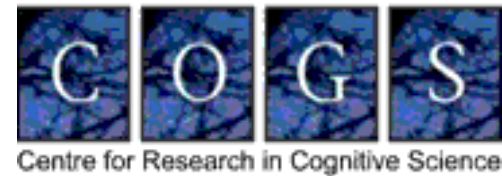
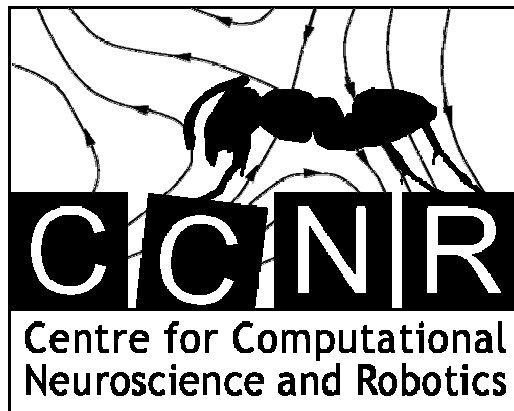


Horizons for the enactive mind

Values, social interaction and play

Ezequiel A. Di Paolo



This talk...

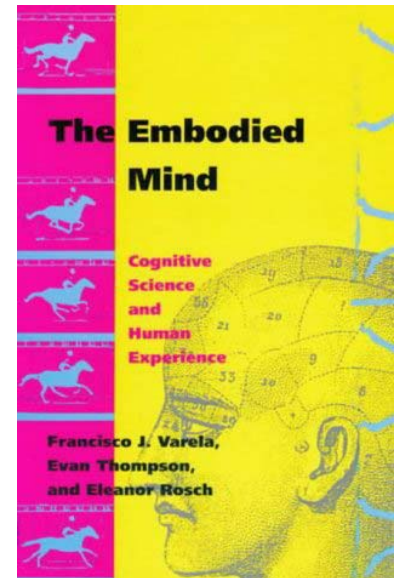
- ... will examine the enactive approach as a novel paradigm for cognitive science,
- ... will point to directions where enactivism can grow,
- ... will demonstrate the usefulness of minimal modelling,
- ... will speculate about enactive views on higher level cognition.

- Much of the work presented here has been carried out in collaboration and conversation with members of the CCNR and COGS at Sussex. In particular, my co-authors *Marieke Rohde* and *Hanne De Jaegher*

- You may direct the difficult questions to them ...

Overview: what is enactivism?

- Defining the enactive approach.
- Exploring its 5 core ideas:
 - Autonomy
 - Sense-making
 - Emergence
 - Embodiment
 - Experience
- Making explicit what enactivism rejects



Overview: value systems

- Enactive value generation.
- *Why do things matter?*
- The problem with evolutionary explanations and built-in value-system architectures.
- Evolutionary robotics models.



Overview: social interaction

- What does an enactive view on social interaction look like?
- Interaction as an autonomous process.
- Rhythm and social understanding.
- Multiple timescales of social interaction.
- Intersubjectivity.



Overview: play

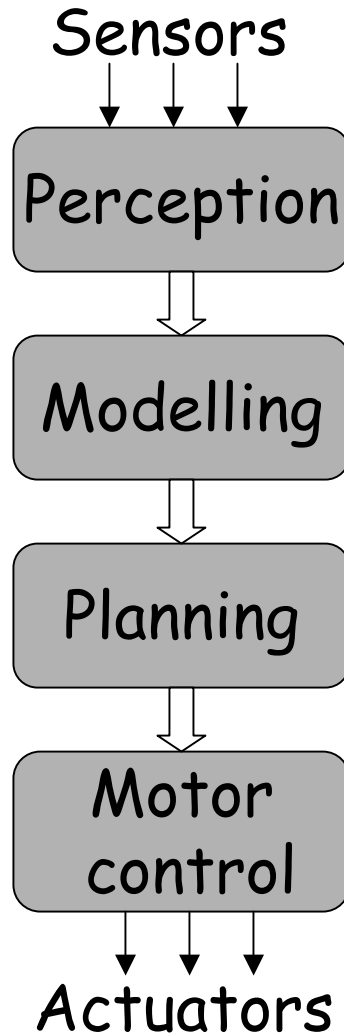
- What sort of transitional activities can take us from embodied skills to human level cognition?
- *What is human cognition all about? (the single sentence version)*
- Beyond “low level” enactivism.
- An enactive perspective on play.



