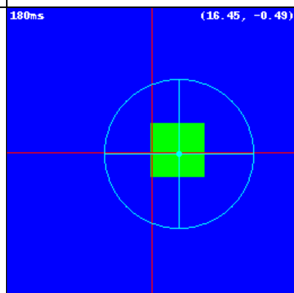
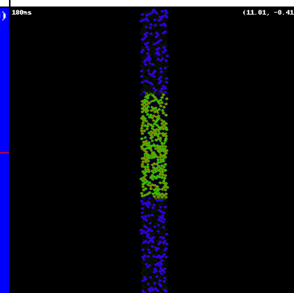
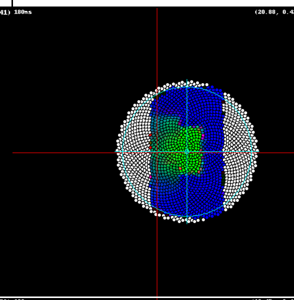
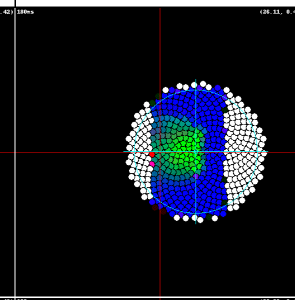
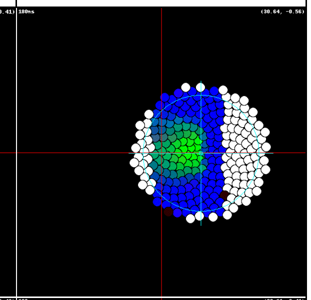
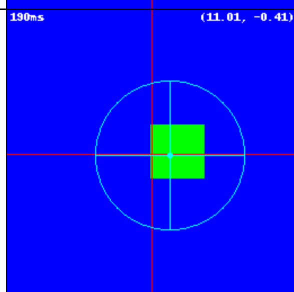
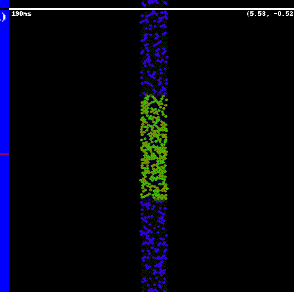
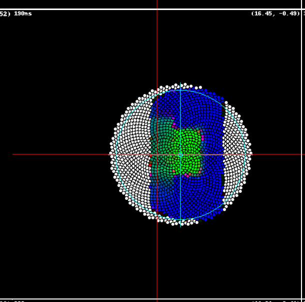
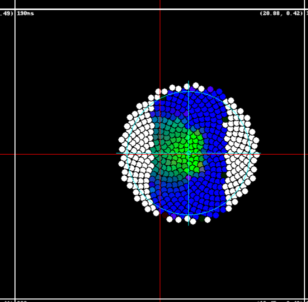
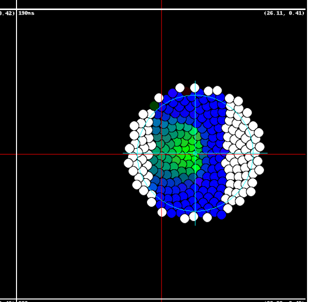
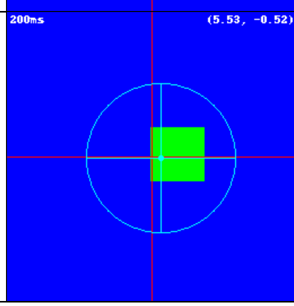
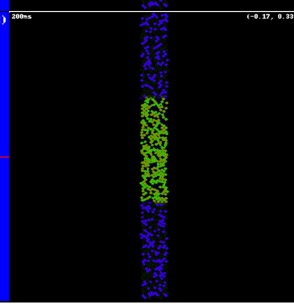
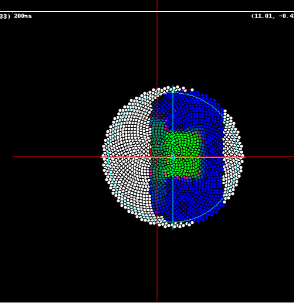
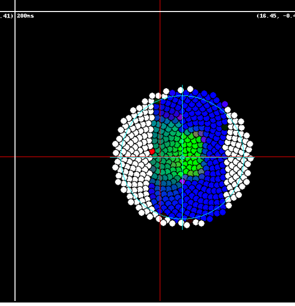
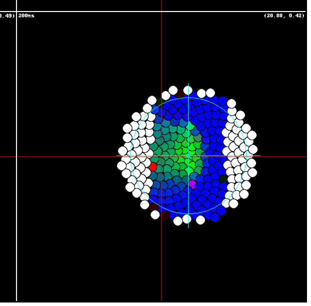
Table 28: Time sequence of narrow slit filling-in over simple object (Square)					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
18					
19					
20					

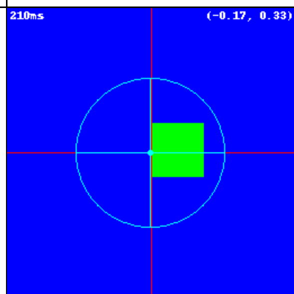
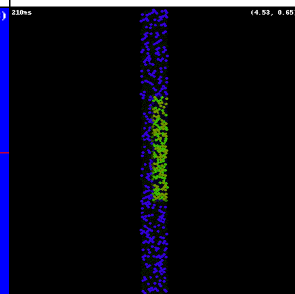
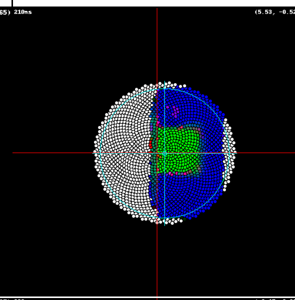
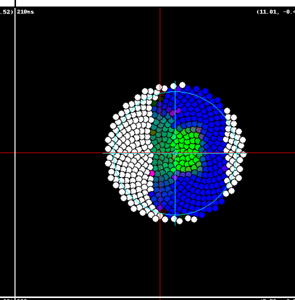
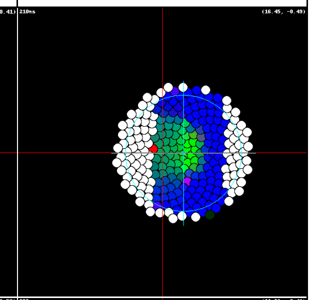
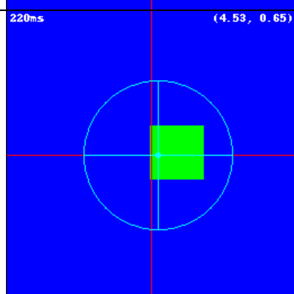
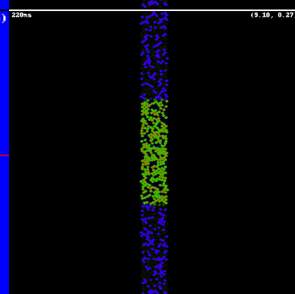
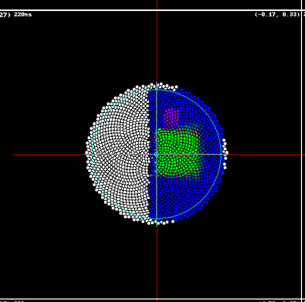
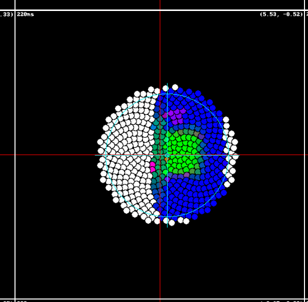
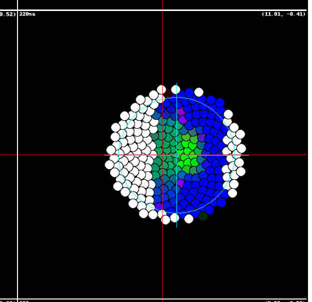
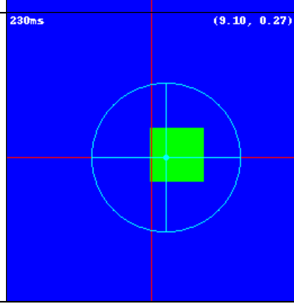
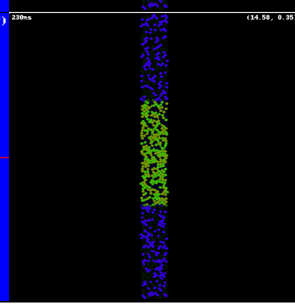
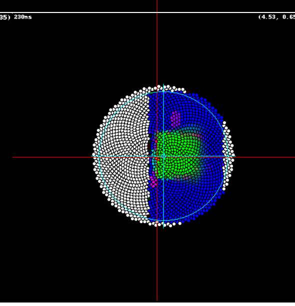
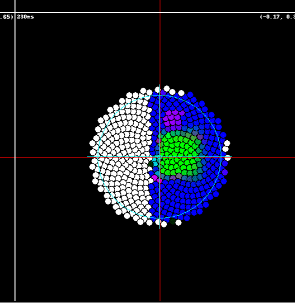
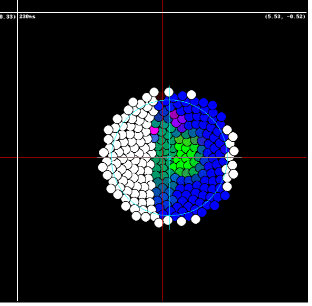
Table 28: Time sequence of narrow slit filling-in over simple object (Square)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
21					
22					
23					

Table 28: Time sequence of narrow slit filling-in over simple object (Square)

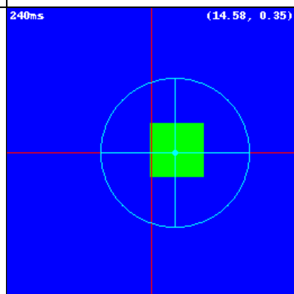
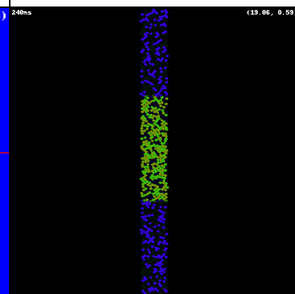
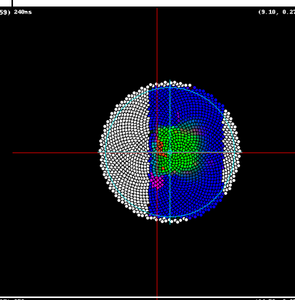
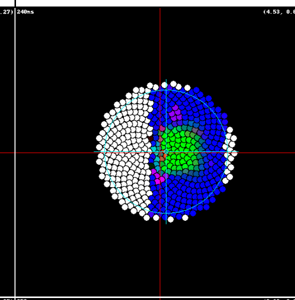
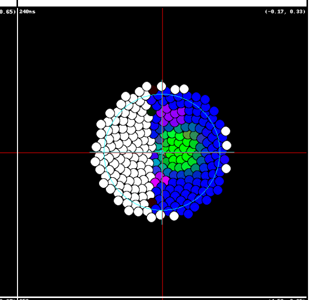
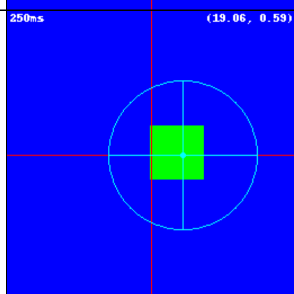
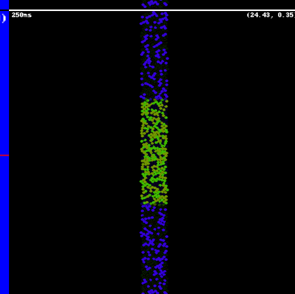
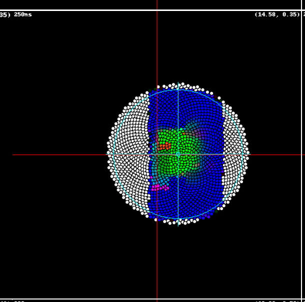
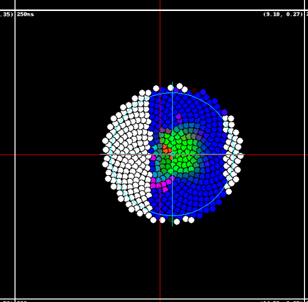
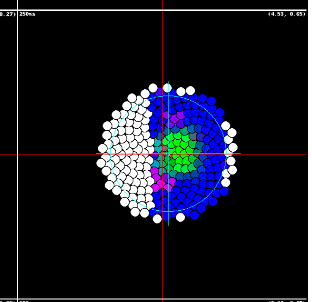
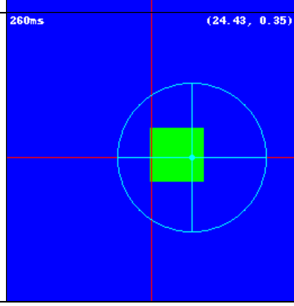
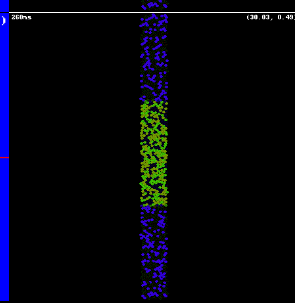
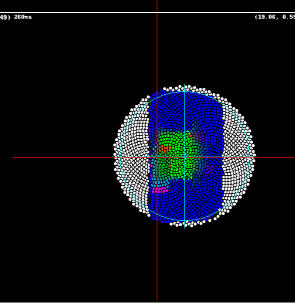
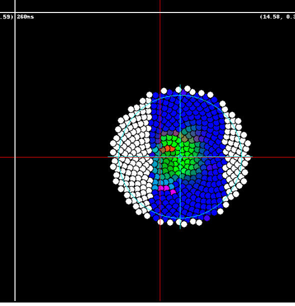
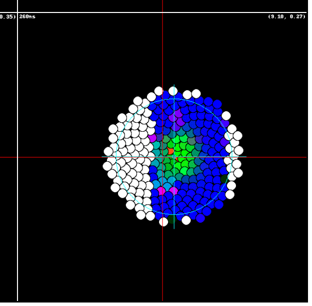
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
24					
25					
26					

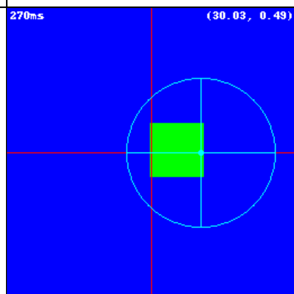
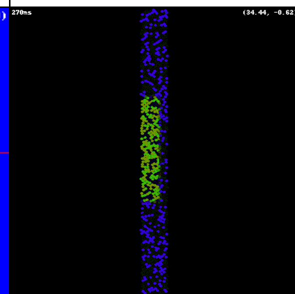
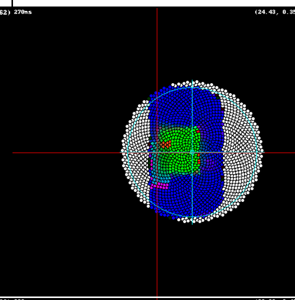
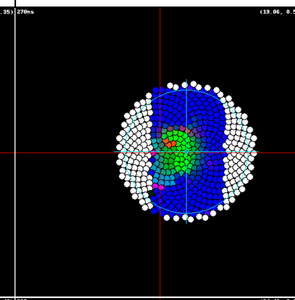
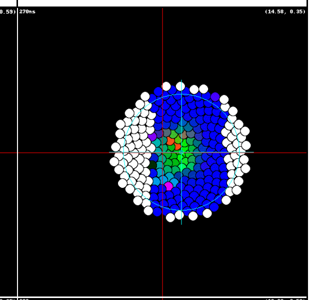
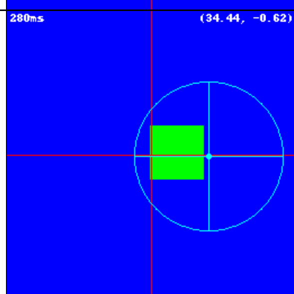
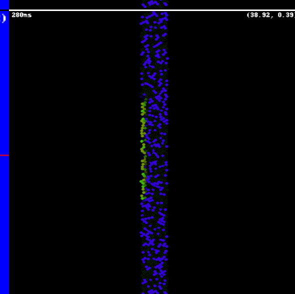
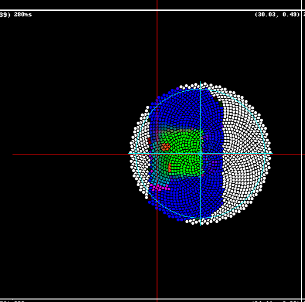
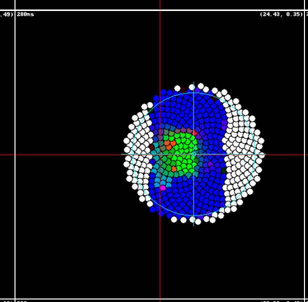
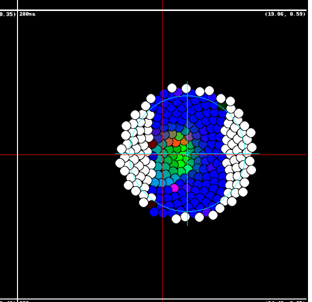
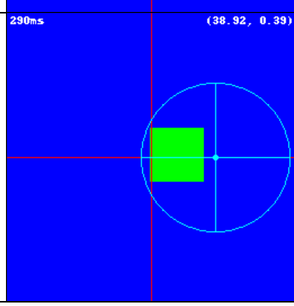
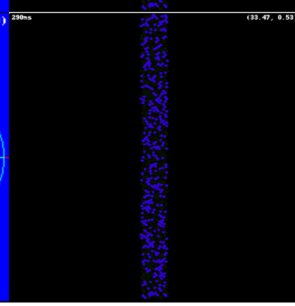
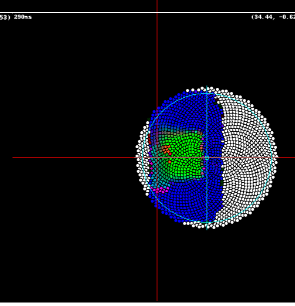
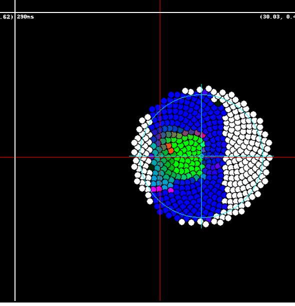
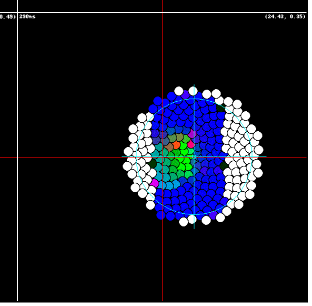
Table 28: Time sequence of narrow slit filling-in over simple object (Square)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
27					
28					
29					

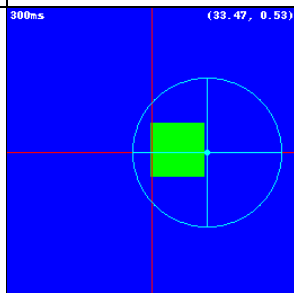
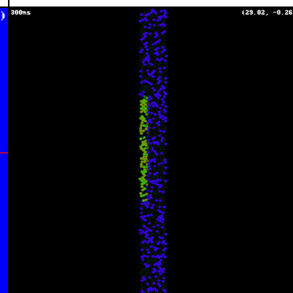
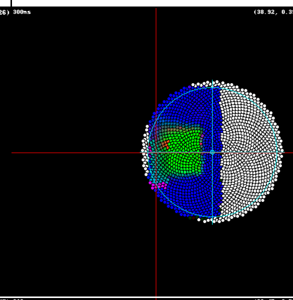
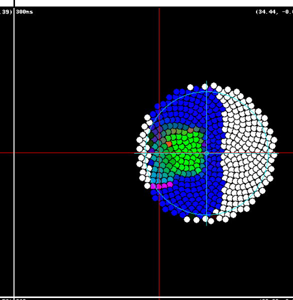
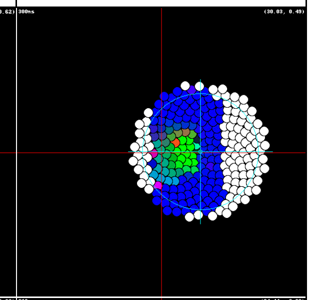
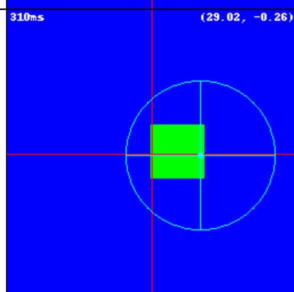
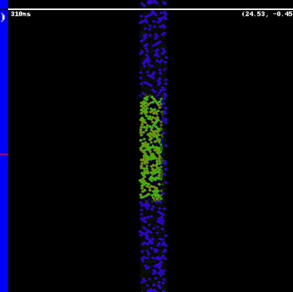
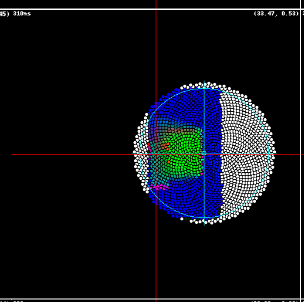
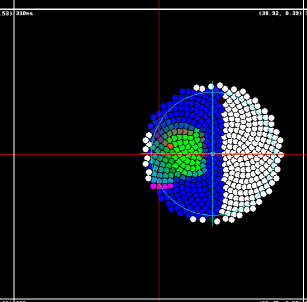
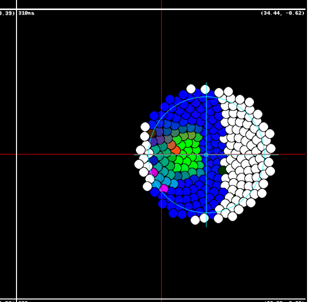
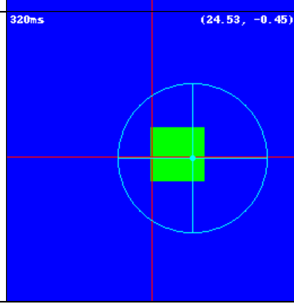
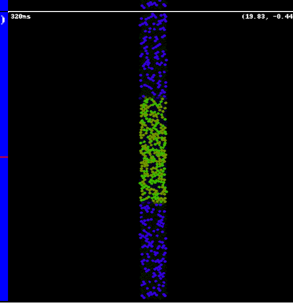
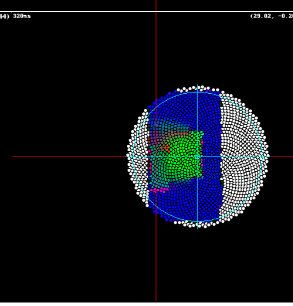
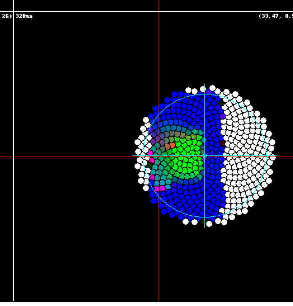
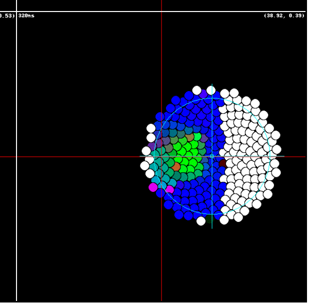
Table 28: Time sequence of narrow slit filling-in over simple object (Square)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
30					
31					
32					

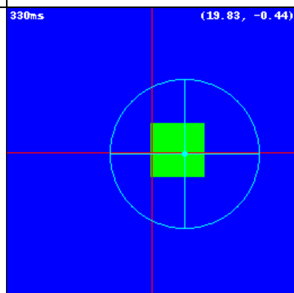
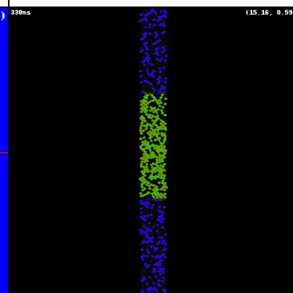
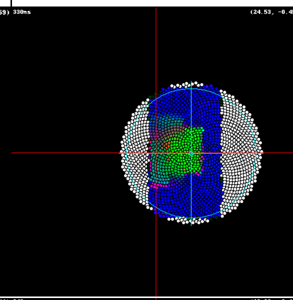
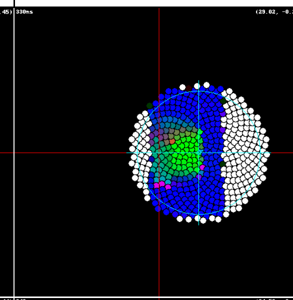
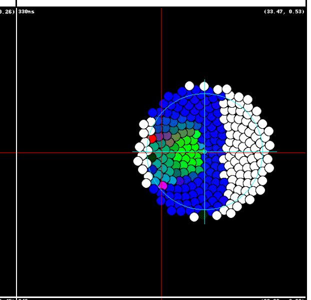
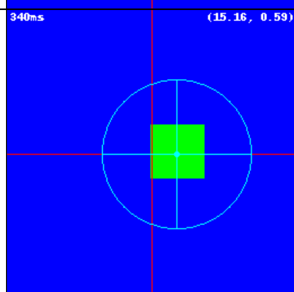
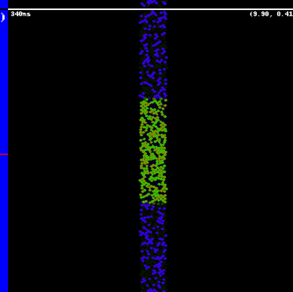
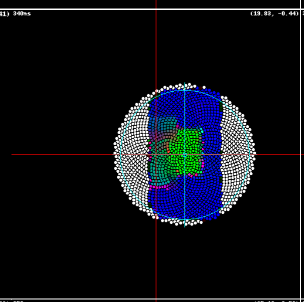
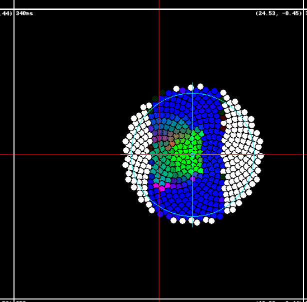
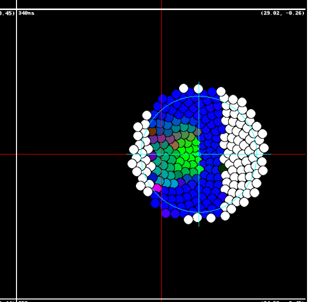
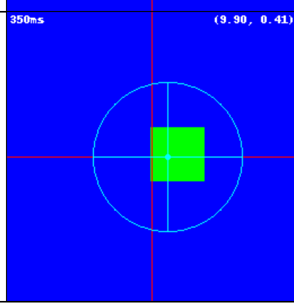
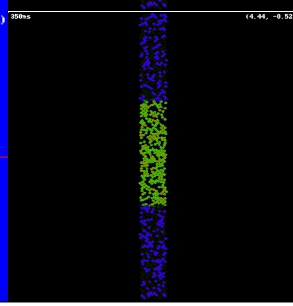
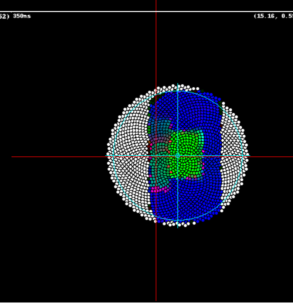
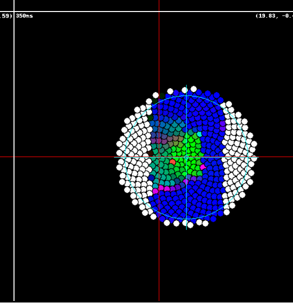
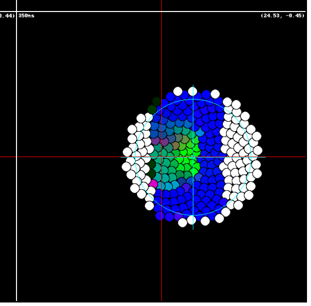
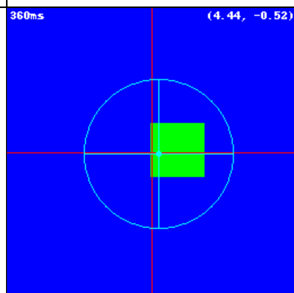
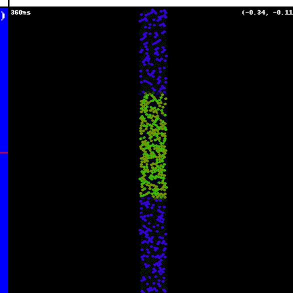
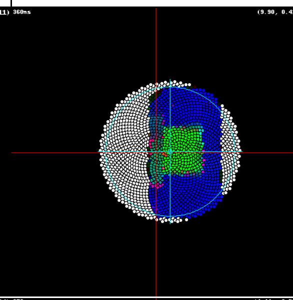
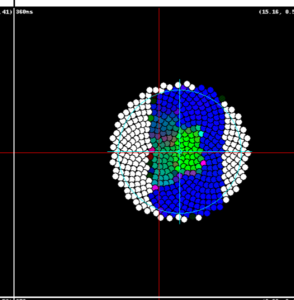
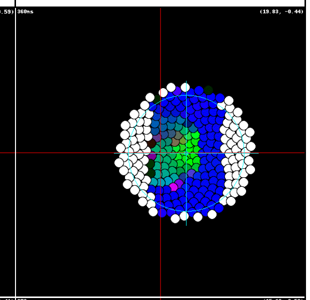
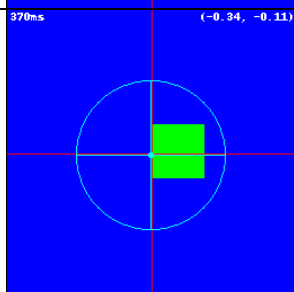
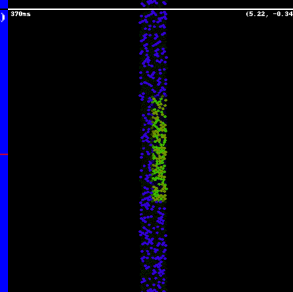
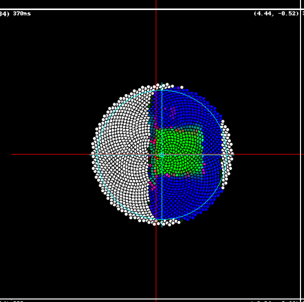
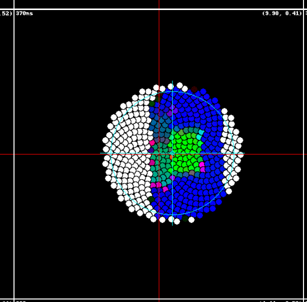
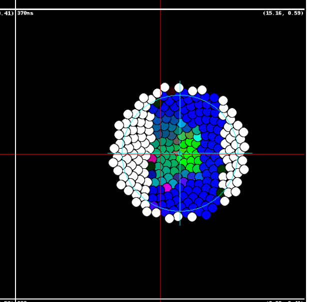
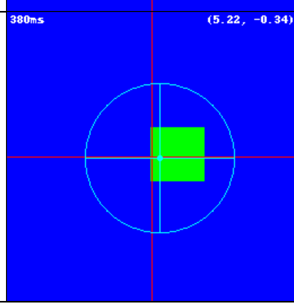
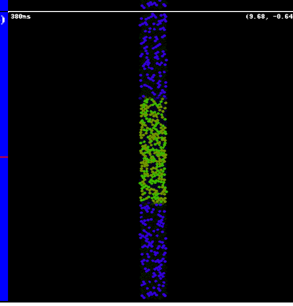
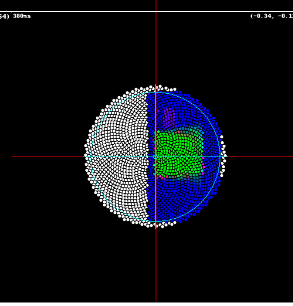
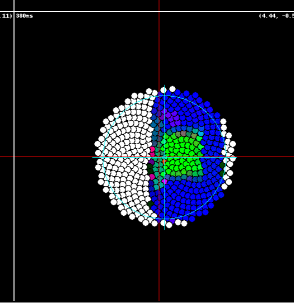
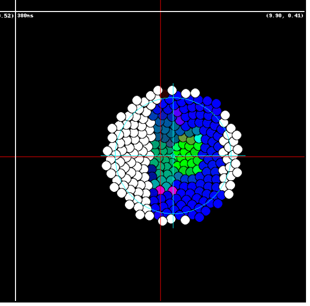
Table 28: Time sequence of narrow slit filling-in over simple object (Square)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
33					
34					
35					

Table 28: Time sequence of narrow slit filling-in over simple object (Square)					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
36					
37					
38					

Appendix B: An emergic model of filling-in the foveal blue scotoma

These supplement the corresponding material in the thesis.

B.1 Subject details

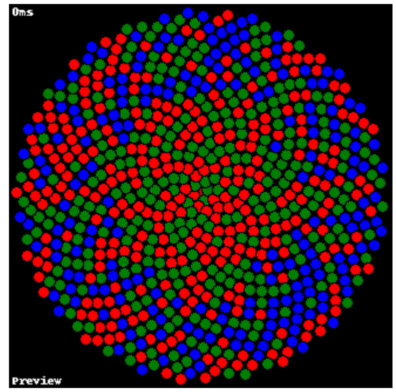


Illustration 30: Retina for foveal blue scotoma

A single virtual subject was used in all six experiments. The *person* is fully characterized by a set of developmental parameters that will be indicated next. Note that development includes a stochastic component so that, for example, while the L:M:S cone ratio may be innately specified, the colour sensitivity type of individual cones is random. Each test had a new incarnation of *person*.

To focus characterization on the filling-in of the blue scotoma phenomenon, a retina with two regions was generated. The inner region was devoid of blue (S) cones having an equal ratio of red (L) and green (M) cones. The outer region had an equal ratio of all three cone sensitivities. The size of the cones did not vary. The parameters of interest are outlined.

```
[Person]
note = blue
srt = 10
sex = ai
age = 18
eyecount = 1
ipd = 0
vsize = 17.0
vieweyez = 50
r0conepix = 6
nodalpt = 17
r0coned = 10.0
r0red = 100
r0green = 100
r1coned = 1.0
r1red = 200
r1green = 200
r1blue = 200
blindx = 0.0
blindy = 0.0
blindr = 0.0
jitmin = 0.1
jitave = 0.7
jitmax = 0.9
p1_0_pixd = 2.0
p1_0_pix = 300
p1_0_scale = 1
p1_0_fanlat = 5.0
p1_0_fandwn = 1.0
p1_1_pixd = 3.0
p1_1_pix = 150
p1_1_scale = 1
p1_1_fanlat = 2.0
p1_1_fandwn = 2.0
p1_2_pixd = 10.0
p1_2_pix = 22
p1_2_scale = 1
p1_2_fanlat = 1.2
p1_2_fandwn = 1.5
```

B.2 Stimuli details

The first test tested the filling-in over the entire blue scotoma via a full white stimulus. Test 2 tested filling-in bounded by the borders of a half white stimulus, while Test 3 & 4 tested filling-in bounded by two borders of a quarter white stimulus wedge, with stationary and moving eyes respectively. Test 5 tested the filling in of an arrow across the scotoma.

B.2.1 Test 1 stimulus: Full white stimulus

This stimulus is used to test the filling-in behaviour over the entire foveal blue scotoma region. A full white stimulus was used. When blue is subtracted from white, then yellow remains. It is the interior yellow that must be filled in by the outer white. The stimulus is fully specified by the following parameters, whose meaning is described in the thesis.

```
[World]
type = Lilac Chaser
note = white
srt = 240
[Lilac Chaser]
llcount = 8
spacing = 0.434782608696
pad = 2.0
fg = #ffffff
bg = #ffffff
gamma = 1.0
grdcount = 2
grdwidth = 4
fixfg = #ffffff
fixsize = 1.0
fixwidth = 1
```

B.2.2 Test 2 stimulus: Half white stimulus

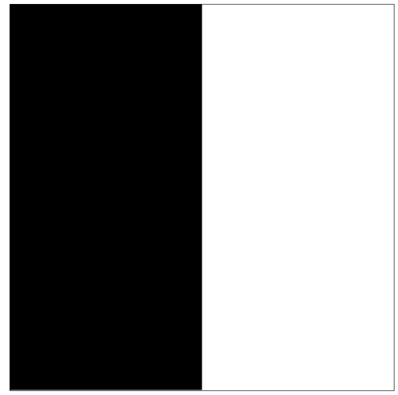


Illustration 31: Half white stimulus

This stimulus is used to test the border respecting capability of the filling-in behaviour over half the foveal blue scotoma region. A half black & white stimulus was used (with one border). When blue is subtracted from white, then yellow remains. It is the interior yellow that must be filled in by the outer white while respecting completed borders. The stimulus is fully specified by the following parameters, whose meaning is described in the thesis. The content of file hWhite.png appears in Illustration 31.

```
[World]              [Image]              iname = hWhite.png
type = Image         wx = 256             ix = 256
note = half white    wy = 256             iy = 256
srt = 200            wbg = #000000
```

B.2.3 Test 3 stimulus: Quarter white stimulus (for stationary eye)

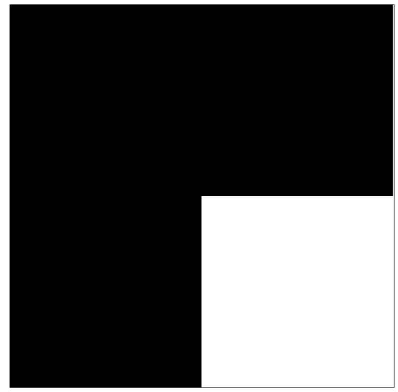


Illustration 32: Quarter white stimulus

This stimulus is used to test the double intersecting border respecting capability of the filling-in behaviour over a quarter of the foveal blue scotoma region. A ¾ black & ¼ white stimulus was used (with two borders). When blue is subtracted from white, then yellow remains. It is the interior yellow that must be filled in by the outer white while respecting completed borders. The stimulus is fully specified by the following parameters, whose meaning is described in the thesis. The content of file qWhite.png appears in Illustration 32.

```
[World]              [Image]              iname = qWhite.png
type = Image         wx = 256             ix = 256
note = q white       wy = 256             iy = 256
srt = 200            wbg = #000000
```

B.2.4 Test 4 stimulus: Quarter white stimulus (for moving eye)

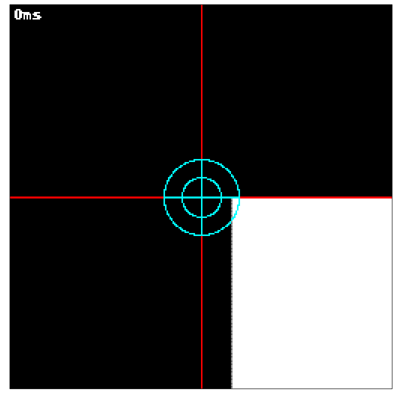


Illustration 33: Quarter white shifted stimulus shown as view with overlay

This stimulus is used to test the double intersecting border respecting capability of the filling-in behaviour over a quarter of the foveal blue scotoma region while the eye is in motion. A ¾ black & ¼ white stimulus was used (with two borders), but shifted to the right to allow the eye to move across. When blue is subtracted from white, then yellow remains. It is the interior yellow that must be filled in by the outer white while respecting completed borders. The stimulus is fully specified by the following parameters, whose meaning is described in the thesis. The content of file qWhite2.png appears in Illustration 33 (minus any overlay).

```
[World]
type = Image
note = q white2
srt = 200

[Image]
wx = 256
wy = 256
wbg = #000000
iname =
qWhite2.png
ix = 256
iy = 256
```

B.2.5 Test 5 stimulus: Arrow stimulus

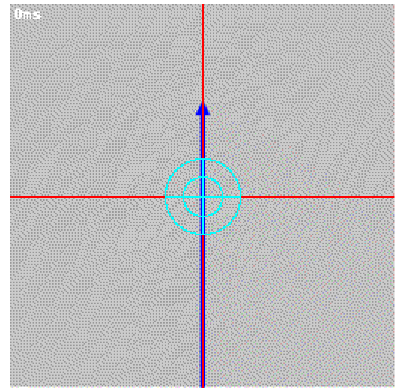


Illustration 34: Blue arrow stimulus
Shown in view with overlay.

This stimulus is used to test the border respecting capability of the filling-in behaviour over a thin arrow crossing the foveal blue scotoma region. A blue arrow is used over a grey background. When blue is subtracted from grey, then a greenish yellow tinge remains. It is the interior greenish yellow that must be filled in by the outer grey while respecting completed borders. Moreover, the blue arrow will appear as dark. It too needs to be filled in with blue. The stimulus is fully specified by the following parameters, whose meaning is described in the thesis. The content of file arrow.png appears with view overlays in Illustration 34 (minus any overlay).

```
[World]
type = Image
note = arrow
srt = 200
```

```
[Image]
wx = 256
wy = 256
wbg = #000000
```

```
iname = arrow.png
ix = 256
iy = 256
```

B.2.6 Test 6 stimulus: Point stimulus

This stimulus is used to test the filling-in behaviour within the foveal blue scotoma as it saccades across a small blue point. The stimulus is fully specified by the following parameters, whose meaning is described in the thesis. The content of file point.png appears with view overlays in Illustration 35.

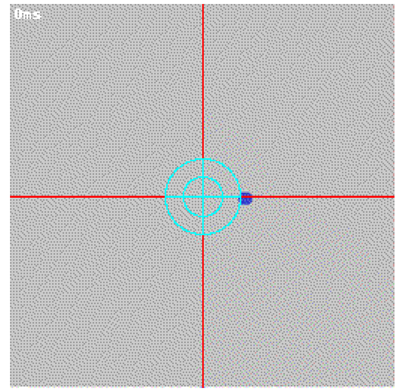


Illustration 35: Point stimulus
Shown in view with overlay.

```
[World]
type = Image
note = arrow
srt = 200

[Image]
wx = 256
wy = 256
wbg = #000000

iname = point.png
ix = 256
iy = 256
```

B.3 Result details

In this section we tabulate a visual frame-by-frame account of results from all tests. Such a frame-by-frame account allows for the extraction of precise timing information useful for quantitative analysis. It takes 59 pages. All these results are reduced to a single web page of animated images, available at

http://emergic.upwize.com/?page_id=165

The animated account (Leibovitz, 2012a) is preferred as an overview showing behavioural dynamics of jitter, filling-in, memory, etc. and makes image stability more salient. It also includes the results in greatest detail – they have been scaled down for print in this supplement, and even smaller in the chapter's *results and discussion* sections.

Each table of results has the following columns. **Time** numerically represents the time tick since the test has started, nominally 10ms/tick. All visual results in that table row are after the tick and computation have finished. **Stimuli** visually represents the stimuli presented to the virtual computer screen, often with retinal overlays. The **Photoreceptor Mosaic** visually represents what the retina senses by looking at the stimuli. **Receptive Fields** at **Level 1**, **Level 2** and **Level 3**, visually represent the three level hierarchy of receptive fields showing their the functional size and placement, not physical size nor placement

B.3.1 Test 1 results: Full white stimulus

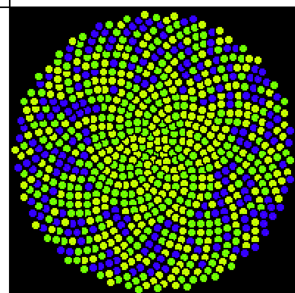
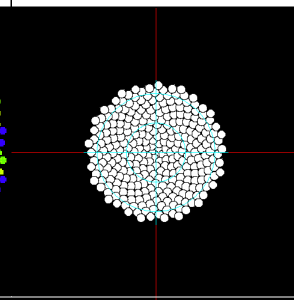
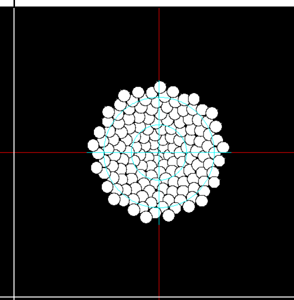
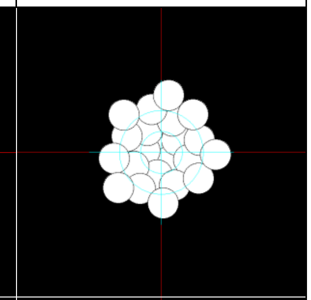
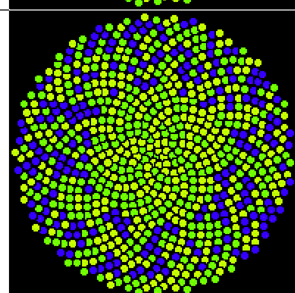
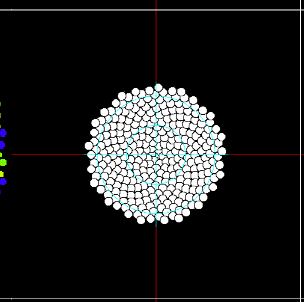
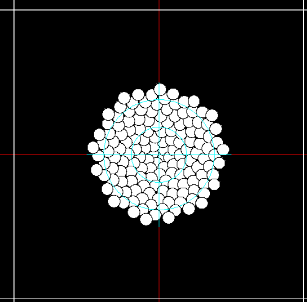
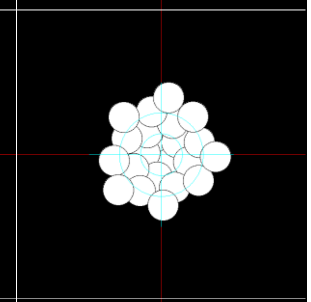
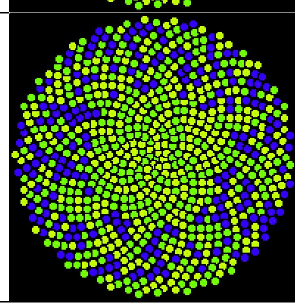
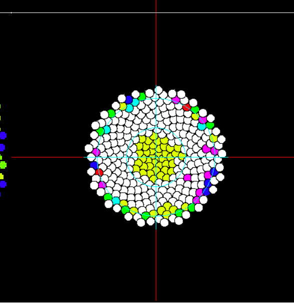
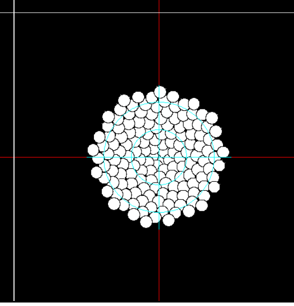
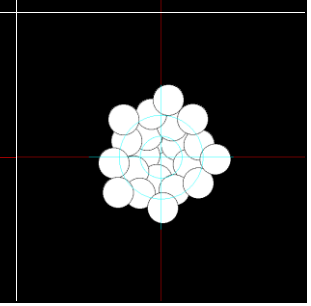
Table 29: Time sequence of filling-in full white stimulus over foveal blue scotoma					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
0					
1					
2					

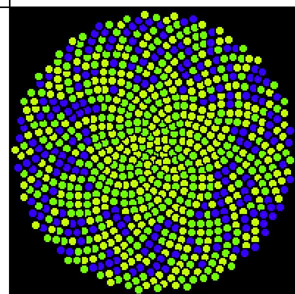
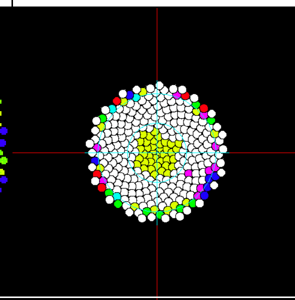
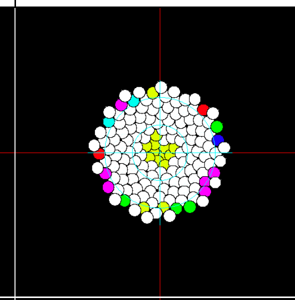
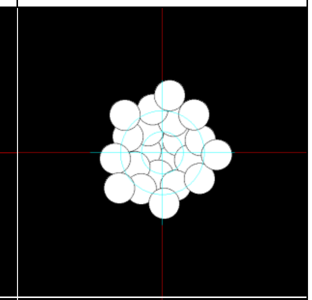
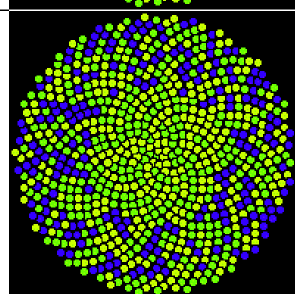
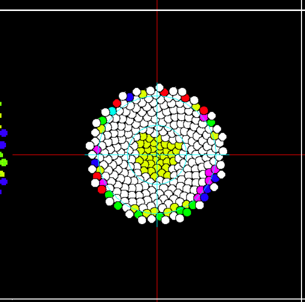
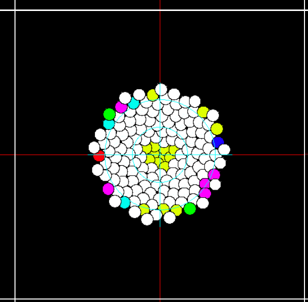
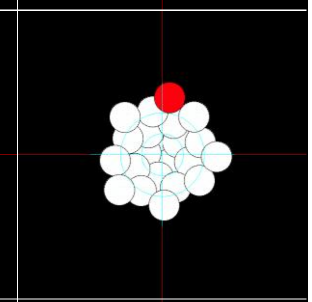
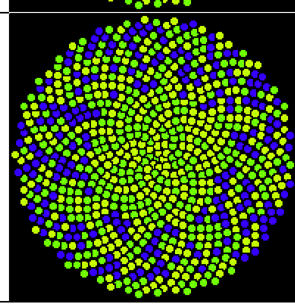
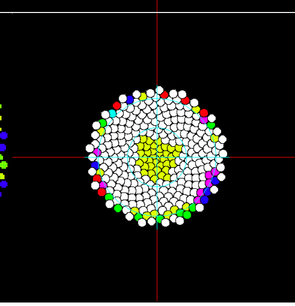
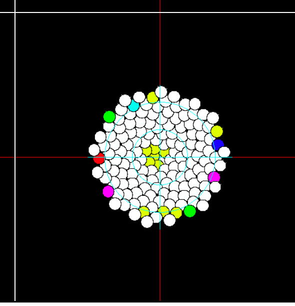
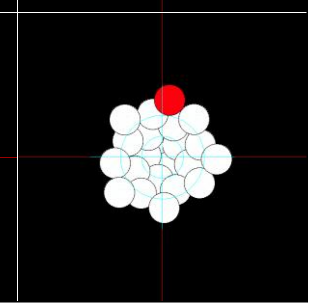
Table 29: Time sequence of filling-in full white stimulus over foveal blue scotoma					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
3					
4					
5					

Table 29: Time sequence of filling-in full white stimulus over foveal blue scotoma

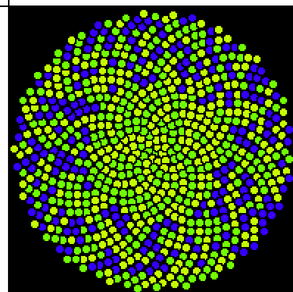
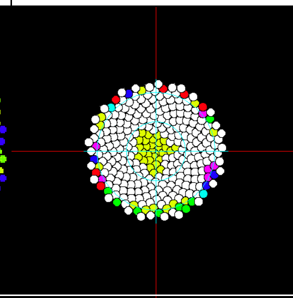
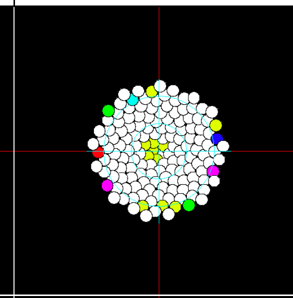
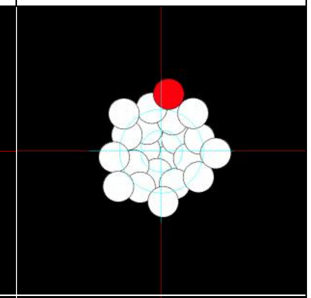
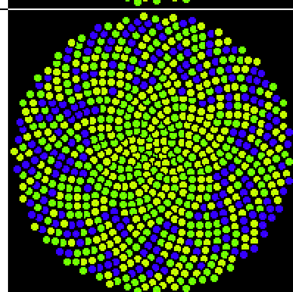
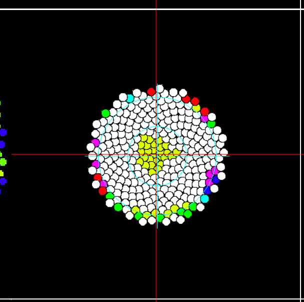
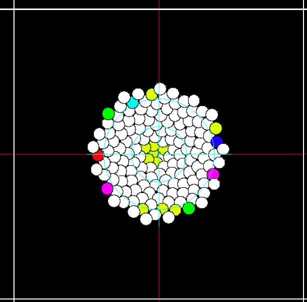
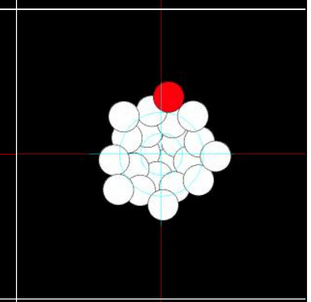
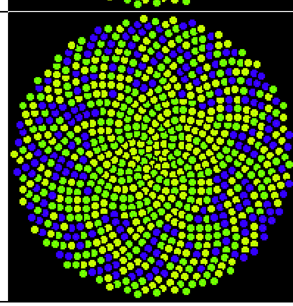
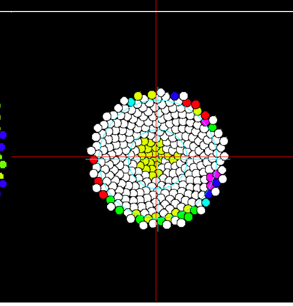
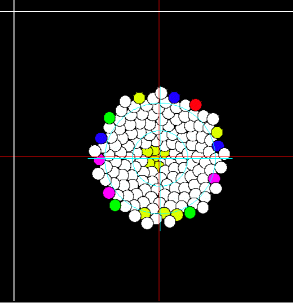
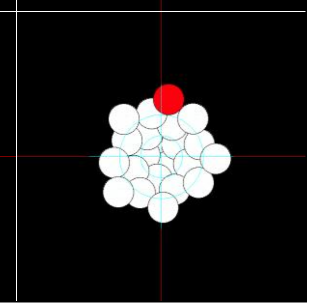
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
6					
7					
8					

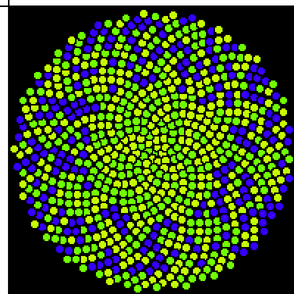
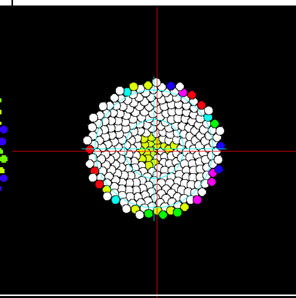
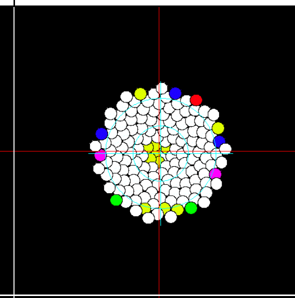
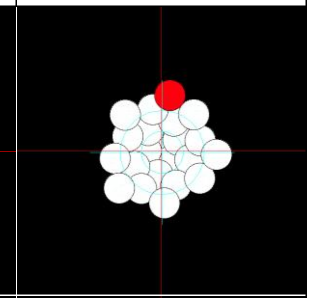
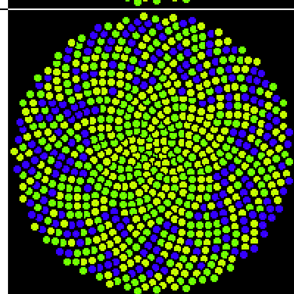
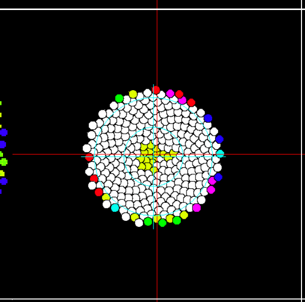
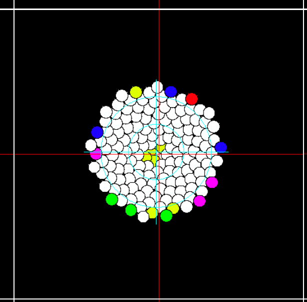
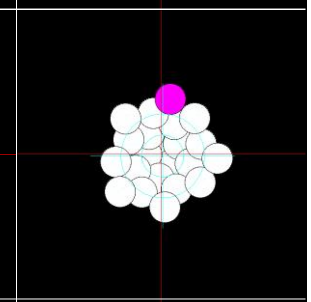
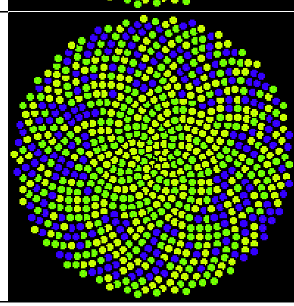
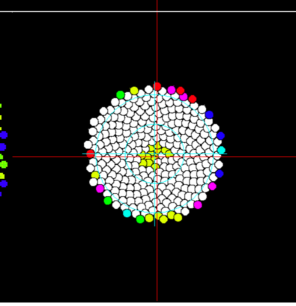
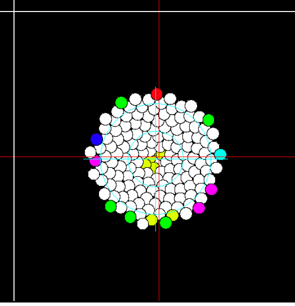
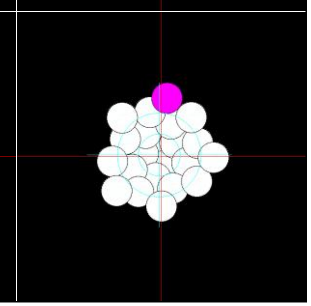
Table 29: Time sequence of filling-in full white stimulus over foveal blue scotoma					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
9					
10					
11					

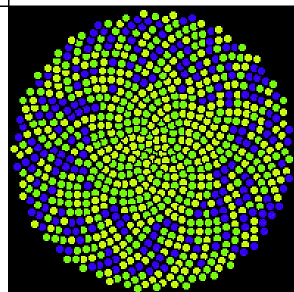
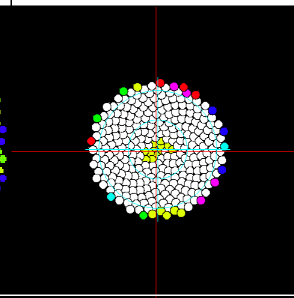
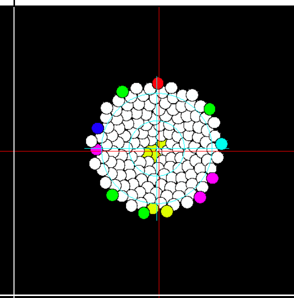
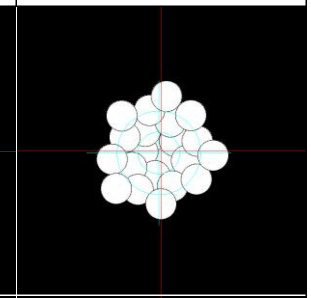
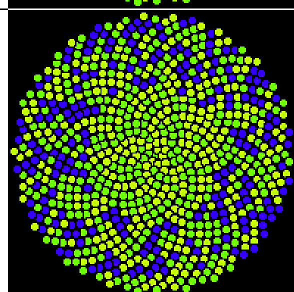
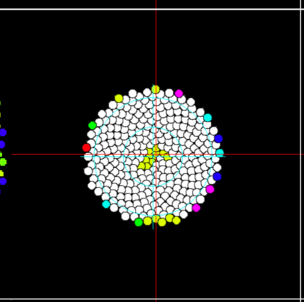
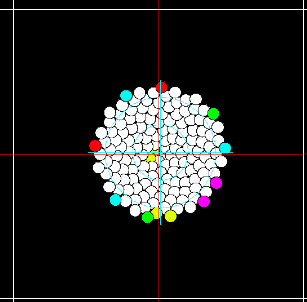
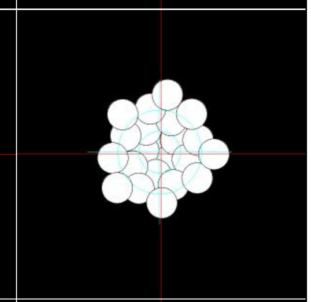
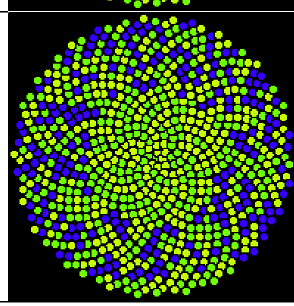
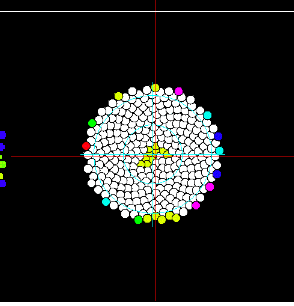
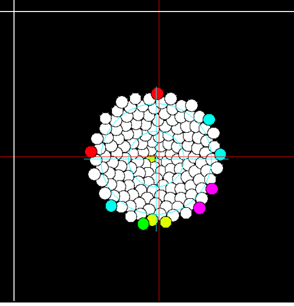
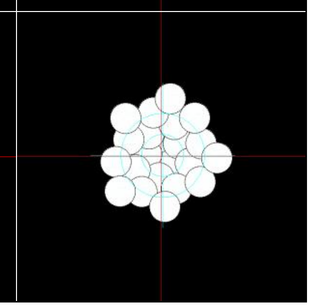
Table 29: Time sequence of filling-in full white stimulus over foveal blue scotoma					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
12					
13					
14					

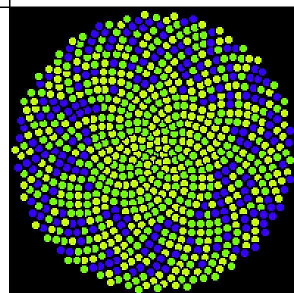
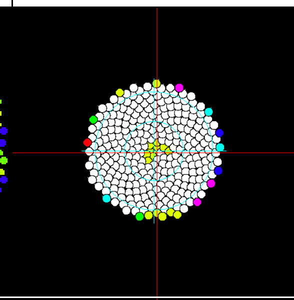
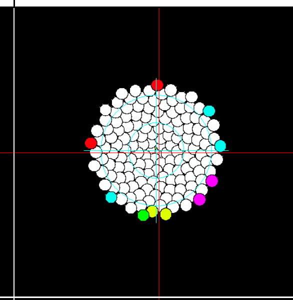
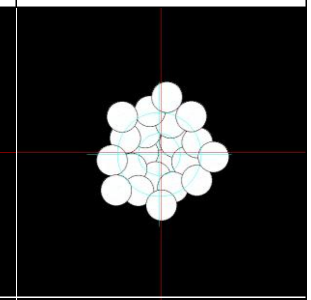
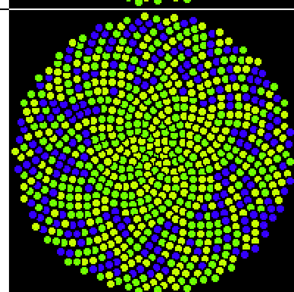
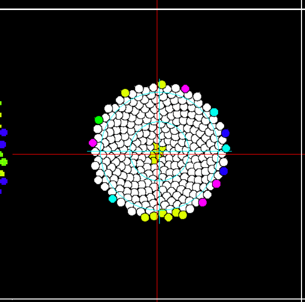
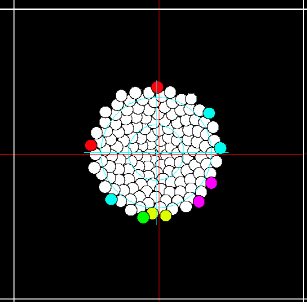
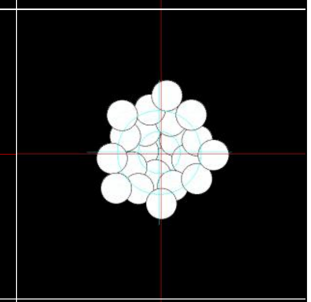
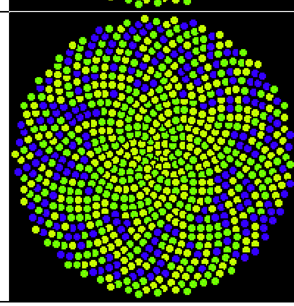
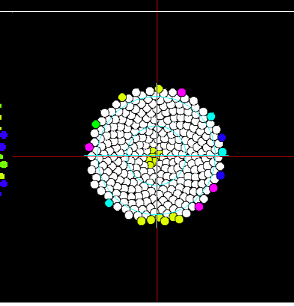
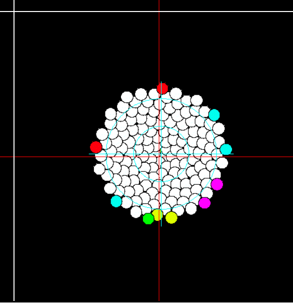
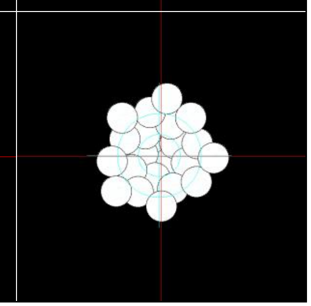
Table 29: Time sequence of filling-in full white stimulus over foveal blue scotoma					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
15					
16					
17					

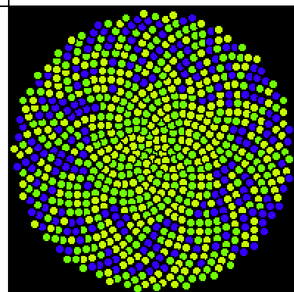
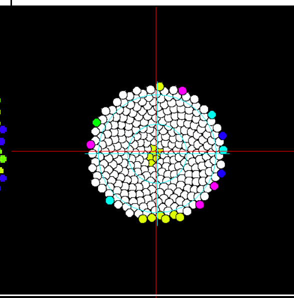
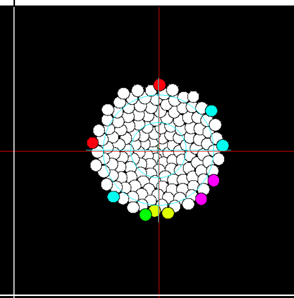
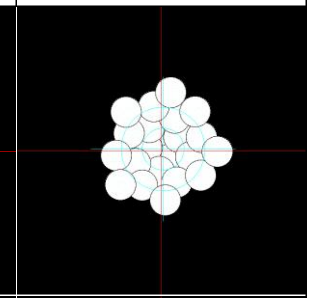
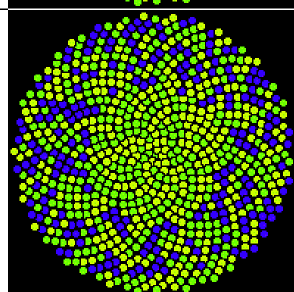
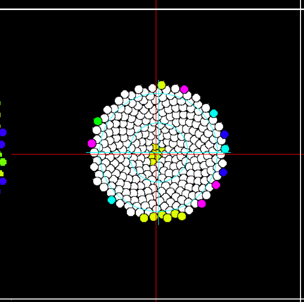
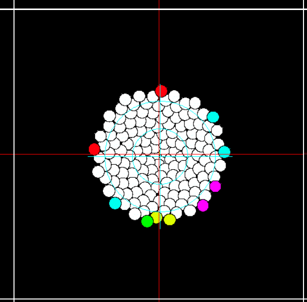
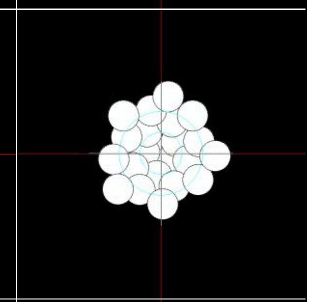
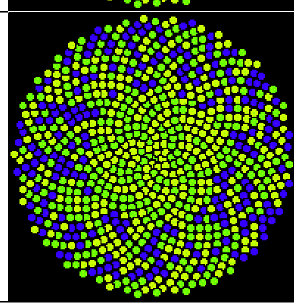
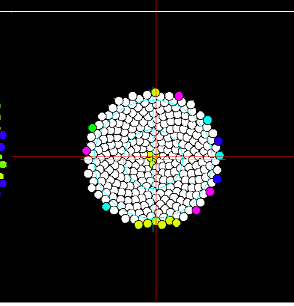
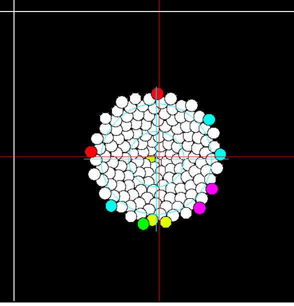
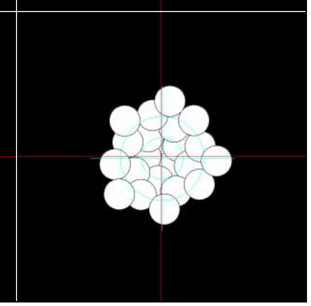
Table 29: Time sequence of filling-in full white stimulus over foveal blue scotoma					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
18					
19					
20					

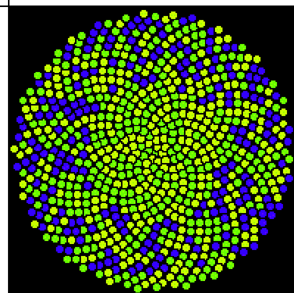
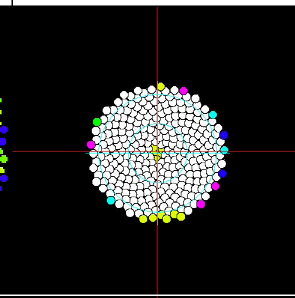
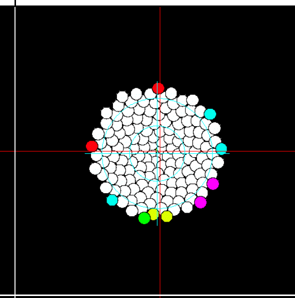
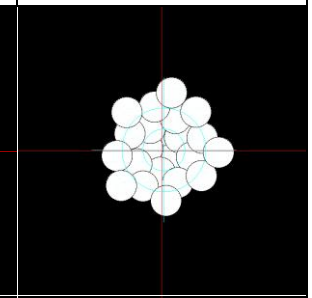
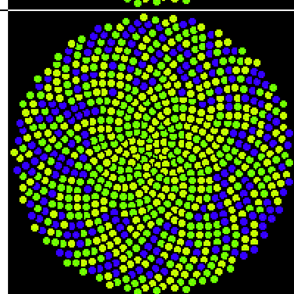
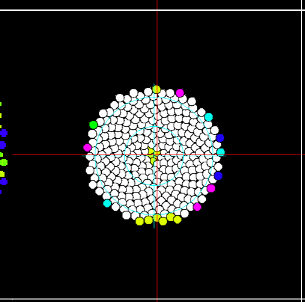
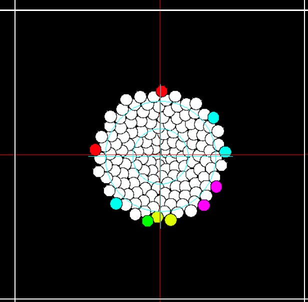
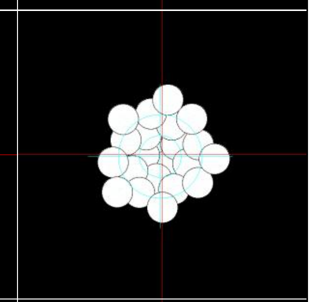
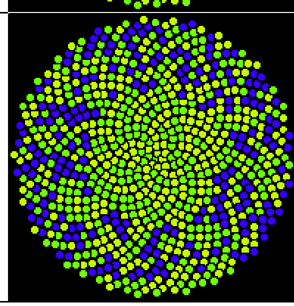
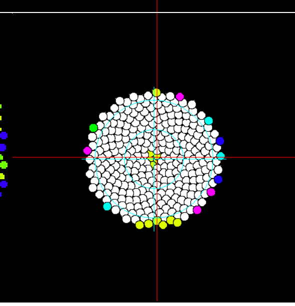
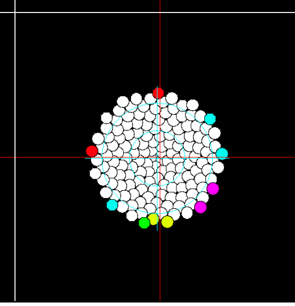
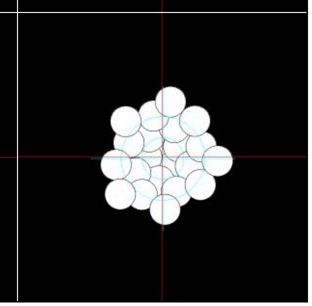
Table 29: Time sequence of filling-in full white stimulus over foveal blue scotoma					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
21					
22					
23					

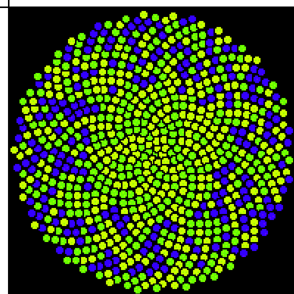
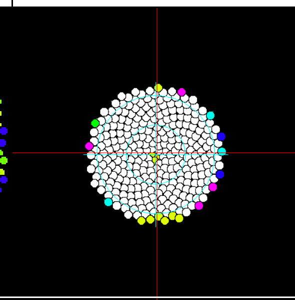
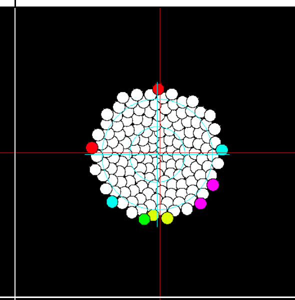
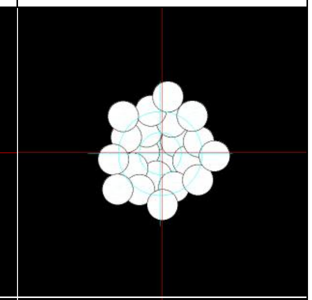
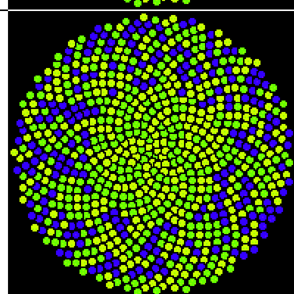
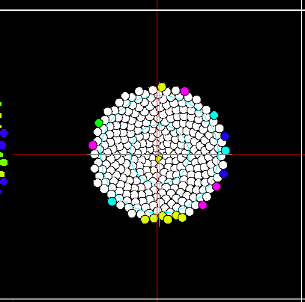
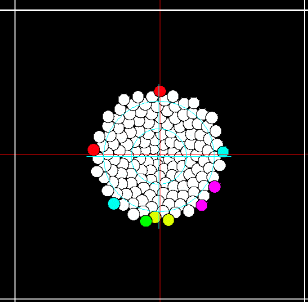
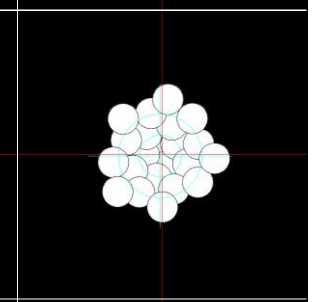
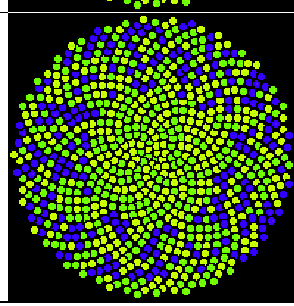
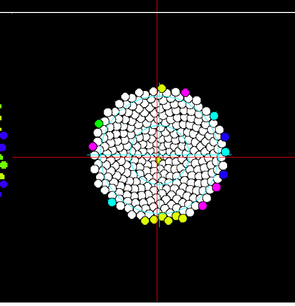
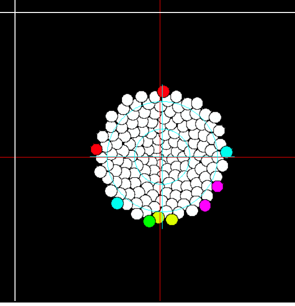
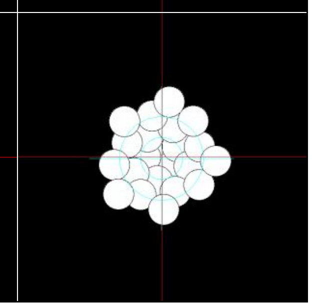
Table 29: Time sequence of filling-in full white stimulus over foveal blue scotoma					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
24					
25					
26					

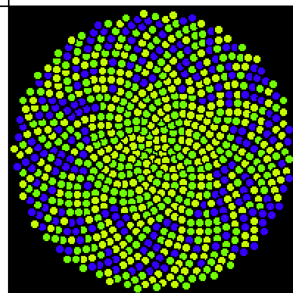
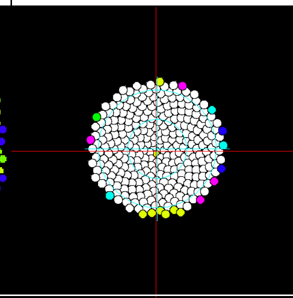
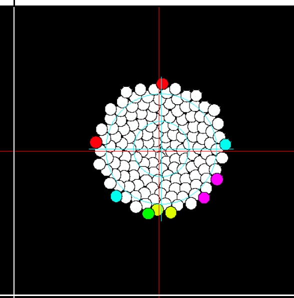
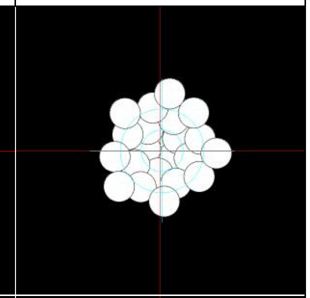
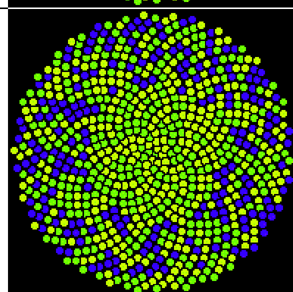
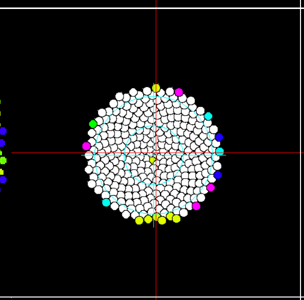
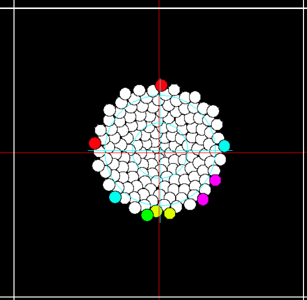
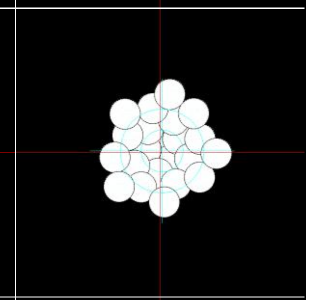
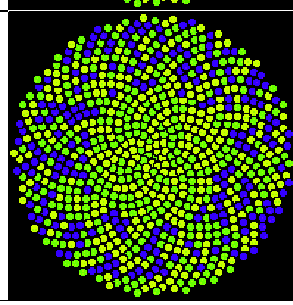
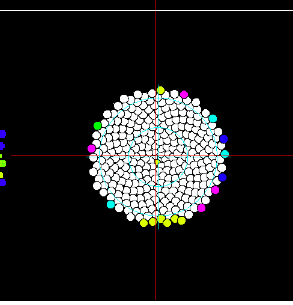
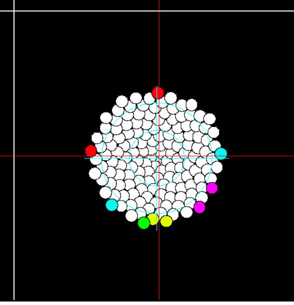
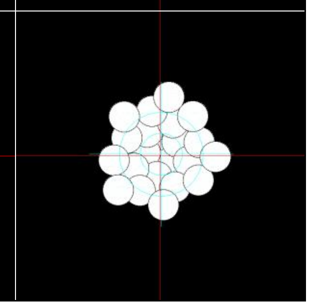
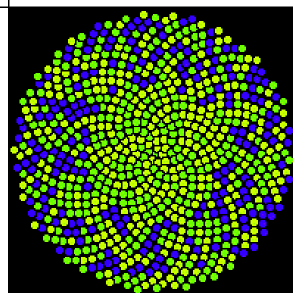
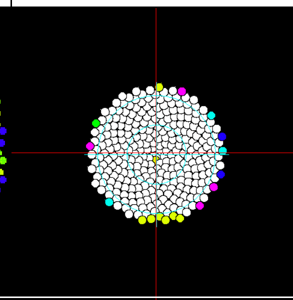
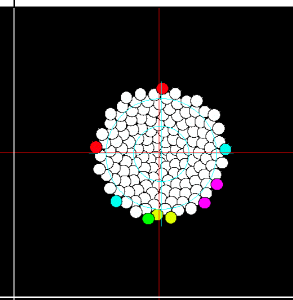
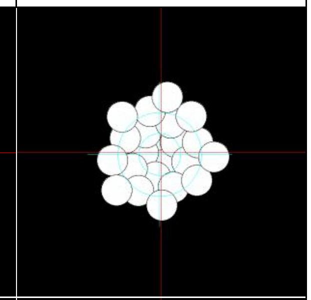
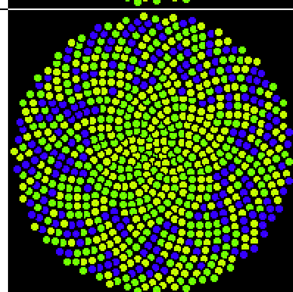
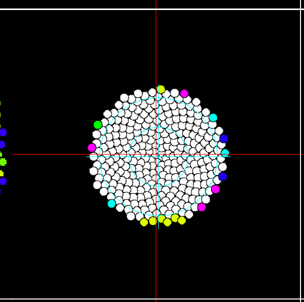
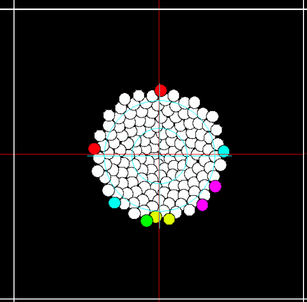
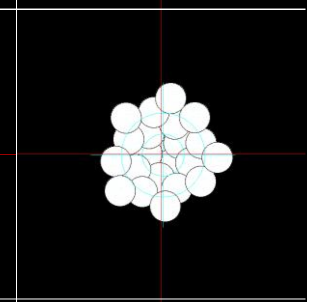
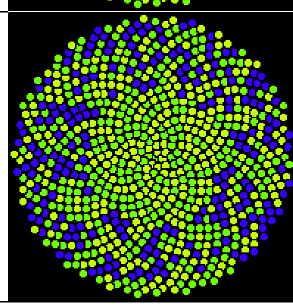
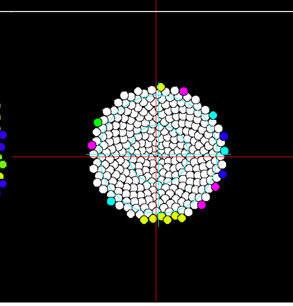
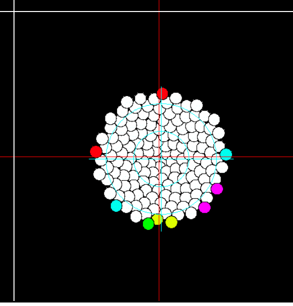
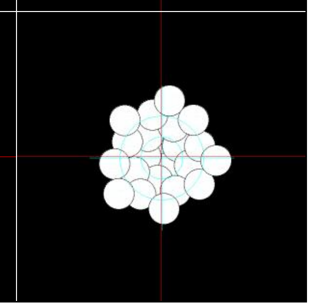
Table 29: Time sequence of filling-in full white stimulus over foveal blue scotoma					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
27					
28					
29					

