FROM SENSORIMOTOR COORDINATION TO ENACTION

Ezequiel Di Paolo, University of Sussex

cognitive science

- The object is *cognition*.
- The question is: *how does it work?*

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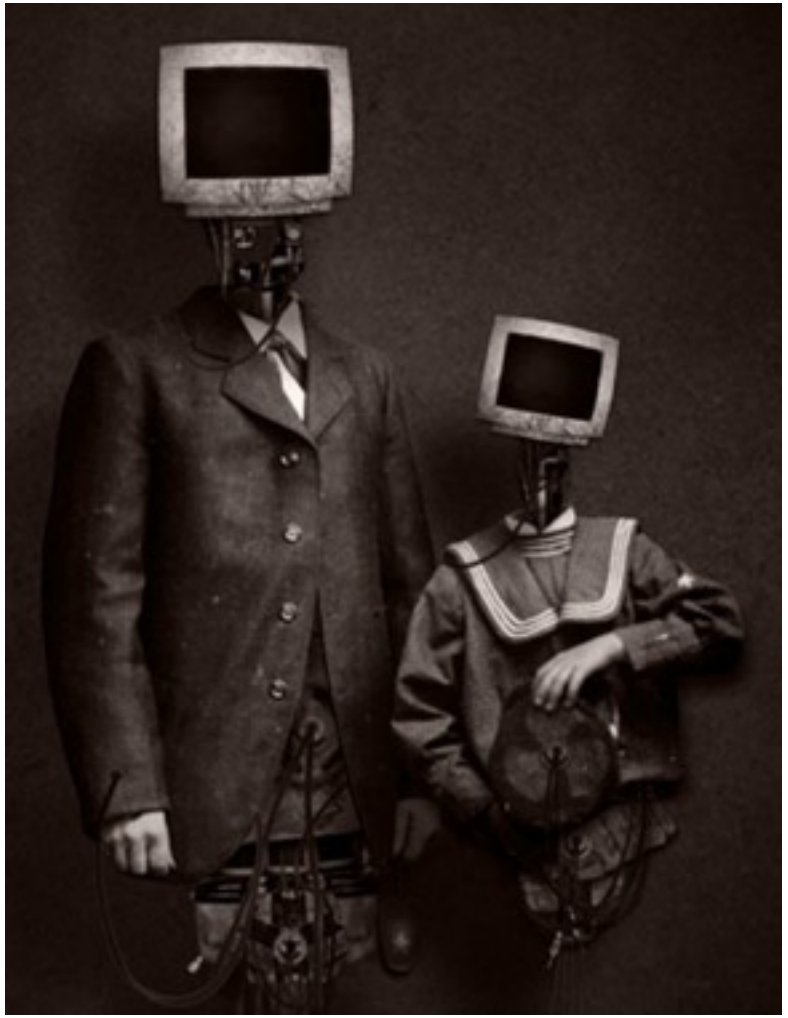
Cognitivism:
Mind = Brain activity =
Information processing.



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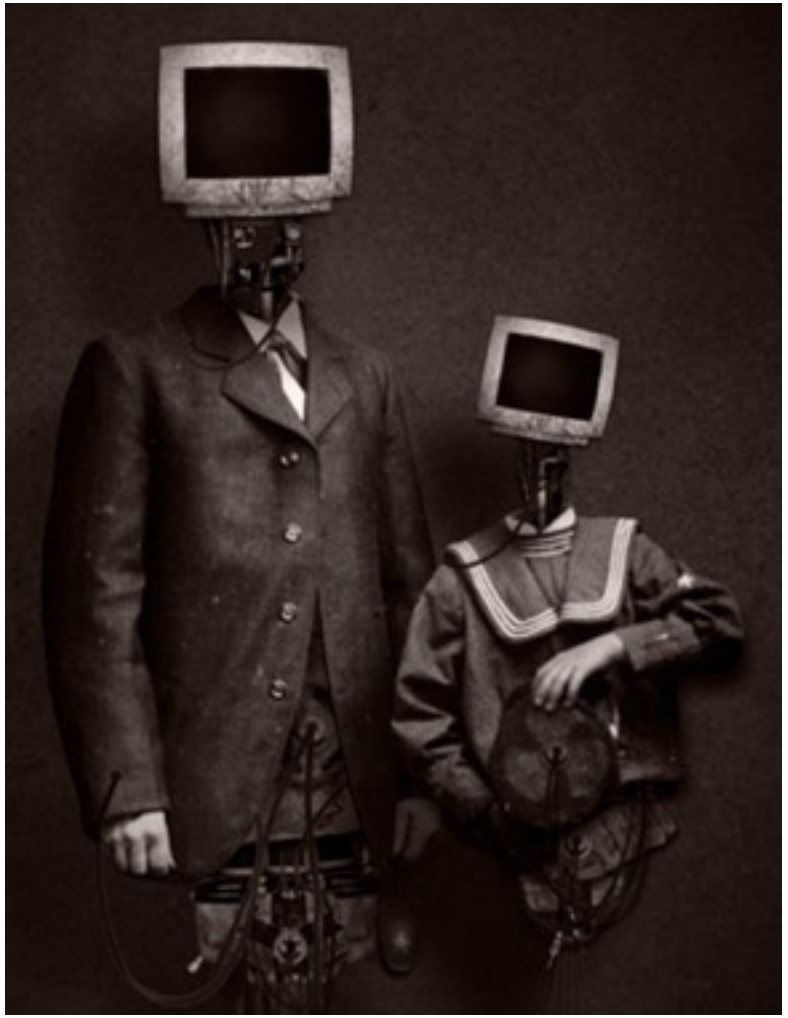
Functionalism



the blind-spots of functionalism

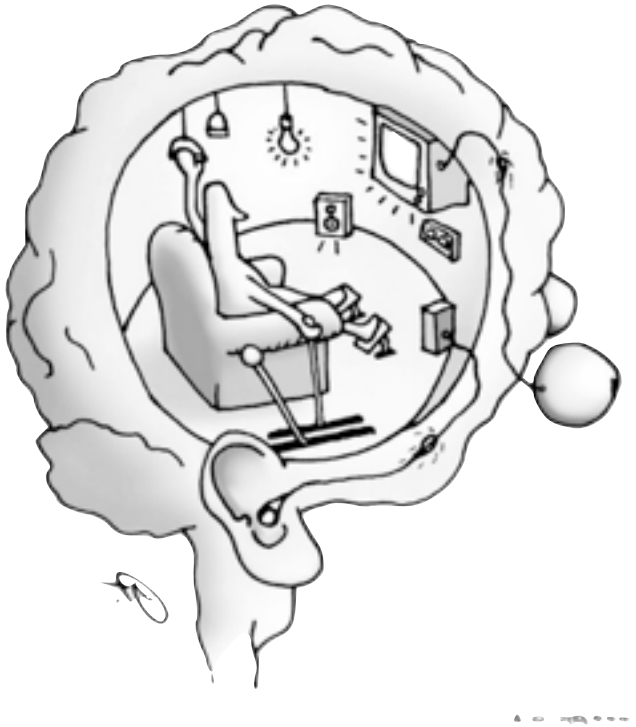
- Issues taken for granted
  - The question of identity/individuation.
  - The question of agency.
  - The question of autonomy.
  - The question of meaning and value.
  - The question of temporality.
  - The question of experience.
  - The question of the self.
  - The question of sociality.
- These questions are never really investigated. The dominant functionalist paradigm in cognitive science is simply blind to them. No progress can be made within this paradigm if you don't assume someone already know the answers. You pass the buck (e.g., to evolution).
- Making science on credit

Part I: perspectives on the body

shallow embodiment, the case for mind "outside the head"

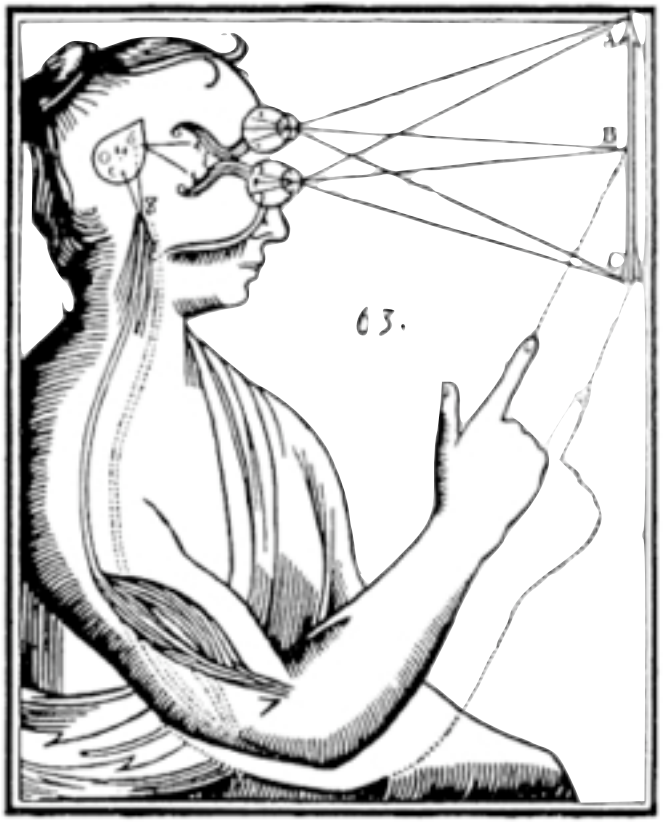
caricatures of perception

Cognitivism



caricatures of perception

Sensorimotor approach



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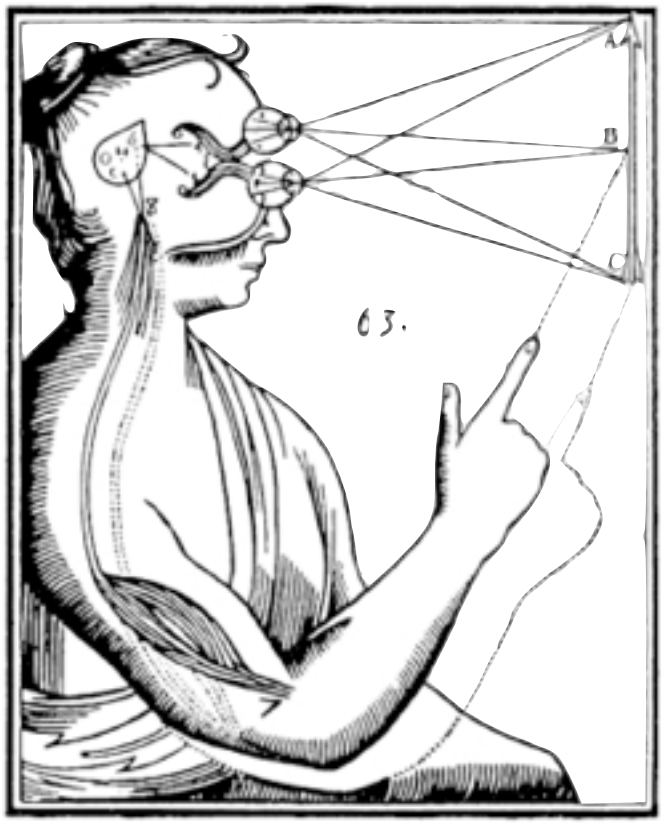
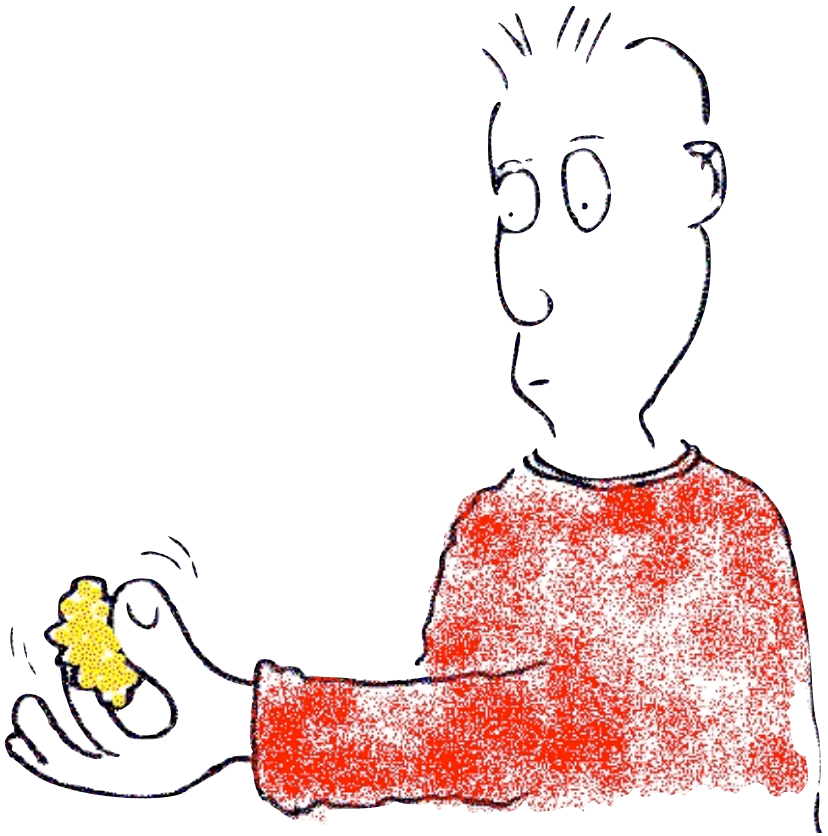


sensorimotor approach



- O'Regan, Noe, Myin, Hurley
- Perception is the mastery of sensorimotor contingencies
- Perception inseparable from action
- Bodily dispositions are therefore crucial

a more situated approach

- The "sensorimotor contingencies" (SMC) approach highlights the embeddedness of the embodied agent in its world. Objects are not perceived independently of bodily dispositions.
- Close to Gibsonian ideas.
- Perception is a form of *know-how*.
- *Zuhandenheit*

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shallow embodiment

SMC and similar approaches are said to be 'embodied'.

This is clearly so in that the particular details of the sensors and effectors, the bodily forms of self-coordination and coupling with the environment, all of these aspects matter because the laws of co-variation giving rise to SMC depend on them.

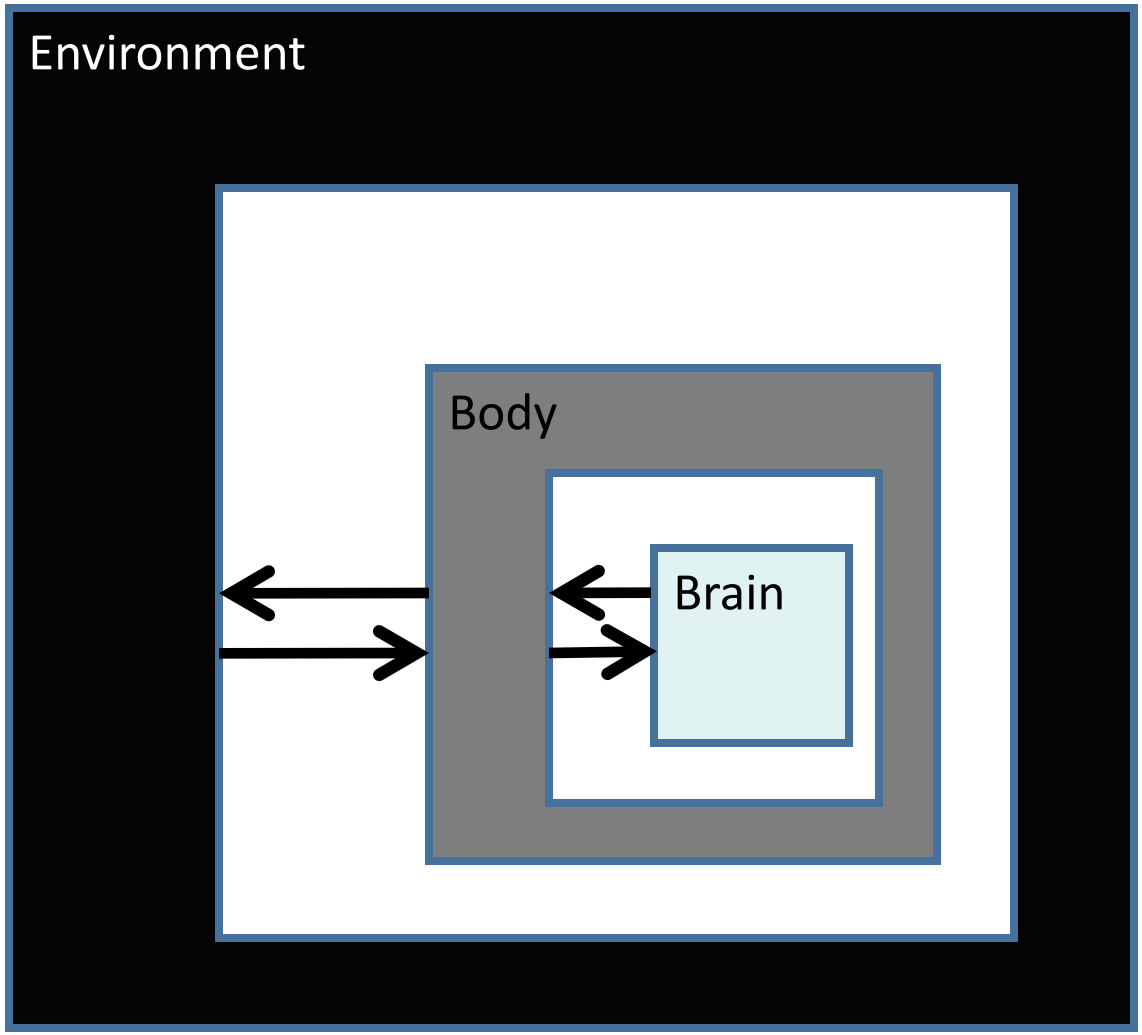
shallow embodiment

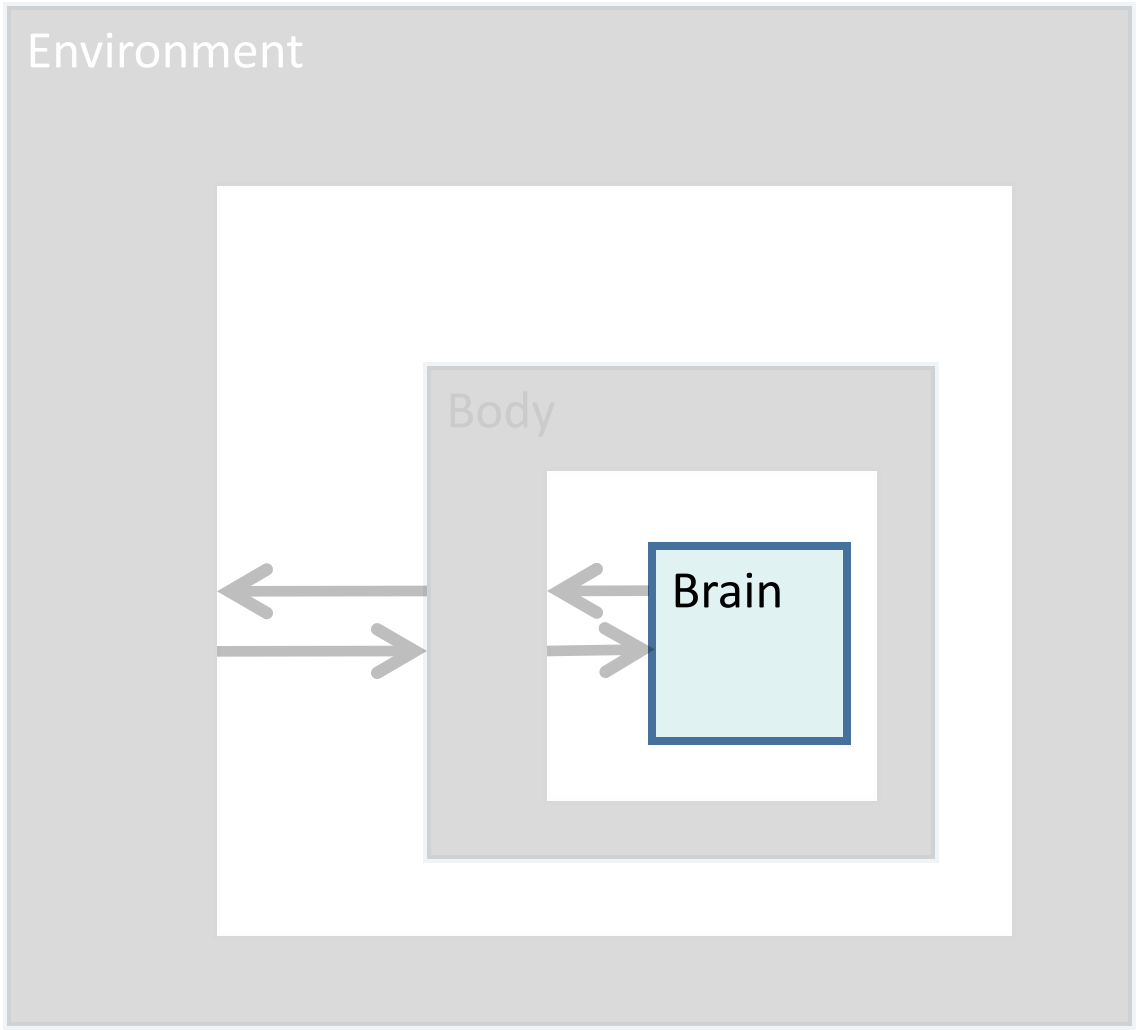
However, nothing prevents interpreting this form of embodiment in the same terms as Andy Clark: The body is a convenient and negotiable information processing device, a way of off-loading computation.