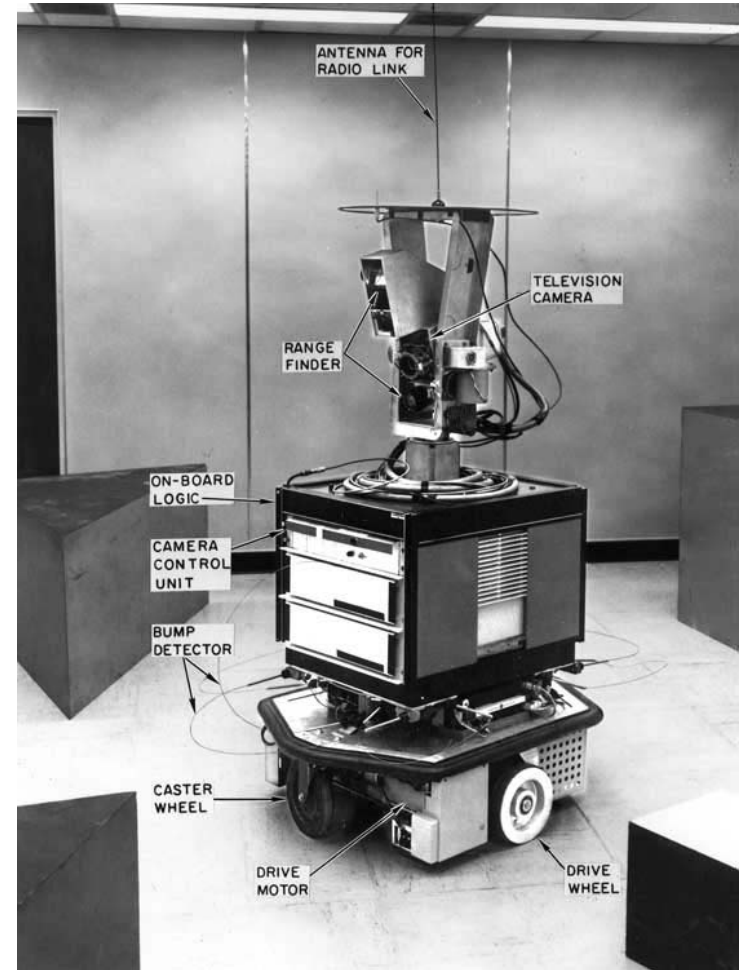
but first...
a 5 min course on evolutionary robotics
(philosophy of mind with a
screwdriver)

GOFAI Robotics

An action-neutral architecture.



"Intelligence"



Action-oriented approach

1. Situatedness:

- Exploitation of an ecological niche
- Ongoing interaction with environment
- Affordances, meaningful action and perception

2. Embodiment:

- Whole agent integrated design
- Closed-loops of sensorimotor interaction
- “Intelligent” sensors and actuators (exploit physics and regularities)

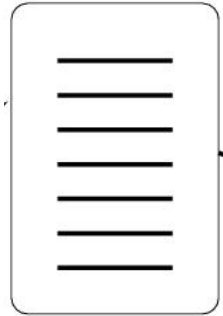
3. Dynamics:

- Real time constraints. Time matters
- Opportunistic, coupling with dynamics of environment
- Loose coupling between simple processes giving rise to robust activity.

Evolutionary Robotics

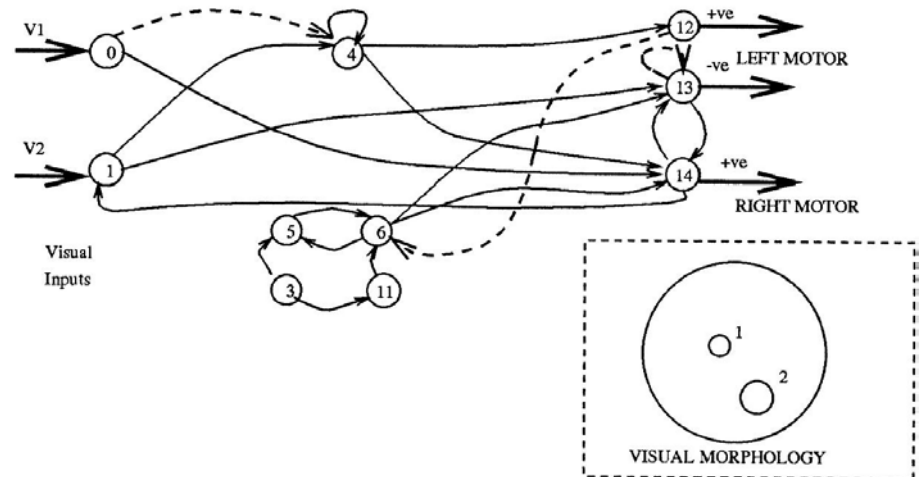
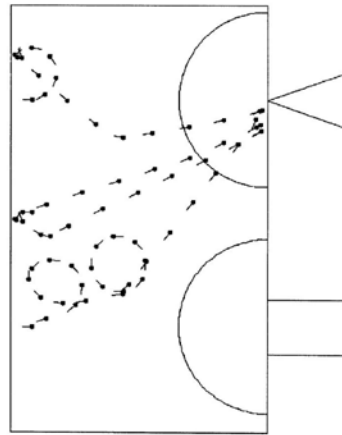
- The use of evolutionary computing techniques for developing autonomous adaptive robots (control system and properties of sensors, motors, and body).
- **Engineering:** Alternative to traditional design techniques suitable for very complex systems. Synthesis of whole systems.
- **Science:** Less prejudiced way of exploring wide class of mechanisms for generating adaptive behaviour. Synthesize and analyse. Fewer preconceptions. Proofs of concept.

