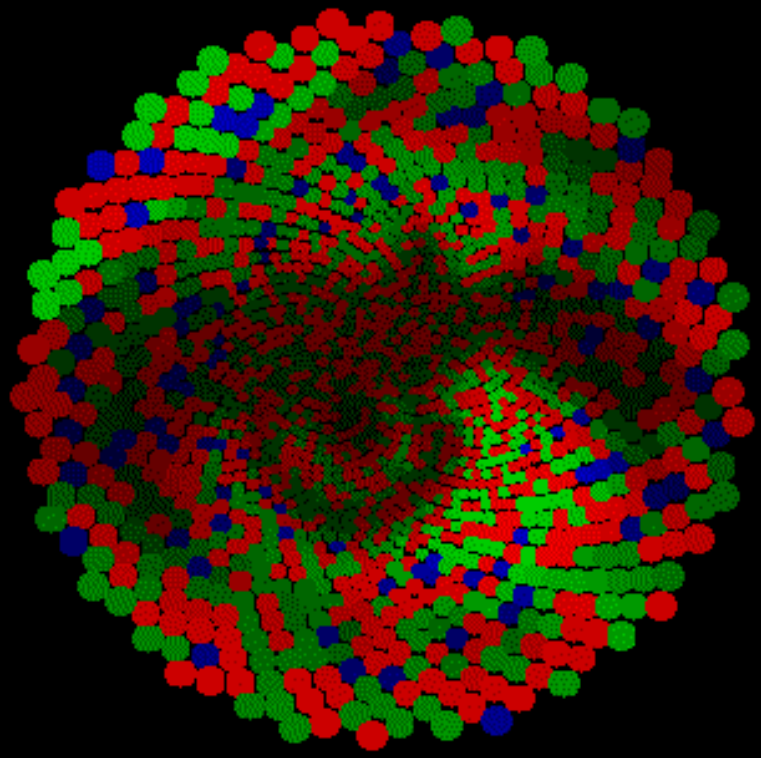


Philosophy Behind the Cognitive Modelling of Virtual Eyeballs

Towards Unity

Introduction

- Not a formal philosopher
  - Head is always in the clouds
- Talk geared towards non-philosophers
  - But philosophy is inescapable – can't hypothesize without
  - Prepare to be assimilated; **do ask questions**
- Not interested in vision per-se,
  - But only in how model validates the ***Emergic Approach*** – an analytic form of process philosophy
  - Model is a thought experiment in unification
    - ***Empirical Philosophy***

Lilac Chaser Illusion

http://en.wikipedia.org/wiki/Lilac_chaser

Demo

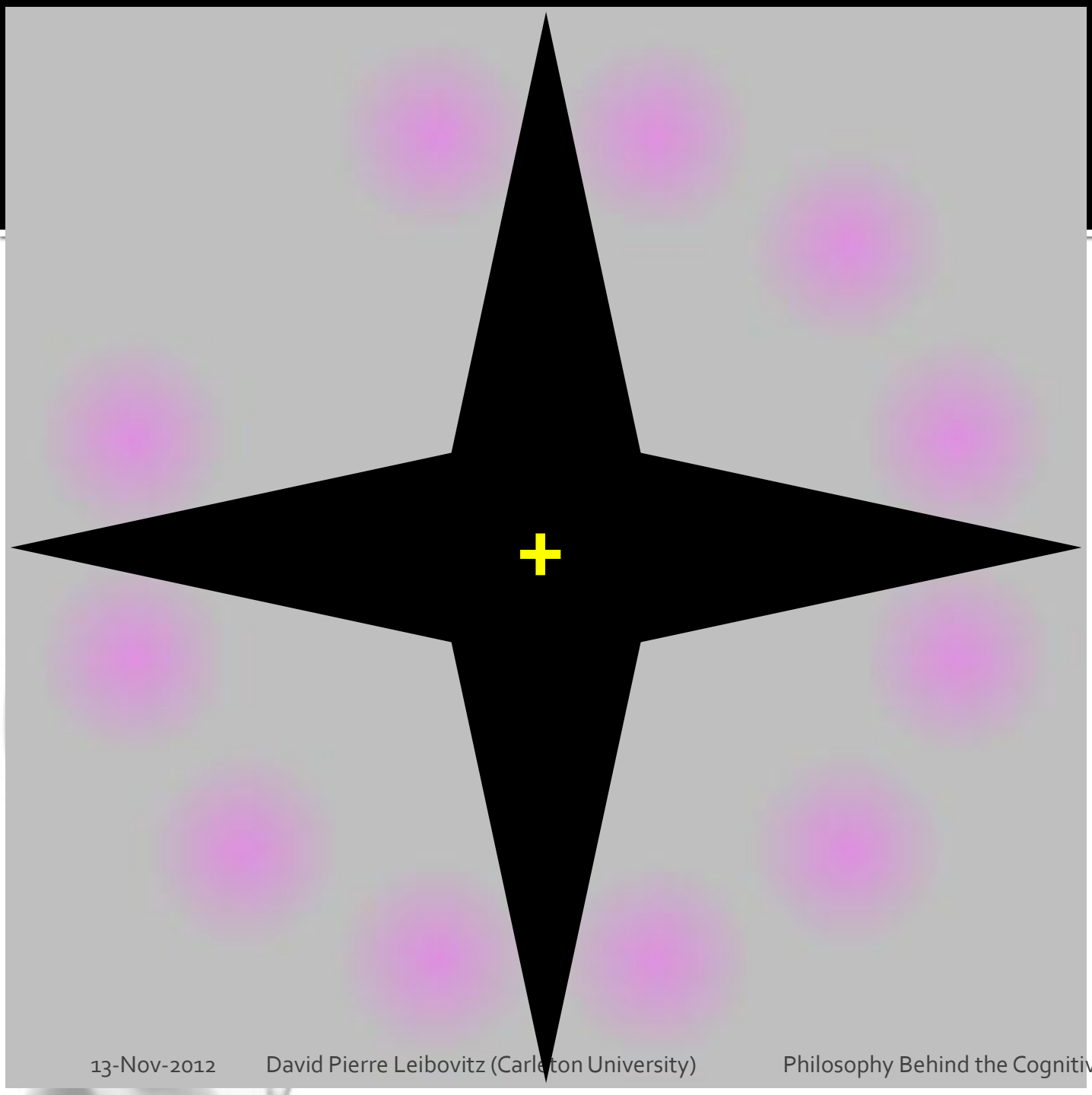
Phenomena & Explanations

- Troxler's fading
  - neural adaptation
- Negative afterimage
  - neural adaptation
  - colour opponent processing
- Perception of motion
  - beta movement

➢ All Defective

Why fade?

- What is being computed?
- What is the purpose of fading?



Adapts Faster!

- Occlusion
- Flicker
- What computed?