SMC is thus subsumed by functionalism and potentially by cognitivism.

shallow embodiment

non-trivial lessons from modeling


Environment
Body
Brain


Environment
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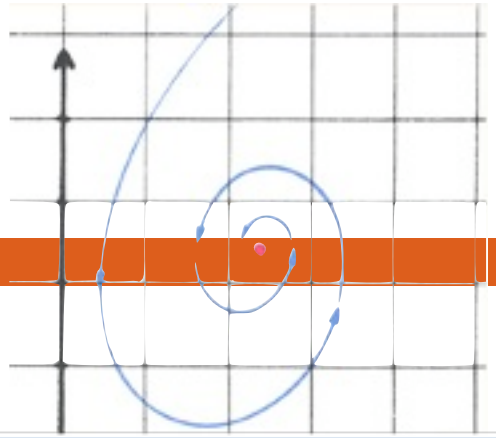
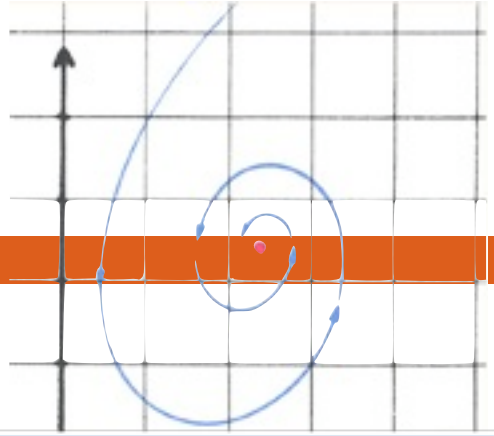
mind in a transient

Behaviour



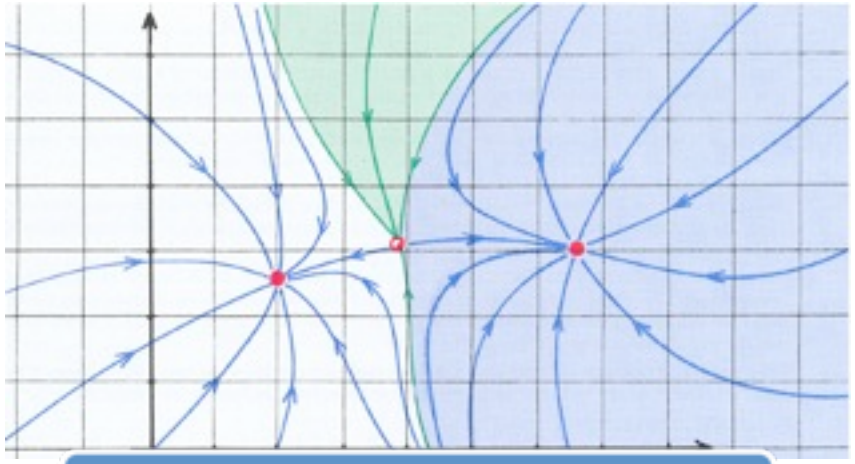
Attractor

Behaviour

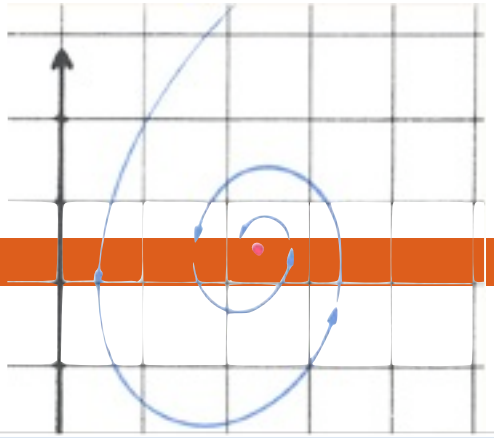


Attractor

Two Behaviours



Two Attractors



Behaviour

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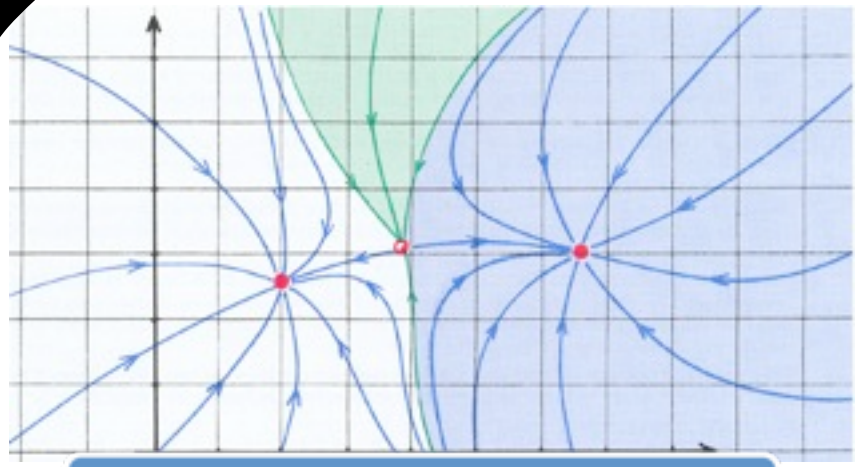


Two Behaviours

Two Attractors

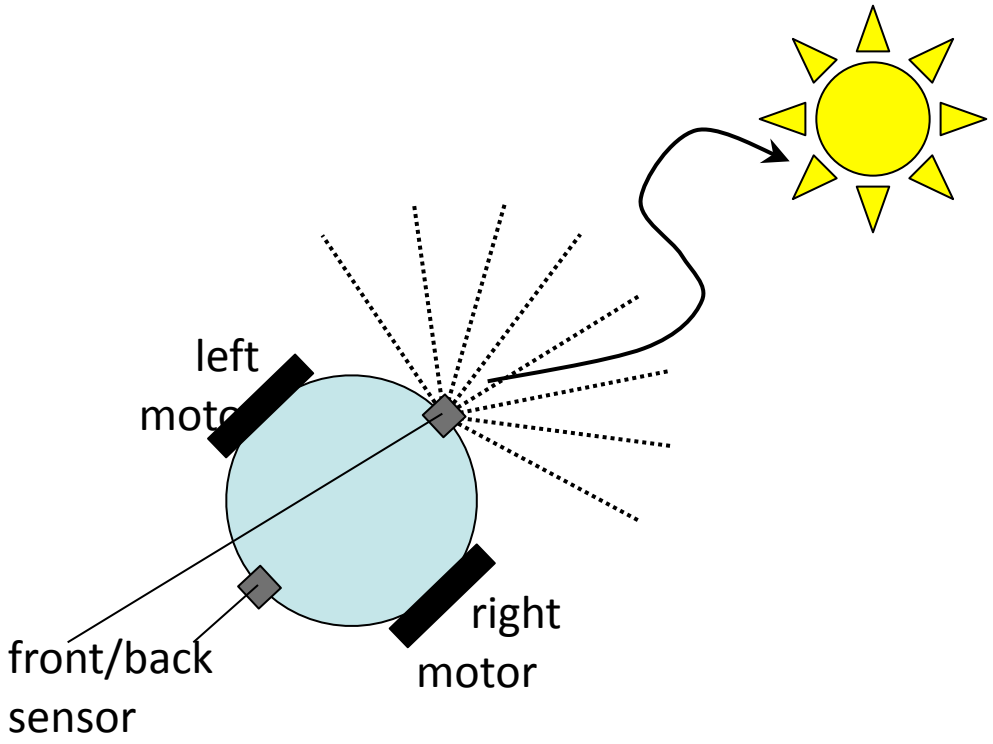
multiple behaviours

A proof of concept.

A simple task: phototaxis

Single light sensor (to the front or the back)

Fine, Buckley, Di Paolo, Bullock, 2008



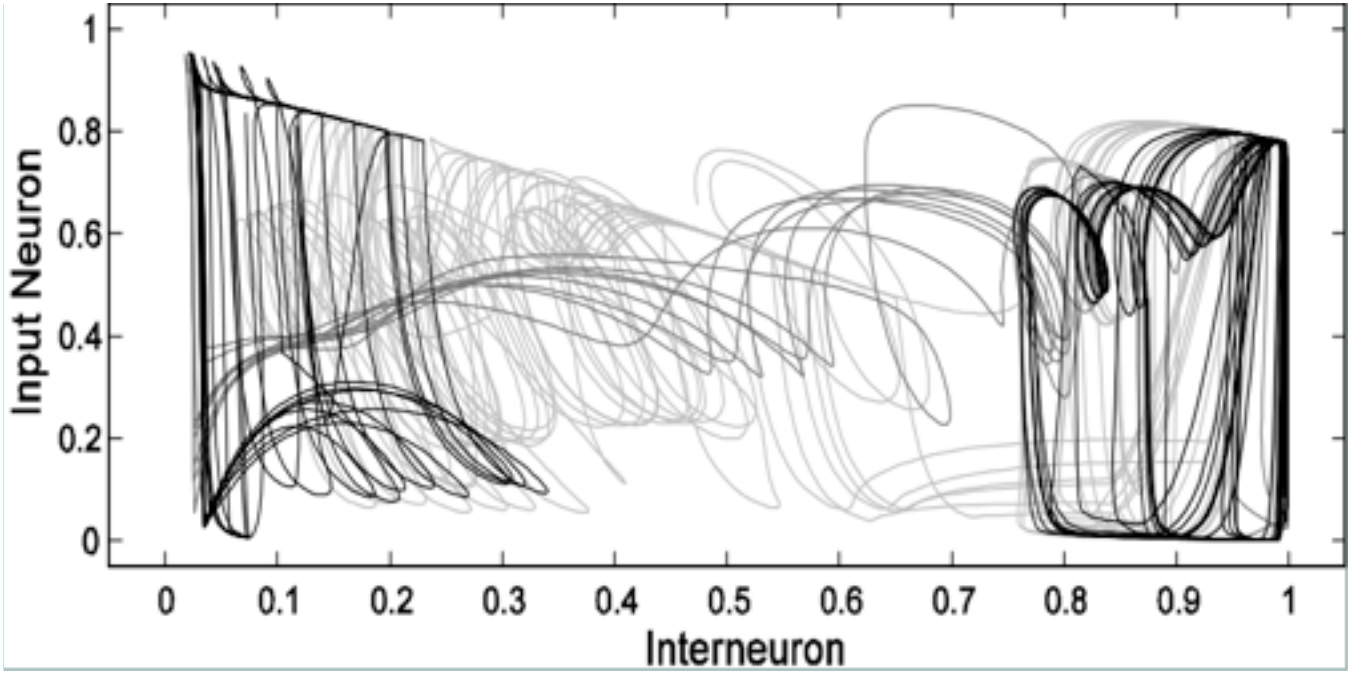
unconstrained controllers

Successful agents evolve

Sensor can be switched position

The agent adapts

Two dynamical modes

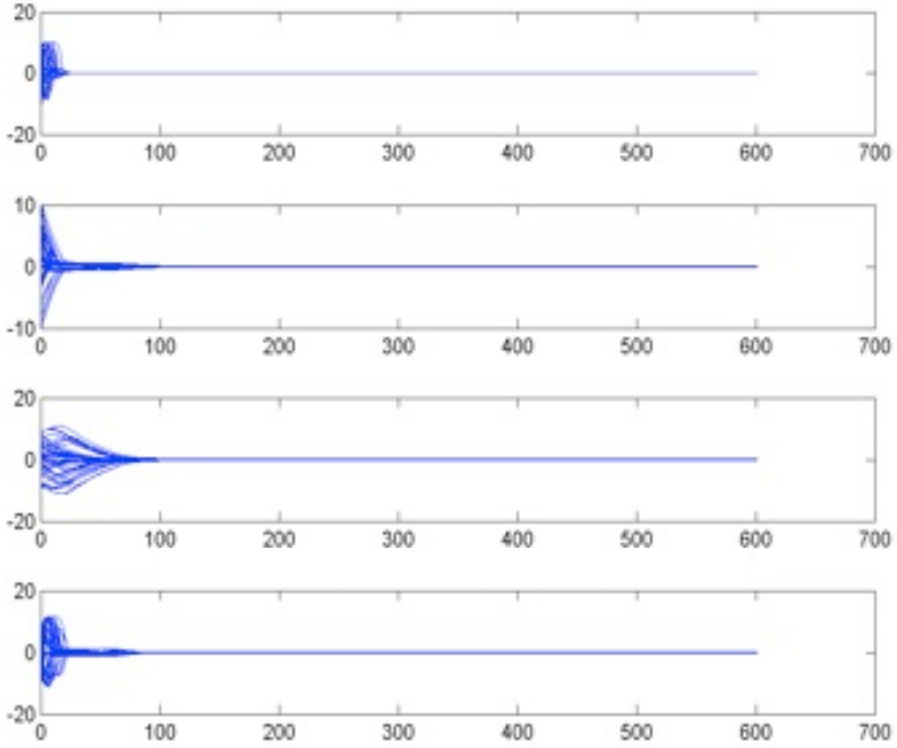


constrained controllers

Single point attractors

ECHO state networks, Liquid-state machines

No long-term memory.



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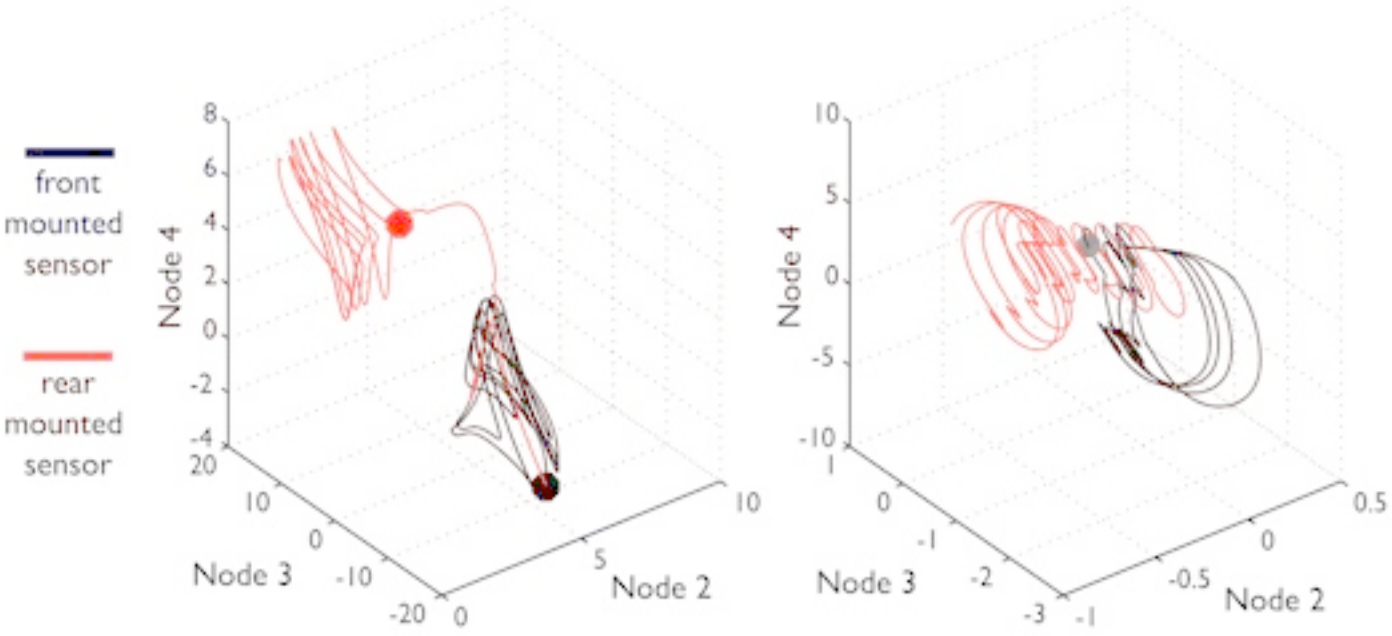
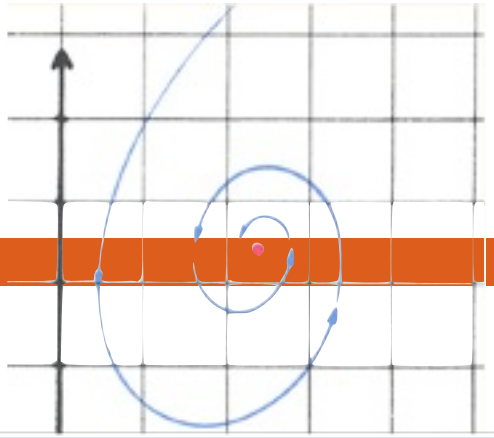
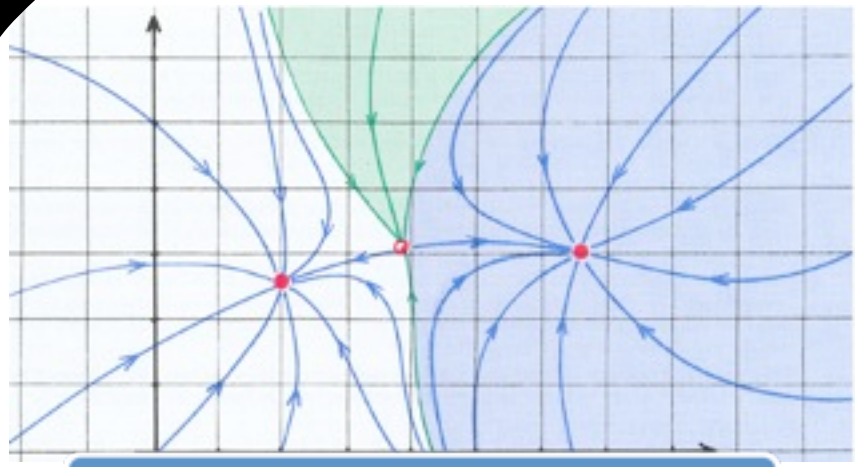




Behaviour

Attractor



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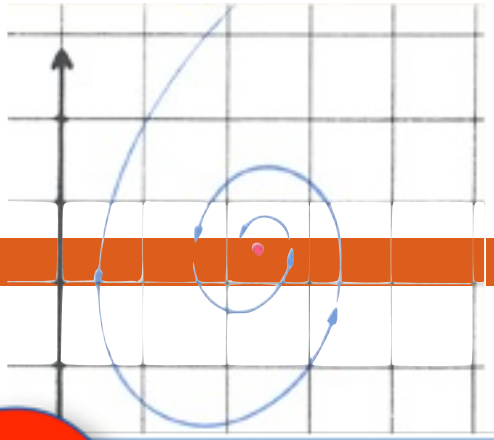

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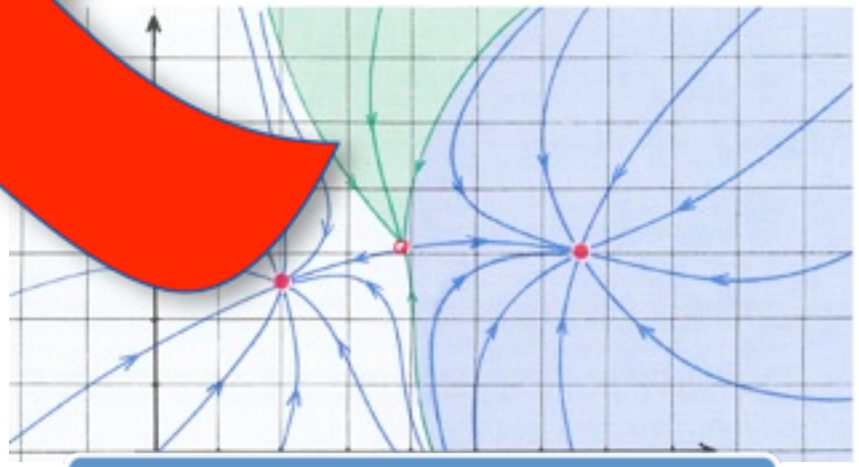