Population of robot genotypes

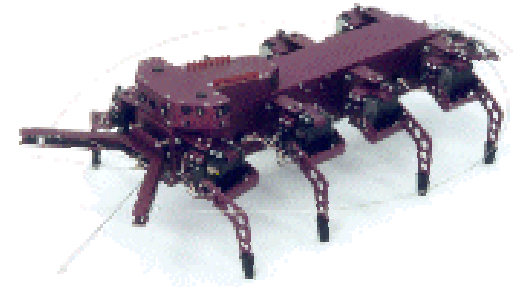


Gantry robot at Sussex

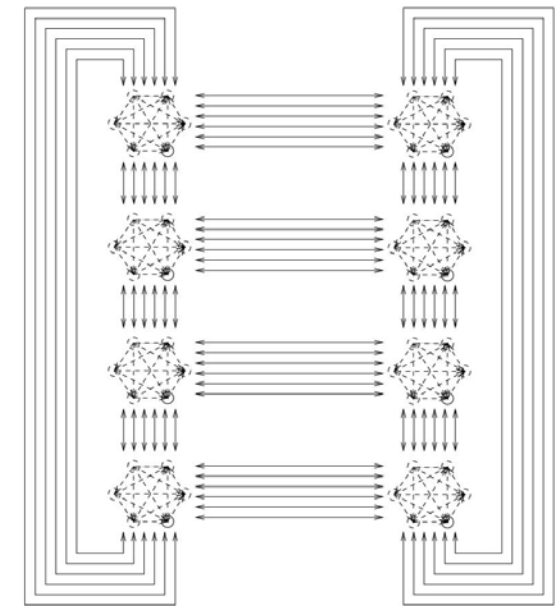
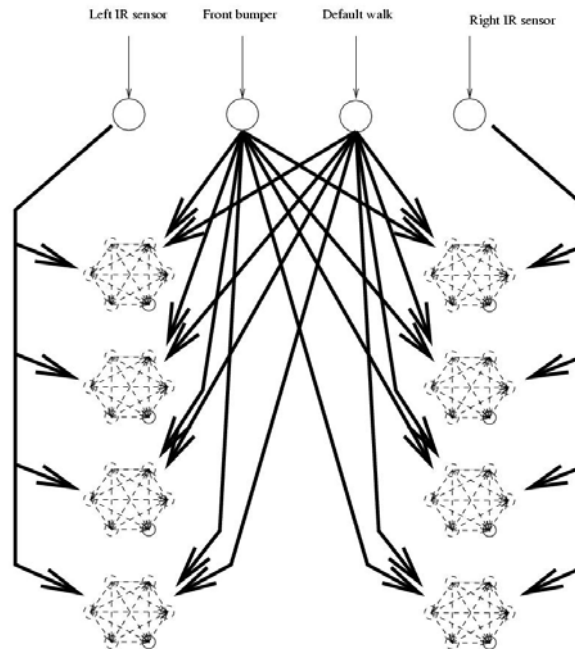
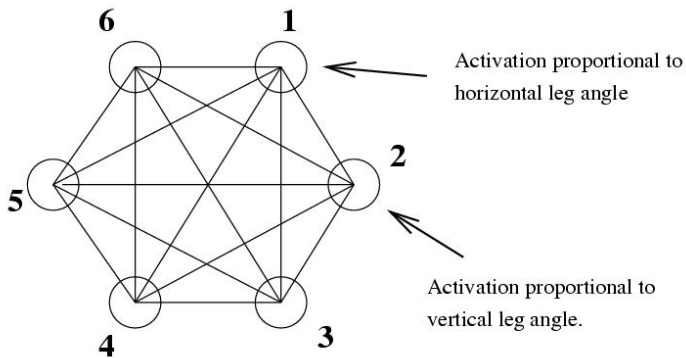
- Harvey, Husbands, Cliff, 1990s.
- Approach a triangle on the wall, evolve neural controller and sensor morphology.
- Visual task = body rotation + sensor morphology + neural controller + environmental regularities