Table 29: Time sequence of filling-in full white stimulus over foveal blue scotoma					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
30					
31					
32					

B.3.2 Test 2 results: Half white stimulus

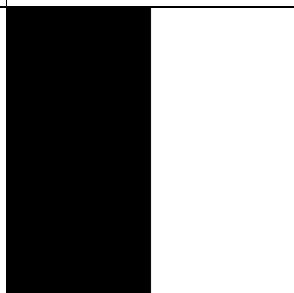
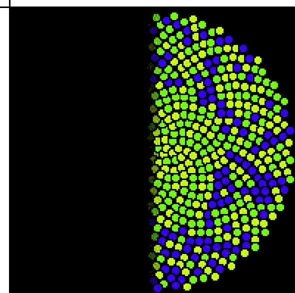
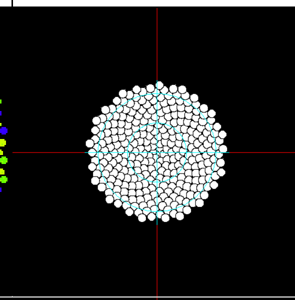
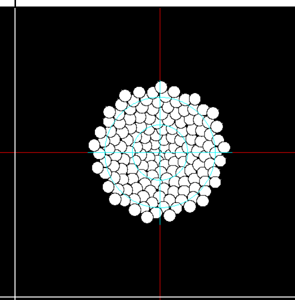
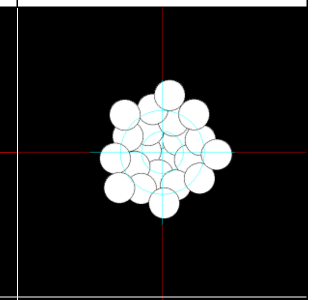
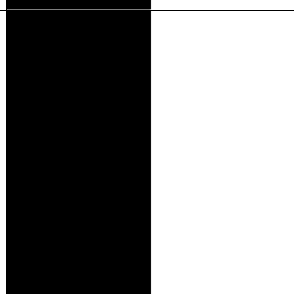
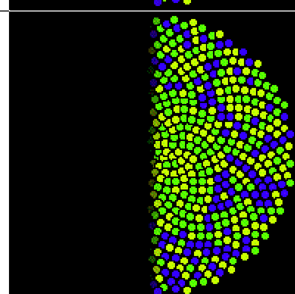
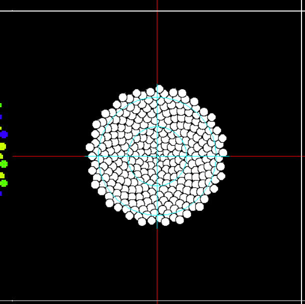
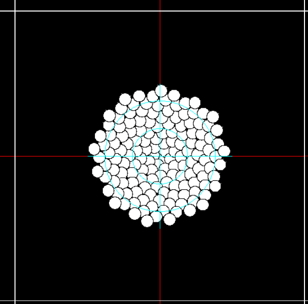
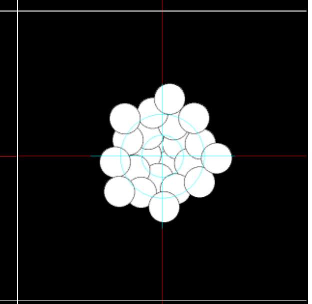
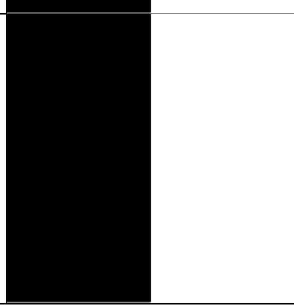
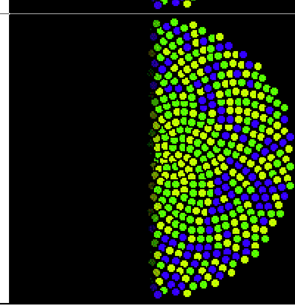
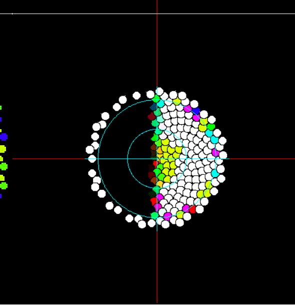
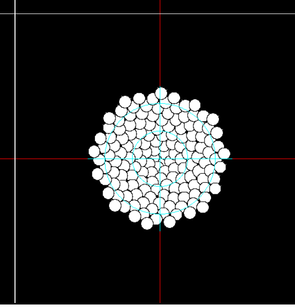
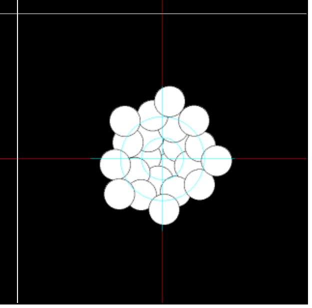
Table 30: Time sequence of filling-in half white stimulus over foveal blue scotoma					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
0					
1					
2					

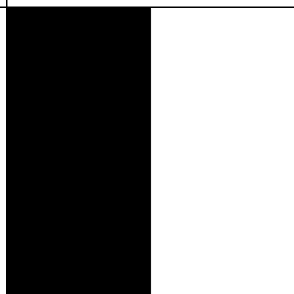
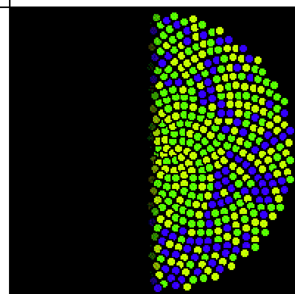
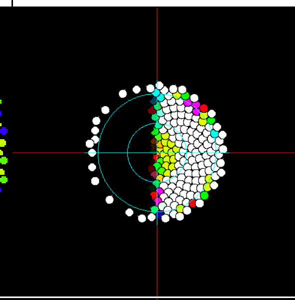
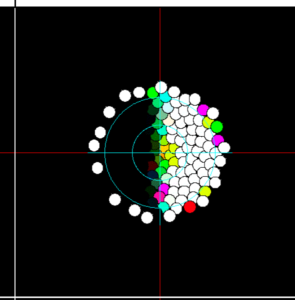
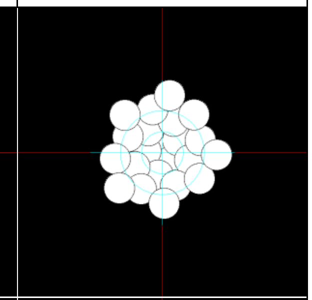
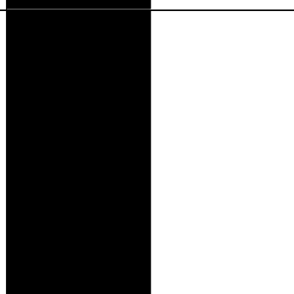
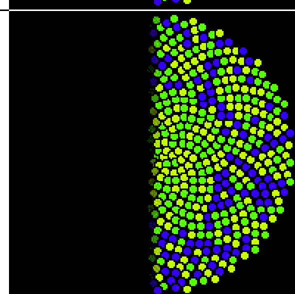
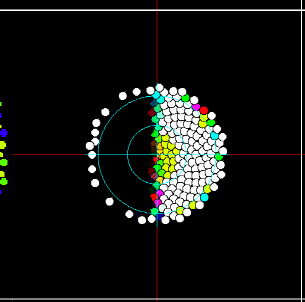
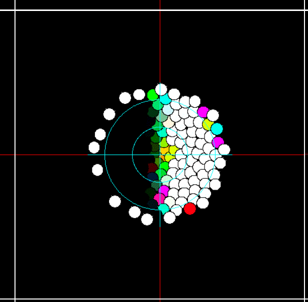
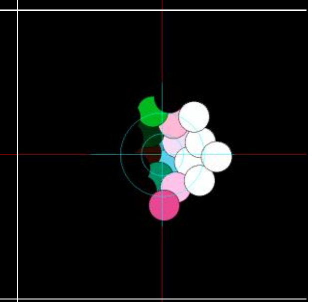
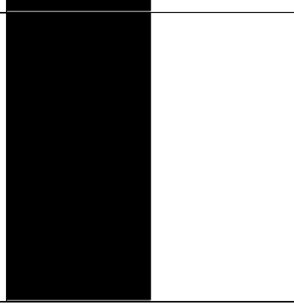
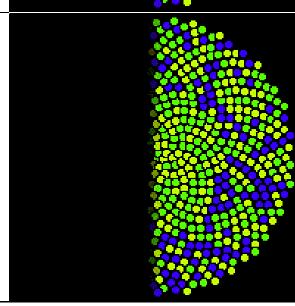
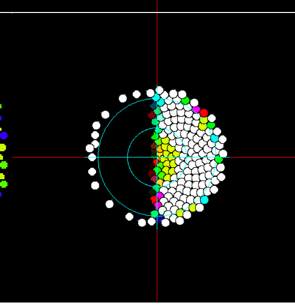
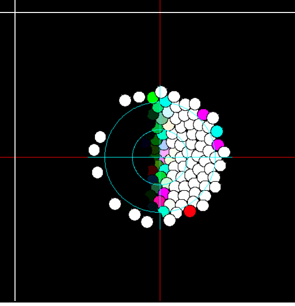
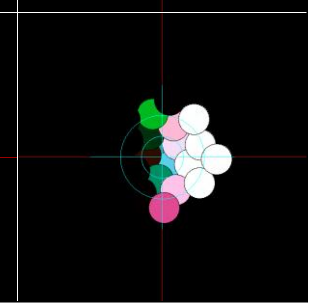
Table 30: Time sequence of filling-in half white stimulus over foveal blue scotoma					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
3					
4					
5					

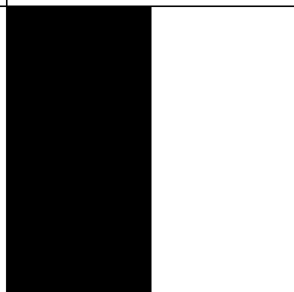
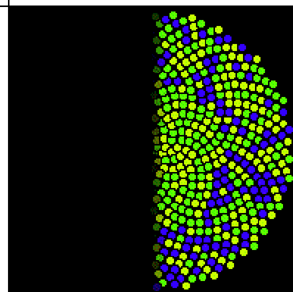
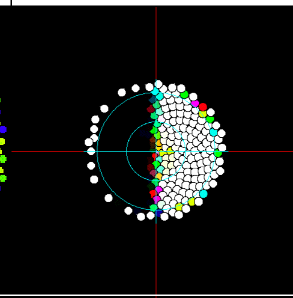
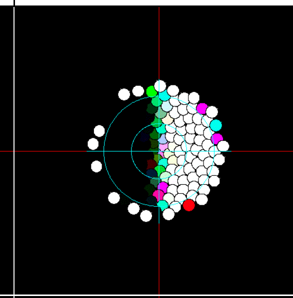
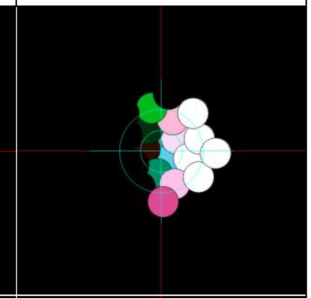
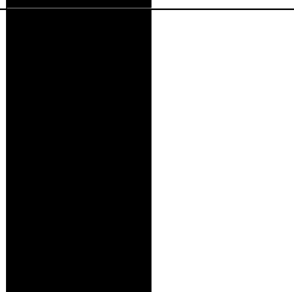
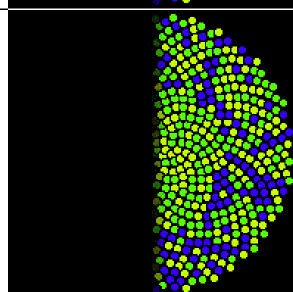
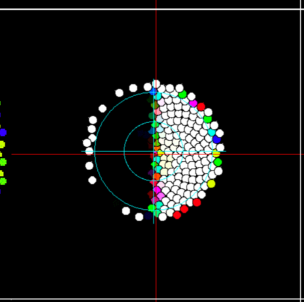
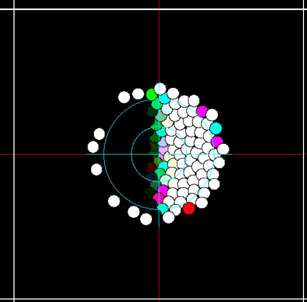
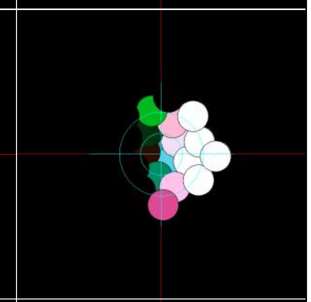
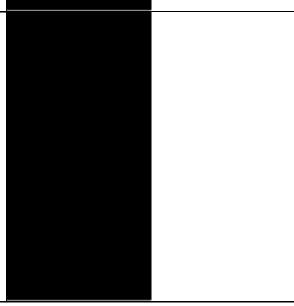
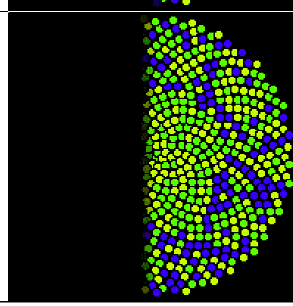
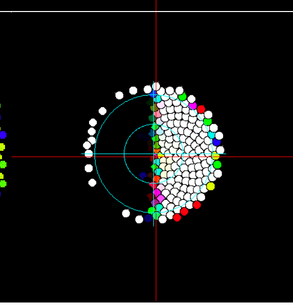
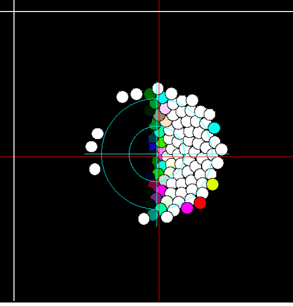
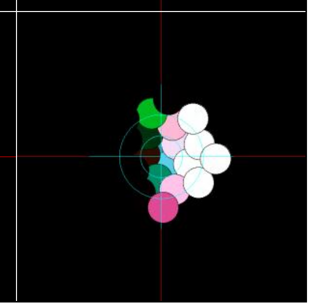
Table 30: Time sequence of filling-in half white stimulus over foveal blue scotoma					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
6					
7					
8					

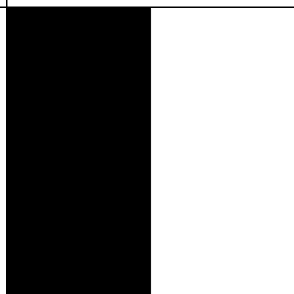
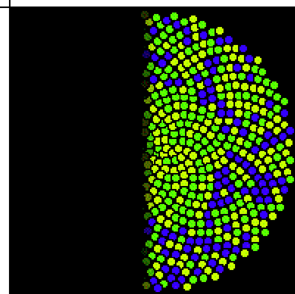
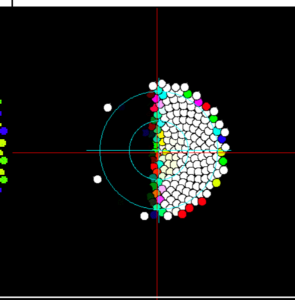
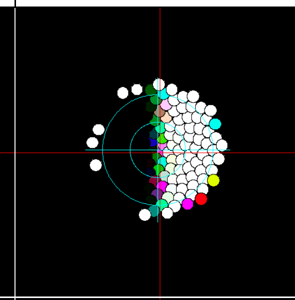
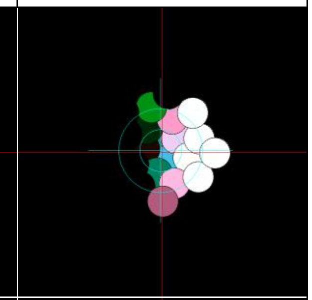
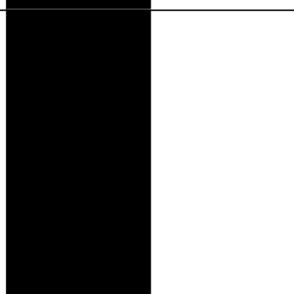
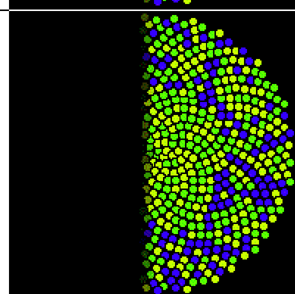
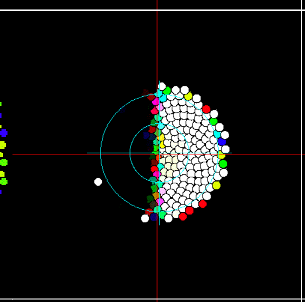
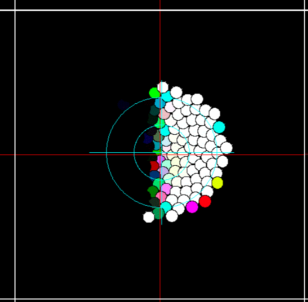
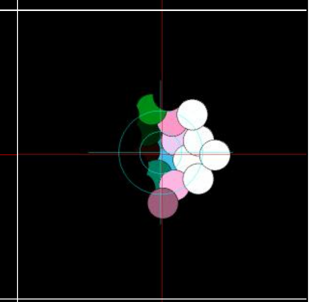
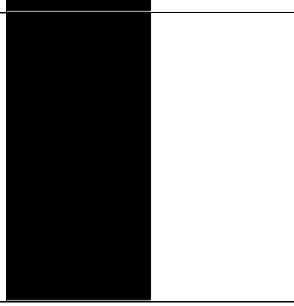
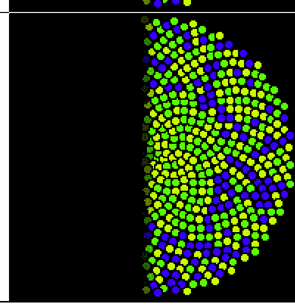
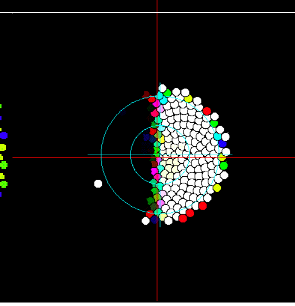
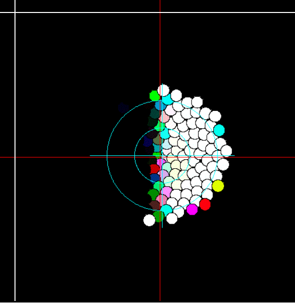
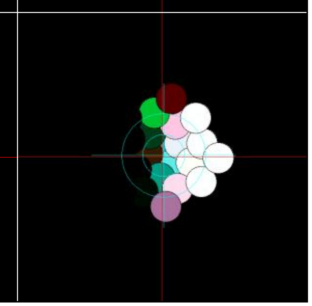
Table 30: Time sequence of filling-in half white stimulus over foveal blue scotoma					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
9					
10					
11					

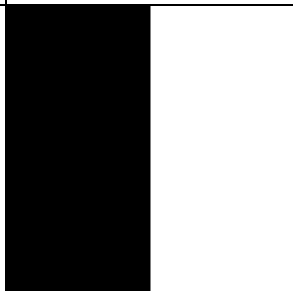
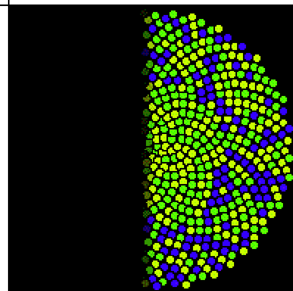
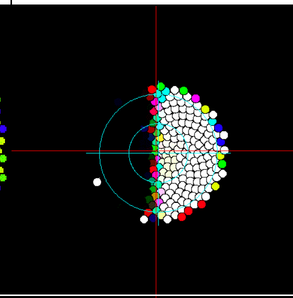
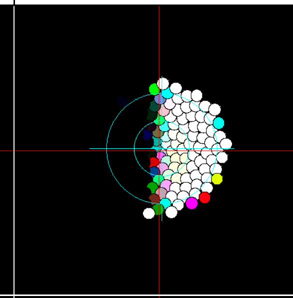
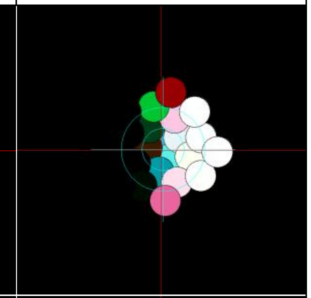
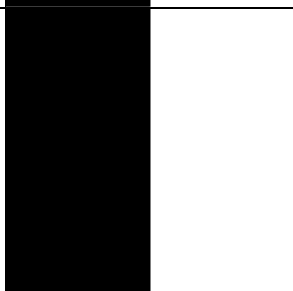
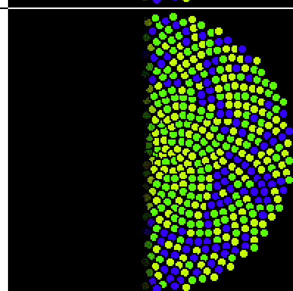
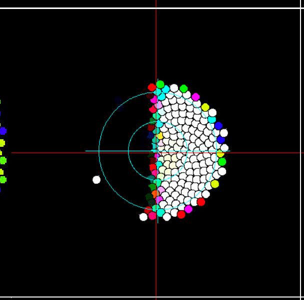
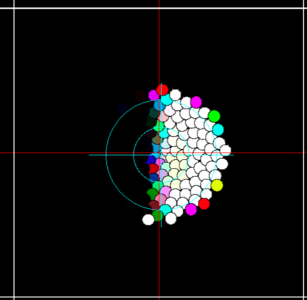
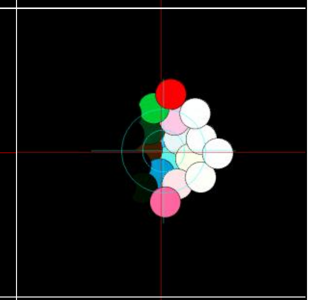
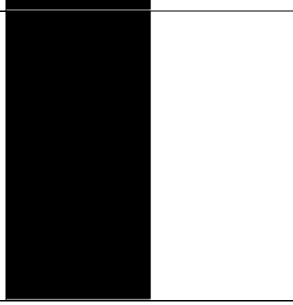
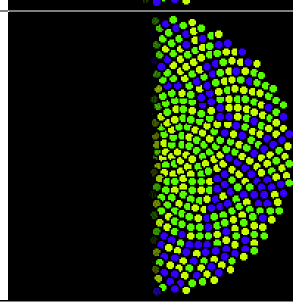
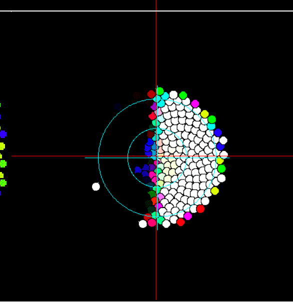
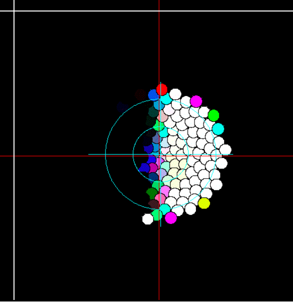
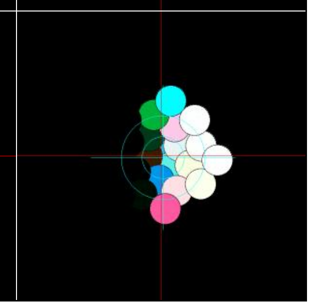
Table 30: Time sequence of filling-in half white stimulus over foveal blue scotoma					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
12					
13					
14					

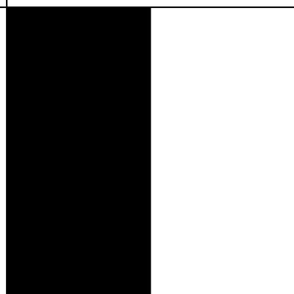
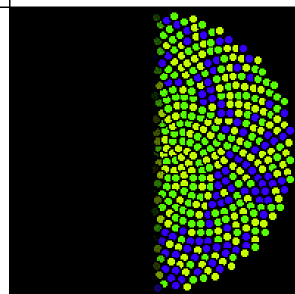
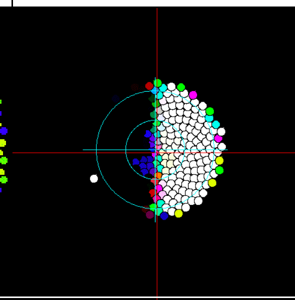
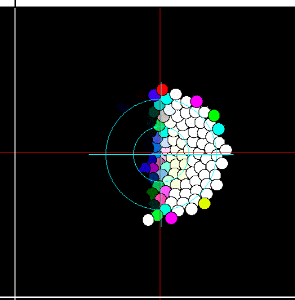
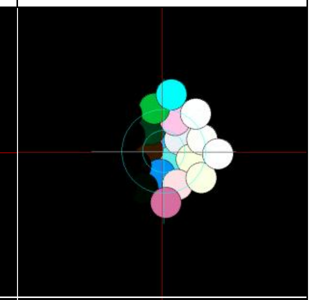
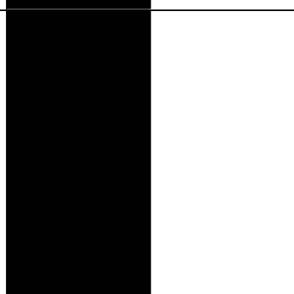
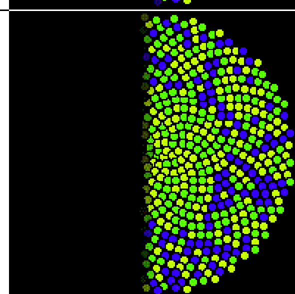
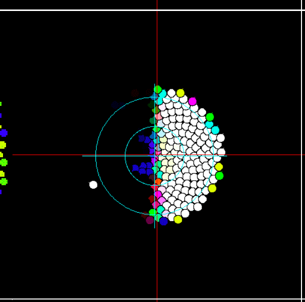
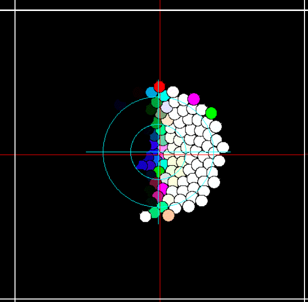
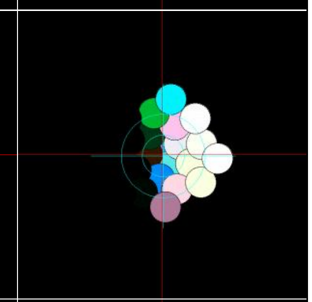
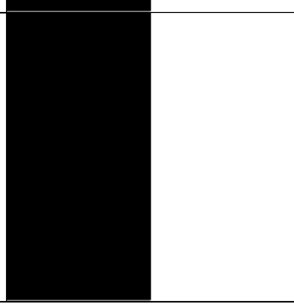
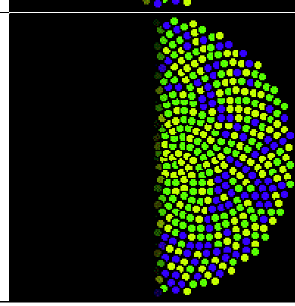
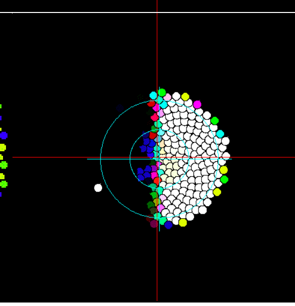
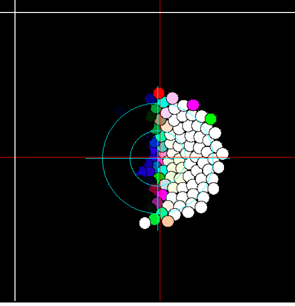
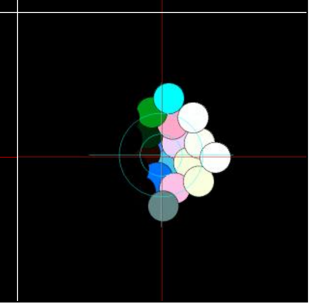
Table 30: Time sequence of filling-in half white stimulus over foveal blue scotoma					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
15					
16					
17					

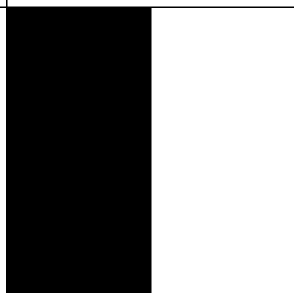
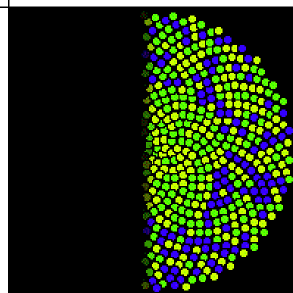
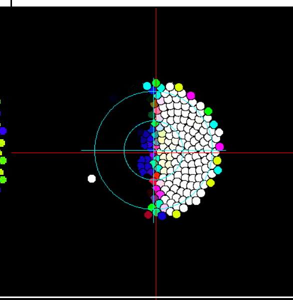
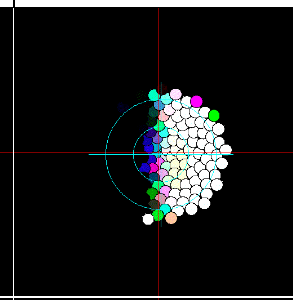
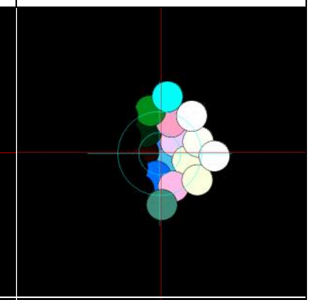
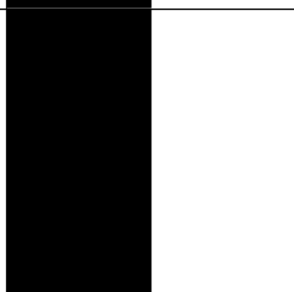
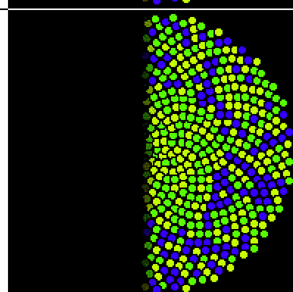
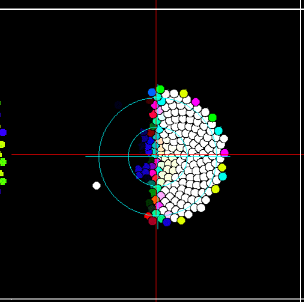
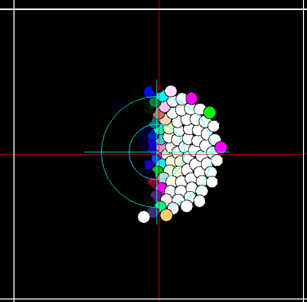
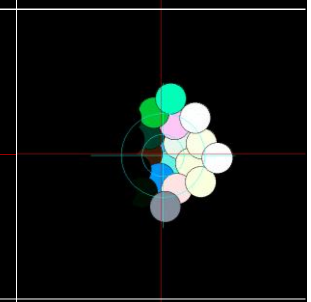
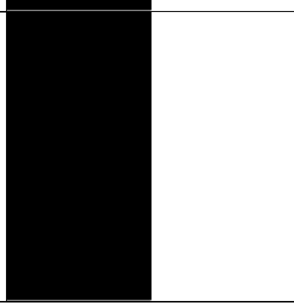
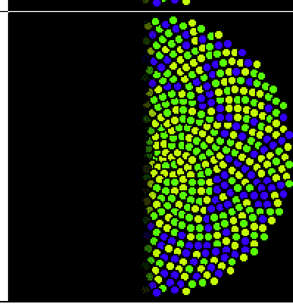
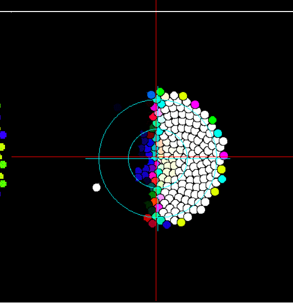
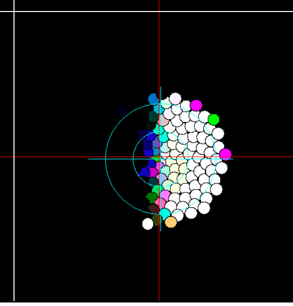
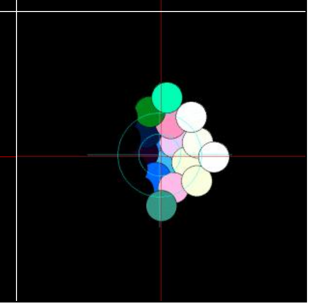
Table 30: Time sequence of filling-in half white stimulus over foveal blue scotoma					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
18					
19					
20					

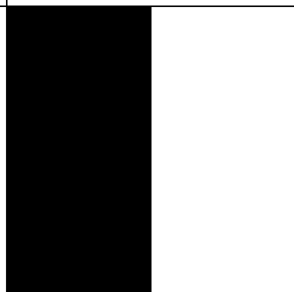
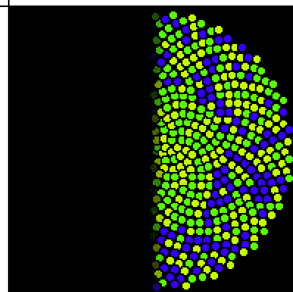
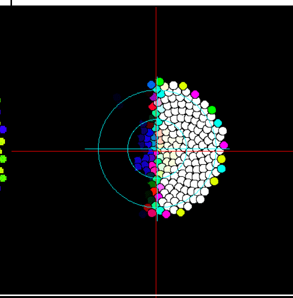
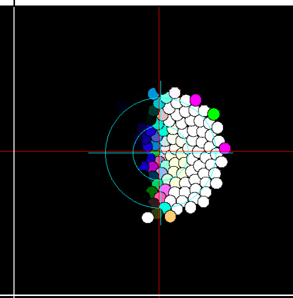
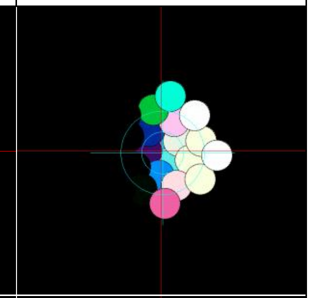
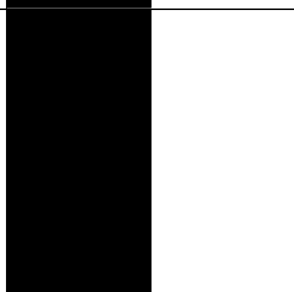
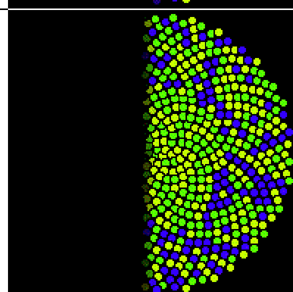
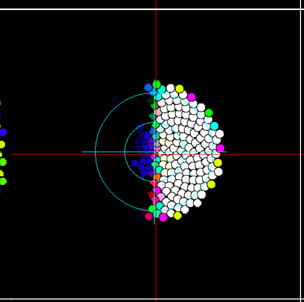
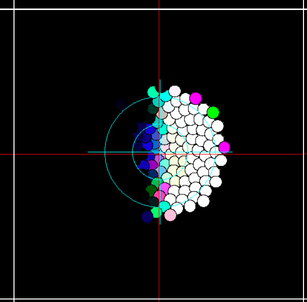
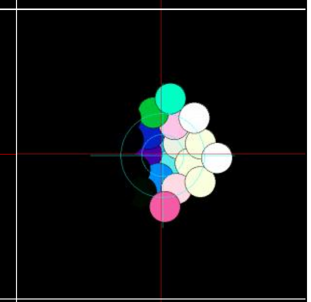
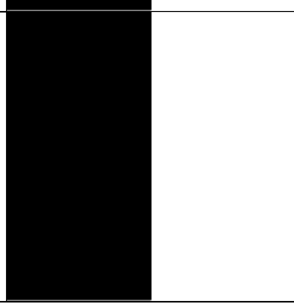
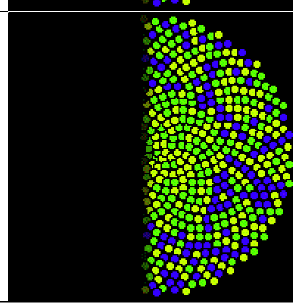
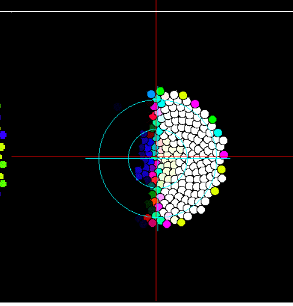
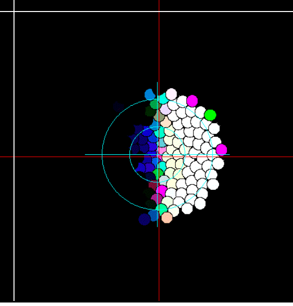
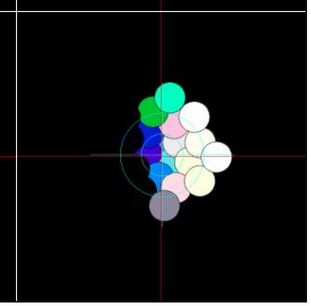
Table 30: Time sequence of filling-in half white stimulus over foveal blue scotoma					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
21					
22					
23					

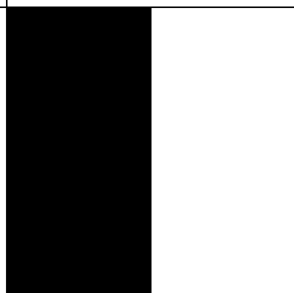
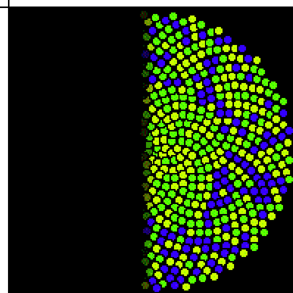
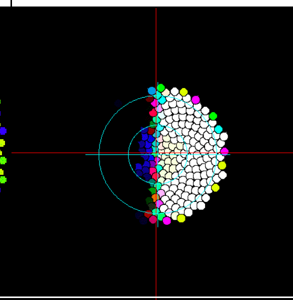
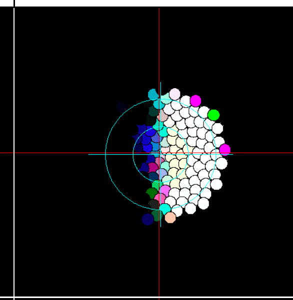
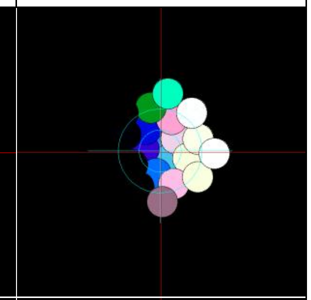
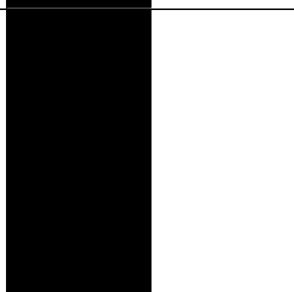
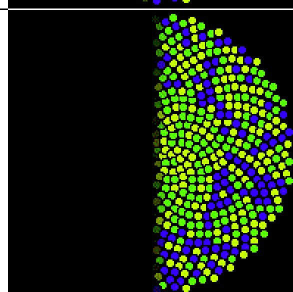
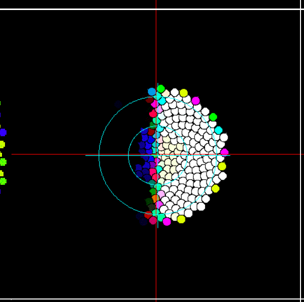
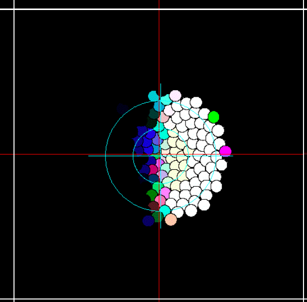
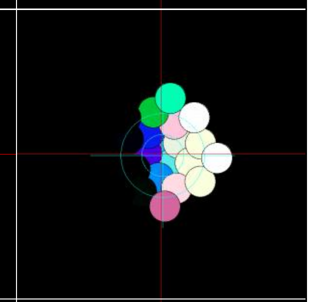
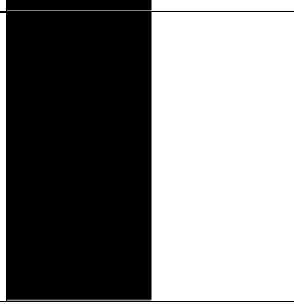
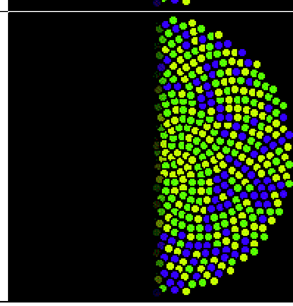
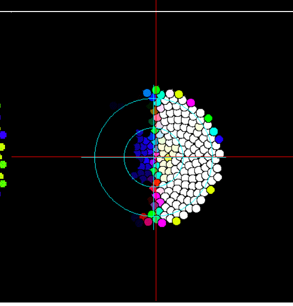
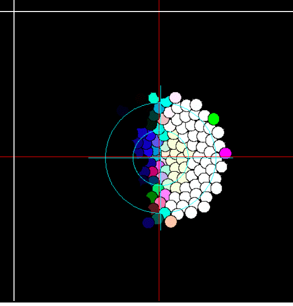
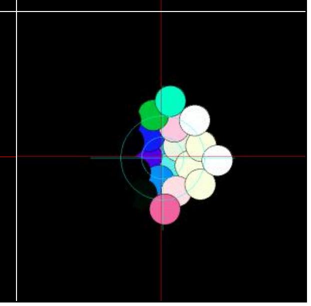
Table 30: Time sequence of filling-in half white stimulus over foveal blue scotoma					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
24					
25					
26					

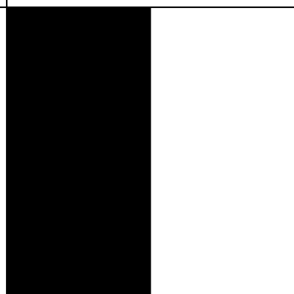
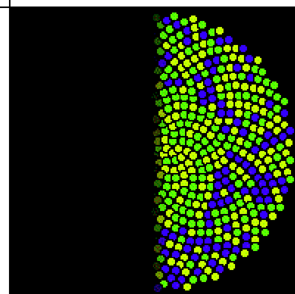
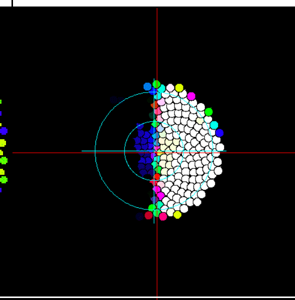
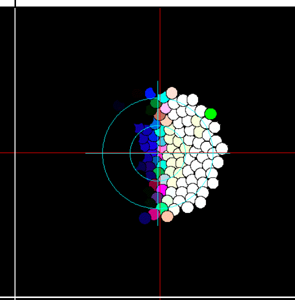
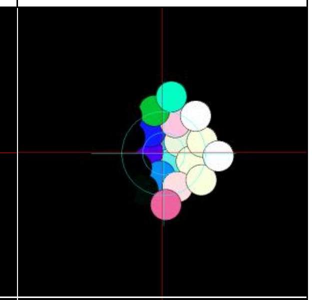
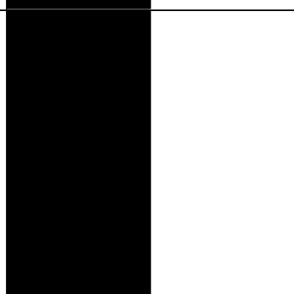
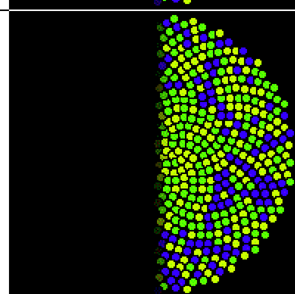
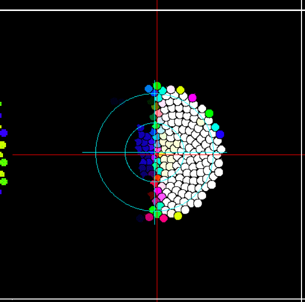
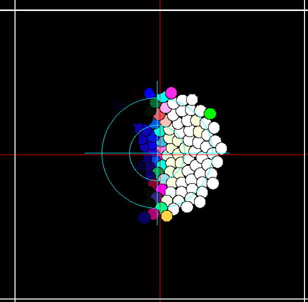
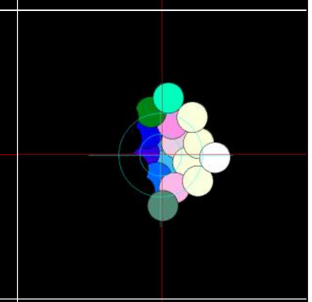
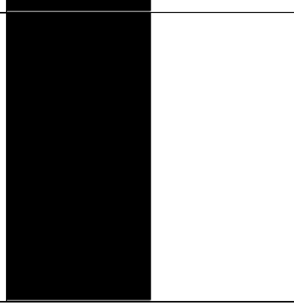
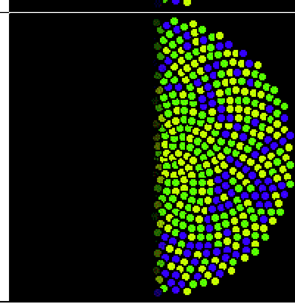
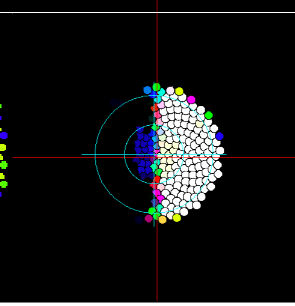
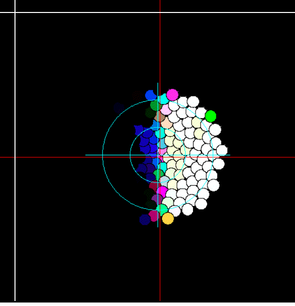
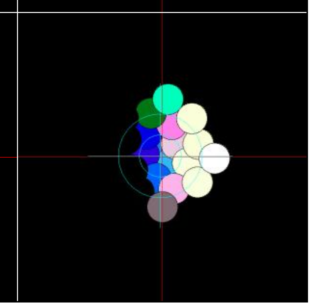
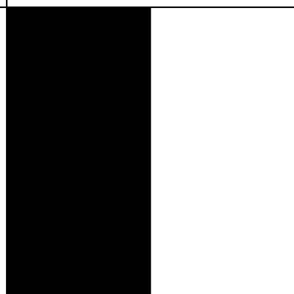
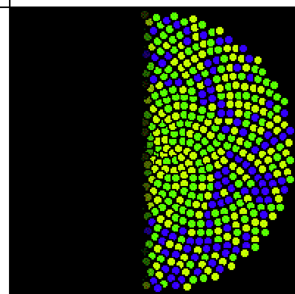
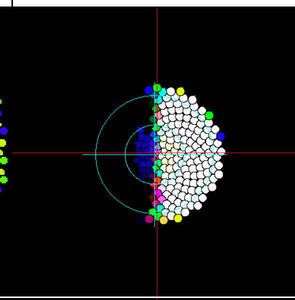
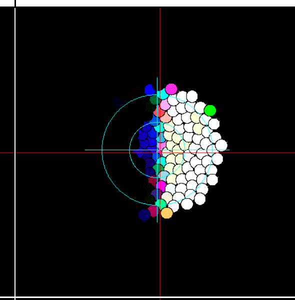
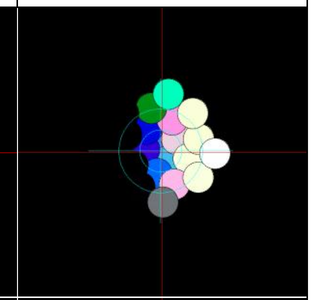
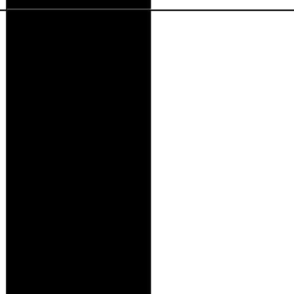
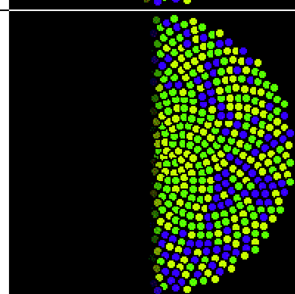
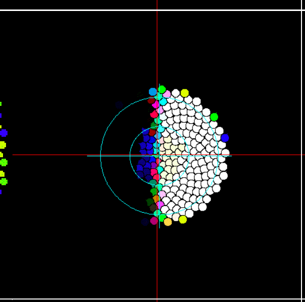
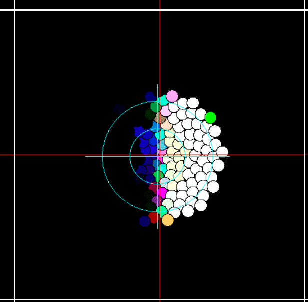
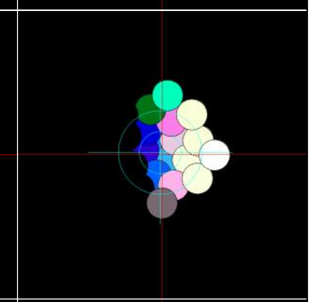
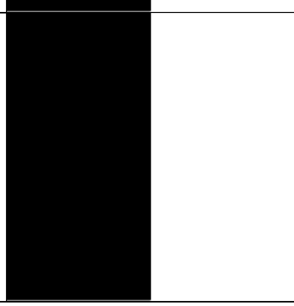
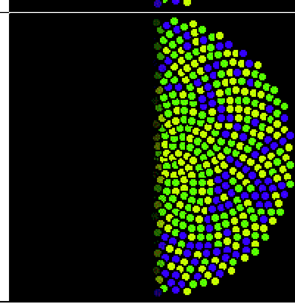
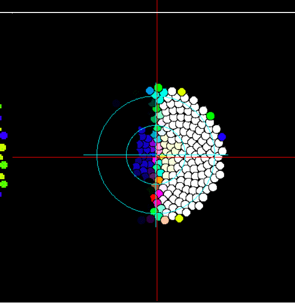
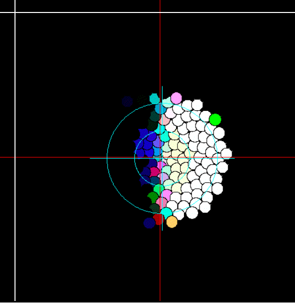
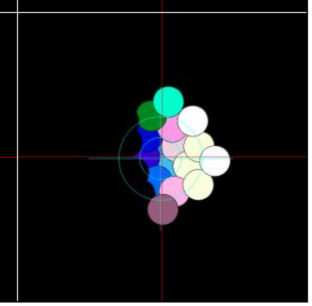
Table 30: Time sequence of filling-in half white stimulus over foveal blue scotoma					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
27					
28					
29					

Table 30: Time sequence of filling-in half white stimulus over foveal blue scotoma					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
30					
31					
32					

B.3.3 Test 3 results: Quarter white stimulus

Table 31: Time sequence of filling-in quarter white stimulus over foveal blue scotoma

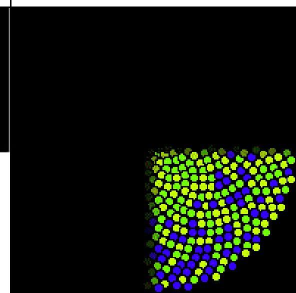
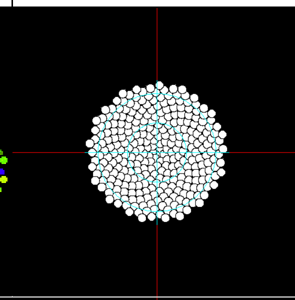
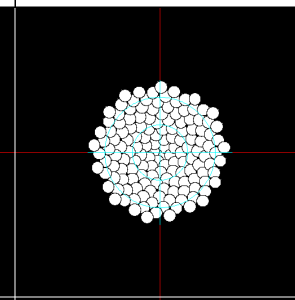
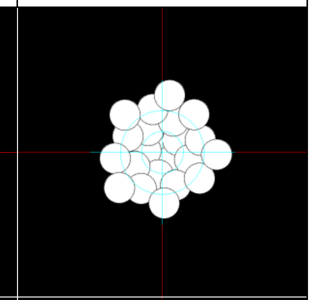
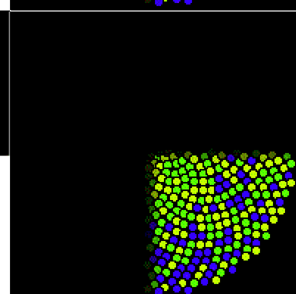
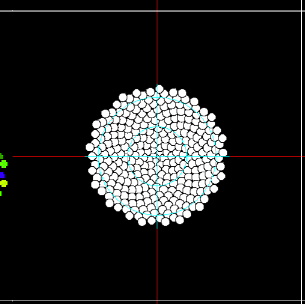
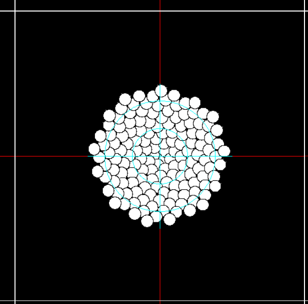
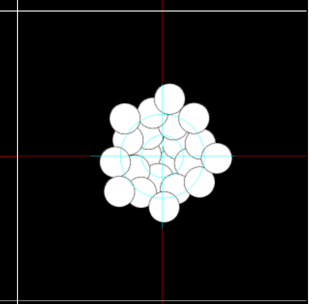
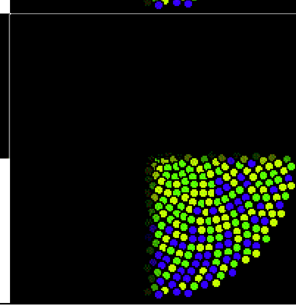
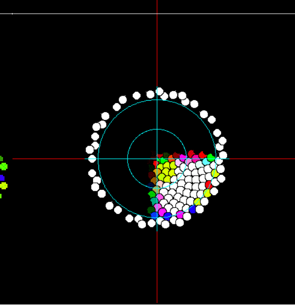
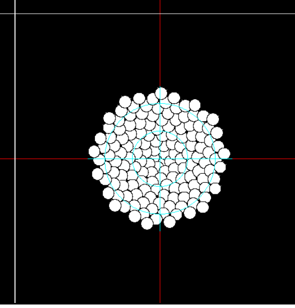
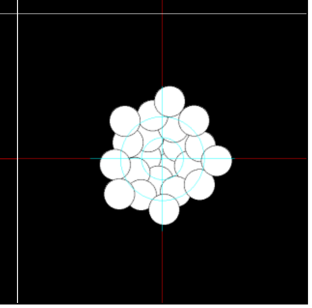
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
0					
1					
2					

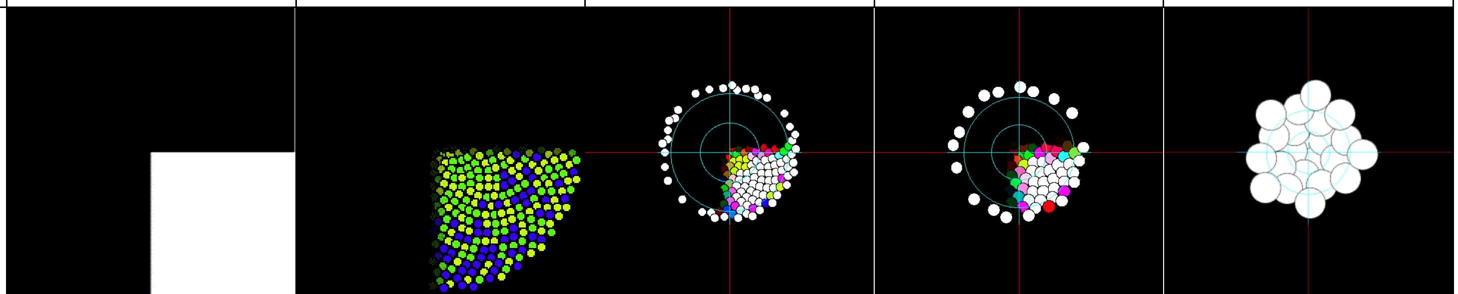
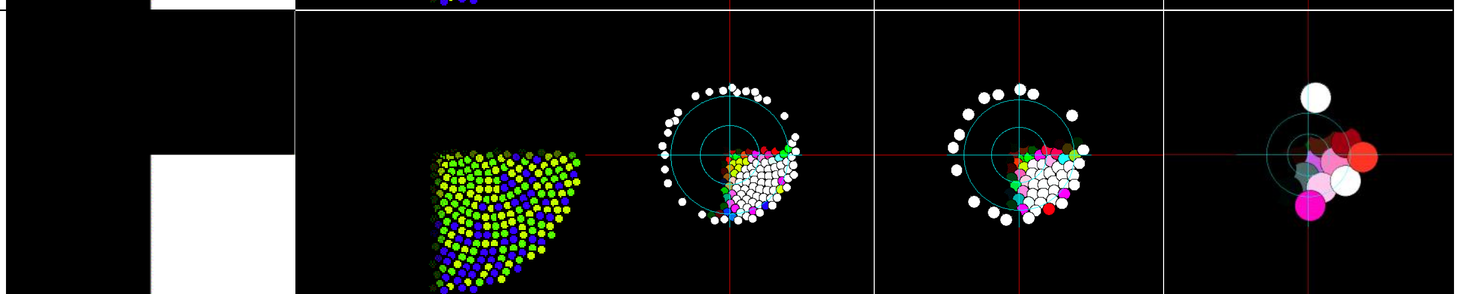
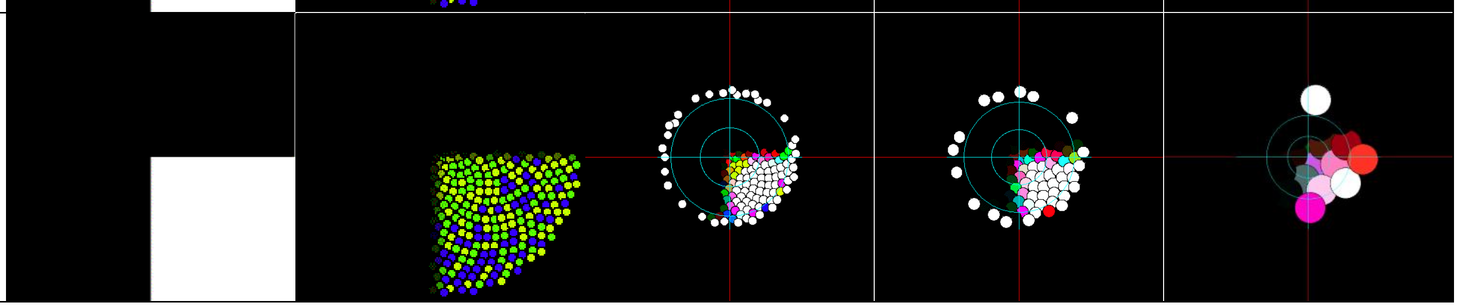
Table 31: Time sequence of filling-in quarter white stimulus over foveal blue scotoma					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
3					
4					
5					

Table 31: Time sequence of filling-in quarter white stimulus over foveal blue scotoma

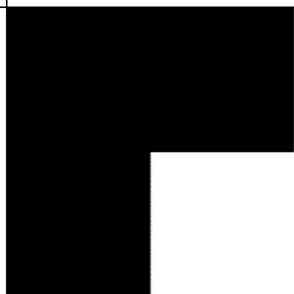
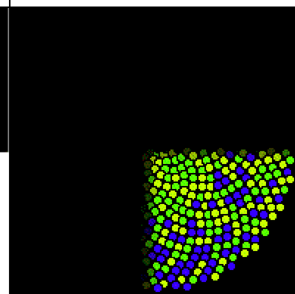
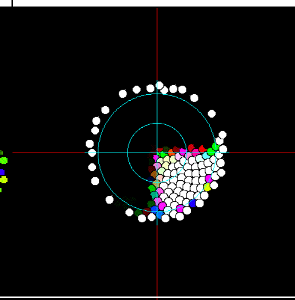
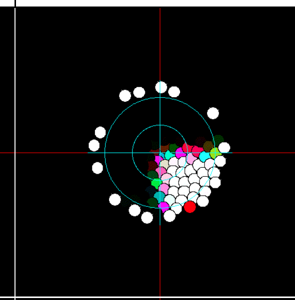
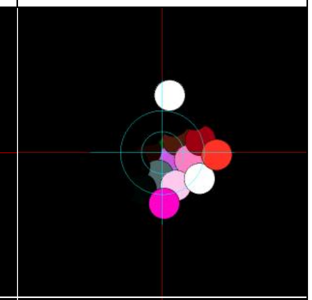
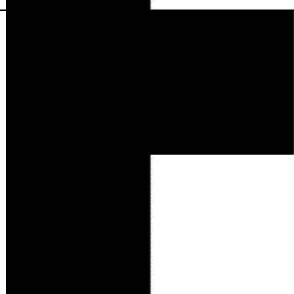
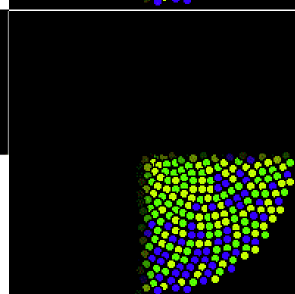
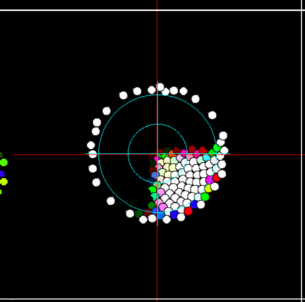
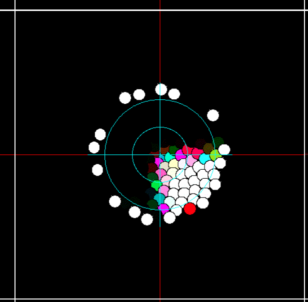
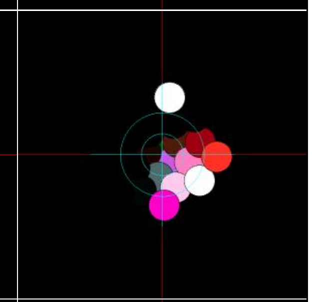
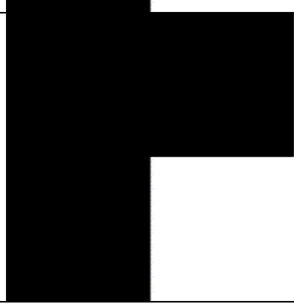
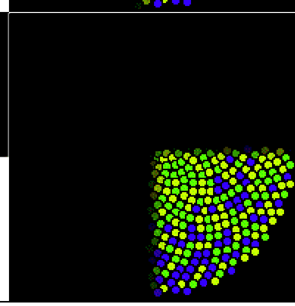
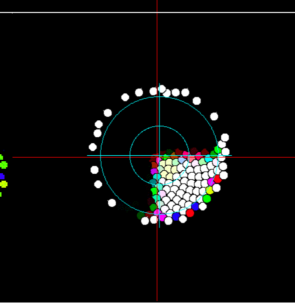
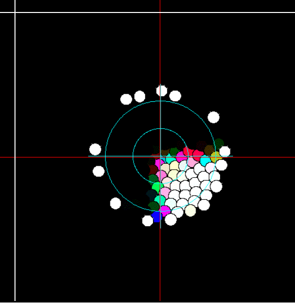
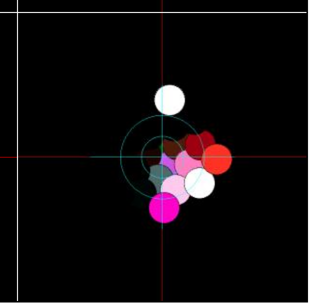
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
6					
7					
8					

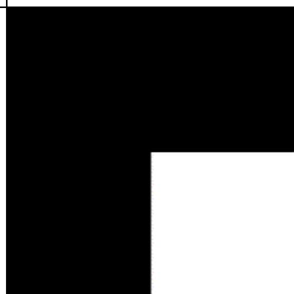
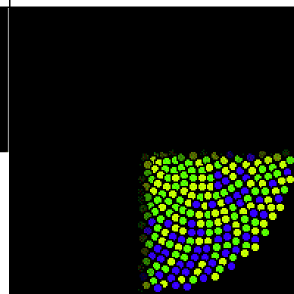
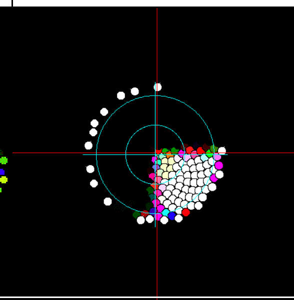
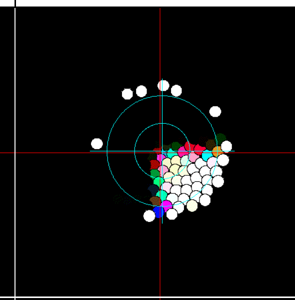
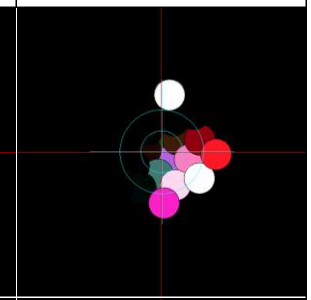
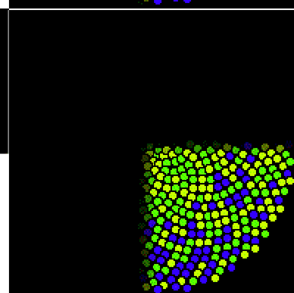
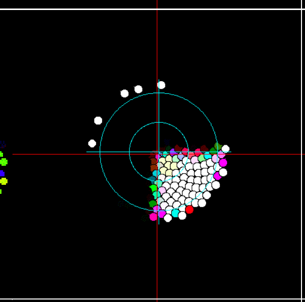
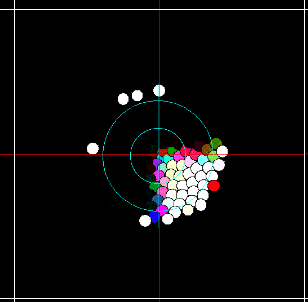
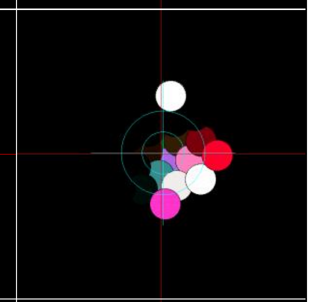
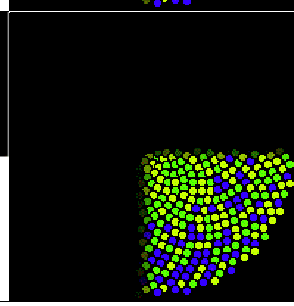
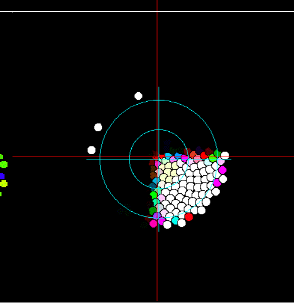
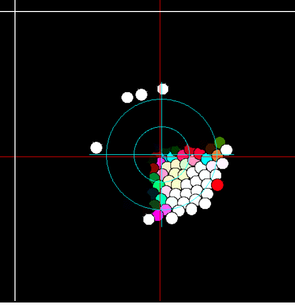
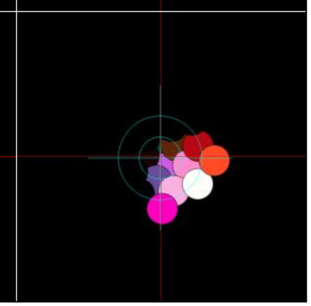
Table 31: Time sequence of filling-in quarter white stimulus over foveal blue scotoma					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
9					
10					
11					

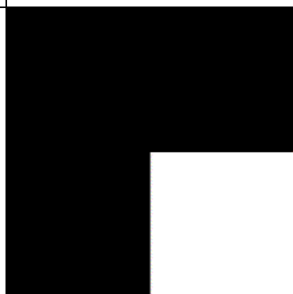
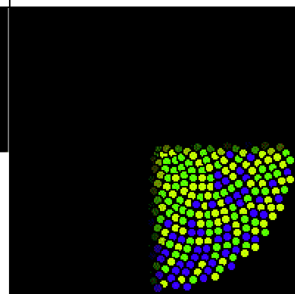
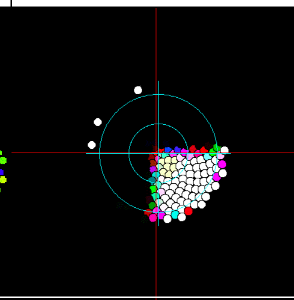
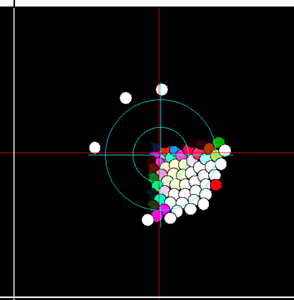
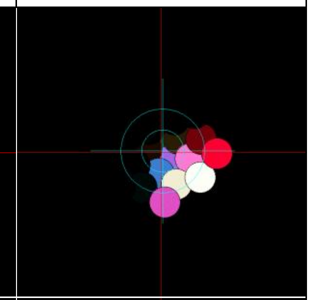
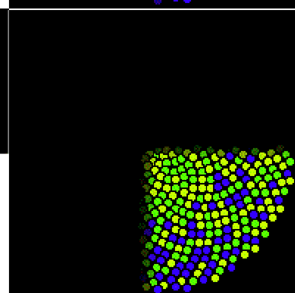
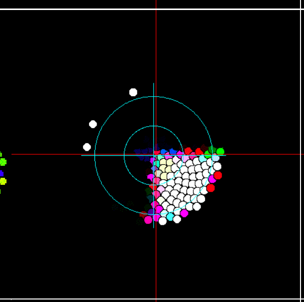
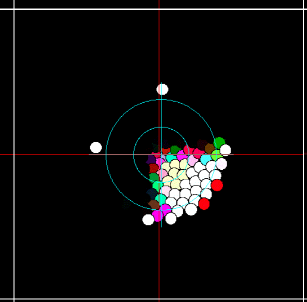
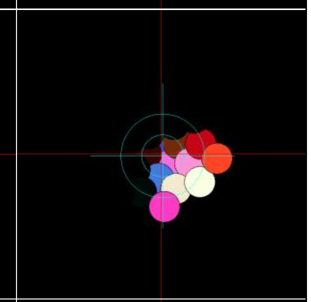
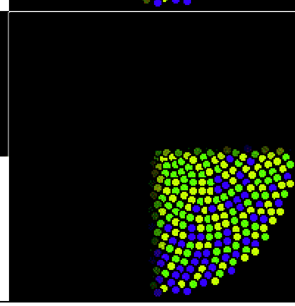
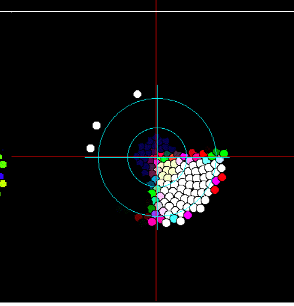
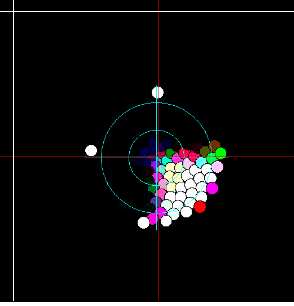
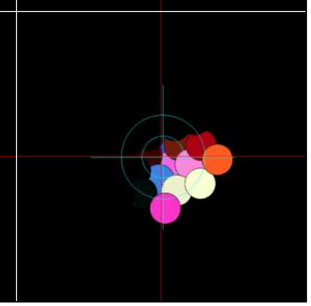
Table 31: Time sequence of filling-in quarter white stimulus over foveal blue scotoma					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
12					
13					
14					

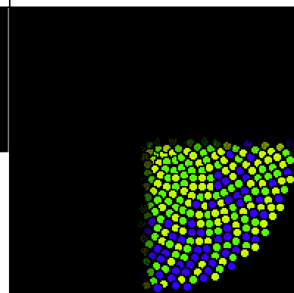
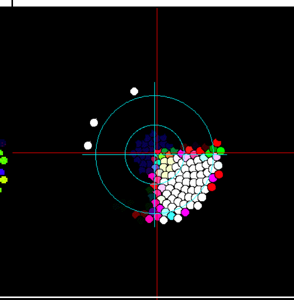
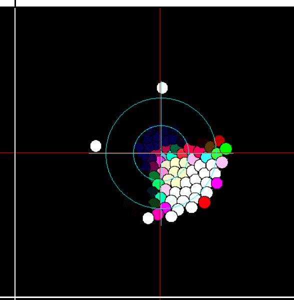
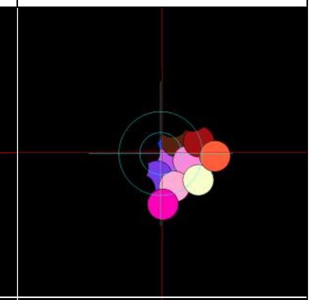
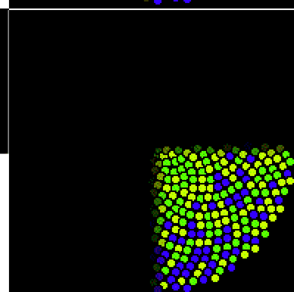
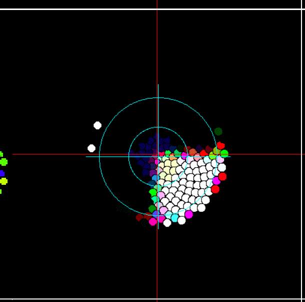
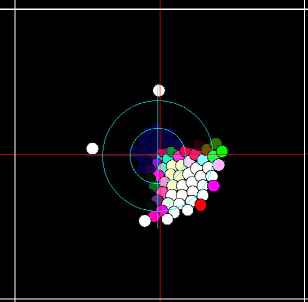
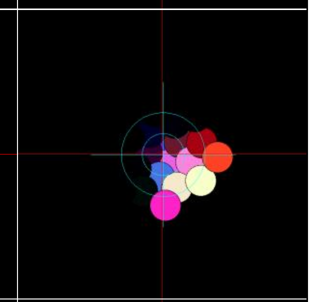
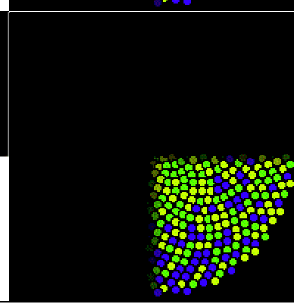
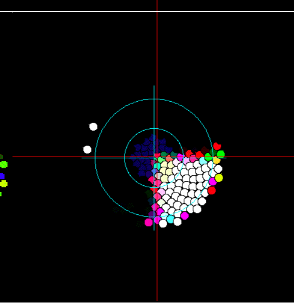
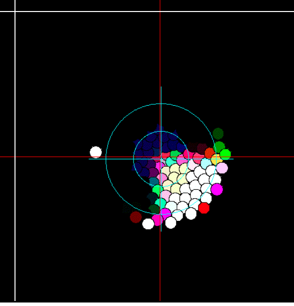
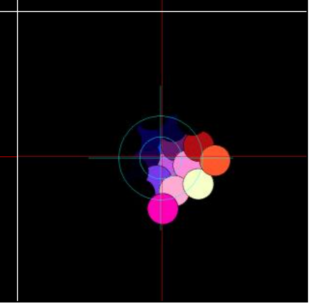
Table 31: Time sequence of filling-in quarter white stimulus over foveal blue scotoma					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
15					
16					
17					

Table 31: Time sequence of filling-in quarter white stimulus over foveal blue scotoma

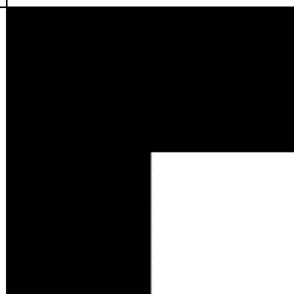
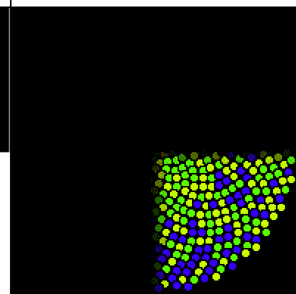
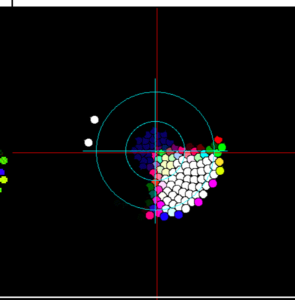
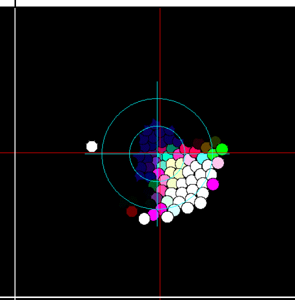
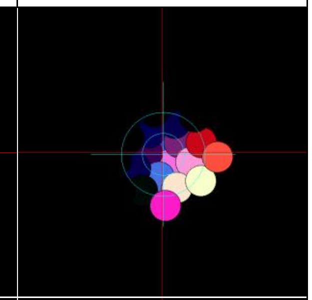
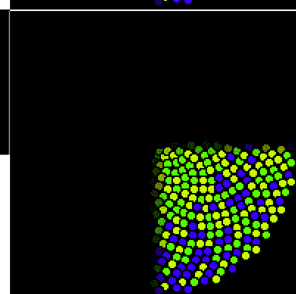
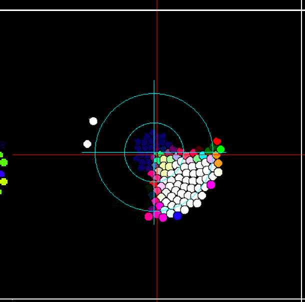
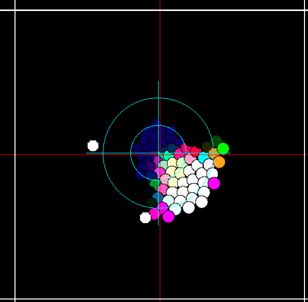
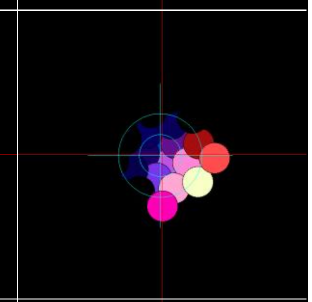
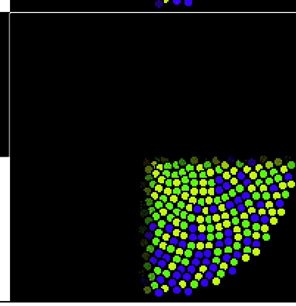
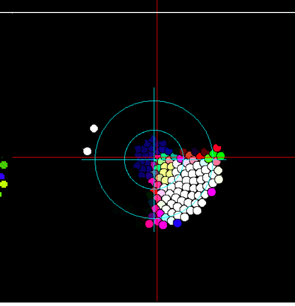
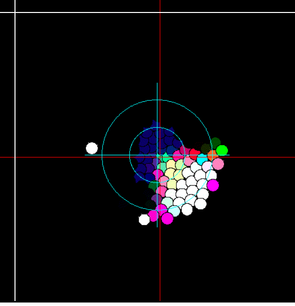
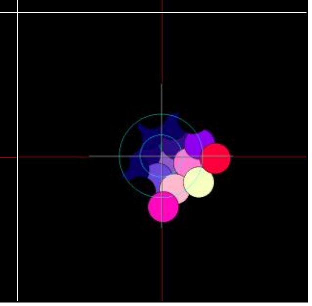
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
18					
19					
20					