"Adaptation"

- Not informative
- Does not specify locus (retinal, LGN, V1, etc.)
  - Colour or edge?
  - Where is edge with blur? Gain control? Levels?
- Confound with attention/consciousness (qualia)
  - **Most vision/perception research is not about perceptual awareness – not about seeing**
  - Do sensory systems adapt (bottom-up) or is attention removed (considered as top-down modulation)
  - Pac-Man Illusion
- Change blindness & Inattentional blindness
  - Sense but do not perceive (even on fovea)
- Filling-in

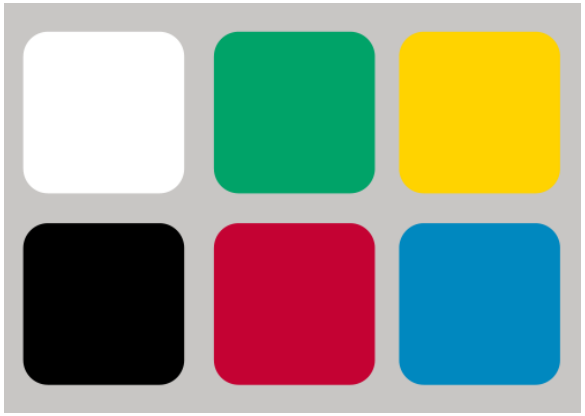
Why Negative Afterimage?

- What is being computed?
- What is the purpose of afterimages?

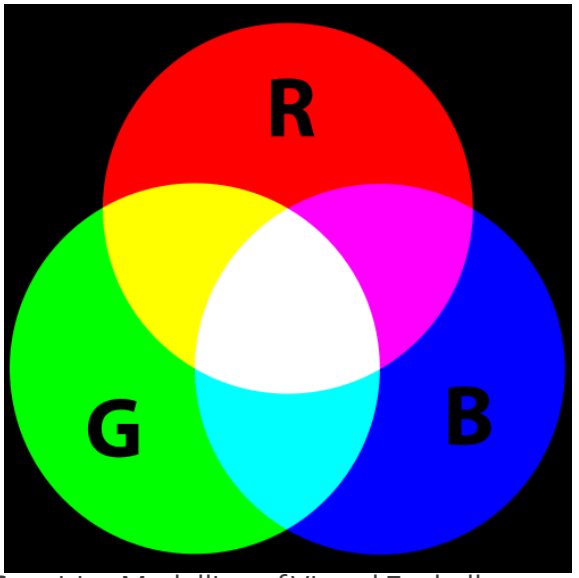
- Why is an afterimage considered as a defect in veridicality while fading is not?
  - Neither is normally witnessed in natural settings
  - Both explained by the same mechanism of adaptation

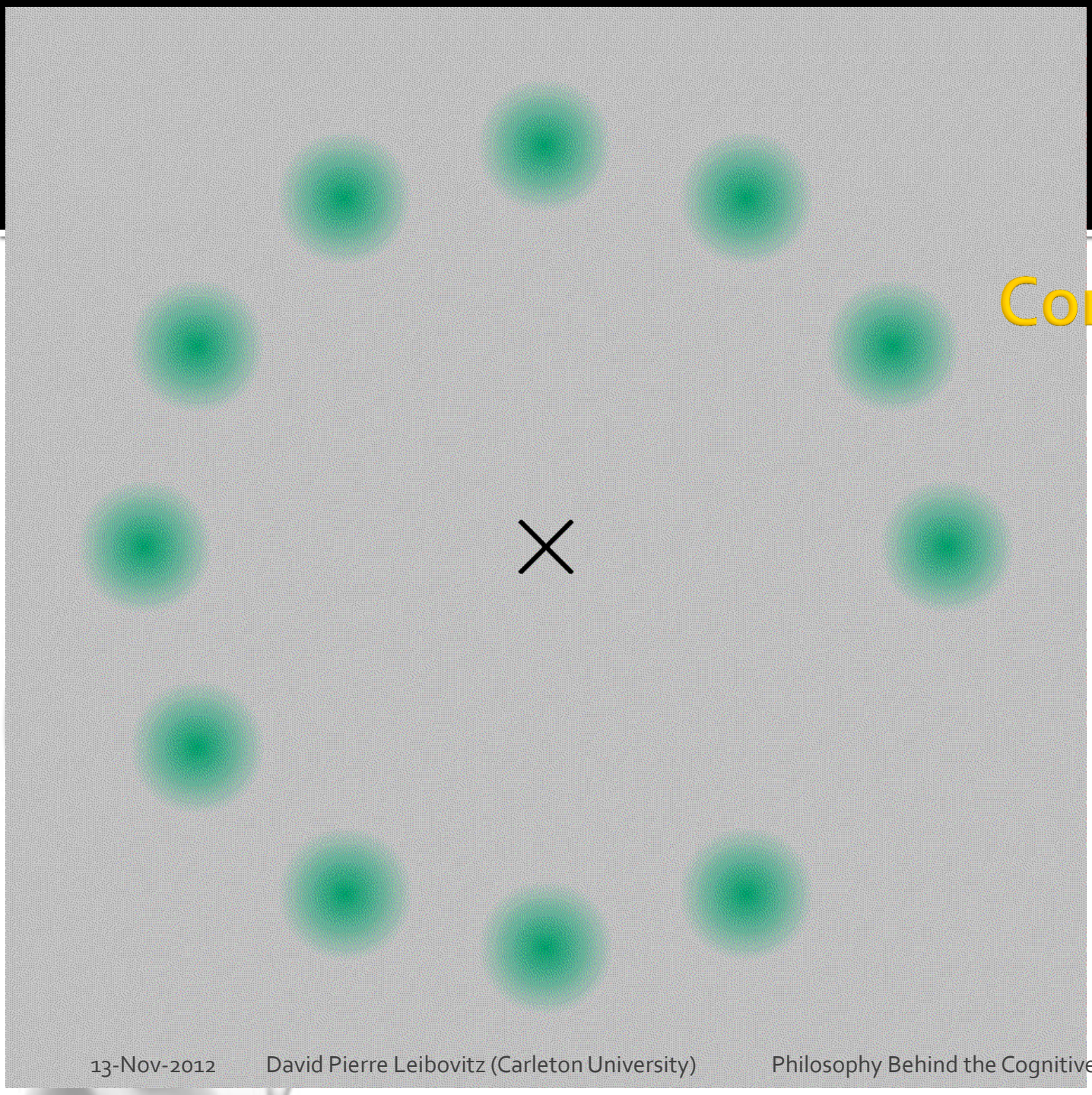
Colour Opponency

- Natural Colour System (NCS)
  - Colour Opponency
  - Unique hues
  - Black/White not truly opponent as
  - Mixture grey is perceivable



- Afterimage perception based on
  - complement colour (additive/subtractive)
  - Primary Colours