Octopod



- Walk straight as fast as possible. Turn left on the spot when obstacle appears on right-hand side and vice versa. Walk backwards if front bumper is hit.



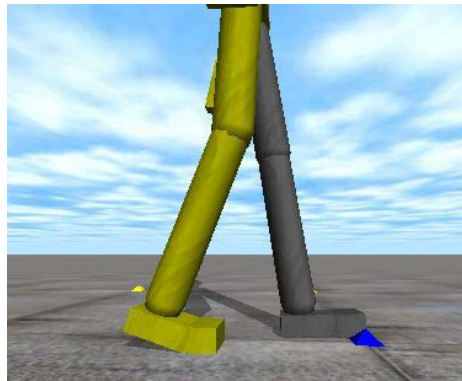
Octopod video



Evolving natural walking

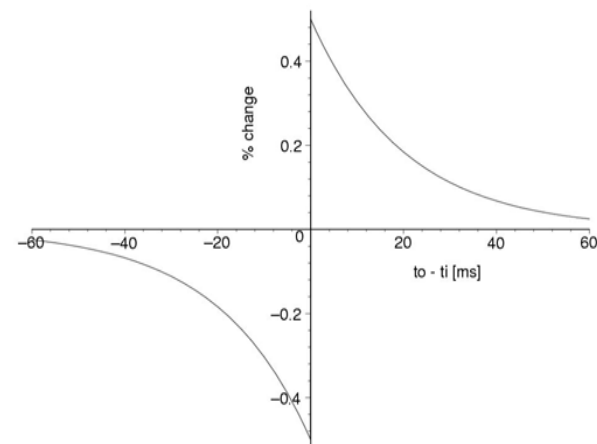
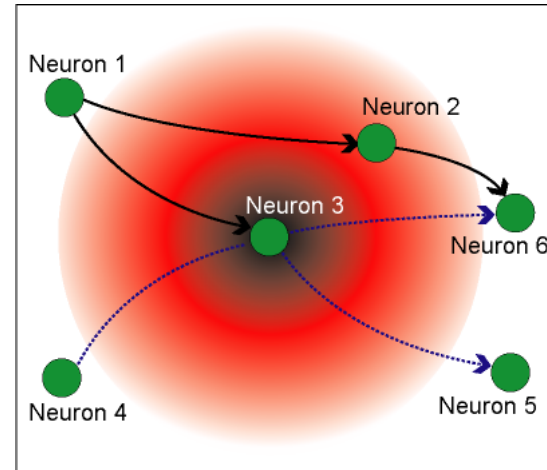


- Full body 32 degrees of freedom including spine
- Physical version currently under construction.
- Vaughan, Harvey, Di Paolo