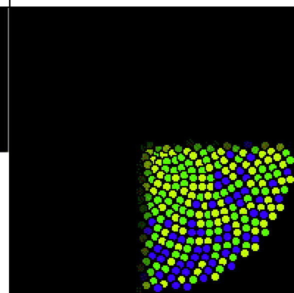
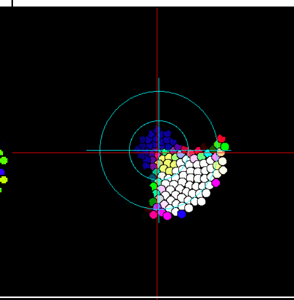
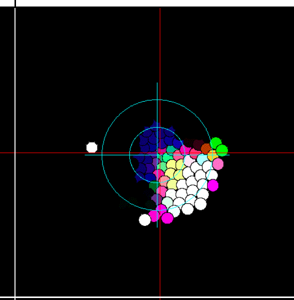
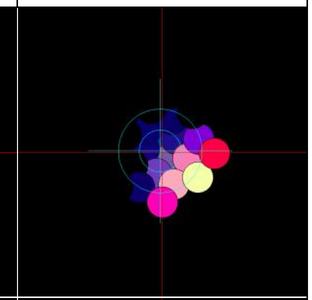
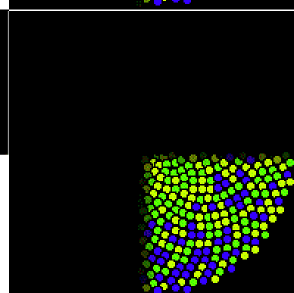
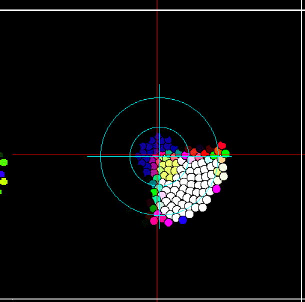
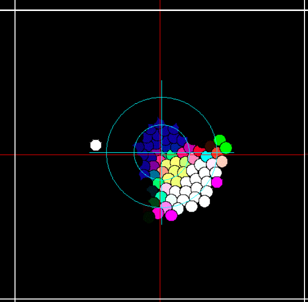
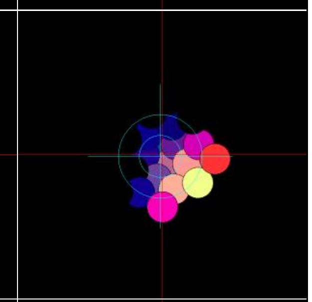
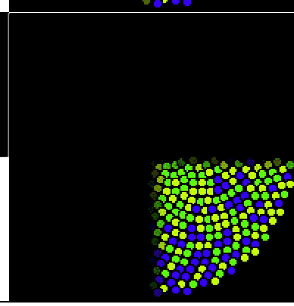
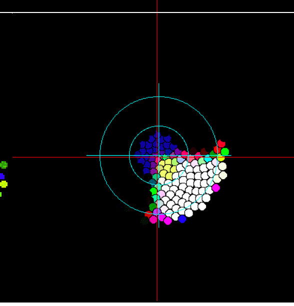
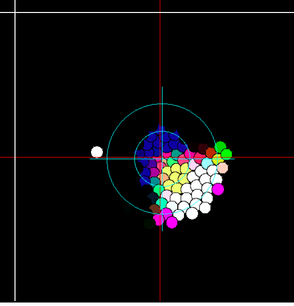
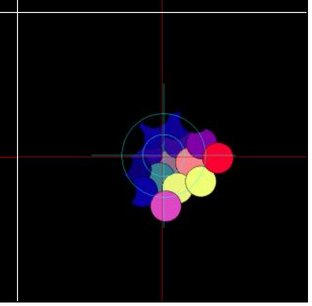
Table 31: Time sequence of filling-in quarter white stimulus over foveal blue scotoma					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
21					
22					
23					

Table 31: Time sequence of filling-in quarter white stimulus over foveal blue scotoma

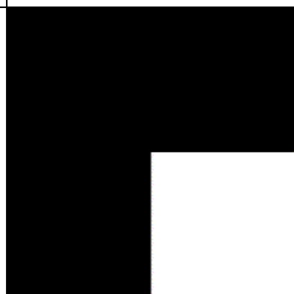
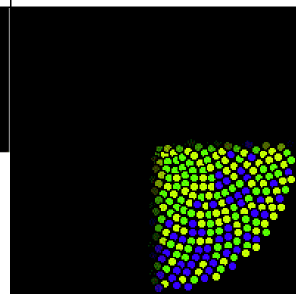
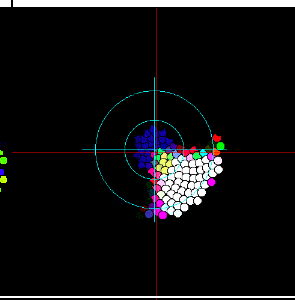
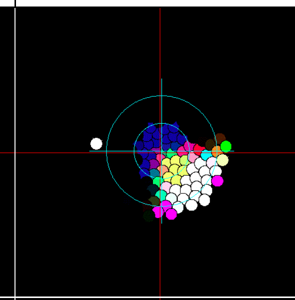
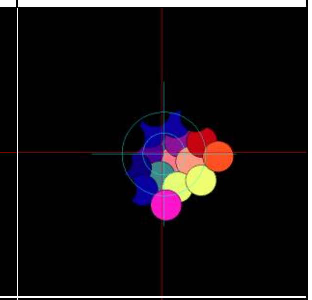
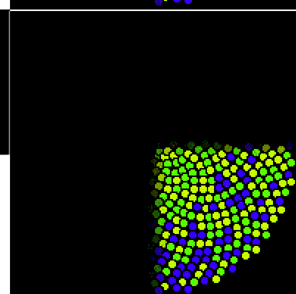
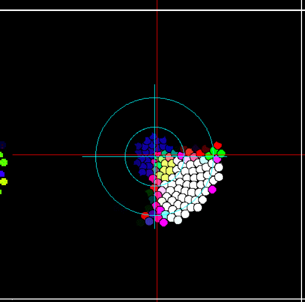
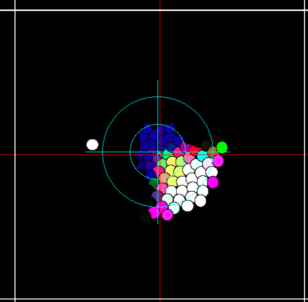
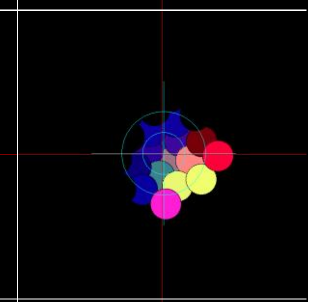
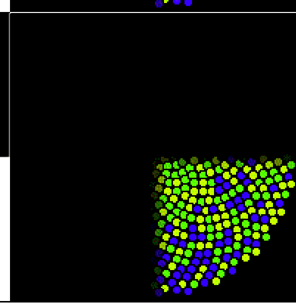
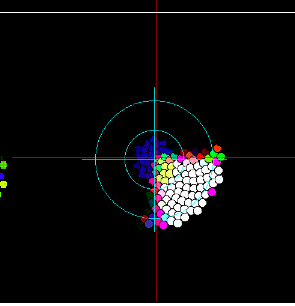
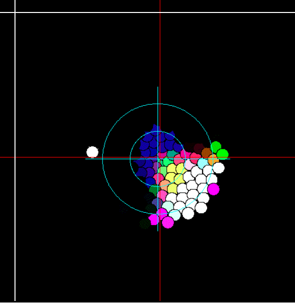
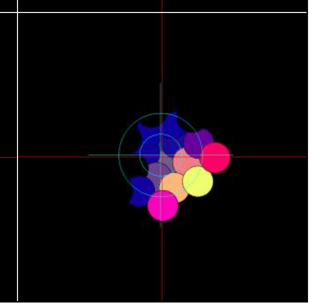
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
24					
25					
26					

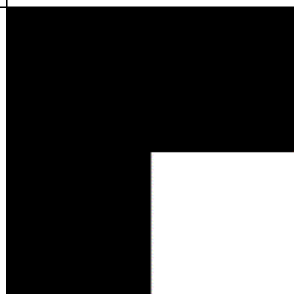
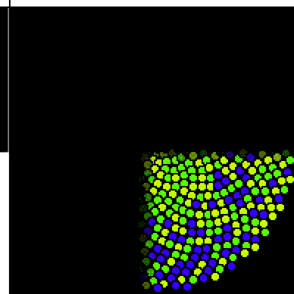
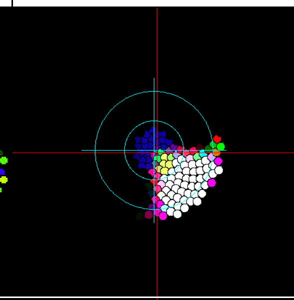
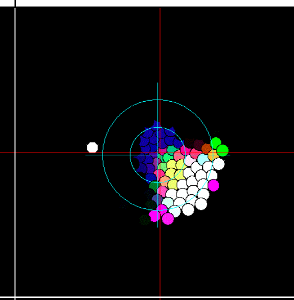
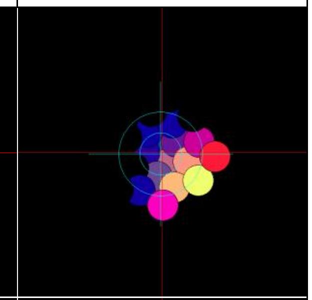
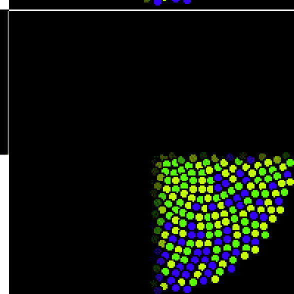
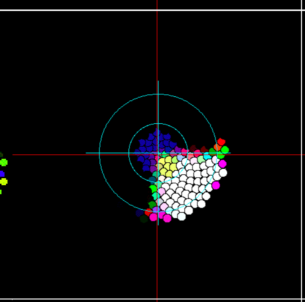
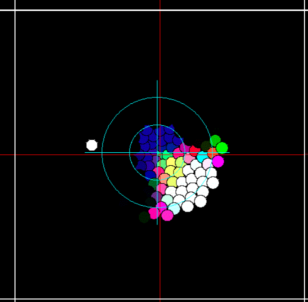
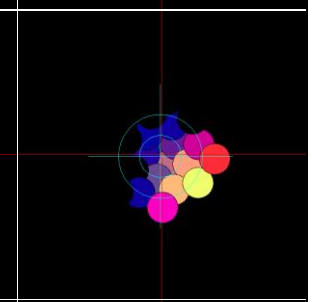
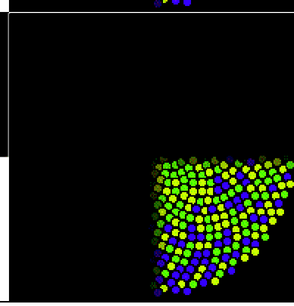
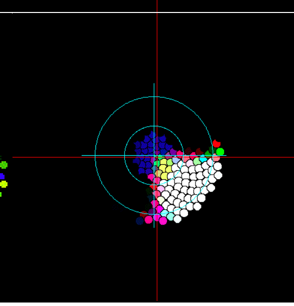
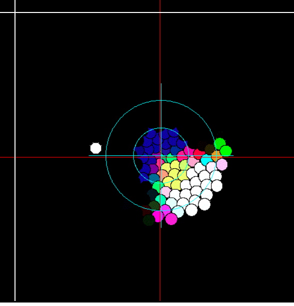
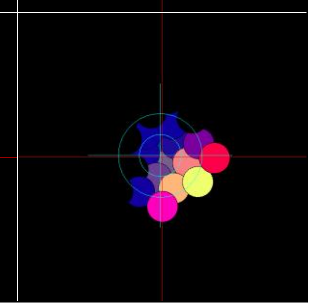
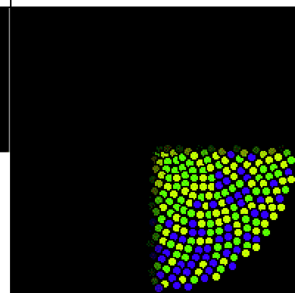
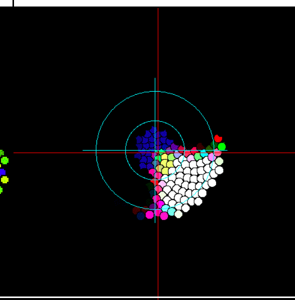
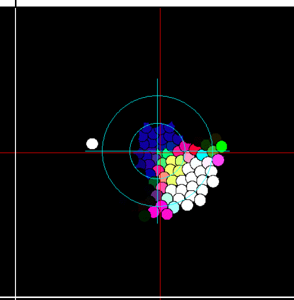
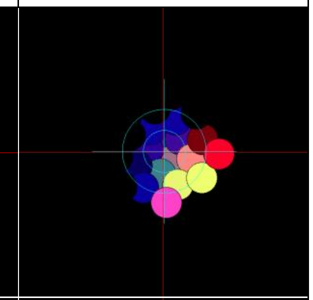
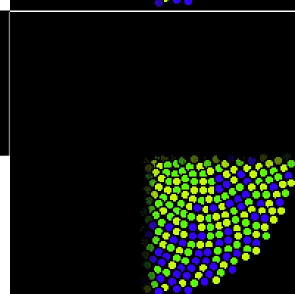
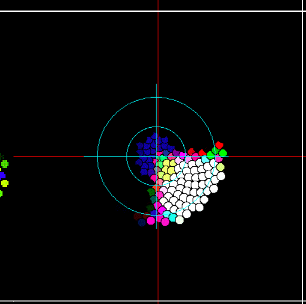
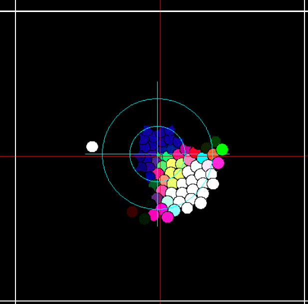
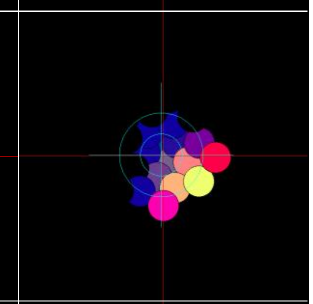
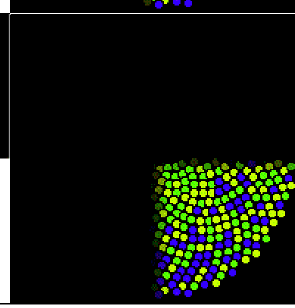
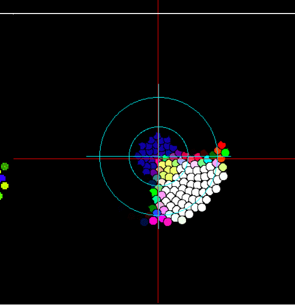
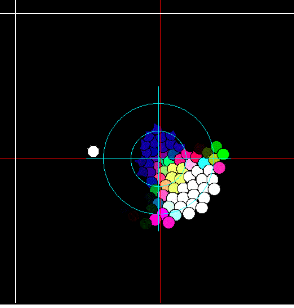
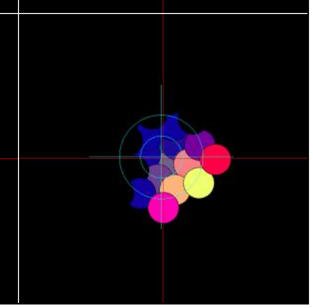
Table 31: Time sequence of filling-in quarter white stimulus over foveal blue scotoma					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
27					
28					
29					

Table 31: Time sequence of filling-in quarter white stimulus over foveal blue scotoma					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
30					
31					
32					

B.3.4 Test 4 results: Quarter white stimulus with saccade

Table 32: Time sequence of filling-in quarter white stimulus with saccade over foveal blue scotoma

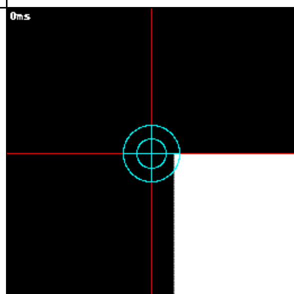
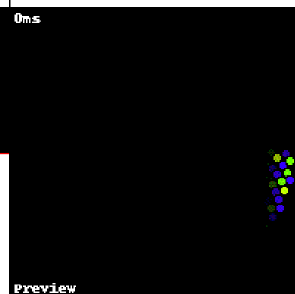
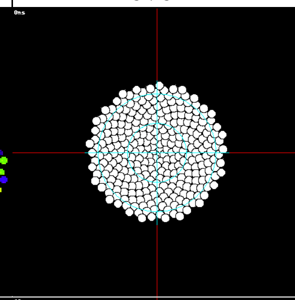
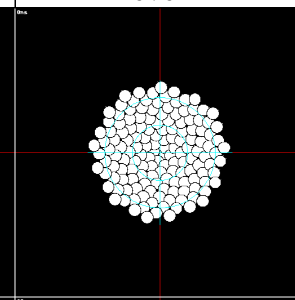
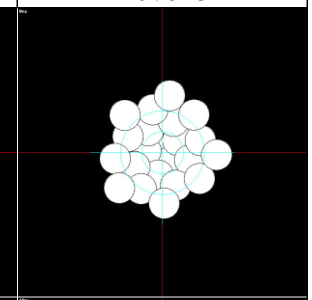
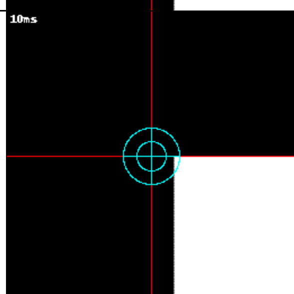
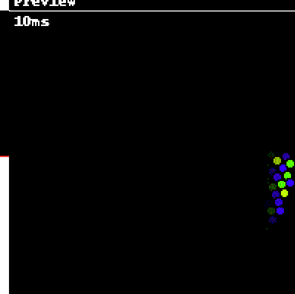
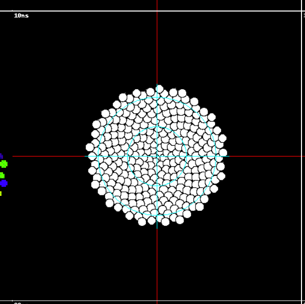
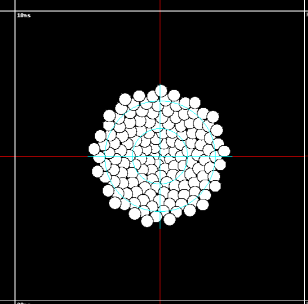
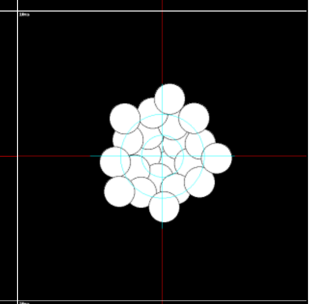
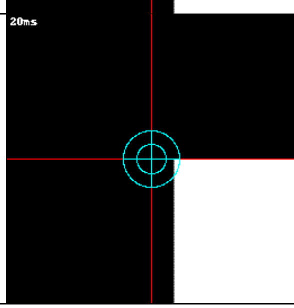
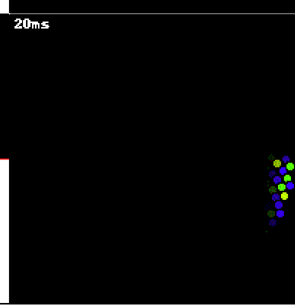
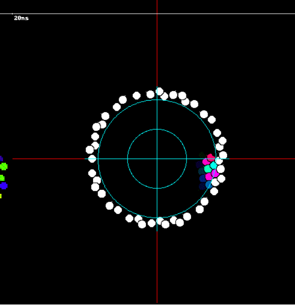
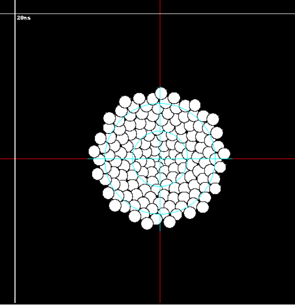
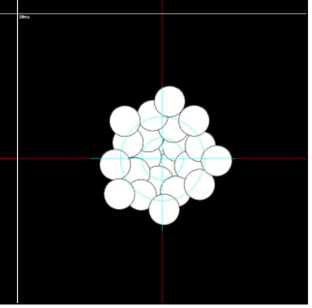
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
0					
1					
2					

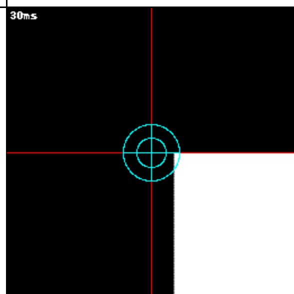
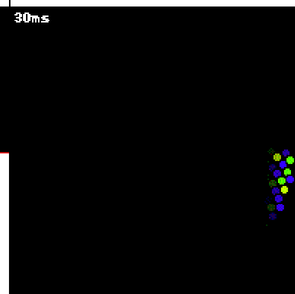
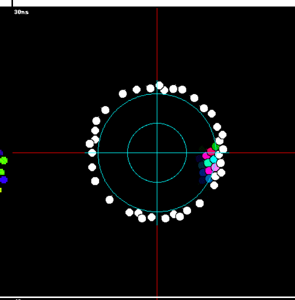
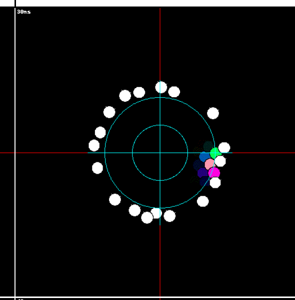
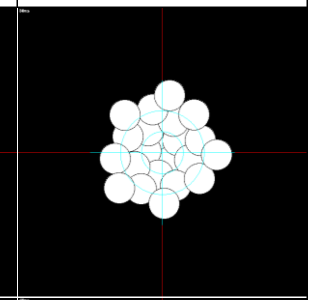
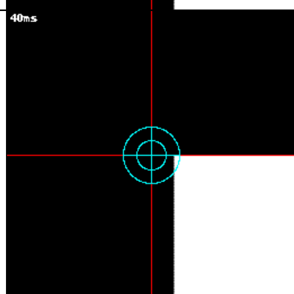
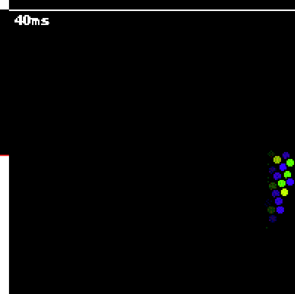
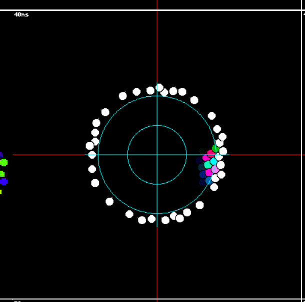
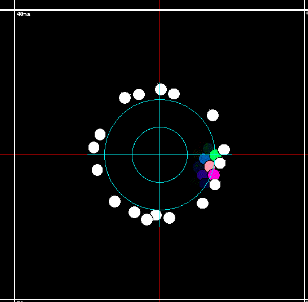
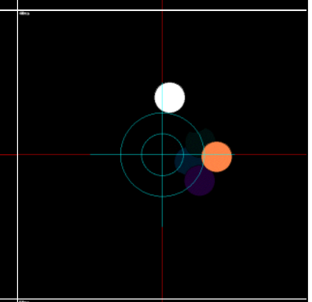
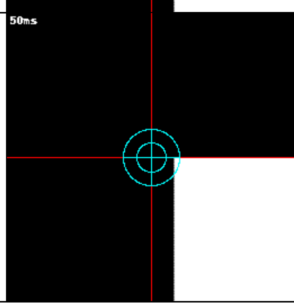
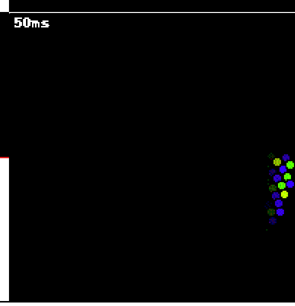
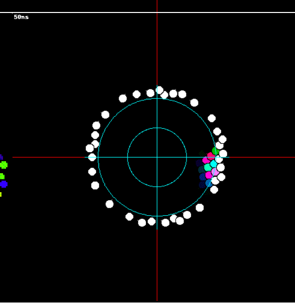
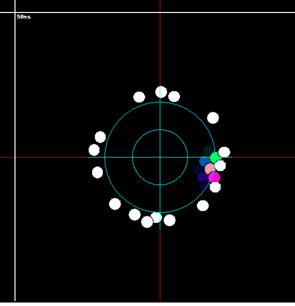
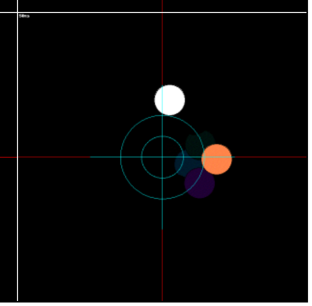
Table 32: Time sequence of filling-in quarter white stimulus with saccade over foveal blue scotoma					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
3					
4					
5					

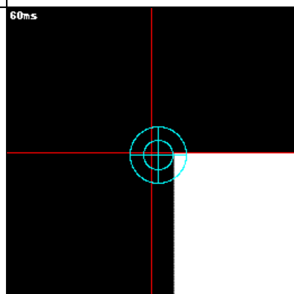
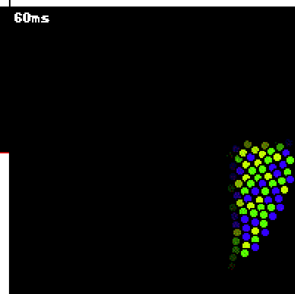
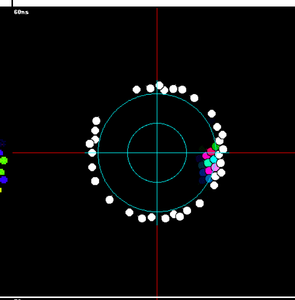
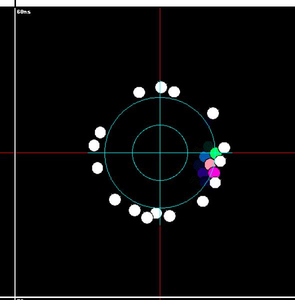
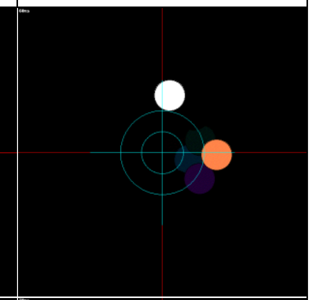
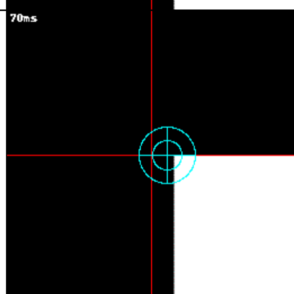
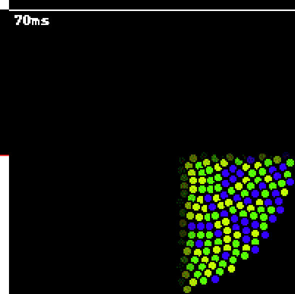
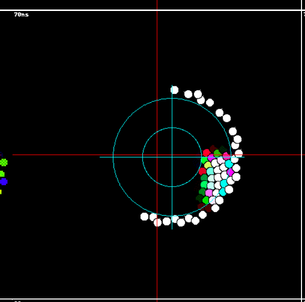
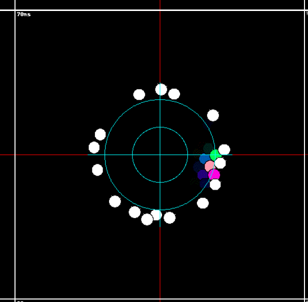
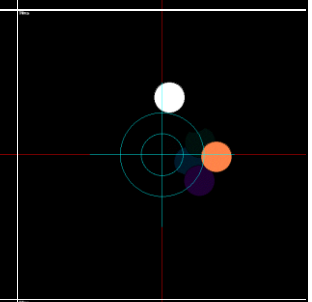
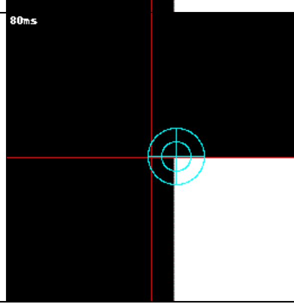
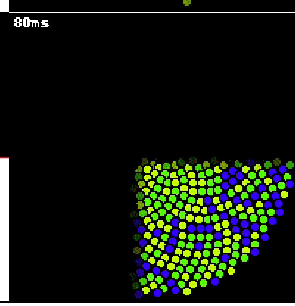
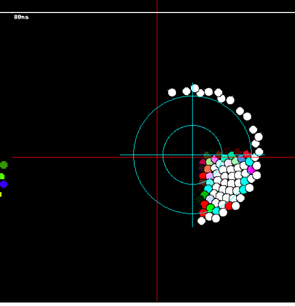
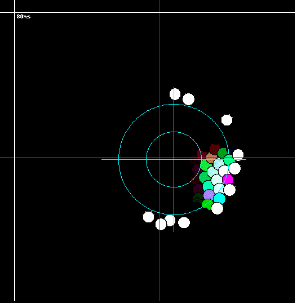
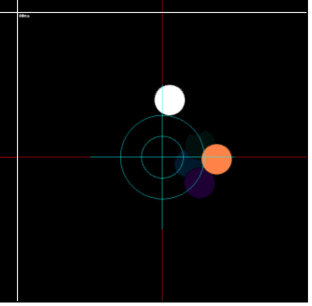
Table 32: Time sequence of filling-in quarter white stimulus with saccade over foveal blue scotoma					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
6					
7					
8					

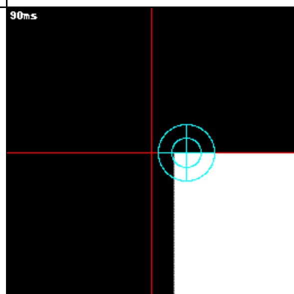
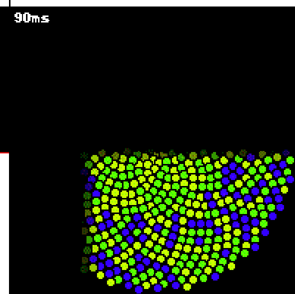
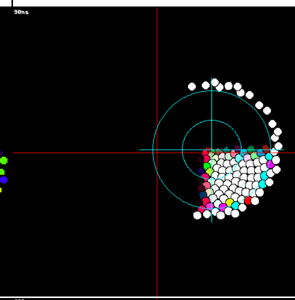
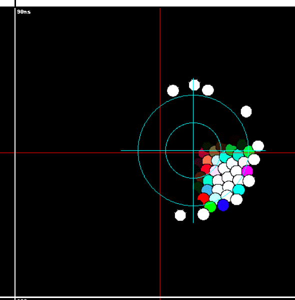
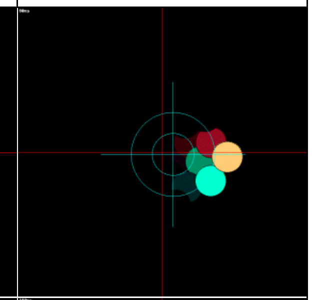
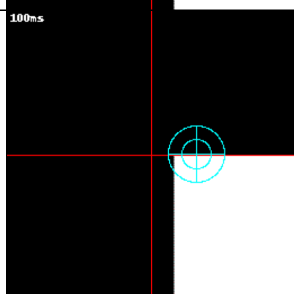
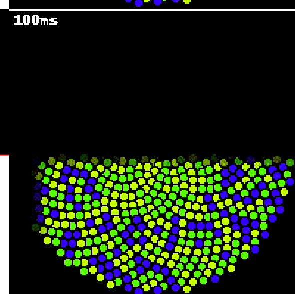
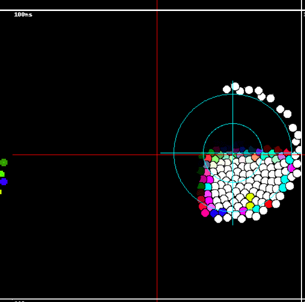
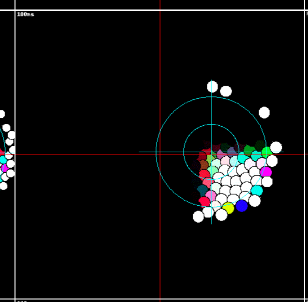
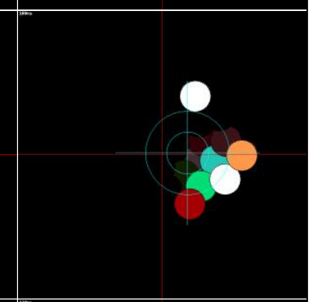
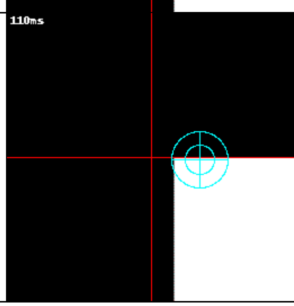
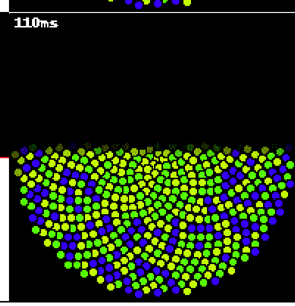
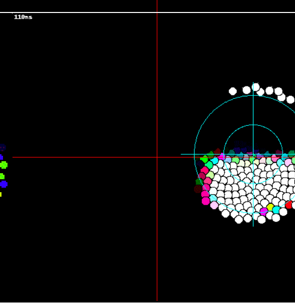
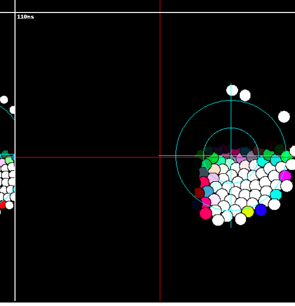
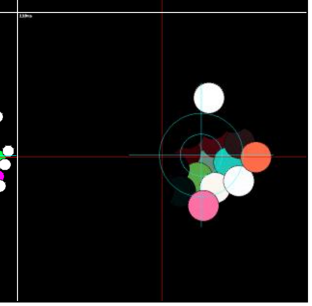
Table 32: Time sequence of filling-in quarter white stimulus with saccade over foveal blue scotoma					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
9					
10					
11					

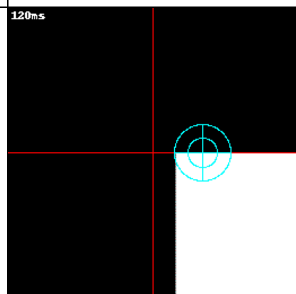
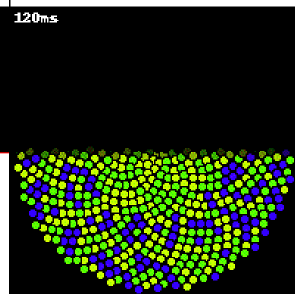
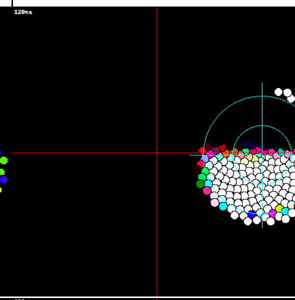
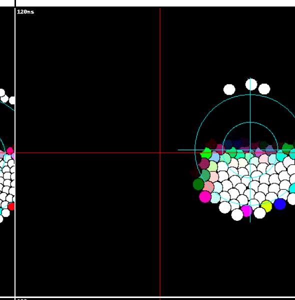
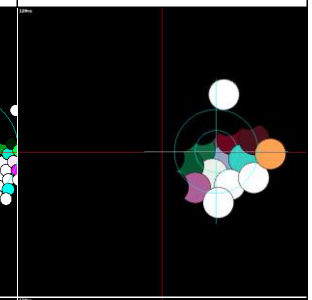
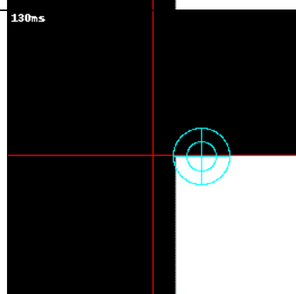
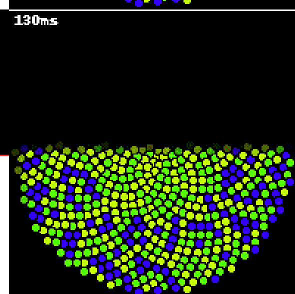
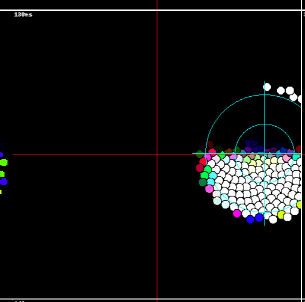
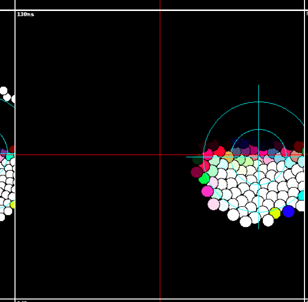
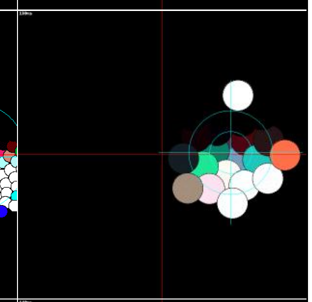
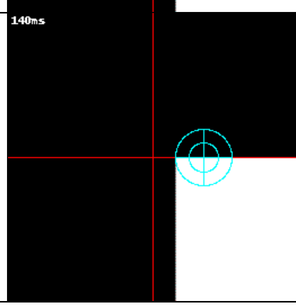
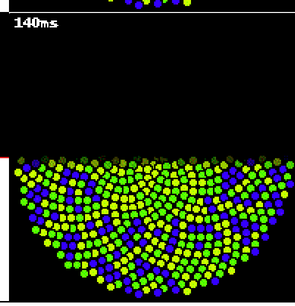
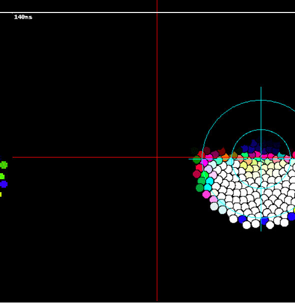
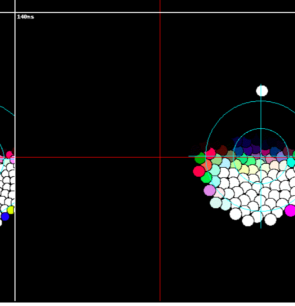
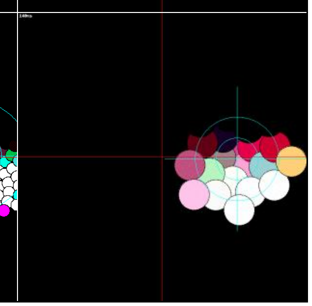
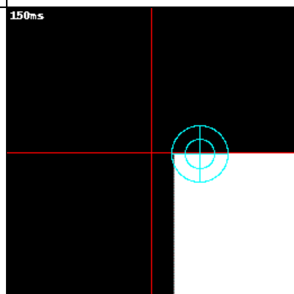
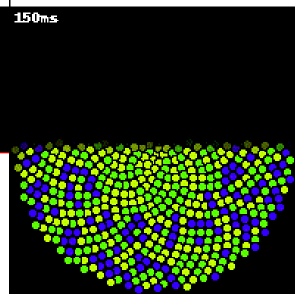
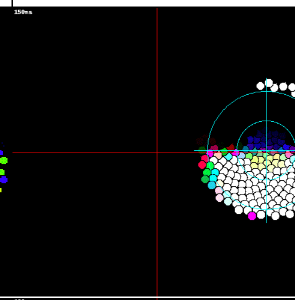
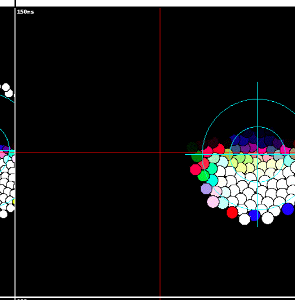
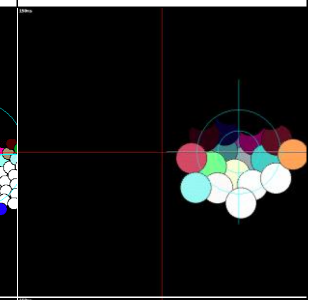
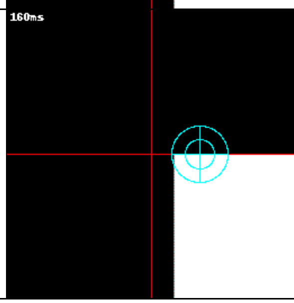
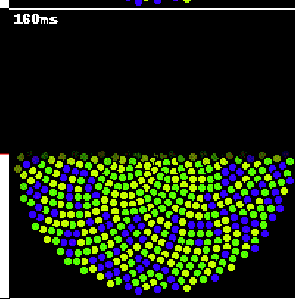
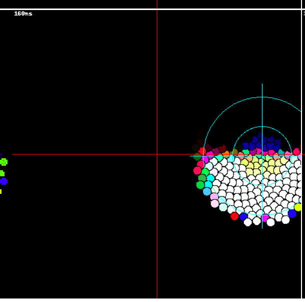
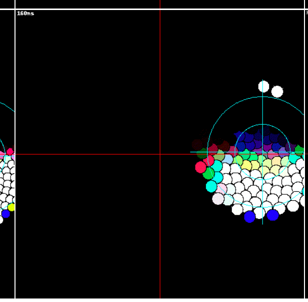
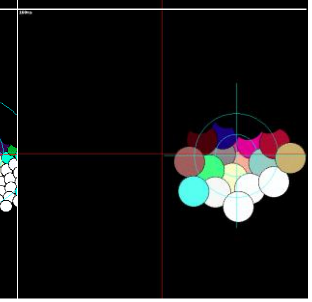
Table 32: Time sequence of filling-in quarter white stimulus with saccade over foveal blue scotoma					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
12					
13					
14					

Table 32: Time sequence of filling-in quarter white stimulus with saccade over foveal blue scotoma					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
15					
16					

B.3.5 Test 5 results: Arrow stimulus

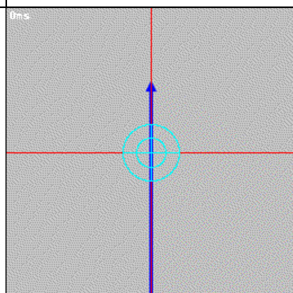
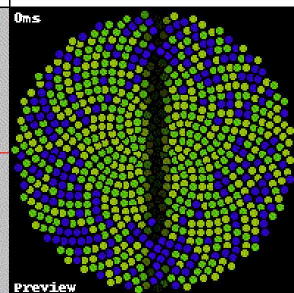
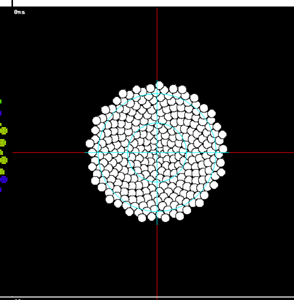
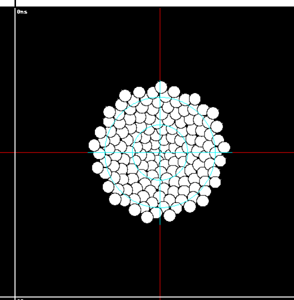
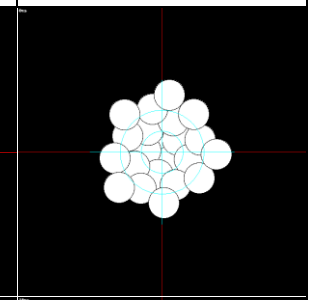
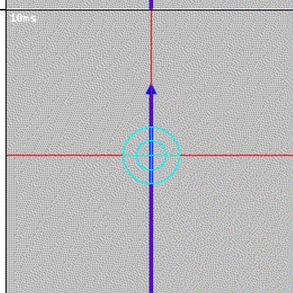
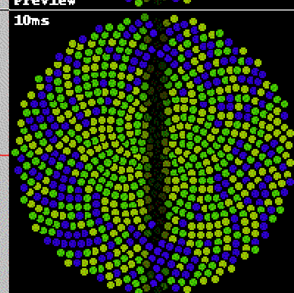
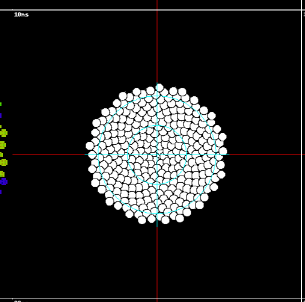
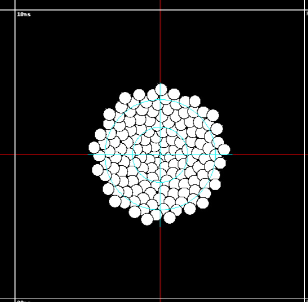
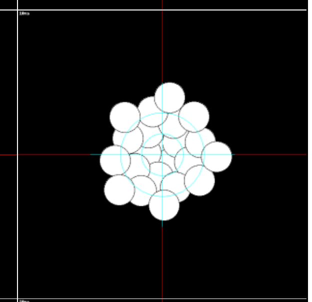
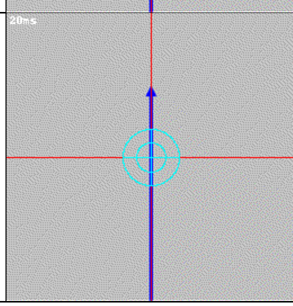
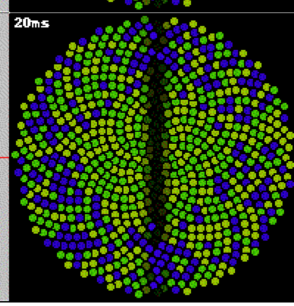
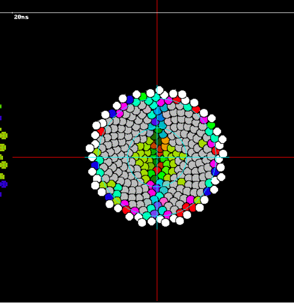
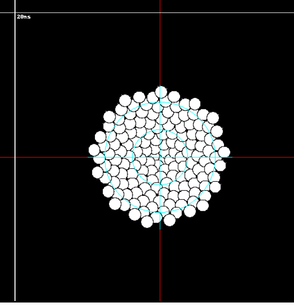
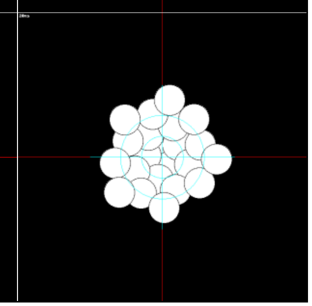
Table 33: Time sequence of filling-in arrow stimulus over foveal blue scotoma					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
0					
1					
2					

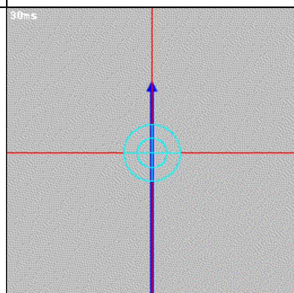
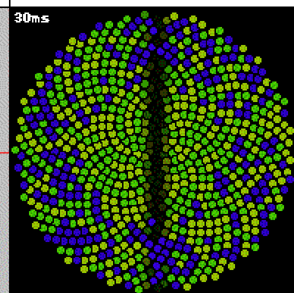
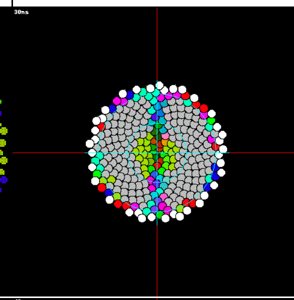
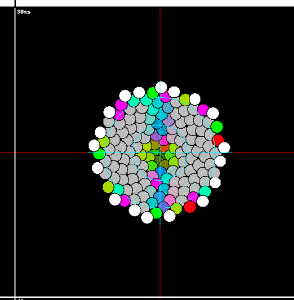
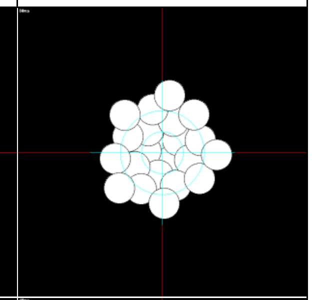
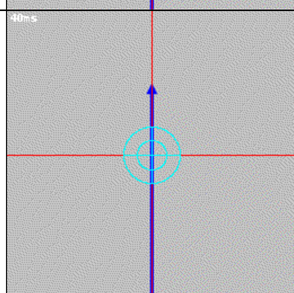
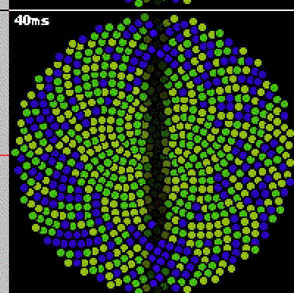
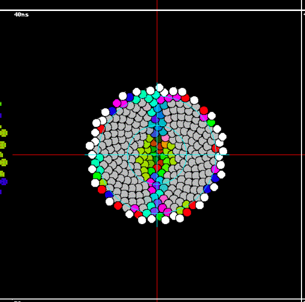
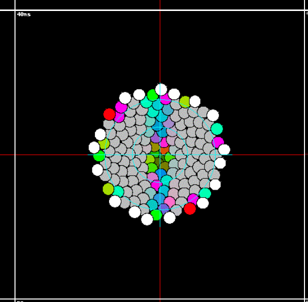
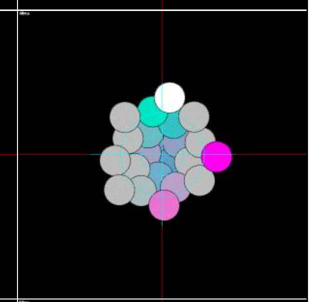
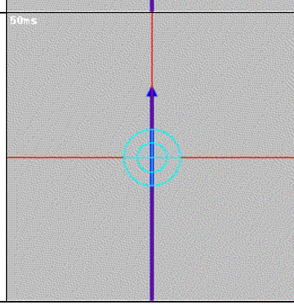
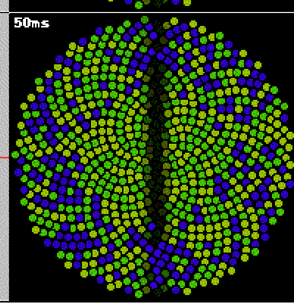
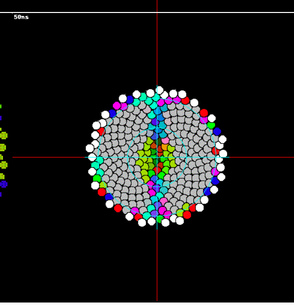
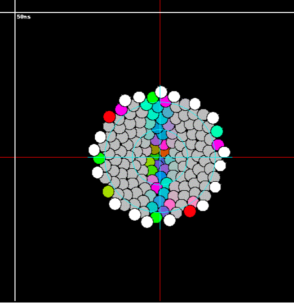
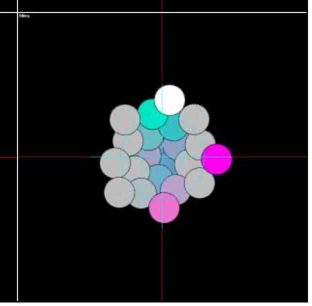
Table 33: Time sequence of filling-in arrow stimulus over foveal blue scotoma					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
3					
4					
5					

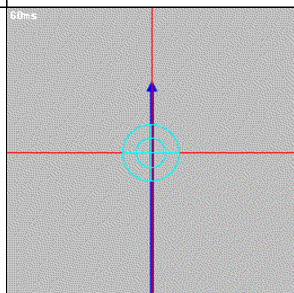
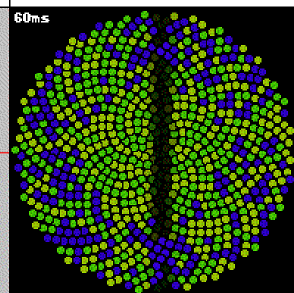
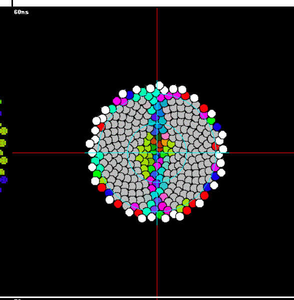
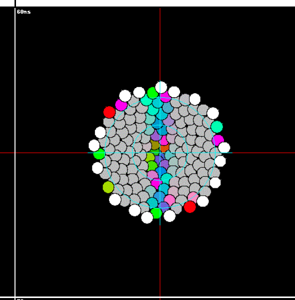
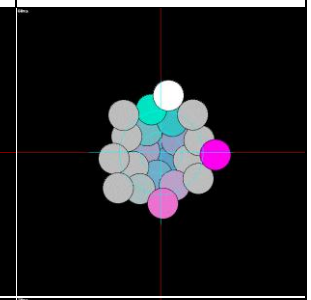
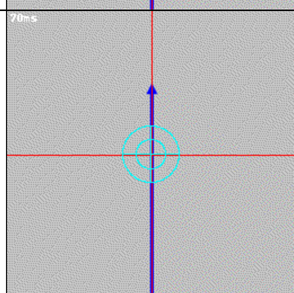
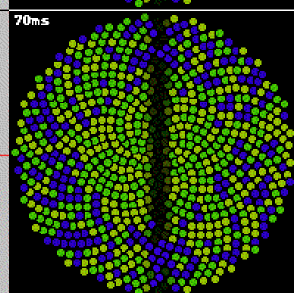
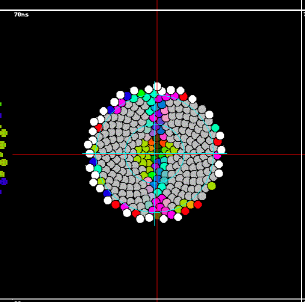
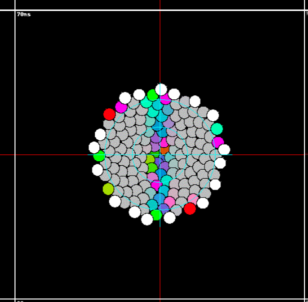
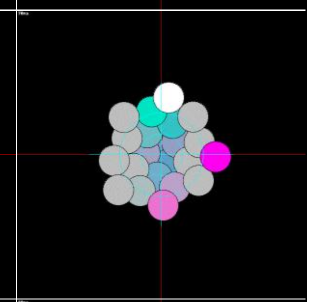
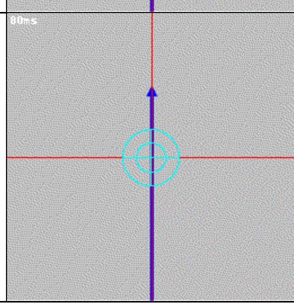
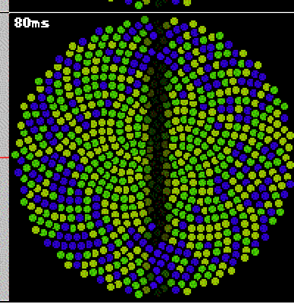
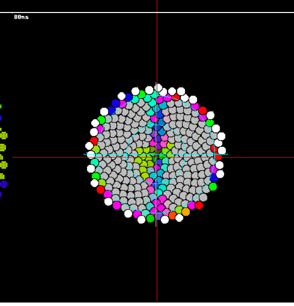
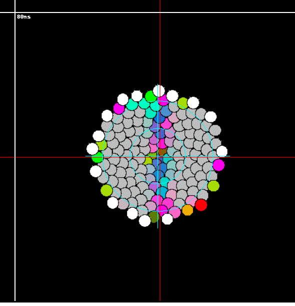
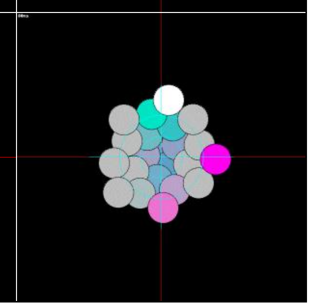
Table 33: Time sequence of filling-in arrow stimulus over foveal blue scotoma					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
6					
7					
8					

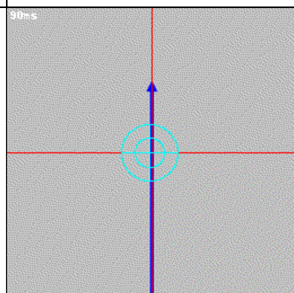
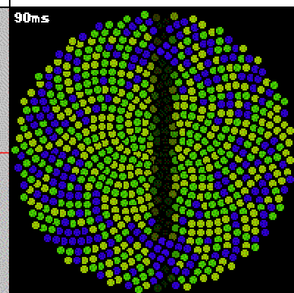
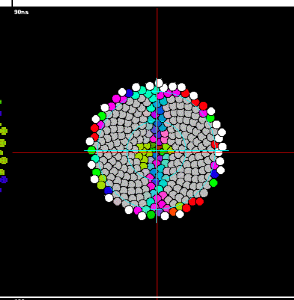
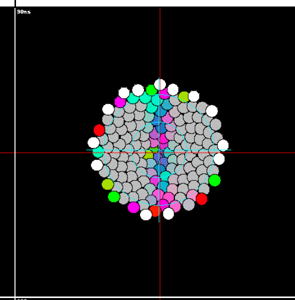
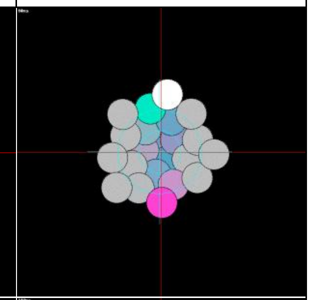
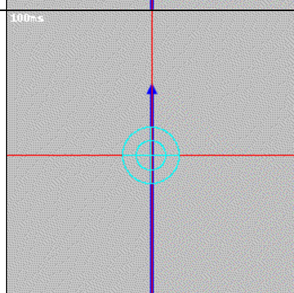
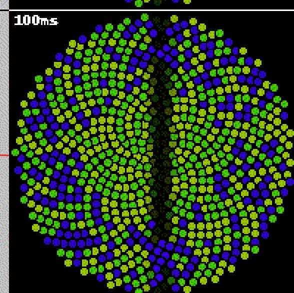
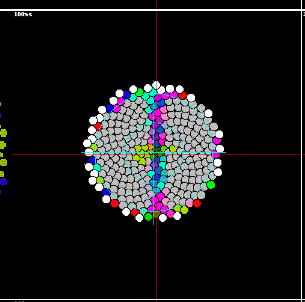
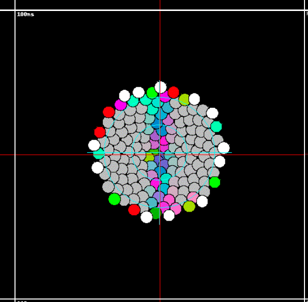
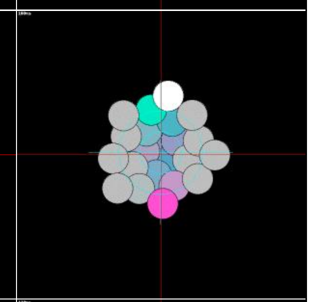
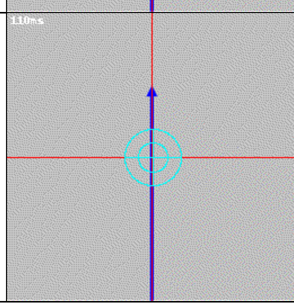
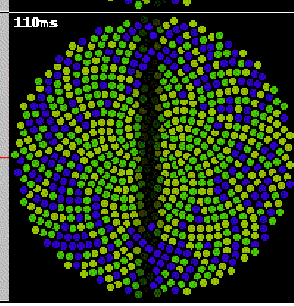
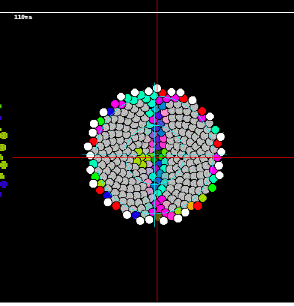
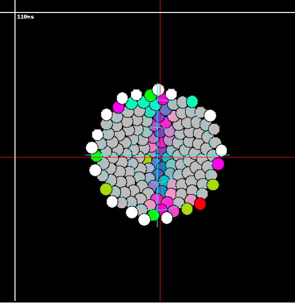
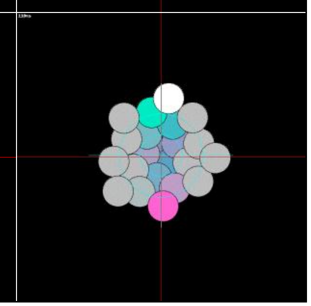
Table 33: Time sequence of filling-in arrow stimulus over foveal blue scotoma					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
9					
10					
11					

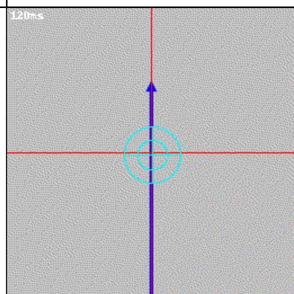
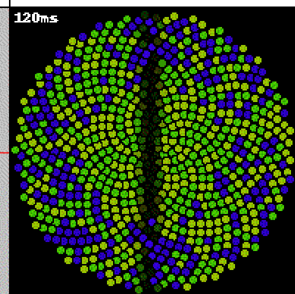
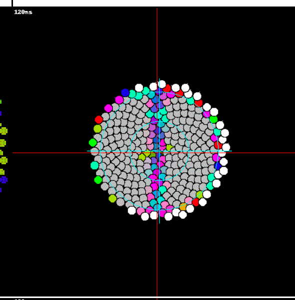
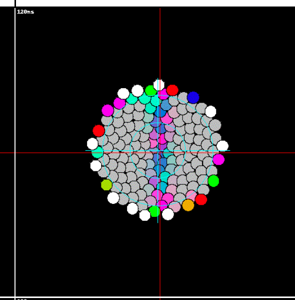
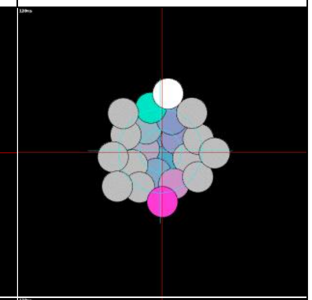
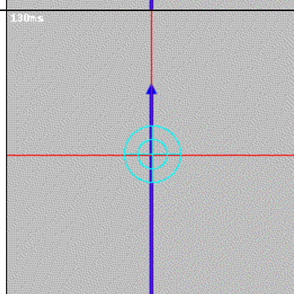
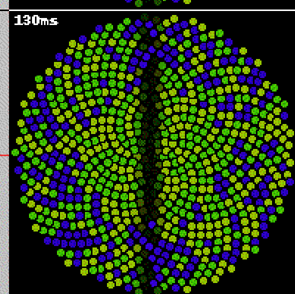
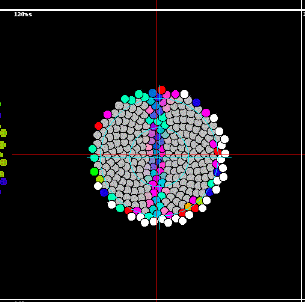
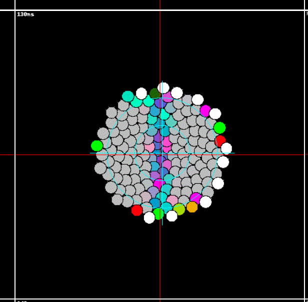
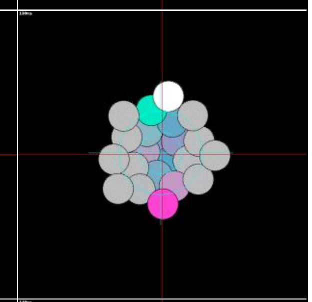
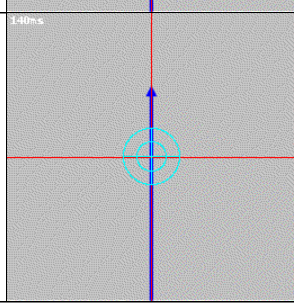
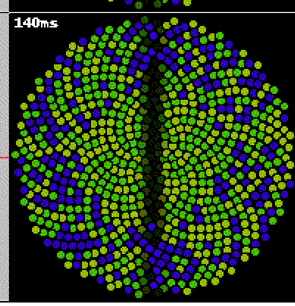
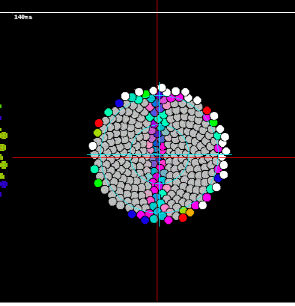
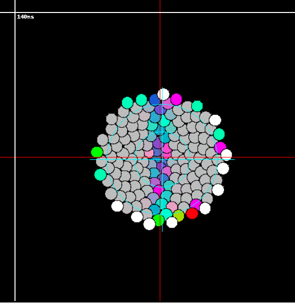
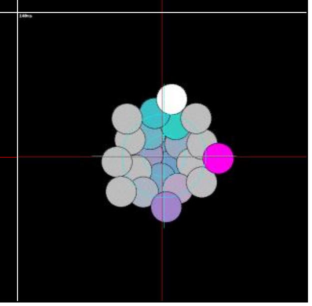
Table 33: Time sequence of filling-in arrow stimulus over foveal blue scotoma					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
12					
13					
14					

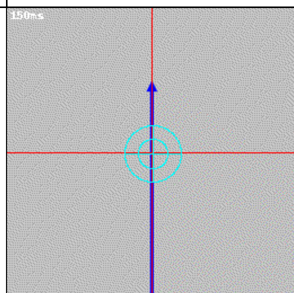
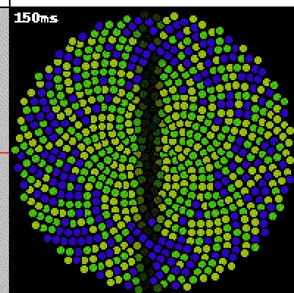
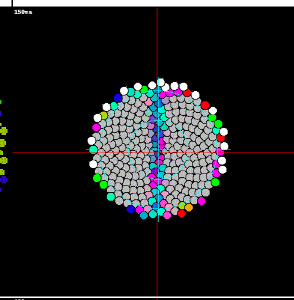
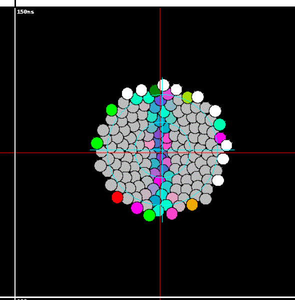
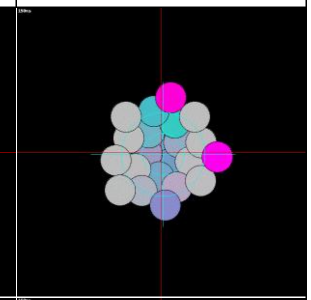
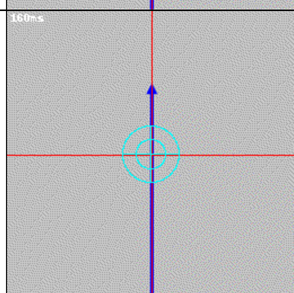
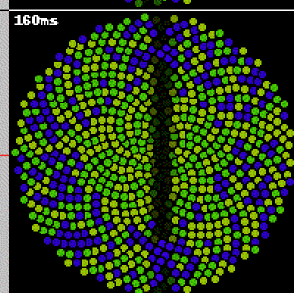
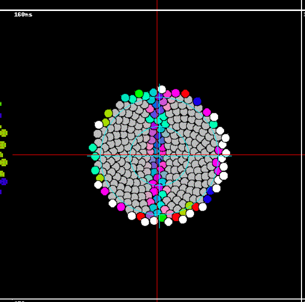
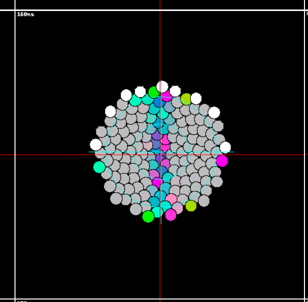
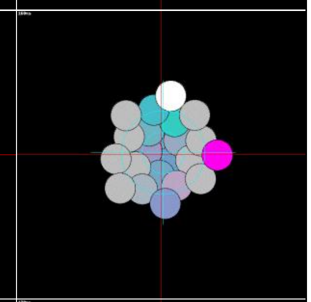
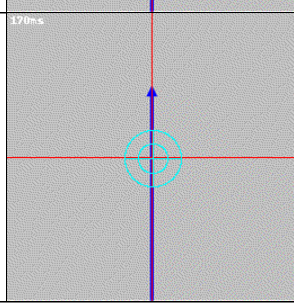
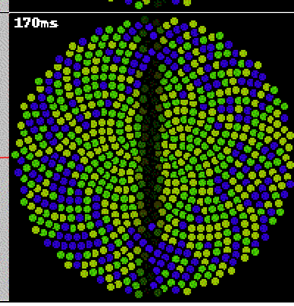
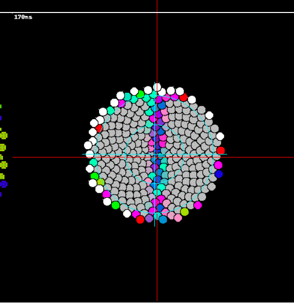
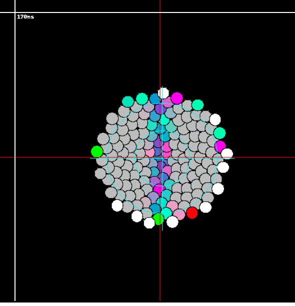
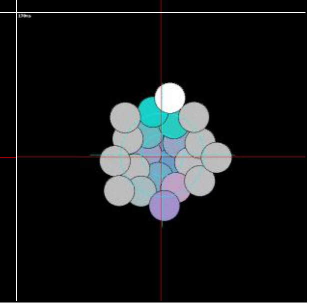
Table 33: Time sequence of filling-in arrow stimulus over foveal blue scotoma					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
15					
16					
17					

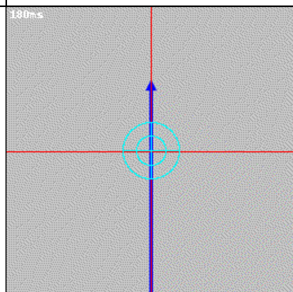
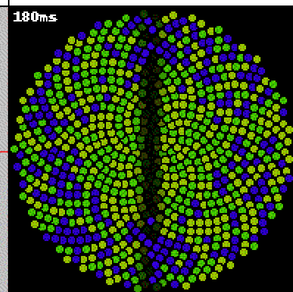
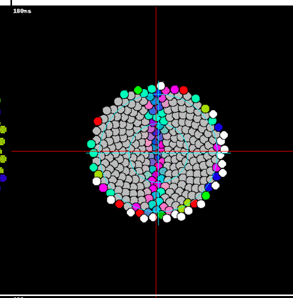
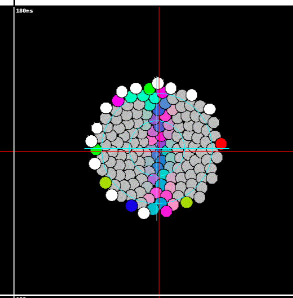
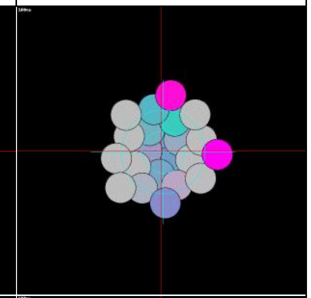
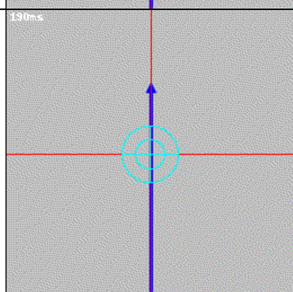
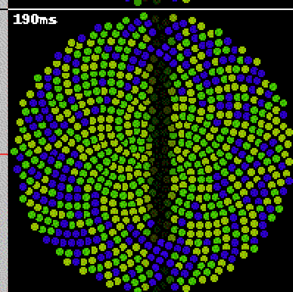
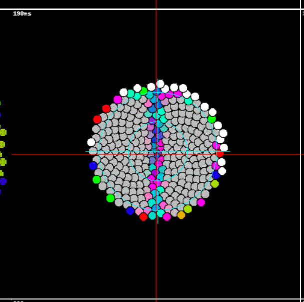
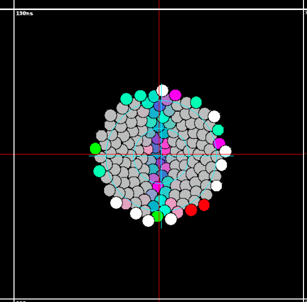
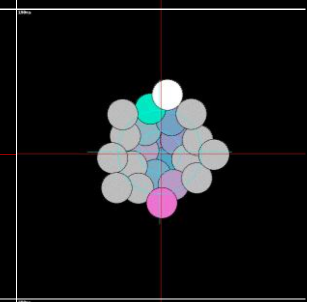
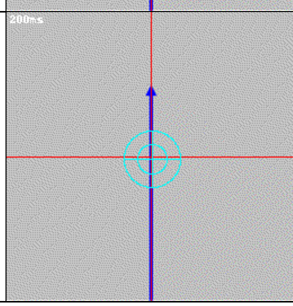
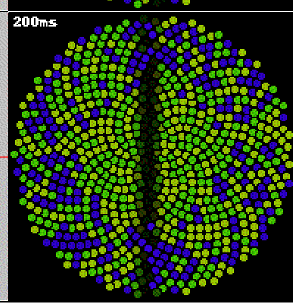
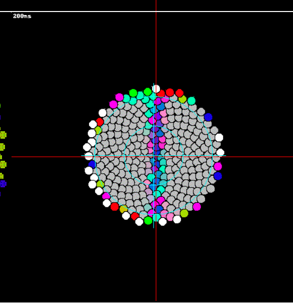
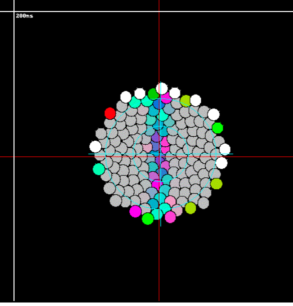
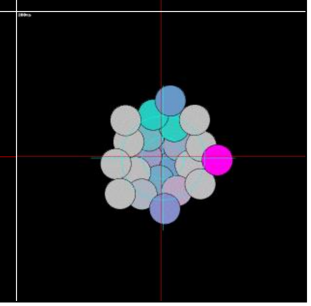
Table 33: Time sequence of filling-in arrow stimulus over foveal blue scotoma					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
18					
19					
20					

Table 33: Time sequence of filling-in arrow stimulus over foveal blue scotoma

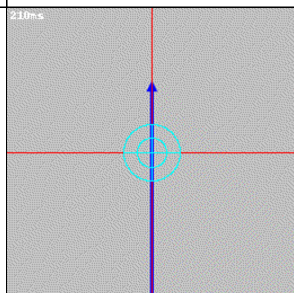
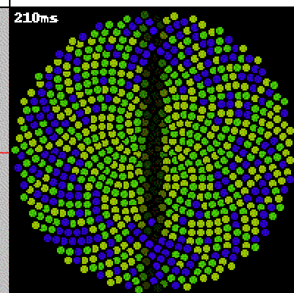
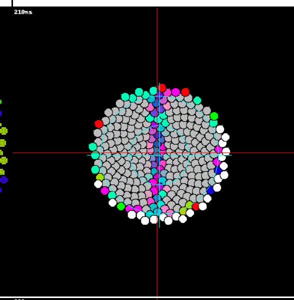
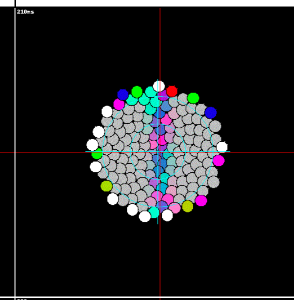
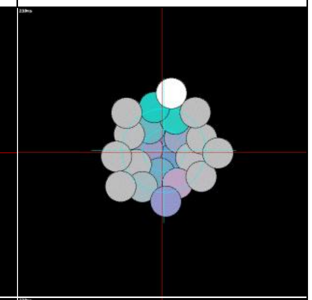
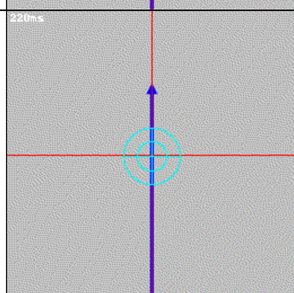
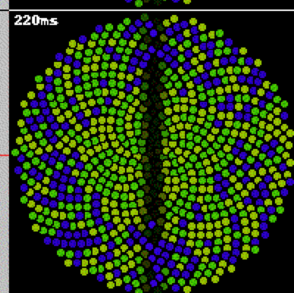
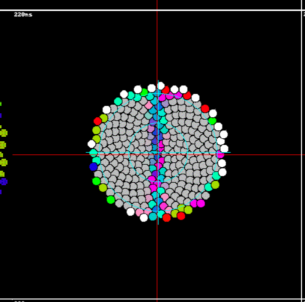
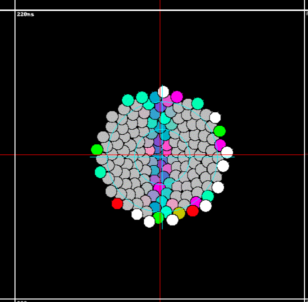
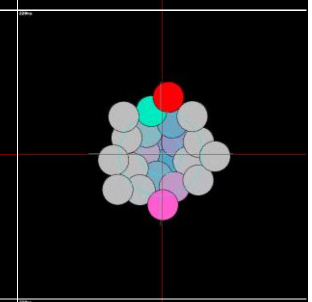
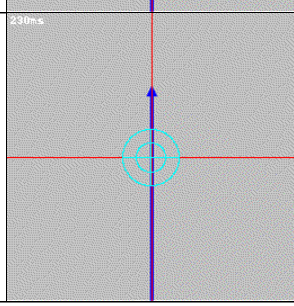
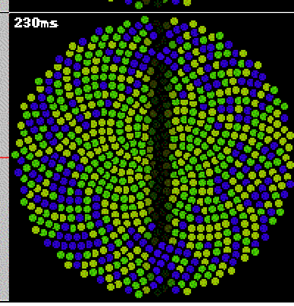
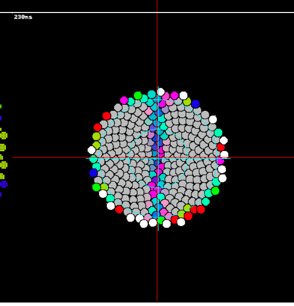
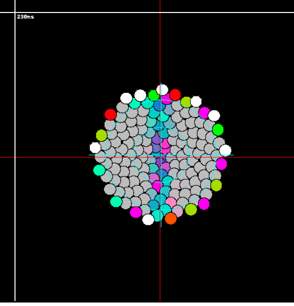
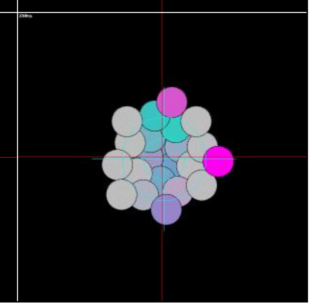
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
21					
22					
23					

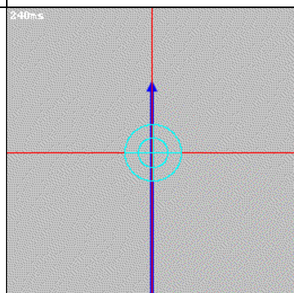
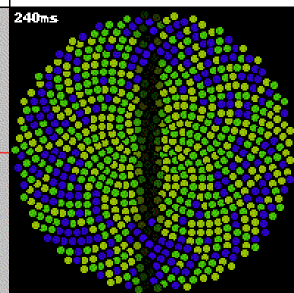
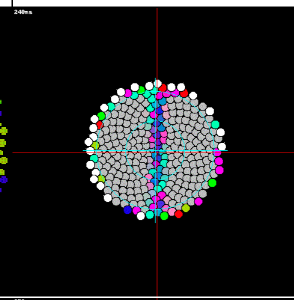
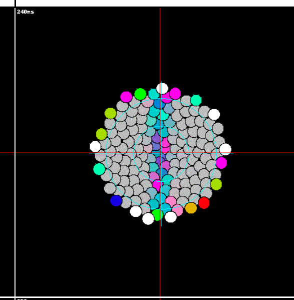
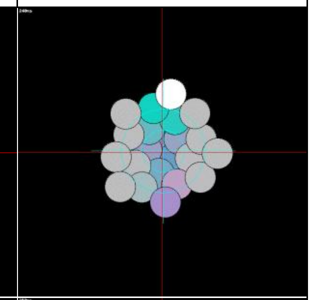
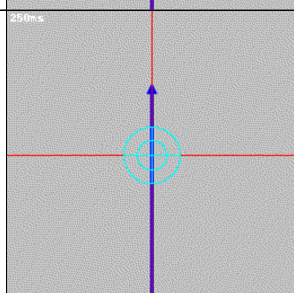
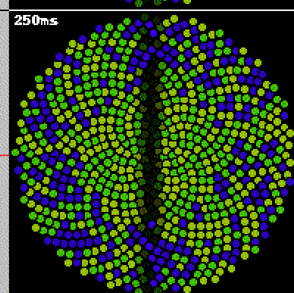
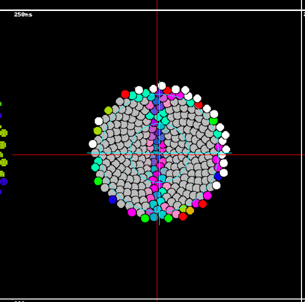
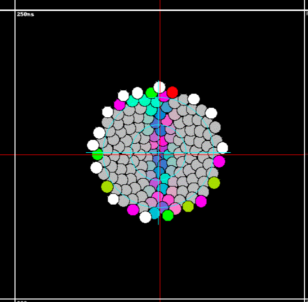
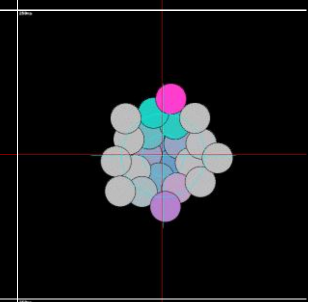
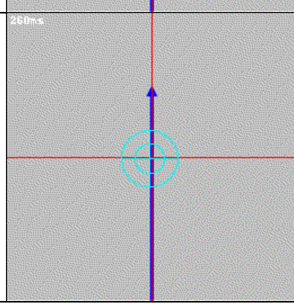
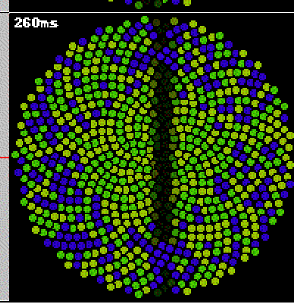
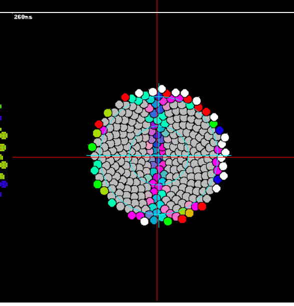
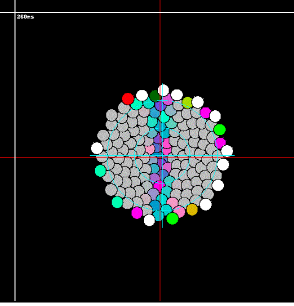
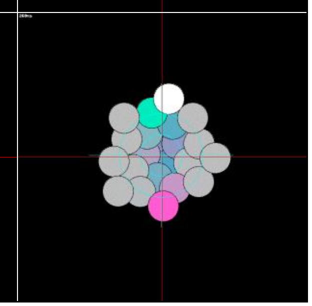
Table 33: Time sequence of filling-in arrow stimulus over foveal blue scotoma					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
24					
25					
26					

