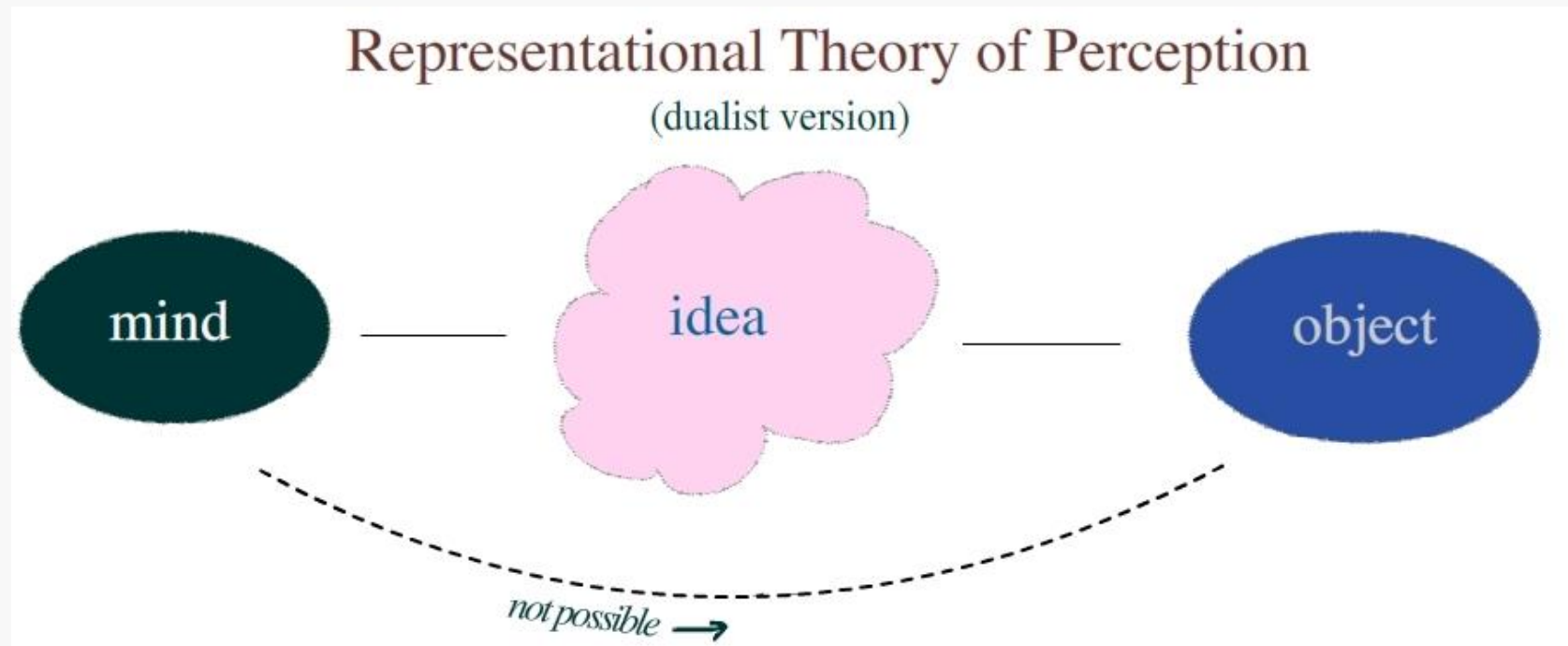# Emergent representations from distributed interactive dynamics

Matthew Spencer, Etienne Roesch, Mark Bishop, Slawomir Nasuto

Representational Realism

Representational Theory of Perception
(dualist version)

mind —— idea —— object

not possible →

Aristotle, Descartes, Locke, Wittgenstein, Gibson, etc...

Representation and Cognition

- Representational realism is appealing because it helps explain abstraction, reasoning, memory, and language

- Problems
  - Meaning:
    - Where does the meaning come from?
    - To whom do they have meaning?
      - Homunculus or Cartesian Dualism?
  - Physicality:
    - Where and how are they physically instantiated?