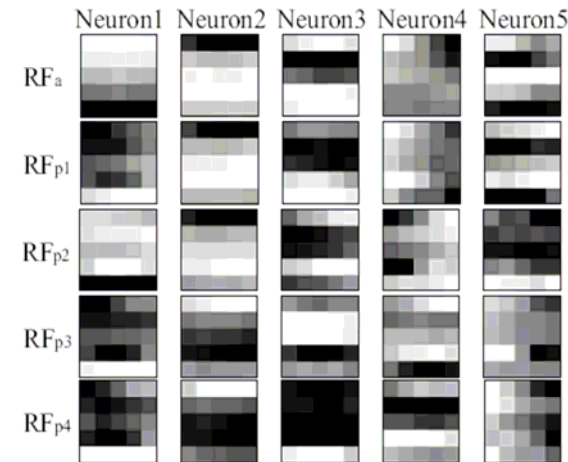
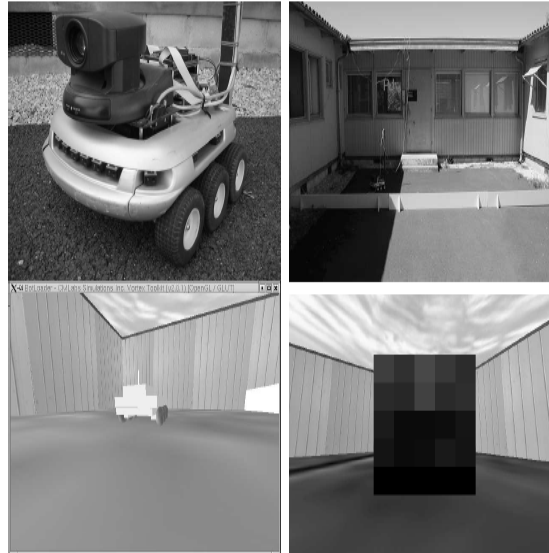
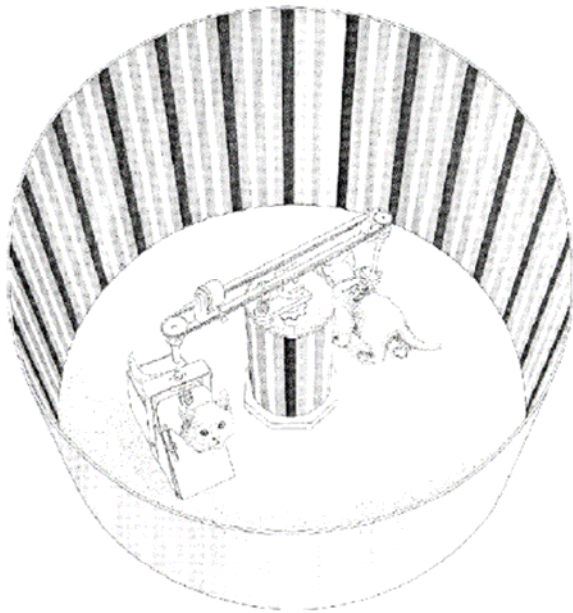


ER and Neuroscience

- GasNets. Neural controllers with diffusible gaseous neuromodulation, Husbands et al.
- Spike-time dependent plasticity, Di Paolo, 2004.



ER and Neuroscience



- Replication of Held and Hein experiment on visuomotor development. Suzuki, Floreano, Di Paolo, 2005

the enactive

the enactive approach

approach

Enactivism: current context

- Is the enactive framework relegated to explaining “cognitively marginal” performance (Clark & Toribio)?
- Should we accept the lessons of enactivism for embodied, engaged, perceptually-saturated, ongoing activity, but resort to traditional views for more sophisticated, high-level cognition?
- Is *enactive* the same as *active*? *Embodied*, the same as *physical*? *Dynamical*, the same as *changing in time*?
- **Reform or revolution??**

The two problems of enactivism

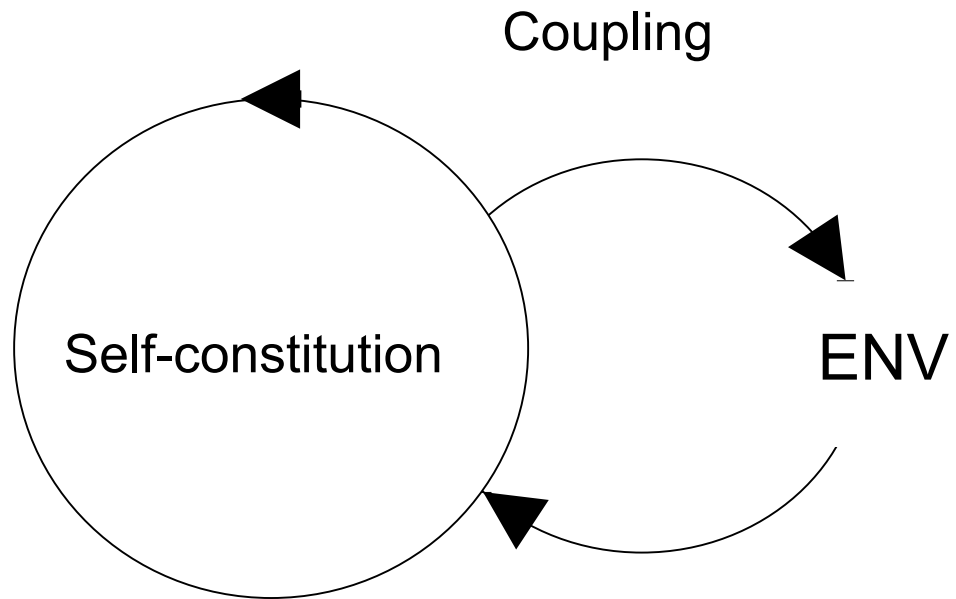
- Watering down.
 - Careless use of the term enactive
 - Pick-and-choose attitude
 - Perceived (maybe real?) lack of coherence
 - Problems of vocabulary, habits of thought, publishing, talking at cross-purposes, disciplinary chauvinism, etc.
- Apparent limited coverage.
 - Good for “low level” cognition
 - Good for “updating” traditional views