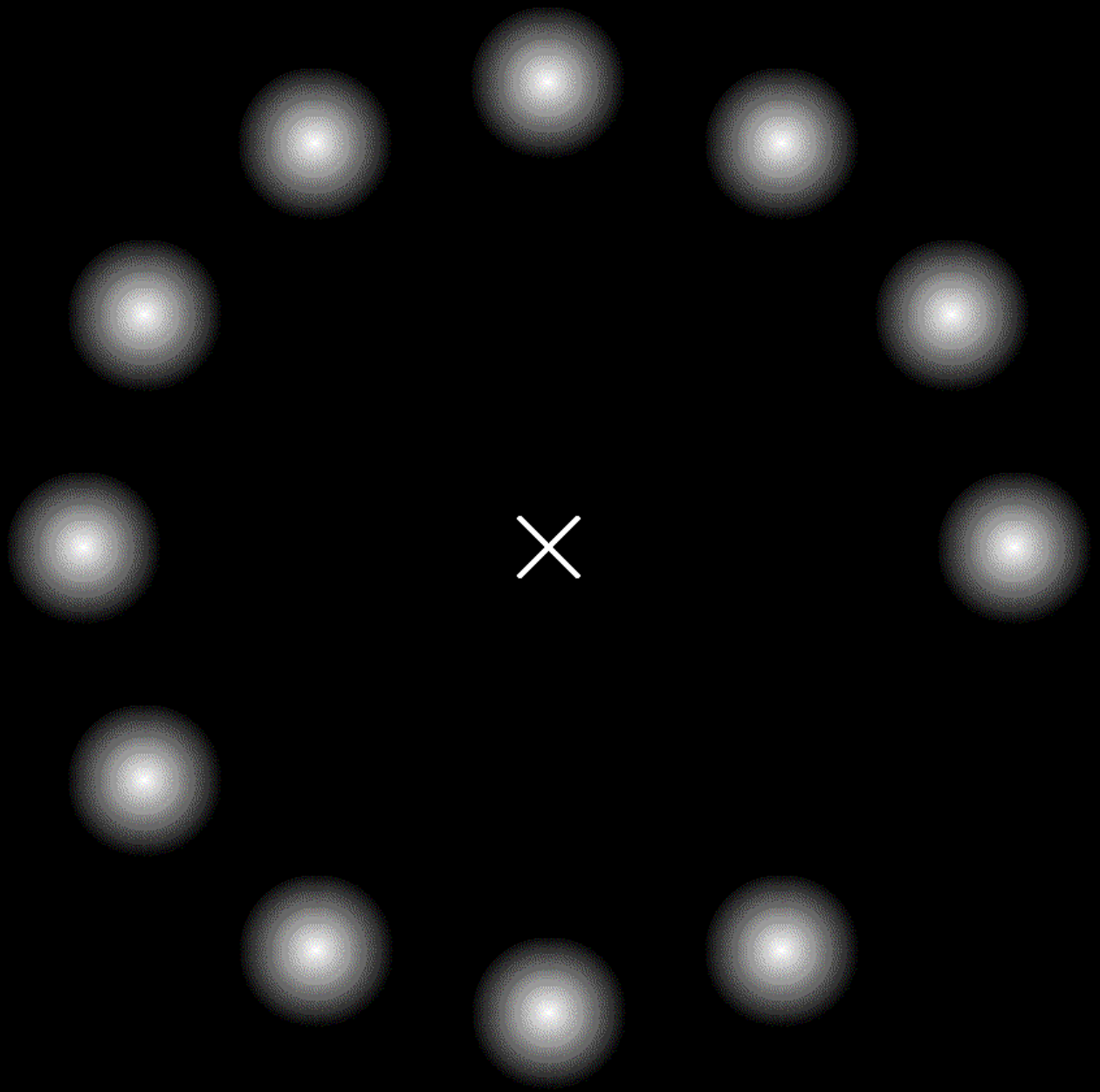


Complement?

NCS Green
(0,159,107)

NCS Red
(196,2,51)

Complement Lilac
(255,96,148)



Mixing?

- Fading
  - Filling-in
- Afterimage
  - Mixed
  - Blacker Black!
  - Imaginary Colours
  - Dark Red? (Benham's Top)

Complement

- Pure complement occurs
  - Not Physiological Explanation
  - Computational or Behavioural Explanation
  - For all aftereffects (colour, motion, etc.)
  - Due to bottom-up & top-down interactions
- We perceive deviations from expectations?
  - Not colour per-se
- On-Off Center-Surround is about
  - Removing non-linearities
  - Subtraction without negatives
  - Mere encoding (not computational level)