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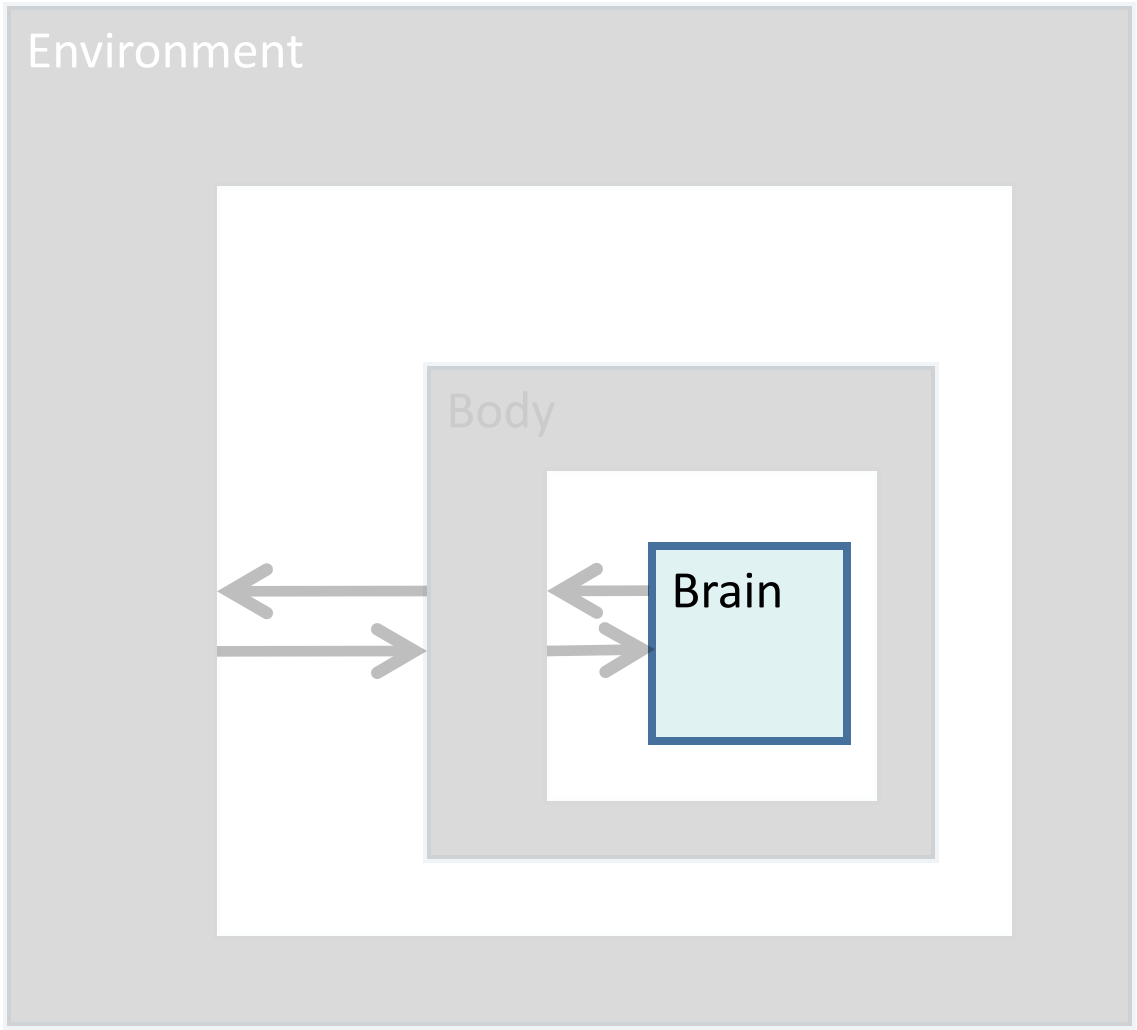
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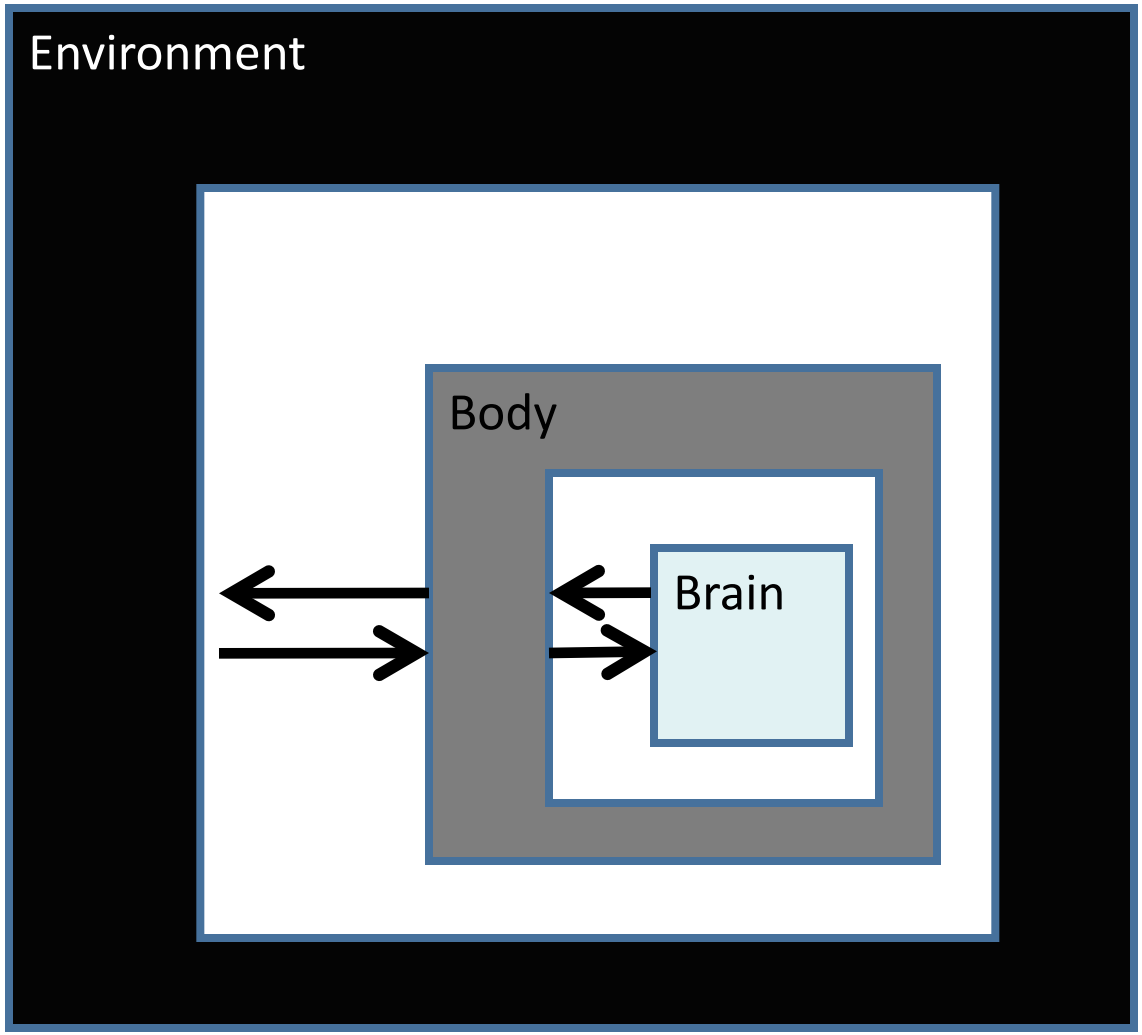
Environment
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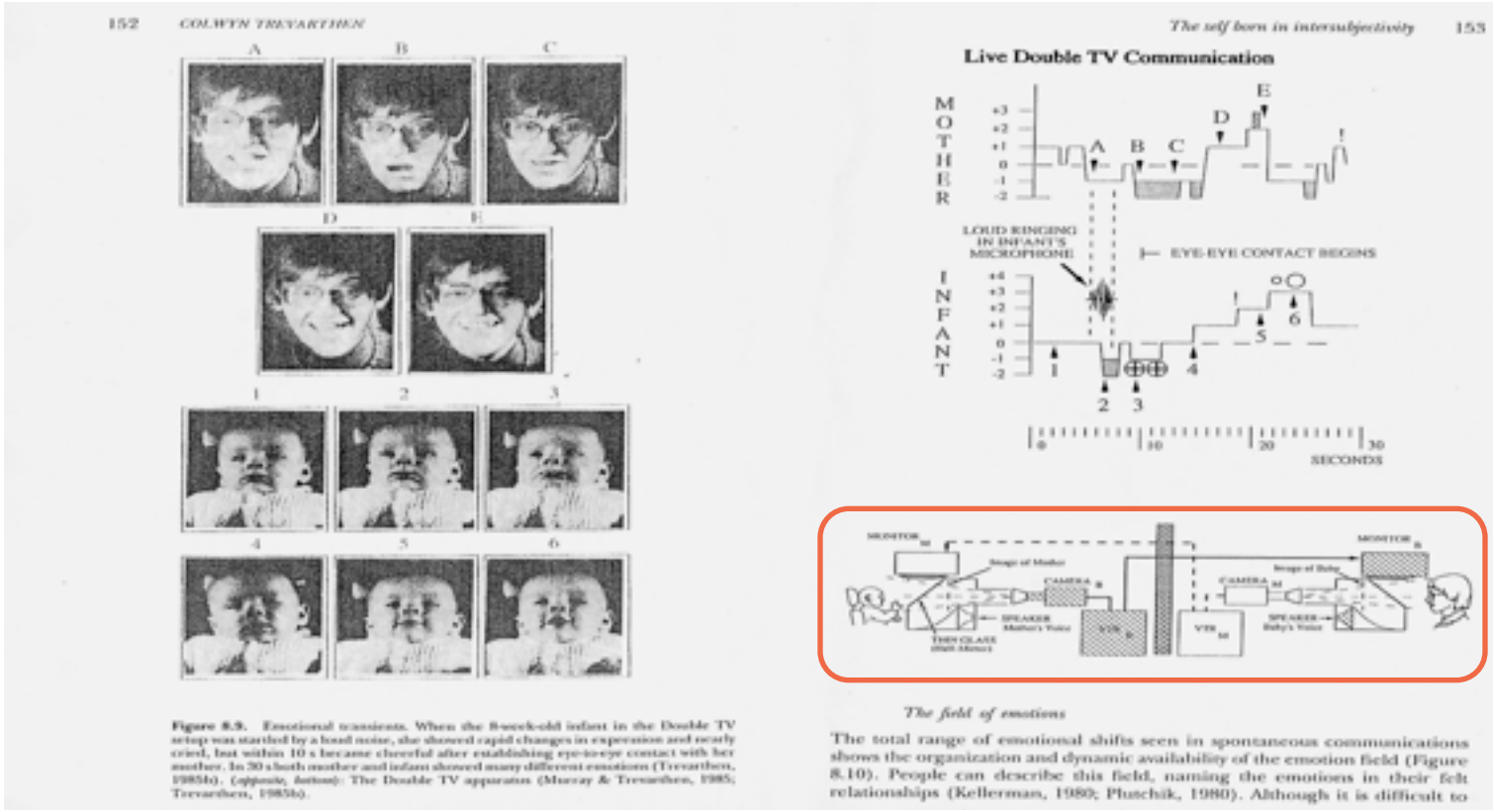
social interaction as a process

sensitivity to social contingency



Mother infant interaction through double TV monitor (Murray & Trevarthen, 1985).

pervasive individualism

- In spite of the striking result of this experiment, proposed explanations remain individualistic.
- Nadel et al (1999) derive from this result the existence of a "contingency detection module", (Gegerly & Watson, 1996)
- The weight of the explanation remains "inside the head" of the infant and ignores the interaction.

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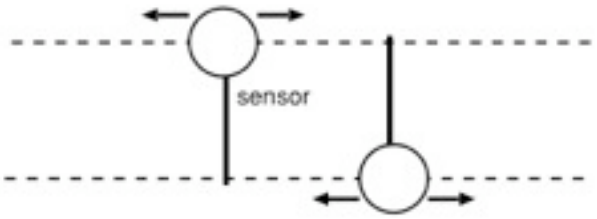
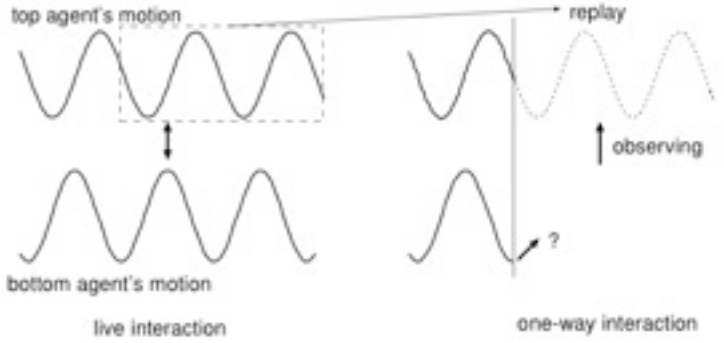
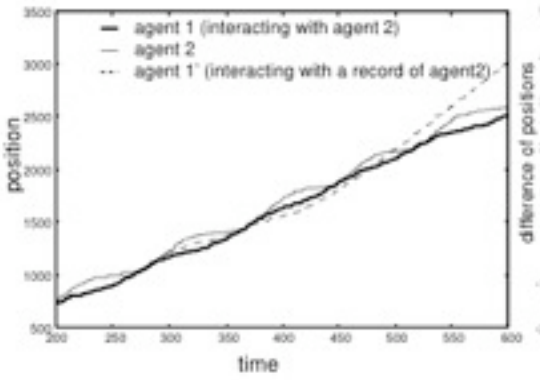
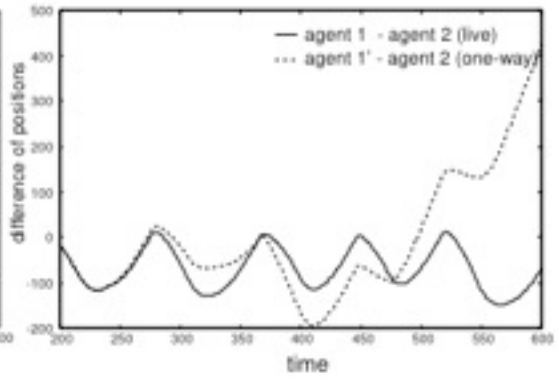
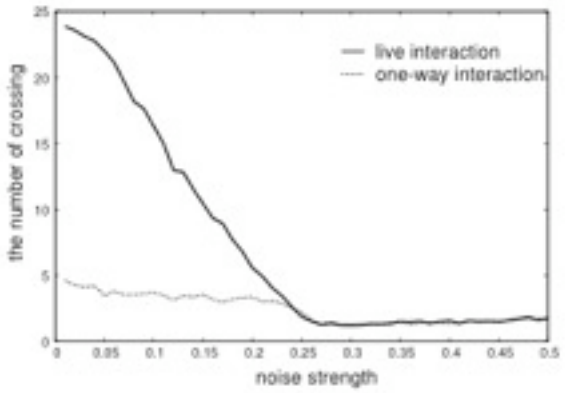
social contingency detection



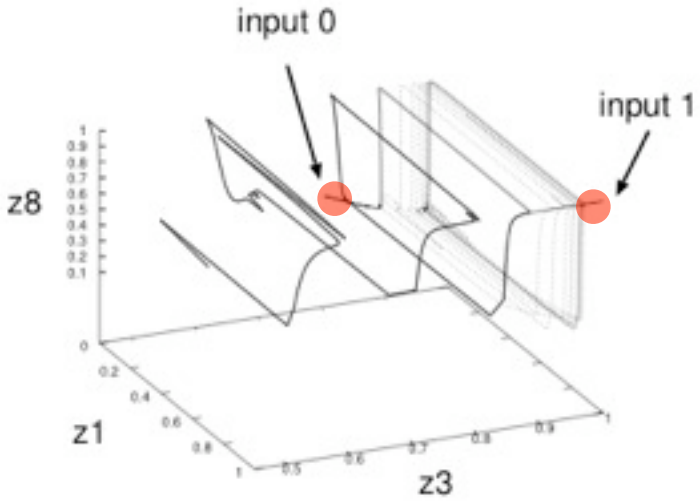




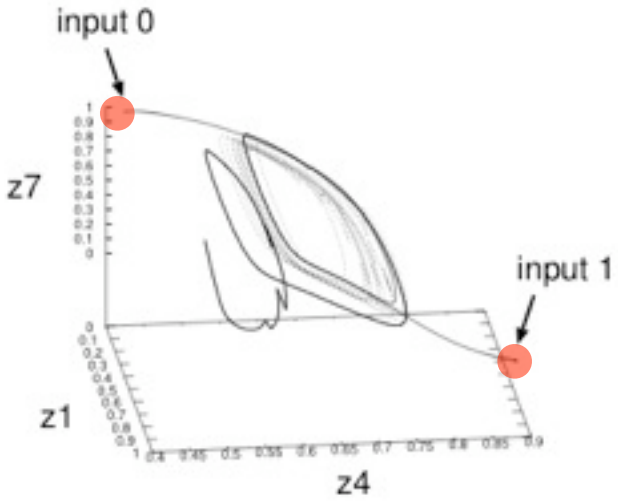




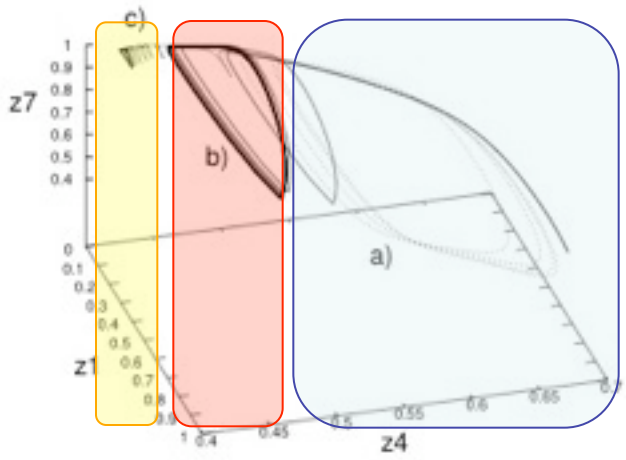
Di Paolo, Rohde, Iizuka (2008), later extended in Froese & Di Paolo (2008)

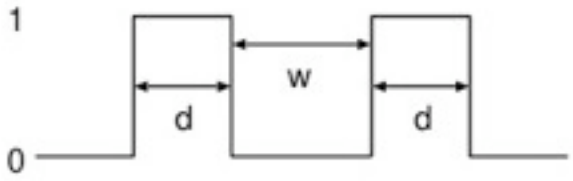


top agent



bottom agent





implications

- The fallacy of deducing the cognitive capabilities of an embodied agent from of the properties of its brain.
- The importance of studying cognitive performance as a temporally extended process involving transient dynamics.
- An interactive explanation for social performance. Interactive hypotheses typically overlooked. Individualistic, third-personal stance in social cognition can be challenged.
- Social interaction as a dynamical process practically ignored in social cognition research (but prevalent in other fields like conversation analysis).

deep lessons from shallow bodies

- Even though it may be subsumed by functionalists, shallow embodiment emphasizes several neglected possibilities:

- 1. Mind-not-in-the-head

- 2. Mind-in-time

- 3. Mind-not-in-the-individual.

Part II: the enactive approach

deep embodiment, continuities between life, mind and society

why do we need to push further?

- In functionalism, even in its dynamics and embodied forms, the key terms of cognition remain undefined:
- Agency is granted ascriptionally and by convention.
- There is no strong concept of autonomy.
- Intentions, values, and meaning are mysterious and packed into boxes with dubious to incoherent status ("value-systems", "representations", etc.)

embodied experience of concern

- Hans Jonas: our experience of *concern* as embodied beings makes teleology undeniable, even if we couldn't reconcile it with efficient causality.

- The supposed triumph of materialism achieved by Darwin only shows that continuity can run both ways. If we are concernful beings, so can other lifeforms be. Where's the cut? Jonas says: *in life itself*.