What needs to be done

- If the enactive view is to get off the ground, the problems must be acknowledged and taken seriously.
- We propose:
 - To attempt to highlight the core concepts of enactivism and show their coherence and radical departure from traditional ideas.
 - To explore extensions of enactive perspectives to non-trivial domains
 - To show one aspect of the enactive methodology (minimal synthetic modelling) at work

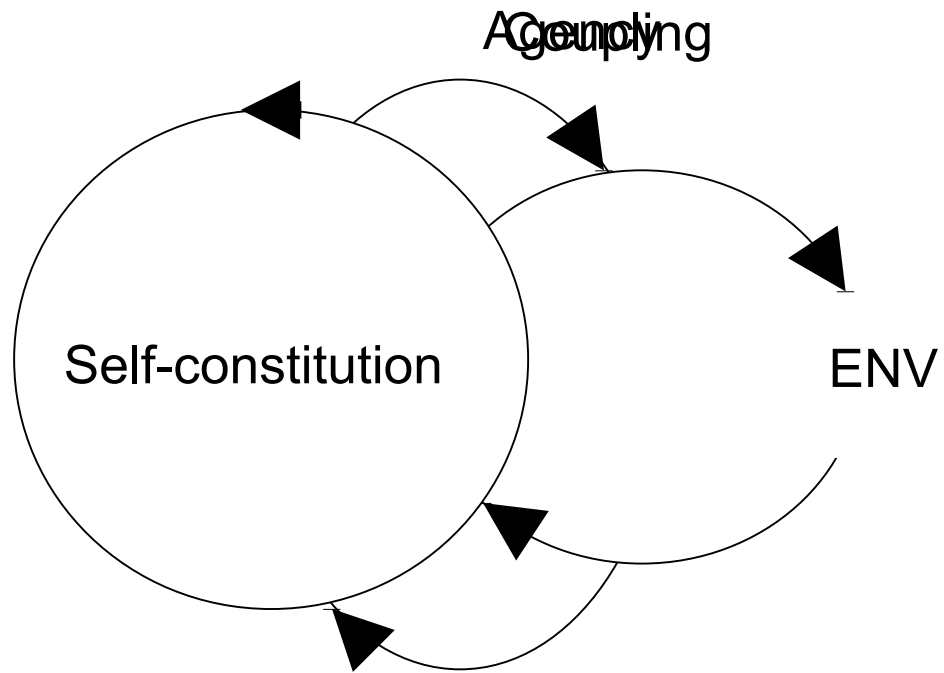
Autonomy

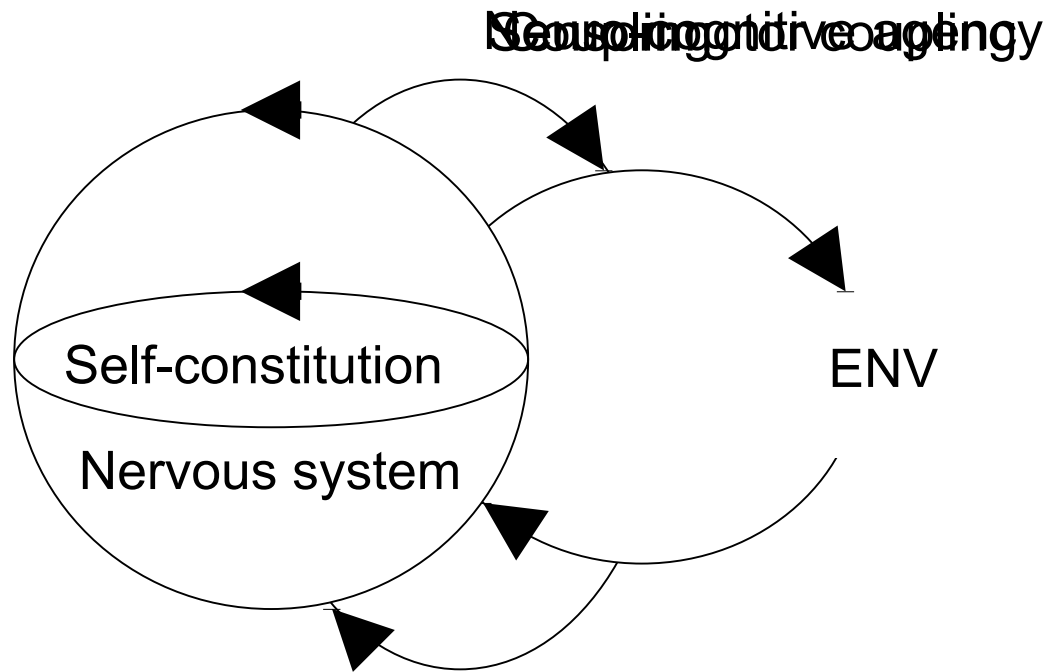
- A cognitive agent is autonomous, it gives itself its own laws.
- How? Only by being able to affect its own constitution this is possible. Only a system able not just to modify itself, but to build itself as an entity.
- **A precarious, self-sustaining process of identity generation.** Classical example: autopoiesis, but others are possible.
- Implication: Forget about internal drives and stimulus-driven cognition. Mind has a proper, irreducible level, that of the autonomous cognitive identity.
- More attention to endogenous dynamics, value and motivation as dynamical principles.