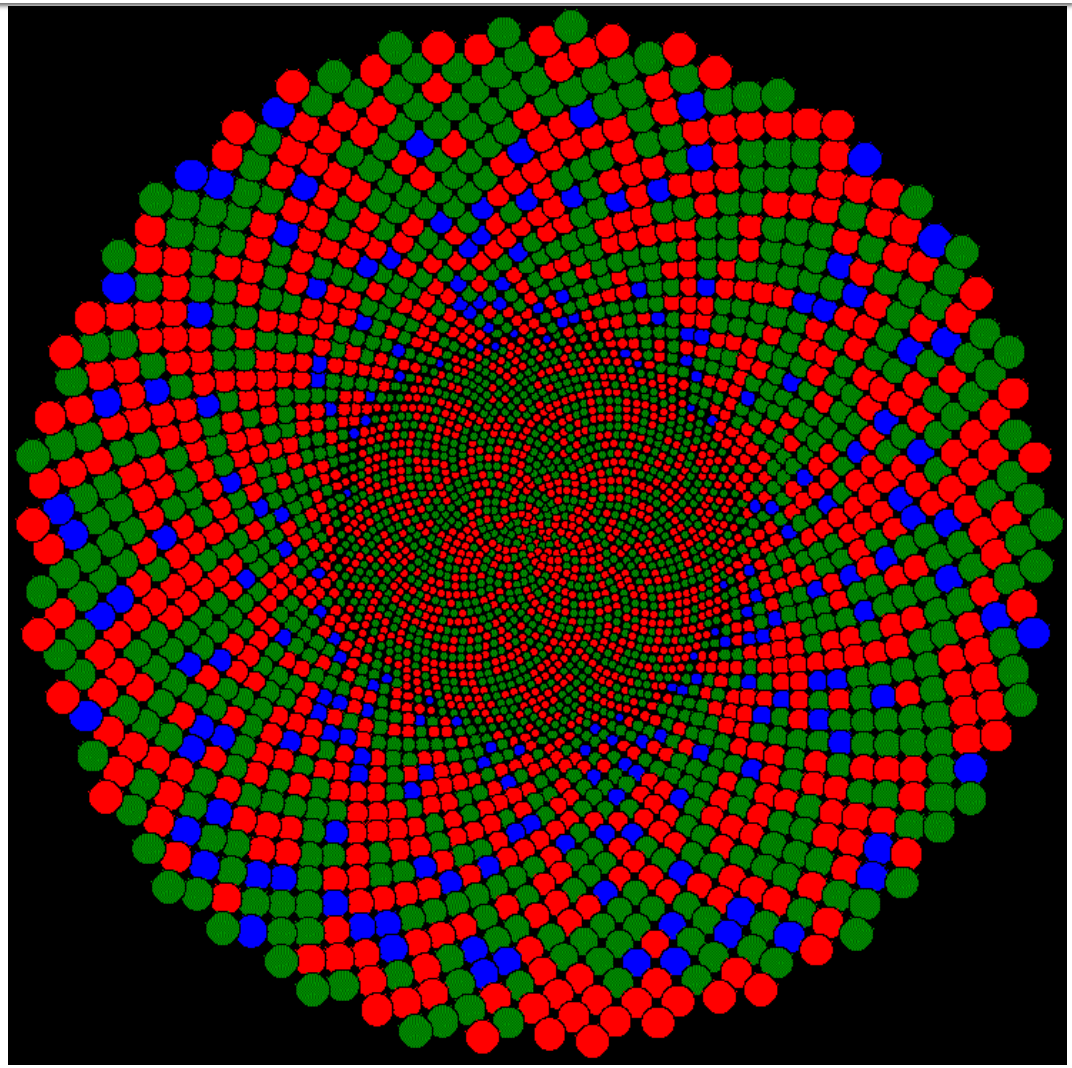
Solution

Solution Summary

- Unified slice (a la Newell)
  - Focus on the interaction of bottom-up and top-down flows of information
  - Biologically plausible – from photoreceptors to high-level cognition (but not symbolic)
  - Intuit single computation that causes many phenomena to emerge
  - Functional and spatiotemporal scale hierarchy
- Virtual Eyeball looking at Illusion
  - Include natural images
  - Include motion in images
  - Allow eye to move (jitter & saccade)
- Ecological
  - Embodied; situated; enactive; interactive

Cone Mosaic

- Foveola
  - No S cones (blue)
  - Must fill-in blue
- Fovea
  - Random & Increasing
    - Biological coordinate transformations
  - Varied M:L ratio
    - How to explain unique hues?
  - Locally hexagonal



Interactive Hierarchy

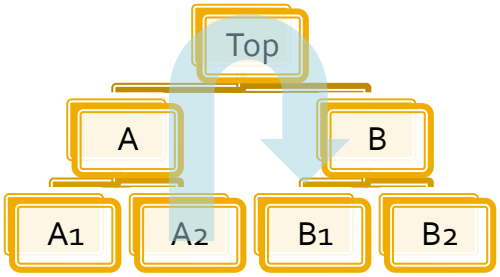
- Pyramid/Hierarchy
  - Functional Hierarchy
  - Spatiotemporal Scale Hierarchy
    - Spatial summation pathway
    - Contrast pathways (finds edges)
  - Interactive
    - Top-Down
    - Bottom-Up
    - Lateral

Classical Information Flow

- Brain Modelling
  - Mostly Bottom-Up (with top-down modulation)
  - Stimulus-Response
  - Response reacted (reflex)
- Mental Modelling
  - Mostly Top-Down (with bottom-up modulation)
  - Intentional: Goal Oriented
  - Stimuli pulled (read)
- Behaviour Modelling
  - Stimulus-Response (controlled)
  - Previous behaviours affect subsequent ones
  - Cybernetic (control theory)

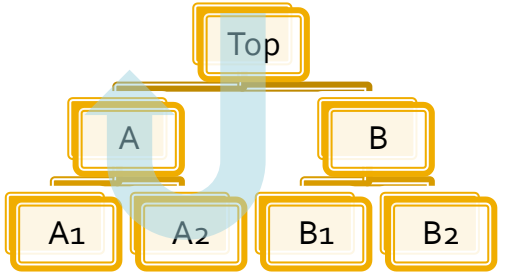
Perception

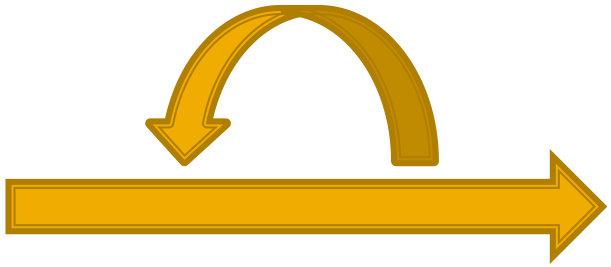
Stimuli - Pushed



Intention

Stimuli - Pulled



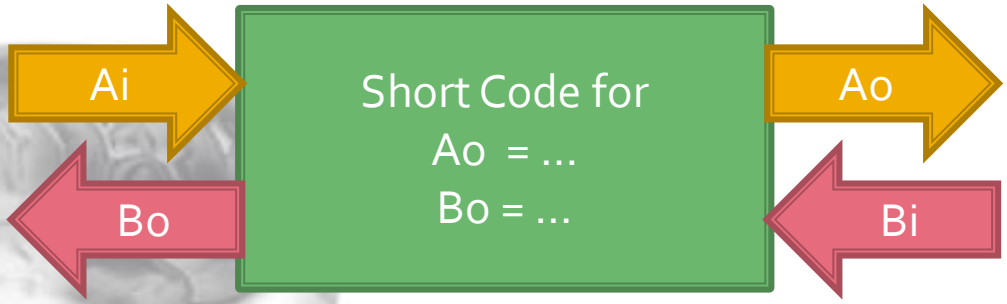


Interaction

- When two particles collide, they interact.