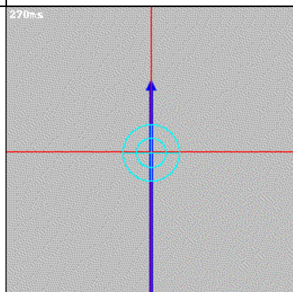
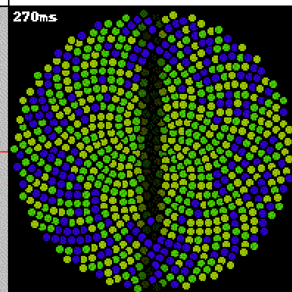
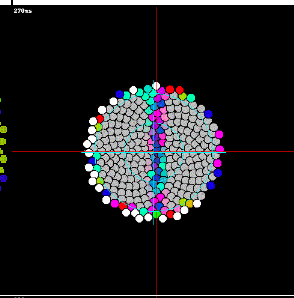
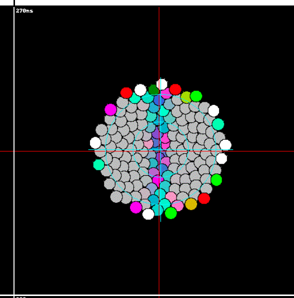
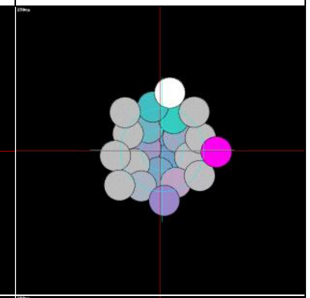
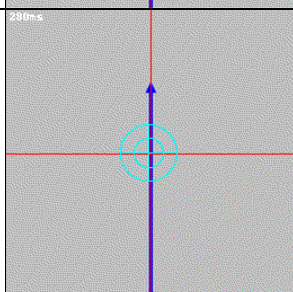
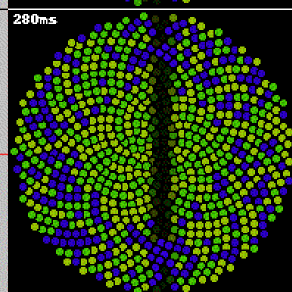
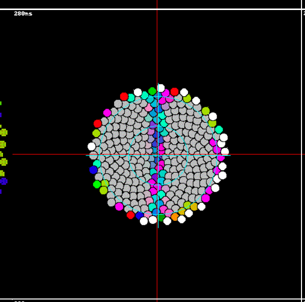
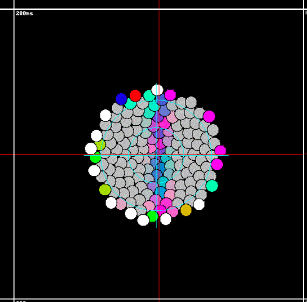
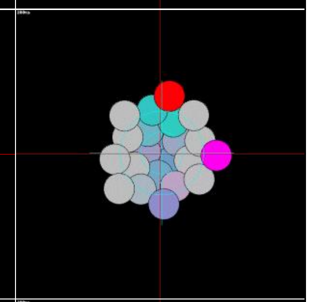
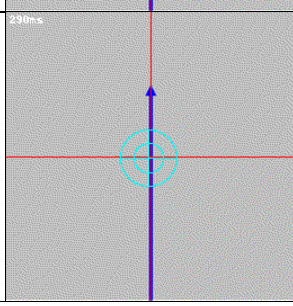
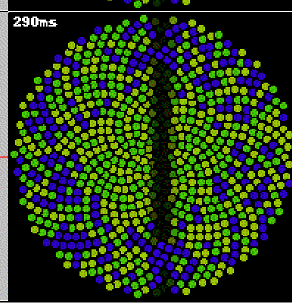
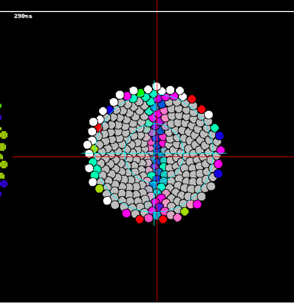
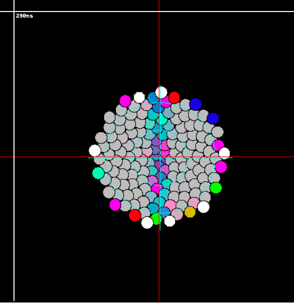
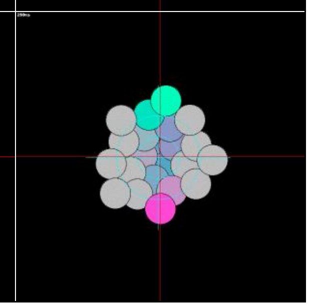
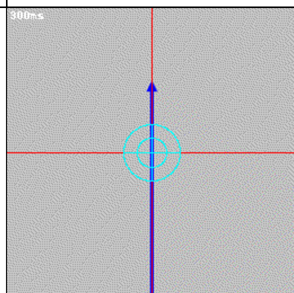
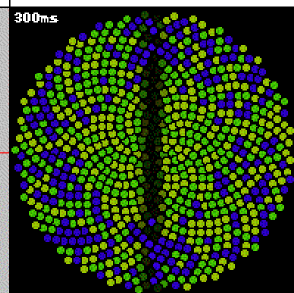
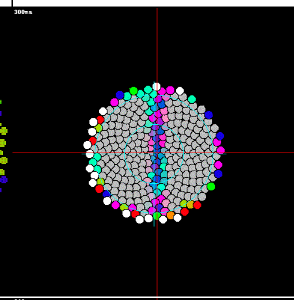
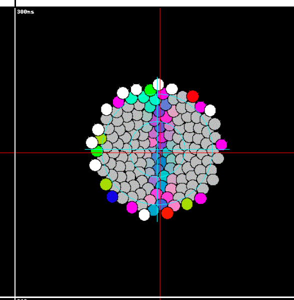
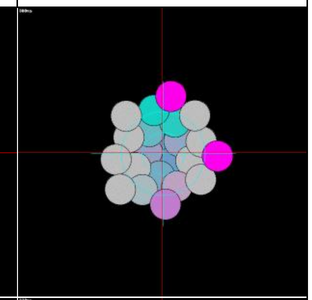
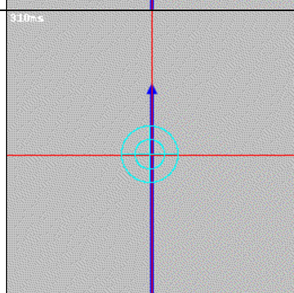
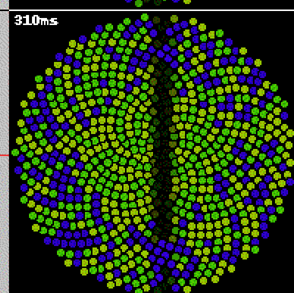
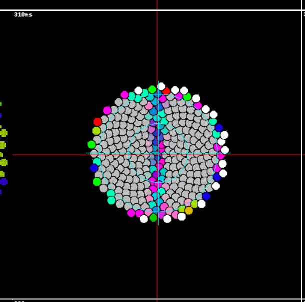
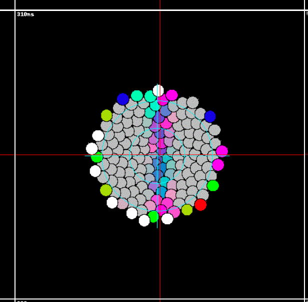
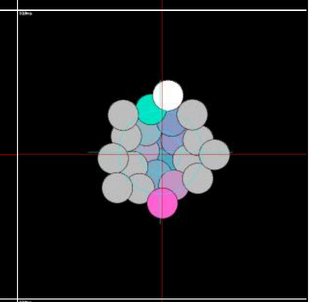
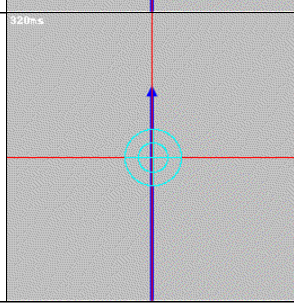
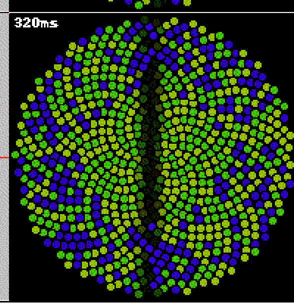
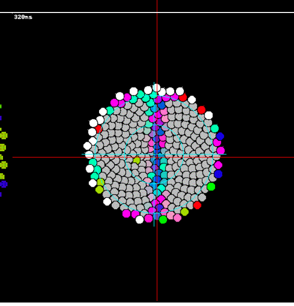
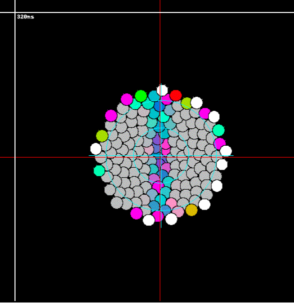
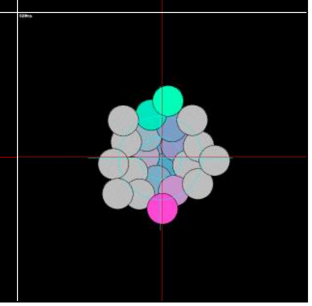
Table 33: Time sequence of filling-in arrow stimulus over foveal blue scotoma					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
27					
28					
29					

Table 33: Time sequence of filling-in arrow stimulus over foveal blue scotoma					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
30					
31					
32					

B.3.6 Test 6 results: Point stimulus with saccade

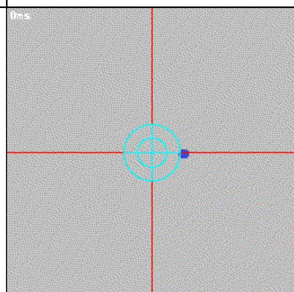
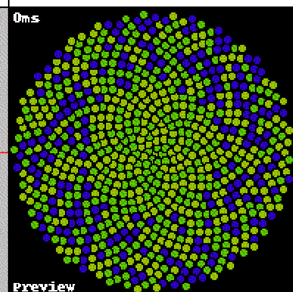
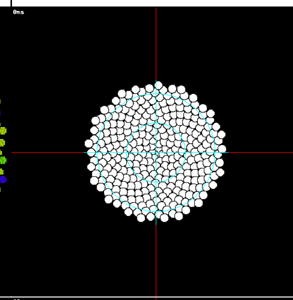
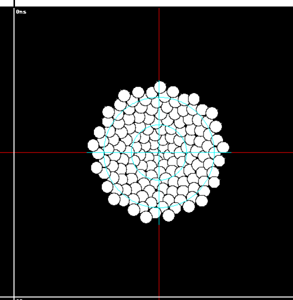
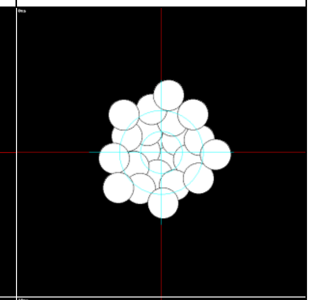
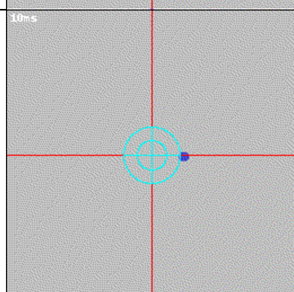
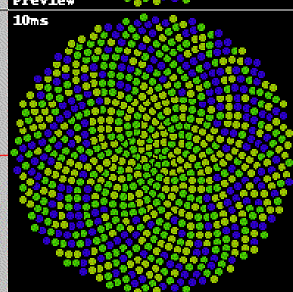
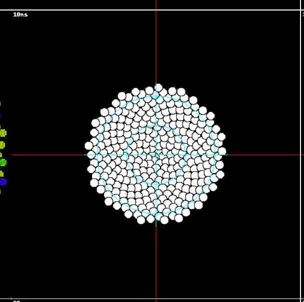
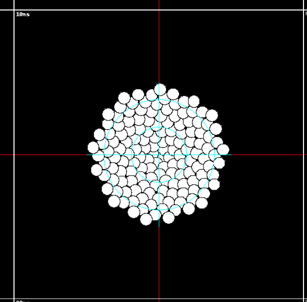
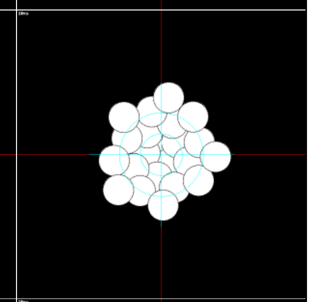
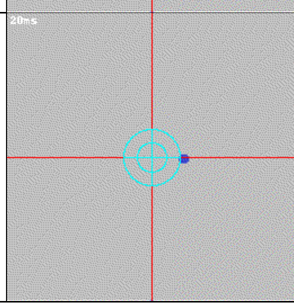
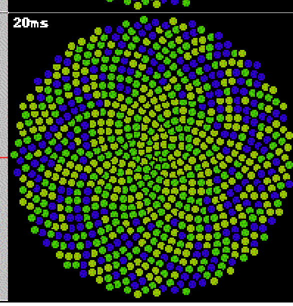
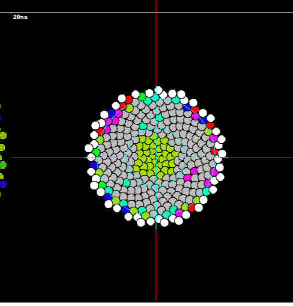
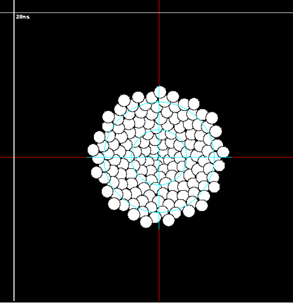
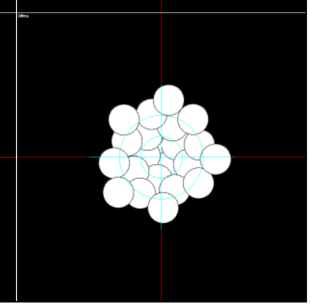
Table 34: Time sequence of filling-in point stimulus with saccade over foveal blue scotoma					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
0					
1					
2					

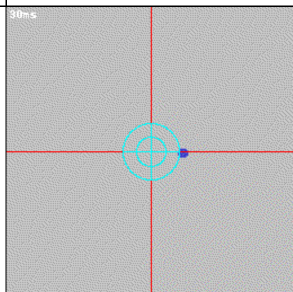
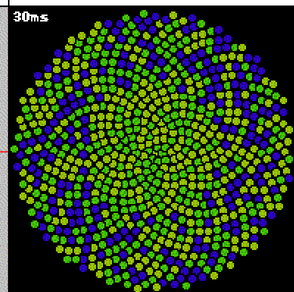
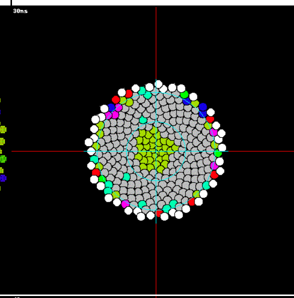
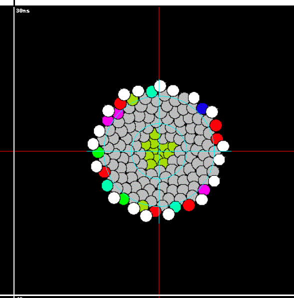
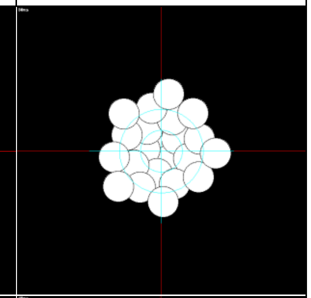
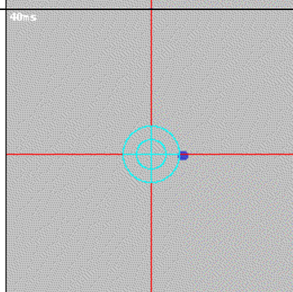
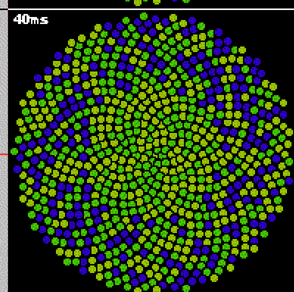
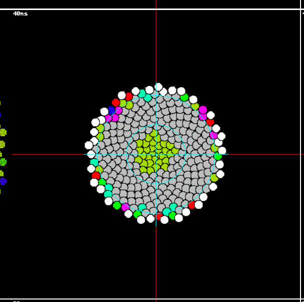
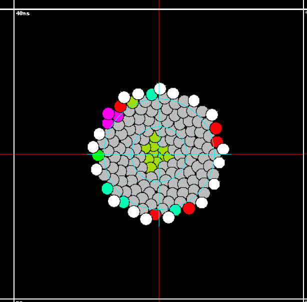
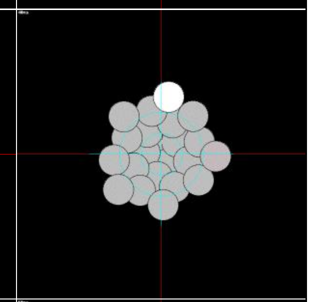
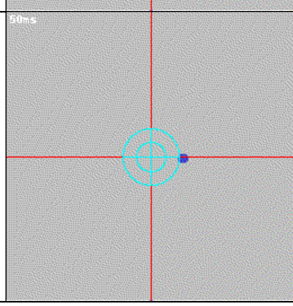
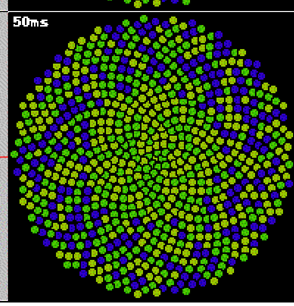
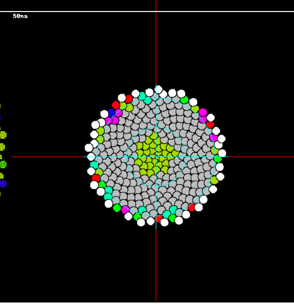
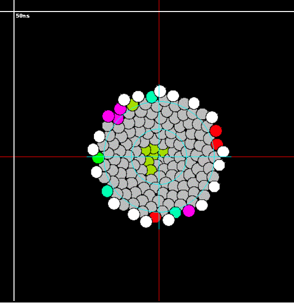
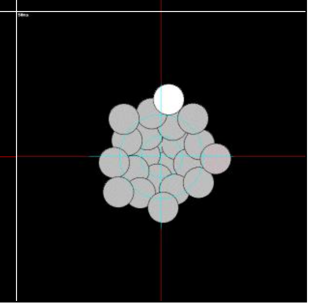
Table 34: Time sequence of filling-in point stimulus with saccade over foveal blue scotoma					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
3					
4					
5					

Table 34: Time sequence of filling-in point stimulus with saccade over foveal blue scotoma

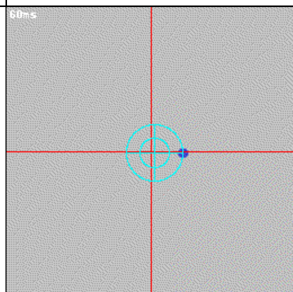
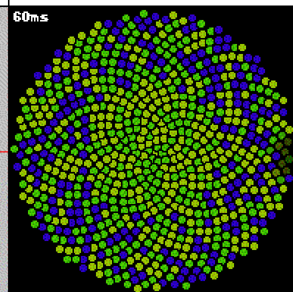
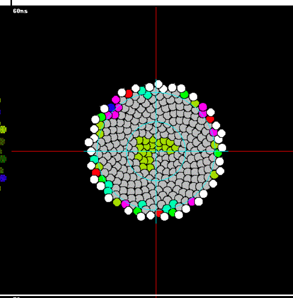
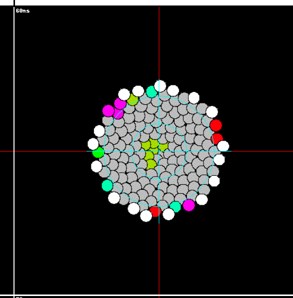
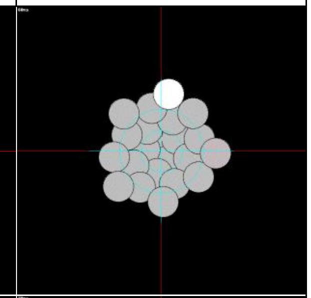
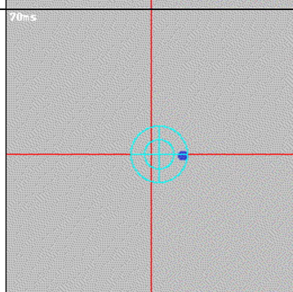
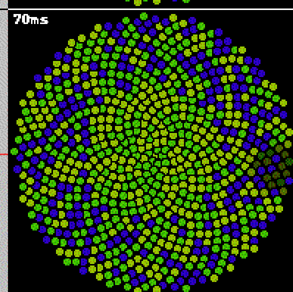
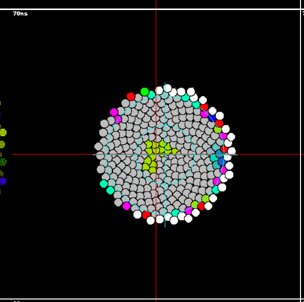
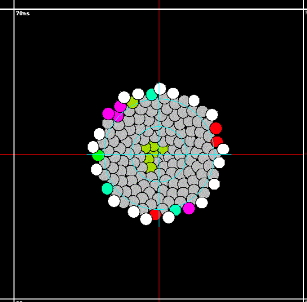
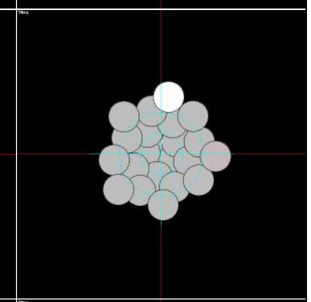
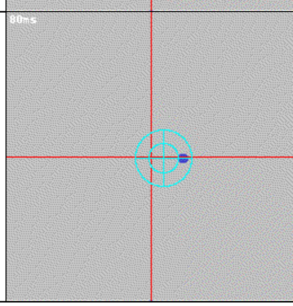
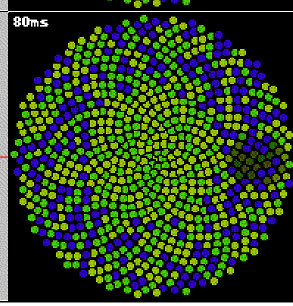
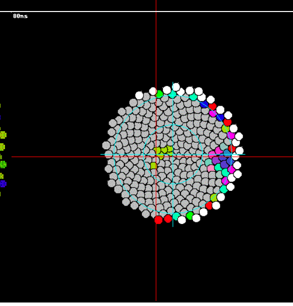
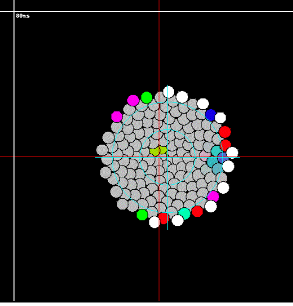
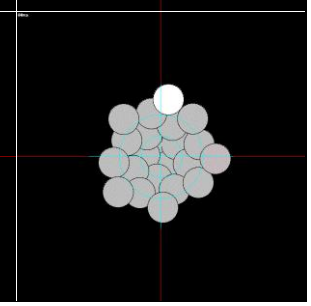
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
6					
7					
8					

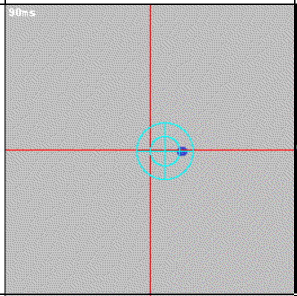
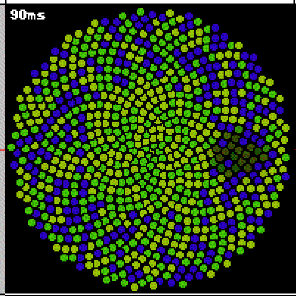
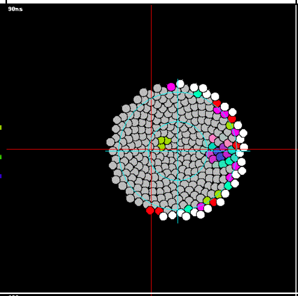
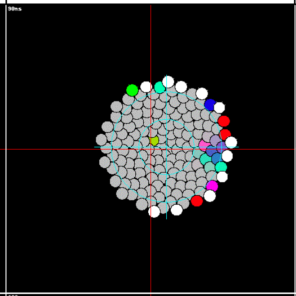
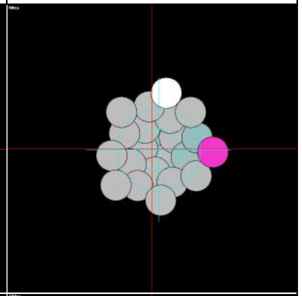
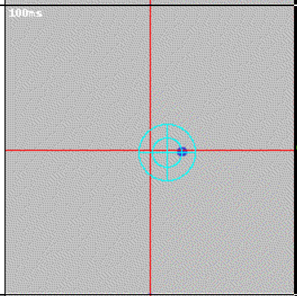
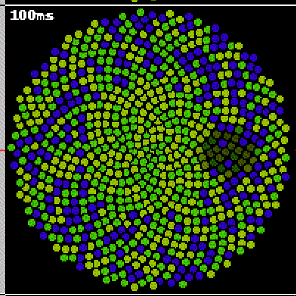
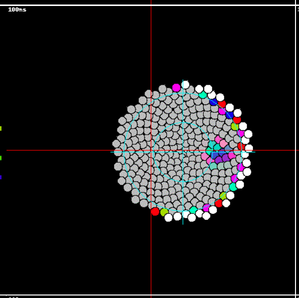
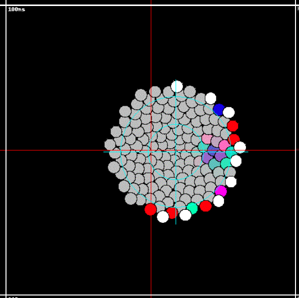
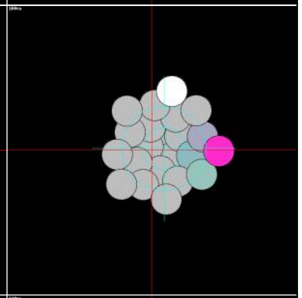
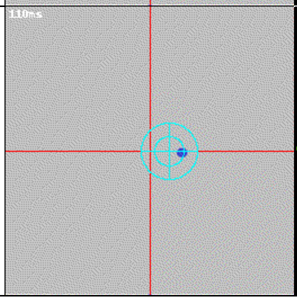
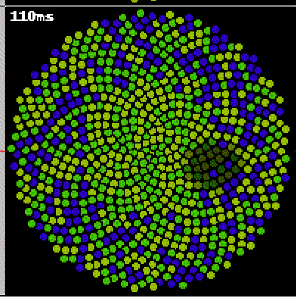
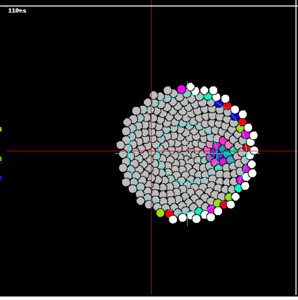
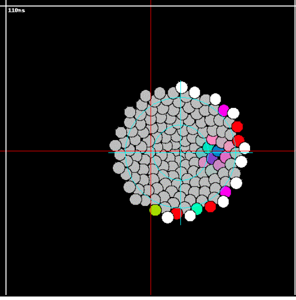
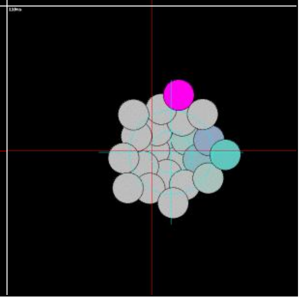
Table 34: Time sequence of filling-in point stimulus with saccade over foveal blue scotoma					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
9					
10					
11					

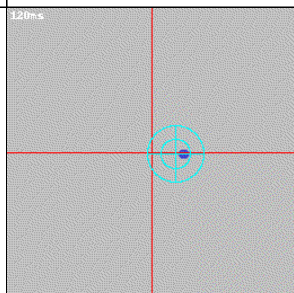
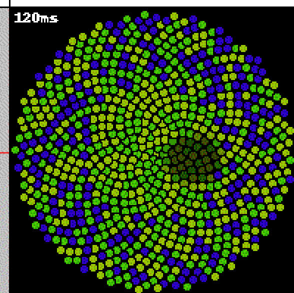
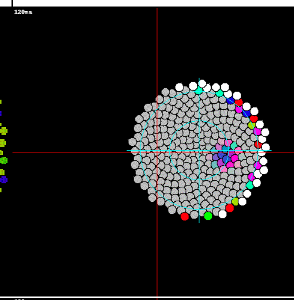
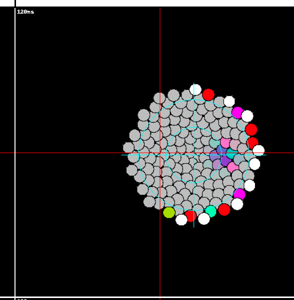
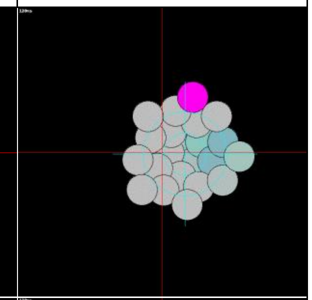
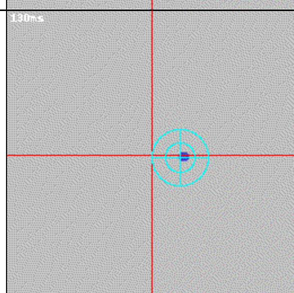
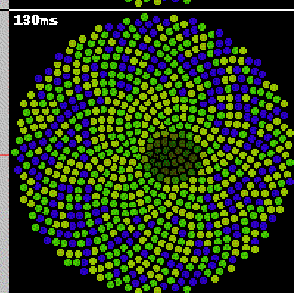
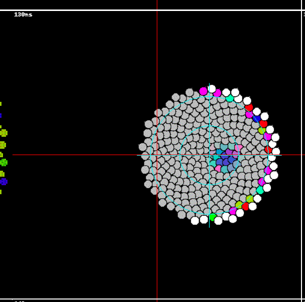
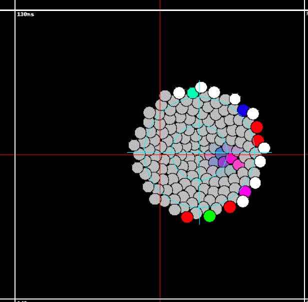
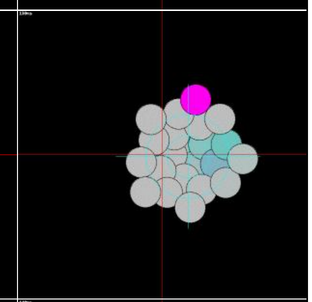
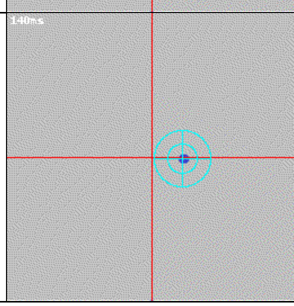
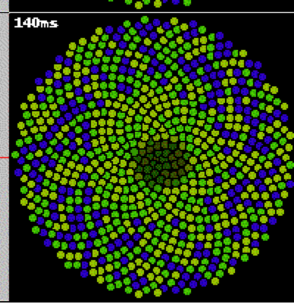
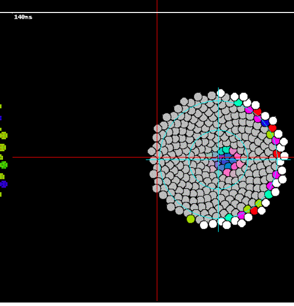
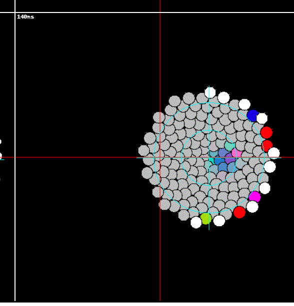
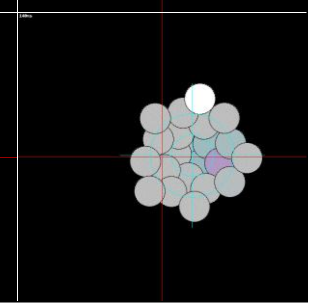
Table 34: Time sequence of filling-in point stimulus with saccade over foveal blue scotoma					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
12					
13					
14					

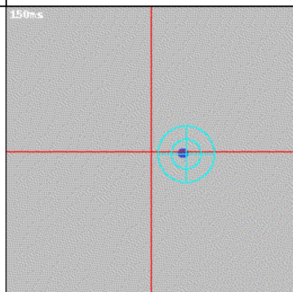
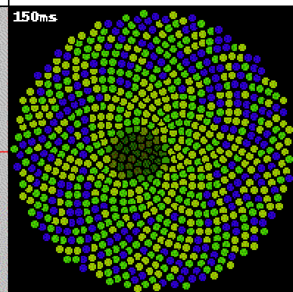
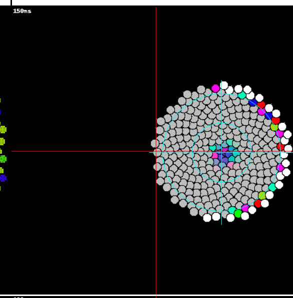
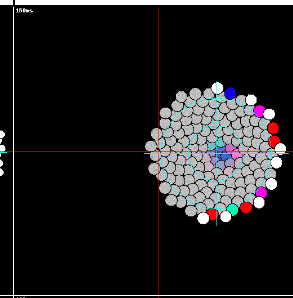
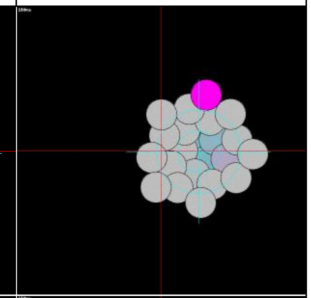
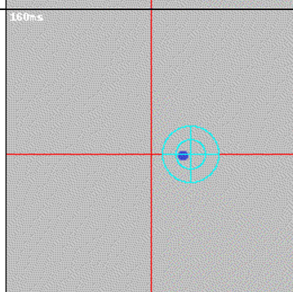
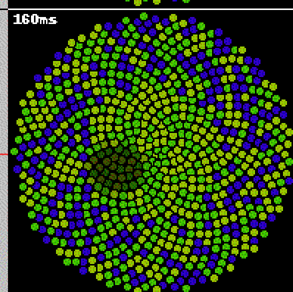
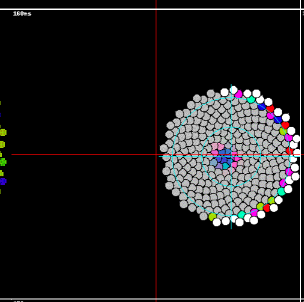
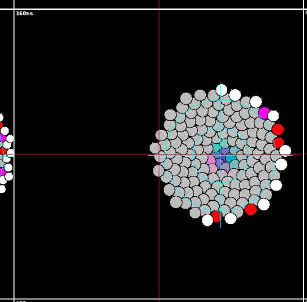
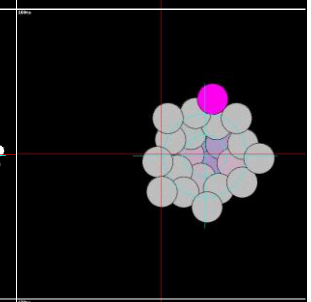
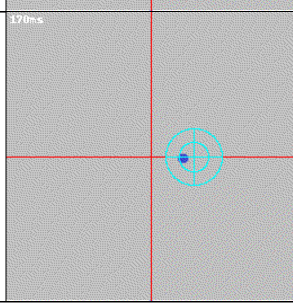
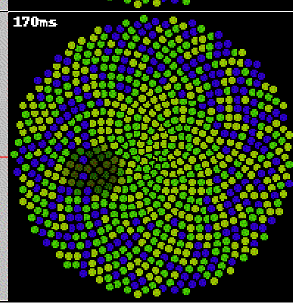
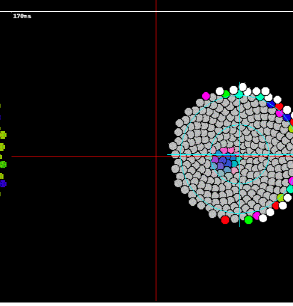
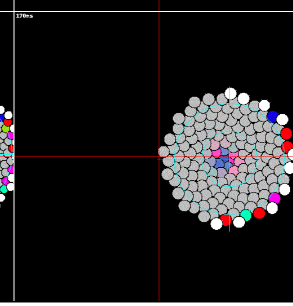
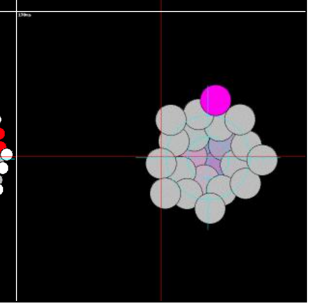
Table 34: Time sequence of filling-in point stimulus with saccade over foveal blue scotoma					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
15					
16					
17					

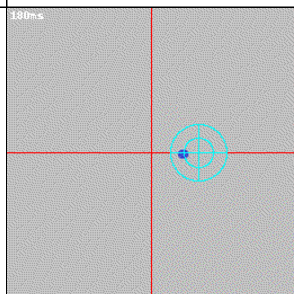
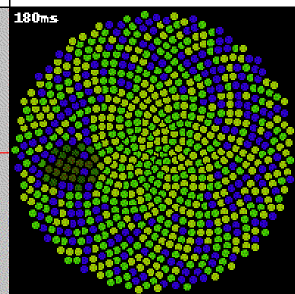
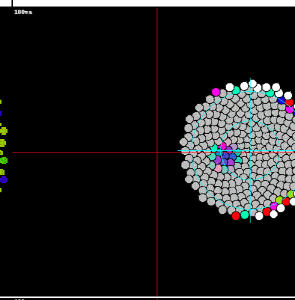
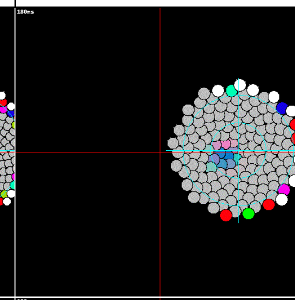
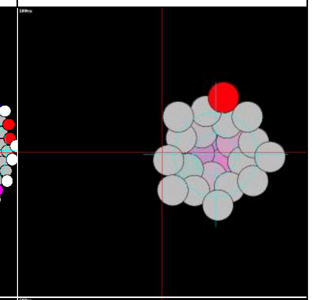
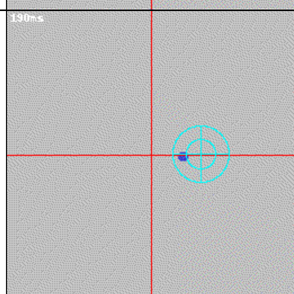
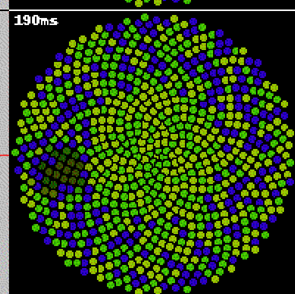
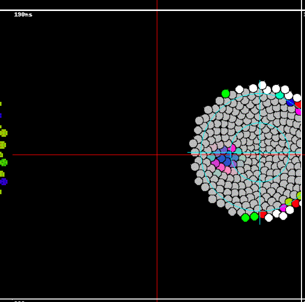
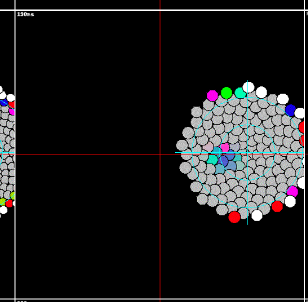
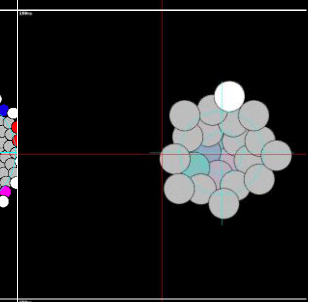
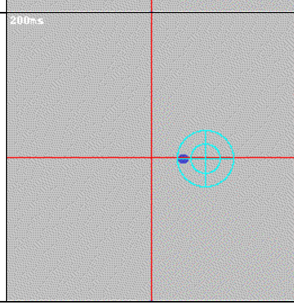
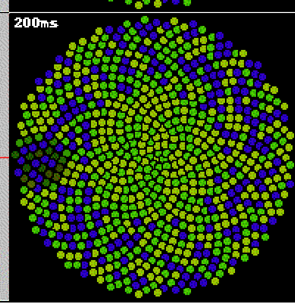
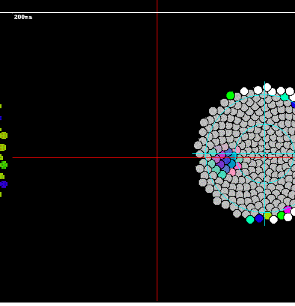
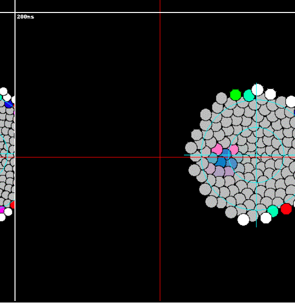
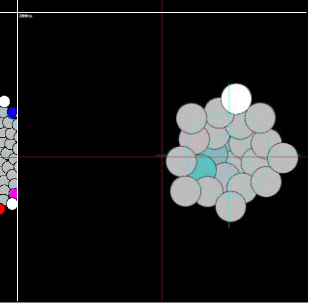
Table 34: Time sequence of filling-in point stimulus with saccade over foveal blue scotoma					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
18					
19					
20					

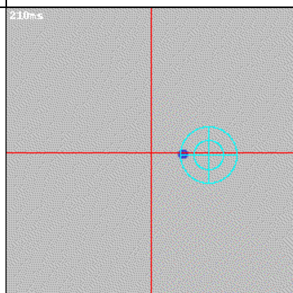
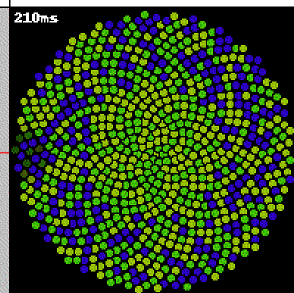
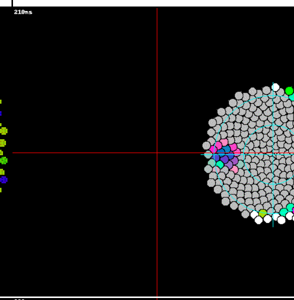
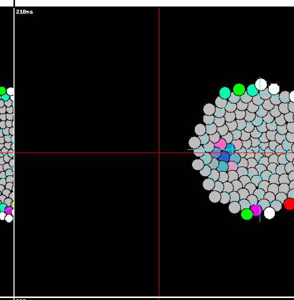
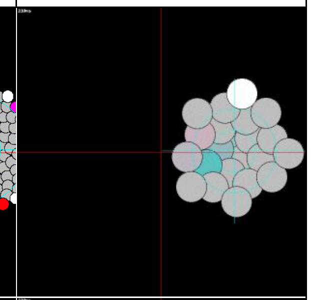
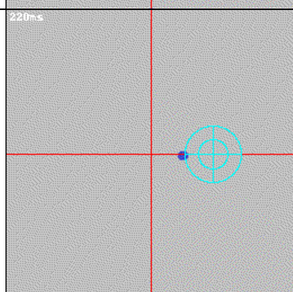
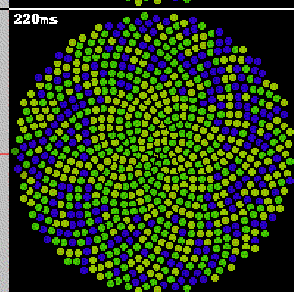
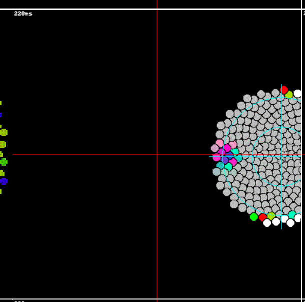
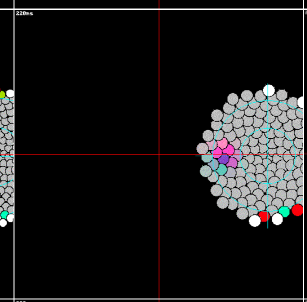
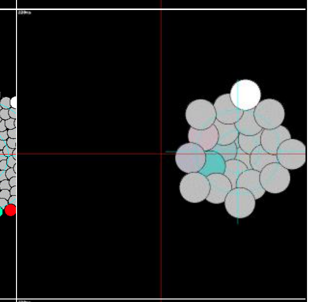
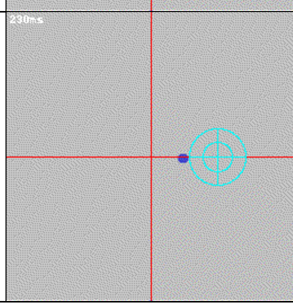
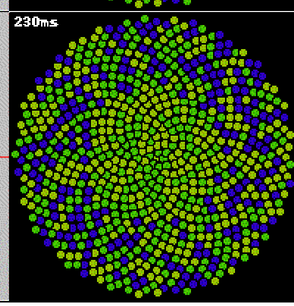
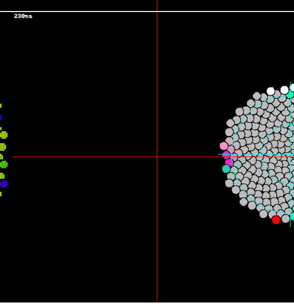
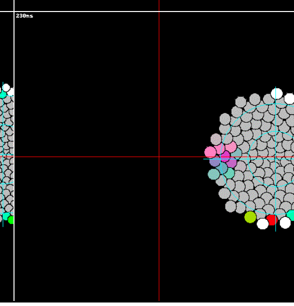
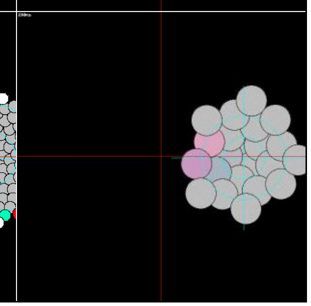
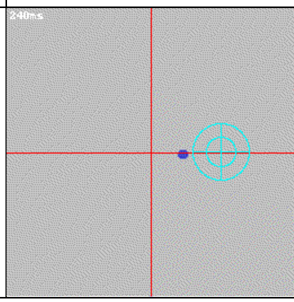
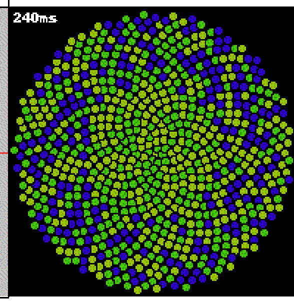
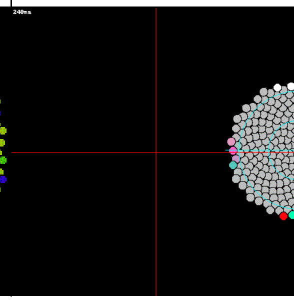
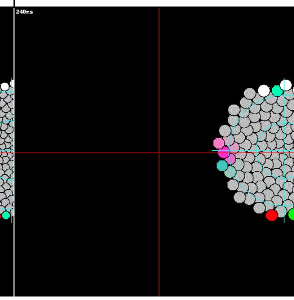
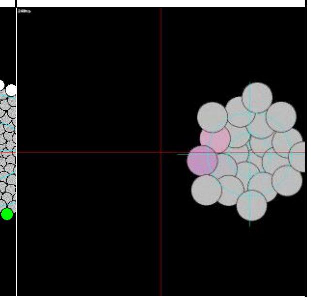
Table 34: Time sequence of filling-in point stimulus with saccade over foveal blue scotoma					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
21					
22					
23					

Table 34: Time sequence of filling-in point stimulus with saccade over foveal blue scotoma					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
24					

Appendix C: An emergic model of filling-in during blinks

These supplement the corresponding material in the thesis.

C.1 Subject details

Three virtual subjects were used in these four tests. Each is fully characterized by a set of developmental and behavioural parameters that will be indicated next. The meaning of these parameters can be found in the thesis. Note that development includes a stochastic component so that, for example, while the L:M:S cone ratio may be innately specified, the colour sensitivity type of individual cones is random. The behavioural parameters, such as eye blink rate are also mentioned in the test procedure.

Originally, eye blink suppression was simulated by detaching a *person* from the *world* being *viewed*, then re-attaching them. This would have been a procedure change. However, we recently place eyed blink configuration parameters within *person*, so they are detailed and highlighted here as well.

C.1.1 Test 1 & 2 stimulus

Same as Test 1 on page 43, but with eye blink configured as highlighted below.

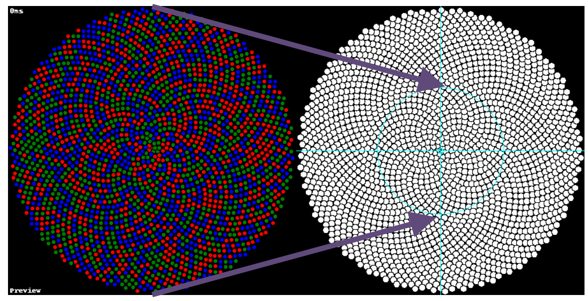


Illustration 36: Test 1 & 2 subject – their photoreceptor and RF1 mosaics

```
[Person]
note = blink
srt = 10
sex = ai
age = 18
eyecount = 1
ipd = 0
vsize = 17.0
vieweyez = 50
r0conepix = 4
nodalpt = 17
r0coned = 8.0
r0red = 1
r0green = 1
r1coned = 1.0
r1red = 800
r1green = 800
r1blue = 800
blindx = 0.0
blindy = 0.0
blindr = 0.0
blink0d = 5
blink1d = 3
jitmin = 0.1
jitave = 0.7
jitmax = 0.9
p1_0_pixd = 2.5
p1_0_pix = 2000
p1_0_scale = 2
p1_0_fanlat = 5.0
p1_0_fandwn = 2.0
p1_1_pixd = 3.0
p1_1_pix = 1390
p1_1_scale = 2
p1_1_fanlat = 2.0
p1_1_fandwn = 2.0
p1_2_pixd = 4.0
p1_2_pix = 782
p1_2_scale = 2
p1_2_fanlat = 1.2
p1_2_fandwn = 1.5
```

C.1.2 Test 3 stimulus

Same as Test 3 in on page 44, but with eye blink configured as highlighted below.

```
[Person]
note = blink
srt = 10
sex = ai
age = 18
eyecount = 1
ipd = 0
vsize = 17.0
vieweyez = 75
r0conepix = 4
nodalpt = 17
r0coned = 8.0
r0red = 1
r0green = 1
r1coned = 1.0
r1red = 800
r1green = 800
r1blue = 800
blindx = 0.0
blindy = 0.0
blindr = 0.0
blink0d = 5
blink1d = 3
jitmin = 0.1
jitave = 0.7
jitmax = 0.9
p1_0_pixd = 2.5
p1_0_pix = 2000
p1_0_scale = 2
p1_0_fanlat = 5.0
p1_0_fandwn = 2.0
p1_1_pixd = 3.0
p1_1_pix = 1390
p1_1_scale = 2
p1_1_fanlat = 2.0
p1_1_fandwn = 2.0
p1_2_pixd = 4.0
p1_2_pix = 782
p1_2_scale = 2
p1_2_fanlat = 1.2
p1_2_fandwn = 1.5
```

C.1.3 Test 4 stimulus

Same as Tests 1-4 on page 115, but with eye blink configured as highlighted below. This *Person* had a large yet simple retina to focus analysis on memory effects related to filling-in. The cones were of the same size throughout and the L:M:S ratio was 1:1:1. Eye blinks were extremely rapid and extended, i.e., they were closed for 2 out of every 3 ticks.

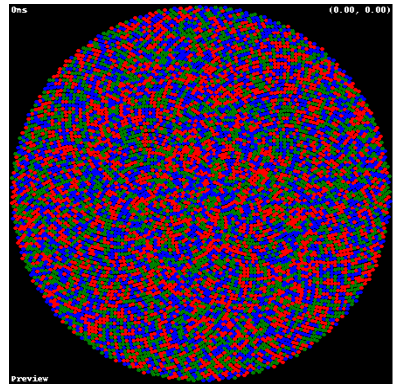


Illustration 37: Test 4 subject – their photoreceptor mosaic

```
[Person]
note = blink
srt = 10
sex = ai
age = 18
eyecount = 1
ipd = 0
vsize = 17.0
vieweyez = 100
r0conepix = 4
nodalpt = 17
r0coned = 4.0
r0red = 1
r0green = 1
r1coned = 1.0
r1red = 3000
r1green = 3000
r1blue = 3000
blindx = 0.0
blindy = 0.0
blindr = 0.0
blink0d = 1
blink1d = 2
jitmin = 0.1
jitave = 0.7
jitmax = 0.9
p1_0_pixd = 2.5
p1_0_pix = 1800
p1_0_scale = 2
p1_0_fanlat = 5.0
p1_0_fandwn = 2.0
p1_1_pixd = 5.0
p1_1_pix = 500
p1_1_scale = 2
p1_1_fanlat = 2.0
p1_1_fandwn = 2.0
p1_2_pixd = 7.5
p1_2_pix = 250
p1_2_scale = 2
p1_2_fanlat = 1.2
p1_2_fandwn = 1.5
```

C.2 Stimuli details

The first three tests characterized temporal filling-in across eye blinks generically. Test 1 used a simple coloured surface stimulus – the block letters spelling LOVE; Test 2 used a natural image stimulus – a picture of Lena; and Test 3 used a dynamic image stimulus with surface gradients – a lilac chaser. Test 4 used a simple square stimulus to test filling-in across rapid and extensive eye-blinks.

C.2.1 Test 1 stimulus: Simple surfaces (Love)

Same as Test 1 on page 46 as in Illustration 38.

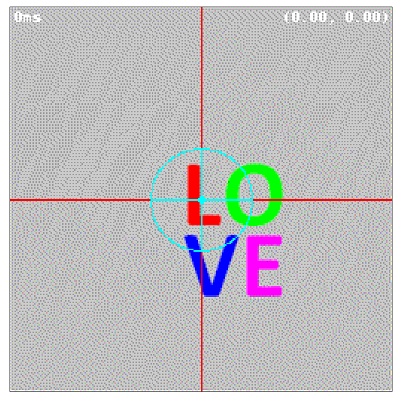


Illustration 38: Test 1 stimulus with view overlays

C.2.2 Test 2 stimulus: Natural image (Lena)

Same as Test 2 on page 47 as in Illustration 39.

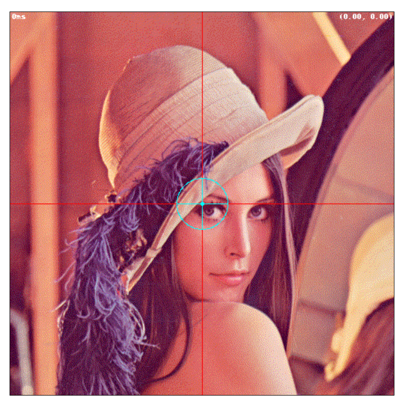


Illustration 39: Test 2 stimulus with view overlays

C.2.3 Test 3 stimulus: Dynamic image with surface gradients (Chaser)

Same as Test 3 on page 48 as in Illustration 40.

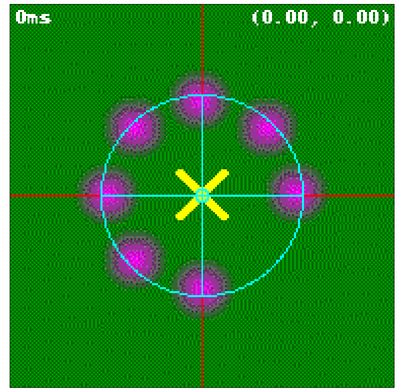


Illustration 40: Test 3 stimulus with view overlays

C.2.4 Test 4: Rapid and extended blinking (Square)

Same as Test 4 on page 117 as in Illustration 41.

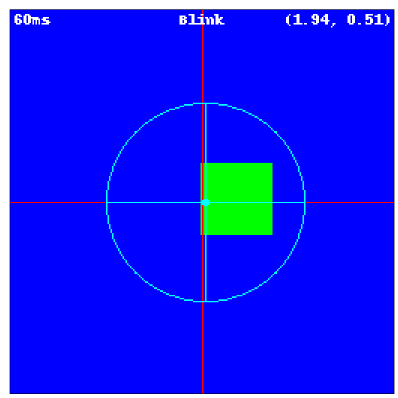


Illustration 41: Test 4 stimulus with view overlays

C.3 Result details

In this section we tabulate a visual frame-by-frame account of results from all experiments. Such a frame-by-frame account allows for the extraction of precise timing information useful for quantitative analysis. It takes 44 pages. All these results are reduced to a single web page of animated images, available at

http://emergic.upwize.com/?page_id=308

The animated account (Leibovitz, 2012a) is preferred as an overview showing behavioural dynamics of filling-out thru blinks and makes image stability across blinks more salient. It also includes the results in greatest detail – they have been scaled down for print in this supplement, and even smaller in the chapter's *results and discussion* sections.

Each table of results has the following columns. **Time** numerically represents the time tick since the test has started, nominally 10ms/tick. All visual results in that table row are after the tick and computation have finished. **Stimuli** visually represents the stimuli presented to the virtual computer screen, often with retinal overlays. The **Photoreceptor Mosaic** visually represents what the retina senses by looking at the stimuli. **Receptive Fields** at **Level 1**, **Level 2** and **Level 3**, visually represent the three level hierarchy of receptive fields showing their the functional size and placement, not physical size nor placement

C.3.1 Test 1 results: Simple surfaces (Love)

Table 35: Time sequence of simple surfaces (Love) with blinks

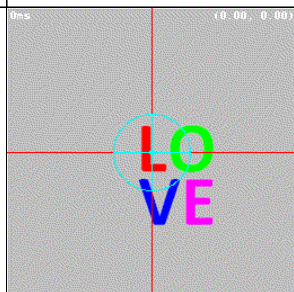
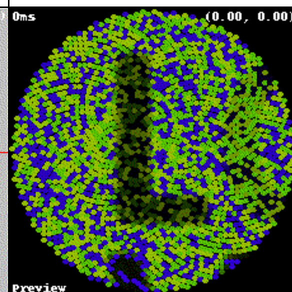
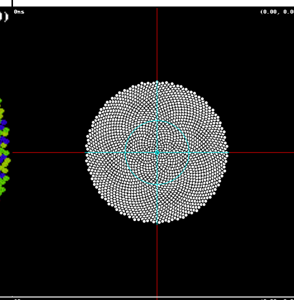
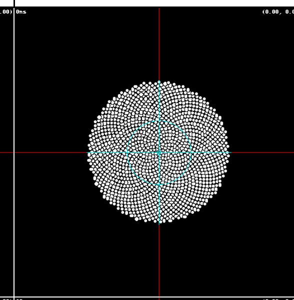
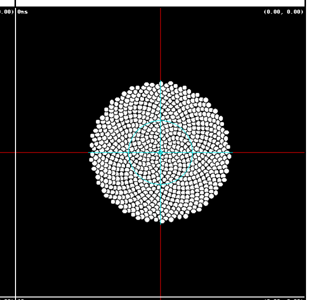
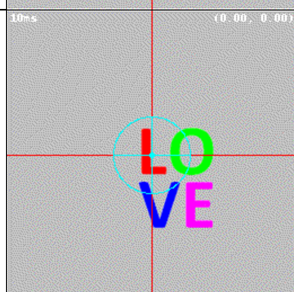
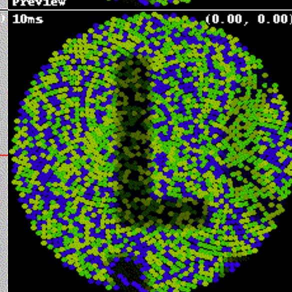
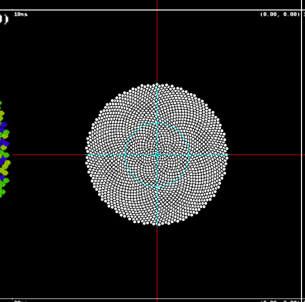
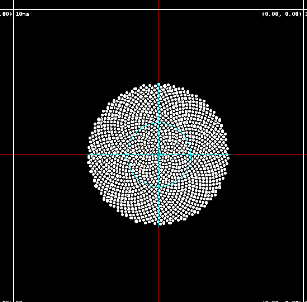
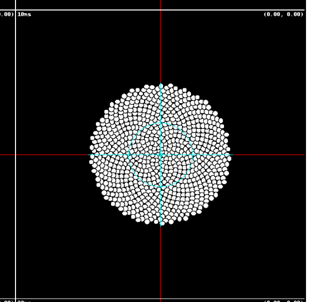
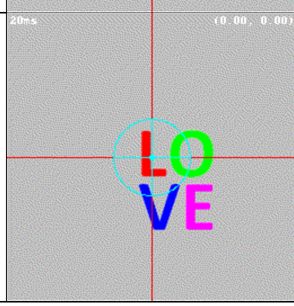
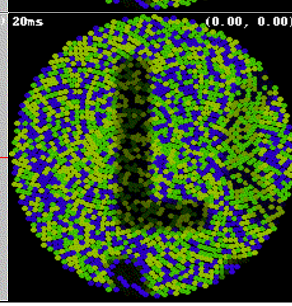
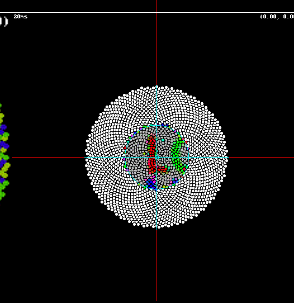
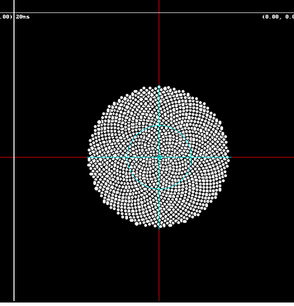
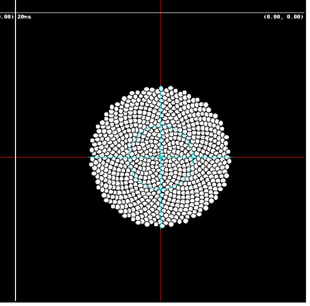
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
0					
1					
2					

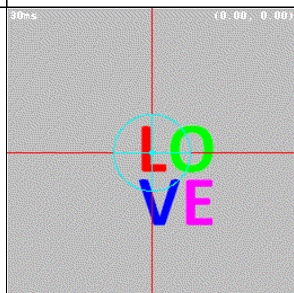
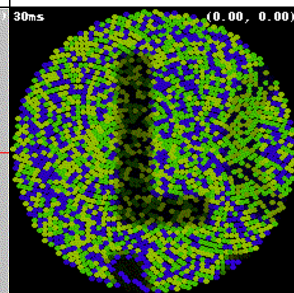
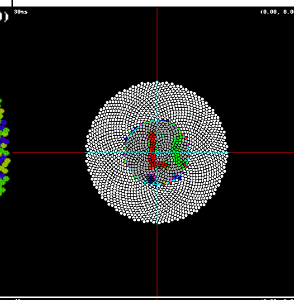
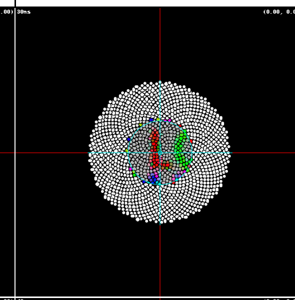
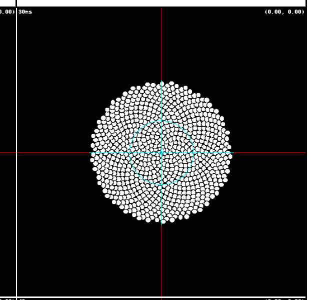
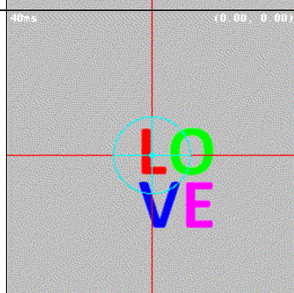
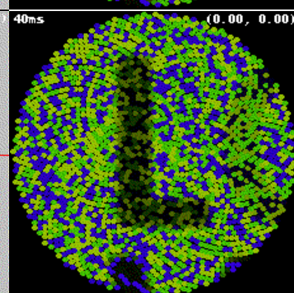
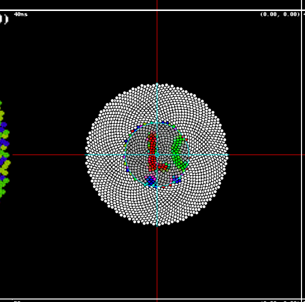
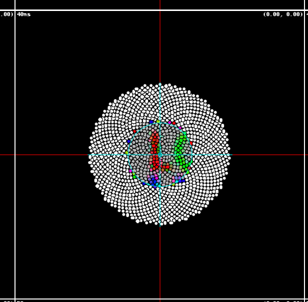
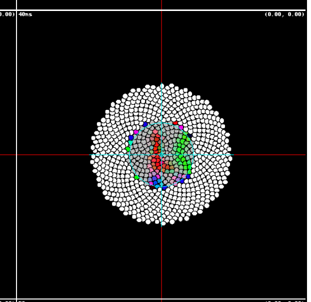
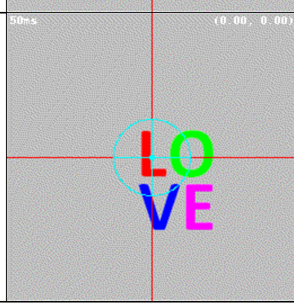
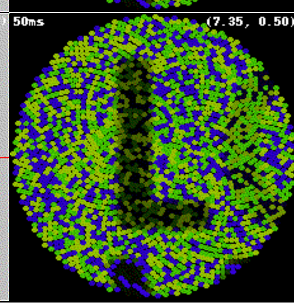
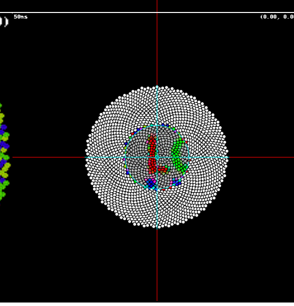
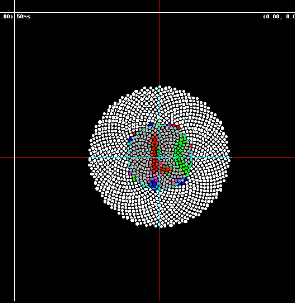
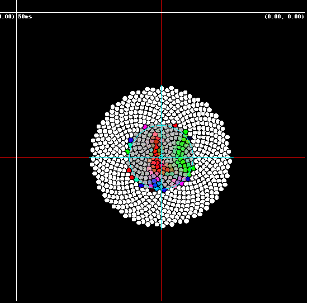
Table 35: Time sequence of simple surfaces (Love) with blinks					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
3					
4					
5					

Table 35: Time sequence of simple surfaces (Love) with blinks

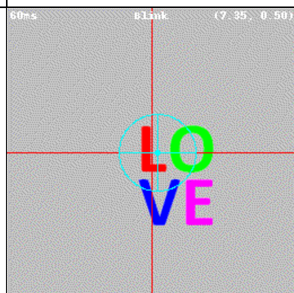
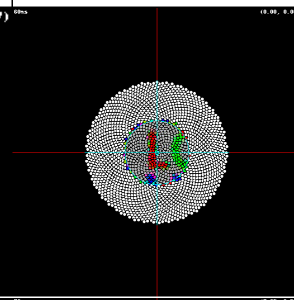
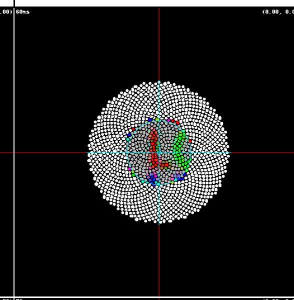
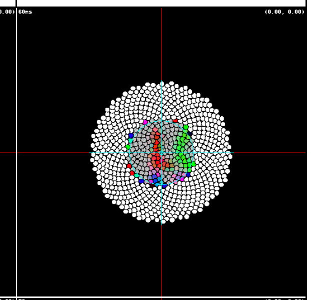
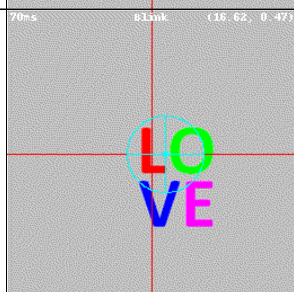
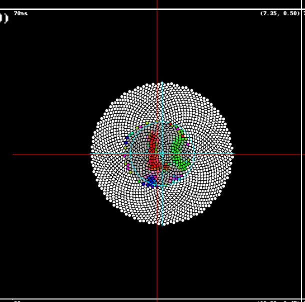
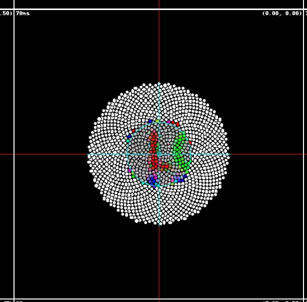
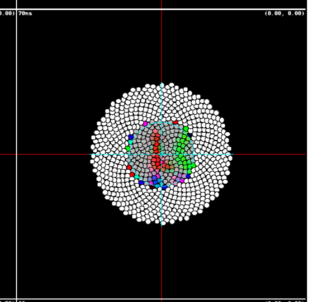
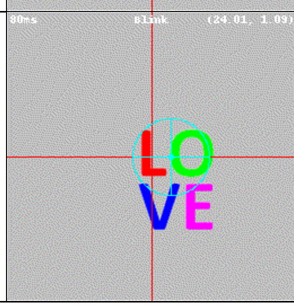
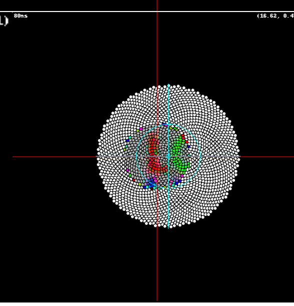
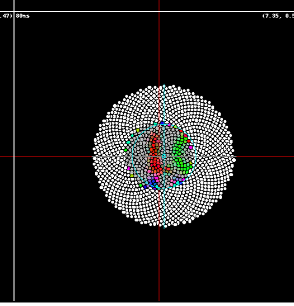
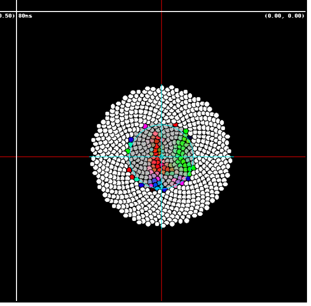
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields Level 1	Receptive Fields Level 2	Receptive Fields Level 3
6					
7					
8					

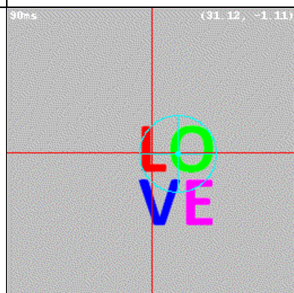
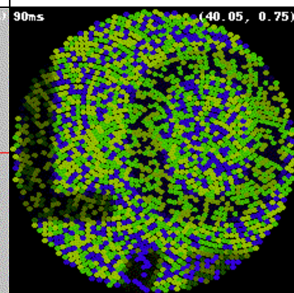
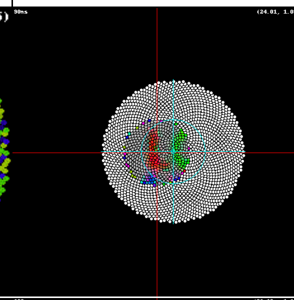
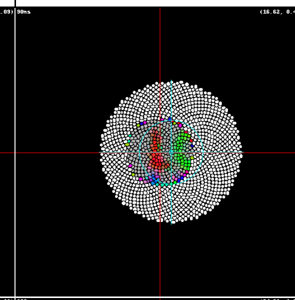
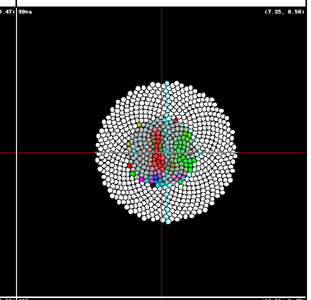
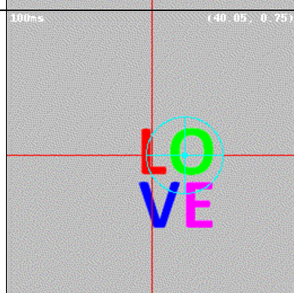
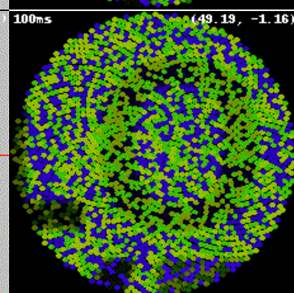
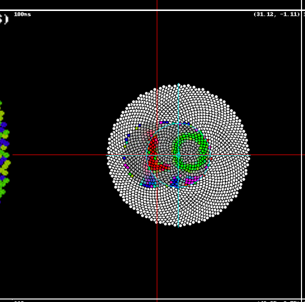
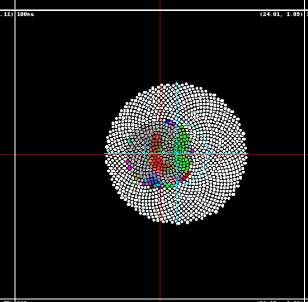
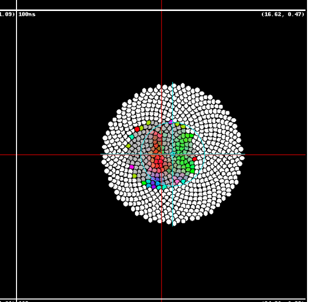
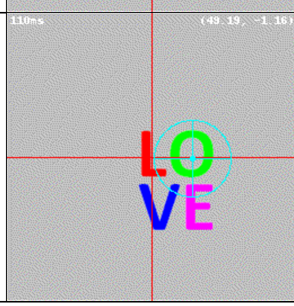
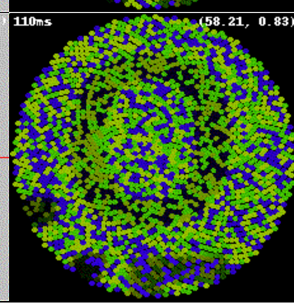
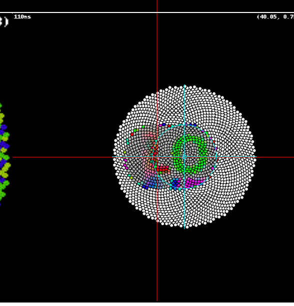
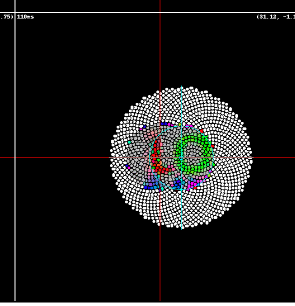
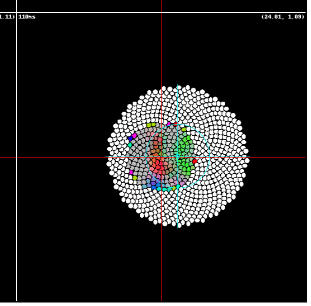
Table 35: Time sequence of simple surfaces (Love) with blinks					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
9					
10					
11					

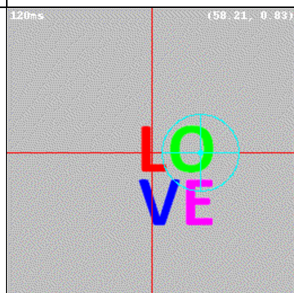
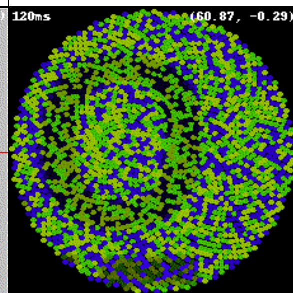
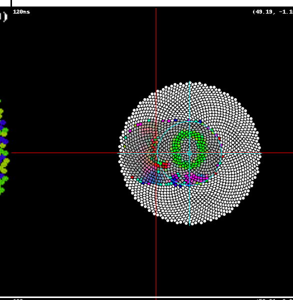
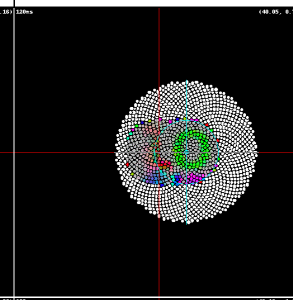
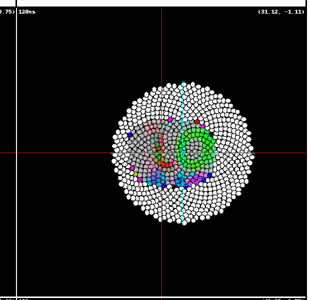
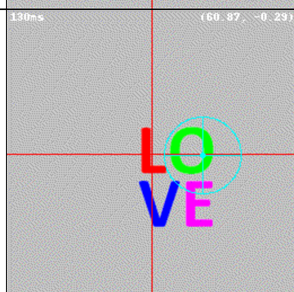
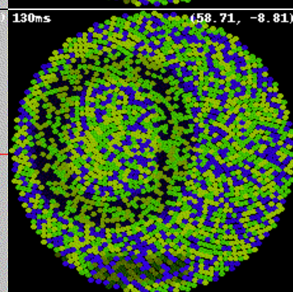
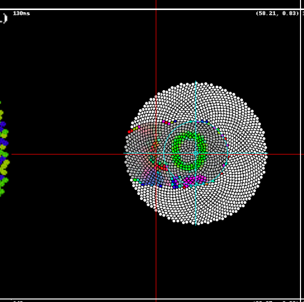
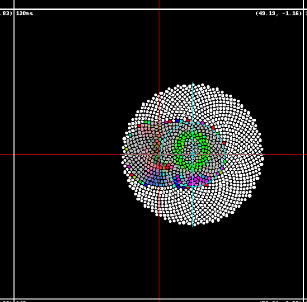
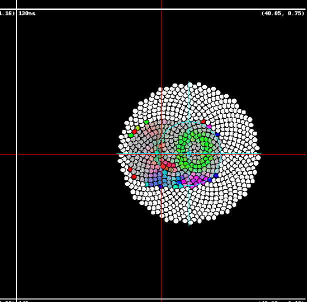
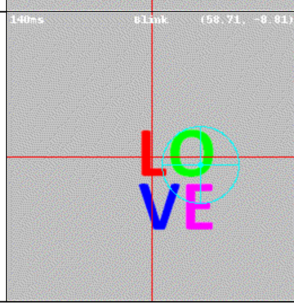
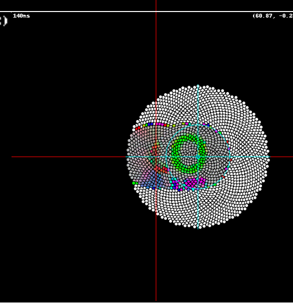
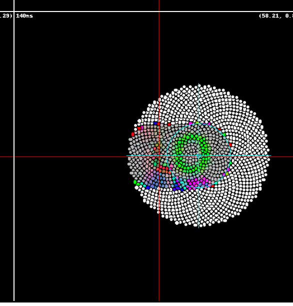
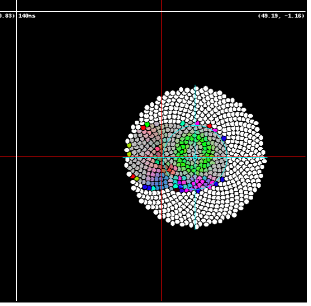
Table 35: Time sequence of simple surfaces (Love) with blinks					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
12					
13					
14					

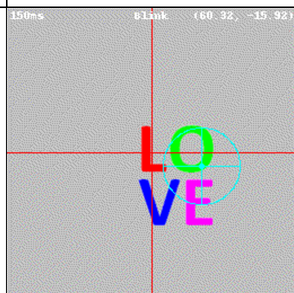
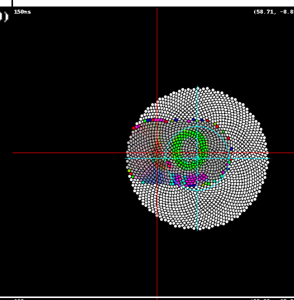
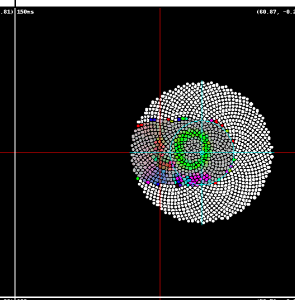
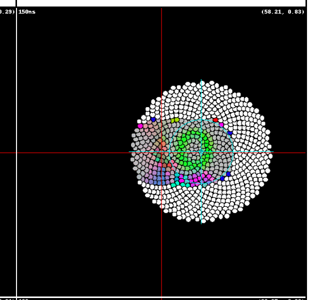
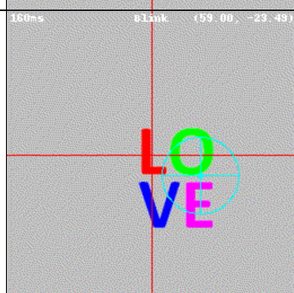
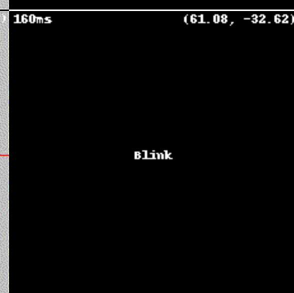
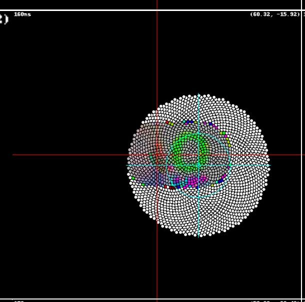
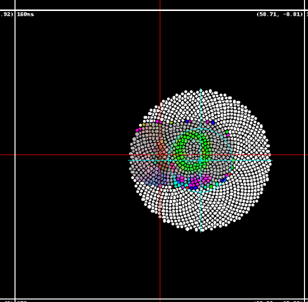
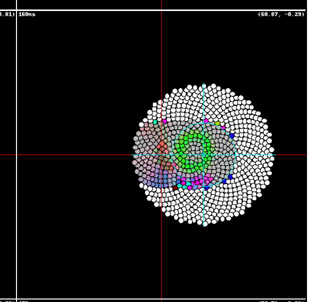
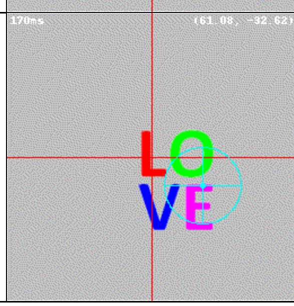
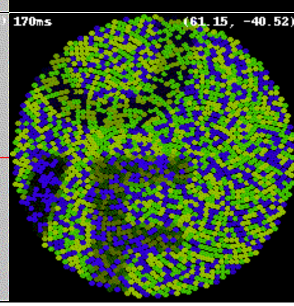
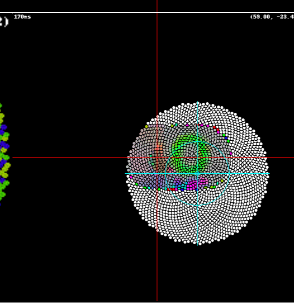
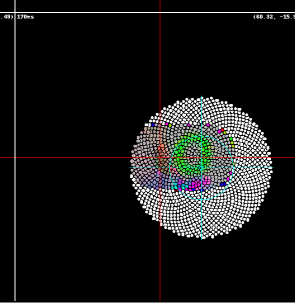
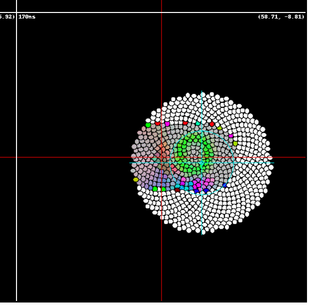
Table 35: Time sequence of simple surfaces (Love) with blinks					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
15					
16					
17					