- *Metabolism*: The material identity of the flowing matter does not coincide with the identity of the body or living *form*. Whenever that happens, the organism dies.

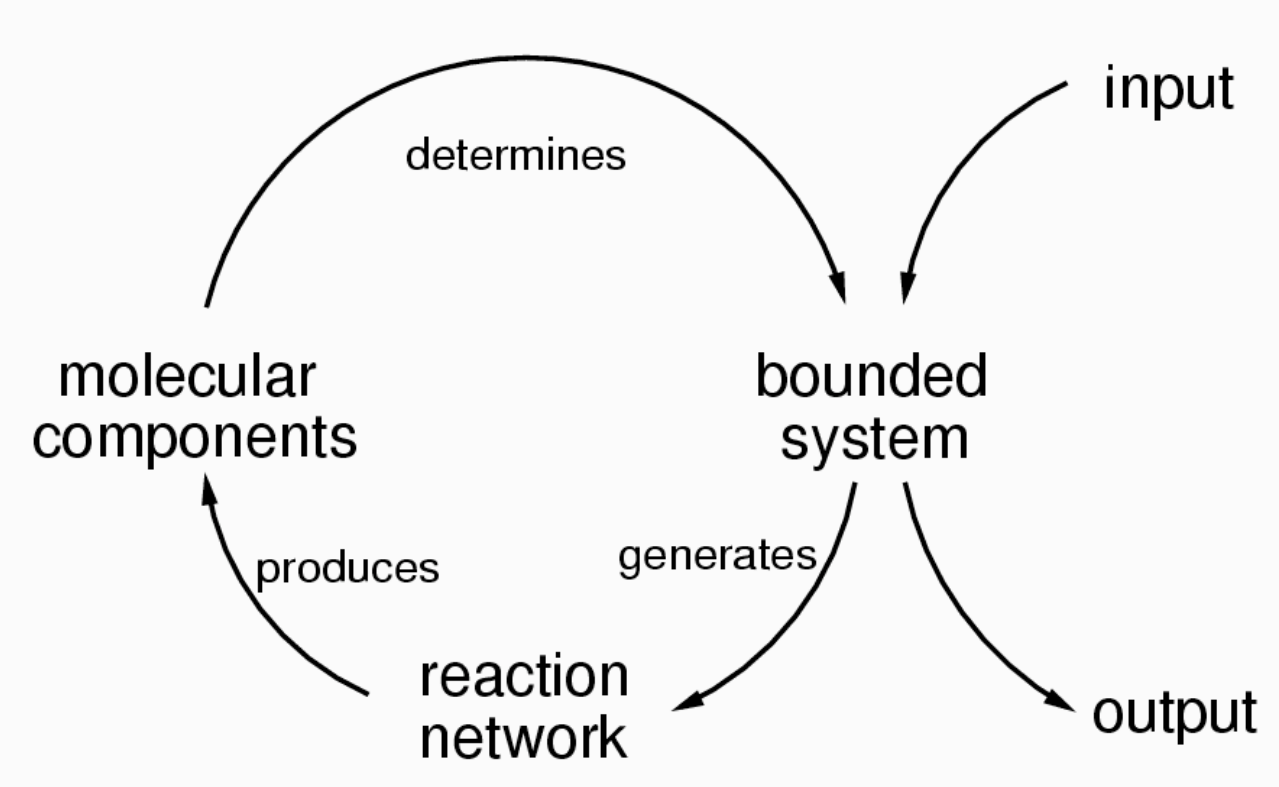
- Thus, an organism has a *formal* and *dynamic* identity, not associated with the persistence of matter.

- Mind in Life.

autopoiesis

Humberto Maturana y Francisco Varela (cf Canguilhem, Hans Jonas, Kant, Schelling, Hegel).

An operational definition of a living system.



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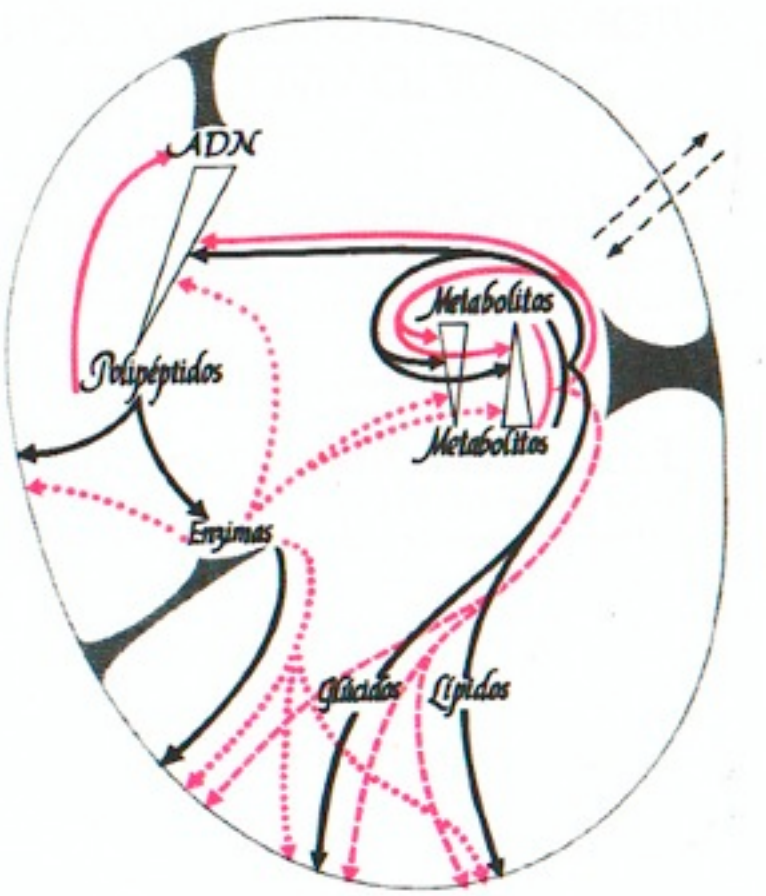

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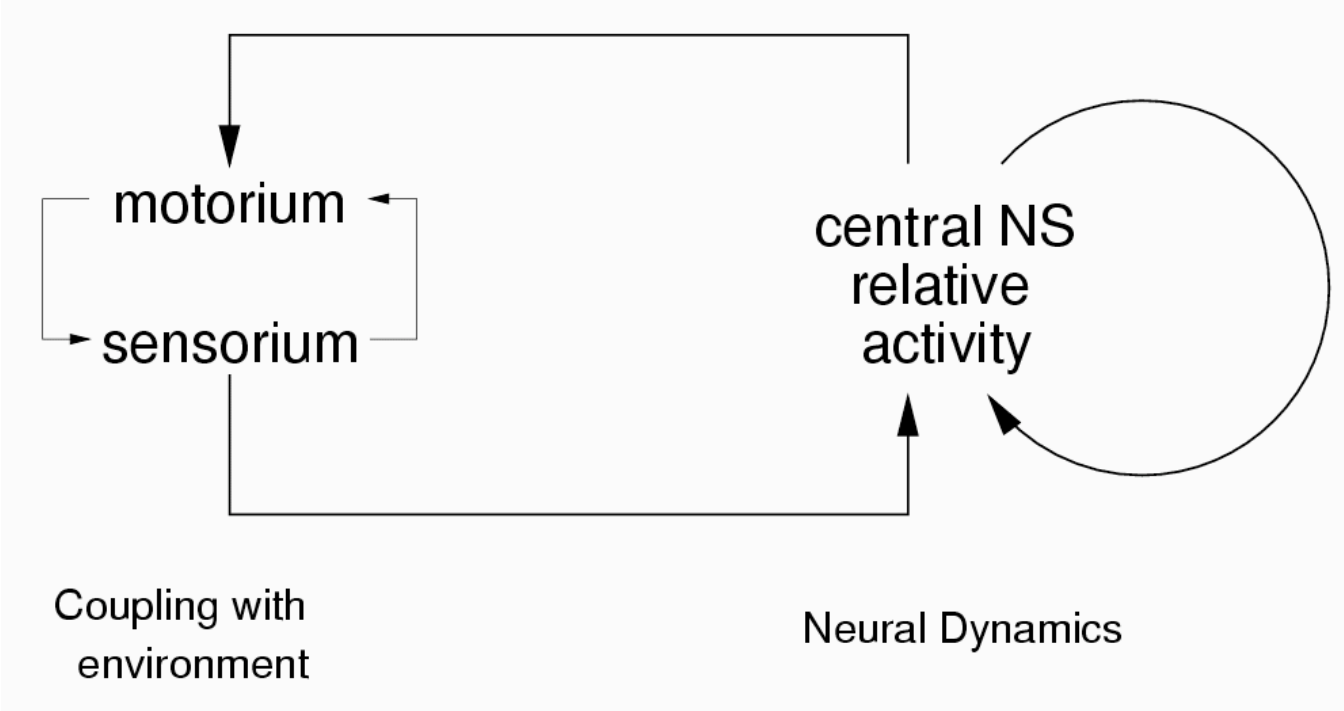

from autopoiesis to cognition

- The key element in any definition of cognition is a grounding of the notion of meaning (broadly construed as sense and value).
- Hans Jonas sketches a pathway from metabolism to mind.
- Weber and Varela (2001) attempt to provide a scientific ground for this idea in their proposal: autopoiesis ⇒sense-making.
- The proposal does not work by itself (Di Paolo, 2005) but can be rescued by the notion of *adaptivity*:
- Sense-making requires self-generated identity + adaptivity.

autonomy

- A cognitive agent is autonomous, it gives itself its own laws.
- How? Only by being able to affect its own constitution this is possible. Only a system able not just to modify itself, but to build itself as an entity.
- *A precarious, self-sustaining process of identity generation.*
- Classical example: autopoiesis, but others are possible.
- Mind has a proper, *irreducible* level, that of the autonomous cognitive identity (forget about *internal drives* and *stimulus-driven cognition*.)
- The question for cognitive science is now not simply *How does it work?* but also *What/who is it?*

definition

An autonomous system is defined as a system composed of several processes that actively generate and sustain an identity under precarious conditions. By identity we refer to the property of operational closure. Operational closure indicates that among the enabling conditions for any constituent process in the system we always find other processes in the system and conversely every process in the system is an enabling condition for some other process. An autonomous system is self-distinct, i.e., a process/component either belongs or not to such a network of enabling conditions. It actively affirming the identity of the system by its own operation. By precarious we mean the fact that in the absence of the organization as a network of processes isolated component processes would tend to run down or extinguish.

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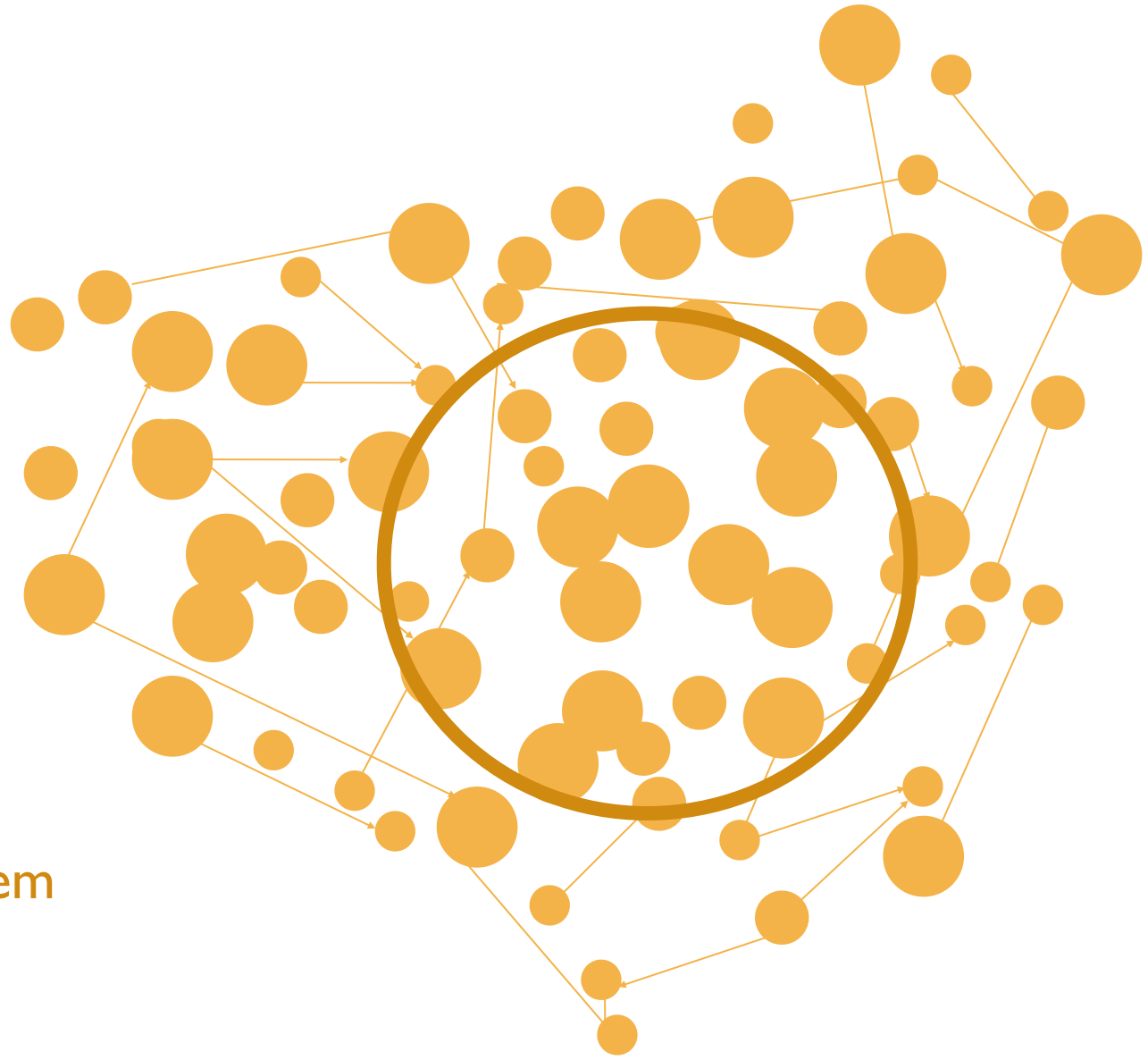
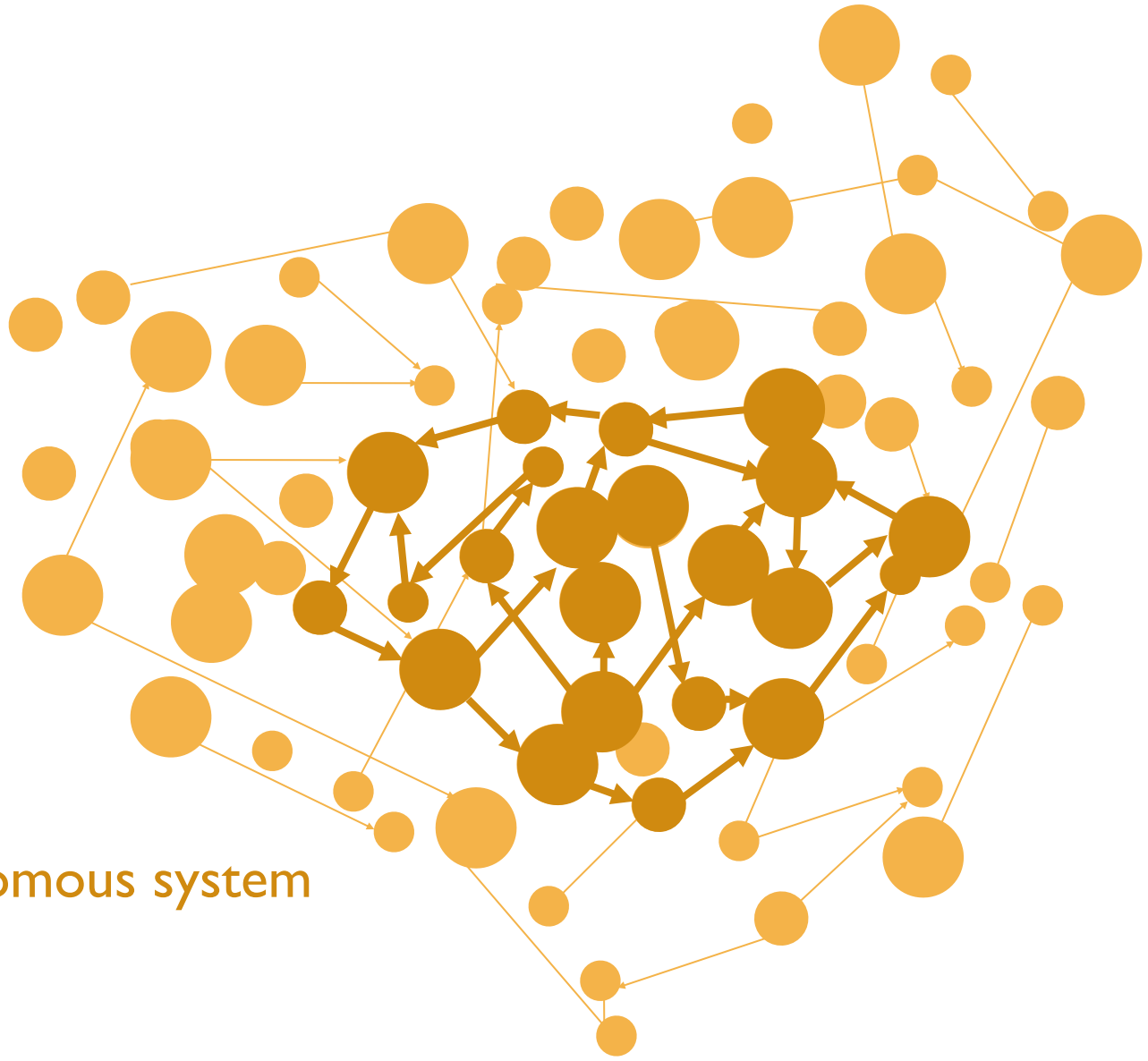
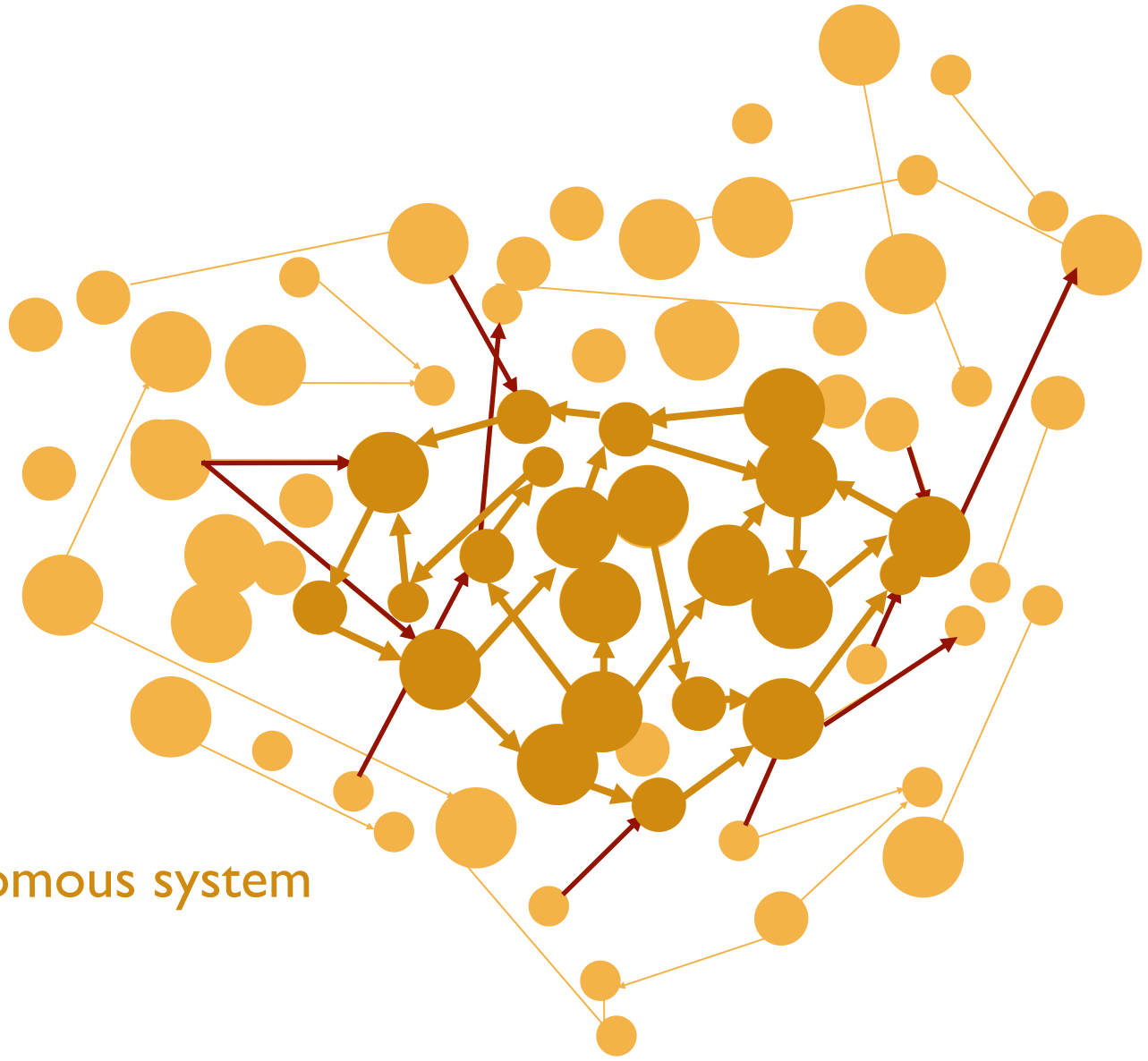