- Traditional accounts get stuck here

Interactivism

- Organisms are recursively self-maintenant far-from equilibrium (FFE) processes
  - FFE: Thermodynamic state requires maintenance (Normativity)
  - Self-maintenant: Multiple normative functions
  - Recursive: Selection of appropriate functions is a function
  - Must anticipate which function is best
- These anticipations can serve as representations

Bickhard, M. H. (2009). The biological foundations of cognitive science. *New Ideas in Psychology*, *27*(1), 75–84.

Bridging the Epistemic Cut

- Dual perspective:
  - A symbol has a meaning
  - A symbol has a physical form
- The semantic potential of a symbol is realized during specific interactions
- Eg. DNA
- The right kind of physical interactions of a dynamical system can support the creation of symbols

Pattee, H. H. (2001). The physics of symbols: bridging the epistemic cut. *Biosystems*, *60*(1-3), 5–21.

Distributed, interactive dynamics

- Population of simple, stochastic agents
  - Balances exploration and exploitation
  - Guesses, checks, and communicates
- Can locate complex structures in a dynamic environment
  - Clusters around structures of interest in the environment
- Stable clusters are dynamic, always changing members
- Stability of clusters = representation?
  - For the human user
  - Only part of the story about shifting the focus from static representations to representations as non-stationary processes
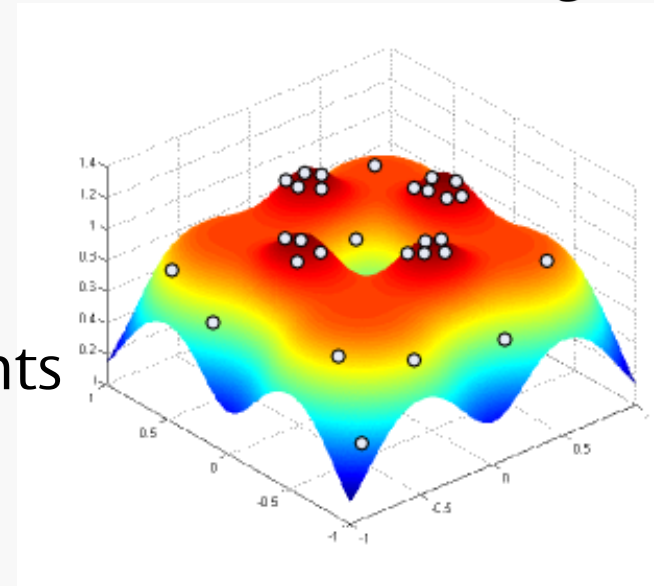
Symbols: Computation vs Cognition

- Symbols used by computers have no meaning to the computer

- The symbols are meaningful to the humans interacting with the computer

- Thus, the meaning emerges from appropriate interaction

- Can symbols arise which have meaning for the computer?
  - Maybe – it depends on the FFE status of the body (Bickhard)
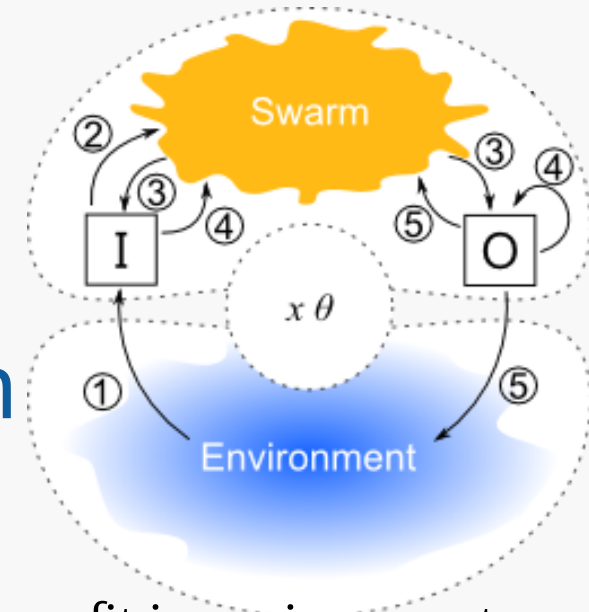
Interaction and Metabolism