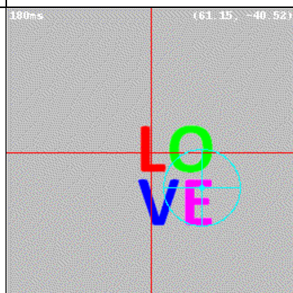
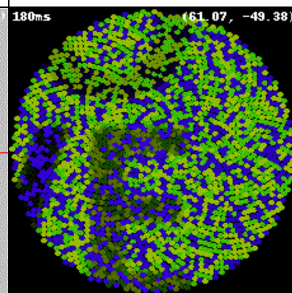
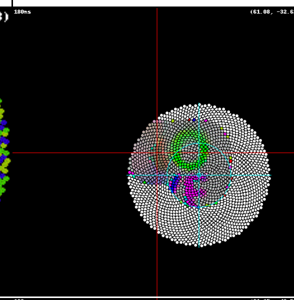
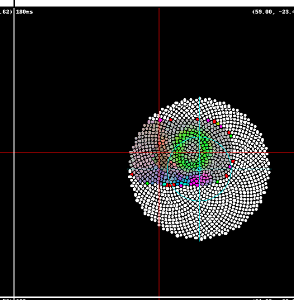
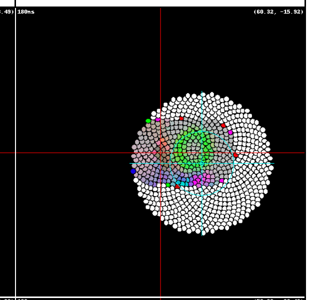
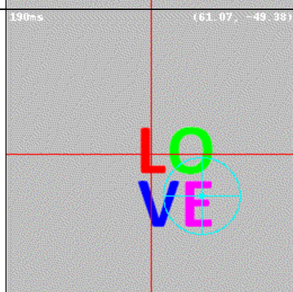
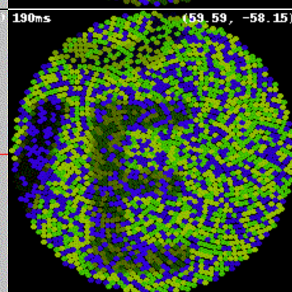
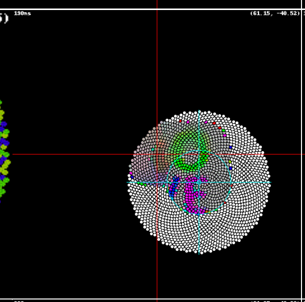
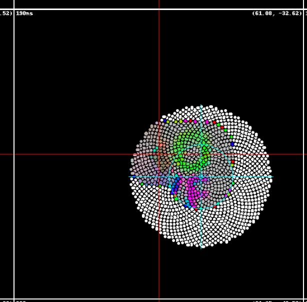
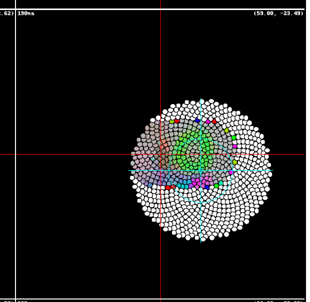
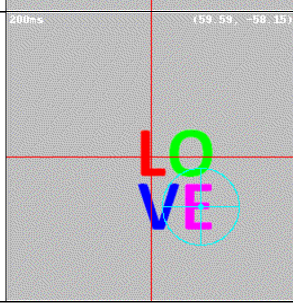
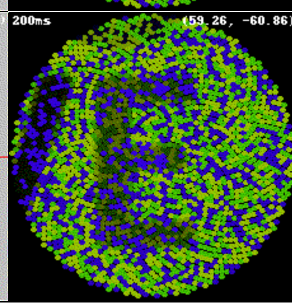
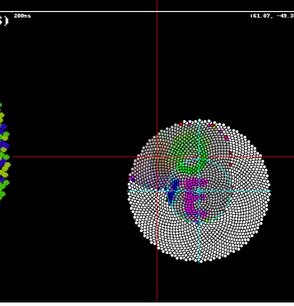
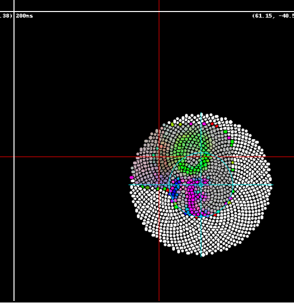
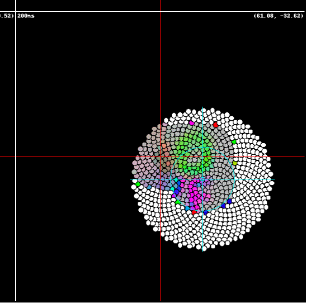
Table 35: Time sequence of simple surfaces (Love) with blinks					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
18					
19					
20					

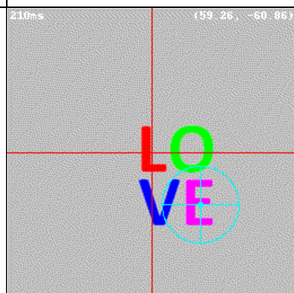
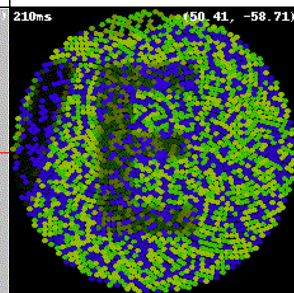
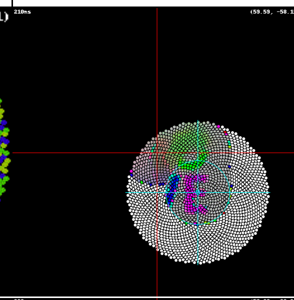
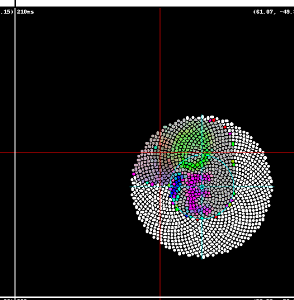
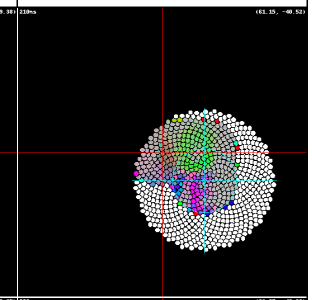
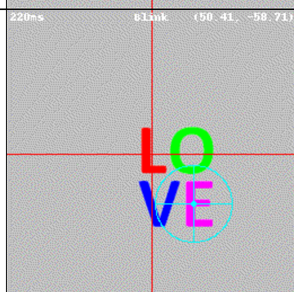
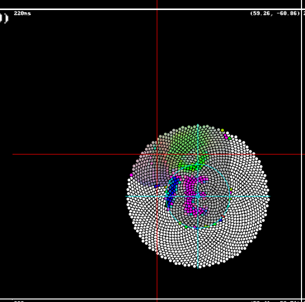
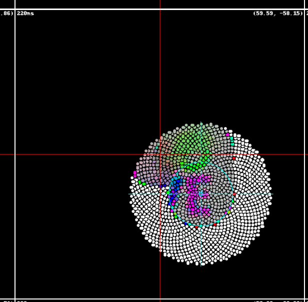
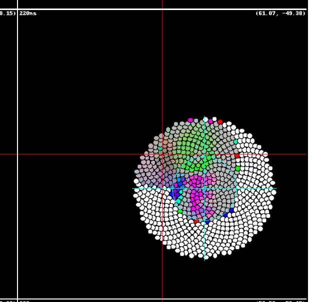
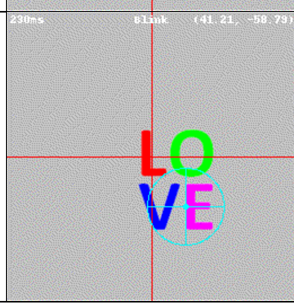
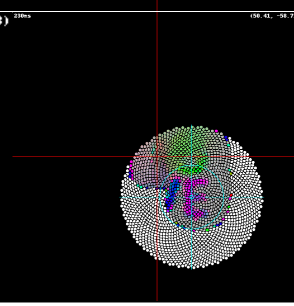
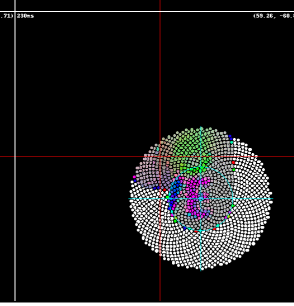
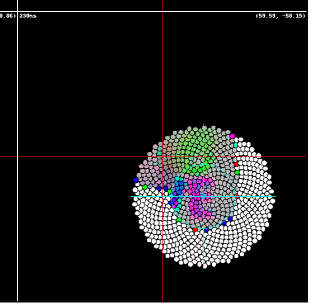
Table 35: Time sequence of simple surfaces (Love) with blinks					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
21					
22					
23					

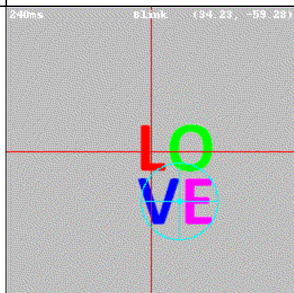
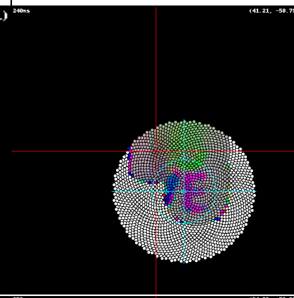
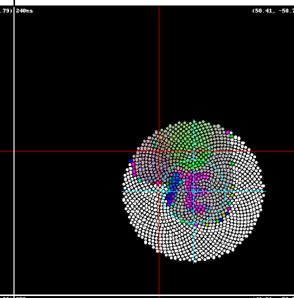
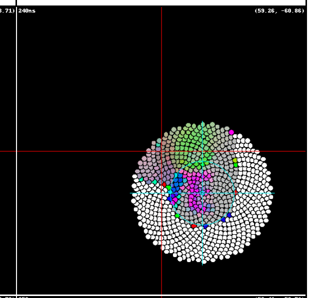
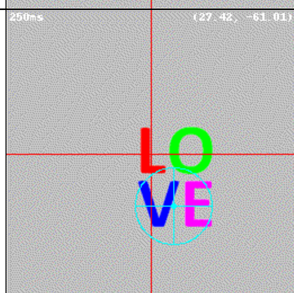
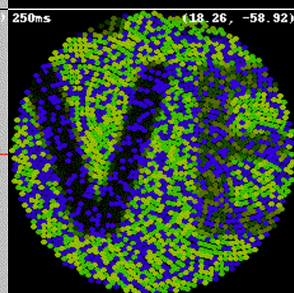
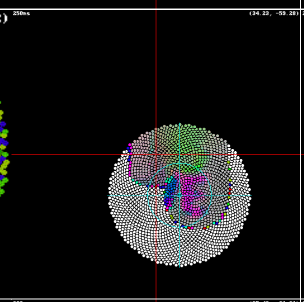
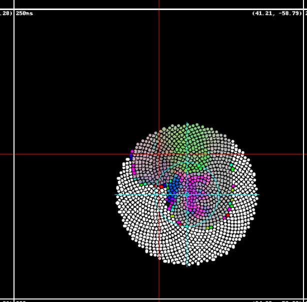
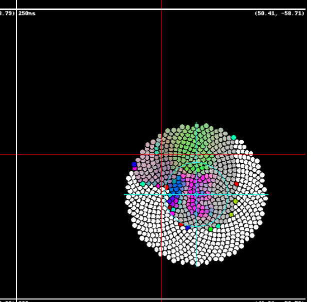
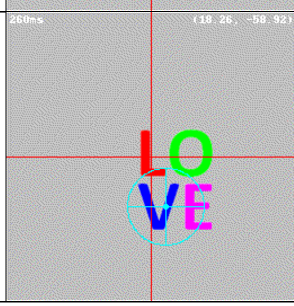
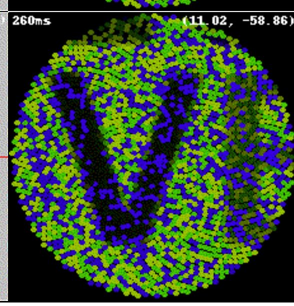
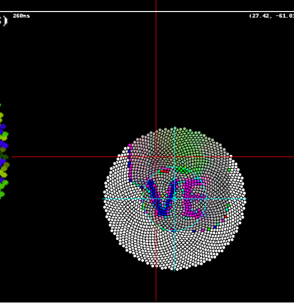
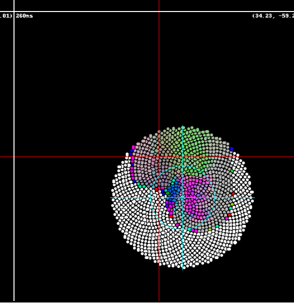
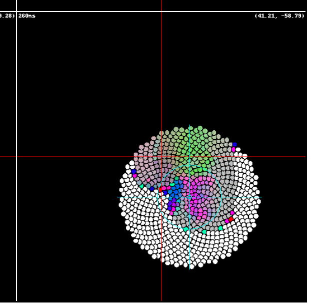
Table 35: Time sequence of simple surfaces (Love) with blinks					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
24					
25					
26					

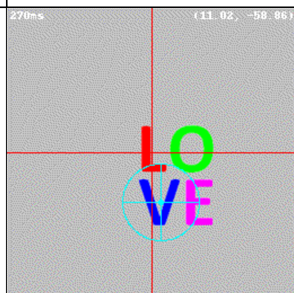
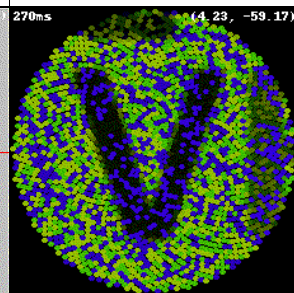
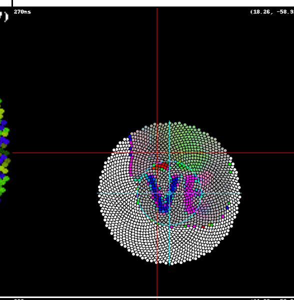
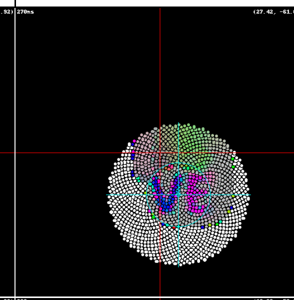
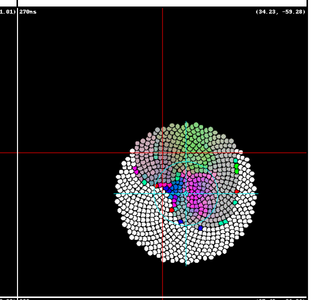
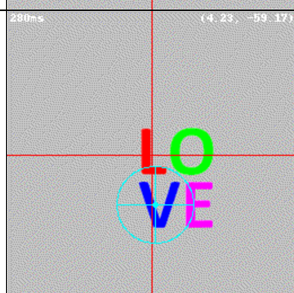
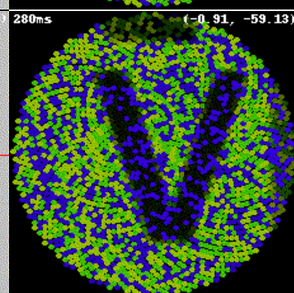
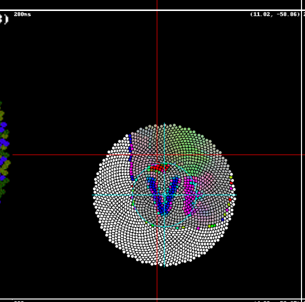
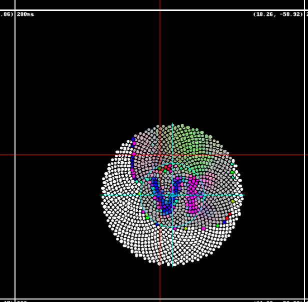
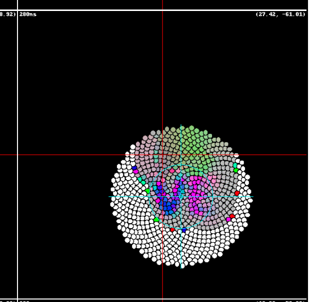
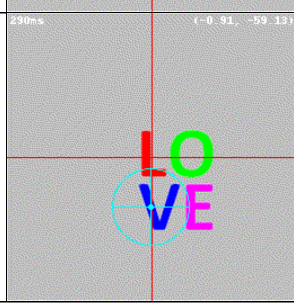
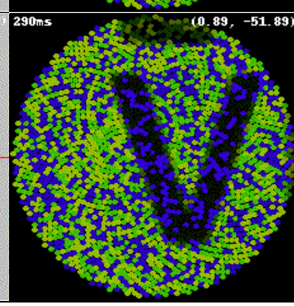
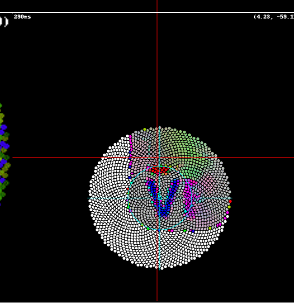
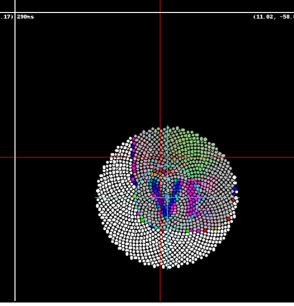
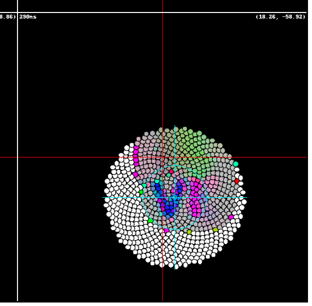
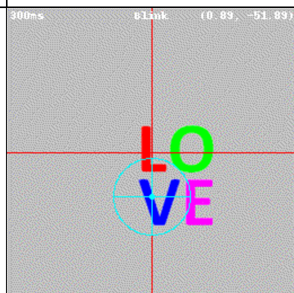
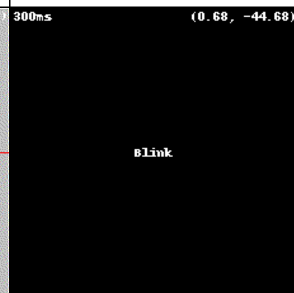
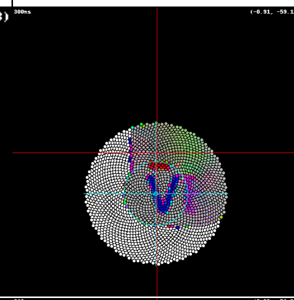
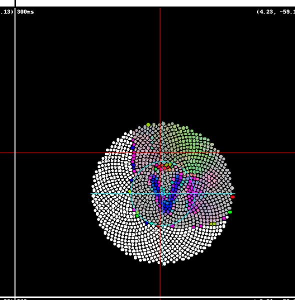
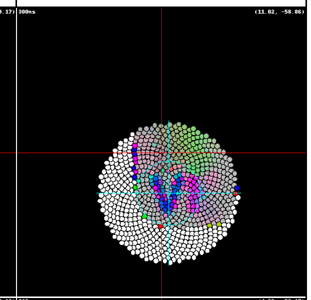
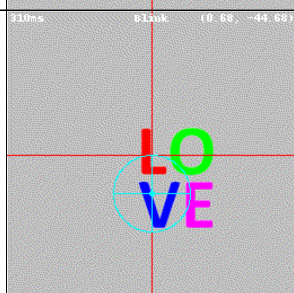
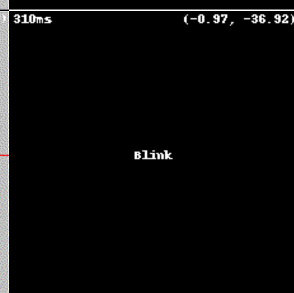
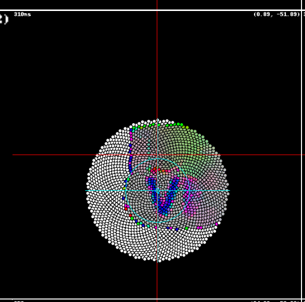
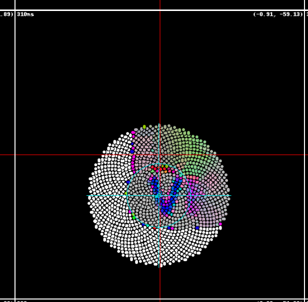
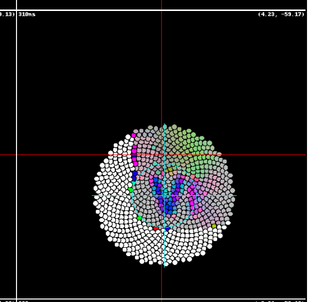
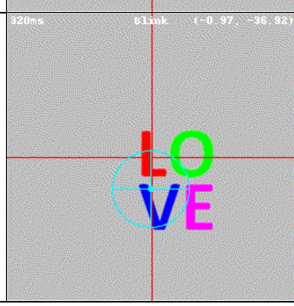
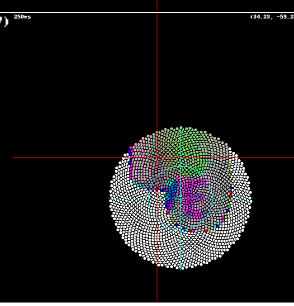
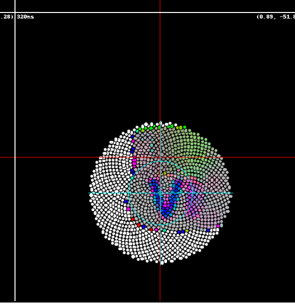
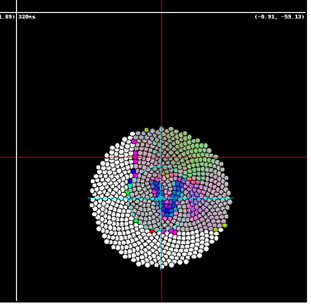
Table 35: Time sequence of simple surfaces (Love) with blinks					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
27					
28					
29					

Table 35: Time sequence of simple surfaces (Love) with blinks					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
30					
31					
32					

C.3.2 Test 2 results: Natural image (Lena)

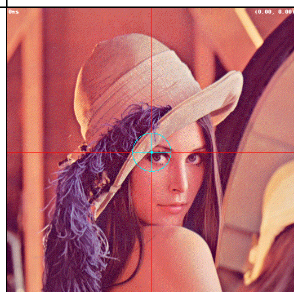
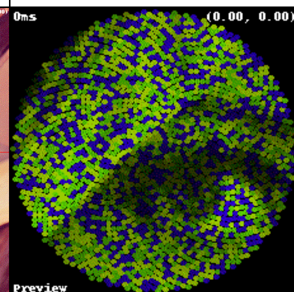
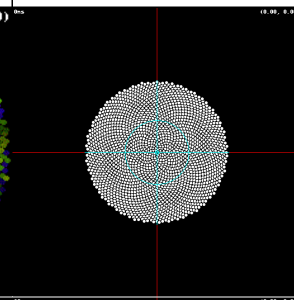
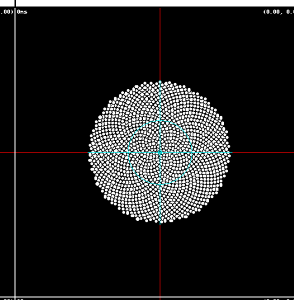
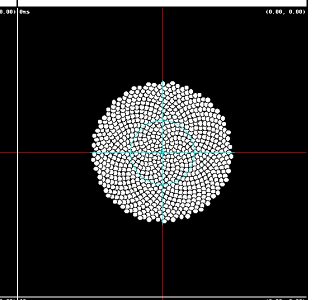
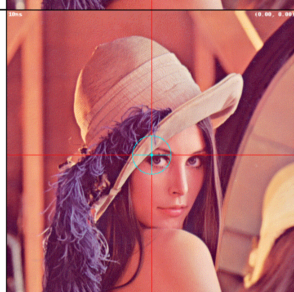
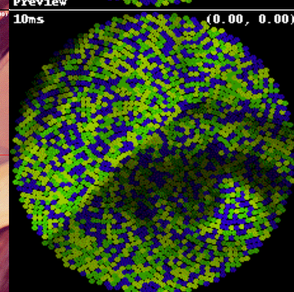
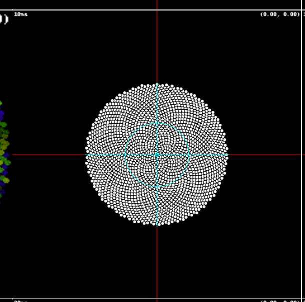
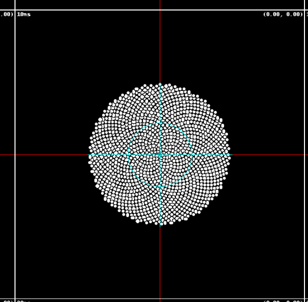
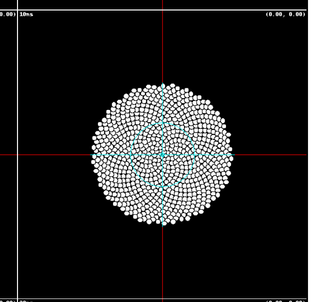
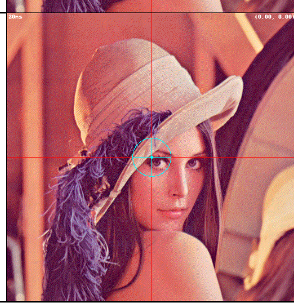
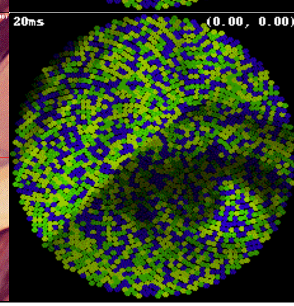
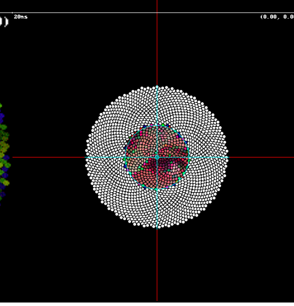
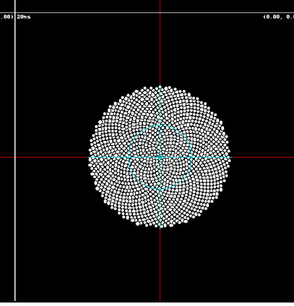
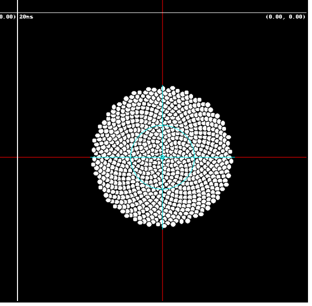
Table 36: Time sequence of natural image with blinks					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
0					
1					
2					

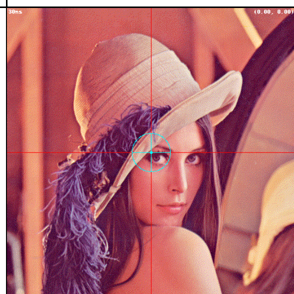
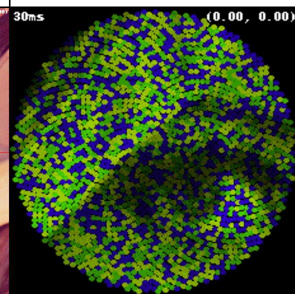
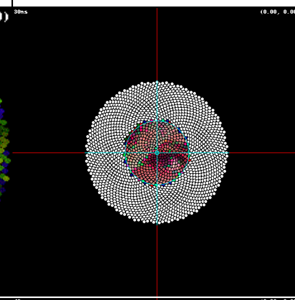
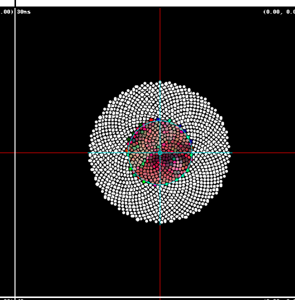
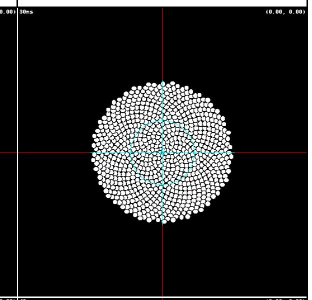
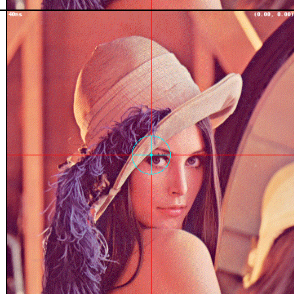
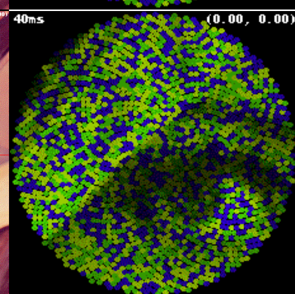
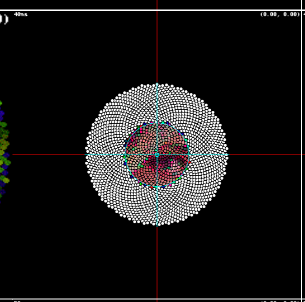
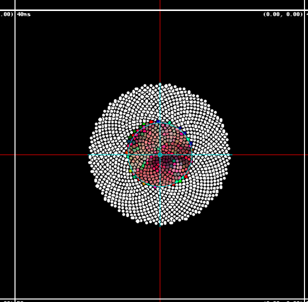
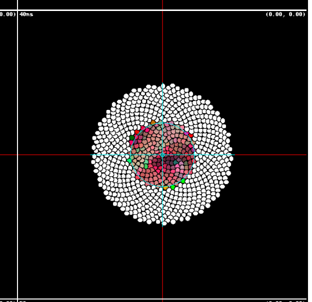
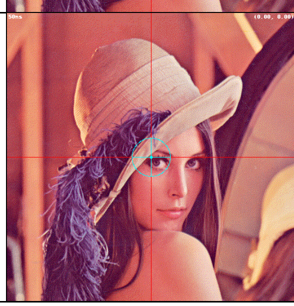
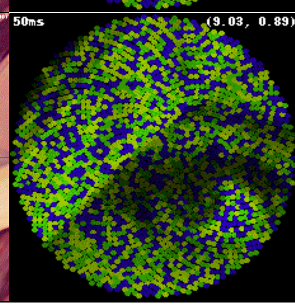
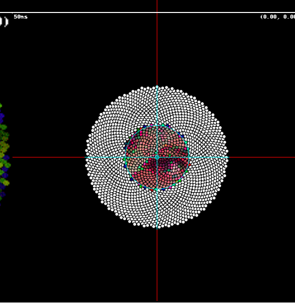
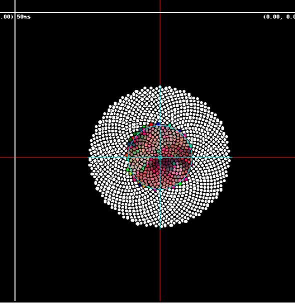
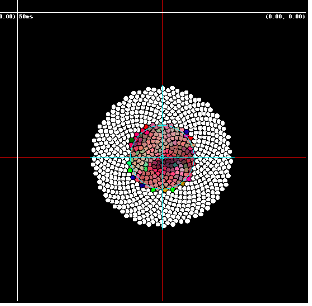
Table 36: Time sequence of natural image with blinks					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
3					
4					
5					

Table 36: Time sequence of natural image with blinks

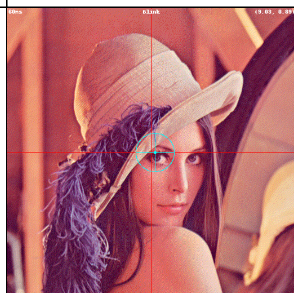
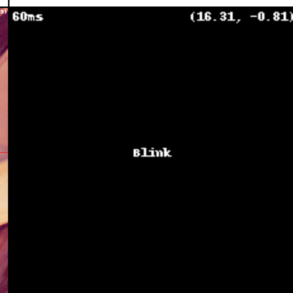
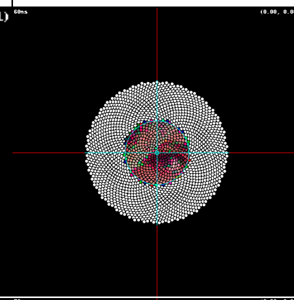
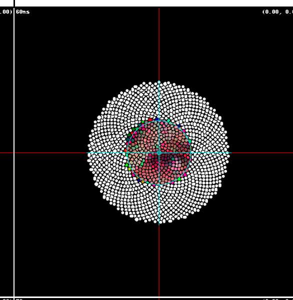
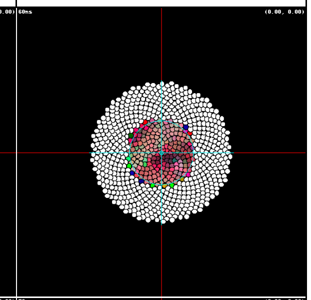
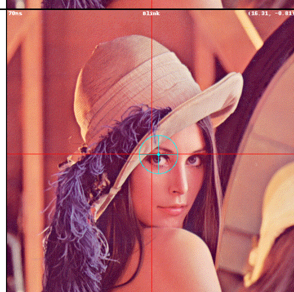
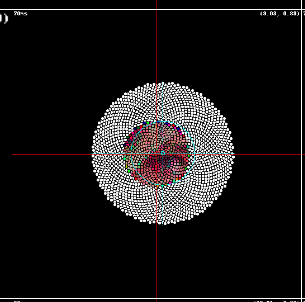
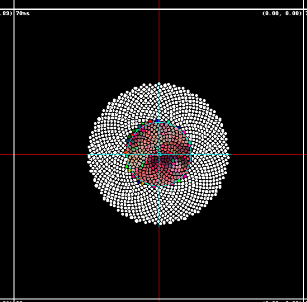
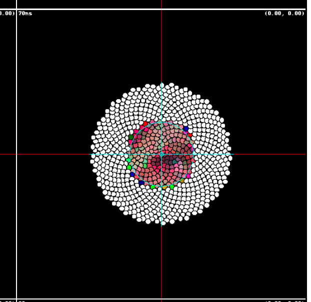
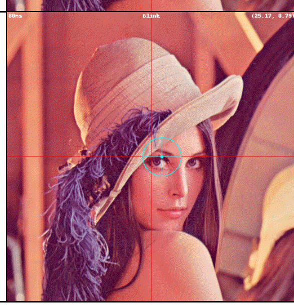
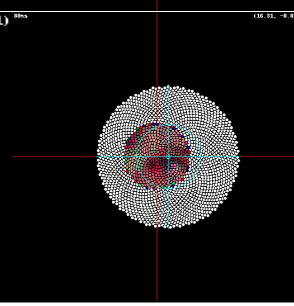
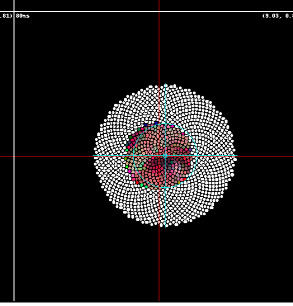
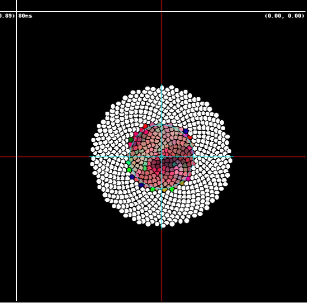
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
6					
7					
8					

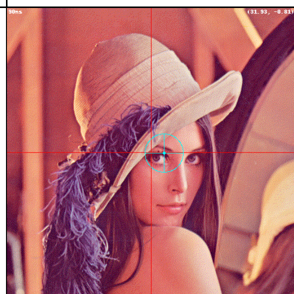
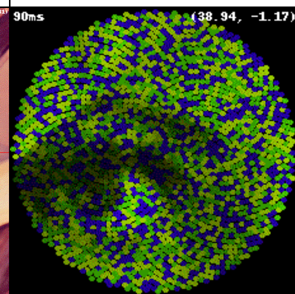
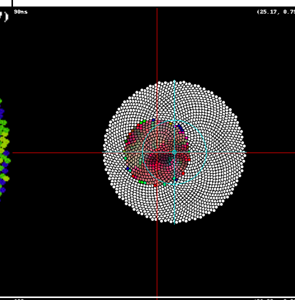
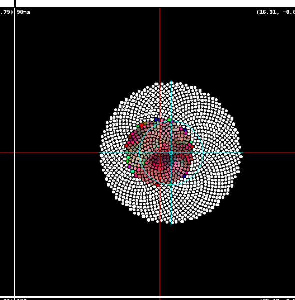
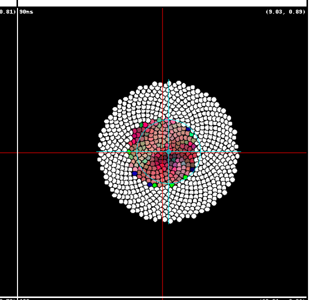
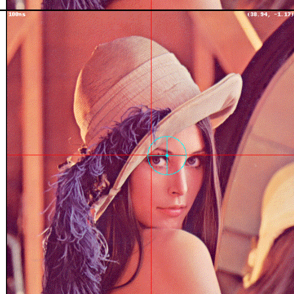
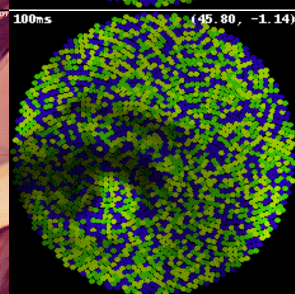
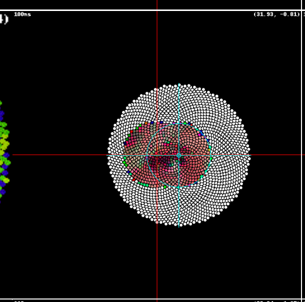
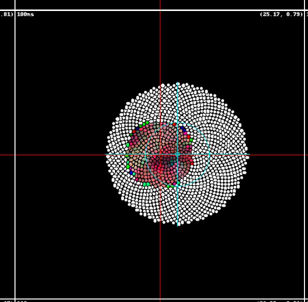
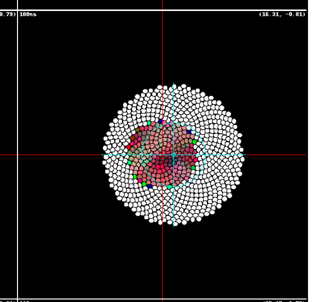
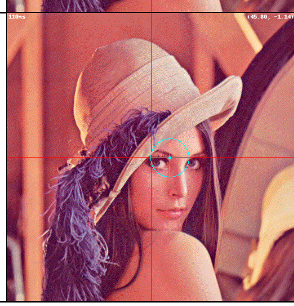
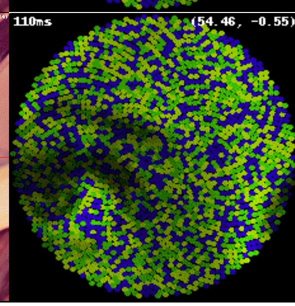
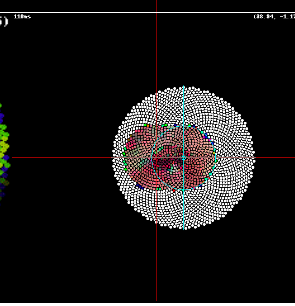
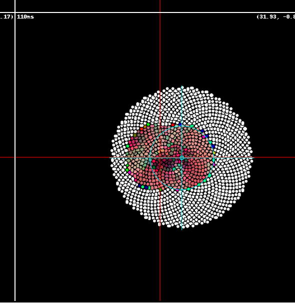
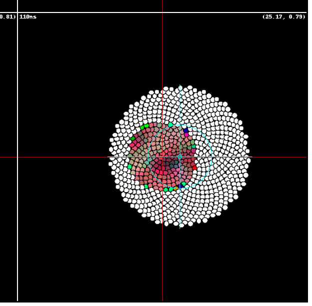
Table 36: Time sequence of natural image with blinks					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
9					
10					
11					

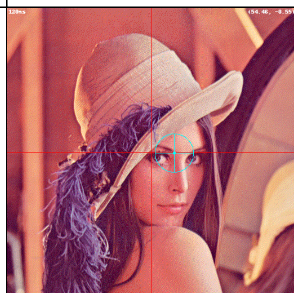
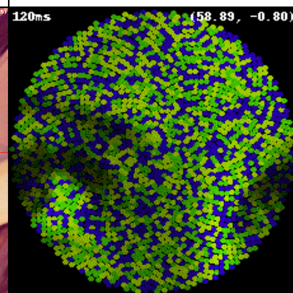
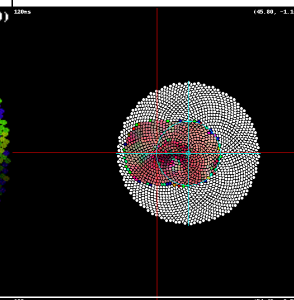
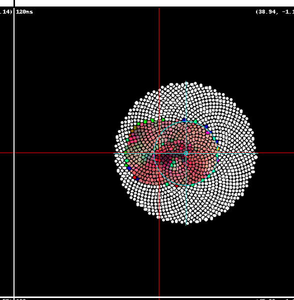
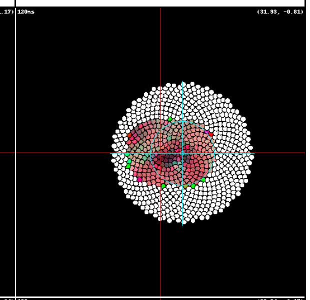
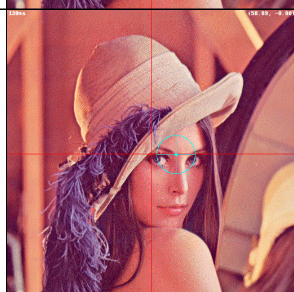
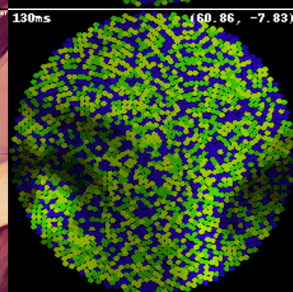
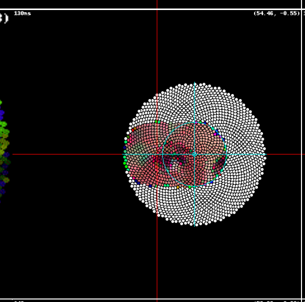
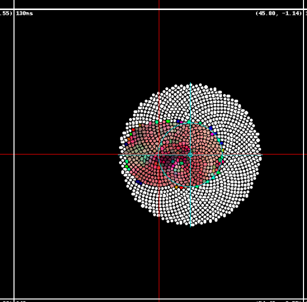
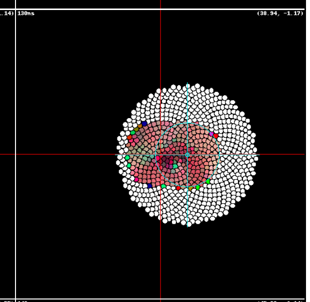
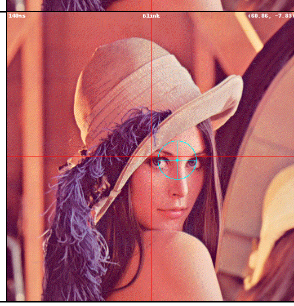
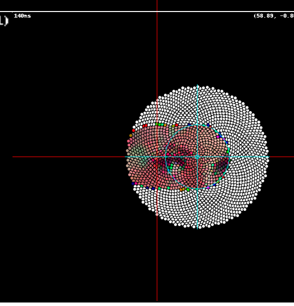
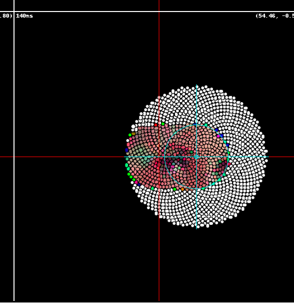
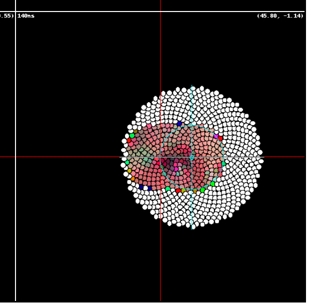
Table 36: Time sequence of natural image with blinks					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
12					
13					
14					

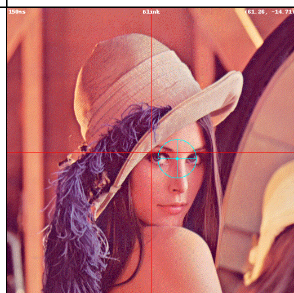
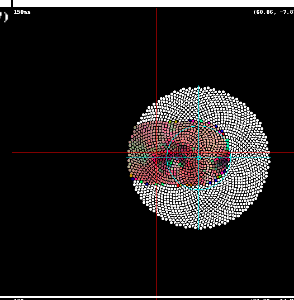
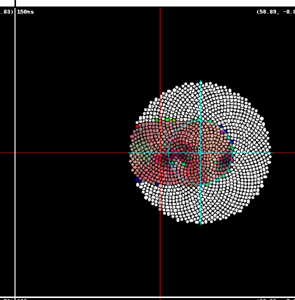
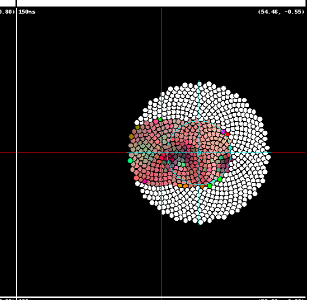
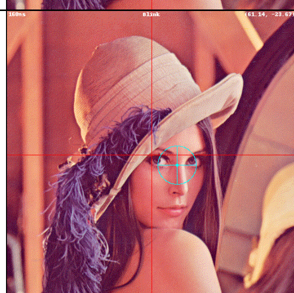
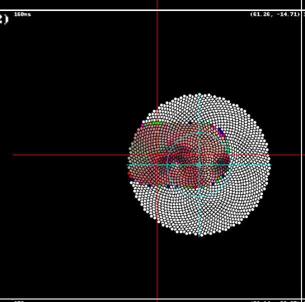
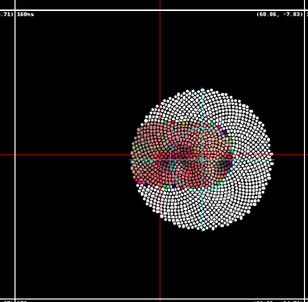
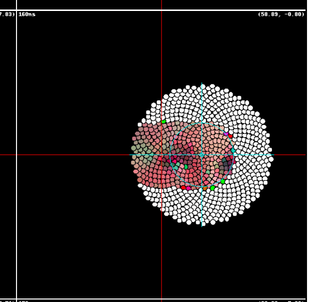
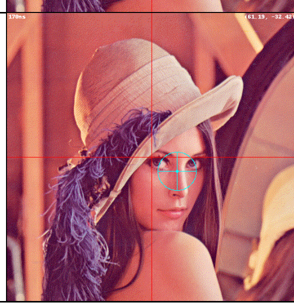
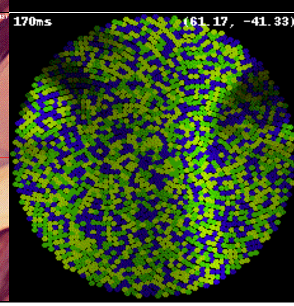
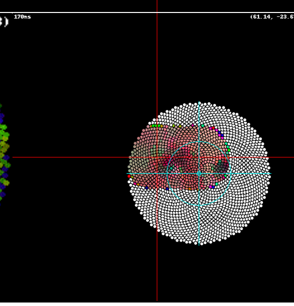
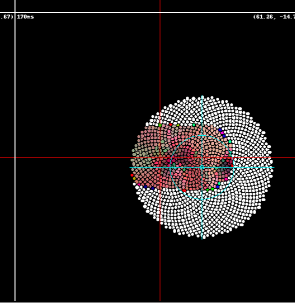
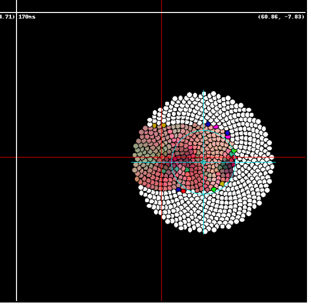
Table 36: Time sequence of natural image with blinks					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
15					
16					
17					

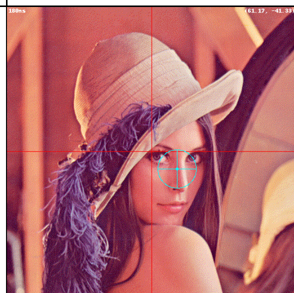
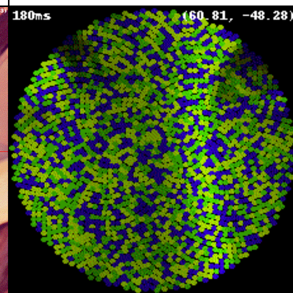
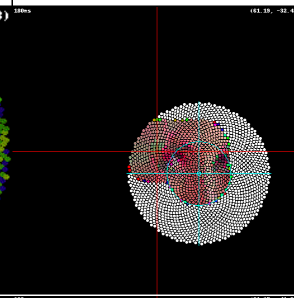
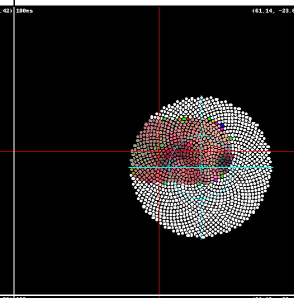
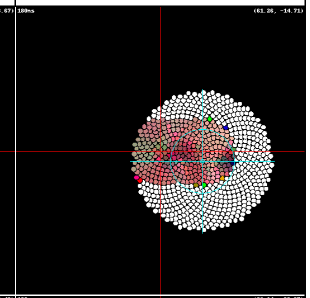
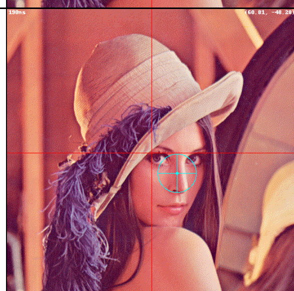
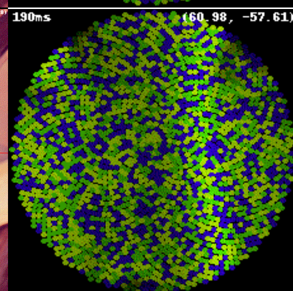
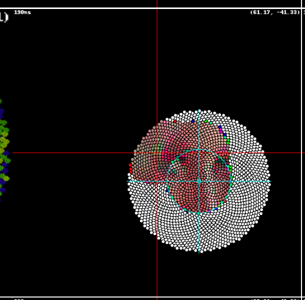
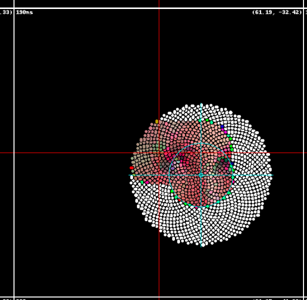
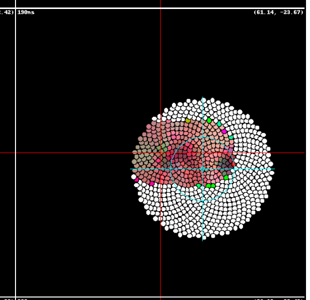
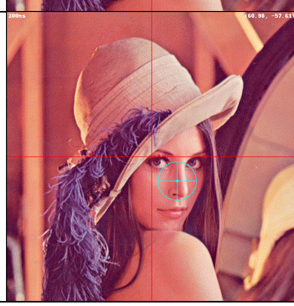
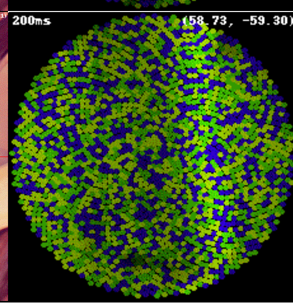
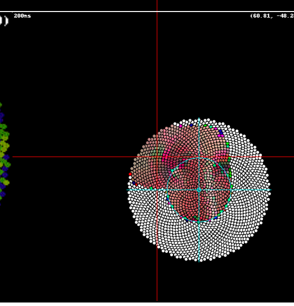
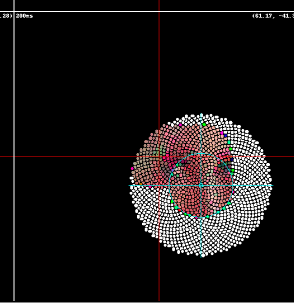
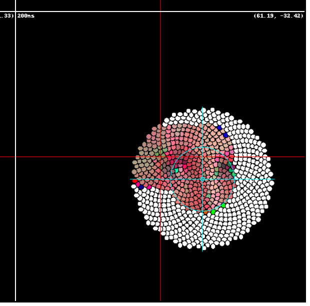
Table 36: Time sequence of natural image with blinks					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
18					
19					
20					

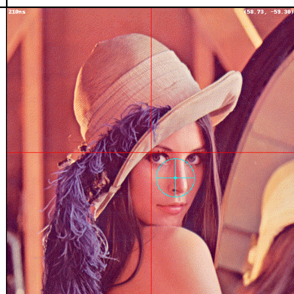
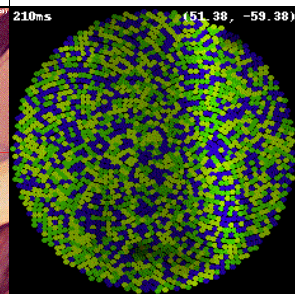
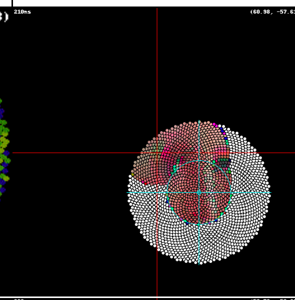
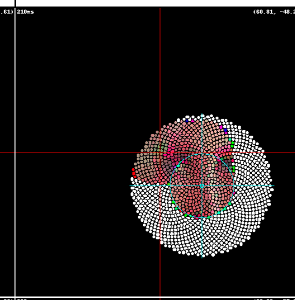
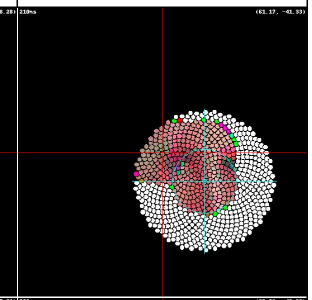
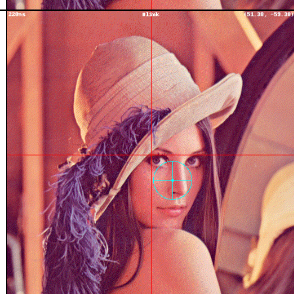
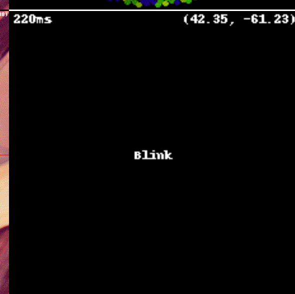
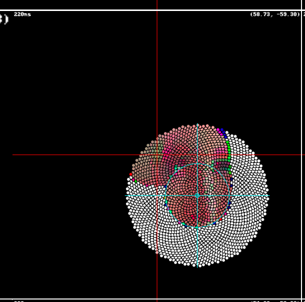
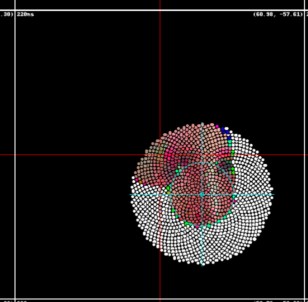
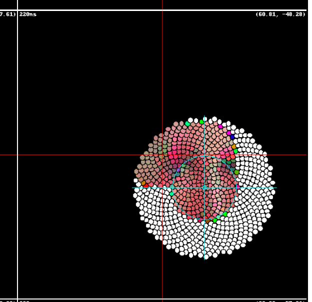
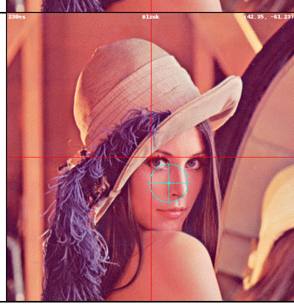
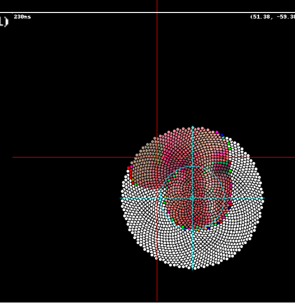
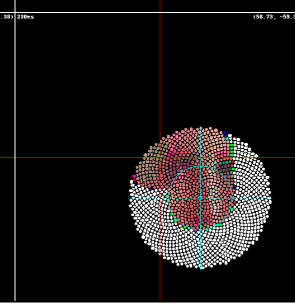
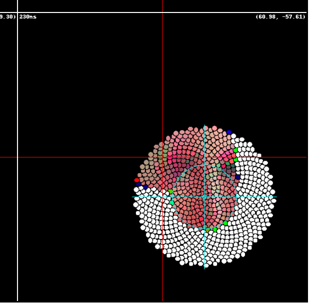
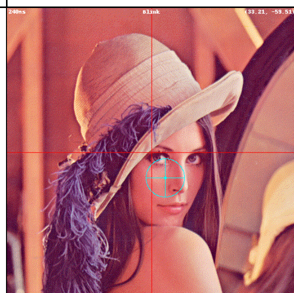
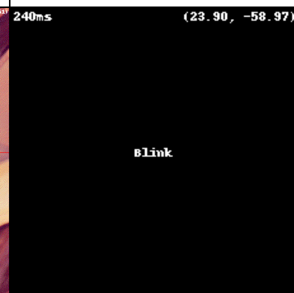
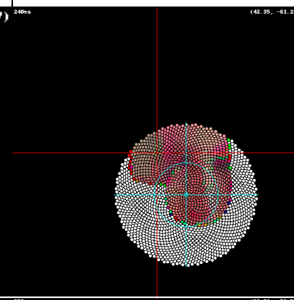
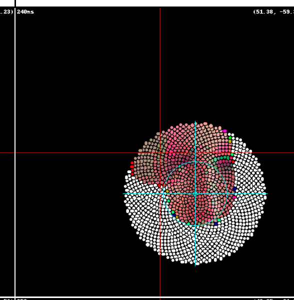
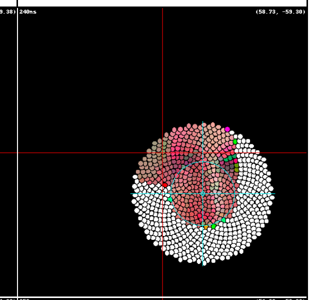
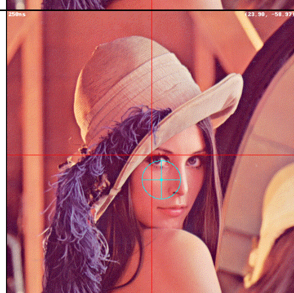
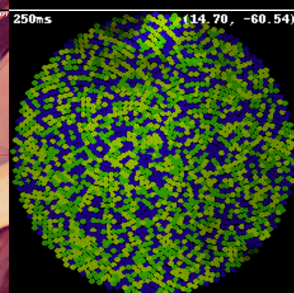
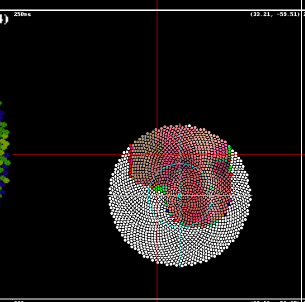
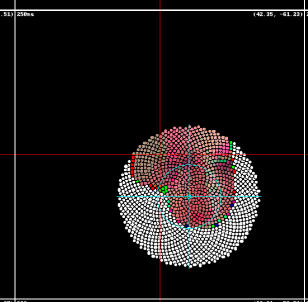
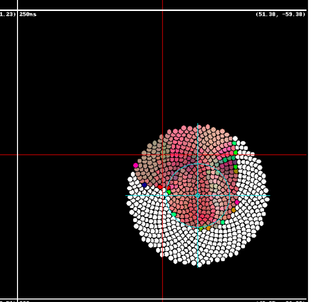
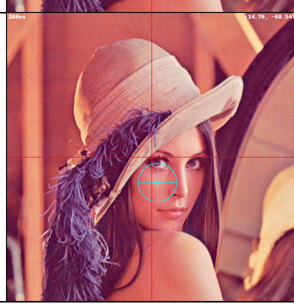
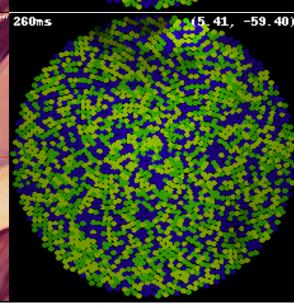
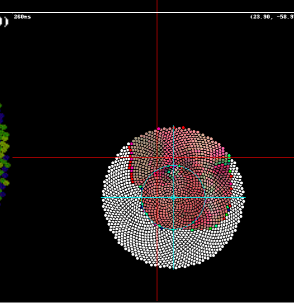
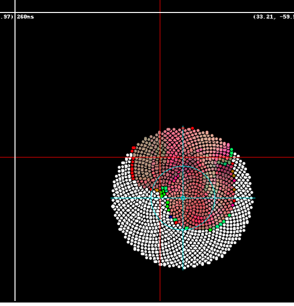
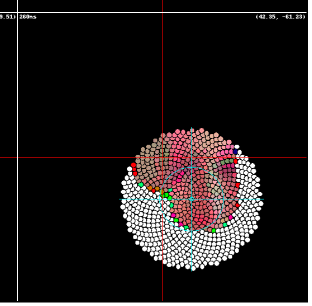
Table 36: Time sequence of natural image with blinks					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
21					
22					
23					

Table 36: Time sequence of natural image with blinks					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
24					
25					
26					

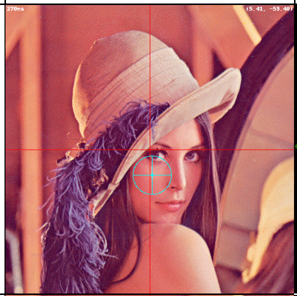
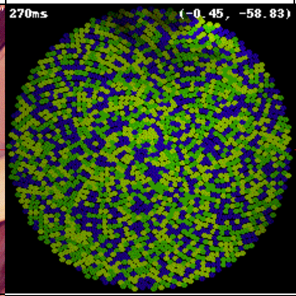
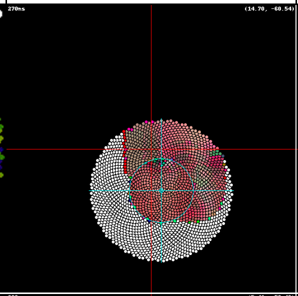
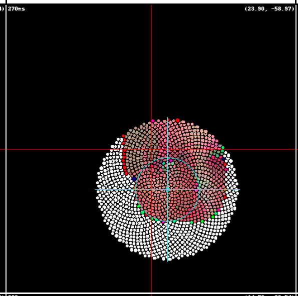
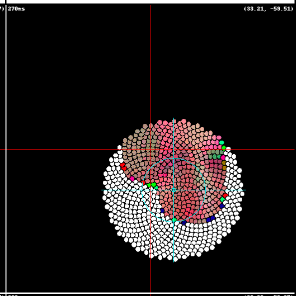
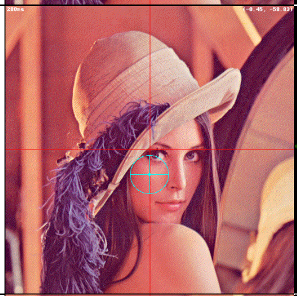
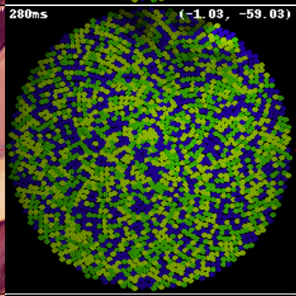
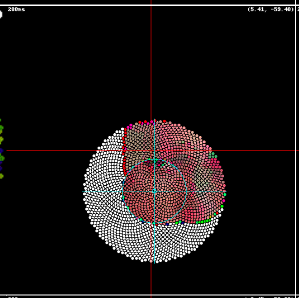
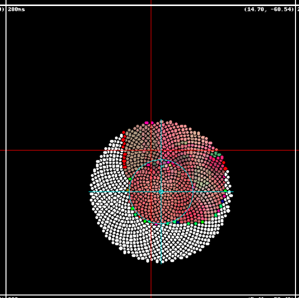
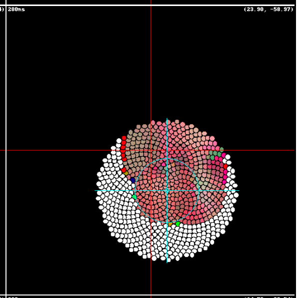
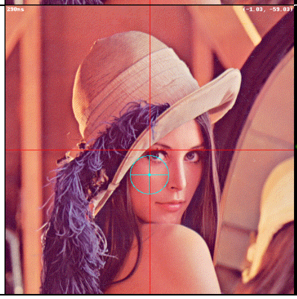
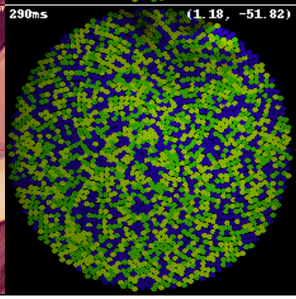
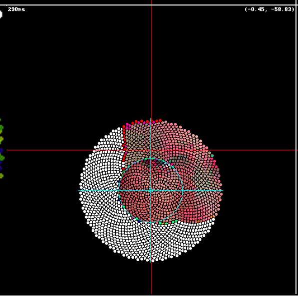
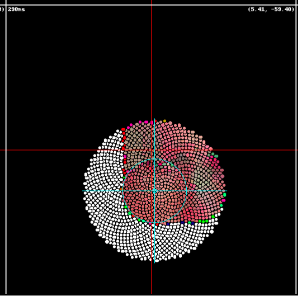
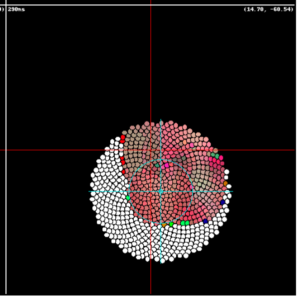
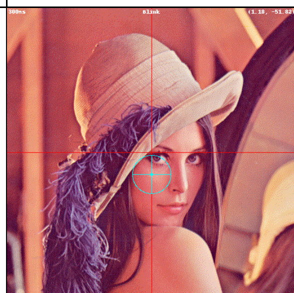
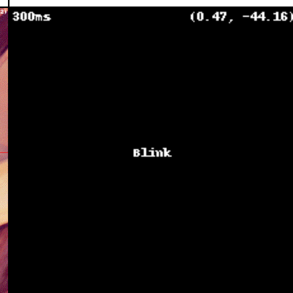
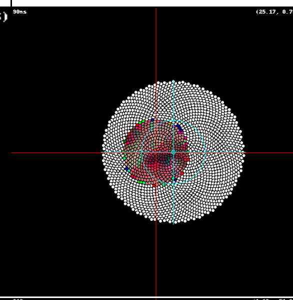
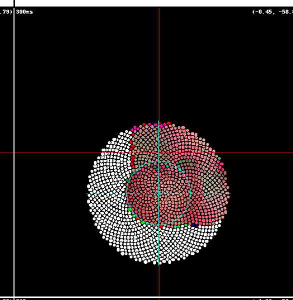
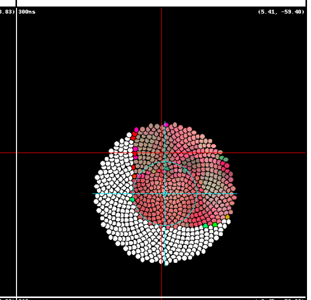
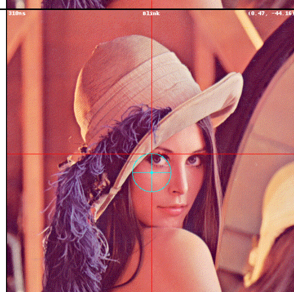
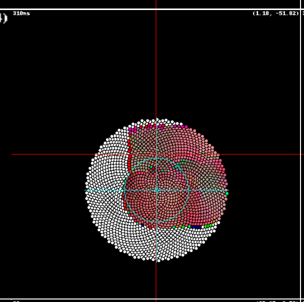
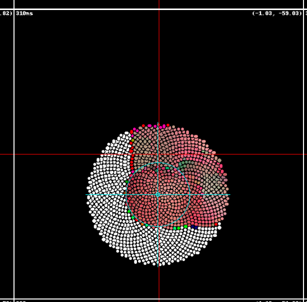
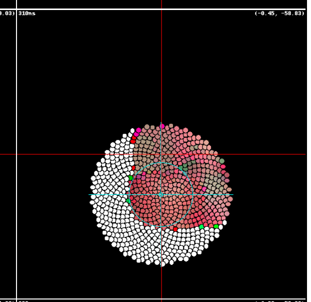
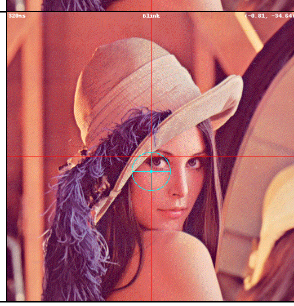
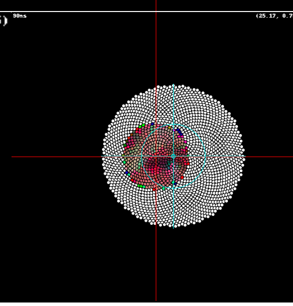
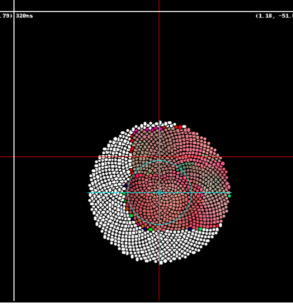
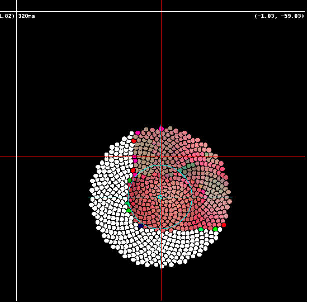
<table>
<tr><th colspan="6">Table 36: Time sequence of natural image with blinks</th></tr>
<tr><th rowspan="2">Time (ticks)</th><th rowspan="2">Stimuli</th><th rowspan="2">Photoreceptor Mosaic</th><th colspan="3">Receptive Fields</th></tr>
<tr><th>Level 1</th><th>Level 2</th><th>Level 3</th></tr>
<tr><td>27</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>28</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>29</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Table 36: Time sequence of natural image with blinks					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
30					
31					
32					

C.3.3 Test 3 results: Dynamic image (Chaser)

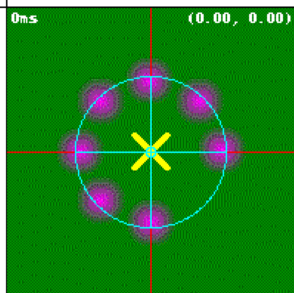
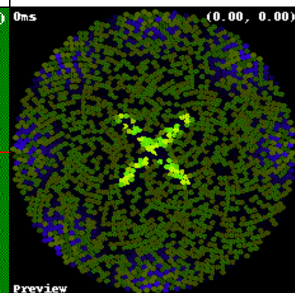
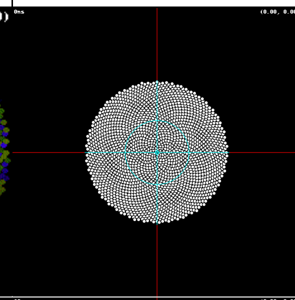
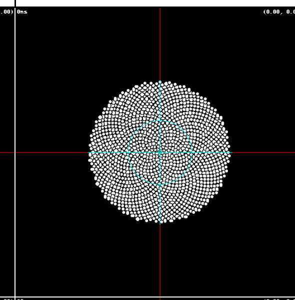
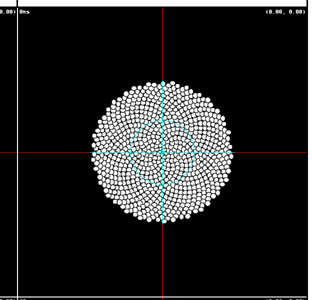
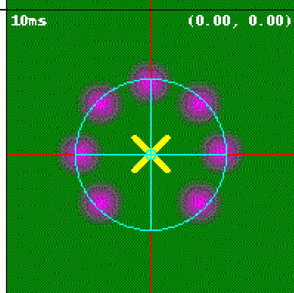
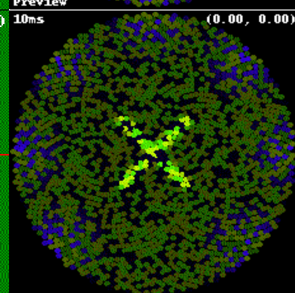
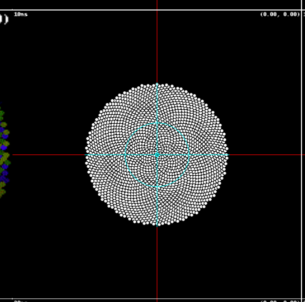
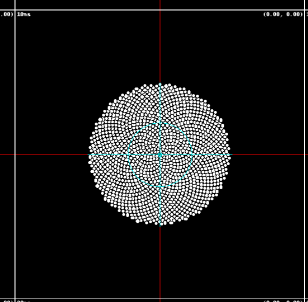
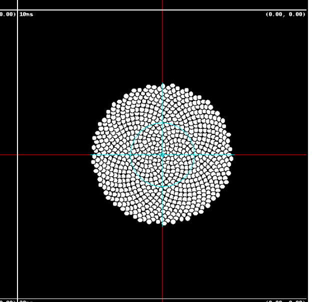
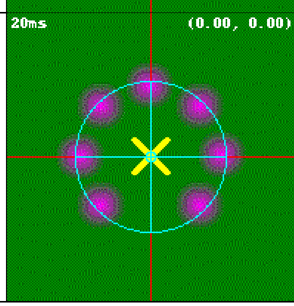
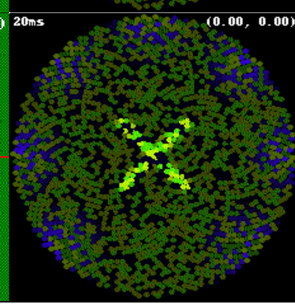
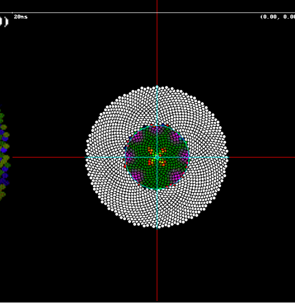
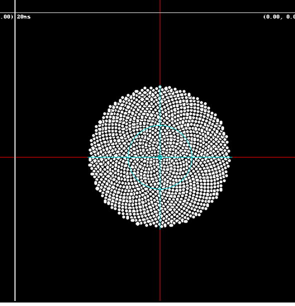
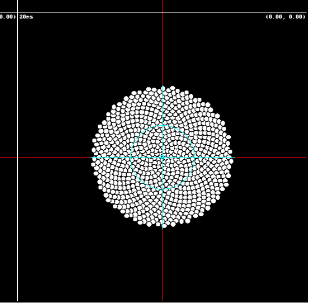
Table 37: Time sequence of dynamic image with blinks					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
0					
1					
2					

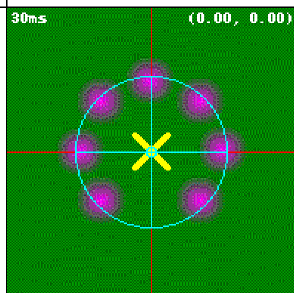
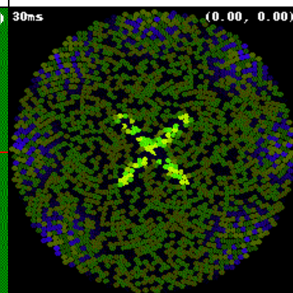
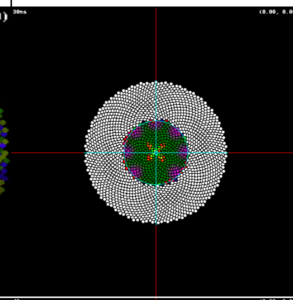
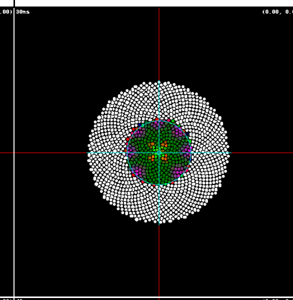
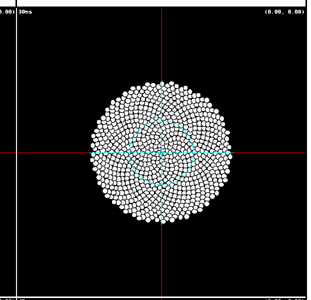
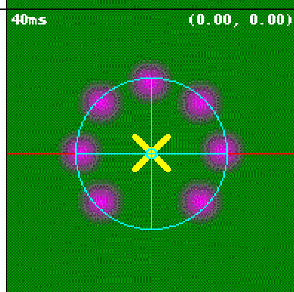
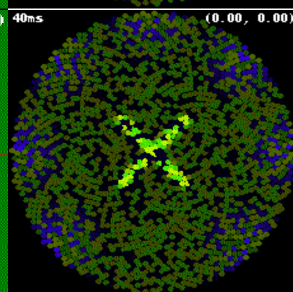
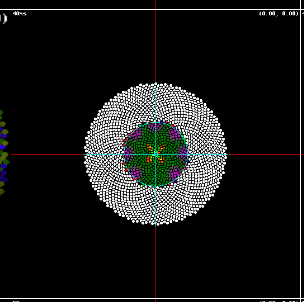
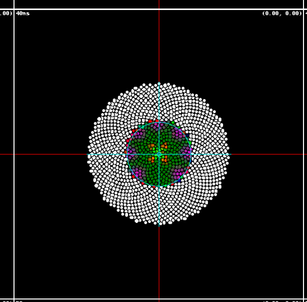
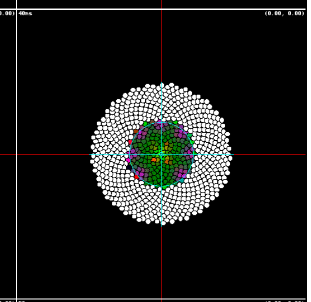
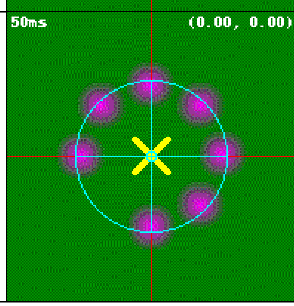
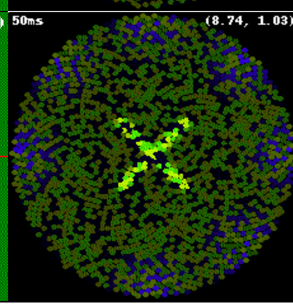
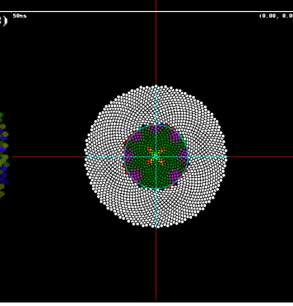
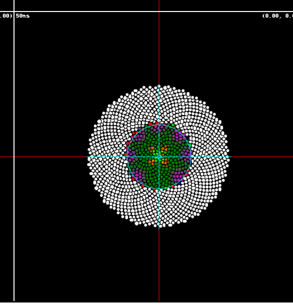
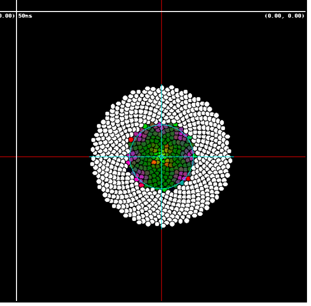
Table 37: Time sequence of dynamic image with blinks					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
3					
4					
5					