A system



An autonomous system



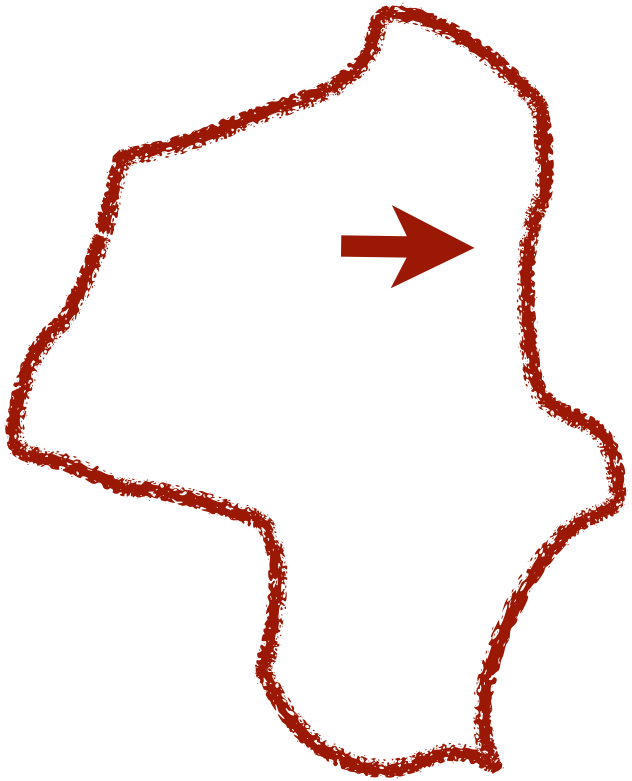
An autonomous system

precariousness

- Is an unavoidable aspect of living systems.
- It is not a positive property, but the lack of permanence of any positive functional property.
- It therefore cannot be captured in functional terms.

sense-making

- A self-generated identity implies a normativity with respect to interactions with the world.
- If the mechanisms are present that allow regulation guided by this normativity, the system is now capable of sense-making, the active engagement with the world in terms of meaning and value.
- Adaptive monitoring and regulation of the states of the system avoiding as a result trajectories that cross the boundary of viability.



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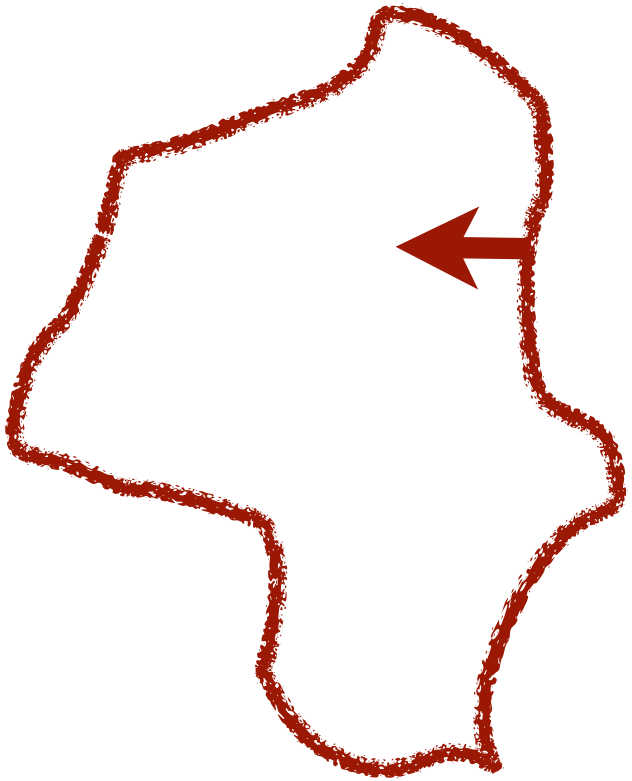

definition of value

- Value, sense, meaning: The consequences of an encounter with the world or an event for the viability of a *precarious* autonomous entity.

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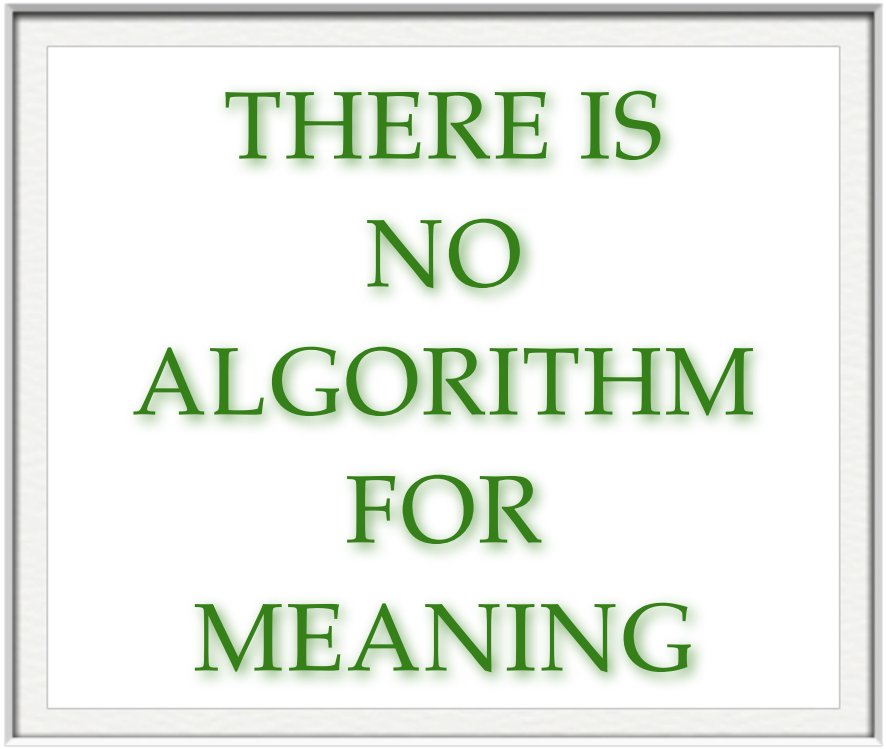

agency

- Three requirements to capture the common use of the term:
- Individuality.
- Asymmetry
- Normativity
- Agency: sense-making of a precarious autonomous identity in the interactive domain - when the system adaptively regulates its coupling with its world.
- (Barandiaran, Di Paolo, Rohde, 2009)

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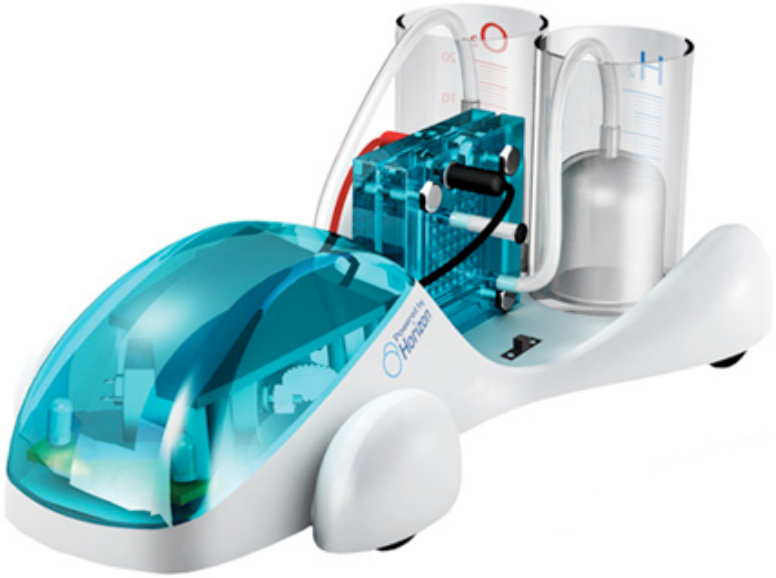

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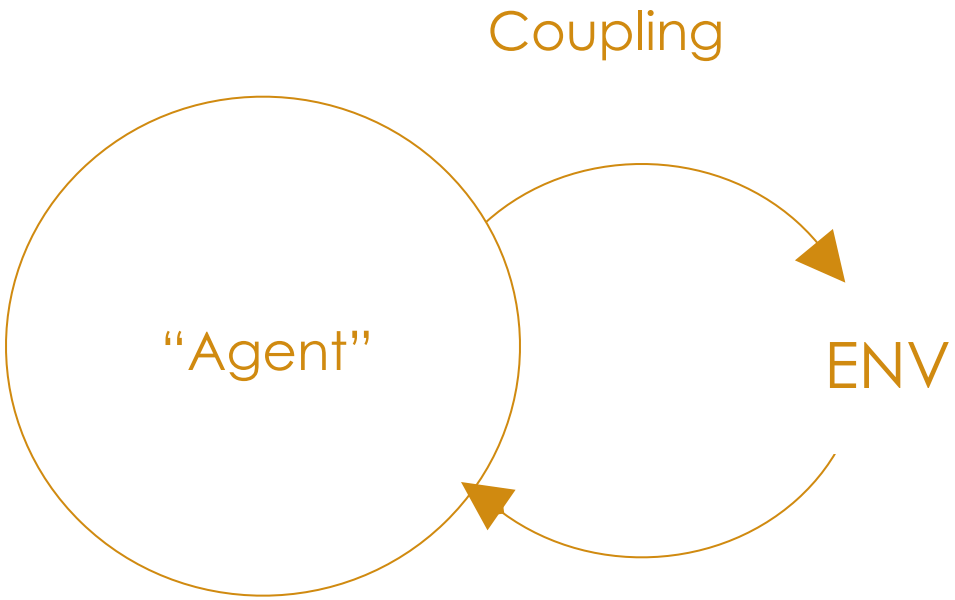
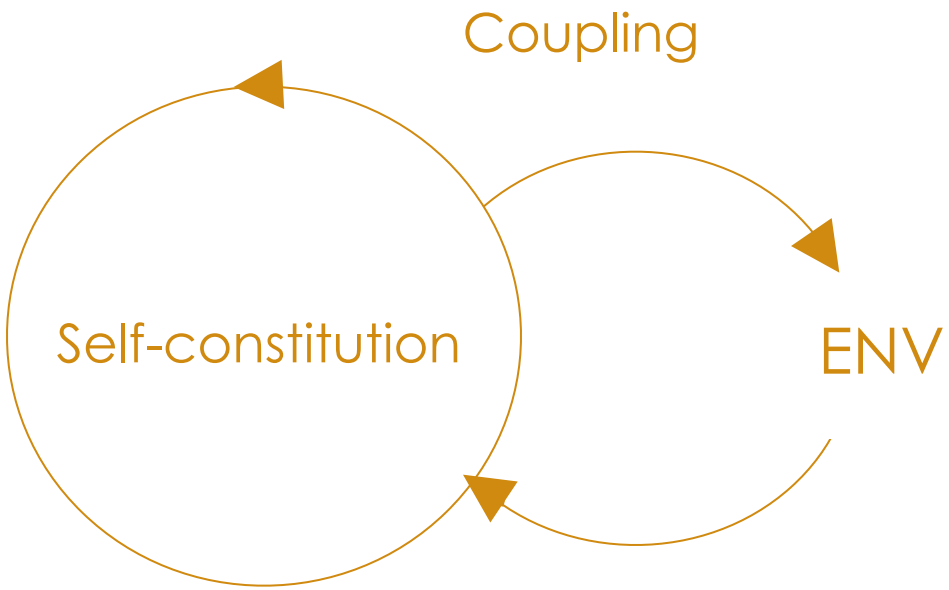
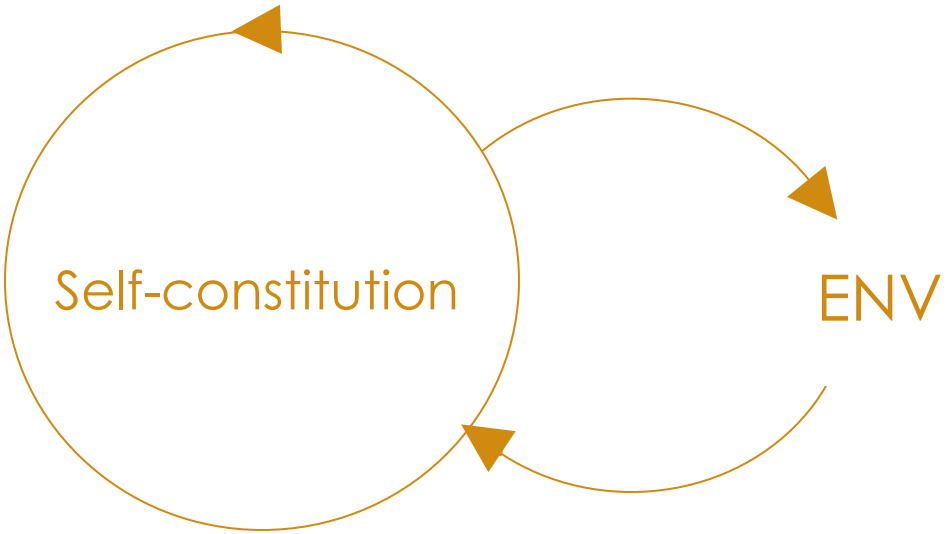

Coupling
“Agent”
ENV

ENV


Coupling
Self-constitution
ENV


Self-constitution
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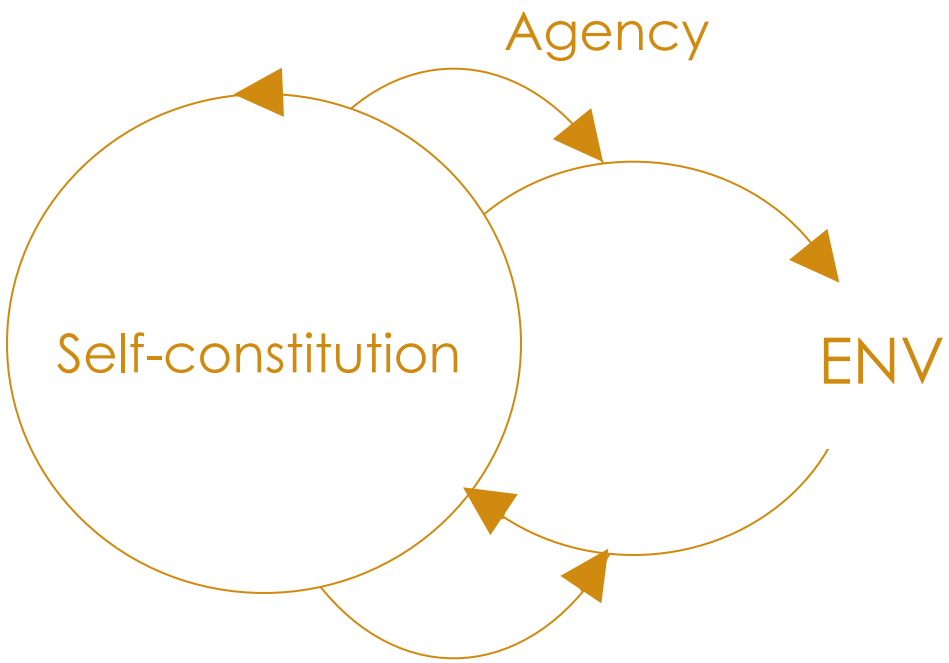
Agency
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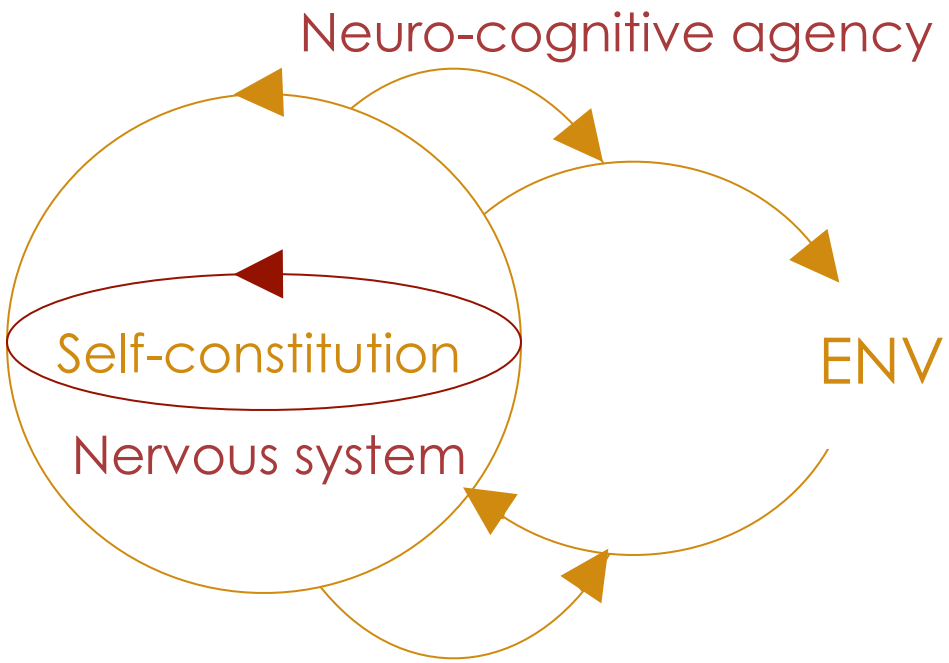
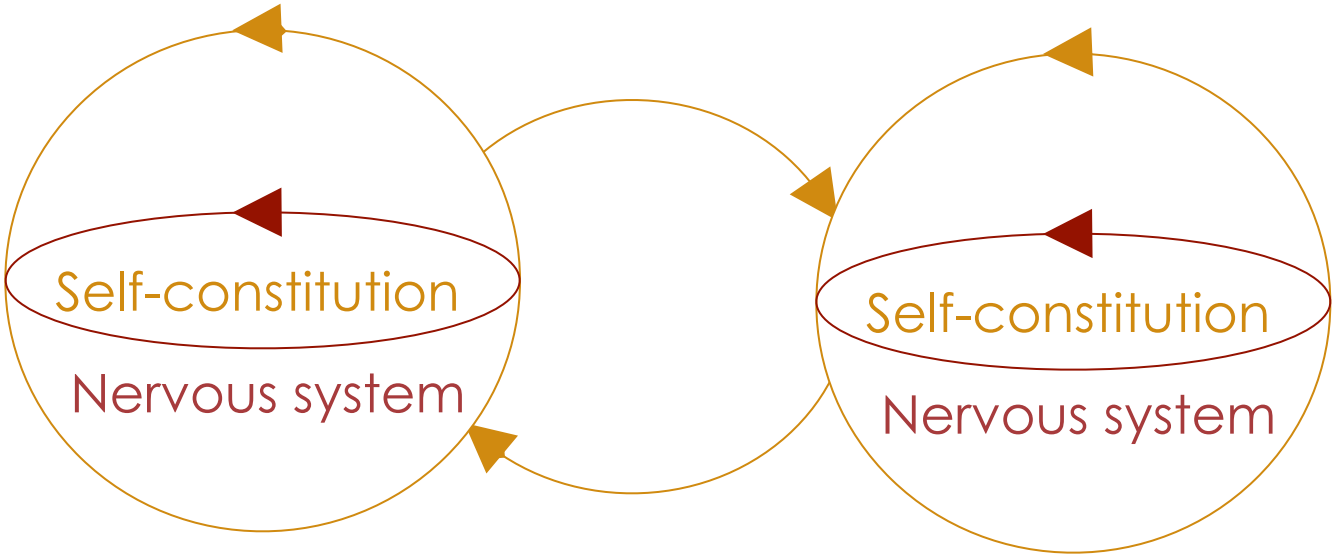
ENV