- Swarm – Embodiment - Environment
  - Organism has multiple functions to draw benefit in environment
  - Swarm represents some control mechanism within an organism
- Available energy drives agent dynamics
- Energetic agents influence organism action
  - More energy ➜ More influential, more often
- Agents bare metabolic consequences of their influence
  - More metabolic benefit ➜ More energy for agents
- Agents are biased towards maximizing future energy

Anticipation

- Forward-looking function selection
  - "In this situation, this action would be beneficial"
- Agents randomly select:
  - Indication of interactive potentiality (target input)
  - Normative function (action output)
- Birth
  - Attempt communication on activation
- Death
  - Deactivate if unused (eg. apoptosis in inactive neurones)

Macroscopic function selection

- Agents compete for function selection
  - More competitive if
    - High energy
    - High indication of interactive potentiality w.r.t. environment
- Winners are more sensitive to future energy intake
- Agents that don't compete are likely to diffuse
  - Explore new anticipations
  - Exploit good anticipations

Consequences

- Causal Effect

$$\Phi_a(t) = \sigma_a(t) \cdot e^{-\frac{1}{\lambda}(t - \tau_a(t))}$$

- Relative benefit
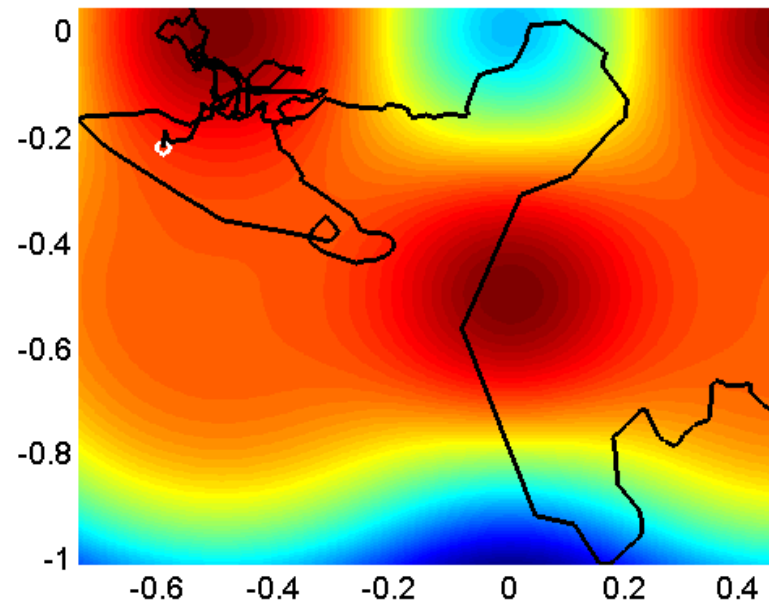
$$B_a(t) = \frac{E(x(t))}{\mu_a(t)}$$