Table 37: Time sequence of dynamic image with blinks

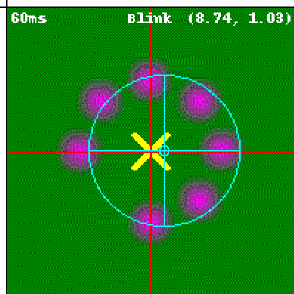
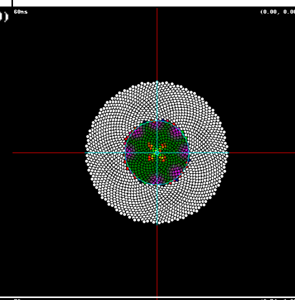
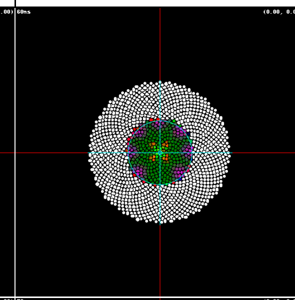
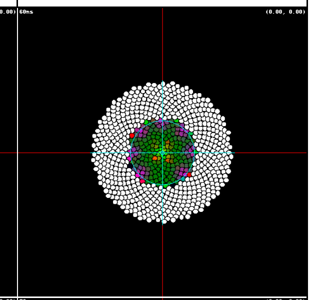
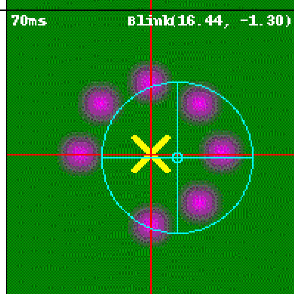
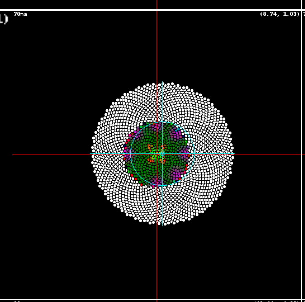
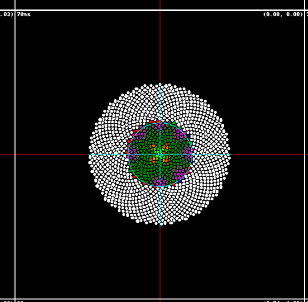
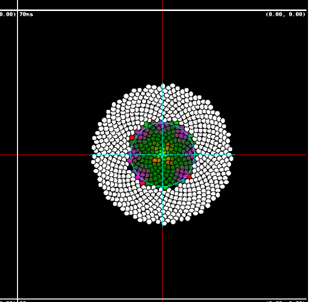
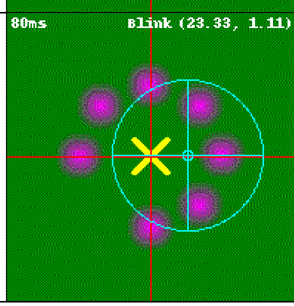
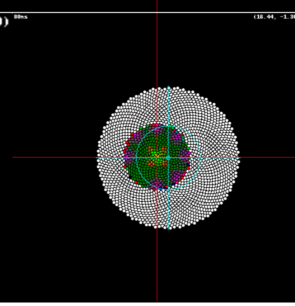
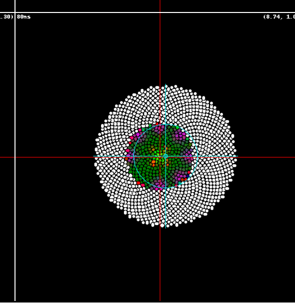
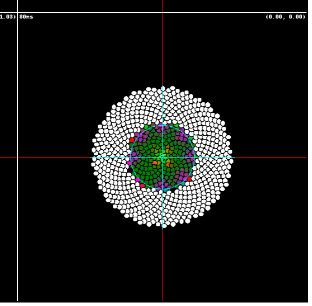
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
6					
7					
8					

Table 37: Time sequence of dynamic image with blinks

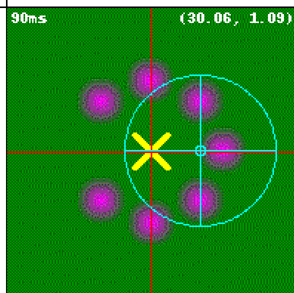
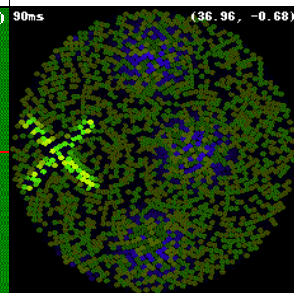
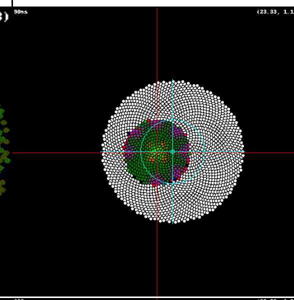
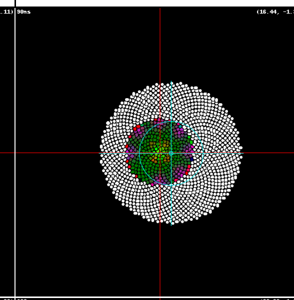
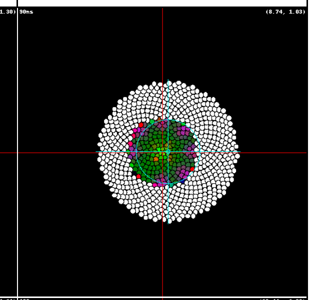
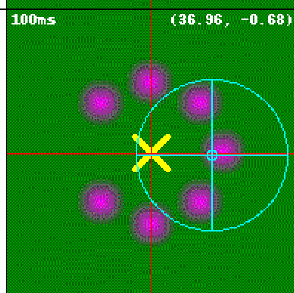
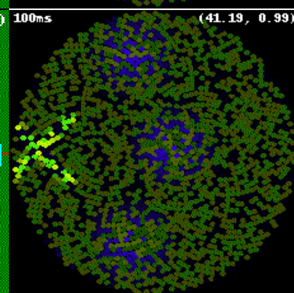
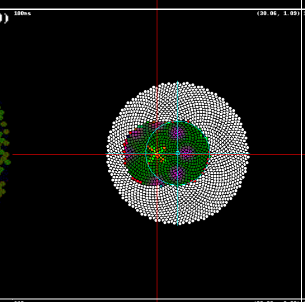
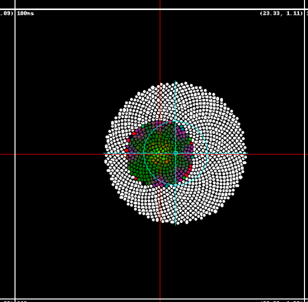
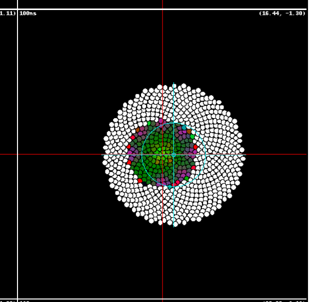
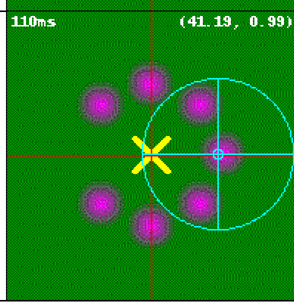
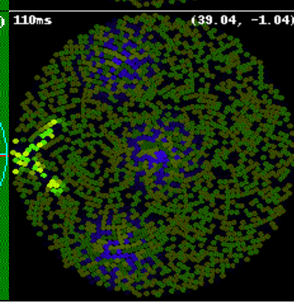
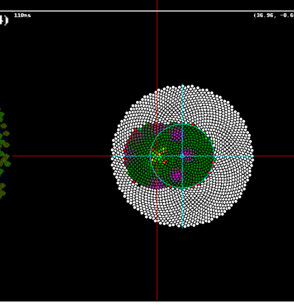
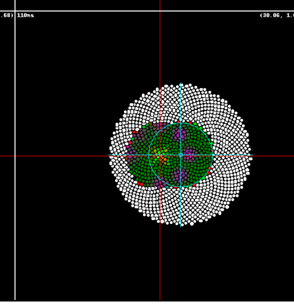
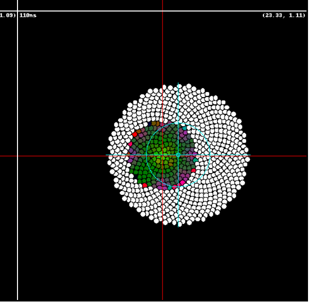
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
9					
10					
11					

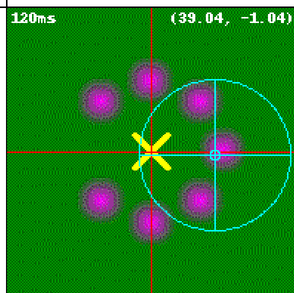
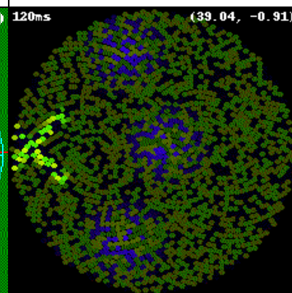
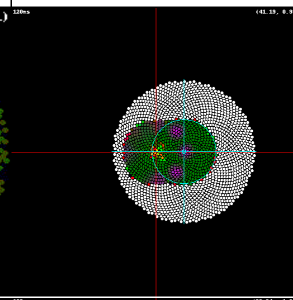
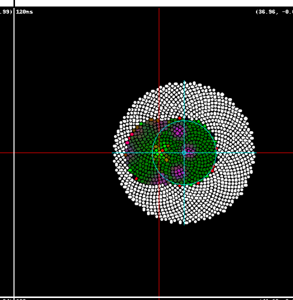
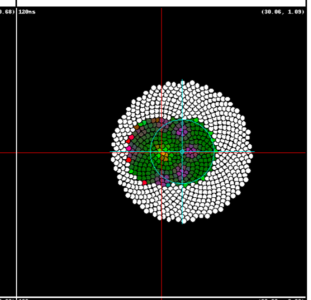
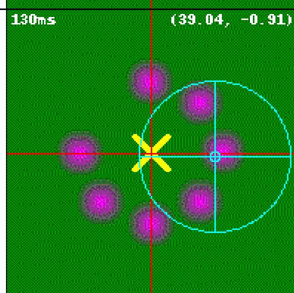
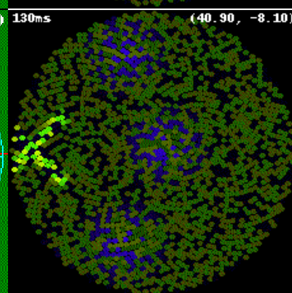
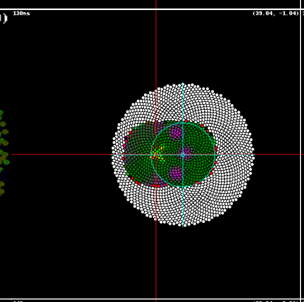
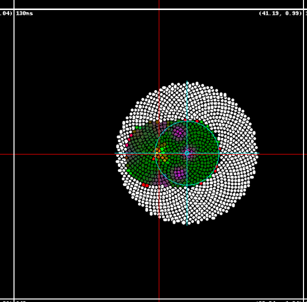
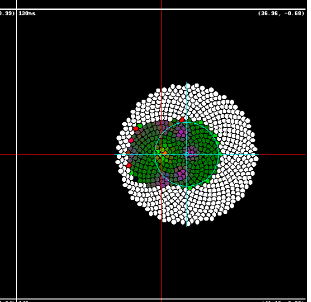
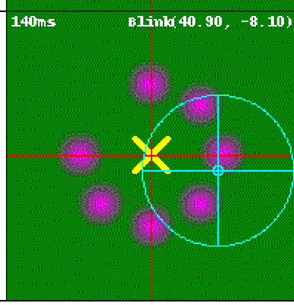
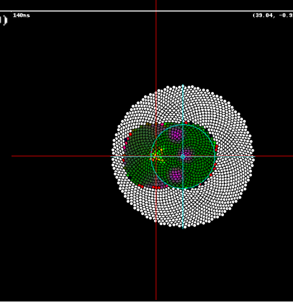
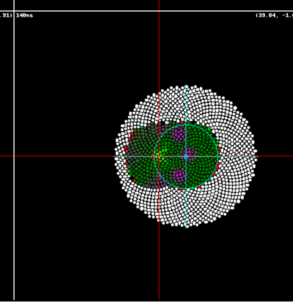
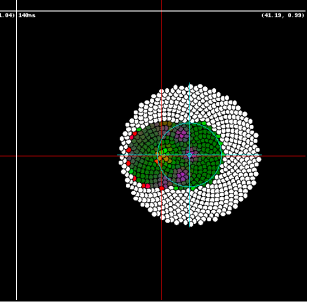
Table 37: Time sequence of dynamic image with blinks					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
12					
13					
14					

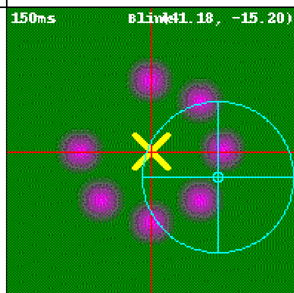
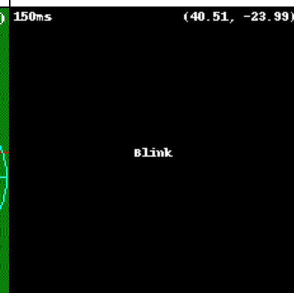
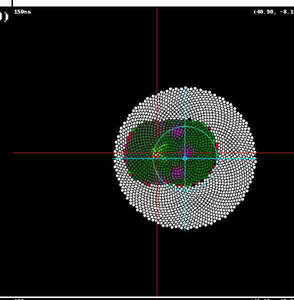
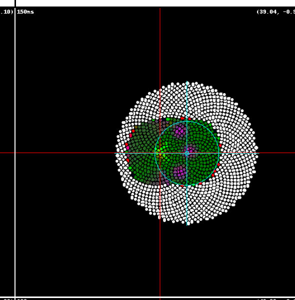
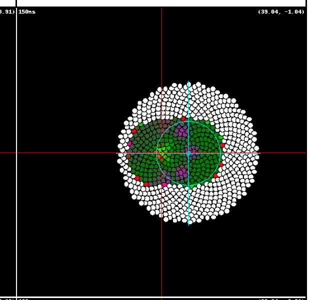
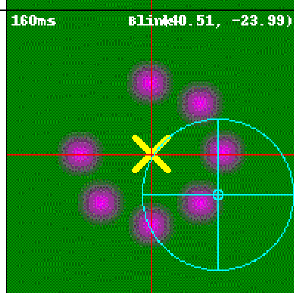
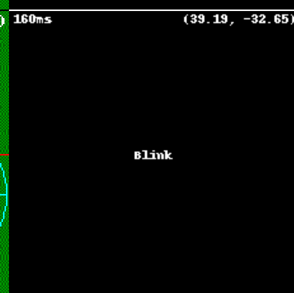
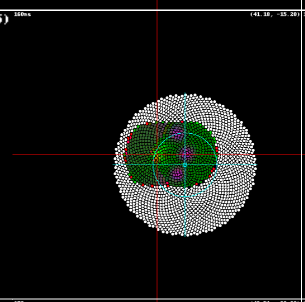
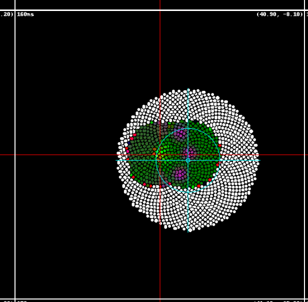
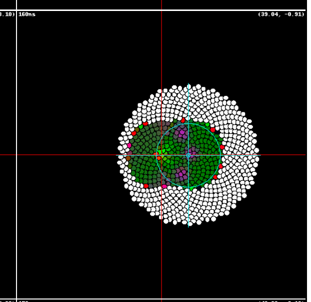
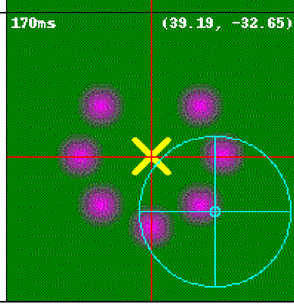
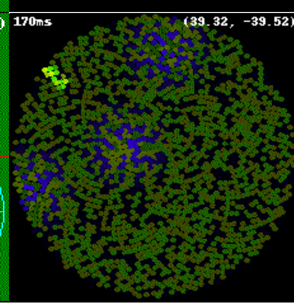
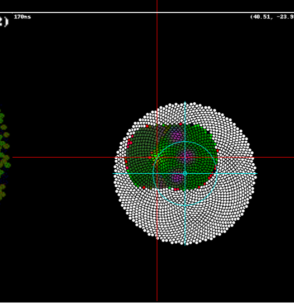
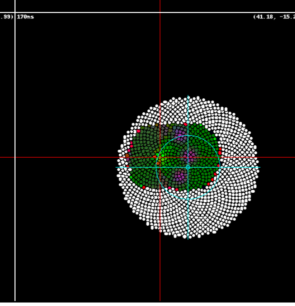
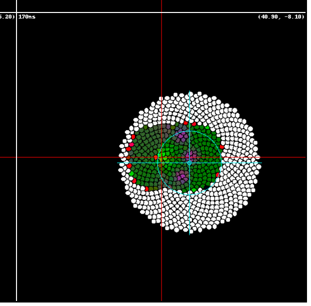
Table 37: Time sequence of dynamic image with blinks					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
15					
16					
17					

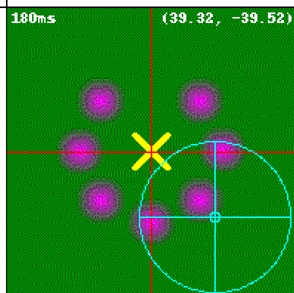
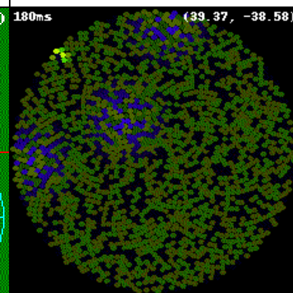
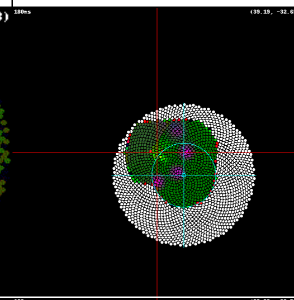
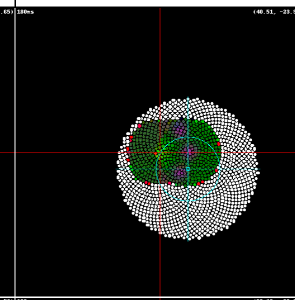
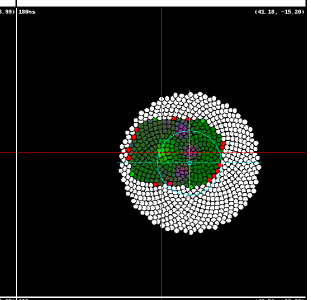
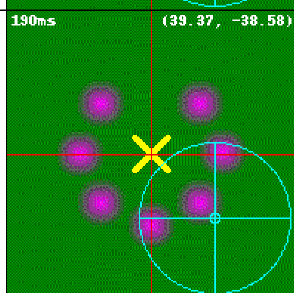
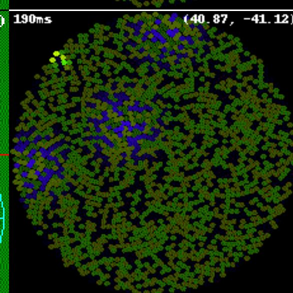
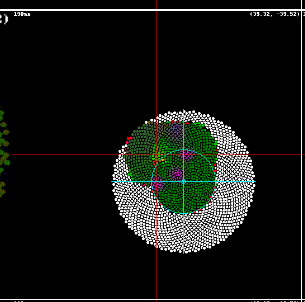
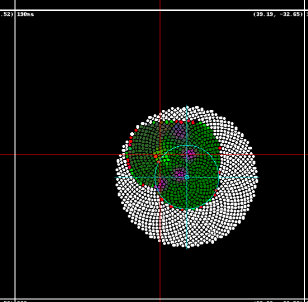
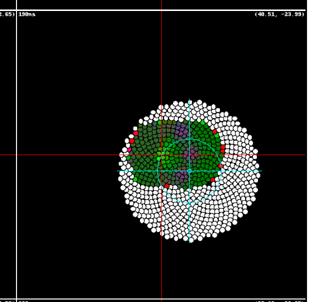
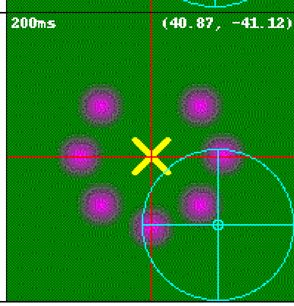
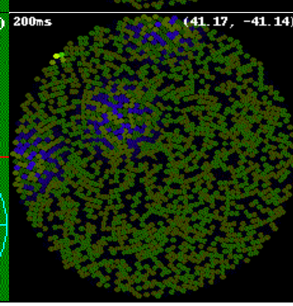
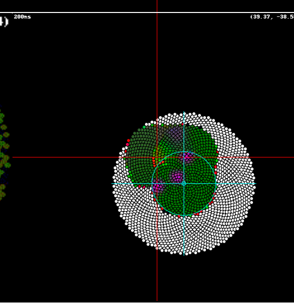
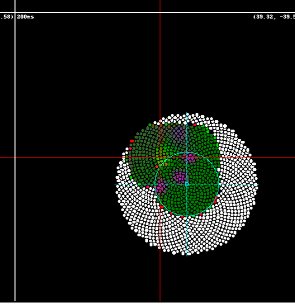
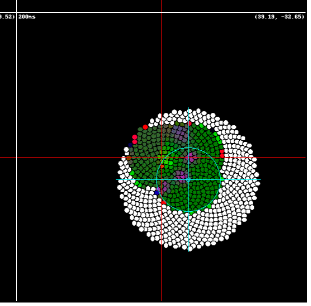
Table 37: Time sequence of dynamic image with blinks					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
18					
19					
20					

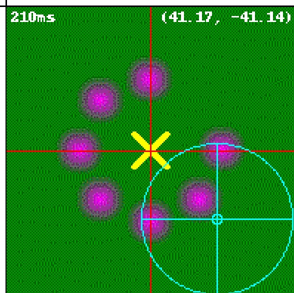
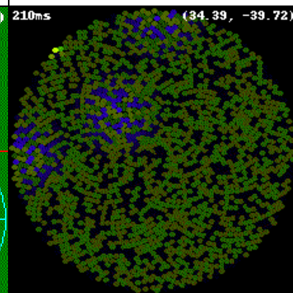
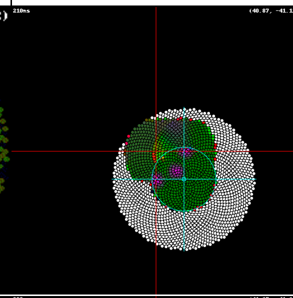
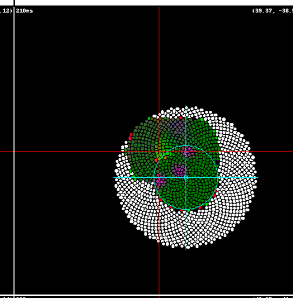
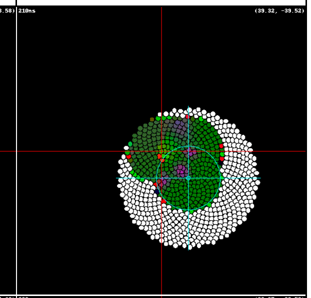
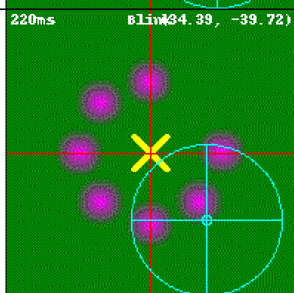
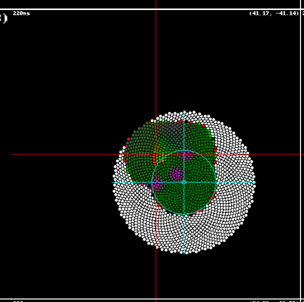
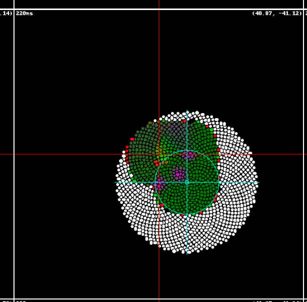
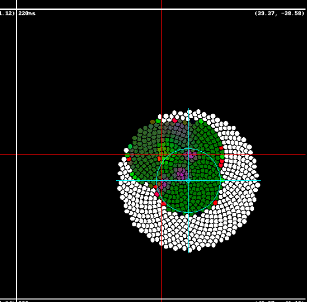
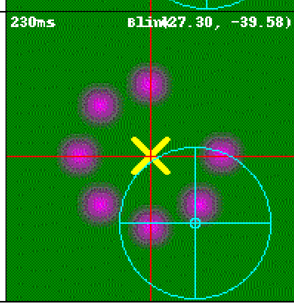
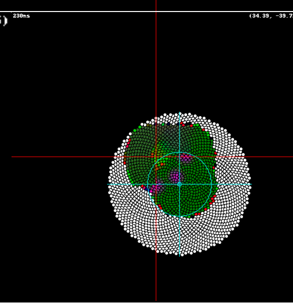
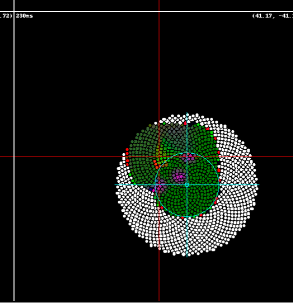
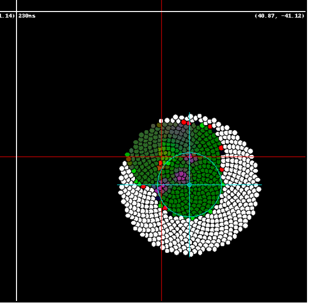
Table 37: Time sequence of dynamic image with blinks					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
21					
22					
23					

Table 37: Time sequence of dynamic image with blinks

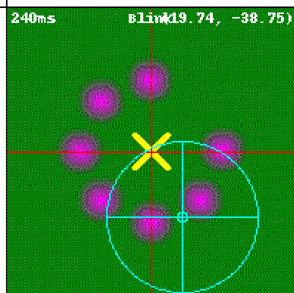
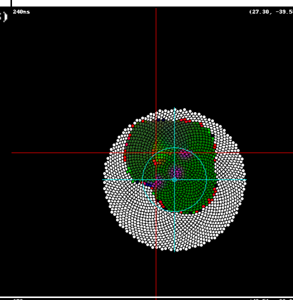
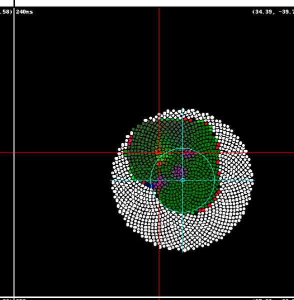
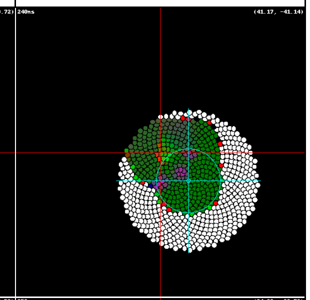
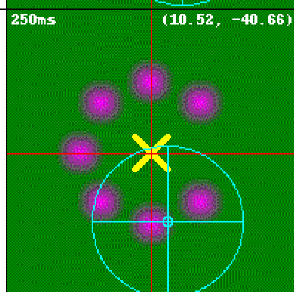
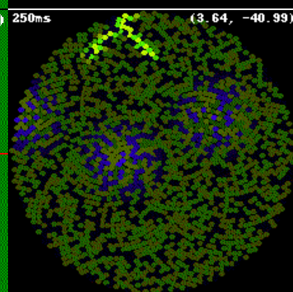
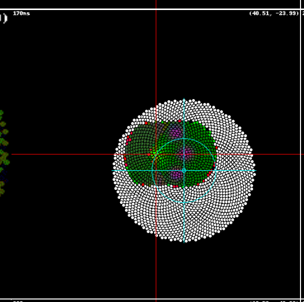
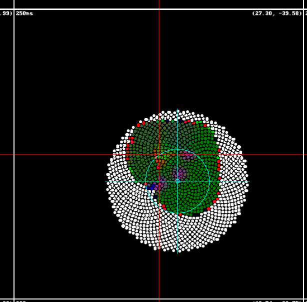
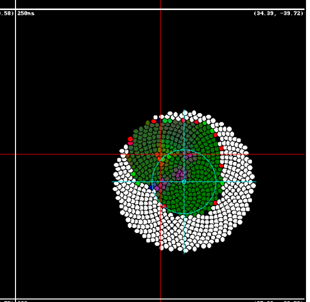
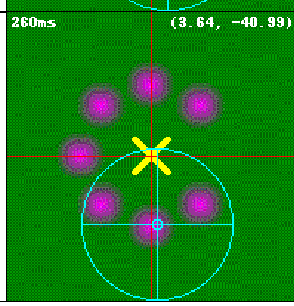
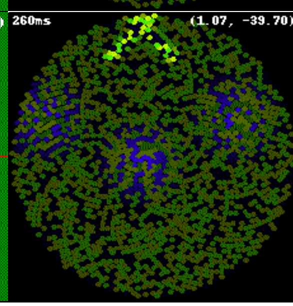
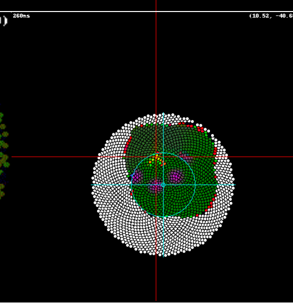
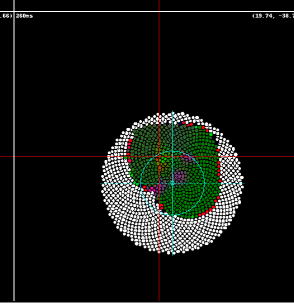
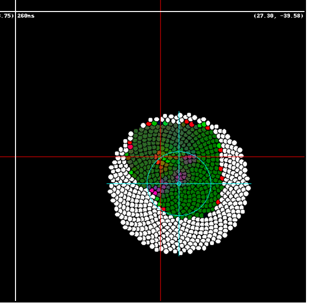
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields Level 1	Receptive Fields Level 2	Receptive Fields Level 3
24					
25					
26					

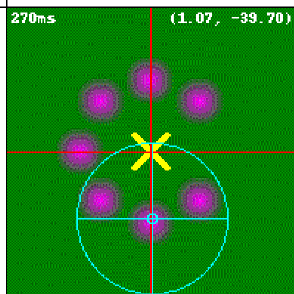
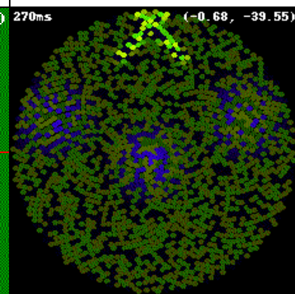
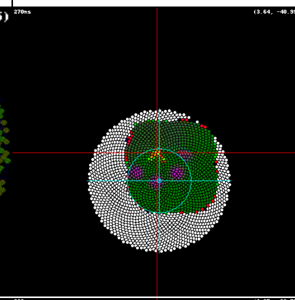
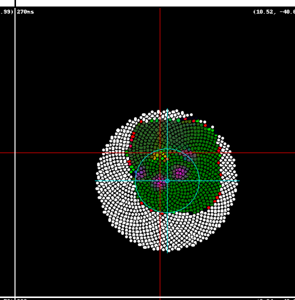
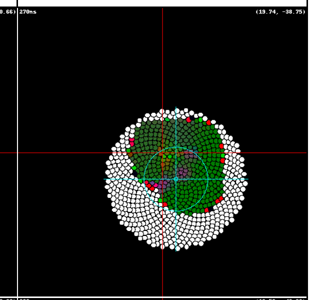
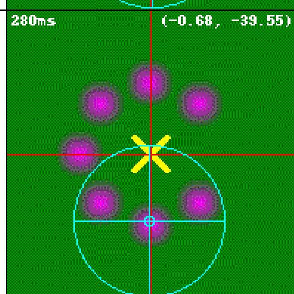
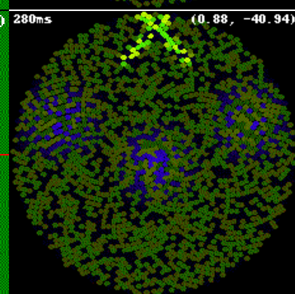
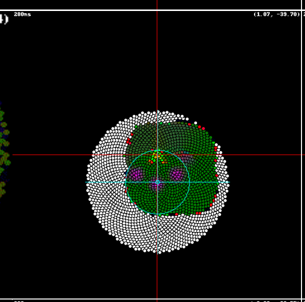
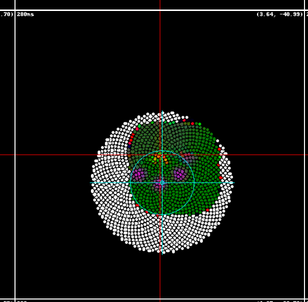
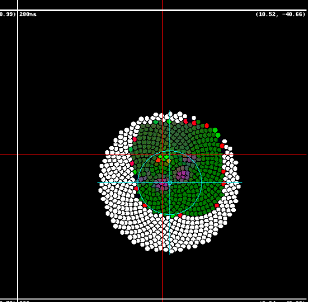
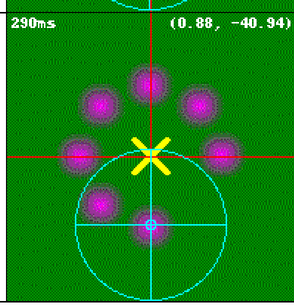
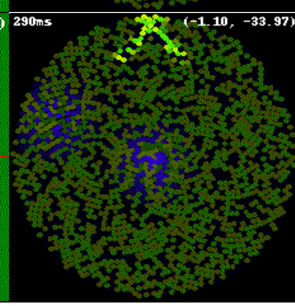
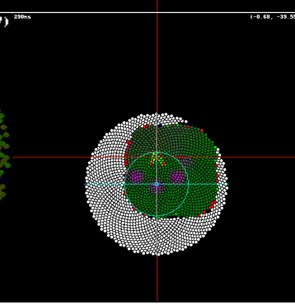
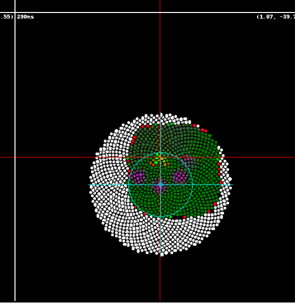
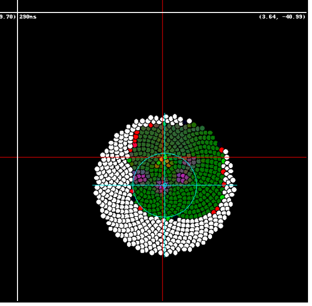
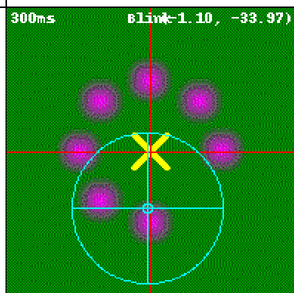
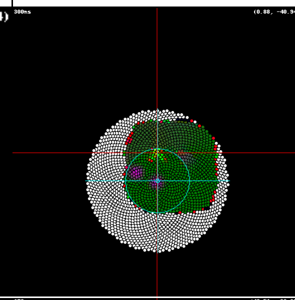
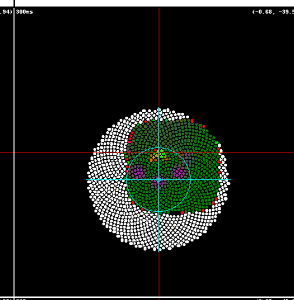
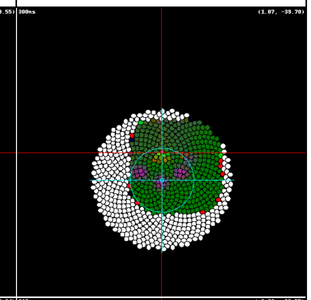
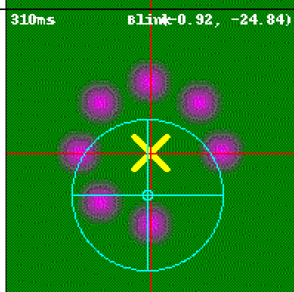
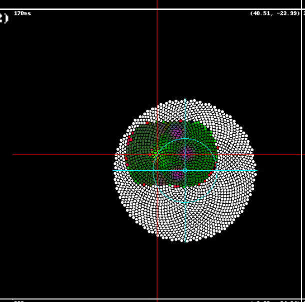
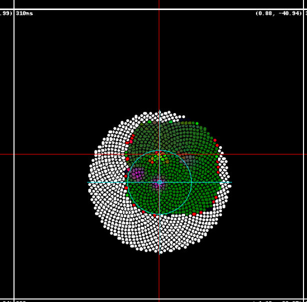
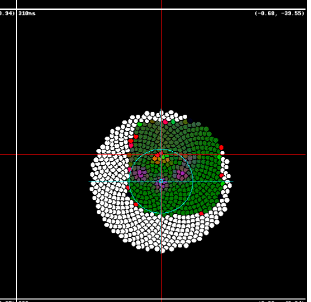
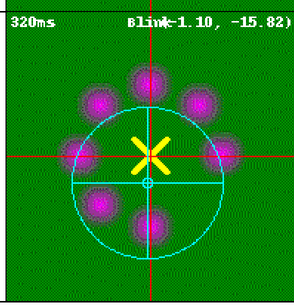
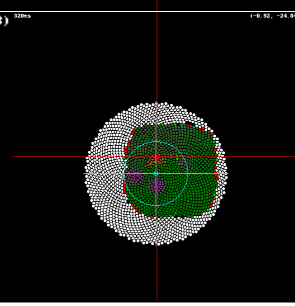
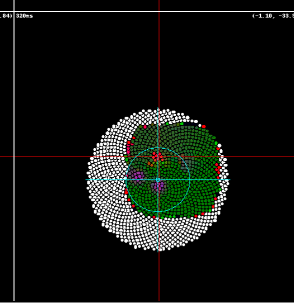
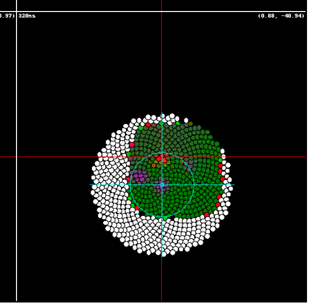
Table 37: Time sequence of dynamic image with blinks					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
27					
28					
29					

Table 37: Time sequence of dynamic image with blinks					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
30					
31					
32					

C.3.4 Test 4 results: Rapid and extended blinking (Square)

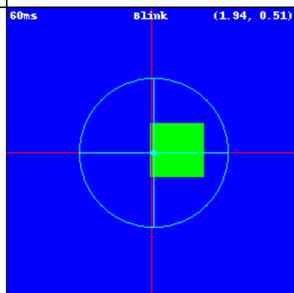
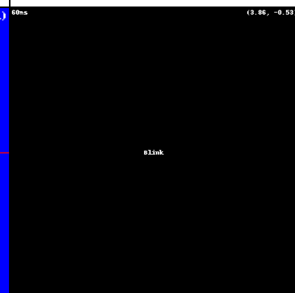
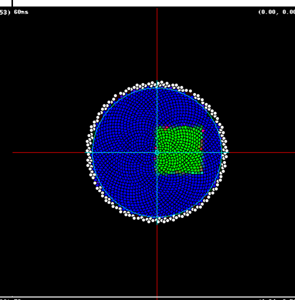
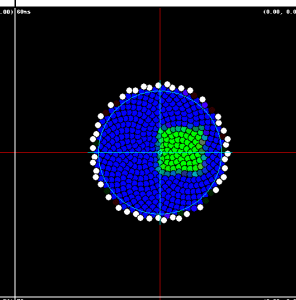
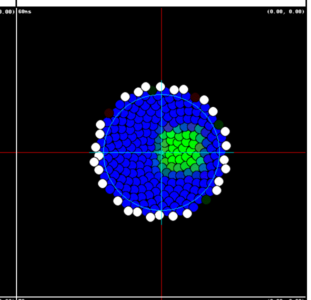
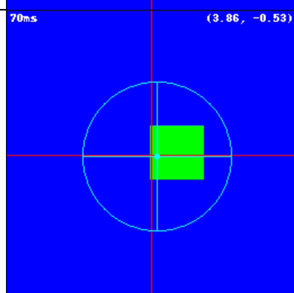
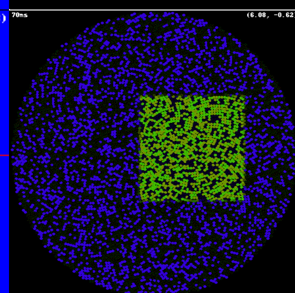
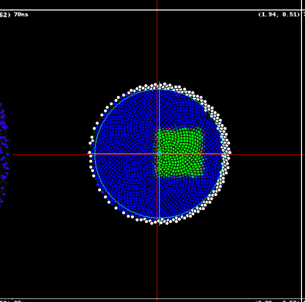
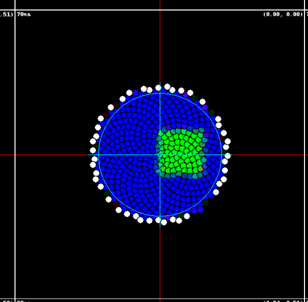
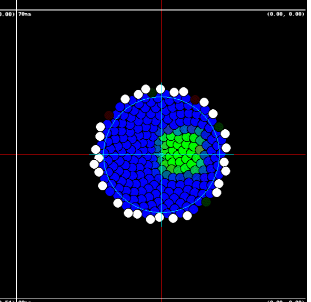
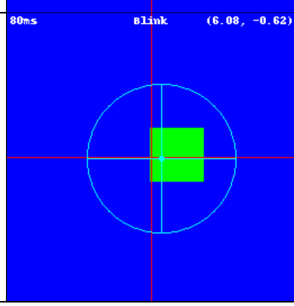
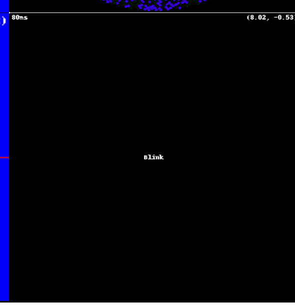
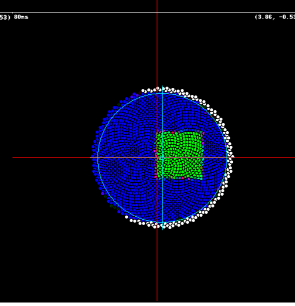
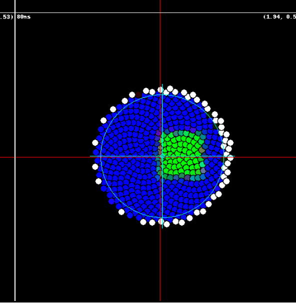
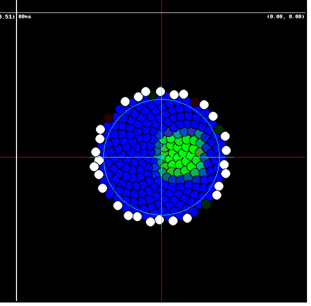
Table 38: Time sequence of simple object with rapid and extended blinking					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
6					
7					
8					

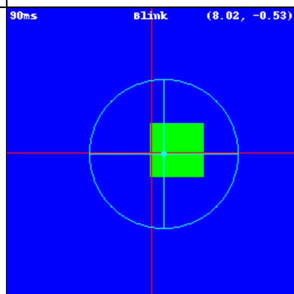
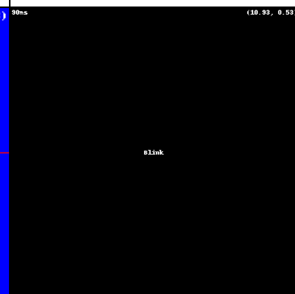
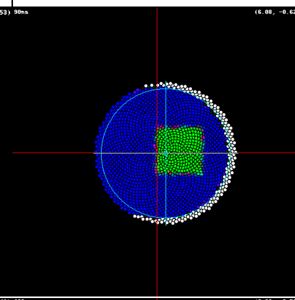
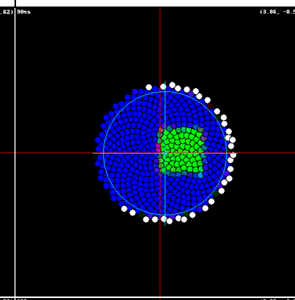
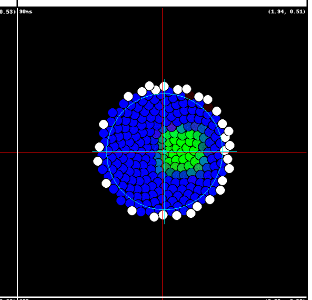
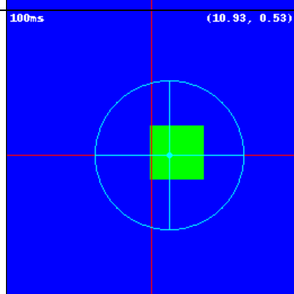
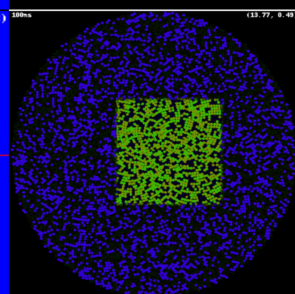
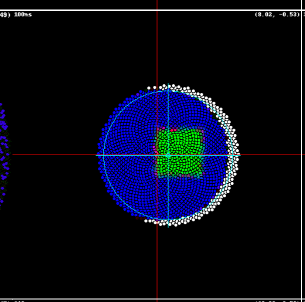
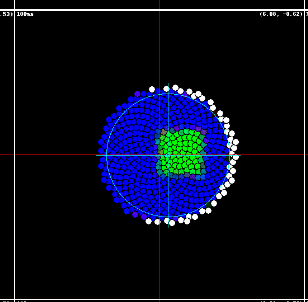
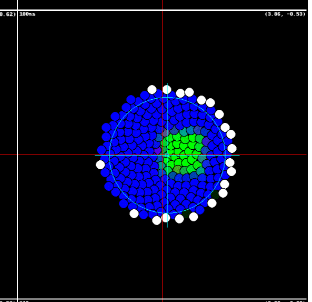
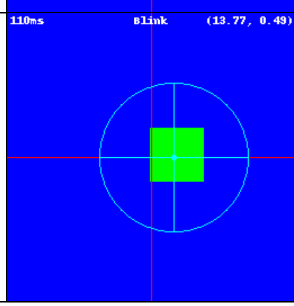
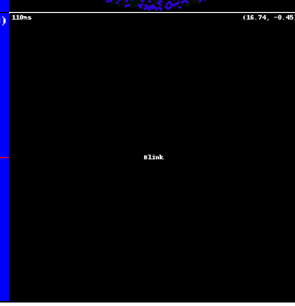
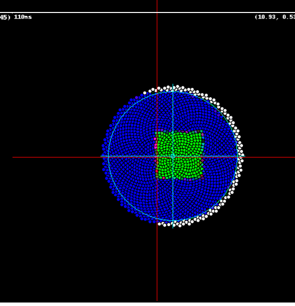
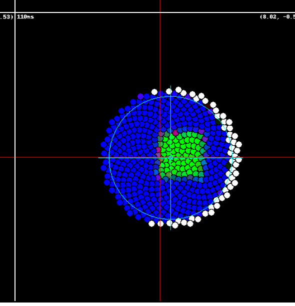
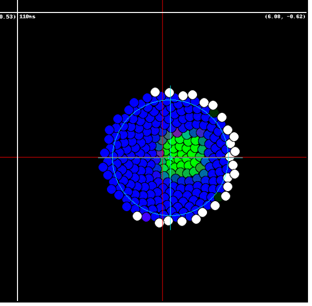
Table 38: Time sequence of simple object with rapid and extended blinking					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
9					
10					
11					

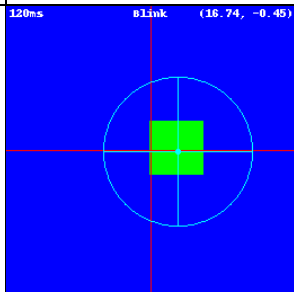
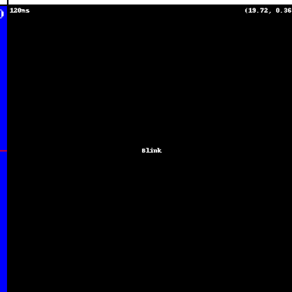
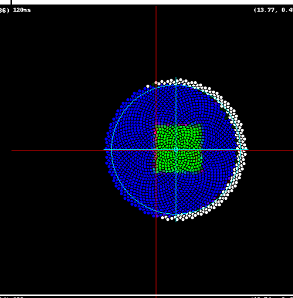
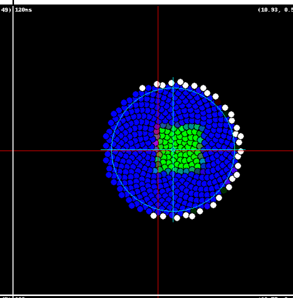
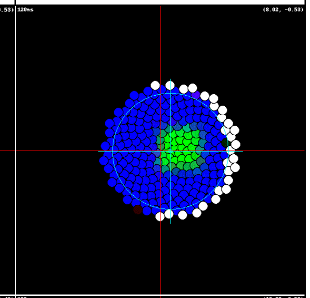
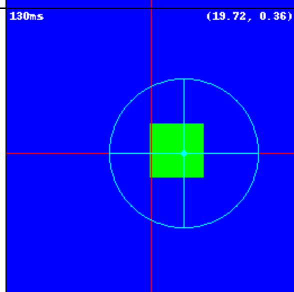
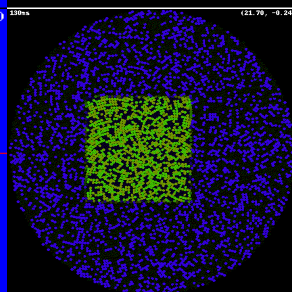
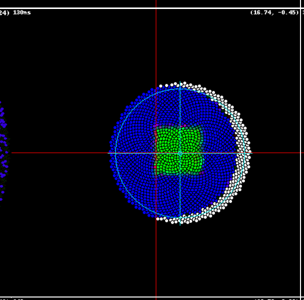
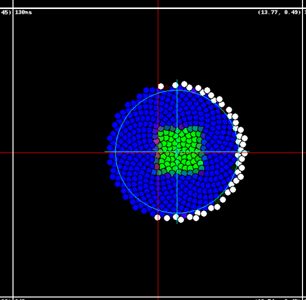
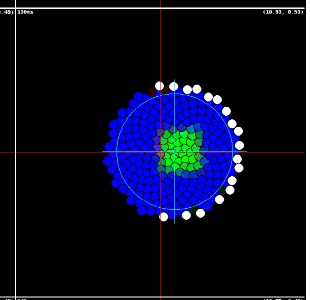
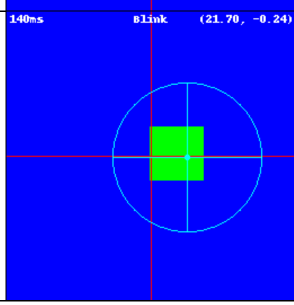
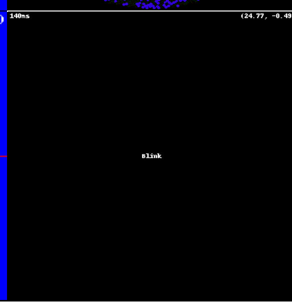
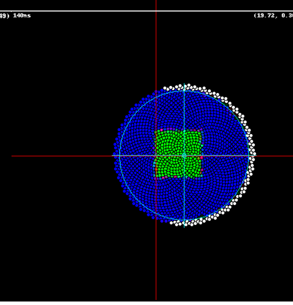
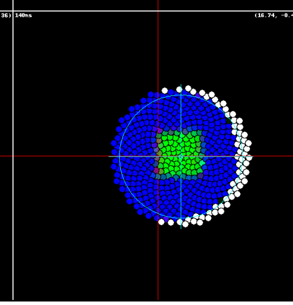
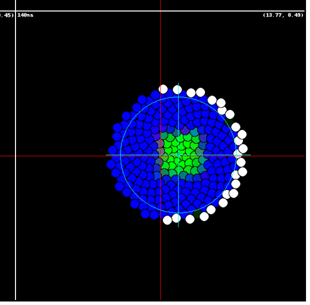
Table 38: Time sequence of simple object with rapid and extended blinking					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
12					
13					
14					

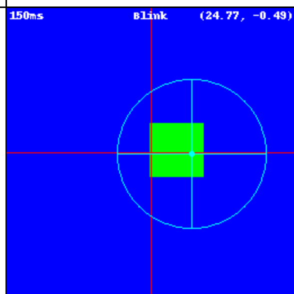
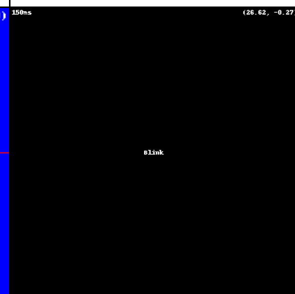
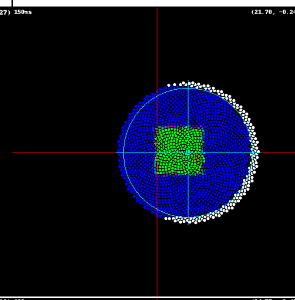
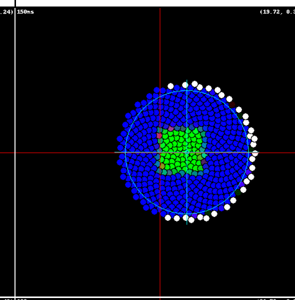
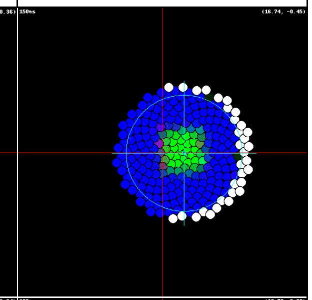
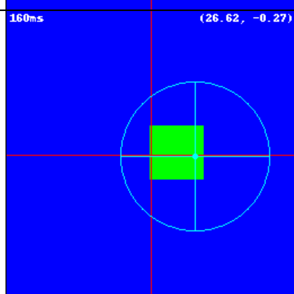
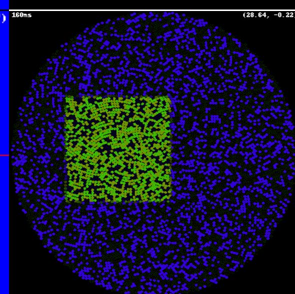
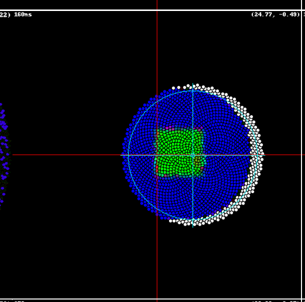
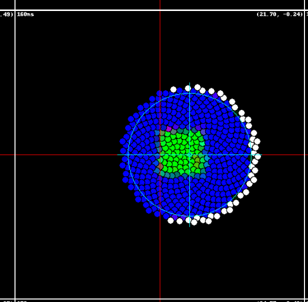
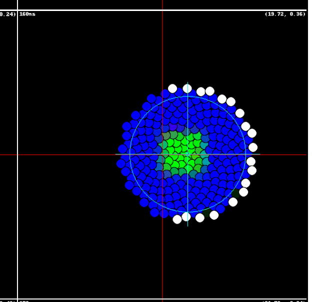
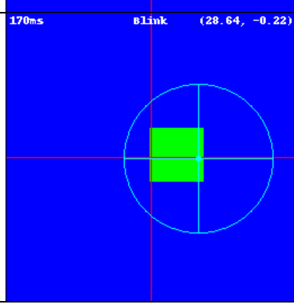
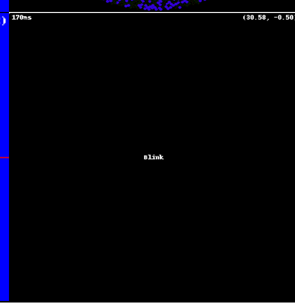
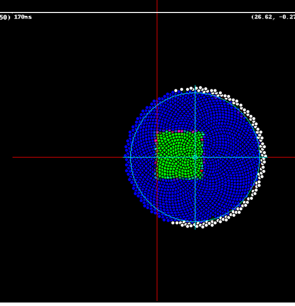
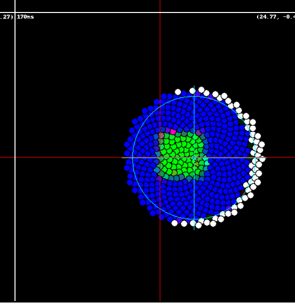
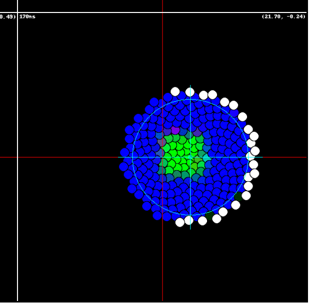
Table 38: Time sequence of simple object with rapid and extended blinking					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
15					
16					
17					

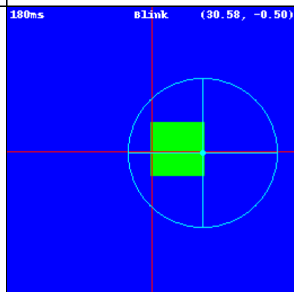
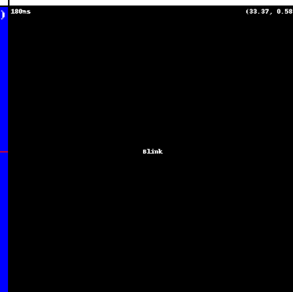
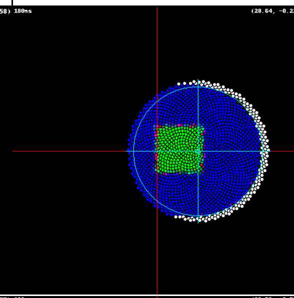
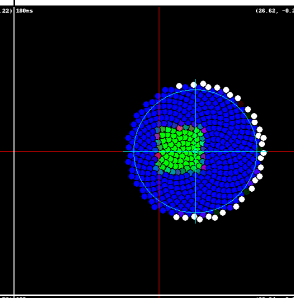
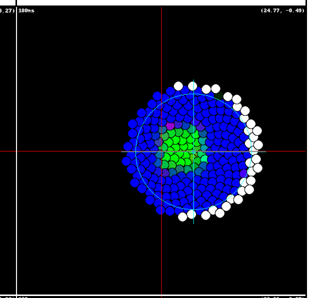
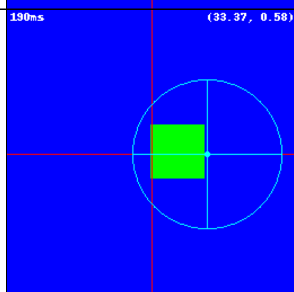
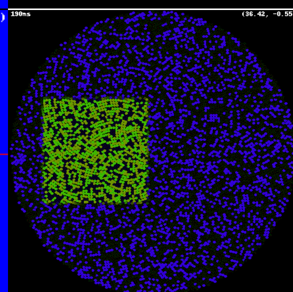
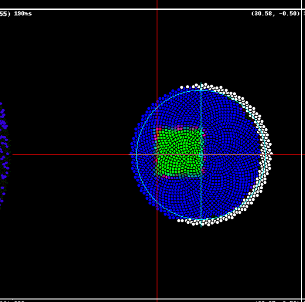
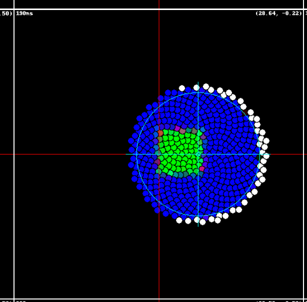
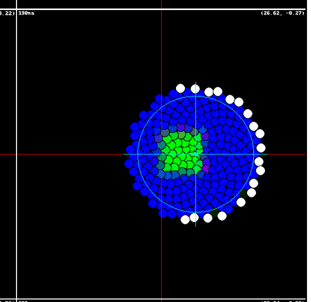
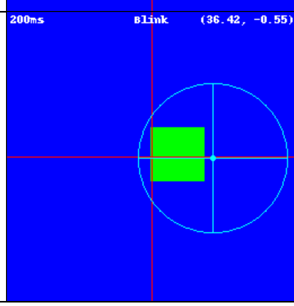
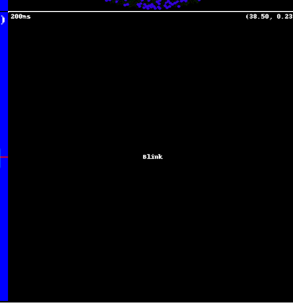
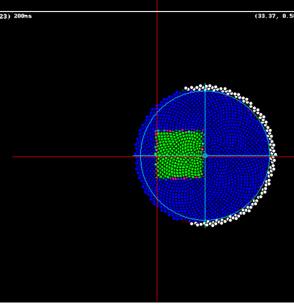
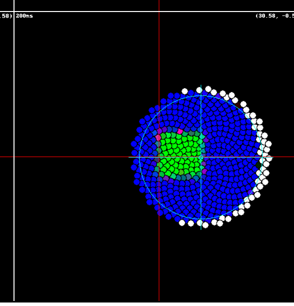
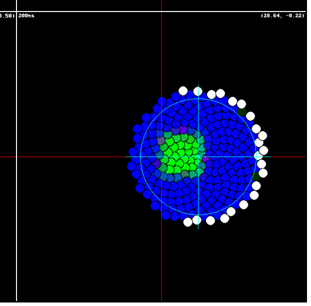
Table 38: Time sequence of simple object with rapid and extended blinking					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
18					
19					
20					

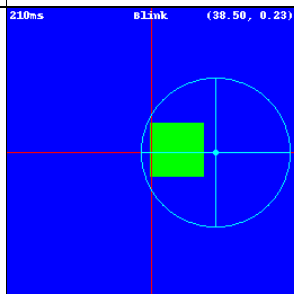
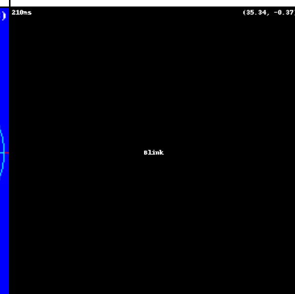
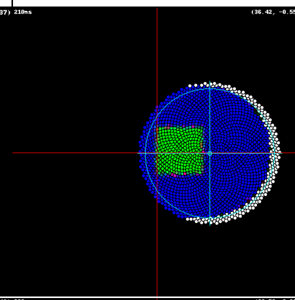
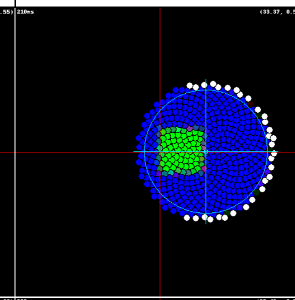
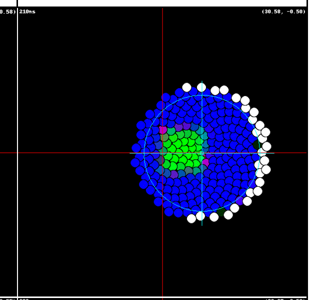
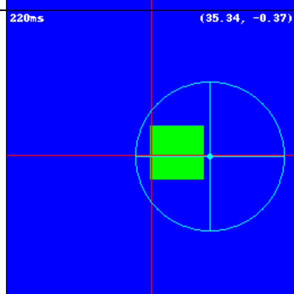
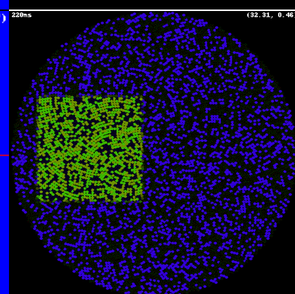
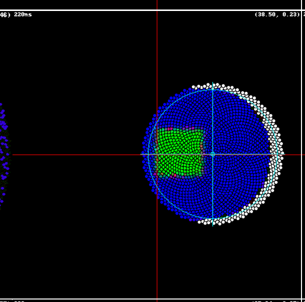
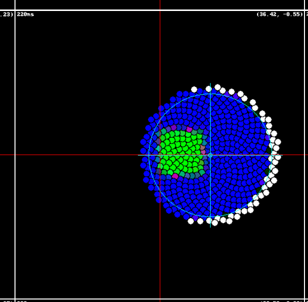
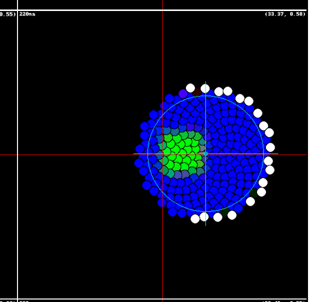
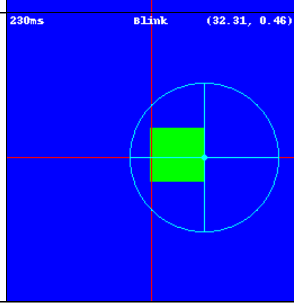
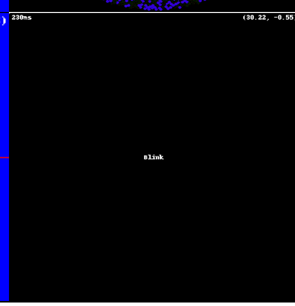
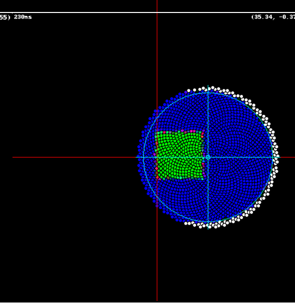
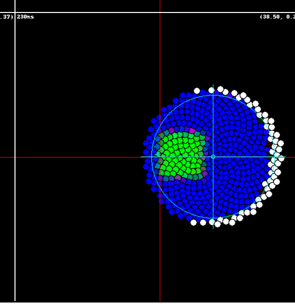
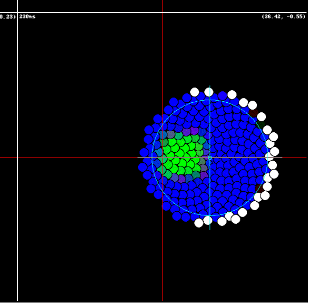
Table 38: Time sequence of simple object with rapid and extended blinking					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
21					
22					
23					

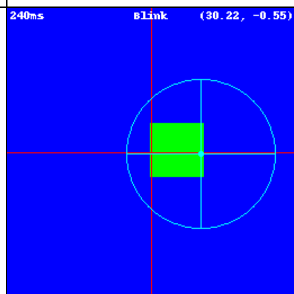
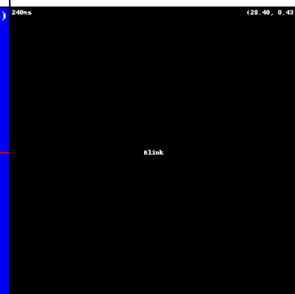
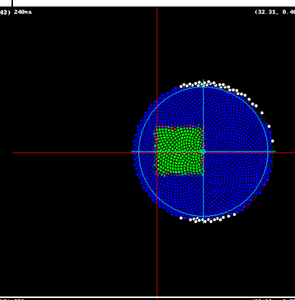
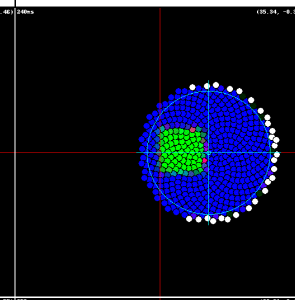
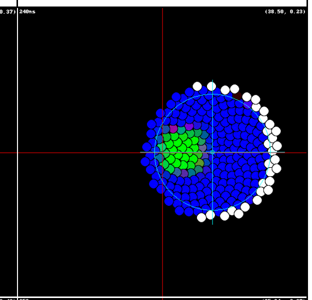
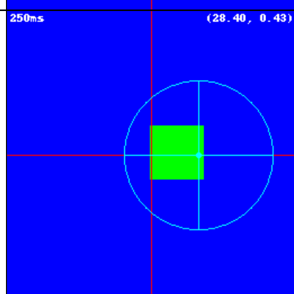
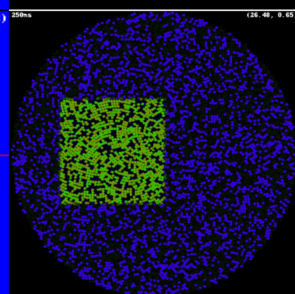
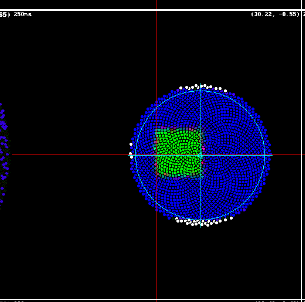
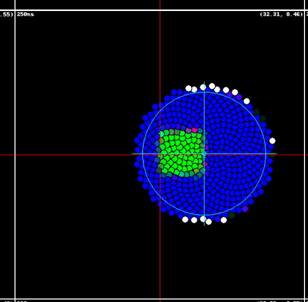
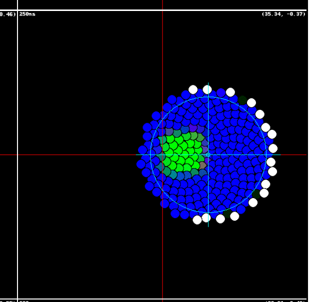
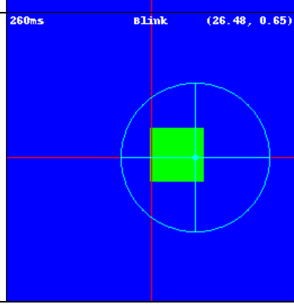
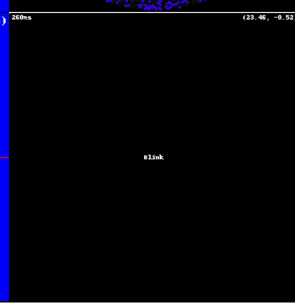
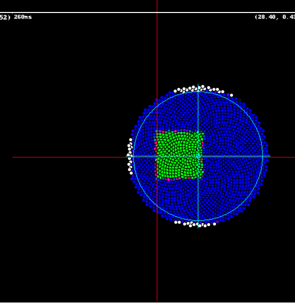
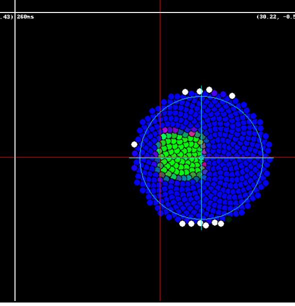
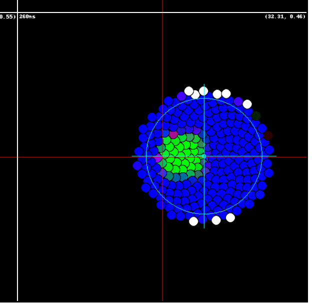
Table 38: Time sequence of simple object with rapid and extended blinking					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
24					
25					
26					

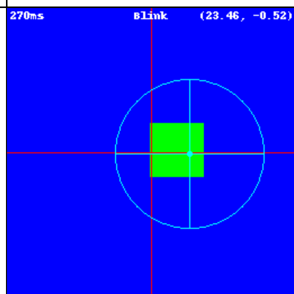
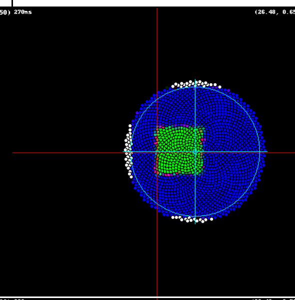
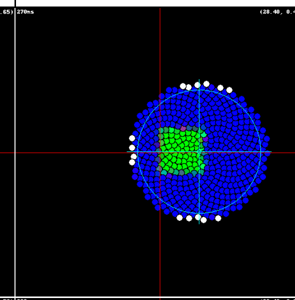
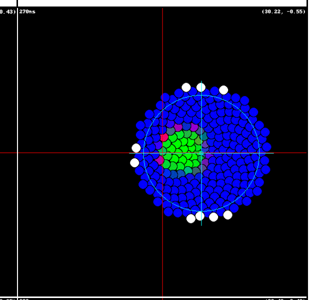
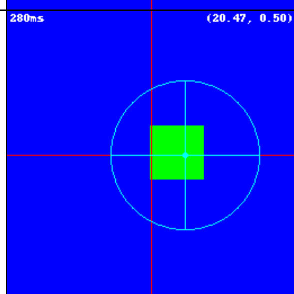
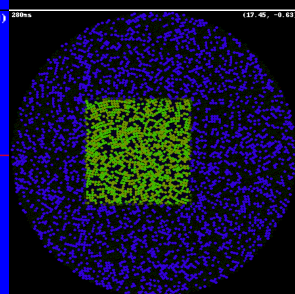
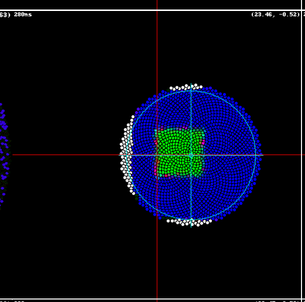
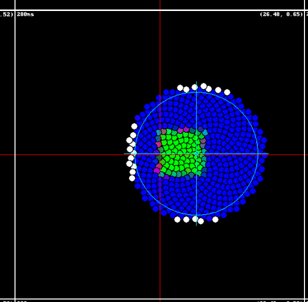
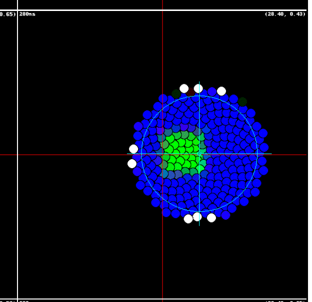
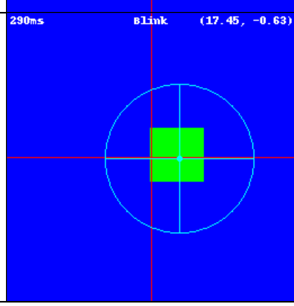
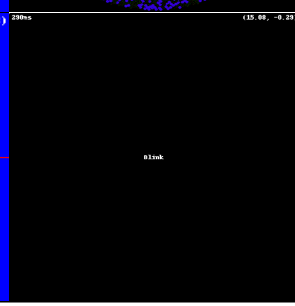
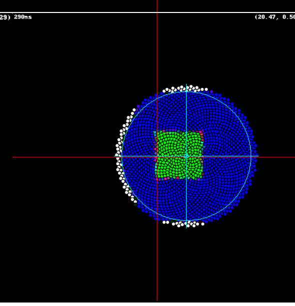
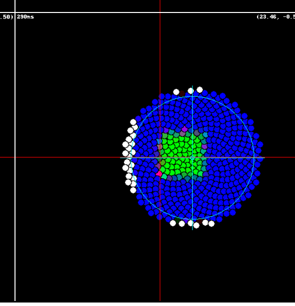
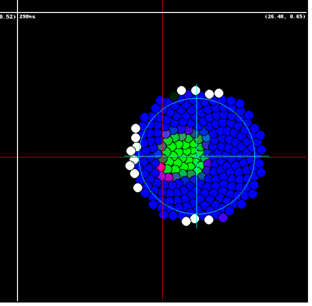
Table 38: Time sequence of simple object with rapid and extended blinking					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
27					
28					
29					

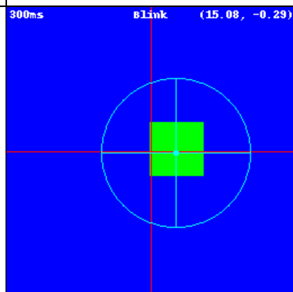
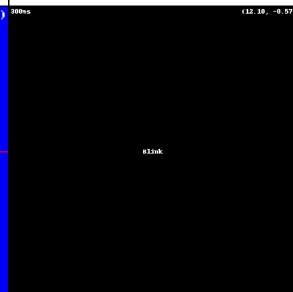
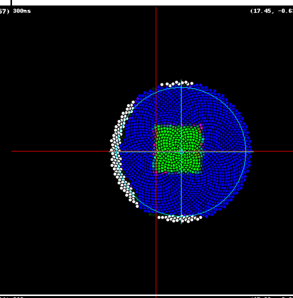
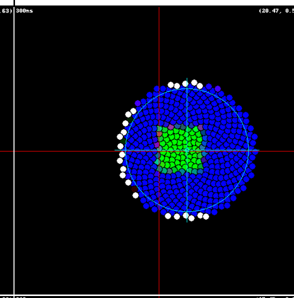
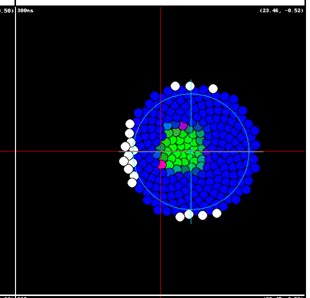
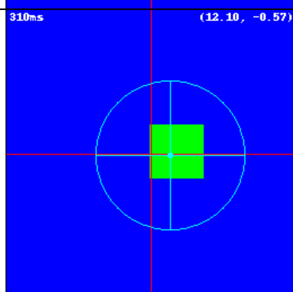
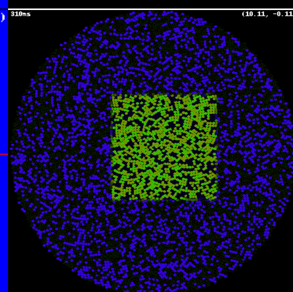
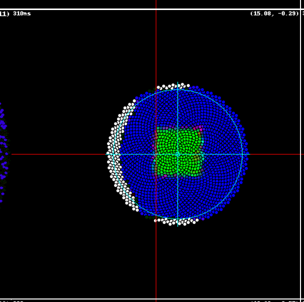
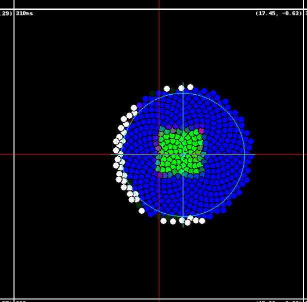
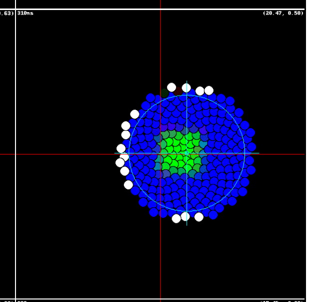
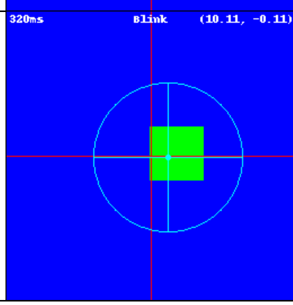
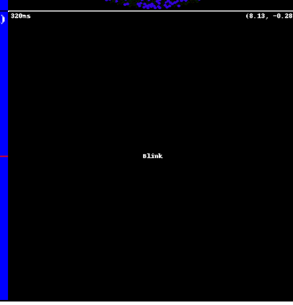
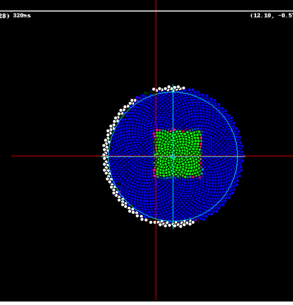
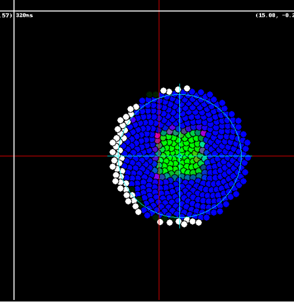
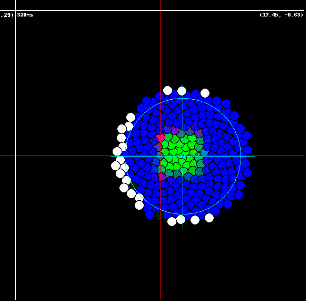
Table 38: Time sequence of simple object with rapid and extended blinking					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
30					
31					
32					

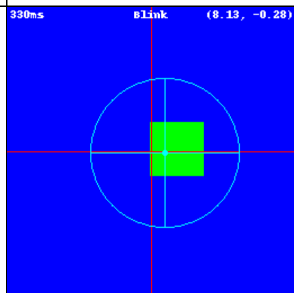
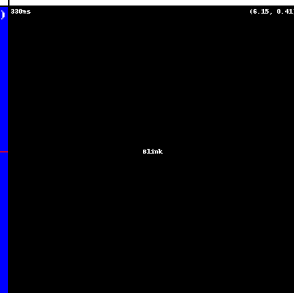
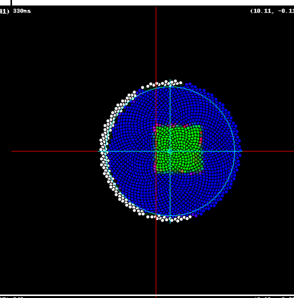
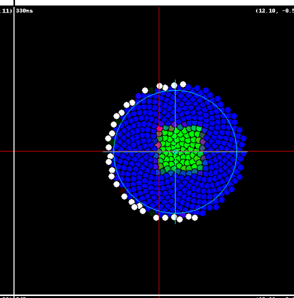
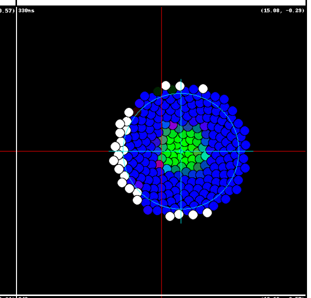
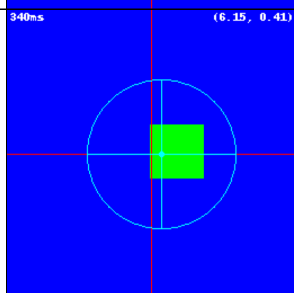
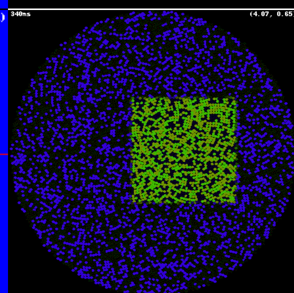
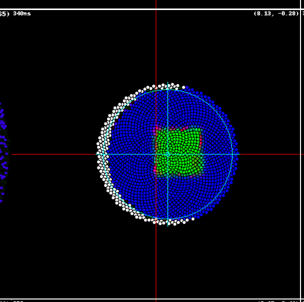
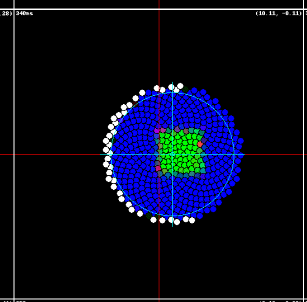
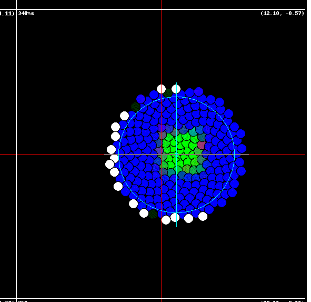
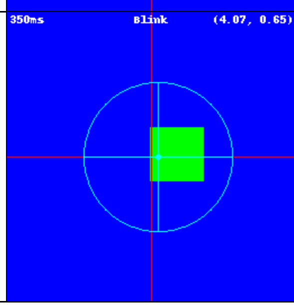
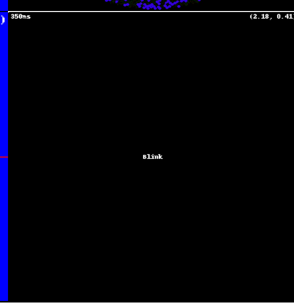
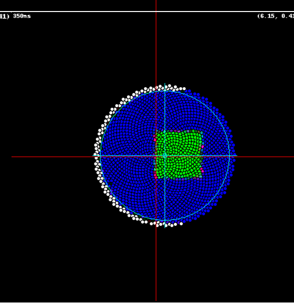
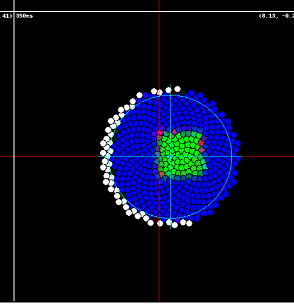
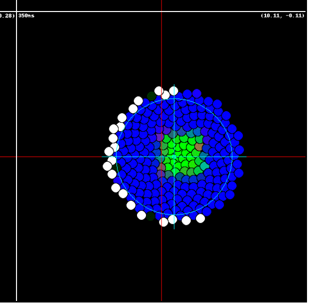
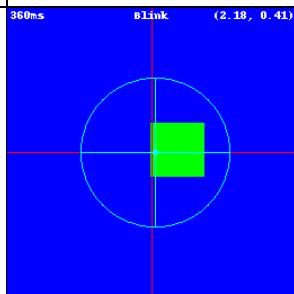
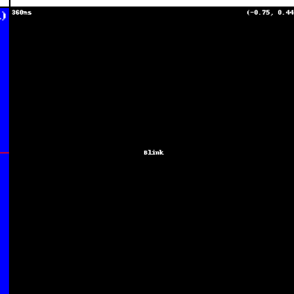
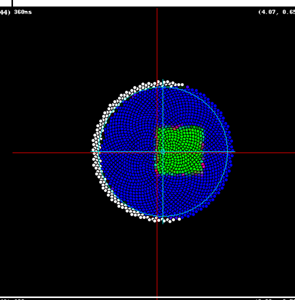
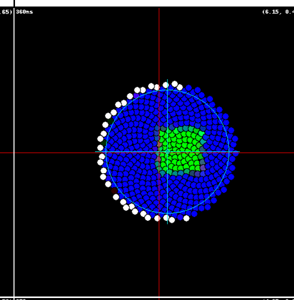
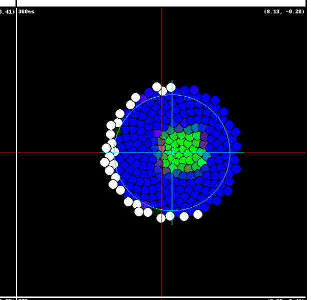
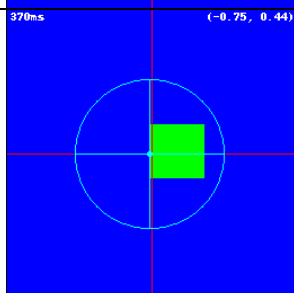
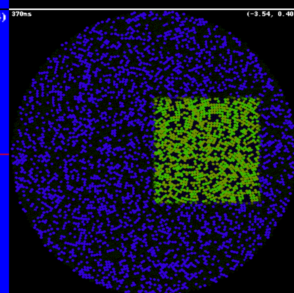
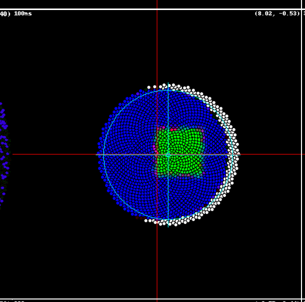
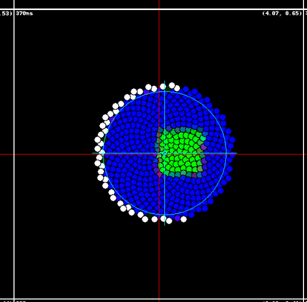
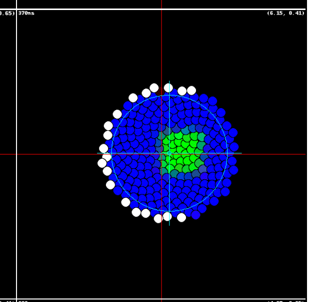
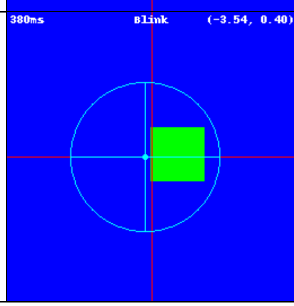
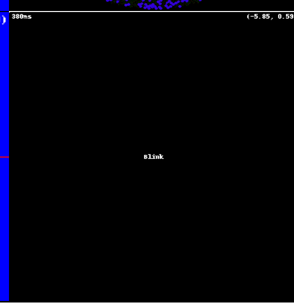
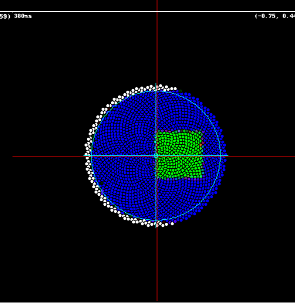
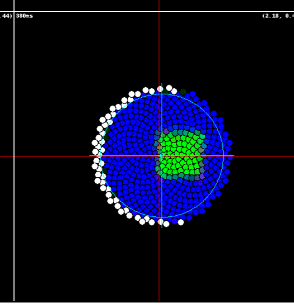
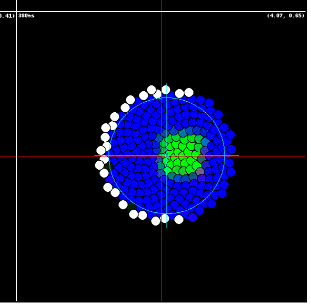
Table 38: Time sequence of simple object with rapid and extended blinking					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
33					
34					
35					

Table 38: Time sequence of simple object with rapid and extended blinking					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
36					
37					
38					

Appendix D: An emergic model of filling-in from imagination

These supplement the corresponding material in the thesis.