A

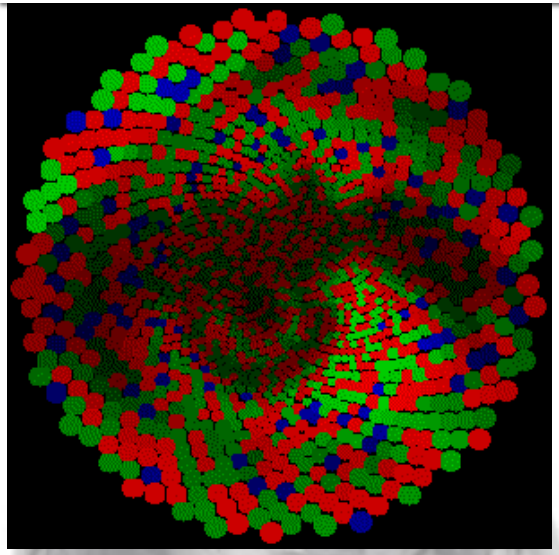
- Informationally, this can be shown as

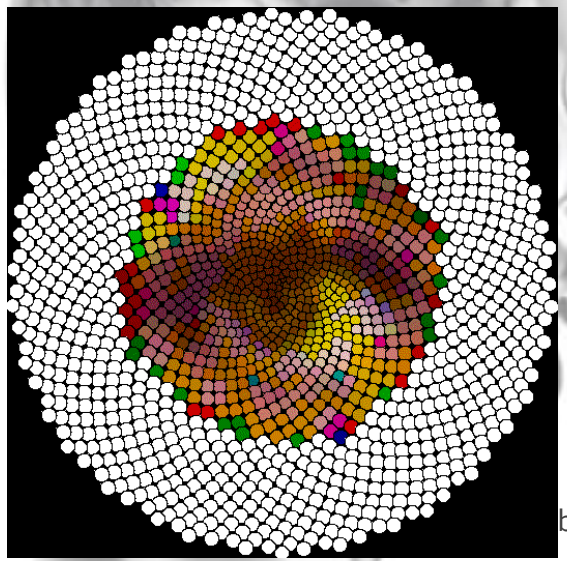


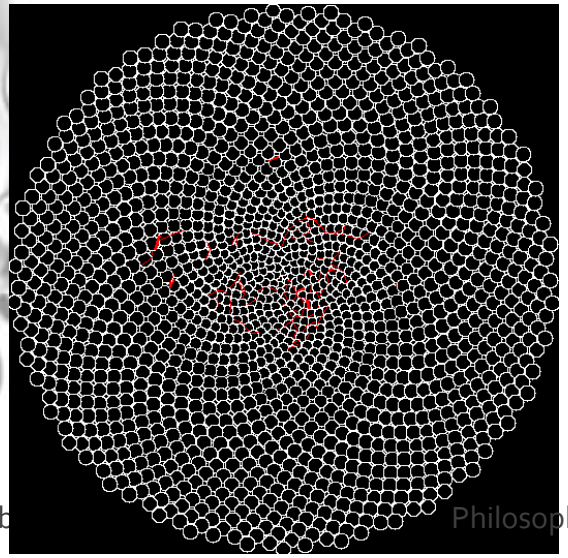
B

- Values transmitted can be complex
  - E.g., n, mean, SD
  - More flow, less dynamic complications

Demonstrate LCM Simulation

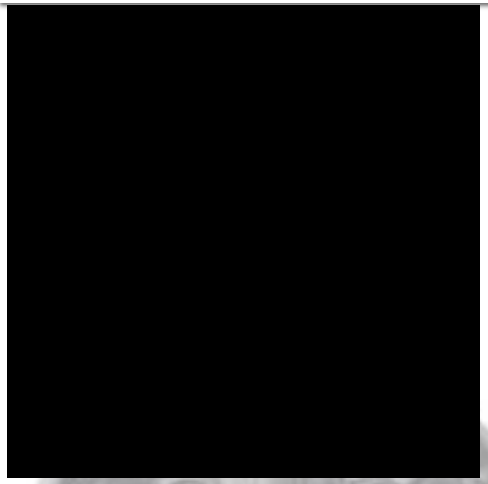


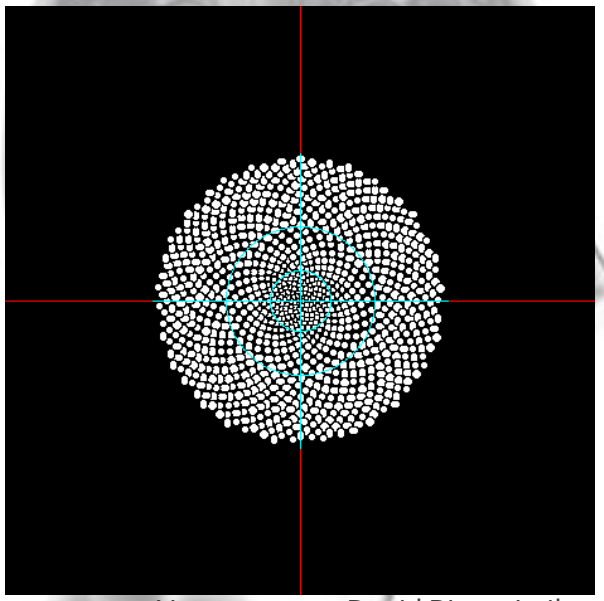




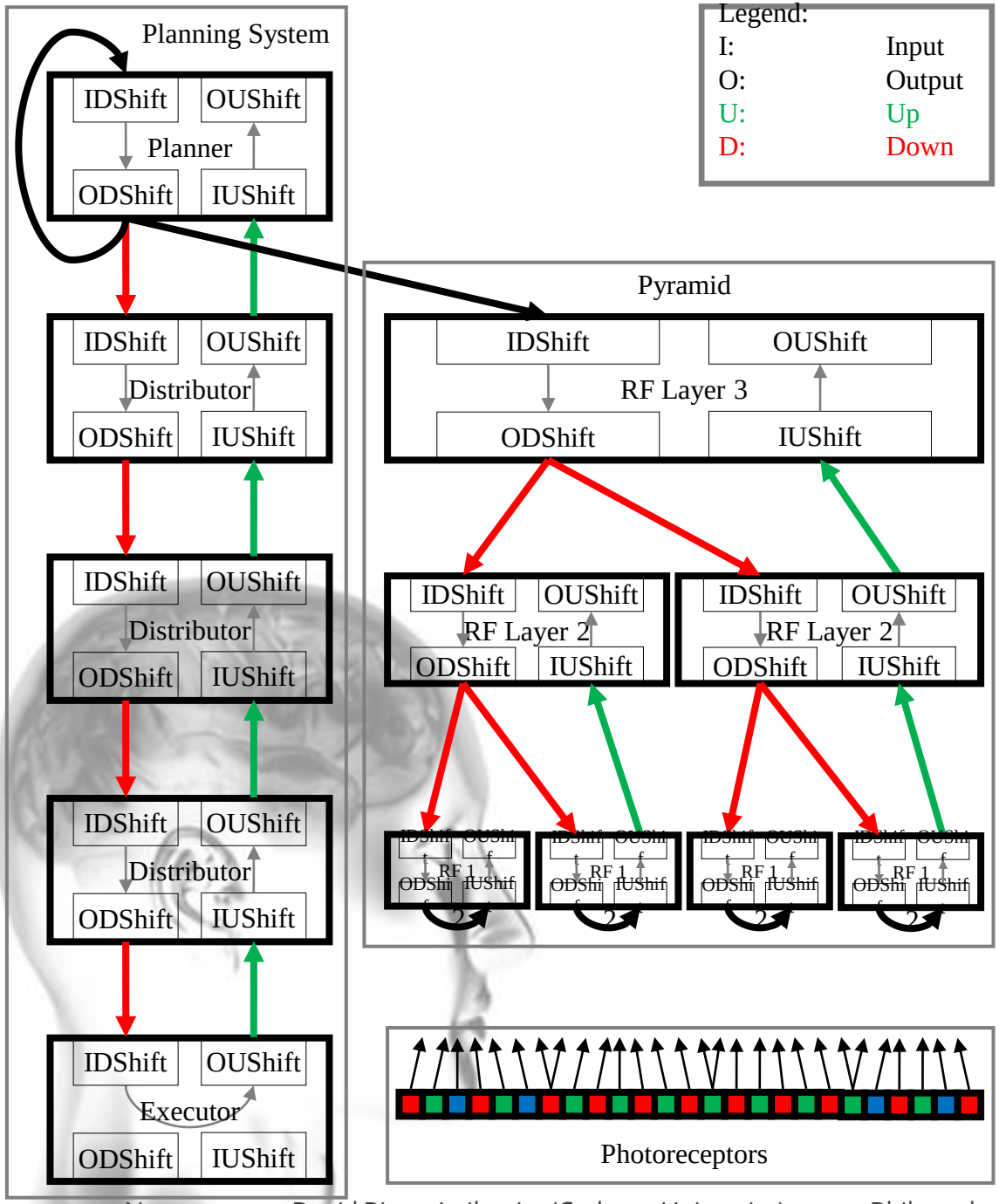
- Jittering on Lena's eye
- Photoreceptor Level
- Two Pathways
  - Spatial Summation
  - Change detection