Neuro-cognitive agency
Self-constitution
Nervous system
ENV


Self-constitution
Nervous system
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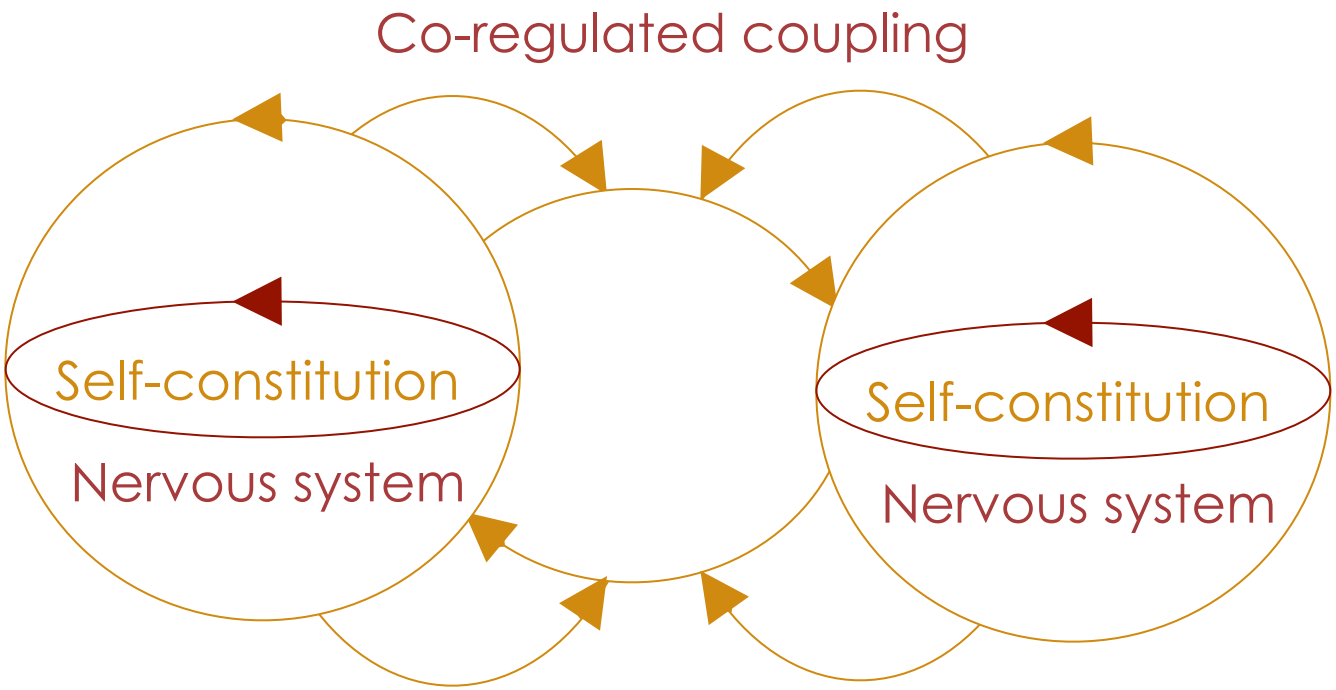
Nervous system


Co-regulated coupling
Self-constitution
Nervous system
Self-constitution
Nervous system

social interaction

- Towards a non-circular definition of the social ("The study of information processing in a social setting is referred to as social cognition", Frith, 2008).

- Two conditions for an interaction being social:

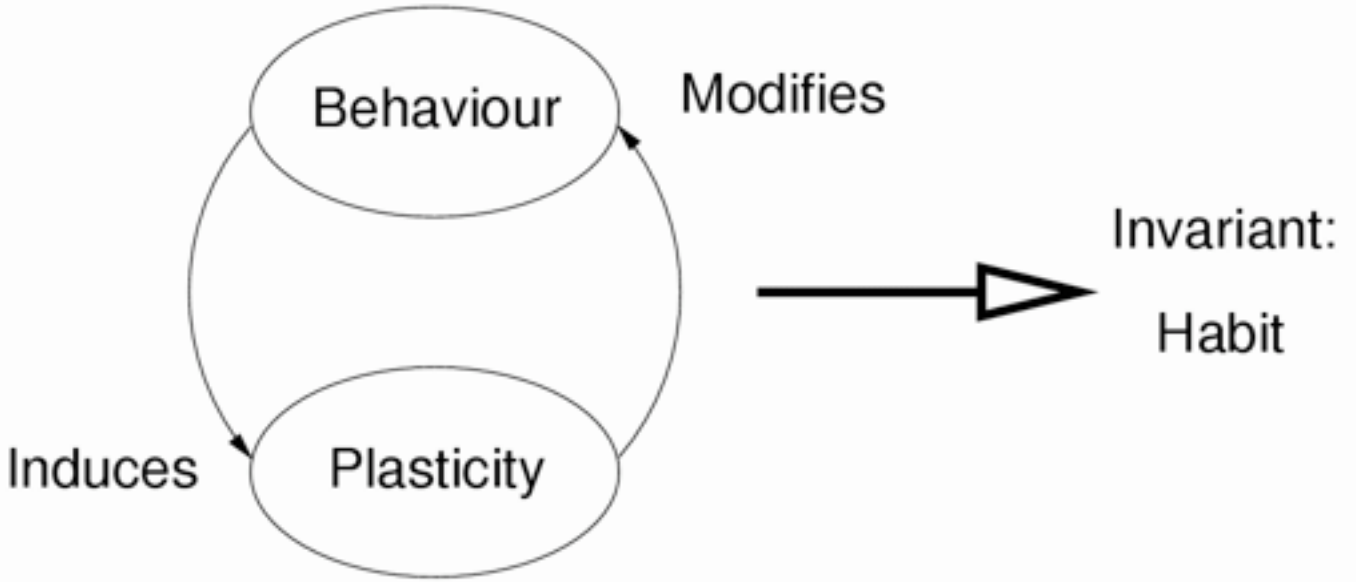
  - Mutual coupling is co-regulated and achieve (temporary) autonomy
  - The autonomy of the interactors is not destroyed in the process

- Social cognition: sense-making in interaction: Participatory Sense-Making.

- Work in collaboration with Hanne De Jaegher (De Jaegher & Di Paolo, 2007).

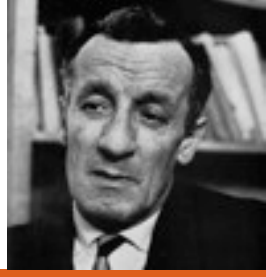
beyond the organism: habits

Hegel, K. Goldstein, J. Dewey, W. James, M. Merleau-Ponty, P. Guillaume, N. Berstein, I. Kohler and others have used the term 'habit' to describe how the body, as an ecological entity, sets itself into stable patterns of action and perception.



Walking
constrains
forms
Path

non-metabolic values



- Animal action has an organization of its own, underdetermined by metabolism. It is enough to posit a similar kind of self-sustaining dynamic form in neural and bodily activity to see how value can also be generated at this level.

- Merleau-Ponty's concept of motor intentionality is the most direct account of this self-affirming property of the body in activity.

- Acts form organized wholes, their form imbues events with meaning, but this meaning "talks" directly to the act, and only indirectly to metabolism.

- So, gestures can be elegant, pauses clumsy, etc.

- New modes of value-generation → New (transient) identity

life on a string

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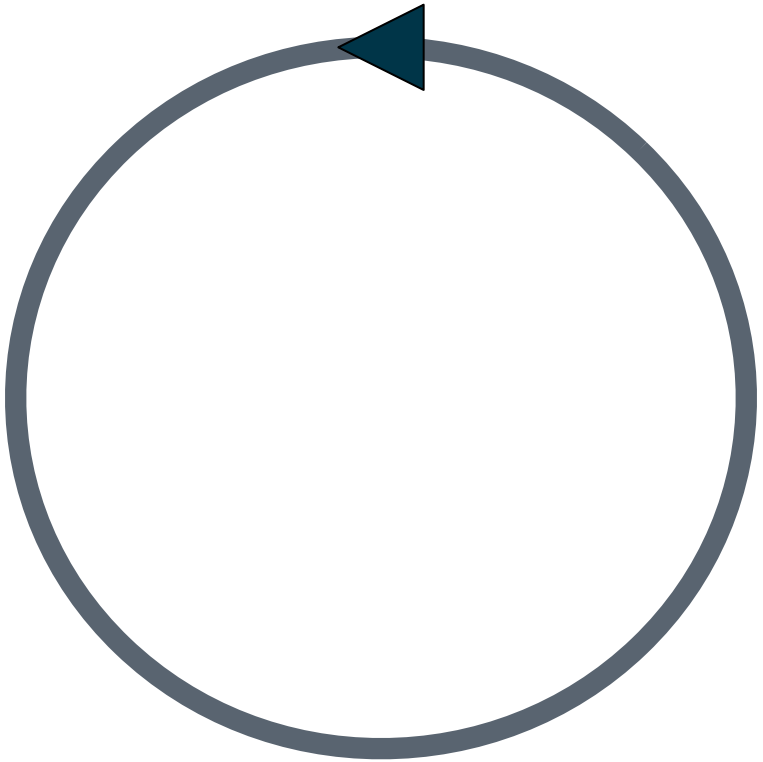


life on a string

life on a string

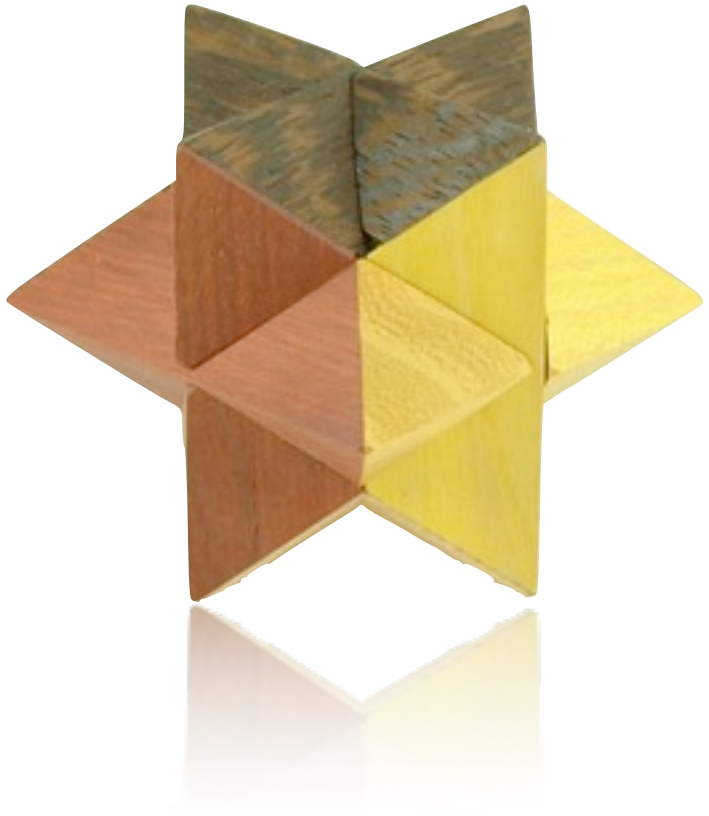
life/mind/society

- Habits introduce their own normativity.
- As metabolism starts to depend on mind, the normativity of mind can influence metabolism.

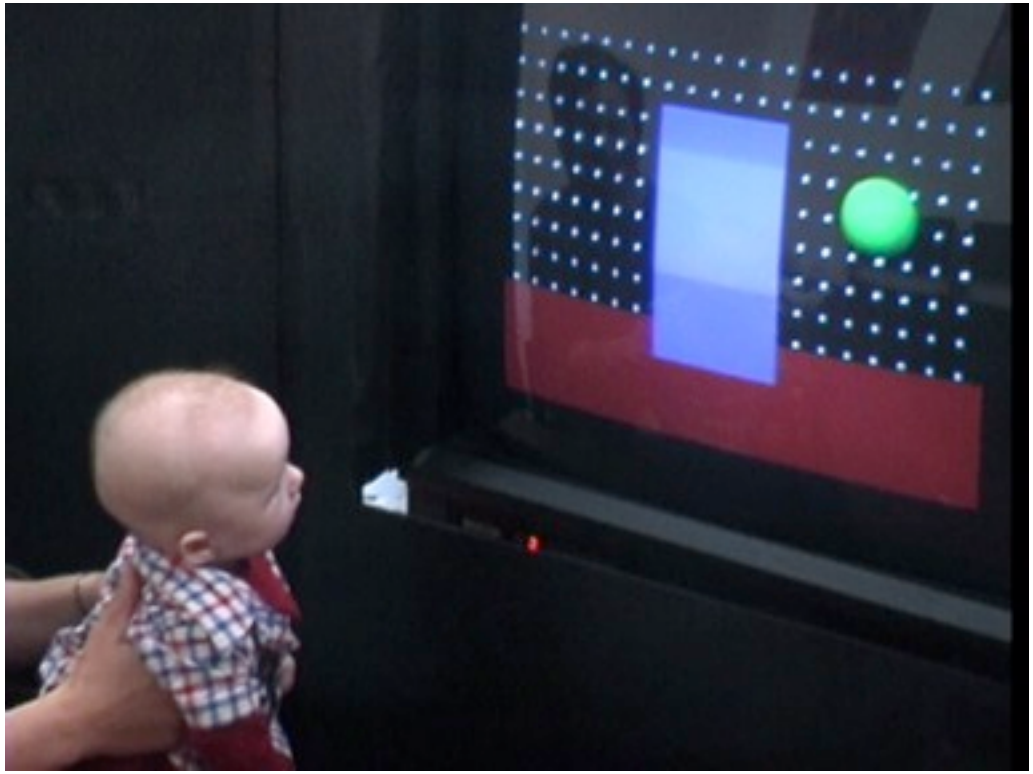
- Habits become mutual translations between the *psychic* and the *somatic*.
- Mind is *re-inscribed* in the body.
- Life/mind is a *new form of life*. Inherently restless, where inner conflicts are likely, and where a psychosomatic order is introduced.
- Similar transitions are to be expected in the social realm and in human agency.
- "Our physiology is a social physiology" (Levins & Lewontin)"
- Hegel (*Philosophy of Mind, part II of Enc.)*, Catherine Malabou.

a special case?

- Isn't abstract perception, the departure point of most philosophies of perception, a rather special case?
- Animals do not engage with the objects of their perceptions in this abstract sense. They are captivated by it, it becomes salient only in terms of an underlying motivation (food, shelter, danger).
- What makes human perceivers "stand against" an object (*Gegenstand*)?



second nature



There's nothing natural about human perception

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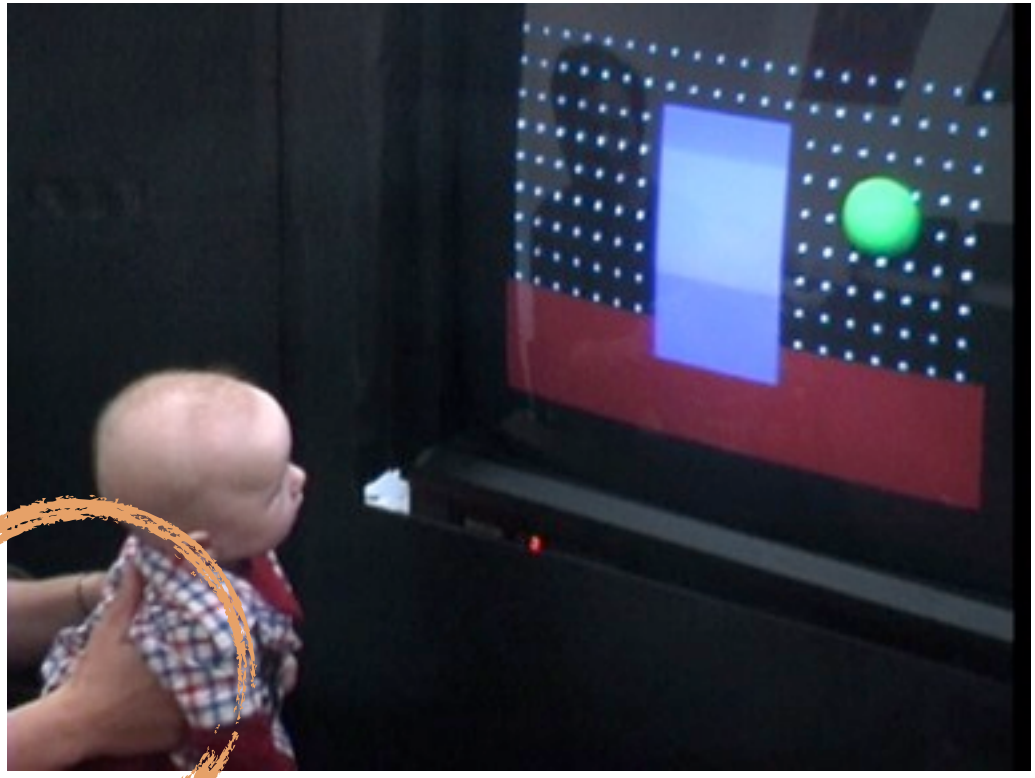