D.1 Subject details

Three virtual subjects were used in these four tests. Each is fully characterized by a set of developmental and behavioural parameters that will be indicated next. The meaning of these parameters can be found in the thesis. Note that development includes a stochastic component so that, for example, while the L:M:S cone ratio may be innately specified, the colour sensitivity type of individual cones is random.

D.1.1 Test 1 subject (Quick)

Same as filling-out for trans-saccadic integration person of Test 1 on page 43 – one can imagine both within the photoreceptor region and without.

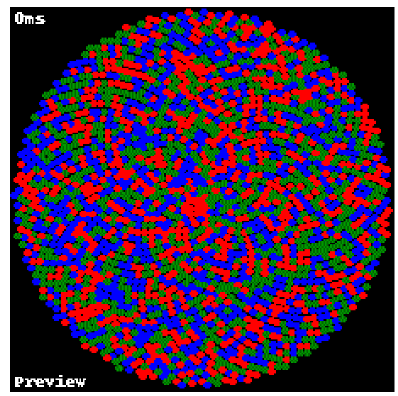


Illustration 42: Imagination Test 1 (Fast) person

```
[Person]
note = Imagine
srt = 10
sex = ai
age = 18
eyecount = 1
ipd = 0
vsize = 17.0
vieweyez = 50
r0conepix = 4
nodalpt = 17
r0coned = 8.0
r0red = 1
r0green = 1
r1coned = 1.0
r1red = 800
r1green = 800
r1blue = 800
blindx = 0.0
blindy = 0.0
blindr = 0.0
jitmin = 0.1
jitave = 0.7
jitmax = 0.9
p1_0_pixd = 2.5
p1_0_pix = 2000
p1_0_scale = 2
p1_0_fanlat = 5.0
p1_0_fandwn = 2.0
p1_1_pixd = 3.0
p1_1_pix = 1390
p1_1_scale = 2
p1_1_fanlat = 2.0
p1_1_fandwn = 2.0
p1_2_pixd = 4.0
p1_2_pix = 782
p1_2_scale = 2
p1_2_fanlat = 1.2
p1_2_fandwn = 1.5
```

Produces 572459 Emergic Links.

D.1.2 Test 2 & 3 subject (Slow)

Similar to Test 1 but with less fan-out to characterize the slowing down of imagination.

```
[Person]
note = Imagine Slow
srt = 10
sex = ai
age = 18
eyecount = 1
ipd = 0
vsize = 17.0
vieweyez = 50
r0conepix = 4
nodalpt = 17
r0coned = 8.0
r0red = 1
r0green = 1
r1coned = 1.0
r1red = 800
r1green = 800
r1blue = 800
blindx = 0.0
blindy = 0.0
blindr = 0.0
jitmin = 0.1
jitave = 0.7
jitmax = 0.9
p1_0_pixd = 2.5
p1_0_pix = 2000
p1_0_scale = 2
p1_0_fanlat = 1.0
p1_0_fandwn = 1.0
p1_1_pixd = 3.0
p1_1_pix = 1390
p1_1_scale = 2
p1_1_fanlat = 1.0
p1_1_fandwn = 1.0
p1_2_pixd = 4.0
p1_2_pix = 782
p1_2_scale = 2
p1_2_fanlat = 1.2
p1_2_fandwn = 1.0
```

Produces 246289 Emergic Links.

D.1.3 Test 4 subject (Slow & Distorted)

Similar to Test 2-3 but with high eccentricity dependent heterogeneity and 10:1 R:G ratio to characterize imagination of straight lines.

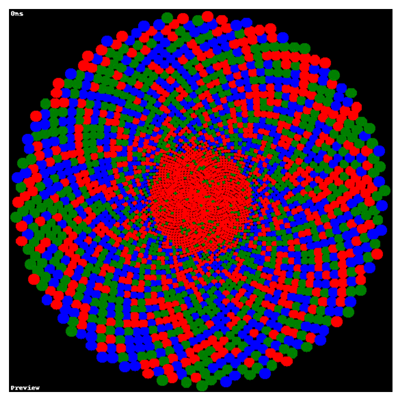


Illustration 43: Imagination Test 4 (Distorted) person

```
[Person]
note = Filling-out
srt = 10
sex = ai
age = 18
eyecount = 1
ipd = 0
vsize = 17.0
vieweyez = 50
r0conepix = 4
nodalpt = 17
r0coned = 8.0
r0red = 1000
r0green = 100
r1coned = 4.0
r1red = 800
r1green = 800
r1blue = 800
blindx = 0.0
blindy = 0.0
blindr = 0.0
jitmin = 0.1
jitave = 0.7
jitmax = 0.9
p1_0_pixd = 2.5
p1_0_pix = 2000
p1_0_scale = 2
p1_0_fanlat = 1.0
p1_0_fandwn = 1.0
p1_1_pixd = 3.0
p1_1_pix = 1390
p1_1_scale = 2
p1_1_fanlat = 1.0
p1_1_fandwn = 1.0
p1_2_pixd = 4.0
p1_2_pix = 782
p1_2_scale = 2
p1_2_fanlat = 1.2
p1_2_fandwn = 1.0
```

D.2 Stimuli details

A single emergic value (for each of the LMS cone sensitivities) is injected at tick=1 into the central RF in the 3rd level. The connectivity of this RF is such that it will distribute this value downwards and laterally. The initializer or *constructor* for the emergic value has the following signature

```
ValueXY((x,y,v,w)…)
```

where

x: the x-coordinate of this sample value

y: the y-coordinate of this sample value

v: the LMS colour value of this sample from 0 to 255

w: the weight assigned to this sample value

…: repeatable, in which case this emergic value represents the descriptive statistics for all the samples weighted accordingly

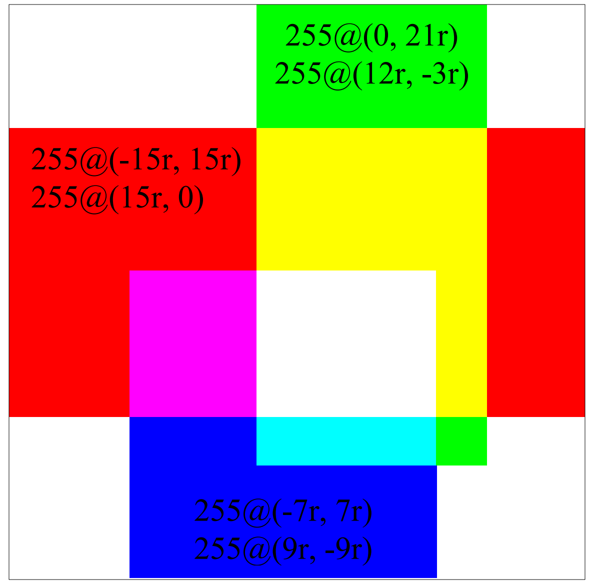


Illustration 44: Imagined rectangles. Three Emergic Values delivered once to the three RGB (LMS) *sensory* pathways of the central RF at Level 3. Intersecting colours shown on GUI with no *perceptual* support within ECM. r=radius of central RF; coordinates represent statistics within Emergic Values (Top Left and Bottom Right corners).

If *r* is the radius of the central RF, then these are the three injected values

L/Red:	`ValueXY((-15*r, 15*r, 255, 9),` `        ( 15*r,    0, 255, 9))`
M/Green:	`ValueXY((    0, 21*r, 255, 9),` `        ( 12*r, -3*r, 255, 9))`
S/Blue:	`ValueXY(( -7*r,  7*r, 255, 9),` `        (  9*r, -9*r, 255, 9))`

This spatial extent of this single set of LMS values is shown in Illustration 44.

D.3 Result details

In this section we tabulate a visual frame-by-frame account of results from all experiments. Such a frame-by-frame account allows for the extraction of precise timing information useful for quantitative analysis. It takes 36 pages. All these results are reduced to a single web page of animated images, available at

http://emergic.upwize.com/?page_id=263

The animated account (Leibovitz, 2012a) is preferred as an overview showing behavioural dynamics of filling-out of imagination, memory, jitter, etc. and makes image stability more salient. It also includes the results in greatest detail – they have been scaled down for print in this supplement, and even smaller in the chapter's *results and discussion* sections.

Each table of results has the following columns. **Time** numerically represents the time tick since the test has started, nominally 10ms/tick. All visual results in that table row are after the tick and computation have finished. **Stimuli** visually represents the stimuli presented to the virtual computer screen, often with retinal overlays. The **Photoreceptor Mosaic** visually represents what the retina senses by looking at the stimuli. **Receptive Fields** at **Level 1**, **Level 2** and **Level 3**, visually represent the three level hierarchy of receptive fields showing their the functional size and placement, not physical size nor placement

D.3.1 Test 1 results: Imagine quickly

Table 39: Time sequence of imagining quickly

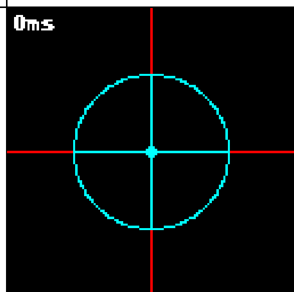
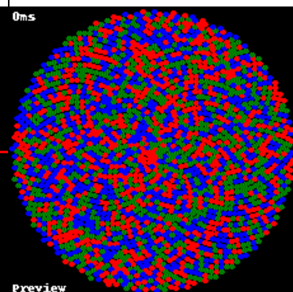
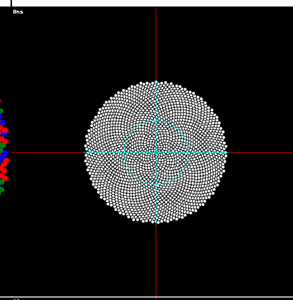
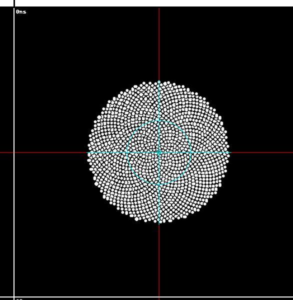
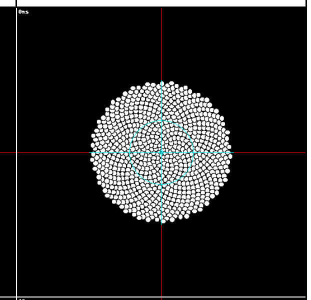
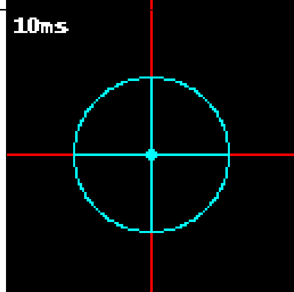
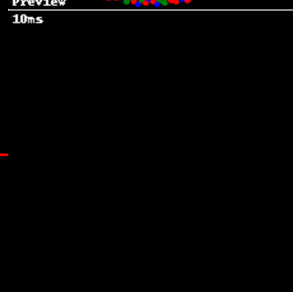
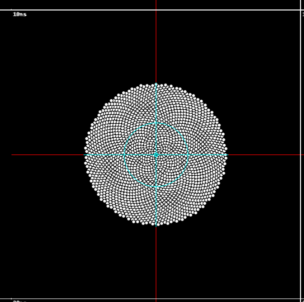
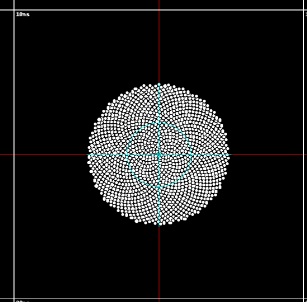
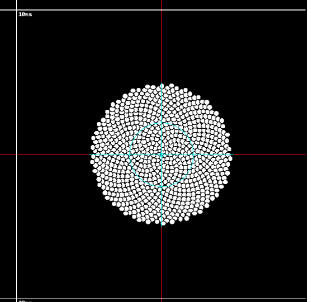
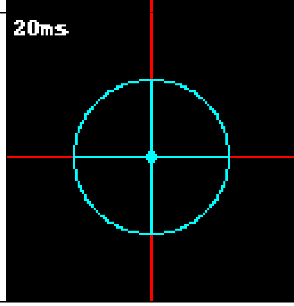
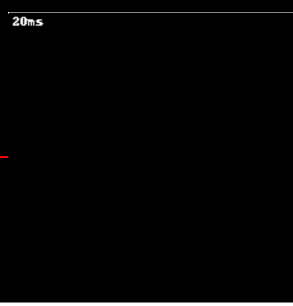
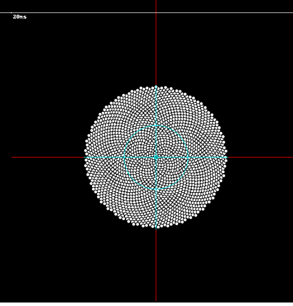
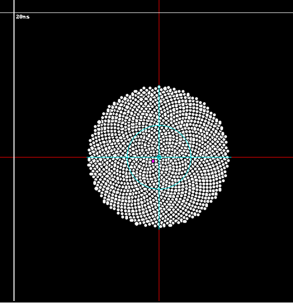
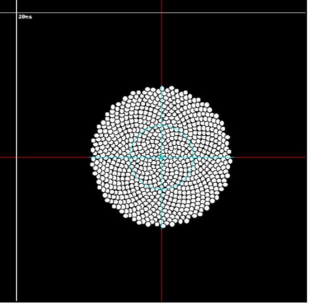
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields Level 1	Receptive Fields Level 2	Receptive Fields Level 3
0					
1					
2					

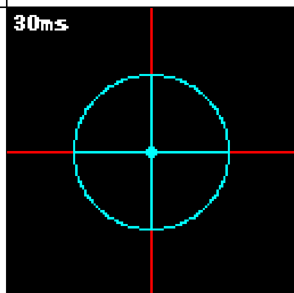
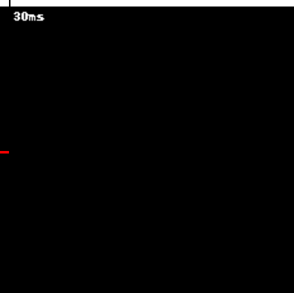
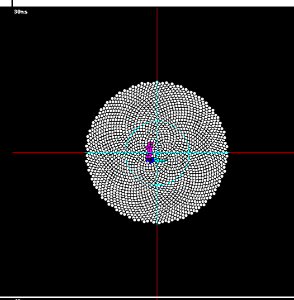
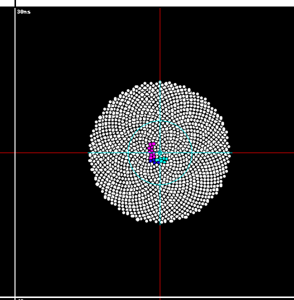
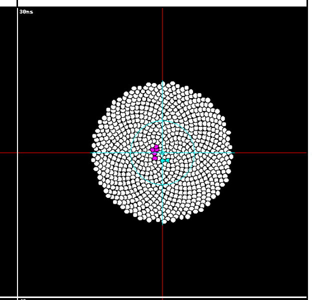
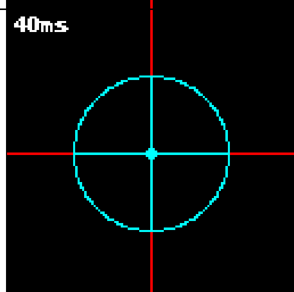
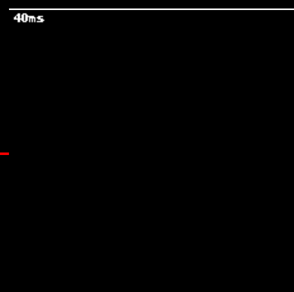
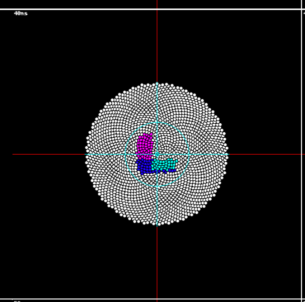
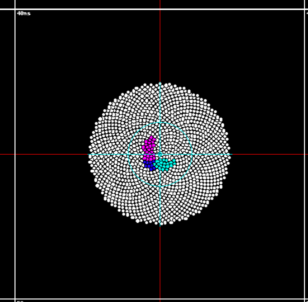
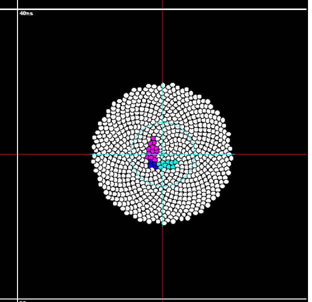
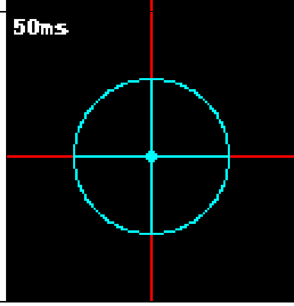
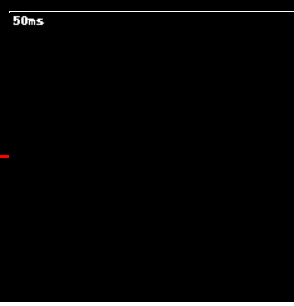
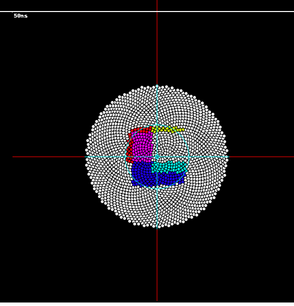
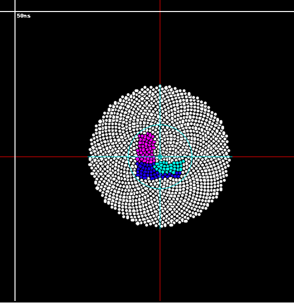
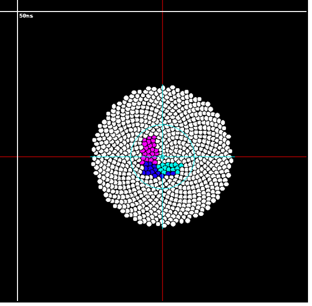
Table 39: Time sequence of imagining quickly					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
3					
4					
5					

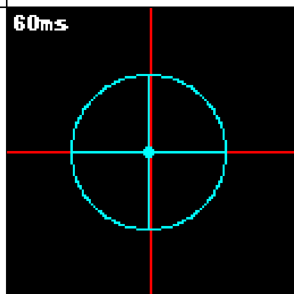
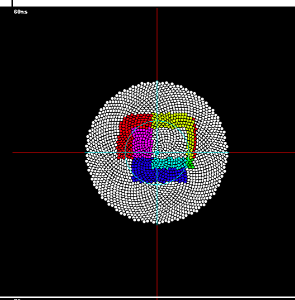
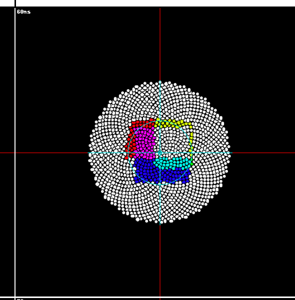
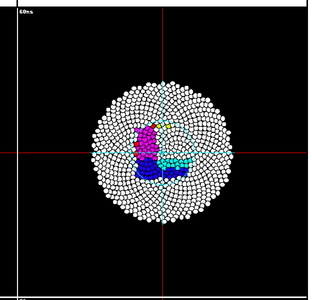
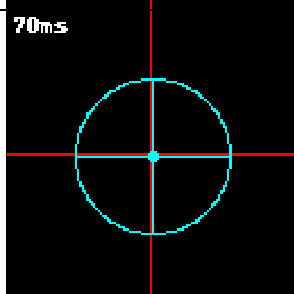
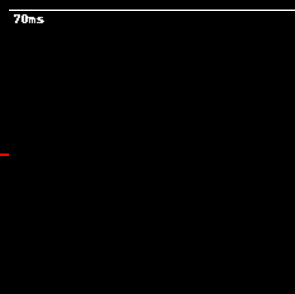
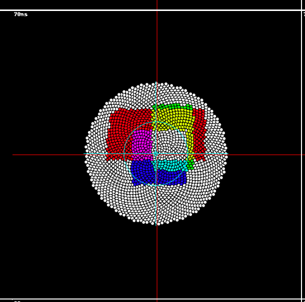
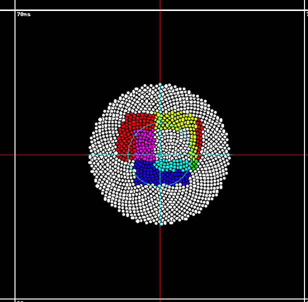
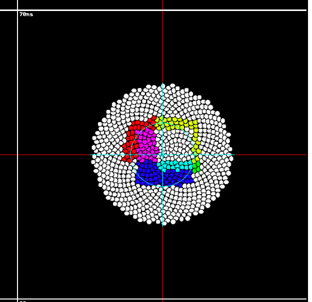
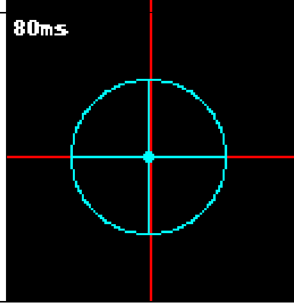
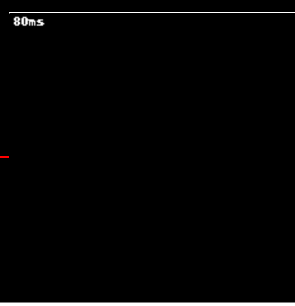
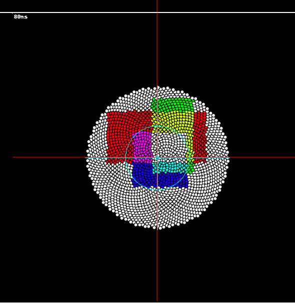
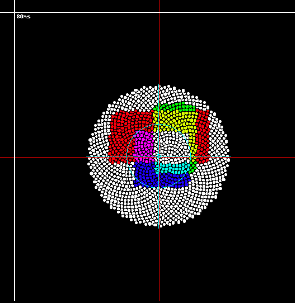
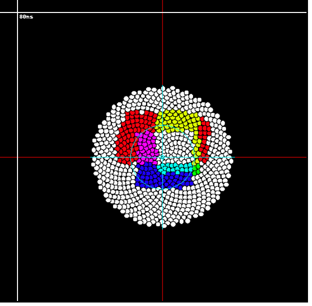
Table 39: Time sequence of imagining quickly					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
6					
7					
8					

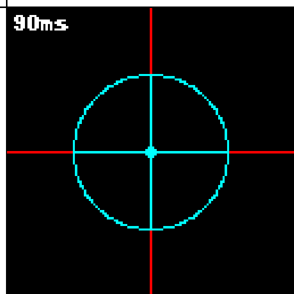
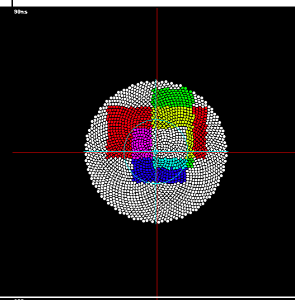
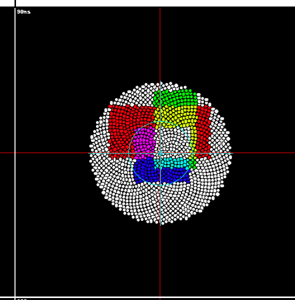
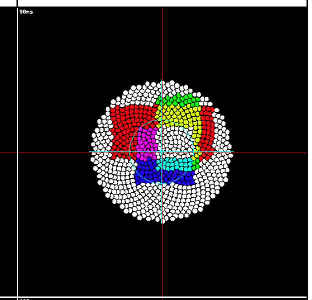
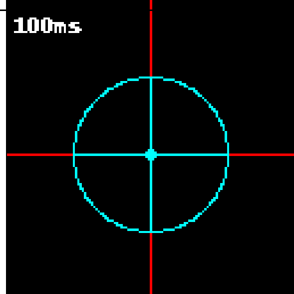
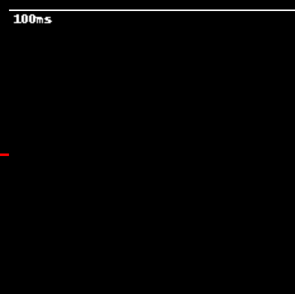
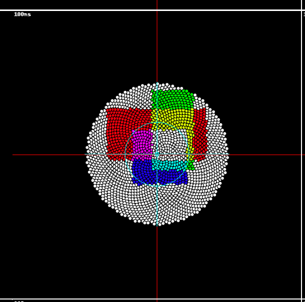
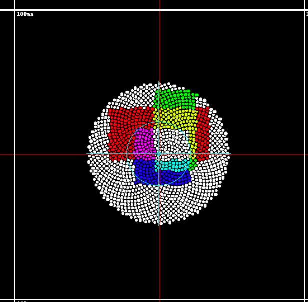
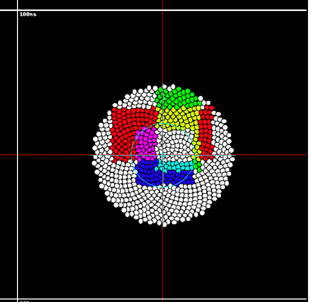
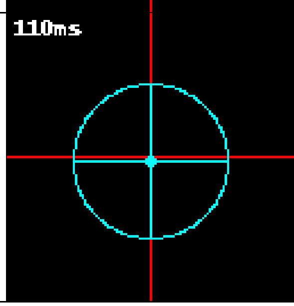
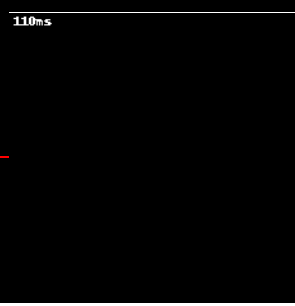
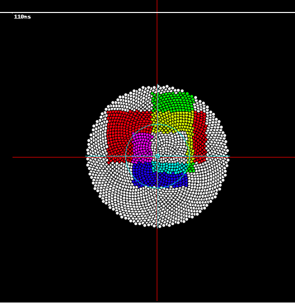
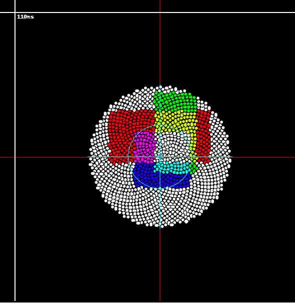
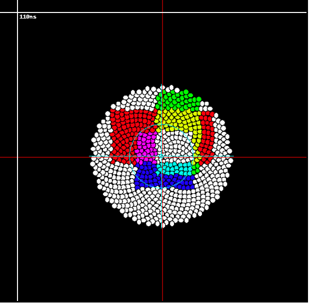
Table 39: Time sequence of imagining quickly					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
9					
10					
11					

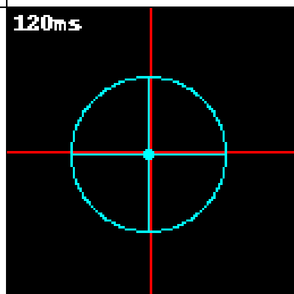
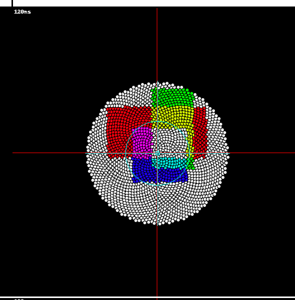
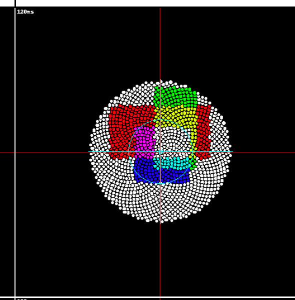
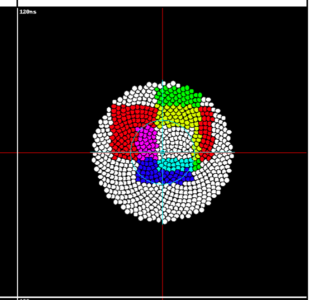
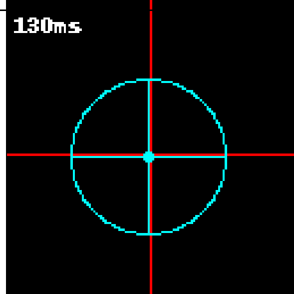
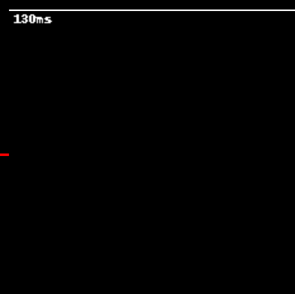
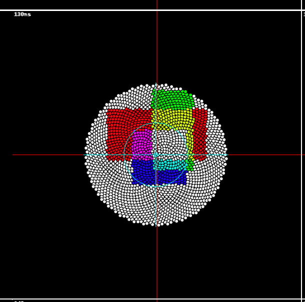
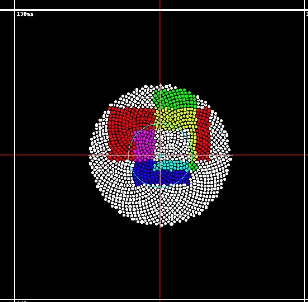
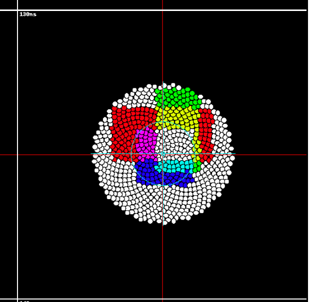
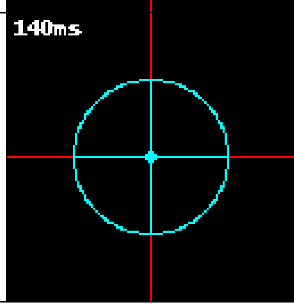
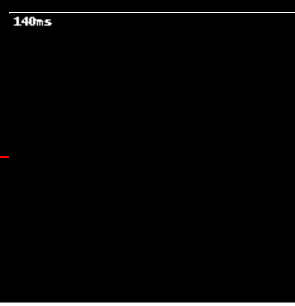
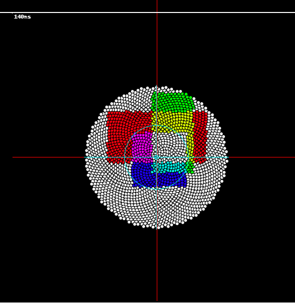
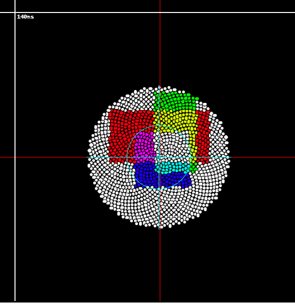
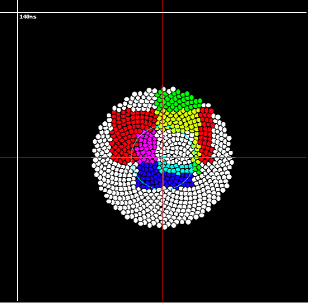
Table 39: Time sequence of imagining quickly					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
12					
13					
14					

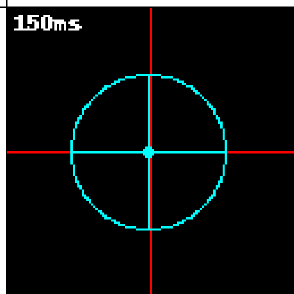
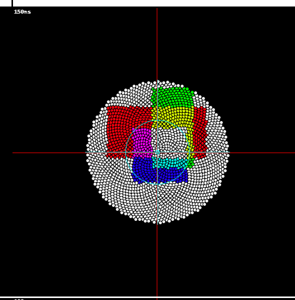
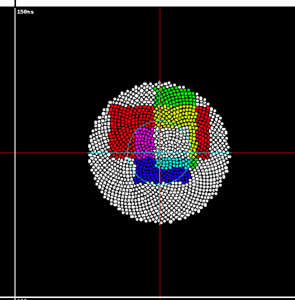
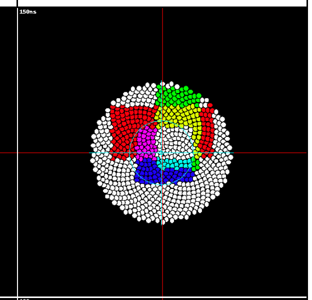
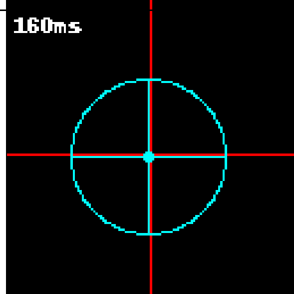
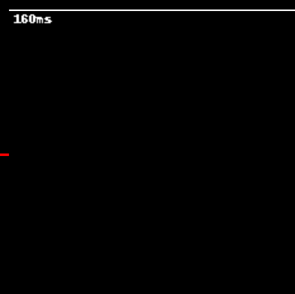
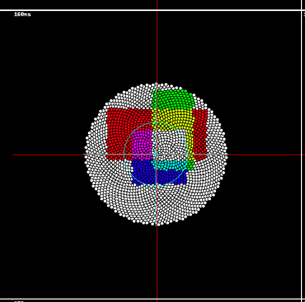
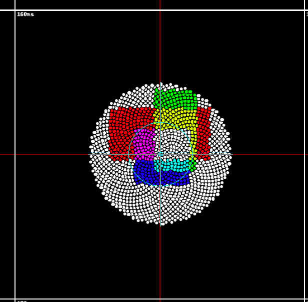
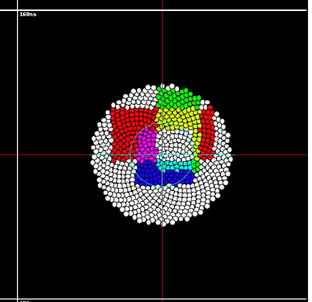
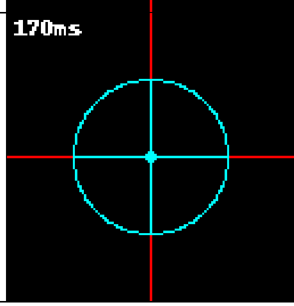
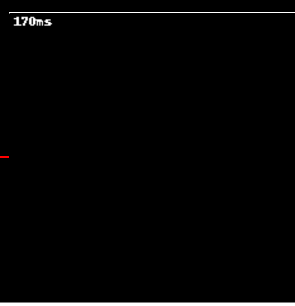
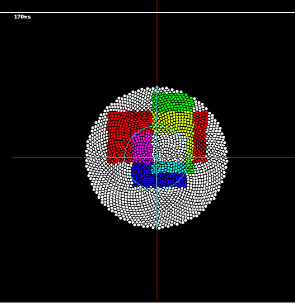
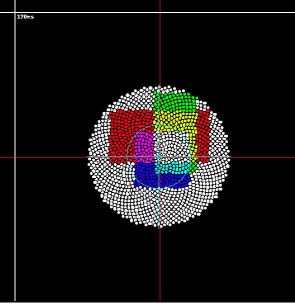
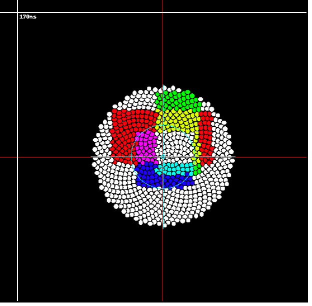
Table 39: Time sequence of imagining quickly					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
15					
16					
17					

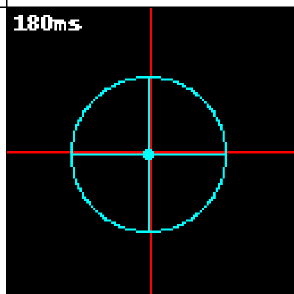
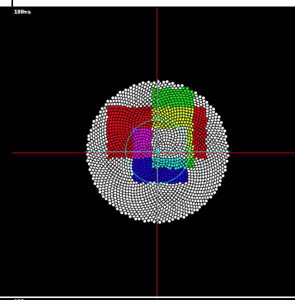
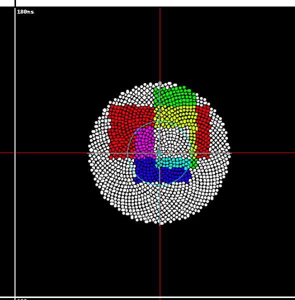
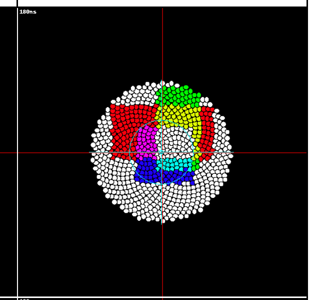
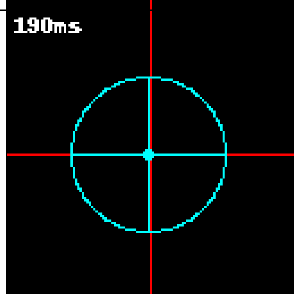
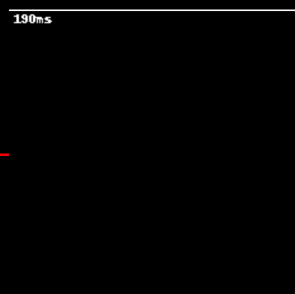
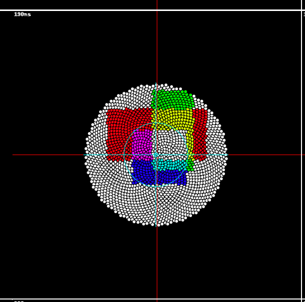
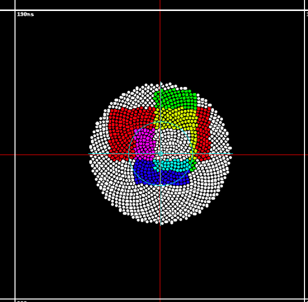
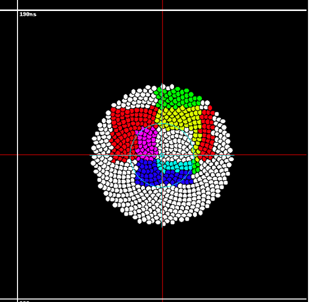
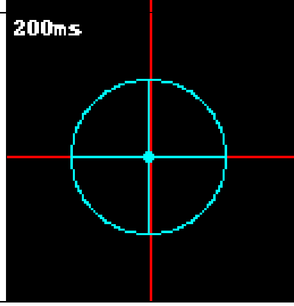
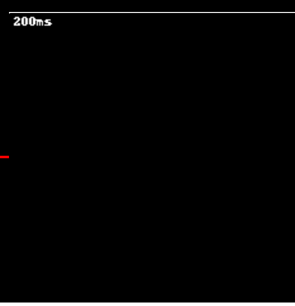
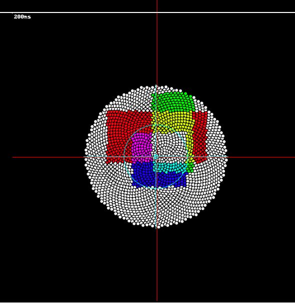
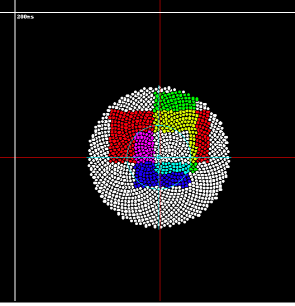
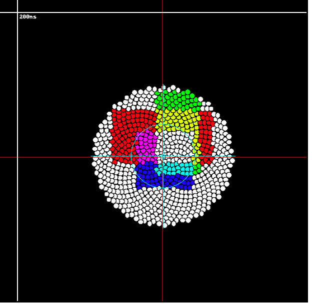
Table 39: Time sequence of imagining quickly					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
18					
19					
20					

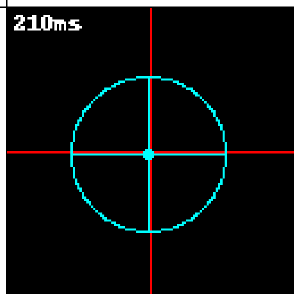
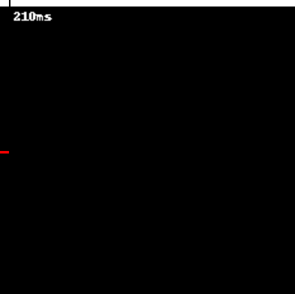
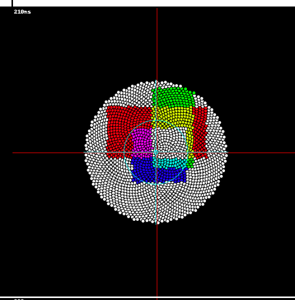
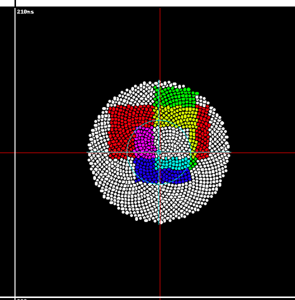
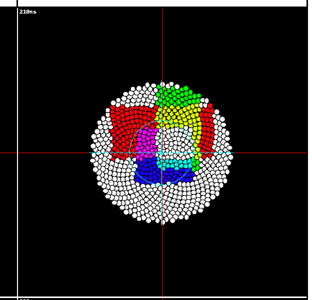
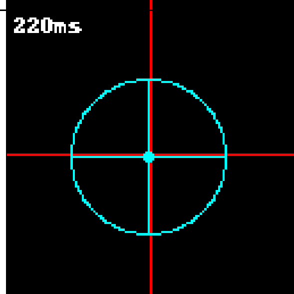
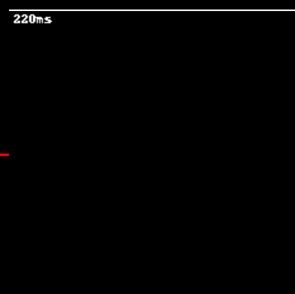
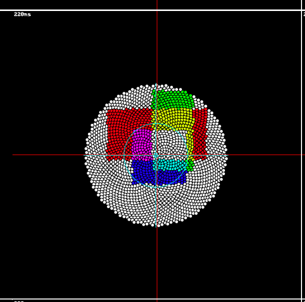
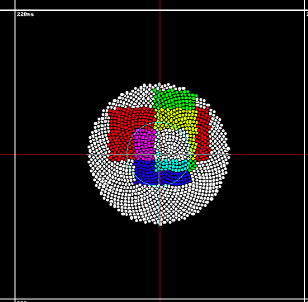
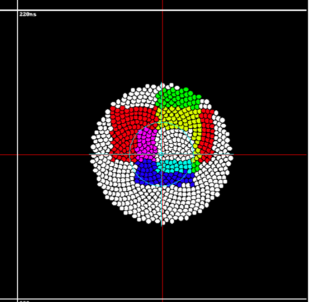
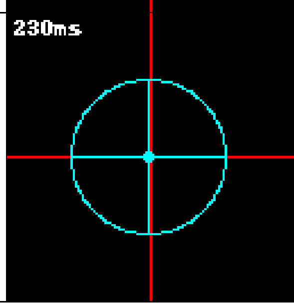
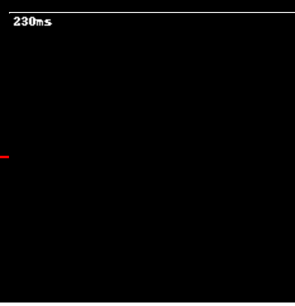
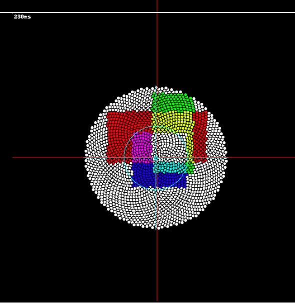
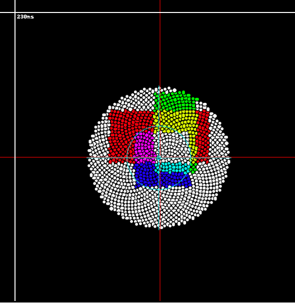
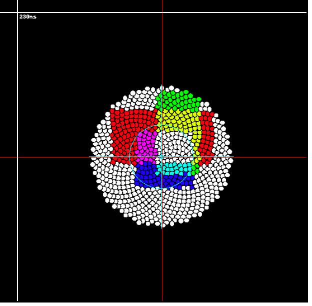
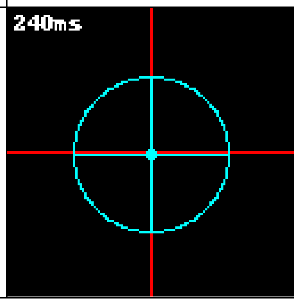
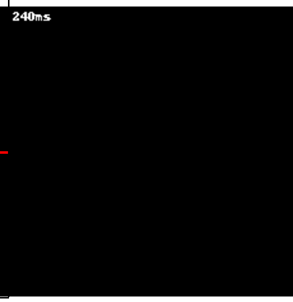
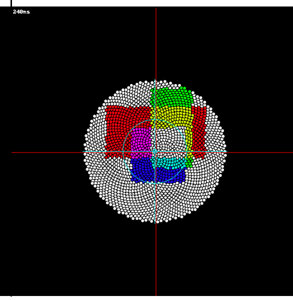
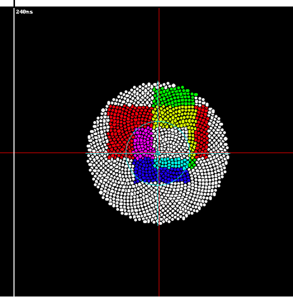
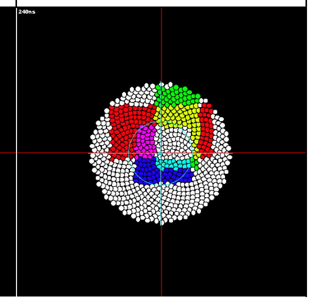
Table 39: Time sequence of imagining quickly					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
21					
22					
23					

Table 39: Time sequence of imagining quickly					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
24					

D.3.2 Test 2 results: Imagine slowly

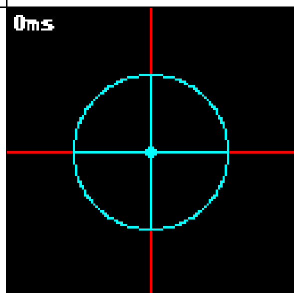
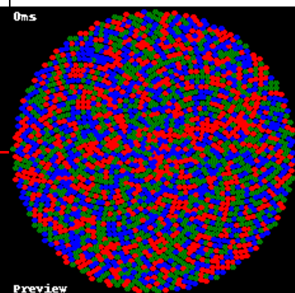
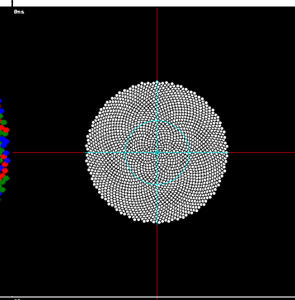
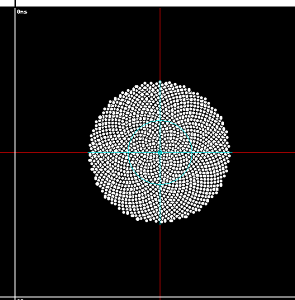
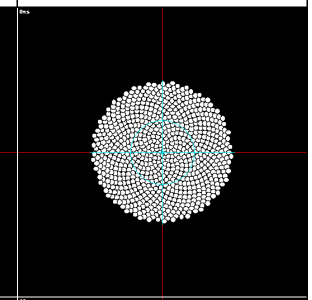
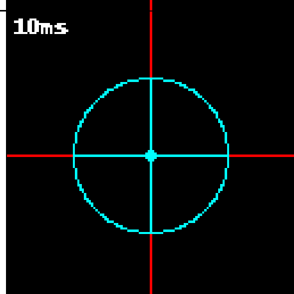
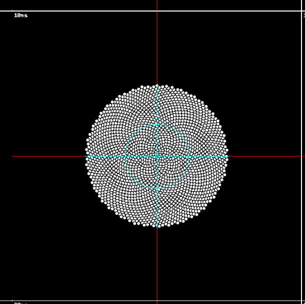
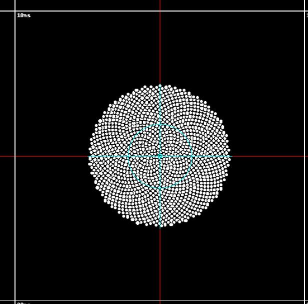
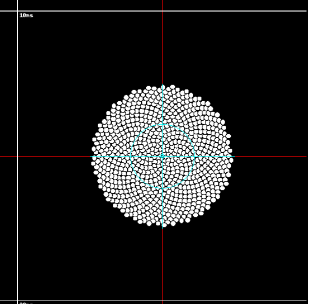
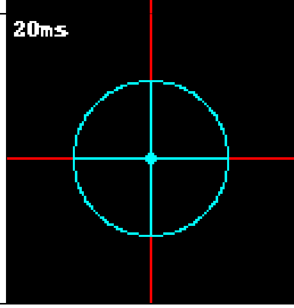
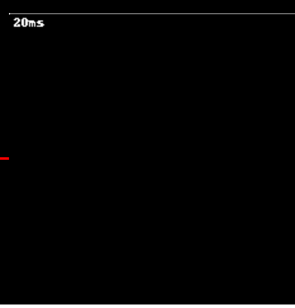
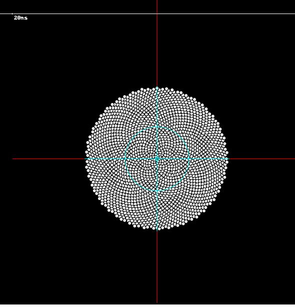
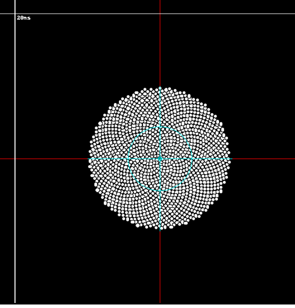
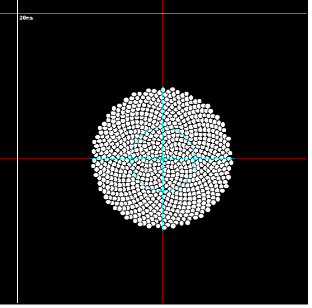
Table 40: Time sequence of imagining slowly					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
0					
1					
2					

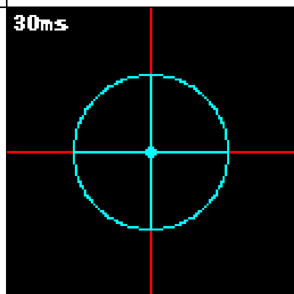
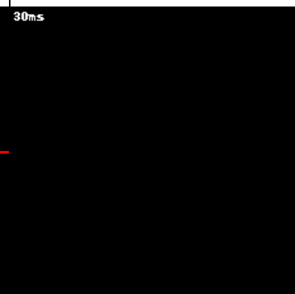
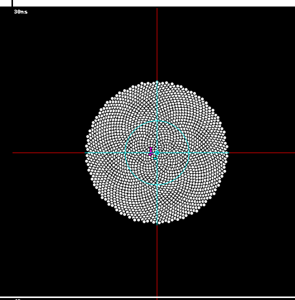
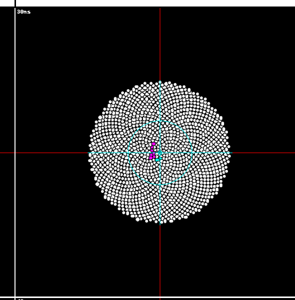
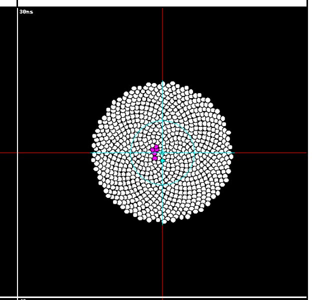
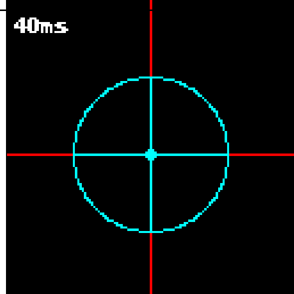
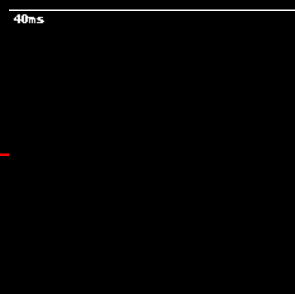
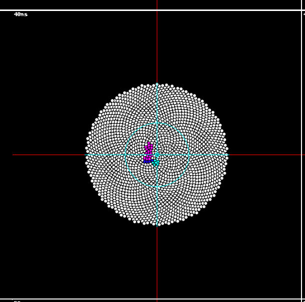
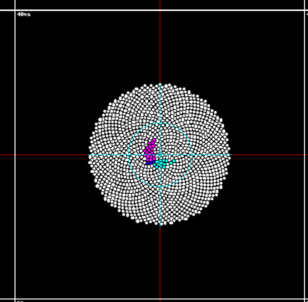
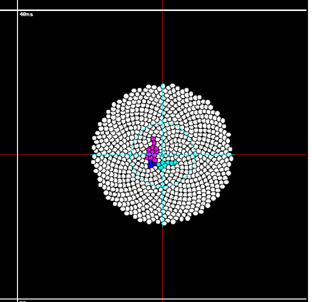
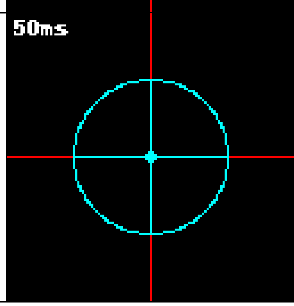
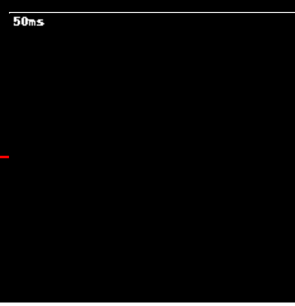
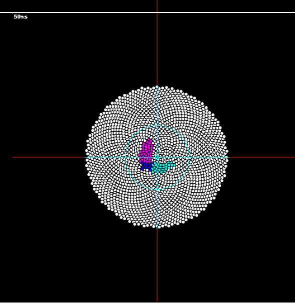
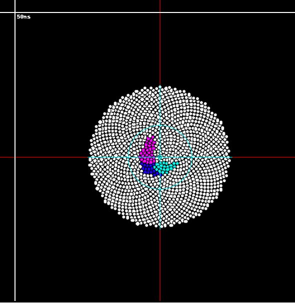
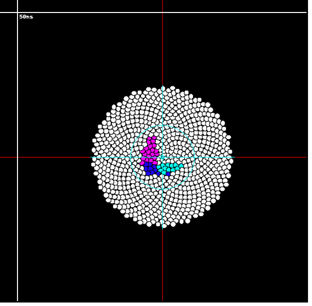
Table 40: Time sequence of imagining slowly					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
3					
4					
5					

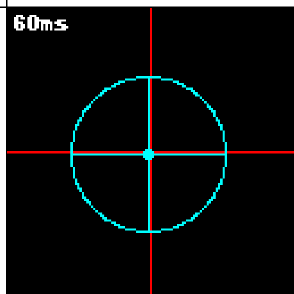
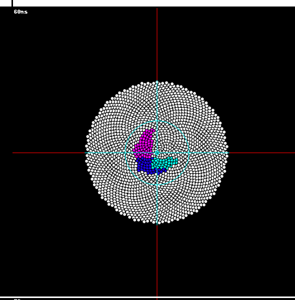
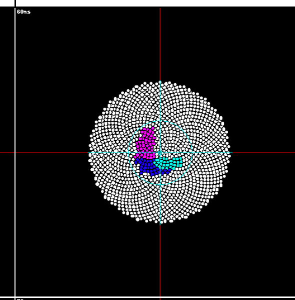
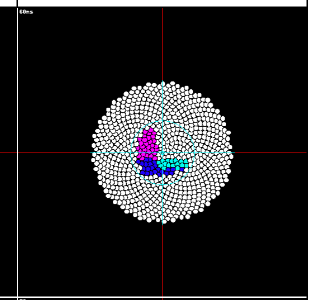
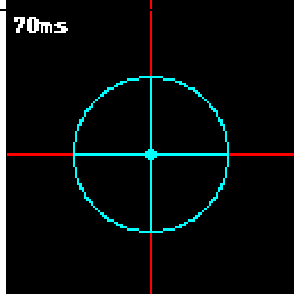
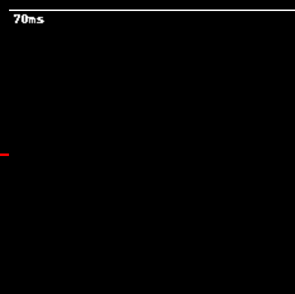
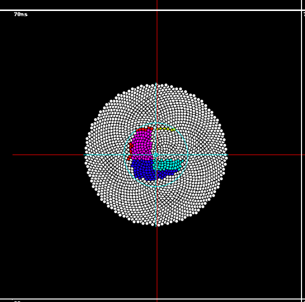
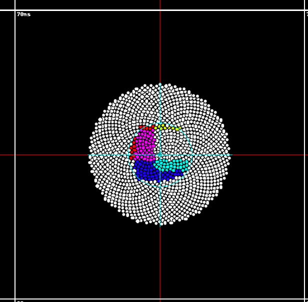
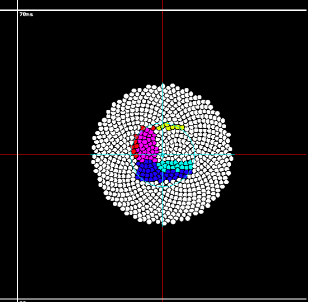
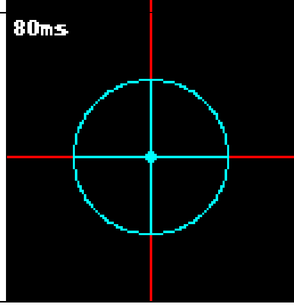
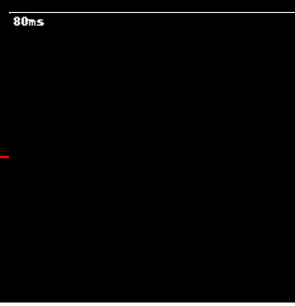
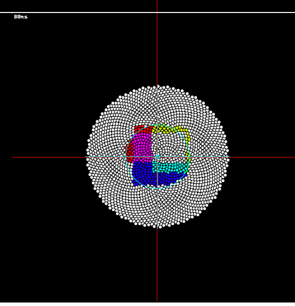
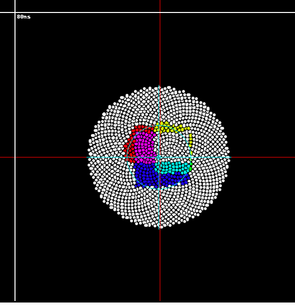
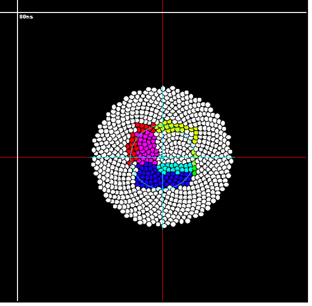
Table 40: Time sequence of imagining slowly					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
6					
7					
8					

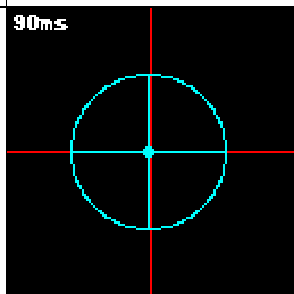
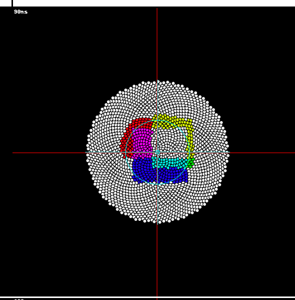
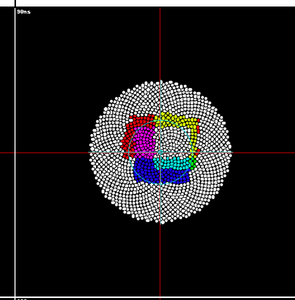
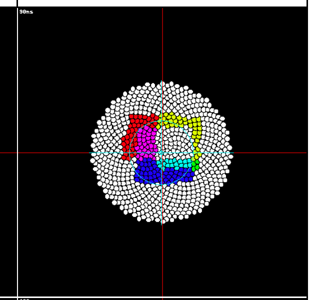
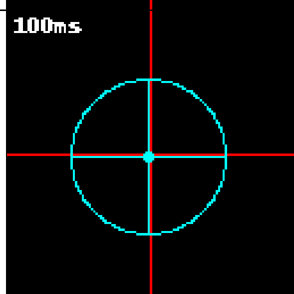
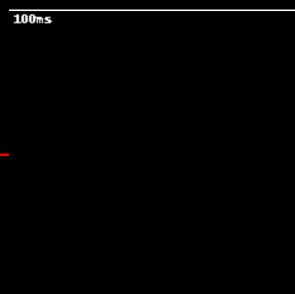
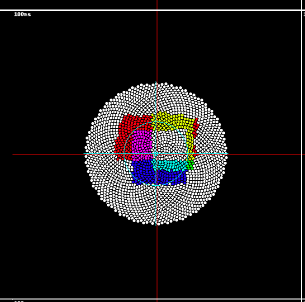
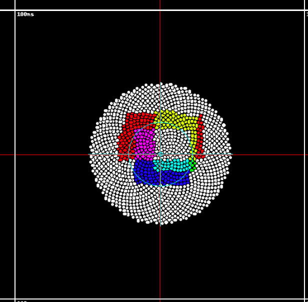
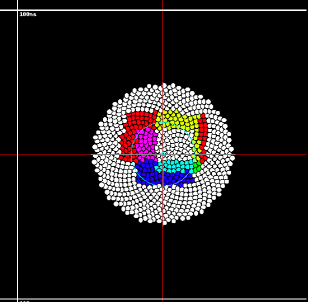
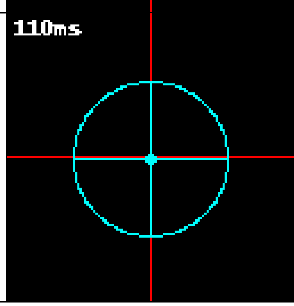
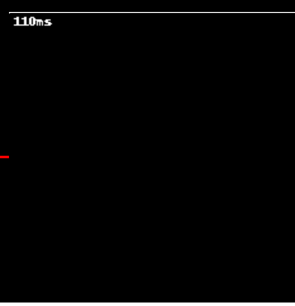
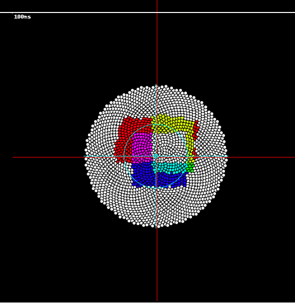
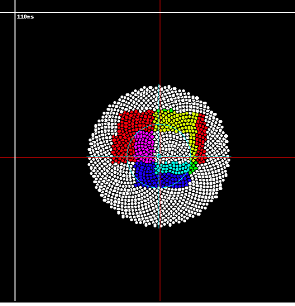
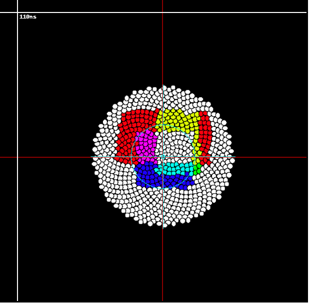
Table 40: Time sequence of imagining slowly					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
9					
10					
11					

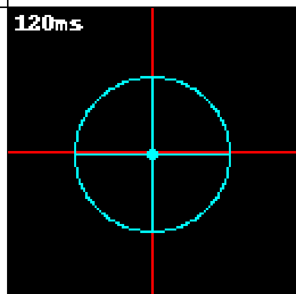
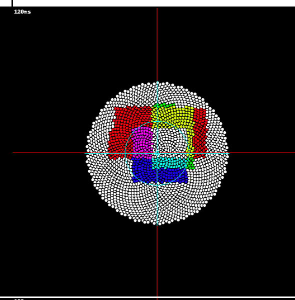
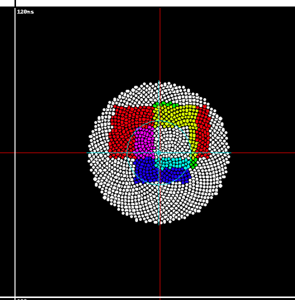
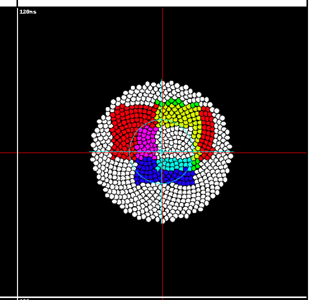
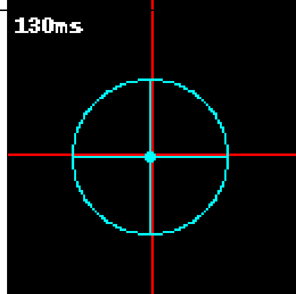
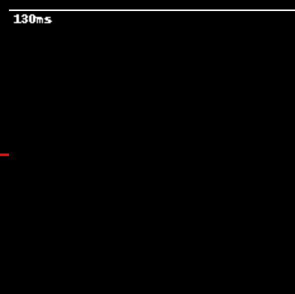
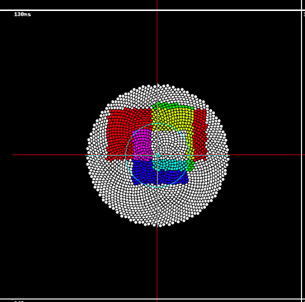
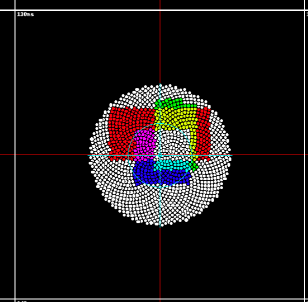
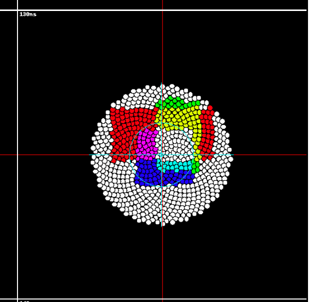
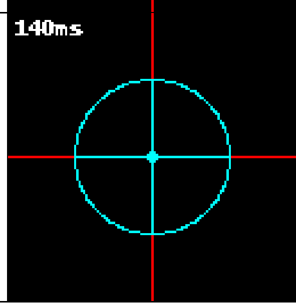
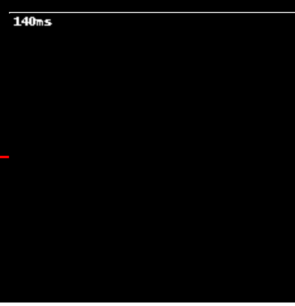
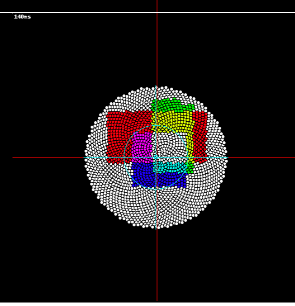
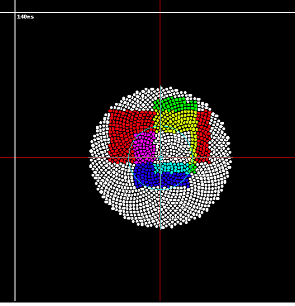
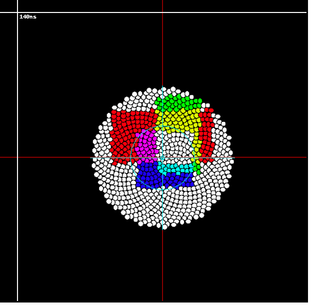
Table 40: Time sequence of imagining slowly					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
12					
13					
14					

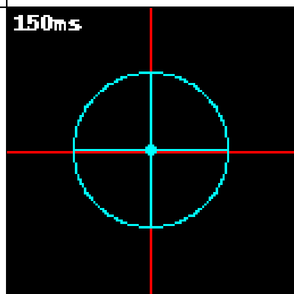
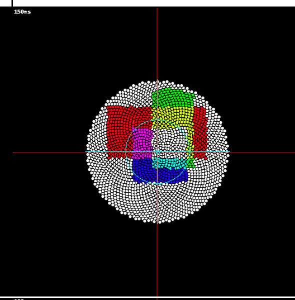
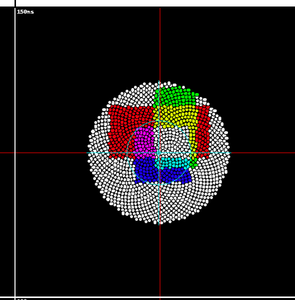
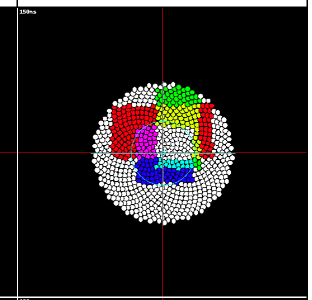
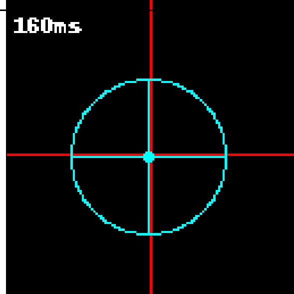
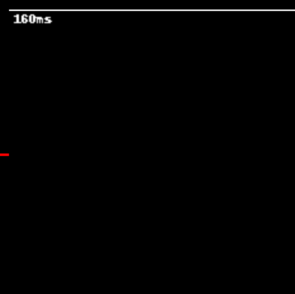
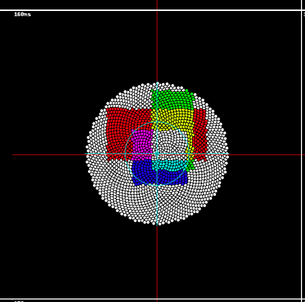
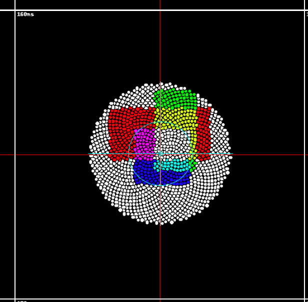
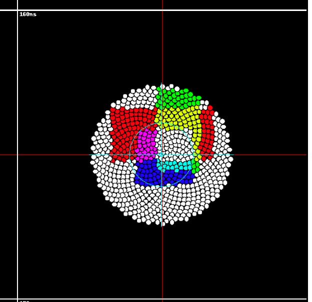
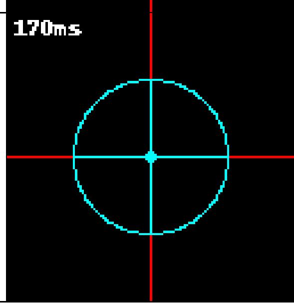
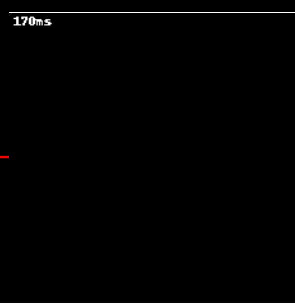
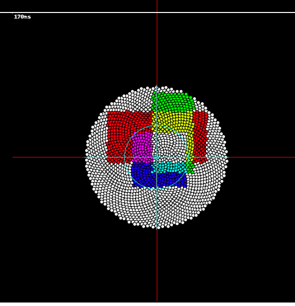
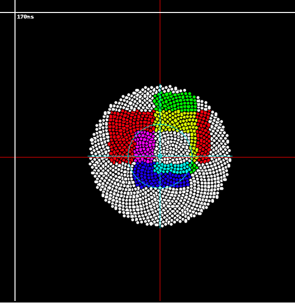
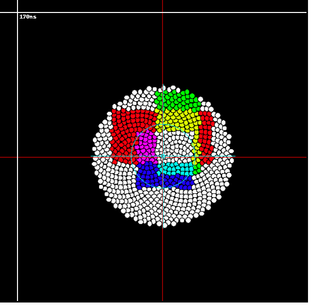
Table 40: Time sequence of imagining slowly					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields Level 1	Receptive Fields Level 2	Receptive Fields Level 3
15					
16					
17					

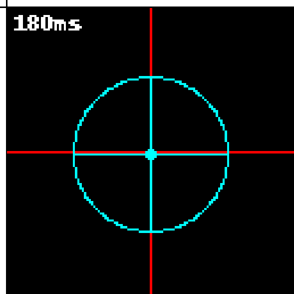
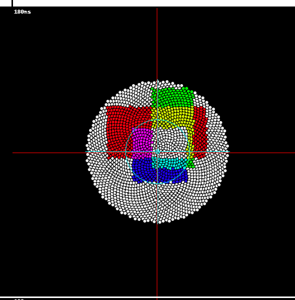
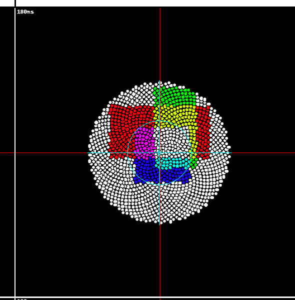
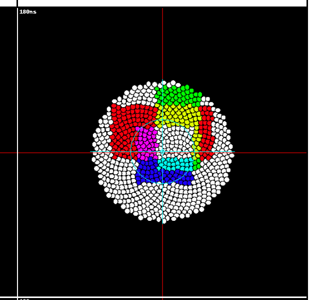
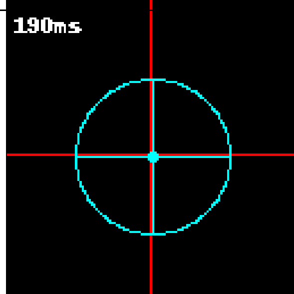
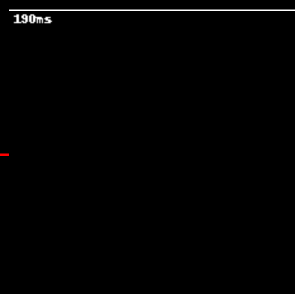
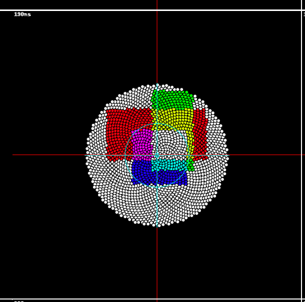
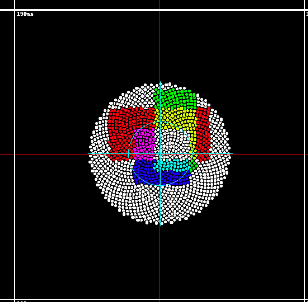
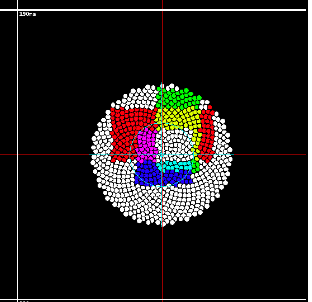
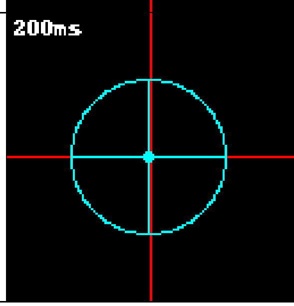
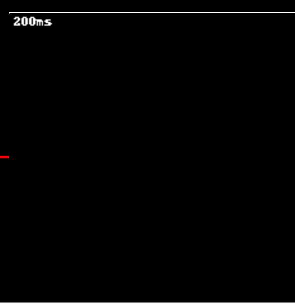
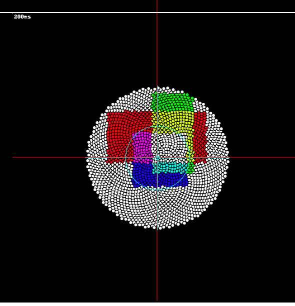
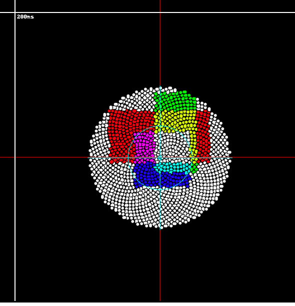
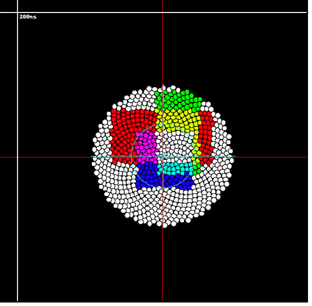
Table 40: Time sequence of imagining slowly					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
18					
19					
20					