Demonstrate LCM Simulation





- Saccade
- Shifting
- Flow-centric stability
- Imagination
  - Gist



Legend:

I:	Input
O:	Output
U:	Up
D:	Down

LCM Model Motor Planning

- Per-Level Shift
  - Flow coherence
  - ~headcentric
- Plausible
  - Grown
  - Corollary discharge
- Lego Bricks

"Single" Computation

- Integrate visual information over time & space
  - Occlusions, Scotomas, Motion Gaps, Blink
    - Interpolate (Fill-in) based on correlations beyond occlusions
    - Fill-in from older stuff when it was beyond occlusion
    - Includes predicted motion
  - Transparency (and shadows)
    - Subtract based on correlations
    - Note: a shadow could be fixated upon
  - Background
    - Suppress to minimize call for attention
- Correlations via expectations
- Jitter when fixated
- Attend to changes
- Note: cyclopean vision; no depth

Phenomena Impacted

- Adaptation; Colour/Chromatic constancy; Fading; Filling-in; Flicker; Image stability; Negative afterimage; Motion perception/interpolation; …
  - Because agent is complete and ecological v.s. oversimplified model
- All these "emerge" indirectly from single computation.
  - Emergic aspects are not explicitly modelled

Philosophic Trade-offs

Modelling

- Every model makes some simplifying assumptions to focus analysis on an aspect of interest
- I'm interested in unification (see why later)
  - Connectionism and Computationalism
  - Bottom-up and top-down (and lateral)
  - Stimulus-response and intentional
- Via
  - information flows of change (process philosophy)
    - Can be symbolic if both symbol/function and be learned and bound
  - While maintaining biological plausibility

Non-linear Interactions

- A few non-linear interacting mechanisms can lead to complicated behaviour and numerous phenomena
  - Do not model system phenomena nor behaviour, but
  - Intuit non-linear mechanisms and their interactions
    - Top-down computational decomposition
- The behaviour of individual mechanisms at mechanistic timeframes is process philosophy
  - The behaviour of system interactions at arbitrarily larger spatiotemporal scales emerges deterministically bottom-up
  - There is no true top nor intermediate levels (why later), only highest level system; and lowest level mechanistic parts
  - Analytical tops are arbitrary (as in pyramids)

Phenomena vs. Data

- Data is an objective movie recording of behaviour via objective instruments/microscopes
  - We will see the snail going in a straight line
- Phenomena is a deviation of data patterns (over any spatiotemporal scale) from theory
  - E.g., apparent retrograde motion
  - Number of possible patterns is infinite
- Lots of micro-theories lead to lots of phenomena and subjective measures
  - If a given behaviour can be measured via two different approaches, then there is no objective measure

Problem

- Too many micro-theories, phenomena & subjective measures tied to local micro-theories
- Cannot see the forest computation for the tree computation
  - And computations are context sensitive as we will see
- Recommend Unification (Allen Newel)
  - Require New Approach

Treatment – Unify

"The first suggestion is to **construct complete processing models** rather than the partial ones we now do."

– Newell, A. (1973). You Can't Play 20 Questions with Nature and Win: Projective Comments on the Papers of this Symposium. In W. G. Chase, *Visual Information Processing: Proceedings of the 8th Symposium on Cognition*.

- Unfortunately, these have not been forthcoming.
  - Why for another day

Solution

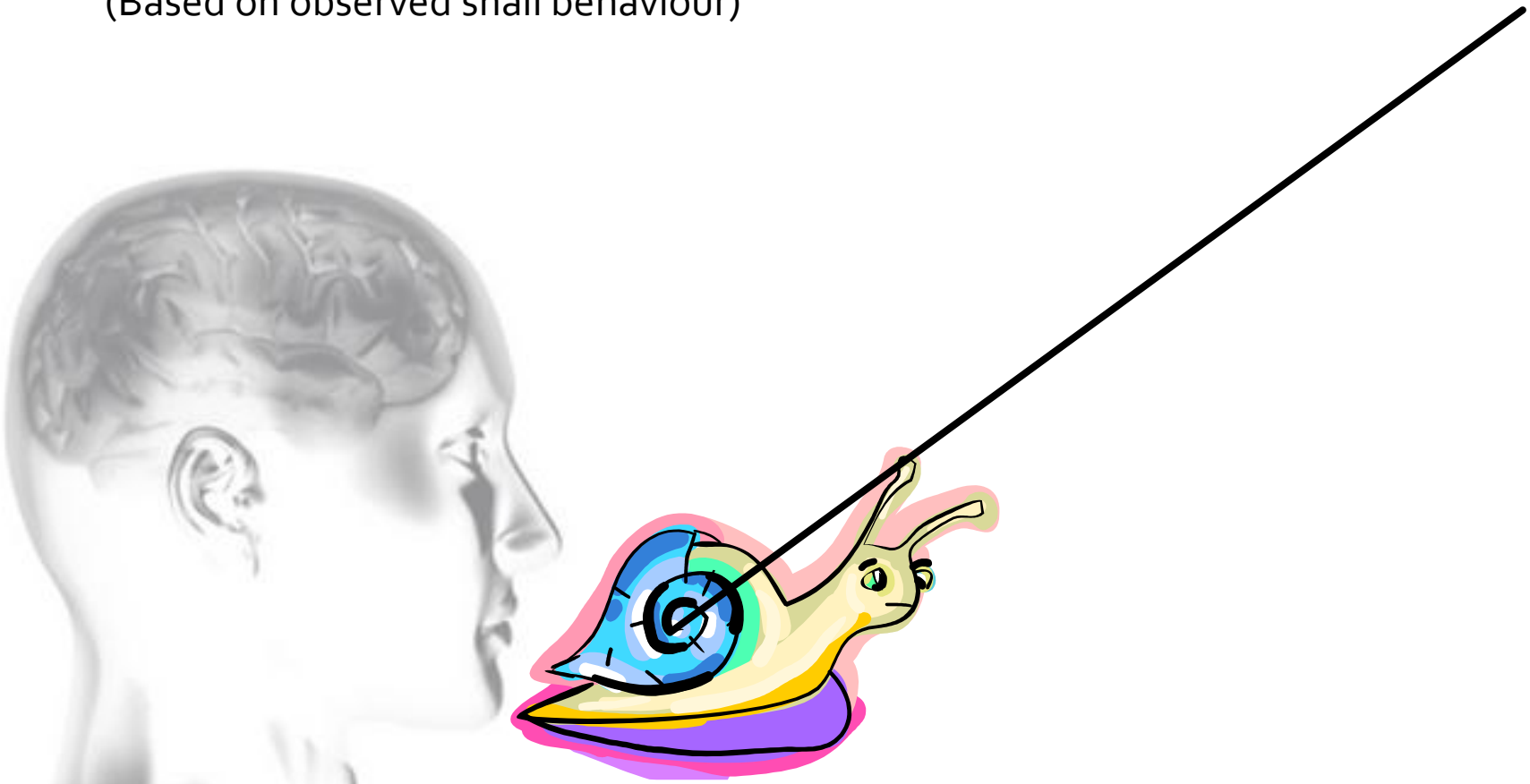
- Unify (as Newell Suggested)
  - Replace software control with HW/SW structure
  - Adopt a process metaphysics (Emergic Approach)
    - Why for another day
  - Note: only 1% of researches need to build such theories, while the rest can continue to explore
- Emergic units half-way between
  - artificial neural network (connectionism)
    - Bottom-up; stimulus-response; reactive
  - Computationalism
    - Top-down; intentional;