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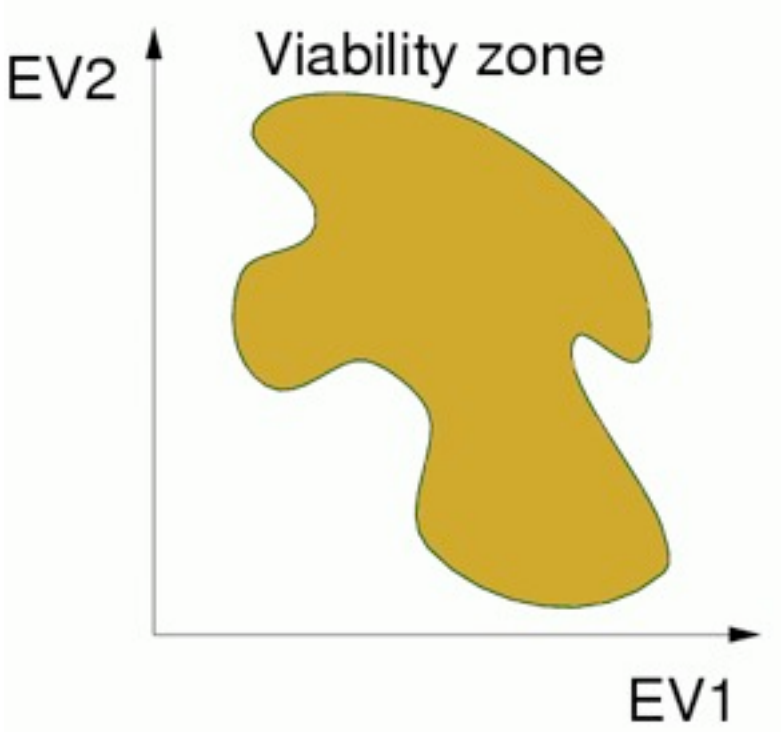
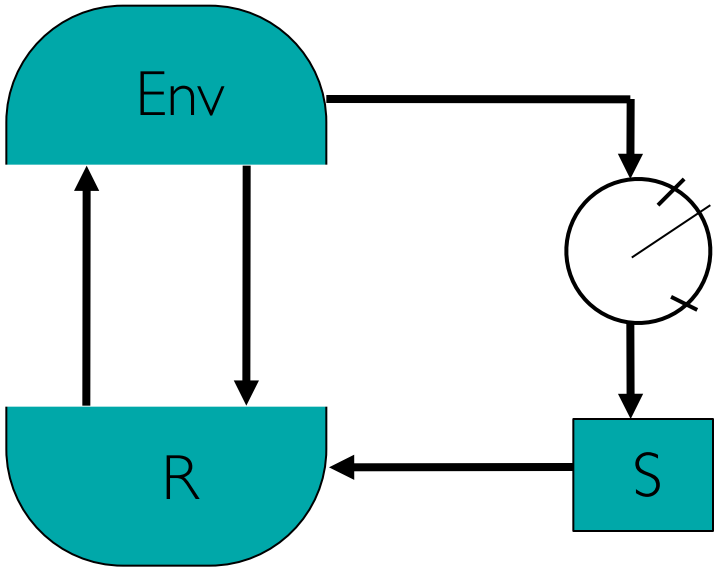
towards modeling sense-making

ultrastability





adaptation to visual inversion

A model of adaptation to inversion of the visual field

Homeostatic neurons, local plasticity

Evolve for homeostasis and phototaxis

Di Paolo, 2000

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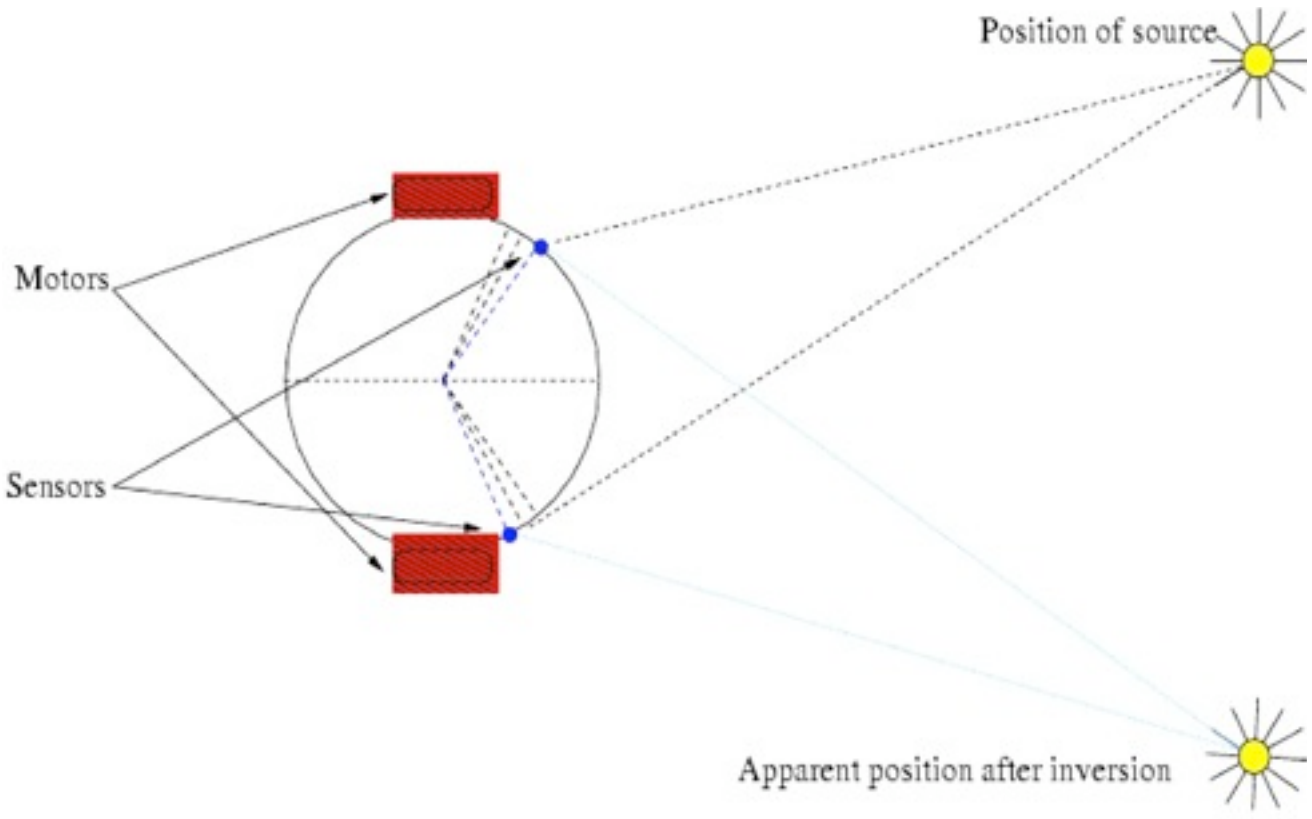

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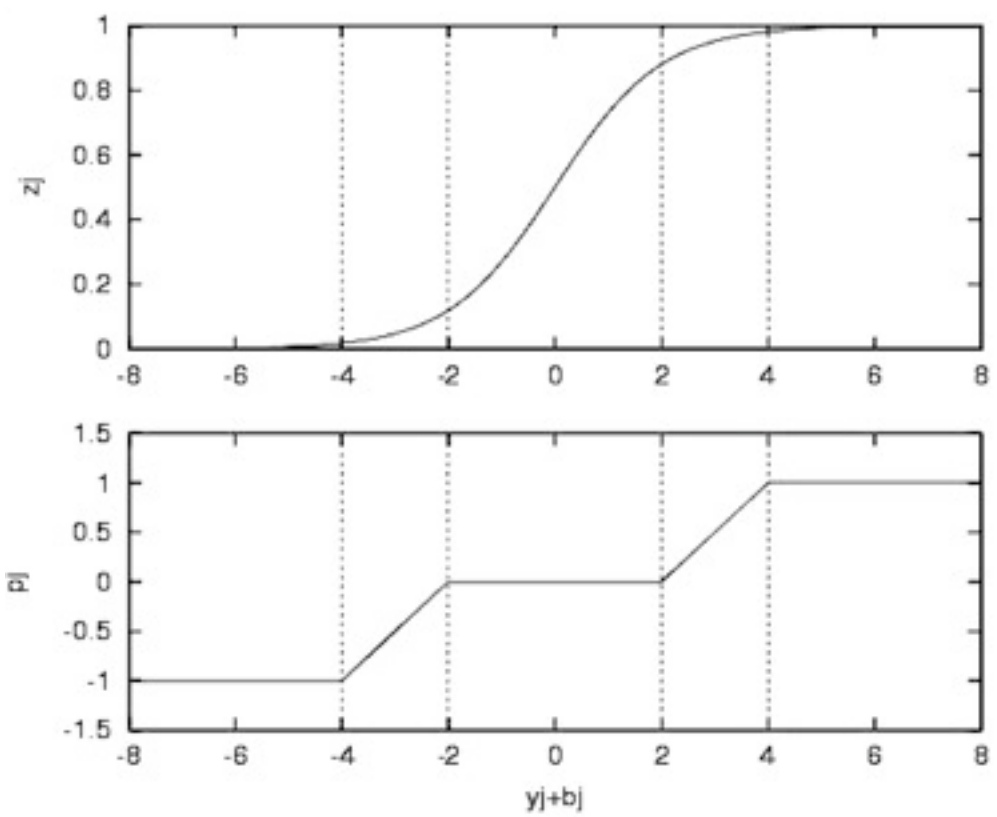

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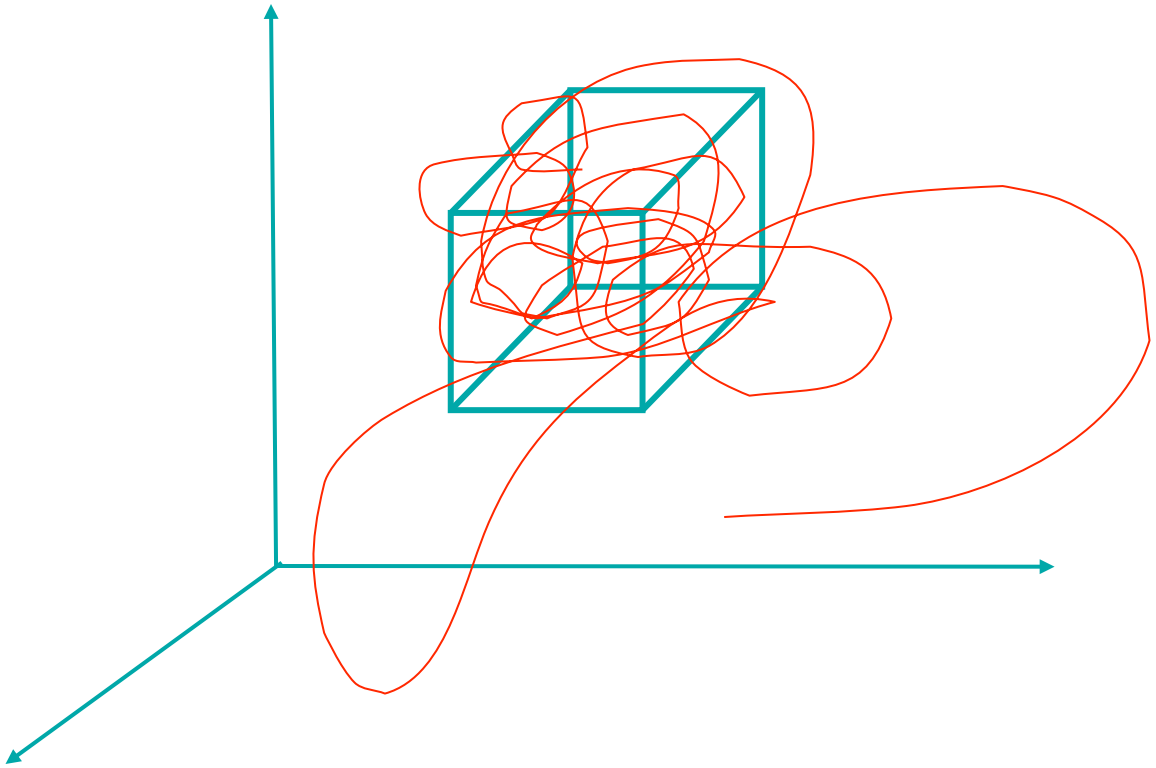

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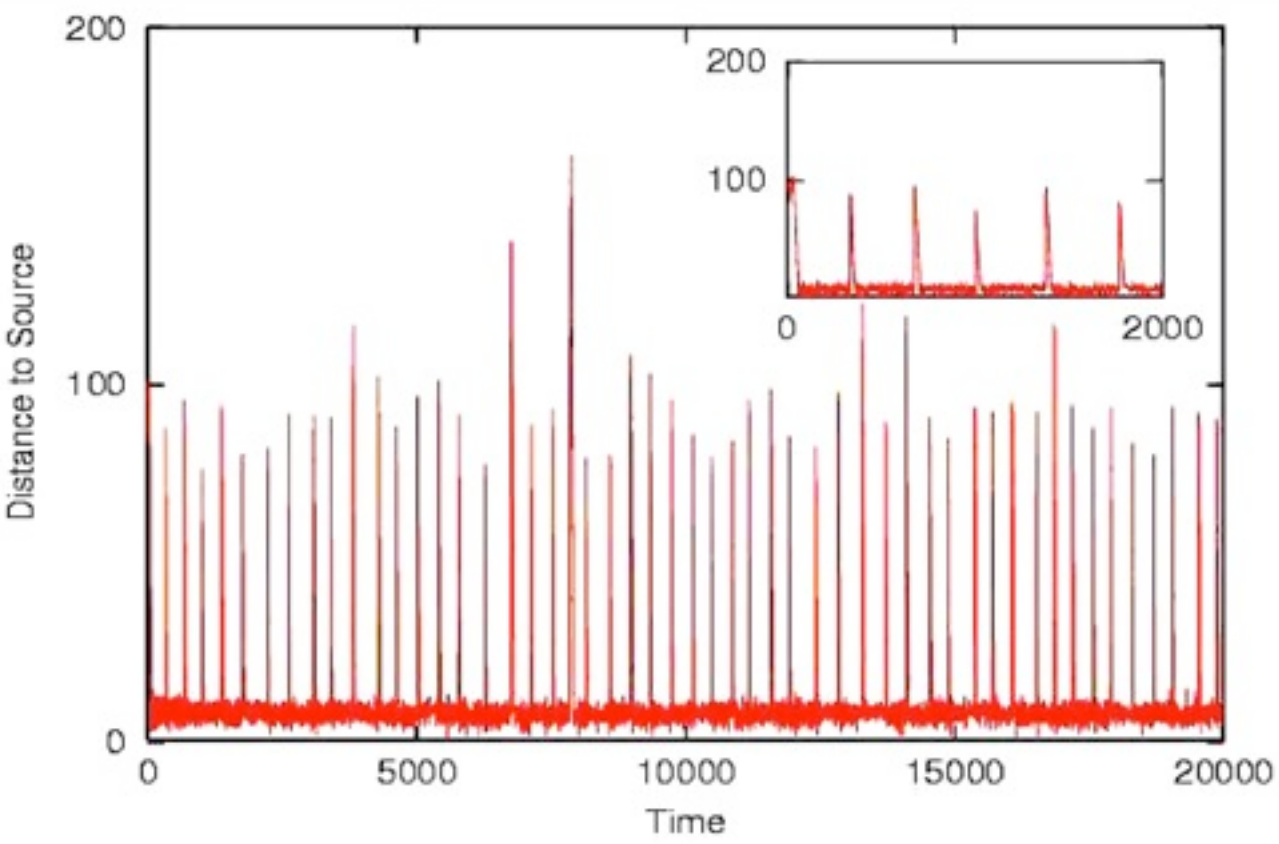

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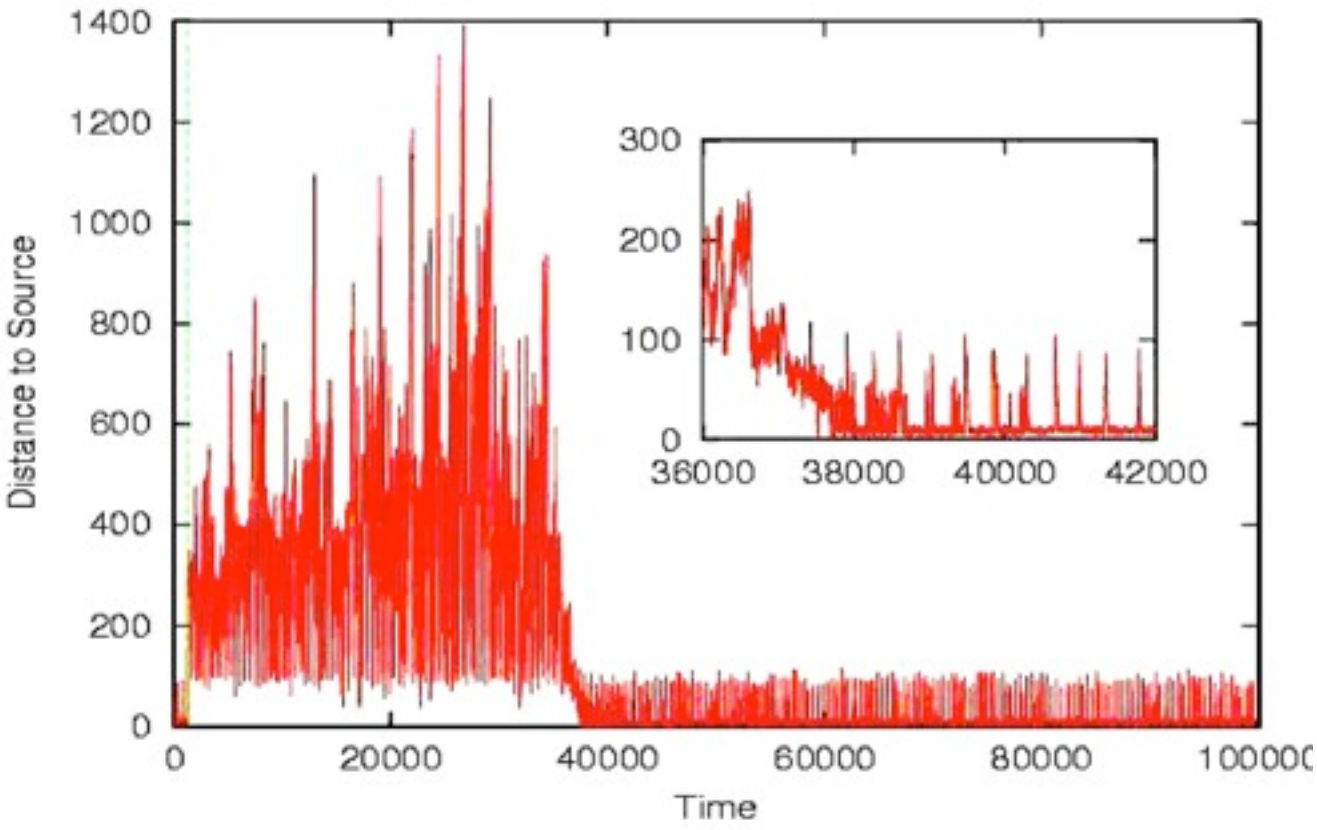
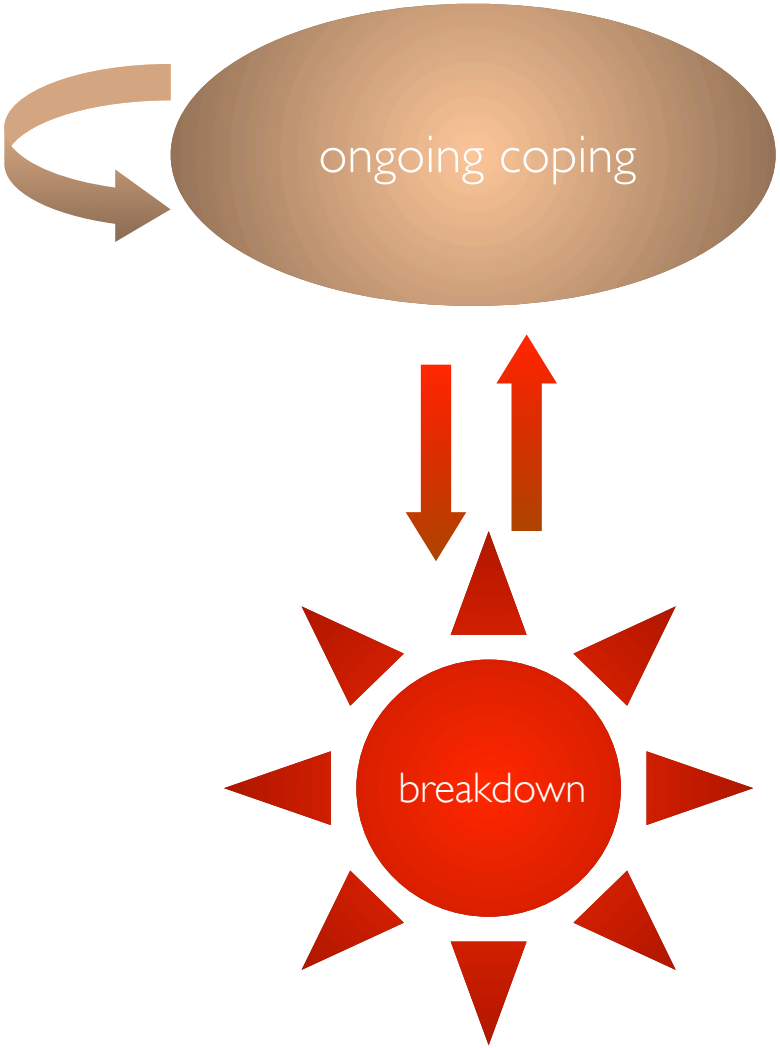


dynamics of every day life



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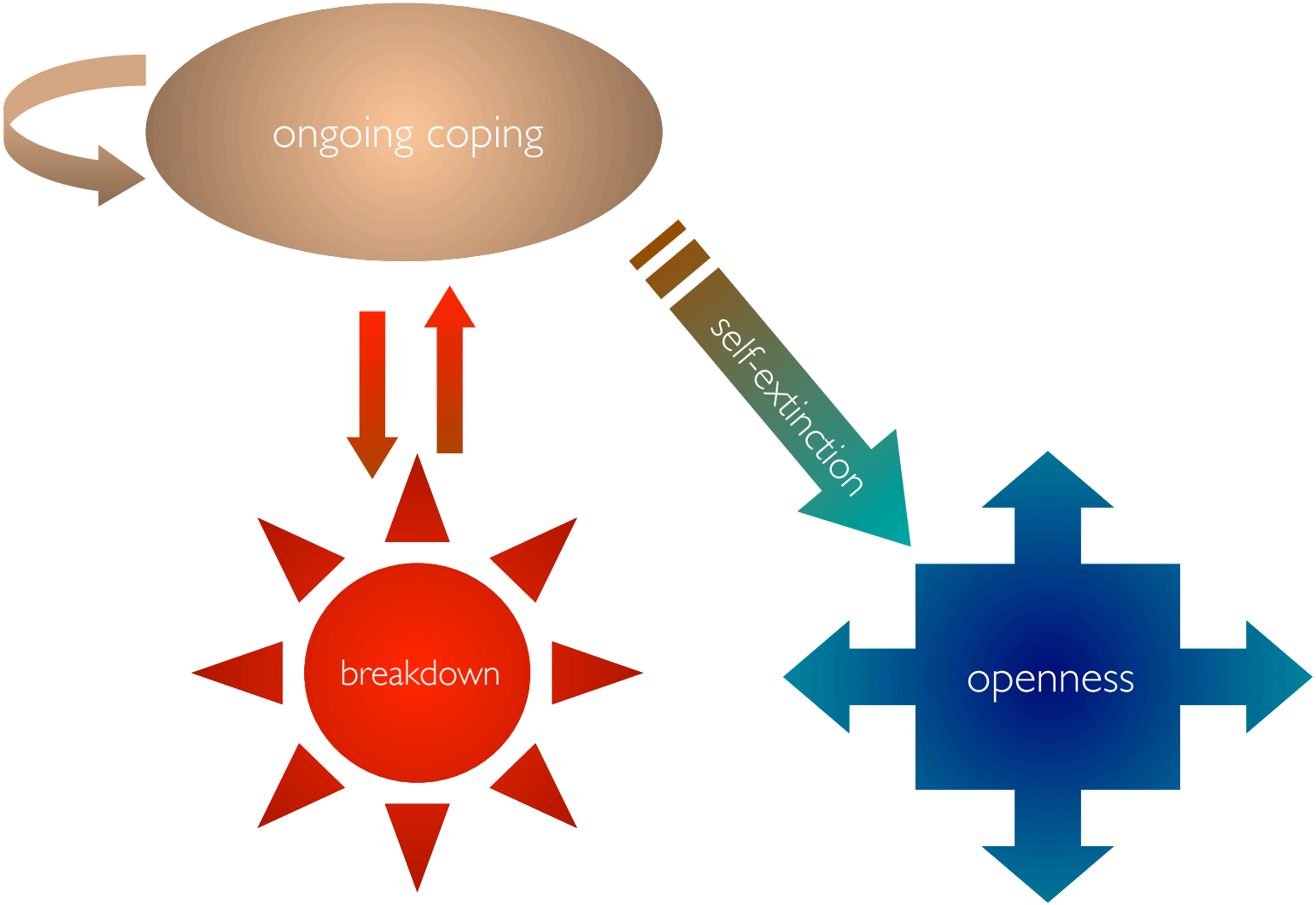