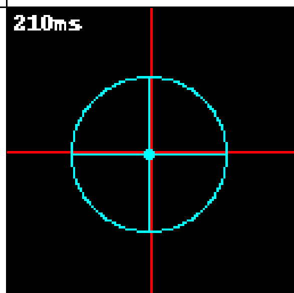
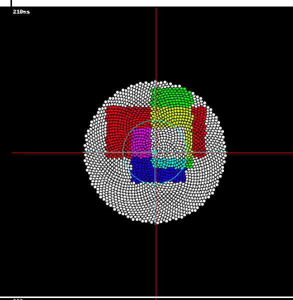
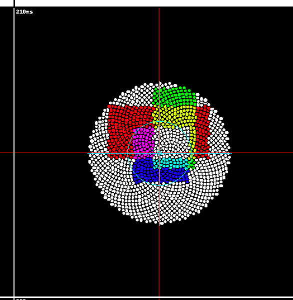
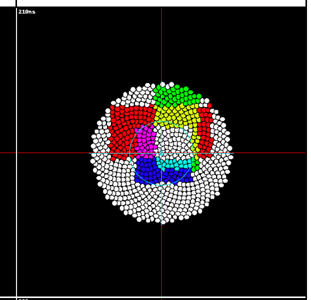
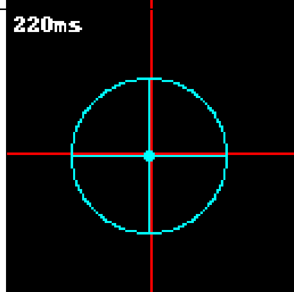
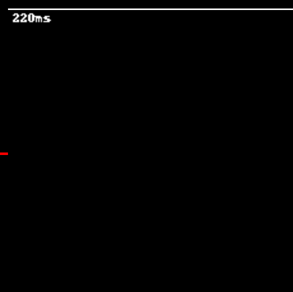
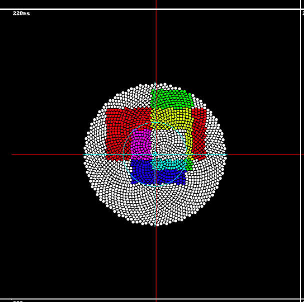
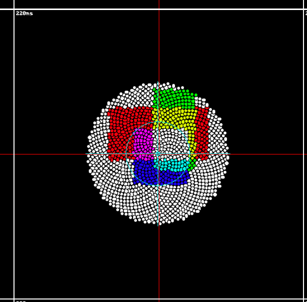
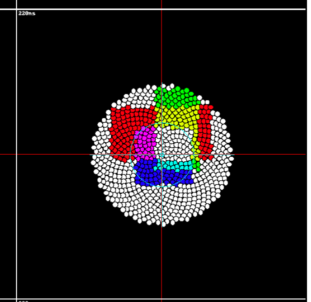
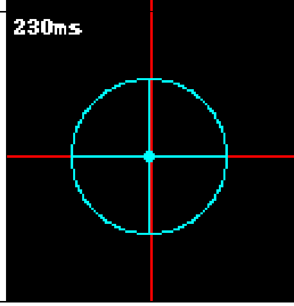
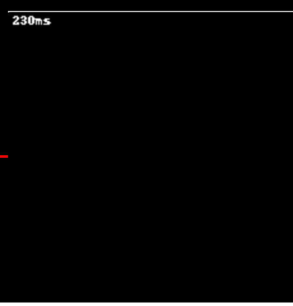
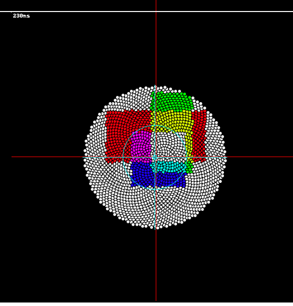
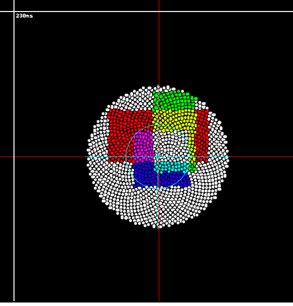
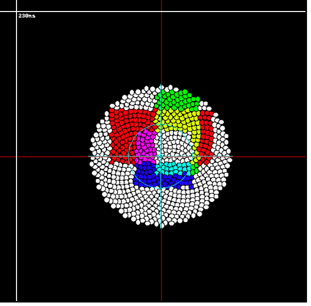
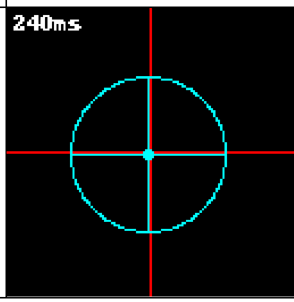
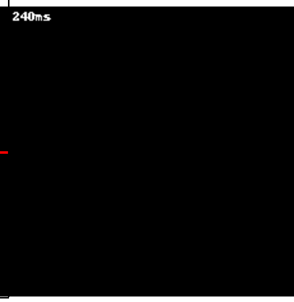
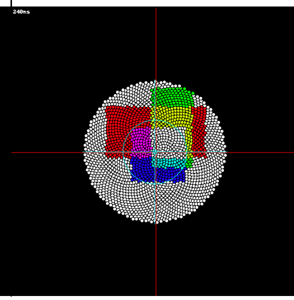
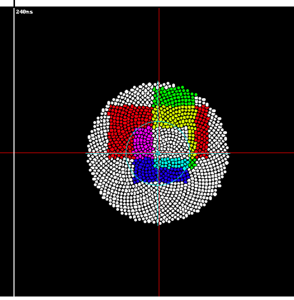
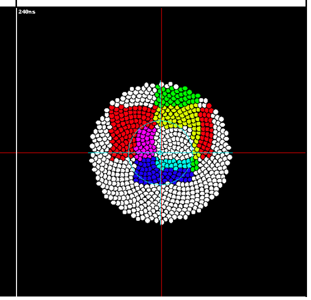
Table 40: Time sequence of imagining slowly					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
21					
22					
23					

Table 40: Time sequence of imagining slowly					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
24					

D.3.3 Test 3 results: Imagine slowly with eye movement

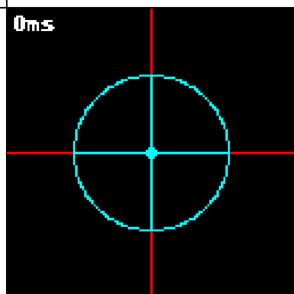
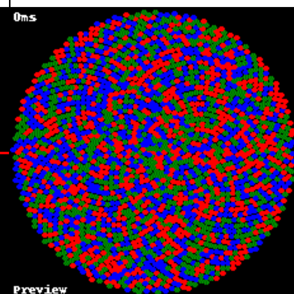
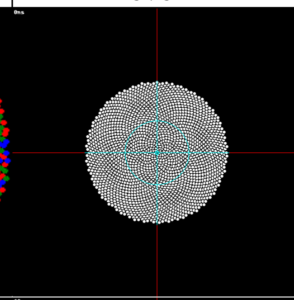
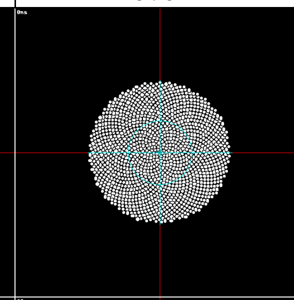
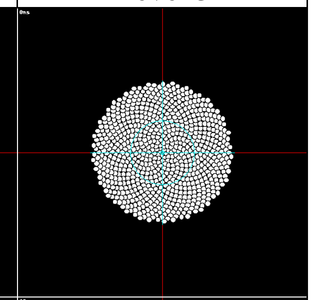
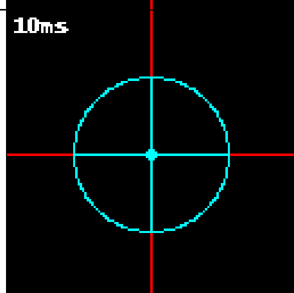
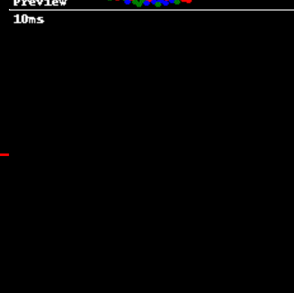
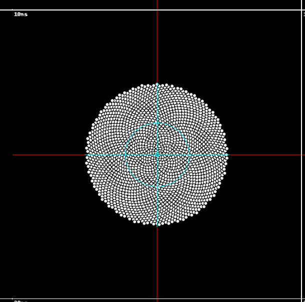
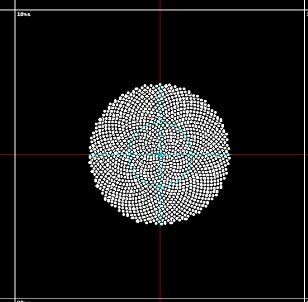
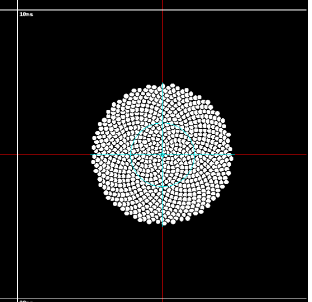
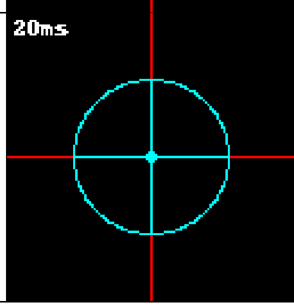
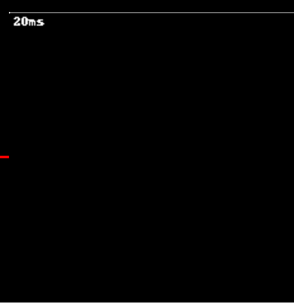
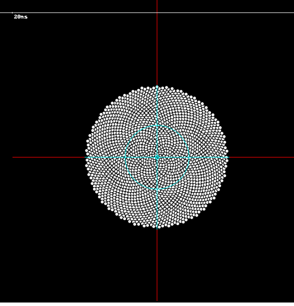
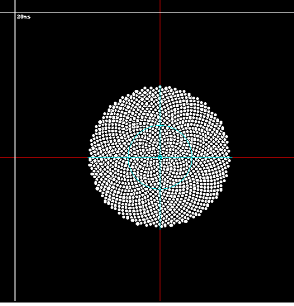
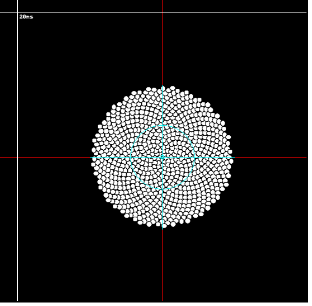
Table 41: Time sequence of imagining slowly with eye movement					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
0					
1					
2					

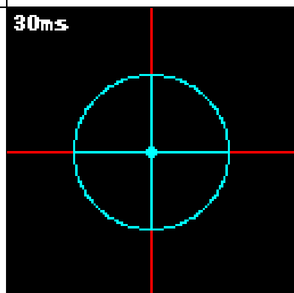
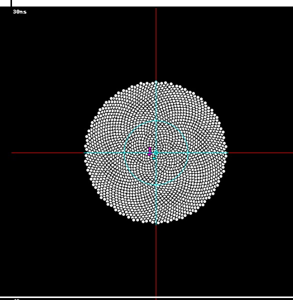
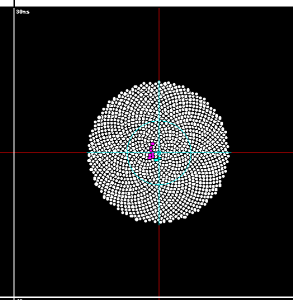
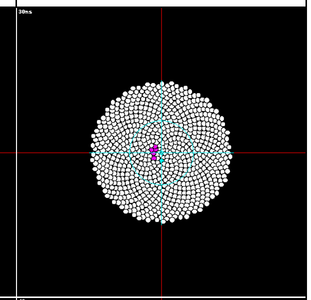
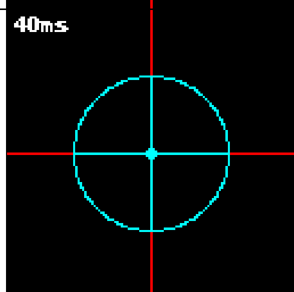
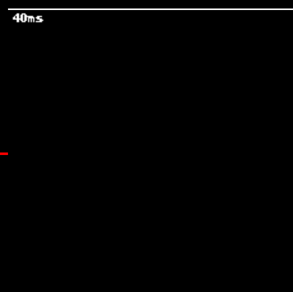
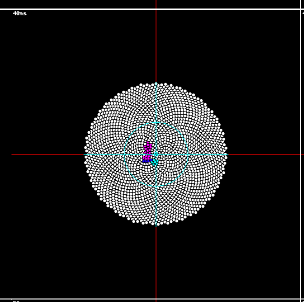
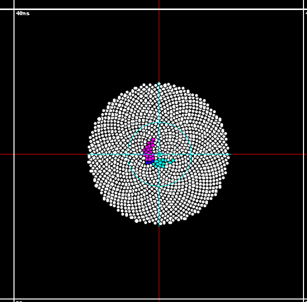
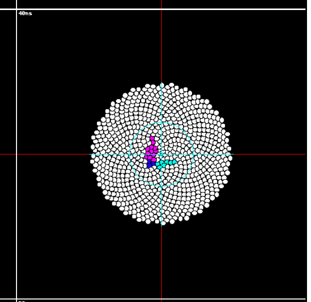
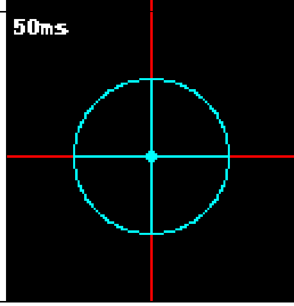
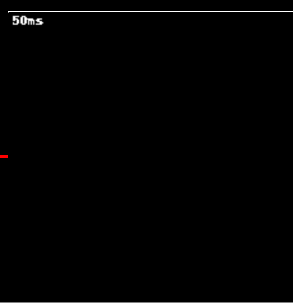
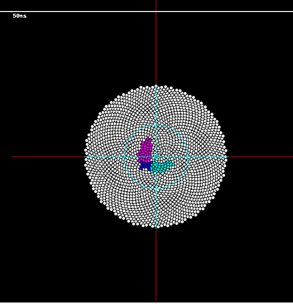
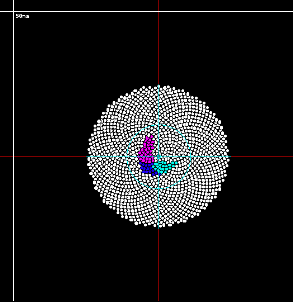
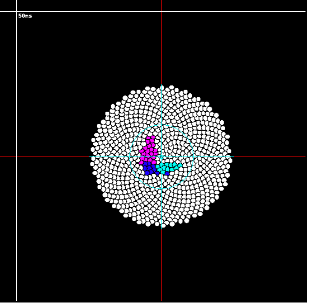
Table 41: Time sequence of imagining slowly with eye movement					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
3					
4					
5					

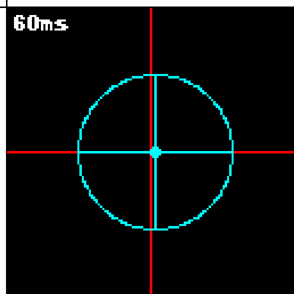
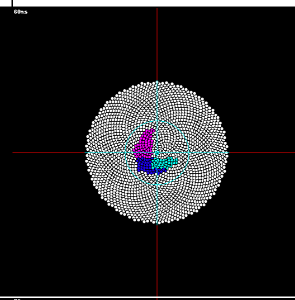
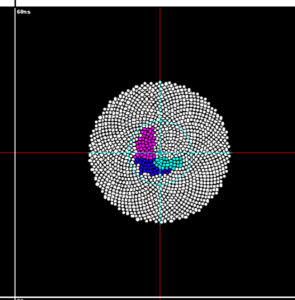
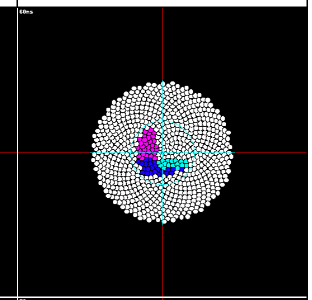
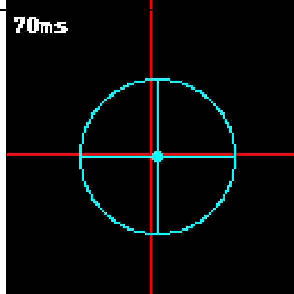
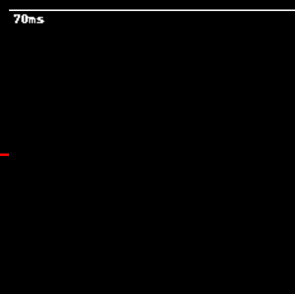
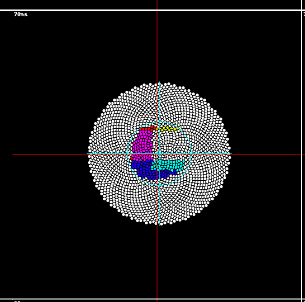
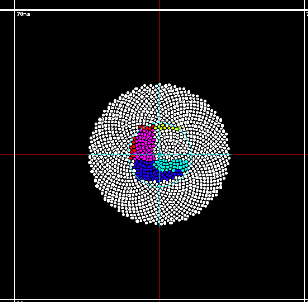
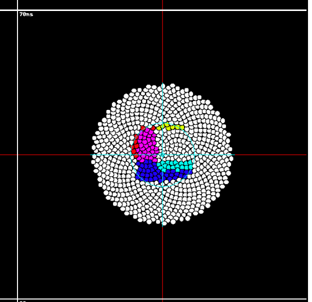
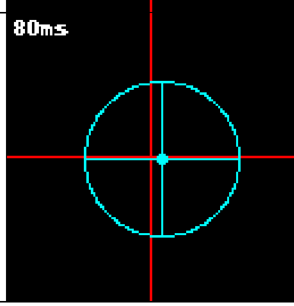
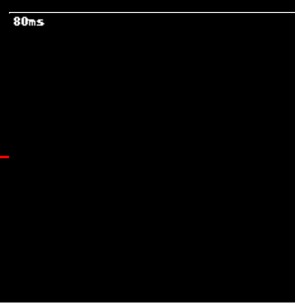
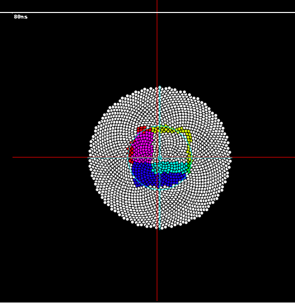
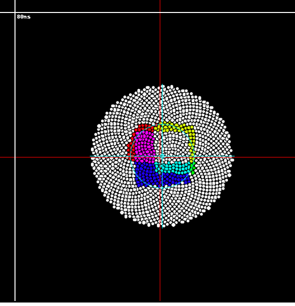
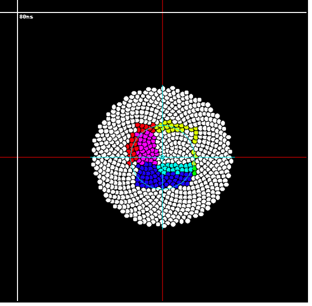
Table 41: Time sequence of imagining slowly with eye movement					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
6					
7					
8					

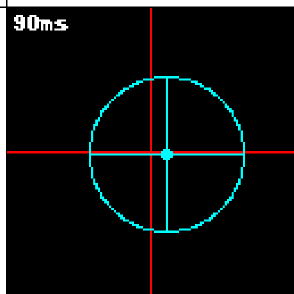
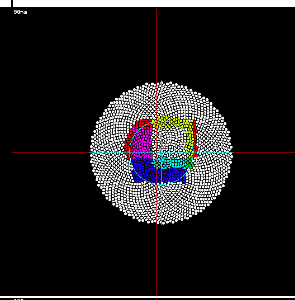
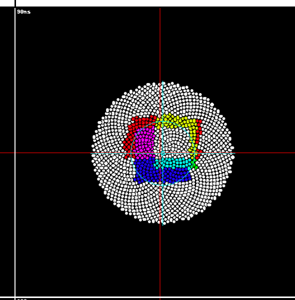
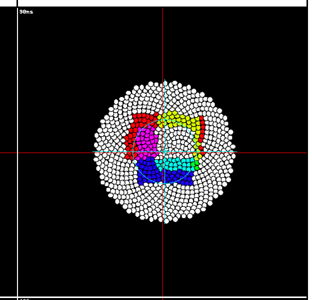
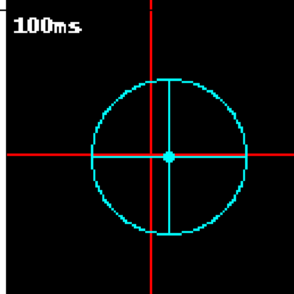
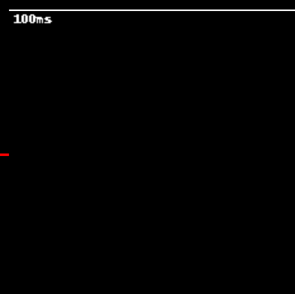
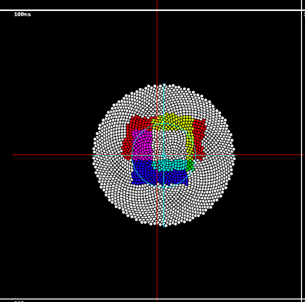
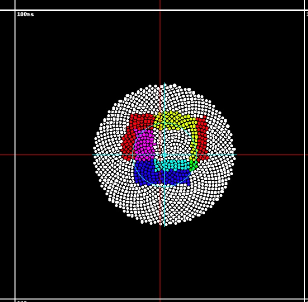
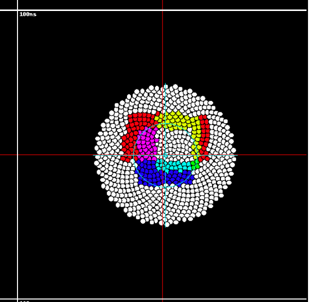
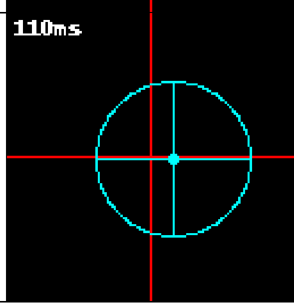
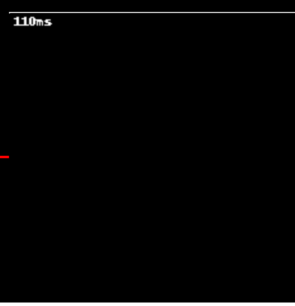
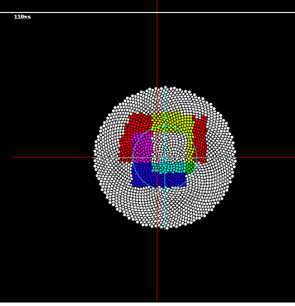
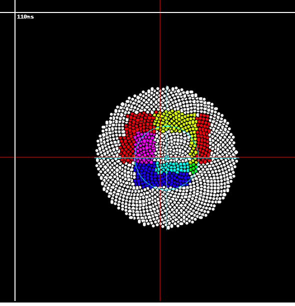
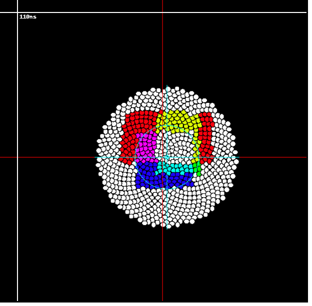
Table 41: Time sequence of imagining slowly with eye movement					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
9					
10					
11					

Table 41: Time sequence of imagining slowly with eye movement

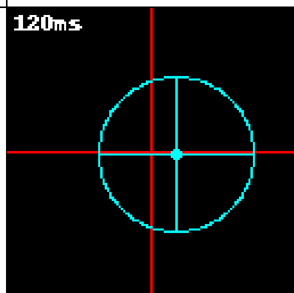
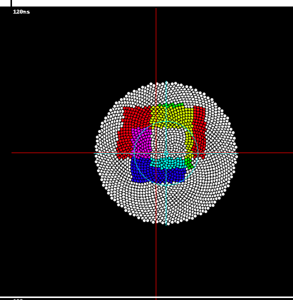
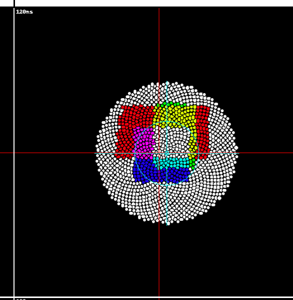
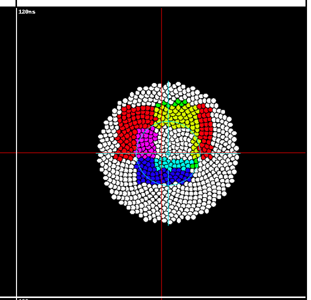
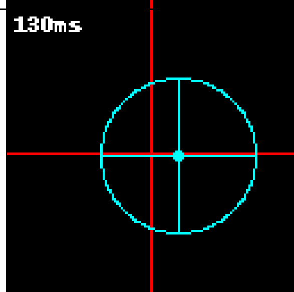
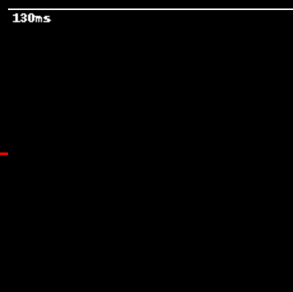
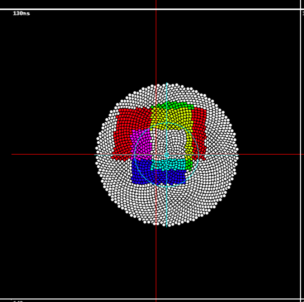
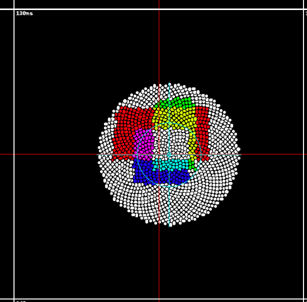
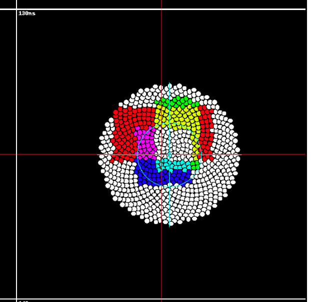
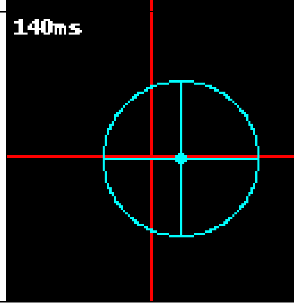
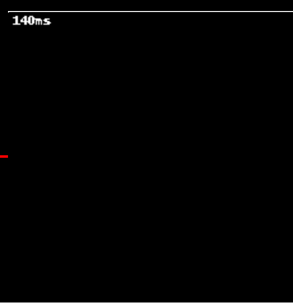
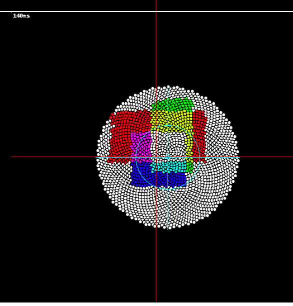
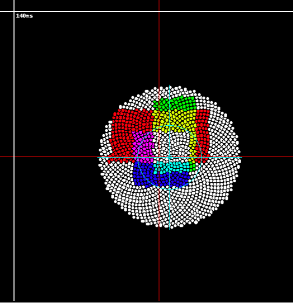
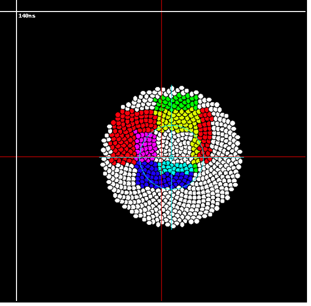
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
12					
13					
14					

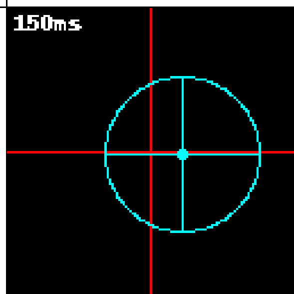
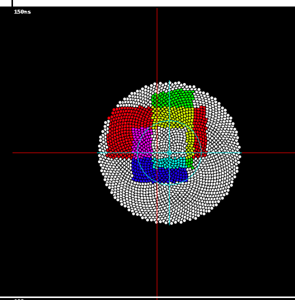
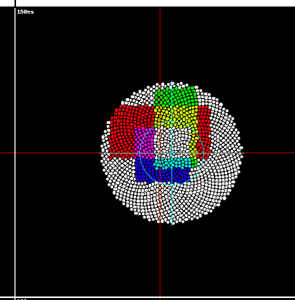
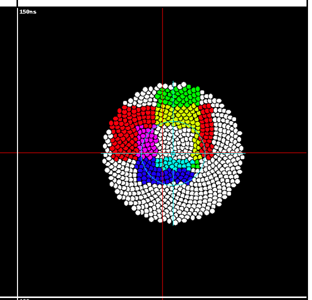
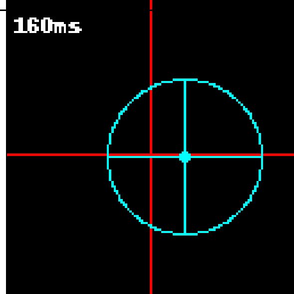
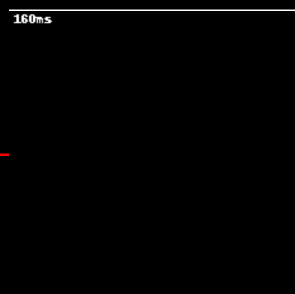
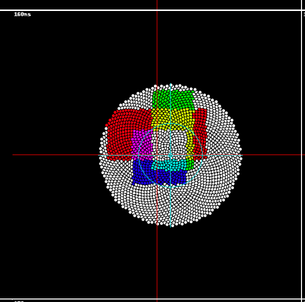
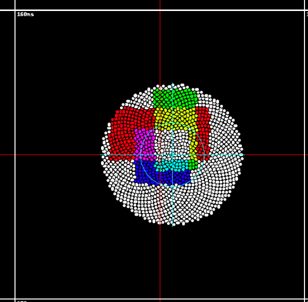
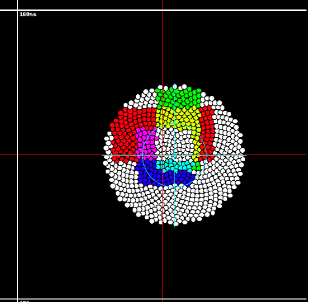
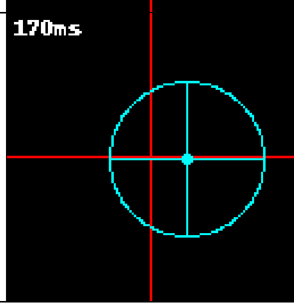
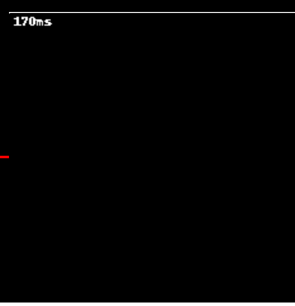
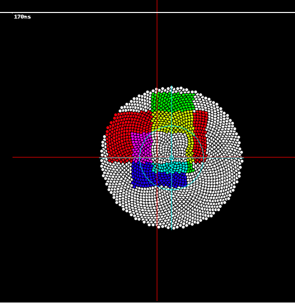
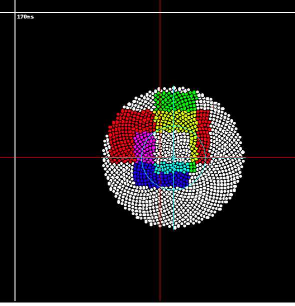
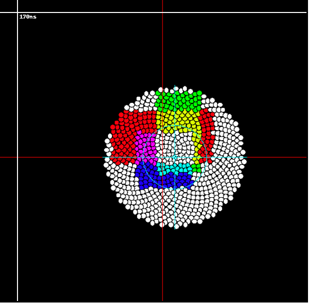
Table 41: Time sequence of imagining slowly with eye movement					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
15					
16					
17					

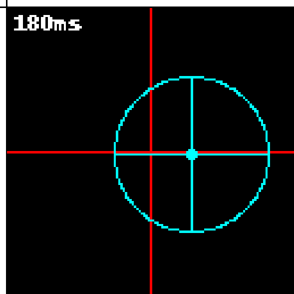
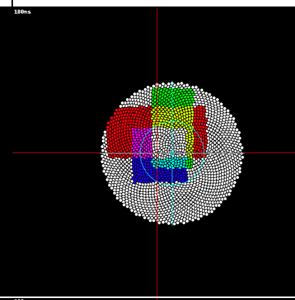
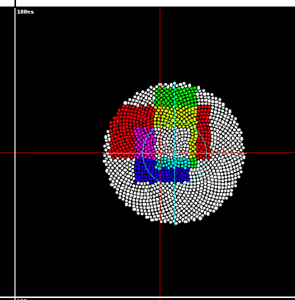
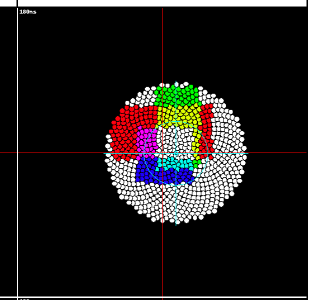
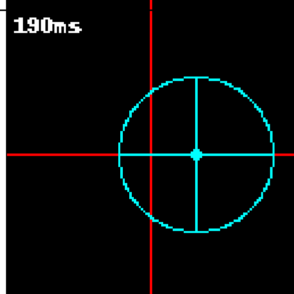
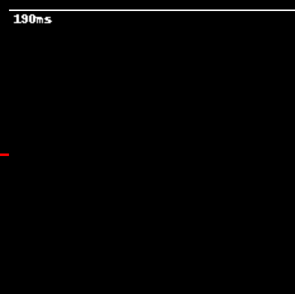
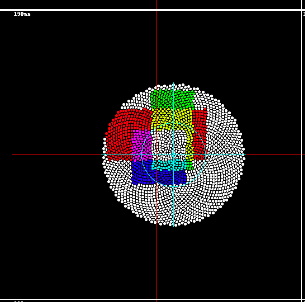
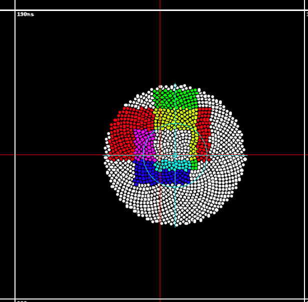
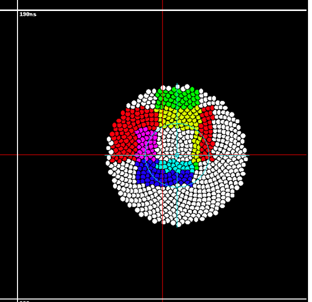
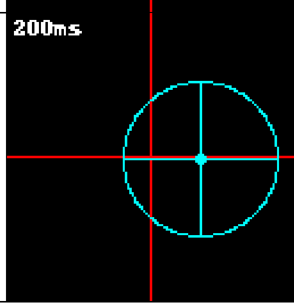
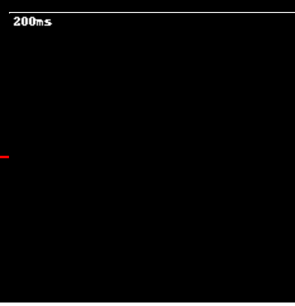
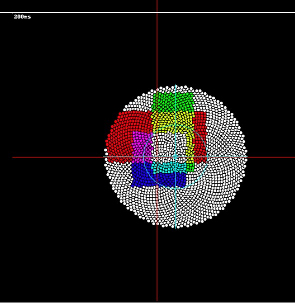
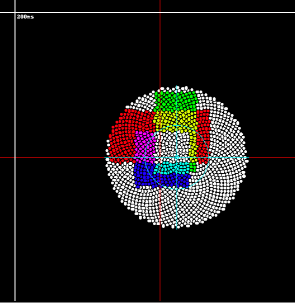
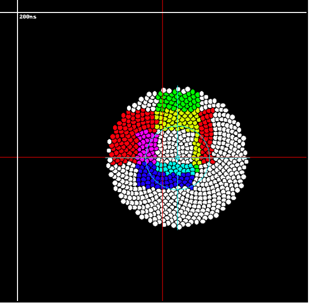
Table 41: Time sequence of imagining slowly with eye movement					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
18					
19					
20					

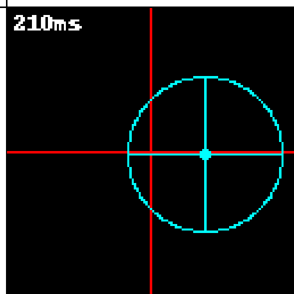
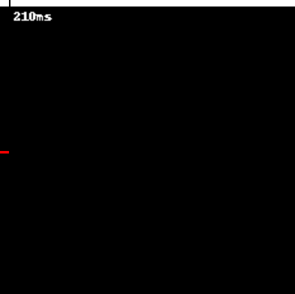
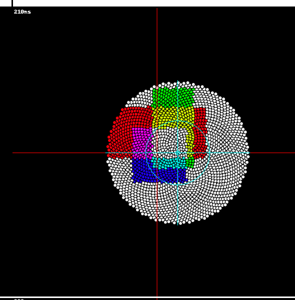
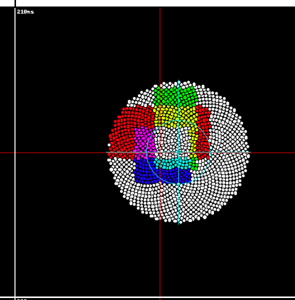
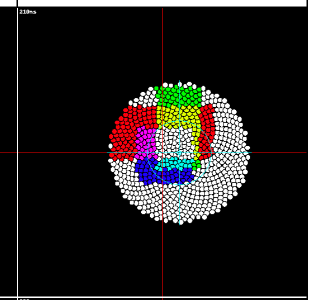
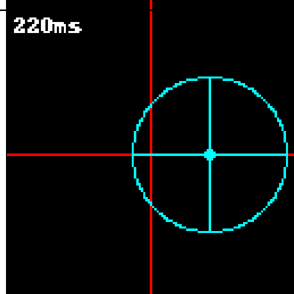
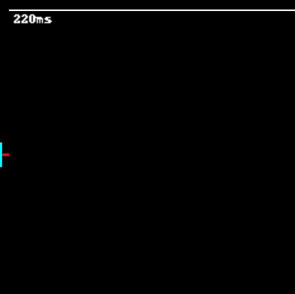
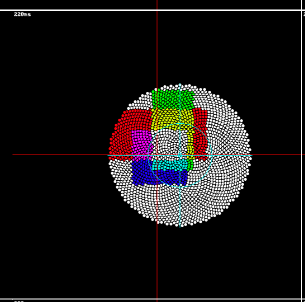
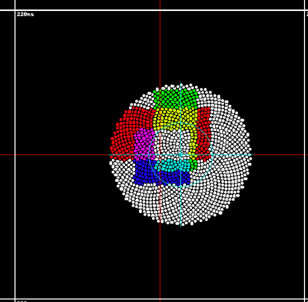
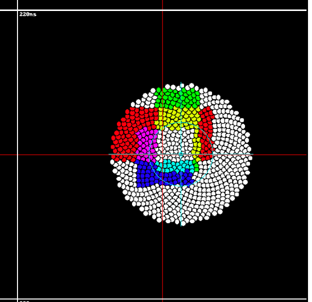
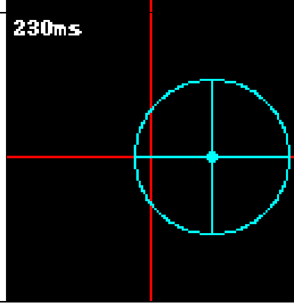
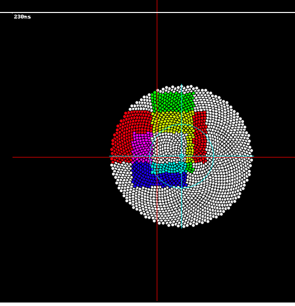
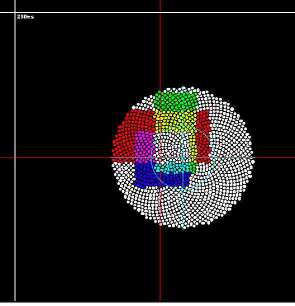
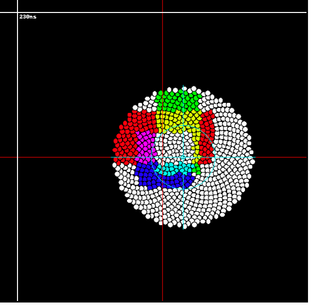
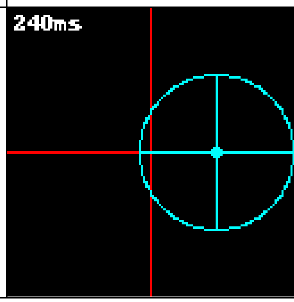
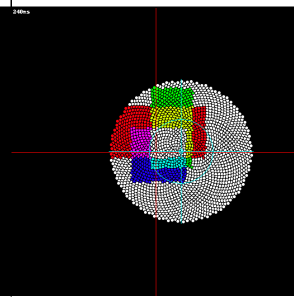
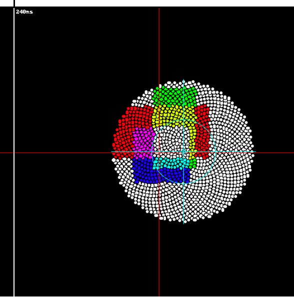
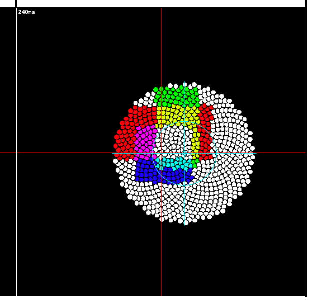
Table 41: Time sequence of imagining slowly with eye movement					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
21					
22					
23					

Table 41: Time sequence of imagining slowly with eye movement					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
24					

D.3.4 Test 4 results: Imagine distorted

Table 42: Time sequence of imagining with distorted mosaic

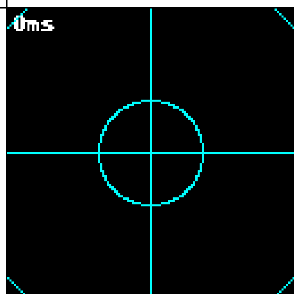
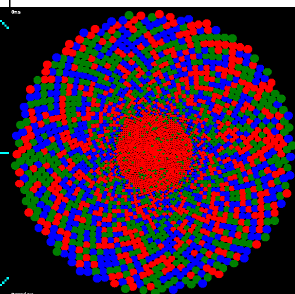
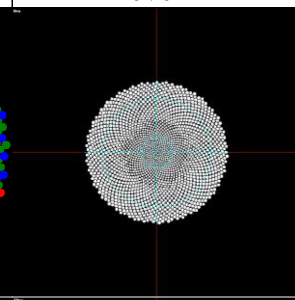
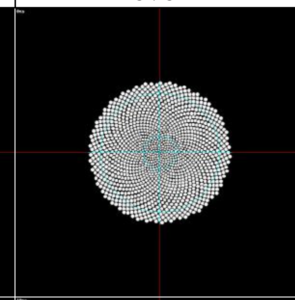
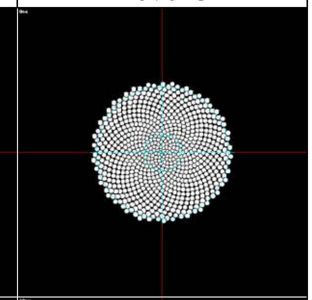
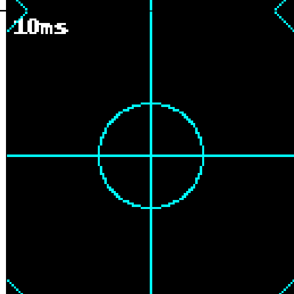
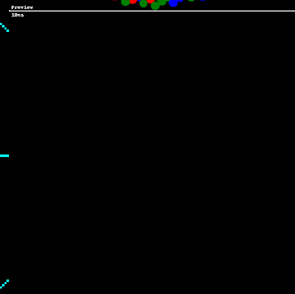
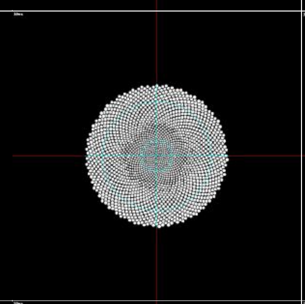
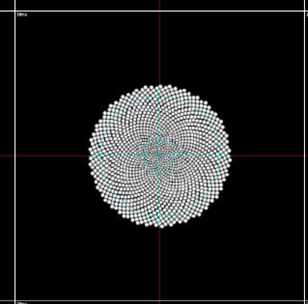
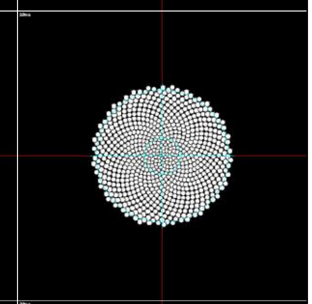
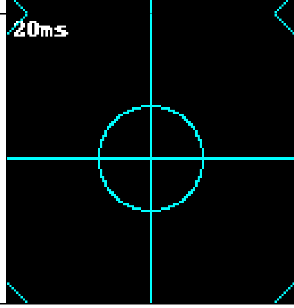
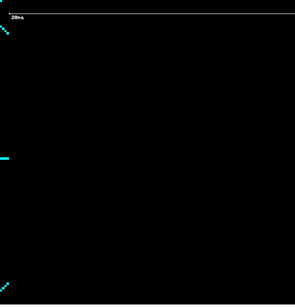
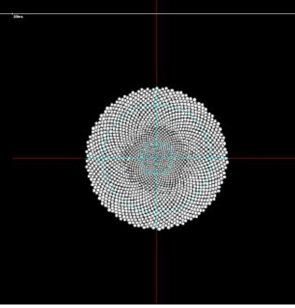
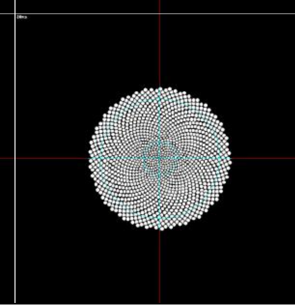
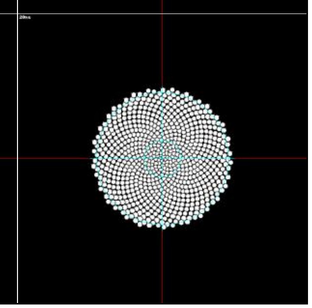
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields Level 1	Receptive Fields Level 2	Receptive Fields Level 3
0					
1					
2					

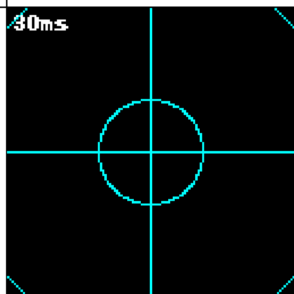
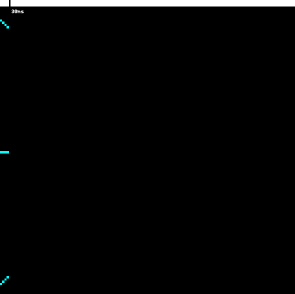
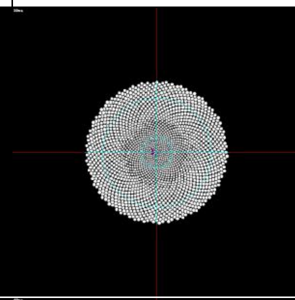
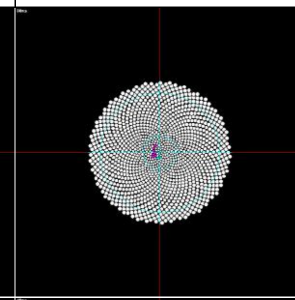
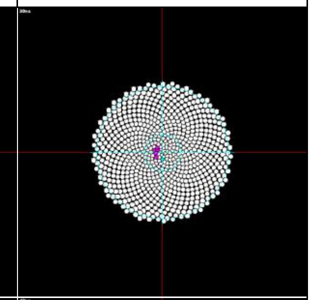
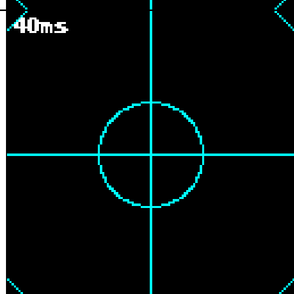
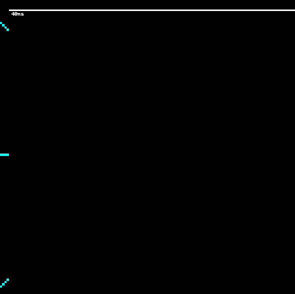
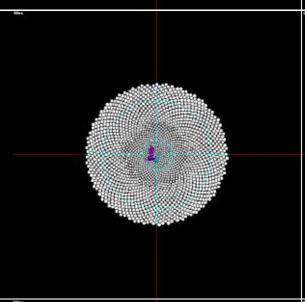
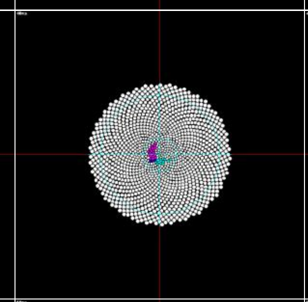
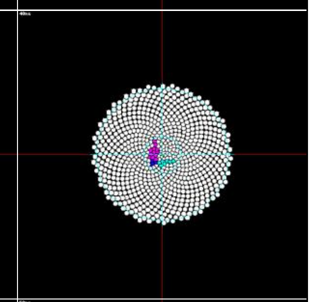
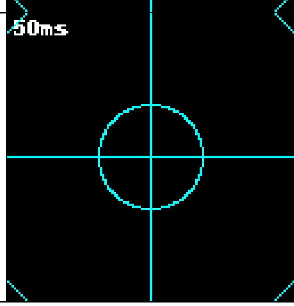
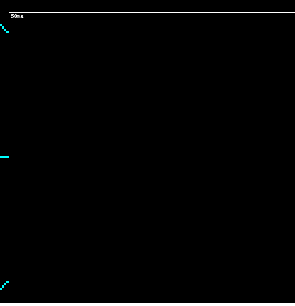
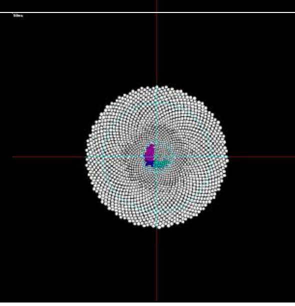
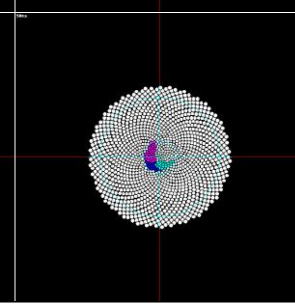
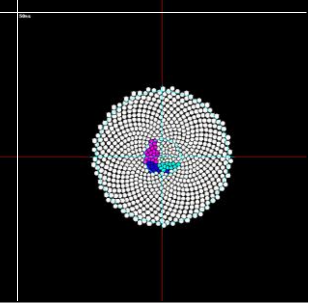
Table 42: Time sequence of imagining with distorted mosaic					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
3					
4					
5					

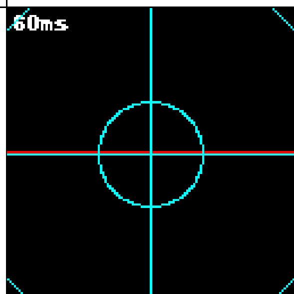
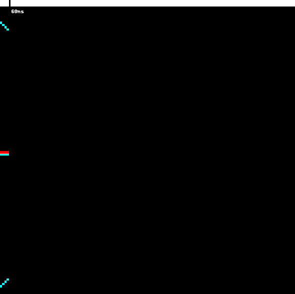
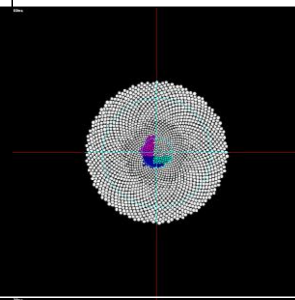
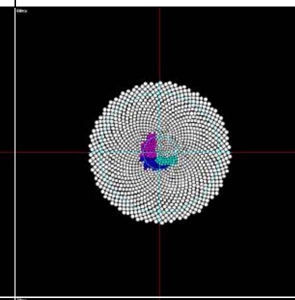
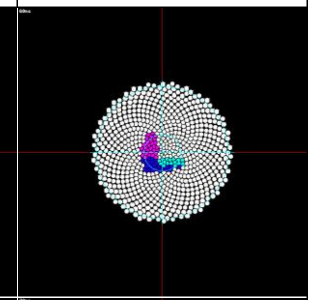
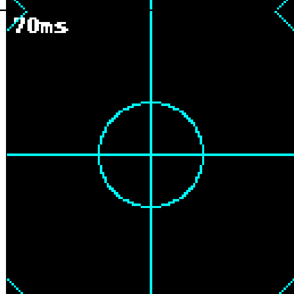
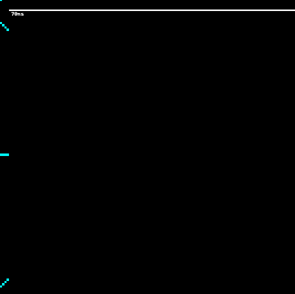
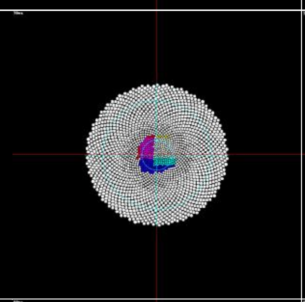
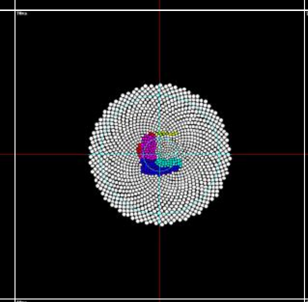
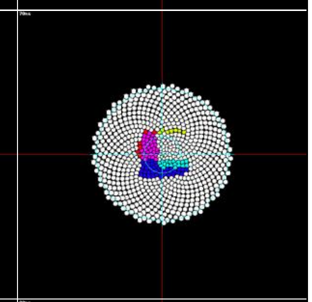
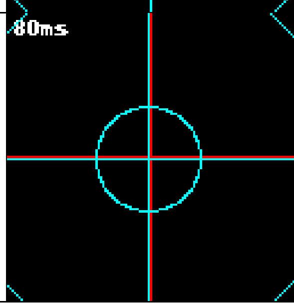
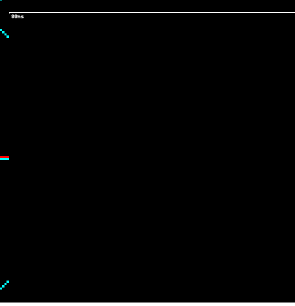
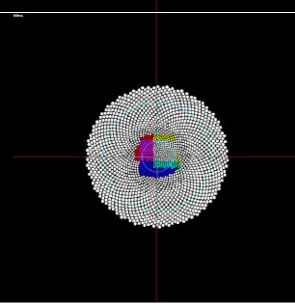
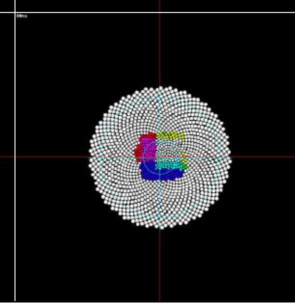
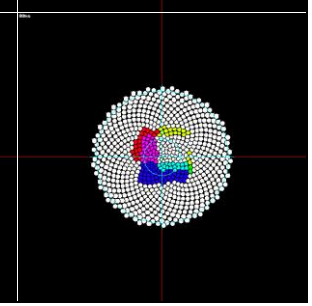
Table 42: Time sequence of imagining with distorted mosaic					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
6					
7					
8					

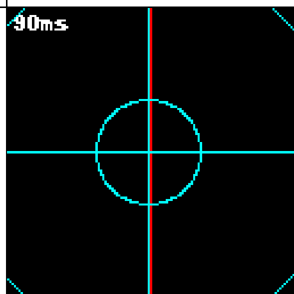
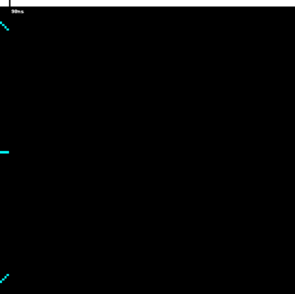
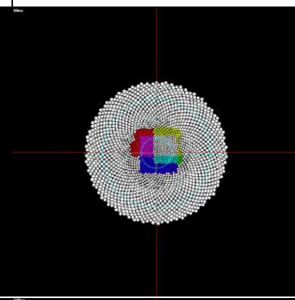
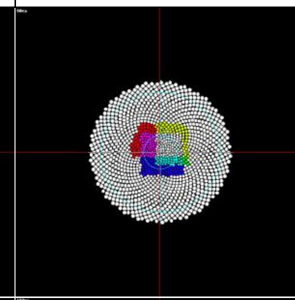
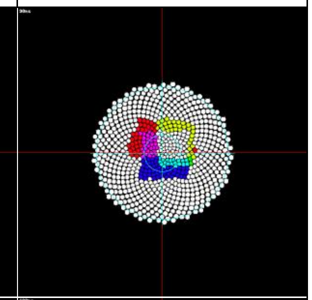
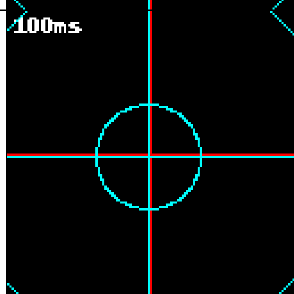
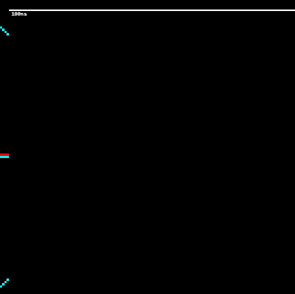
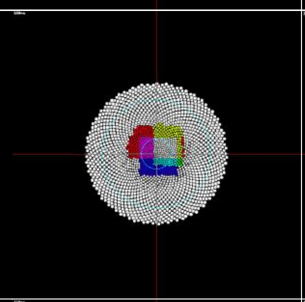
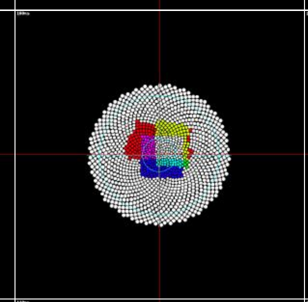
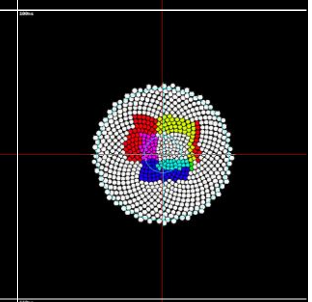
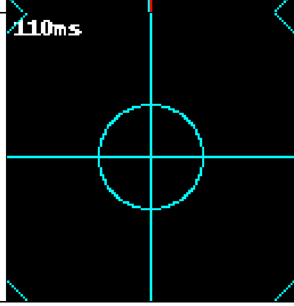
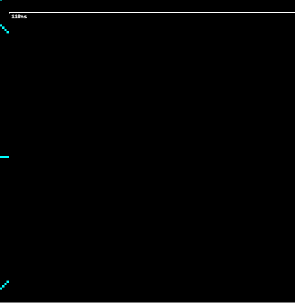
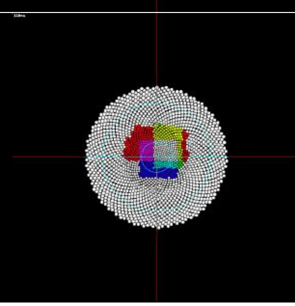
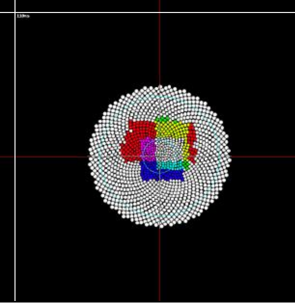
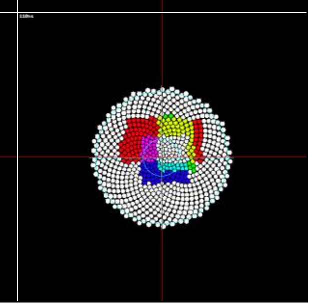
Table 42: Time sequence of imagining with distorted mosaic					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
9					
10					
11					

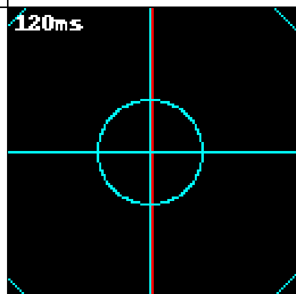
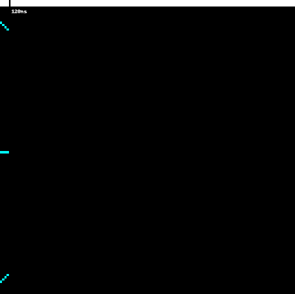
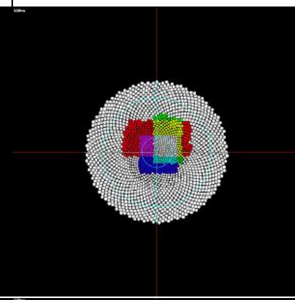
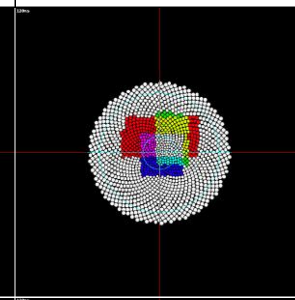
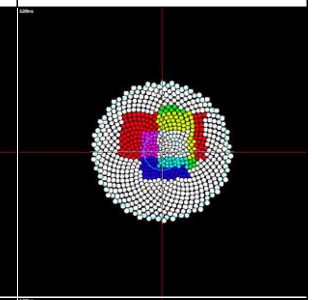
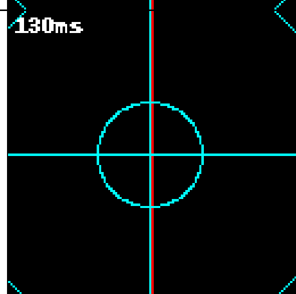
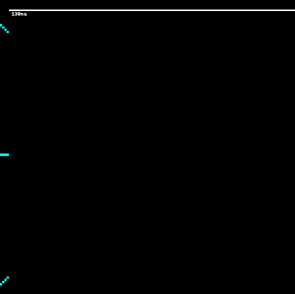
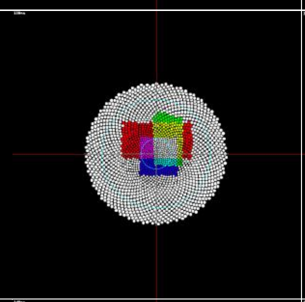
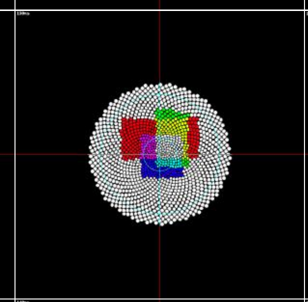
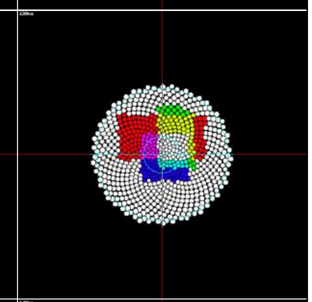
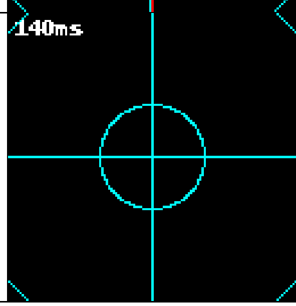
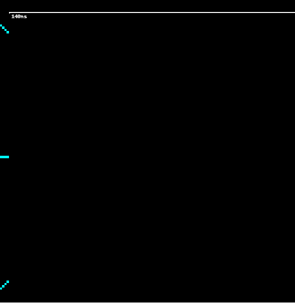
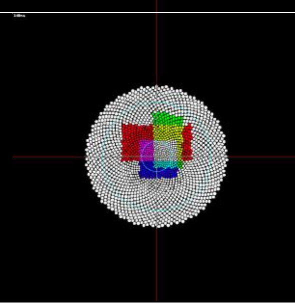
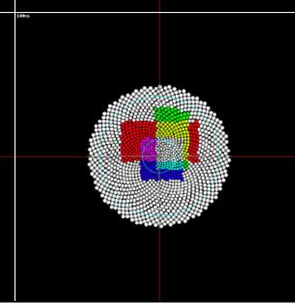
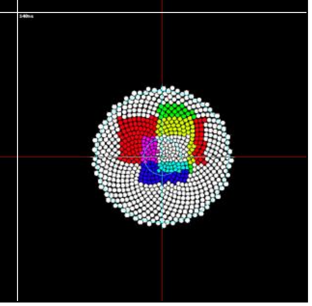
Table 42: Time sequence of imagining with distorted mosaic					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
12					
13					
14					

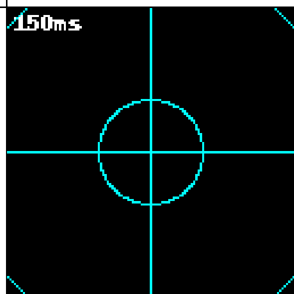
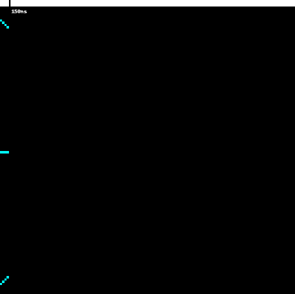
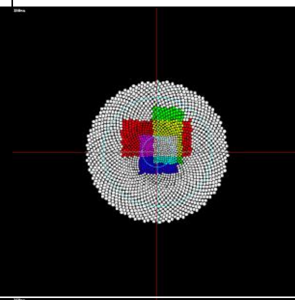
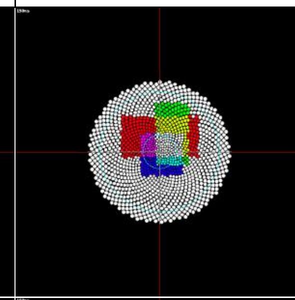
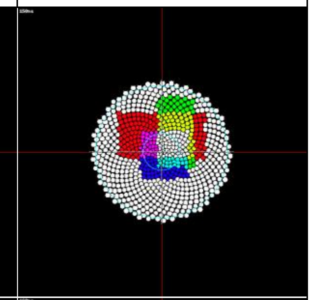
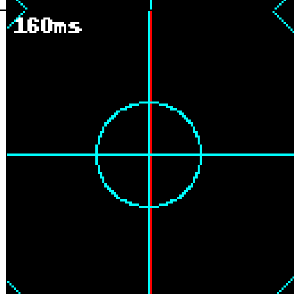
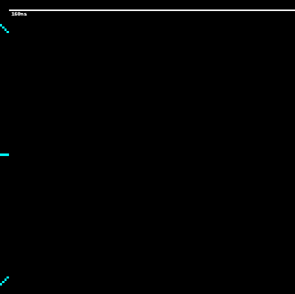
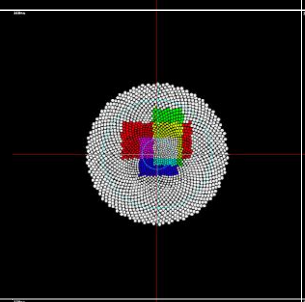
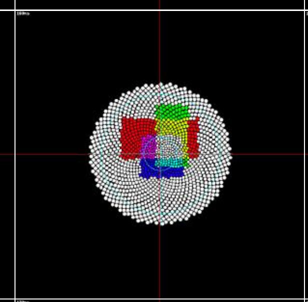
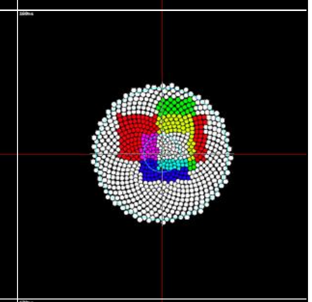
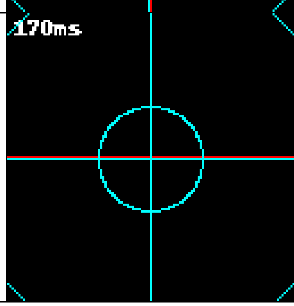
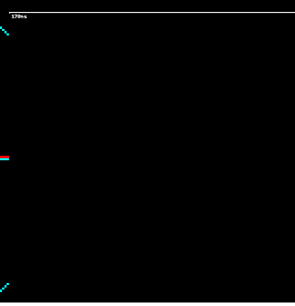
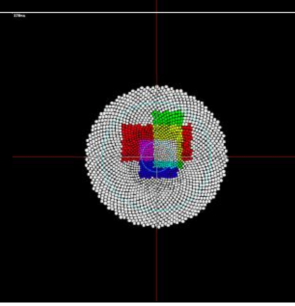
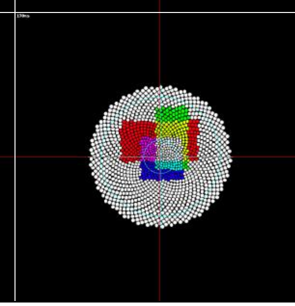
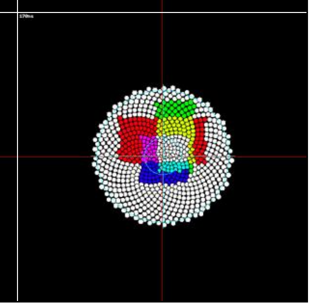
Table 42: Time sequence of imagining with distorted mosaic					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
15					
16					
17					

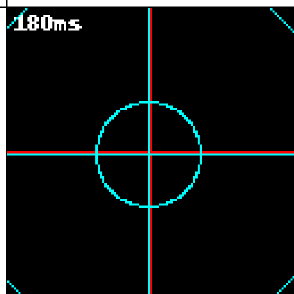
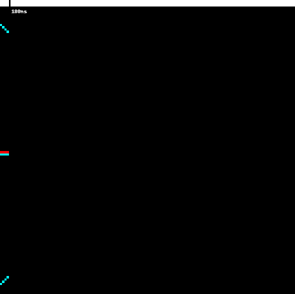
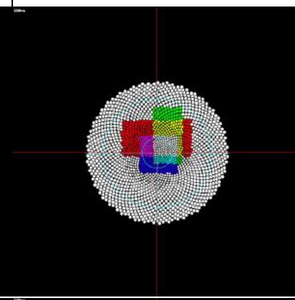
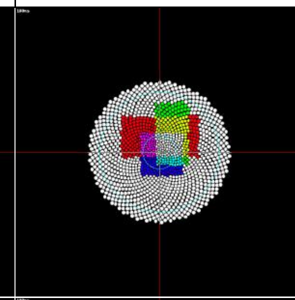
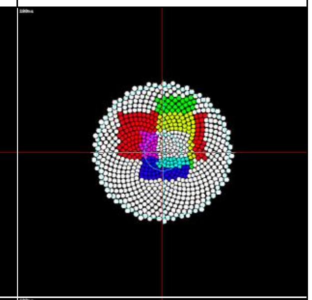
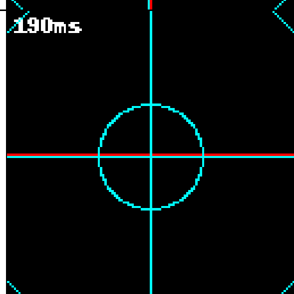
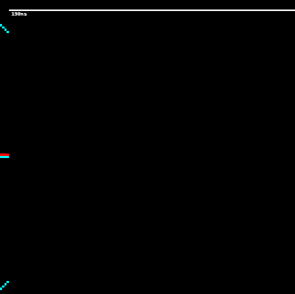
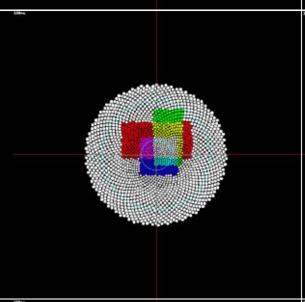
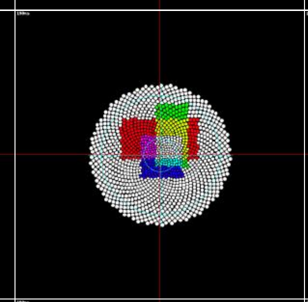
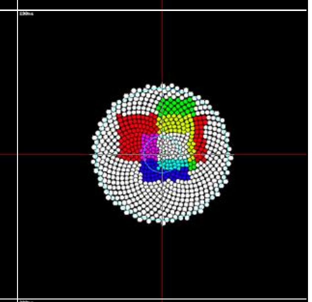
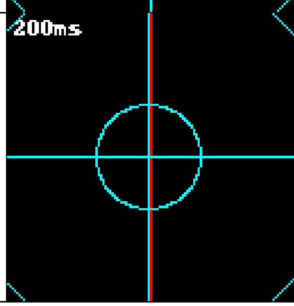
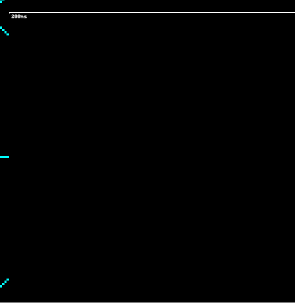
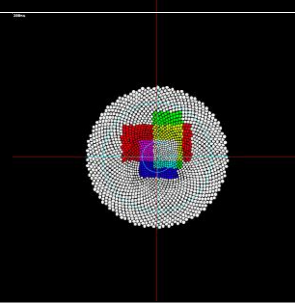
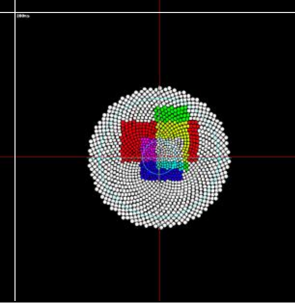
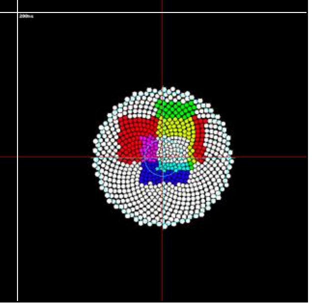
Table 42: Time sequence of imagining with distorted mosaic					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
18					
19					
20					

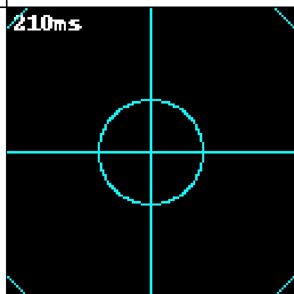
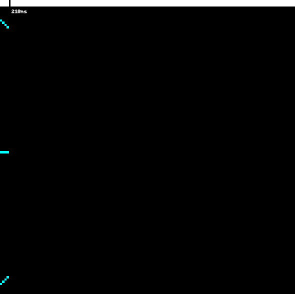
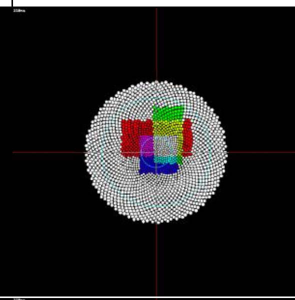
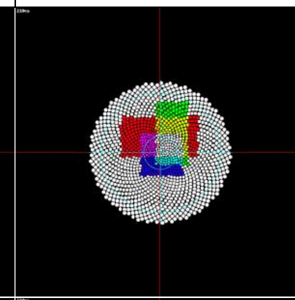
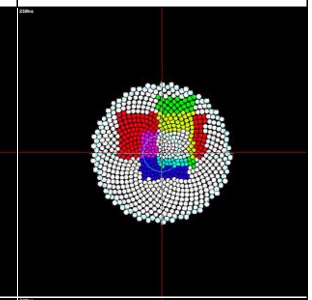
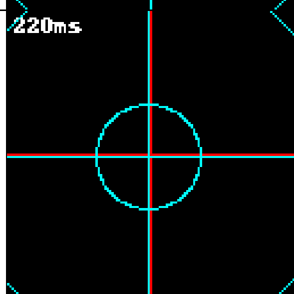
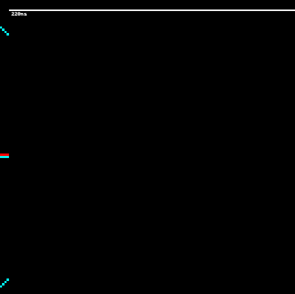
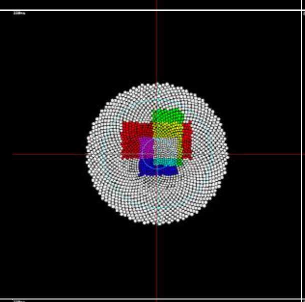
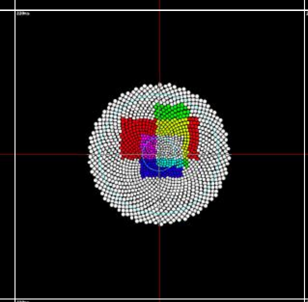
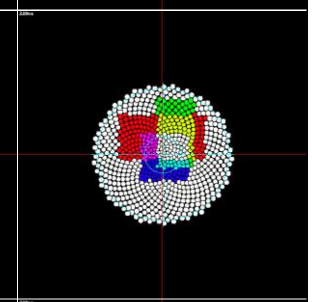
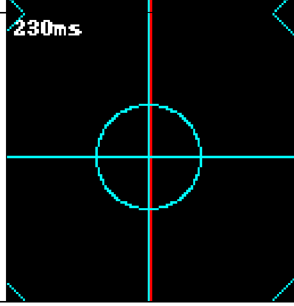
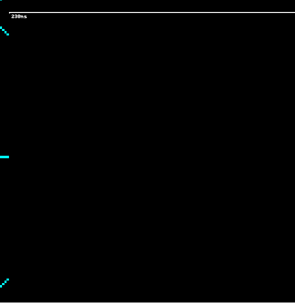
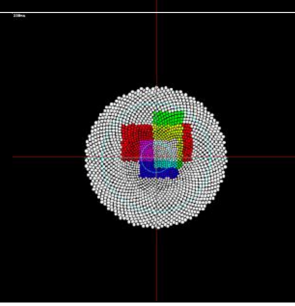
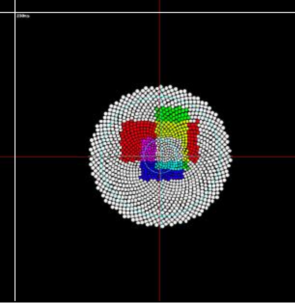
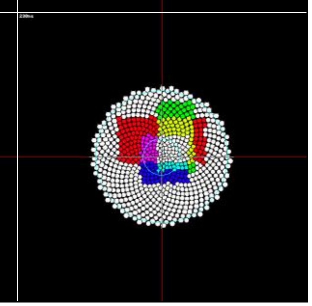
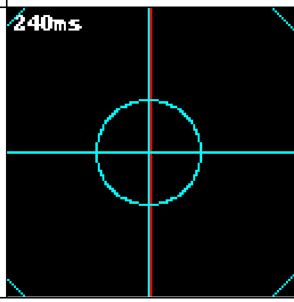
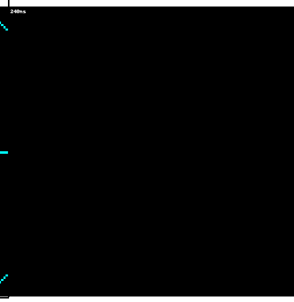
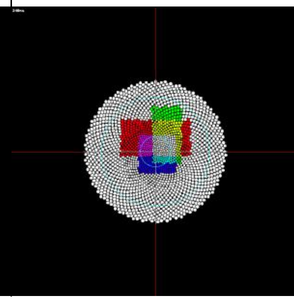
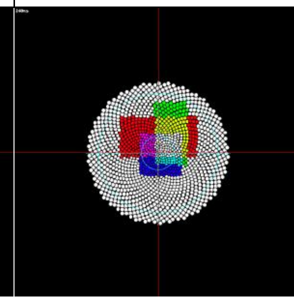
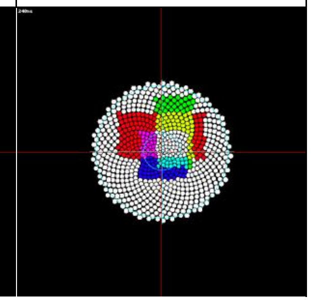
Table 42: Time sequence of imagining with distorted mosaic					
Time (ticks)	Stimuli	Photoreceptor Mosaic	Receptive Fields		
			Level 1	Level 2	Level 3
21					
22					
23					

Table 42: Time sequence of imagining with distorted mosaic					
Time (ticks)	**Stimuli**	**Photoreceptor Mosaic**	**Receptive Fields**		
			Level 1	**Level 2**	**Level 3**
24					

References

Francis, G., & Grossberg, S. (1996). Cortical dynamics of boundary segmentation and reset: persistence, afterimages, and residual traces. *Perception*, *25*(5), 543–67. doi:10.1068/p250543

Leibovitz, D. P. (2012a). A Unified Cognitive Model of Visual Filling-In Based on an Emergic Network Architecture - Animated Test Results. *Emergic Approach*. Retrieved from http://emergic.upwize.com/?page_id=26

Leibovitz, D. P. (2012b). Modelling visual processing via emergence. *Talk presented to the 22nd Annual Meeting of the Canadian Society for Brain, Behaviour and Cognitive Science (CSBBCS 2012)*. Kingston, Ontario. Retrieved from http://72.15.54.247/ocs/index.php/meeting/2012/paper/view/376

Leibovitz, D. P., & West, R. (2012). Cognitive Re-Use via Emergic Networks (Poster). *11th International Conference on Cognitive Modeling (ICCM 2012)* (Vol. In Press). Berlin, Germany. Retrieved from http://www.iccm2012.com/proceedings/papers/0013/index.html

Picard, R. W. (1995). Light-years from Lena: video and image libraries of the future. *Proceedings., International Conference on Image Processing* (Vol. 1, pp. 310–313). IEEE Comput. Soc. Press. doi:10.1109/ICIP.1995.529708

Spillmann, L., Otte, T., Hamburger, K., & Magnussen, S. (2006). Perceptual filling-in from the edge of the blind spot. *Vision research*, *46*(25), 4252–7. doi:10.1016/j.visres.2006.08.033

Wald, G. (1967). Blue-Blindness in the Normal Fovea. *Journal of the Optical Society of America*, *57*(11), 1289–1301. doi:10.1364/JOSA.57.001289