- Energy demand

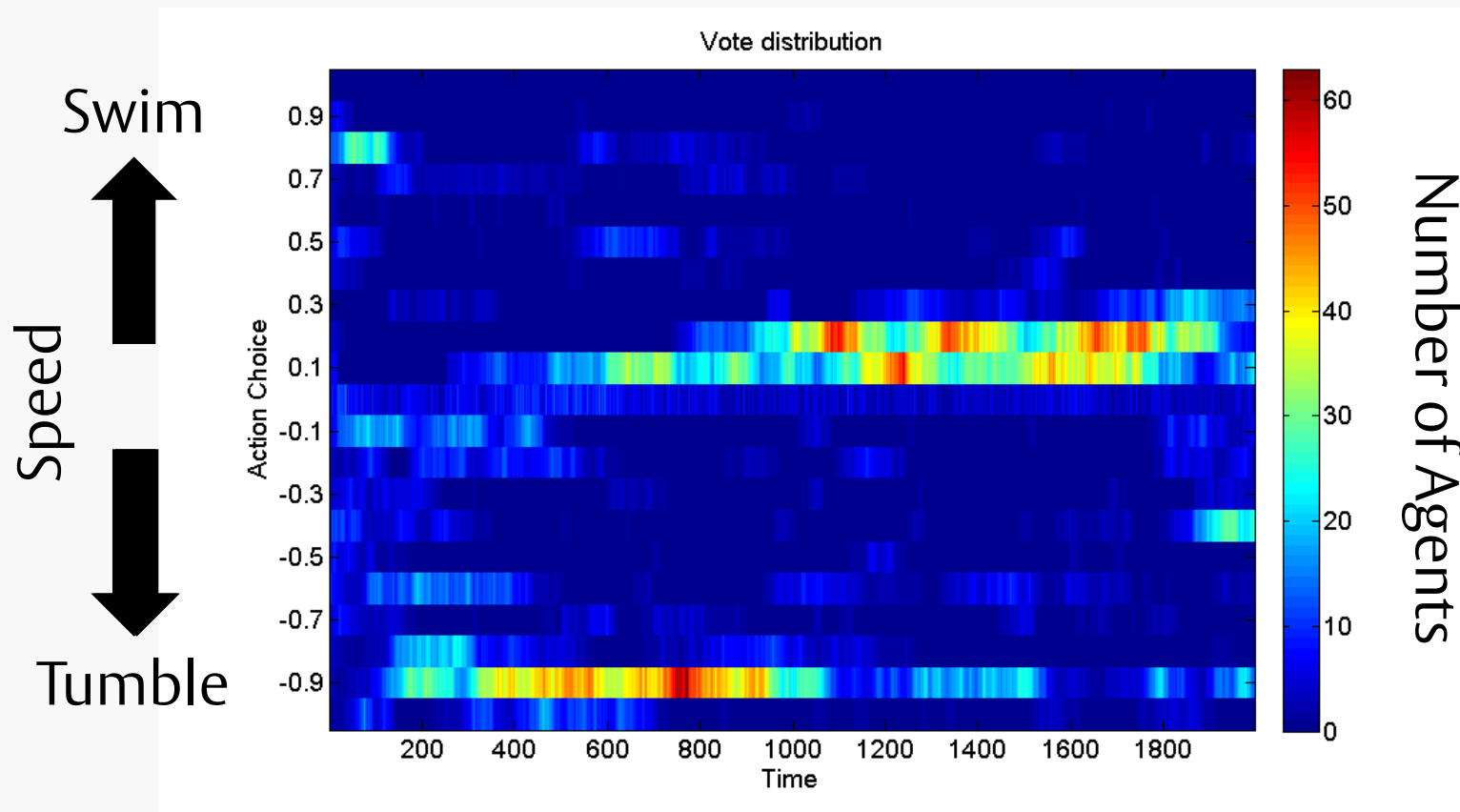$$d_a(t) = (1 - \Phi_a(t)) + \Phi_a(t) \cdot B_a(t)$$