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*.
- **Sense-making** is to actively relate to the environment in terms of meaning and value. Non-Gibsonian.
- This property underlies all cognition. Necessary and sufficient.
- **Agency**: when the system regulates its relation with its world
- **Behaviour**: The control and selection of what physical exchanges to suffer. It has intentional structure, it may fail or succeed.





Emergence

- The enactive answer to the “How does it work?” question.
- Autonomous identity is already emergent and so is sense-making. They refer to processes happening at a relational/organizational level which is not that of the self-constructive processes that constitute the cognitive system. Two requirements:
- Properties and processes are distinguished at a different level of identity than those of the processes originally observed .
- The new level processes act as modulation for the dynamics of the lower level (reciprocal “causation”).
- Collective decision making in bees, stock markets, etc.
- Non-reductive naturalism.

Embodiment

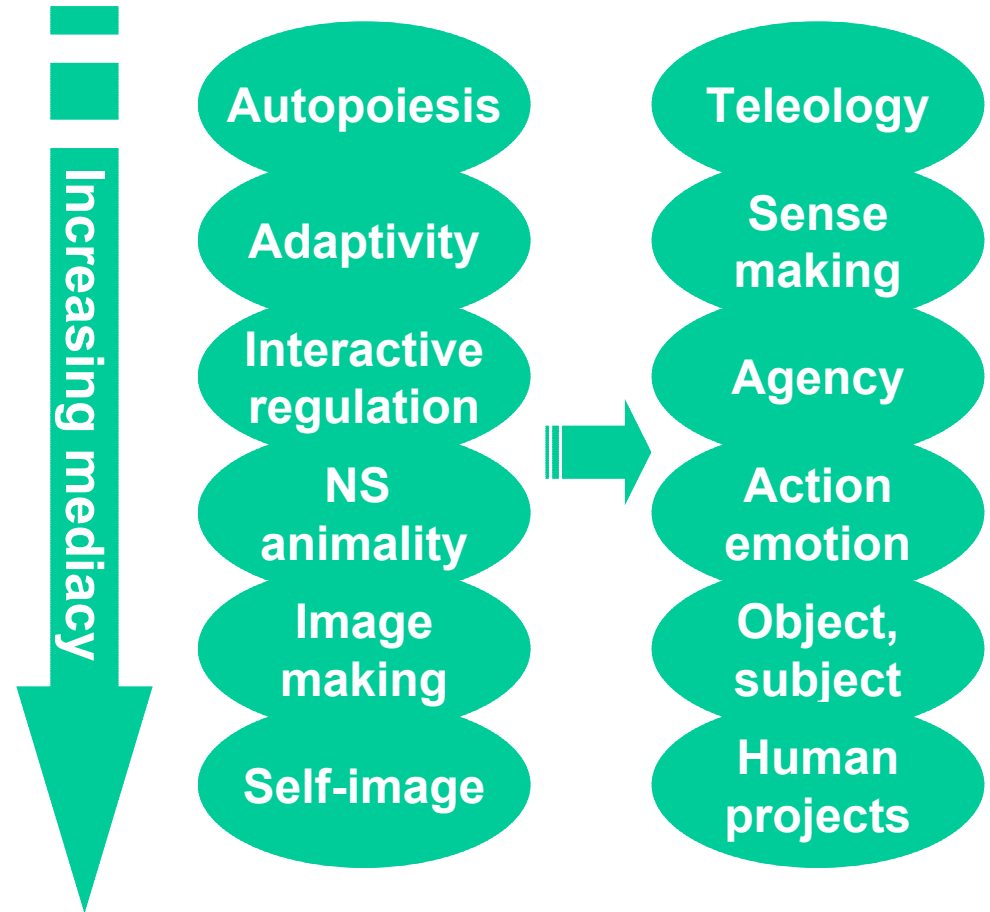
- The body is *non-trivially* implied in cognitive activity.
- The body is not a puppet! Mind is a living body acting in its world.
- Embodied mind: a necessary redundancy.
- Cartesianism is so pervasive because human beings do funny things with their bodies (go on diets, run marathons, obey self-issued orders, etc.) but we need a particularly flexible morphology and an appropriate socio-cultural context to be able to do these tricks.
- Cartesian dualists are not stupid!