Joints

- Plato suggested we butcher nature at her natural joints
- Worked well for physical joints at different levels of analysis
  - Objective measures
    - Colour & Temperature emerge at different levels
      - Structural colours
      - From processes
  - Objective microscopes
  - Reduced top-down; bridged bottom-up via processes
- Cannot work for non-physical
  - No microscopes
  - No objective measure – each paradigm has own
  - Coherence (via unification) is only option

Computationalism

What does a straight line compute?
(Based on observed snail behaviour)



Computationalism

Computationalism

Computationalism

- Can show that a straight line computes all possible functions (and their inverses)
  - Similar to Putnam's rock (1988)
  - This type of "computation" has no execution semantics
- All depends on how one labels (or measures) the X and Y axes
- Interpretation of behaviour is of infinite variety
  - Is context dependant
  - Top-down decomposition of system into computation and function

How can a Snail Execute

- Run straight on a treadmill; generate electricity; pipe that into a Turing Machine
- Be the "electron" that goes through a Turing Machine, much like Searle goes in a straight execution path through the Chinese room
- At some point, the snail must actually transmit energy to a sensor or effector in order to interact with the world.
- A transistor statistically controls millions of electrons – each has a measure of "free will"
- Our physical transportation networks along with our social constructions such as signs, driving on right, etc. statistically control our actions as we navigate the world. What do we compute? What do we do?
  - Process philosophy is about doing and has no intentionality beyond survival of the fittest which even viruses manage to do
  - Computation is an analytical activity that adds an arbitrary intentionality to incomplete (feedforward) analysis. Surprisingly, we are forced to do so as part of our world sense making (usually wrong).

Levels/Kinds of Analysis

- Kinds:
  - Computational level has denotational/functional semantics
  - Implementation level has execution/simulation semantics
  - Keep kinds apart
- Levels are ordinarily of great spatiotemporal scales apart
  - Neuron fires every 5ms
  - Unit of conscious thought 50ms
  - Same scale so cannot have levels between neuron and mind
  - Compare to 10^6–10^7 number of ATP molecules required to effect a single action potential

Decomposition/Recomposition

- Marr had holistic view of levels; but
  - Mostly feed-forward (bottom-up) execution
  - Top-down specification (as any good engineer)
    - From highly speculative to biology
  - Had crisp computations and functions

- I suggest to iterate over
  - Top-down computational decomposition due to context
    - Must include recursion/interaction
    - Keep computation/function as a fuzzy goal
    - No microscope so only unification can constrain
  - Bottom-up execution recomposition using physically objective biological parts
    - Towards a fuzzy computational goal
    - End up with an emergic computation infinitely more subtle/complex
      - Satisfices
    - Mother nature/evolution was not a top-down designer

Empirical Philosophy

- We want (ideally the smallest) set of coherent conceptions
  - Simplify globally; complicate locally
- Philosophise
  - Typically not analytic/operationalized
  - Typically not global
  - Method of rational dialog
- Computational + Unify
  - Method of computers

Parting Remarks

"vision science is not just one branch of cognitive science, but the single most **coherent, integrated, and successful** branch of cognitive science."

– Palmer, S. E. (1999). *Vision Science: Photons to Phenomenology*

Reality

"However, the mechanism of brightness induction evident in several optical illusions, is **not yet understood even after 200 years of intense research** that saw George Berkeley, Maxwell, Helmholtz and the modern Gestalt school, that include both the intrinsic image theorists as well as the anchoring model theorists, following the "top-down" approach on one hand and Weber, Fechner, Mach, succeeded by the modern contrast theorists following the "bottom-up" approach on the other."

— Ghosh, K., & Bhaumik, K. (**2010**). Complexity in Human Perception of Brightness: A Historical Review on the Evolution of the Philosophy of Visual Perception. *Journal of Biological Sciences*, *10*(1), 17-35