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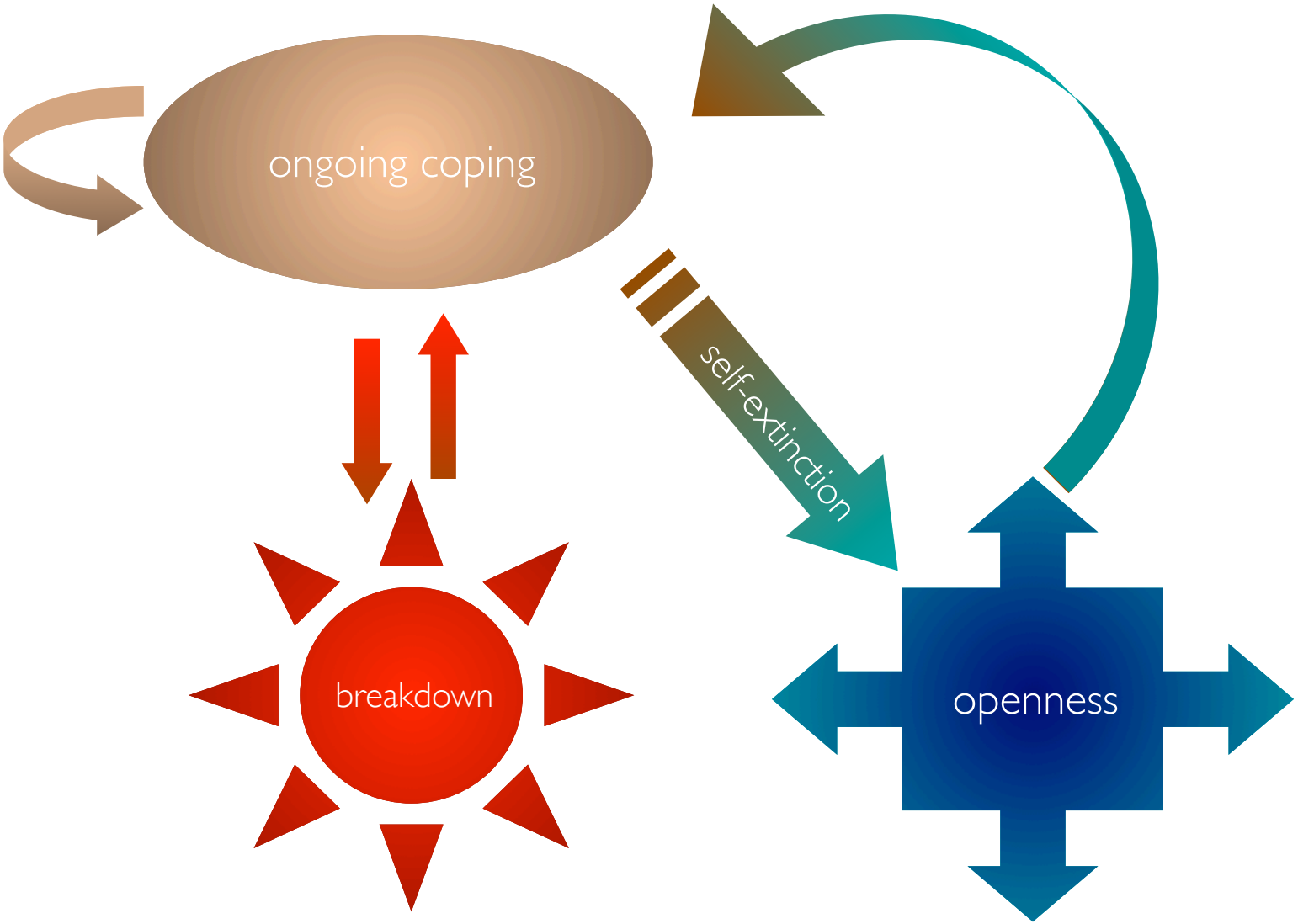
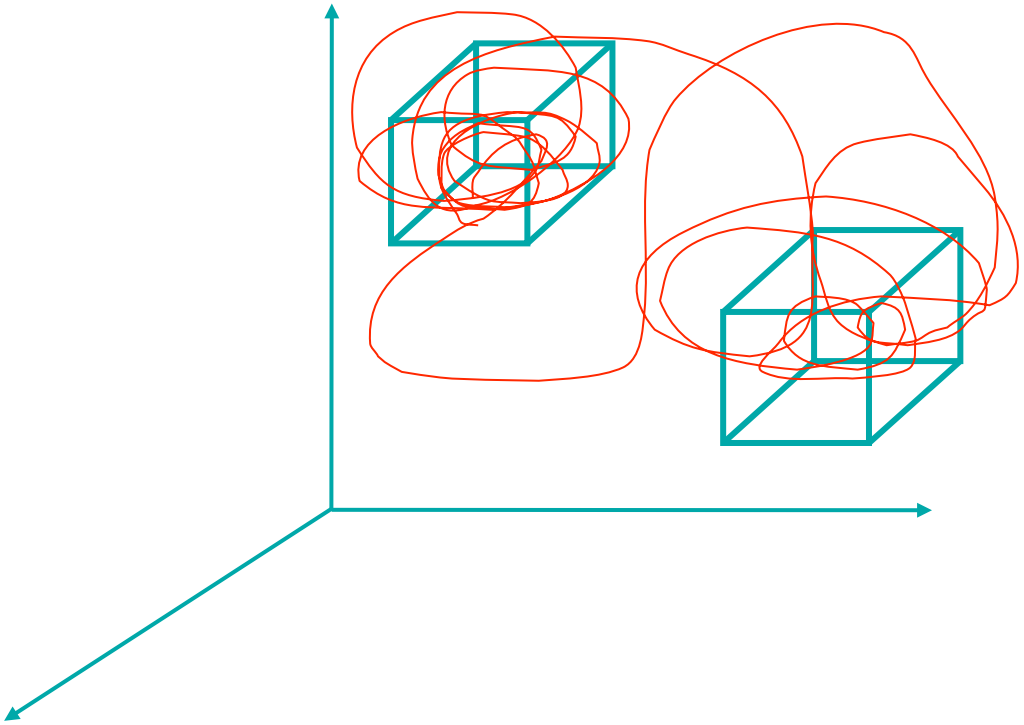


towards autonomous goal-setting

Can a system change its preferences autonomously?

Two homeostatic regions, two behaviours

Iizuka & Di Paolo, 2007



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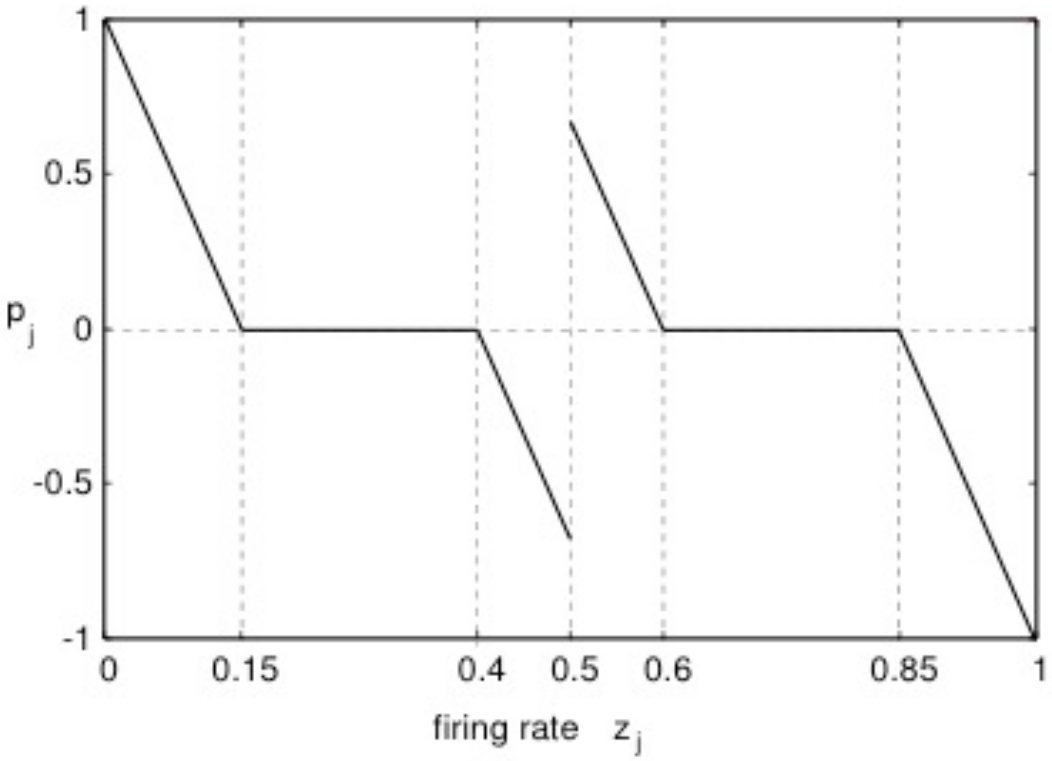

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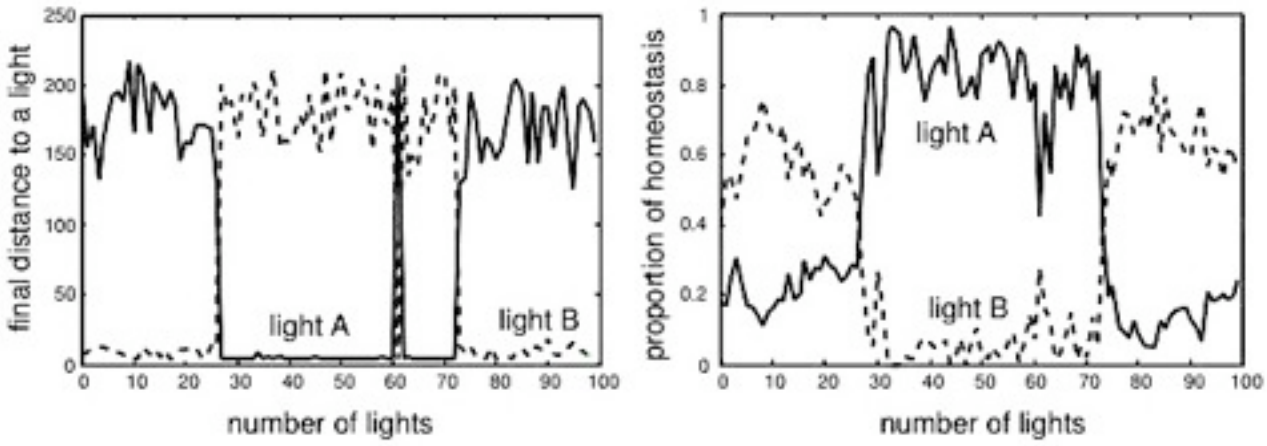
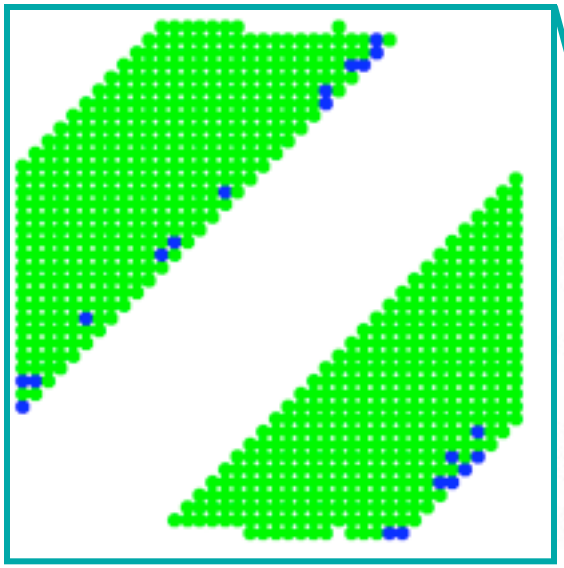
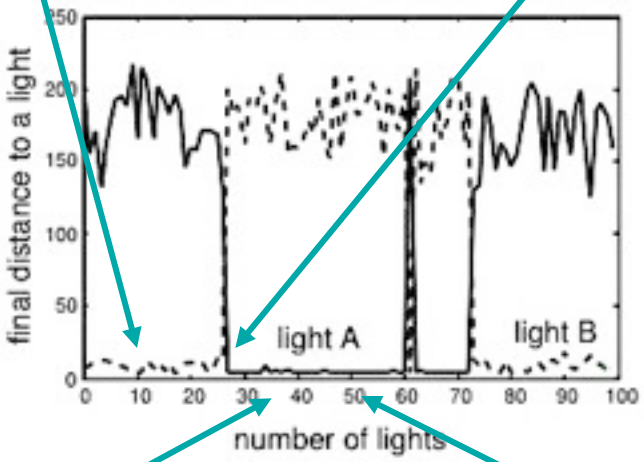
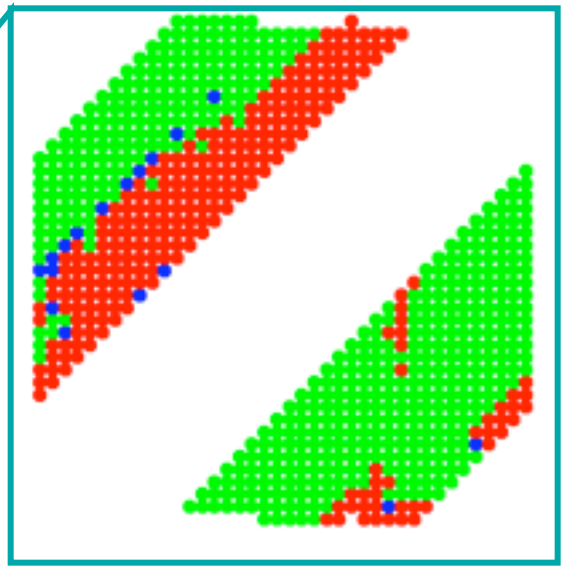
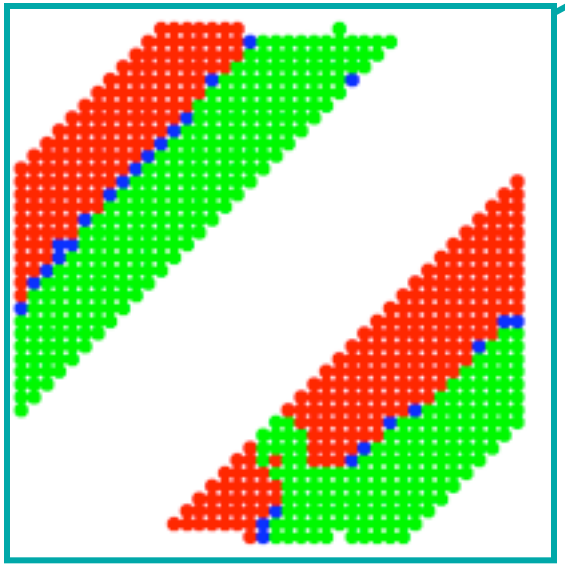


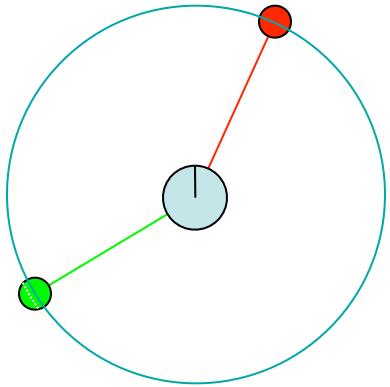
Landscape of preference

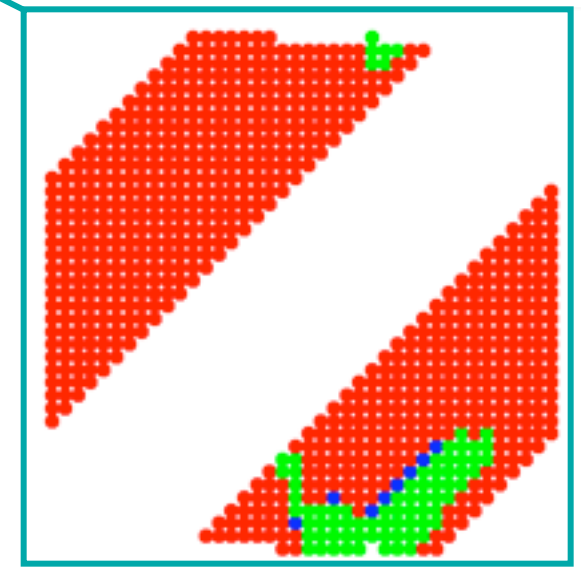












conclusions

horizons

- Shallow embodiment:
  - Moves beyond computationalism by showing non-trivial dependence on the situated body (out-of-the-head).
  - Significant contributions to novel theorising and modeling.
  - But susceptible of being interpreted in purely functionalist terms.
- Deep embodiment:
  - The body precarious, the most basic source of significance.
  - Enaction: A non-reductive and naturalistic approach to the mind
  - Sceptical of functionalism (representationalism, boxology), neuro-centrism and individualism.
  - Provides operational definitions of autonomy, agency, values, sense-making and social interaction.
  - A real alternative with open challenges and *horizons*.

Barandiaran, X., Rohde, M. and Di Paolo, E. A. (2009) Defining agency: individuality, normativity, asymmetry and spatio-temporality in action. *Adaptive Behavior*, 17: 367-386

De Jaegher, H, & Di Paolo, E. A., (2007) Participatory sense-making: an enactive approach to social cognition. *Phenomenology and the Cognitive Sciences,* 6,485 -507.

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Thank you

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embodiment

- During the last 2 decades there has been an increasing (but not uniform) acceptance of the role of the body for understanding the mind.
- Embodiment: The body is not an artifact controlled by the mind (or brain) but a structure embedded in the world that shapes our cognitive capabilities.
- Cognitive linguistics: homologies between bodily structures and habits with formal and metaphorical structures in language and mathematics (Lakoff, Johnson, Nuñez).
- Robotics: exploitation of sensorimotor structures organized by the action of agents and the creation of meaningful contexts.
- Philosophy of mind, neuroscience: Phenomenological perspectives clarifying the concepts such as body schema, body image, sense of agency, sense of ownership, etc. in combination with novel empirical research (e.g., Shaun Gallagher).