- Energy distribution

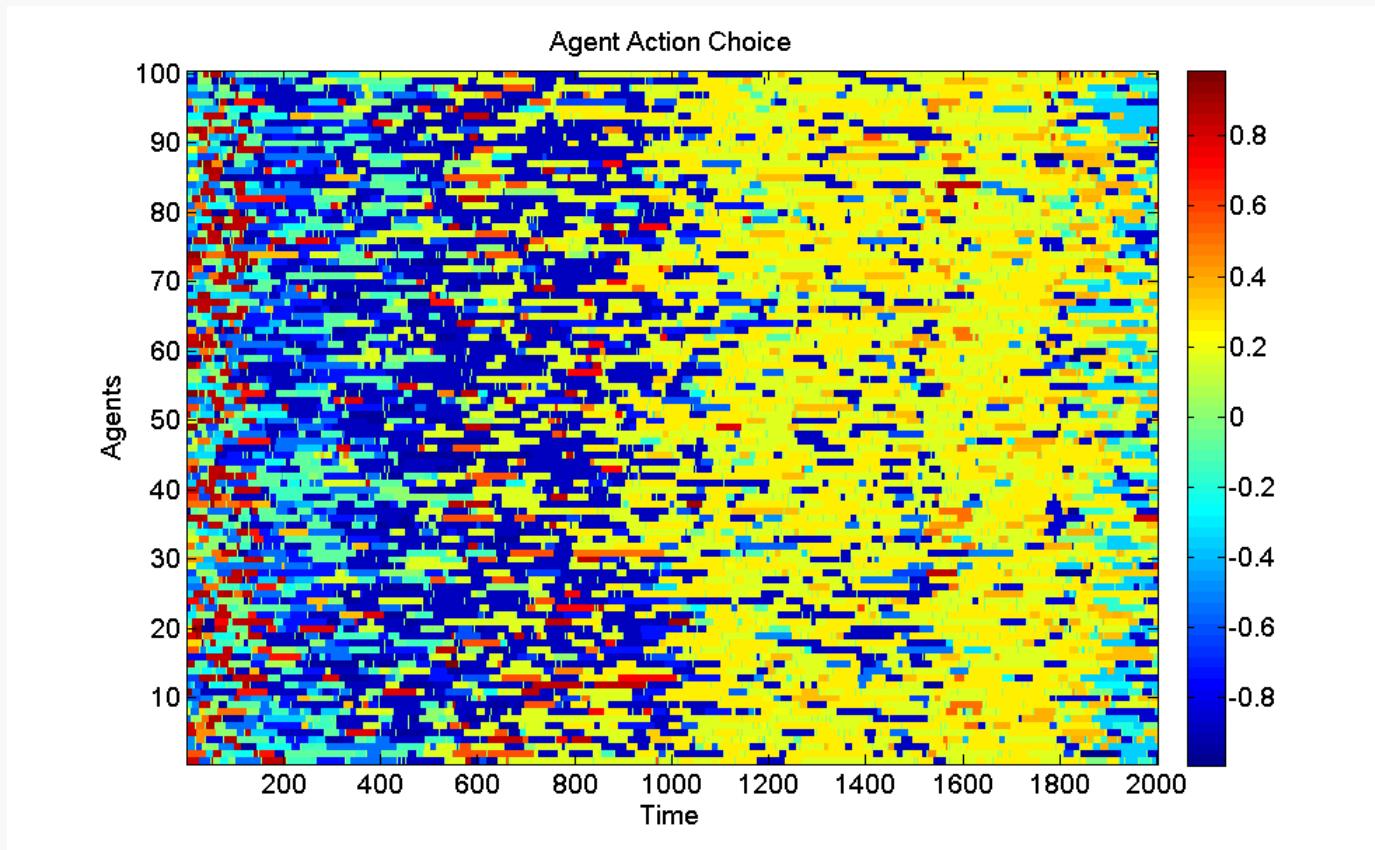$$\Delta e_a(t) = \frac{d_a(t)}{\sum_a d_a(t)} \cdot E(x(t))$$

Demonstration

- Example of a RSMFFE process with only two functions:
    - Bacterium in sugar gradient
    - Rotate its flagella to swim or tumble

Results - Clusters

Results – Transience

Discussion

- Elaborated on the foundations established by Bickhard and Pattee
  - Representation of anticipation of beneficial interaction
  - Representation from constrained dynamics
- Future oriented representations (not past-oriented)
  - Anticipations about future benefit
  - Function selection reinforced through future metabolism
- Caricature example of dynamics that can be instantiated differently at different scales

Future Considerations

- Persistence of representations
  - Representations used for future reasoning
  - Longer time-scales
  - Abstraction and complex symbols

- Communication of representations
  - Language

Thank You

Questions?

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