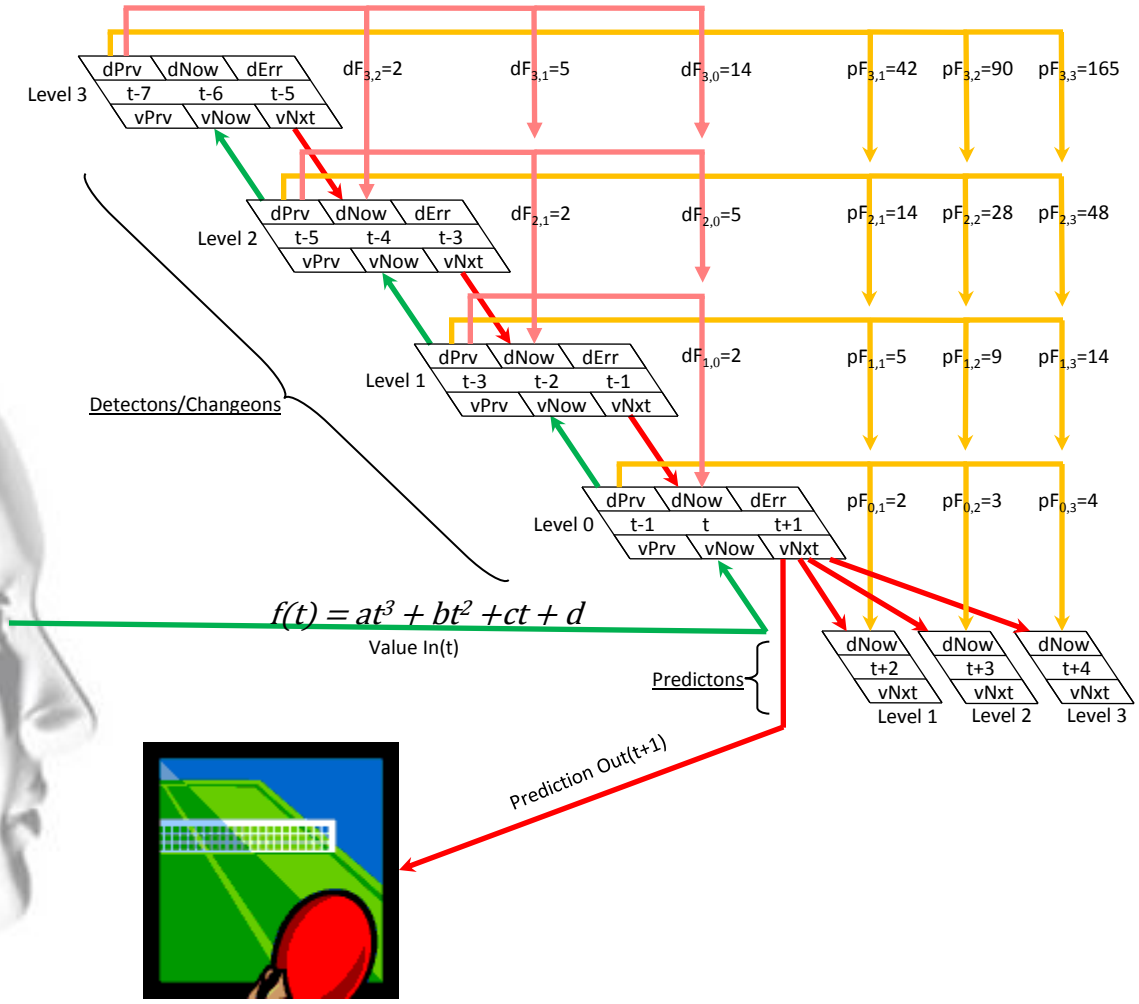
Q & A

- About Cognitive Model of Visual Perception?
  - Unification?
  - Top-down vs. Bottom-up (Analysis vs. Engineering)
  - "Adaptation"
- About Lilac Chaser Illusion?
  - Fading, Negative Afterimage, Motion
- About Philosophy?
  - For non-philosophers?
  - Process/Emergic Philosophy; change; flow

Backup

Process Network Example

- Automatically generates missing info
  - blink
  - Optical blind spot
- Continuous Interaction
  - Bottom-up
  - Top-down
- Incremental Learning of Dynamics
  - Not solution
  - No substance (weights)
  - Adaptive
- Incremental Levels
  - Improve accuracy
- No Delay
  - 8 Spreadsheet Columns
- Delay
  - Need Network
  - +Efferents
- Far Predictors
  - Not needed



Recursion & Philosophy

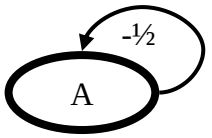
- Current "substance" philosophy cannot handle recursion
  - "This sentence is false." ← True or False?
    - Gödel's **incompleteness theorems**
    - Tarski's **semantic theory of truth**
  - Zeno's Paradoxes of Motion & Time
    - Recursion highlights that continuous change cannot be analytically broken up into discrete steps/values. Requires an infinity of steps and infinitesimally small values.
  - Identity and Change
    - Heap of Sand – arbitrariness of definitions; DSM
    - Ship of Theseus
    - Are you the same person today as after, losing an arm, being tortured?
- Need a Process Philosophy

Unity – Classical Non-Empirical

Time	Psychology – Behaviour	Medicine - Symptom	Physics - Property
	Temperament (=Myers-Briggs)	Humour	Element
Spring	Sanguine, Artisan Aspire, Inspire, Extrovert, Sensitive, Compassionate, Thoughtful, Forgetful	Blood Courageous, Hopeful, Amorous	Air Hot & Wet Power, Spirit
Summer	Choleric, Idealist Energy, Ambition, Assertive, Passion, Lead	Yellow Bile Easily Angered, Bad Tempered	Fire Hot & Dry
Autumn	Melancholic, Guardian Thoughtful, Considerate, Worried, Perfectionist, Independent, Focused	Black Bile Despondent, Sleepless, Irritable	Earth Cold & Dry Heaviness, Matter, Fertility
Winter	Phlegmatic, Rational Content, Kind, Accepting, Affectionate, Receptive, Shy, Stable, Relaxed	Phlegm Calm, Unemotional	Water Cold & Wet
Timeless	Divine, Unchanging, Pure		Aether, Space Clear, Essence

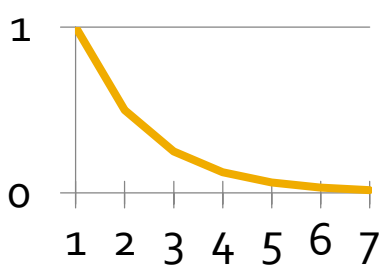
Process Metaphysics – Simple Process Example

- A simple observed process is analytic and formulated as

  "A becomes of –A/2" or A += -A/2 or 

  (1)

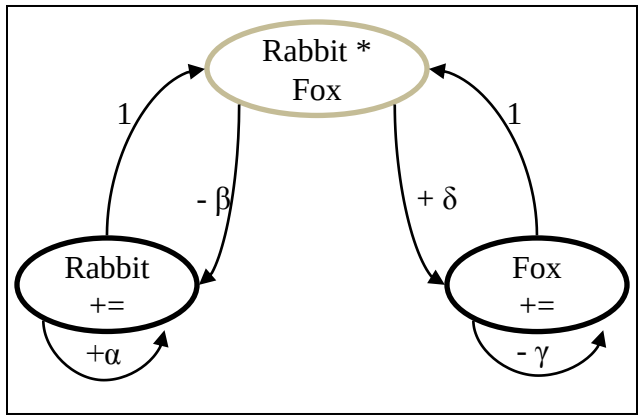
- The change operator ("+=")
  - Usually small snippets of functional code rather than "+="
- Example could produce the sequence {1, ½, ¼, … $1/2^n$} every Δt

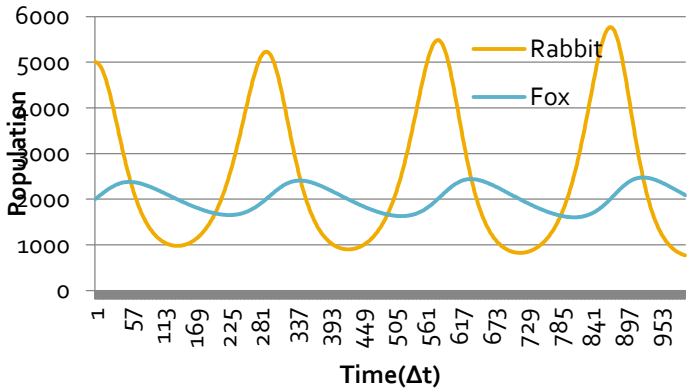


  - This could represent a battery becoming discharged
  - Note: non-linear exponential behaviour emerges despite being simply a linear sum of parts. This is due to recursion.
- Process eventually must have self-reference (recursion)
  - Allows it to change over time even if stimuli removed
  - (This is explicitly not allowed in Causal Bayesian Networks)

Process Metaphysics – Simple Process Ensemble

- All processes in a system interact continuously and are shown in an ensemble. Here is the Lotka–Volterra predator-prey example
  - *Rabbit* += (α**Rabbit*) – (β**Rabbit***Fox*)
  - *Fox* += – (γ**Fox*) + (δ**Rabbit***Fox*)
- The Rabbit*Fox term is not recursive, is not independent, has no observable reality and is simply shown for simplicity
  - Represents the chance that fox and rabbits will meet
  - Has no delays
- RHS influence LHS often
  - Interactively
  - Terms of Opposition (+ vs. -)
- System is time invariant





Research Problems

- **P1) What obstacles prevent the modelling of unified cognitive systems beyond a certain set of interactions?**
- **P2) What are some viable solutions?**