Experience

- Central thematically and methodologically. Not an embarrassment as for cognitivism. There is an “inner” affect side to all cognitive activity.
- Taken more and more seriously as a constraint, typically isomorphism between mechanistic explanations, their emergent properties and phenomenology. (eg, skill acquisition, inner time-consciousness)
- A pragmatic circulation between science and experience (Varela, Gallagher, van Gelder, etc).
- Scientific explanations of the mind will involve appealing to practice. Ontological-epistemological co-constitution.

Life/mind continuity

- Hans Jonas.
- Some principles:
- Metabolism already implies value.
- The mediacy/freedom thread.
- More freedom implies more precariousness.
- Transitions are value-generating.
- New forms of life.



Metabolism and identity



- Hans Jonas discerns some “special goings-on” in the organismic body: the constant exchange of matter with its surroundings, its *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.
...
- Metabolism maintains its organisation assuring its durability in the face of randomising events (*precariousness*). Metabolism produces ... more metabolism.

Emotion: the primacy of movement

- Organisms have a relation of **needful freedom** to their world.
- Animals expand this freedom by the intervening distance and time interval between their needs and their conditions of satisfaction. Distance gives origin to **perception** and **action**.
- In so doing, they develop the basic structure of tension and satisfaction we find in all life, into a complex **emotional life** involving e.g., *desire* of the goal perceived but not yet attained, *fear* of the danger that closes in, and *greed* in the chase of a prey.

Further on the scale of mediacy

- **Objectivity/subjectivity.** After movement and interaction over distance, further detachment is enabled by those senses that allow the simultaneous perception of invariant manifolds without direct interference on the perceived “object”: i.e., **sight**.
- **Truth/detachment.** The capability for **image-making** enables the passage to humanity by freeing us from acting only with respect to our present situation.
- **Image of man.** Finally, turning image-making upon ourselves defines our life as a **project**. The subjective centre is divided, and only humans can know happiness or frustration.

The argument for sense-making

- A. autopoiesis is a process that defines a unity and a norm: to keep the unity going and distinct,
- B. encounters with the external world are “evaluated” by the system (through the autopoietic machinery) as contributing or not to the maintenance of self-production, consequently
- C. autopoiesis implies sense-making, an intrinsic perspective of value on the world.
- Weber and Varela, 2001.

Some perfectly viable behaviours



Ezequiel Di Paolo



University of Sussex

Definition of adaptivity

Adaptivity is:

A system's capacity, in certain circumstances, to regulate its states in relation to its boundary of viability with the result that, if the states are sufficiently near the boundary, then:

1. tendencies are distinguished and acted upon depending on whether the states approach or recede from the boundary and,
2. as a consequence, tendencies of the first kind are moved closer to or transformed into tendencies of the second.

Adaptivity and sense-making

Autopoiesis + Adaptivity → Sense-making

- Adaptivity allows events to be evaluated with respect to the viability norm, **while the organism is still living**. Dangerous tendencies (breakdowns) can be recognized contemporaneously (Di Paolo, 2005).
- It is a graded concept, it introduces a graded internal norm.
- Its severity is *appreciated* by the amount of adaptive resources deployed to compensate for it. Not by an objective distance to the boundary (e.g., radiation is dangerous but we don't possess adaptive responses to its presence, therefore it doesn't feel dangerous.)

Sense-creation

- How can value be given to encounters that don't directly affect self-production?
- If autopoiesis were enough for sense-making, how could snowprints be meaningful if they are not themselves either edible or lethal?
- Recursive adaptivity can be a solution. It works on tendencies of states and so allows for expanding mediation.



Temporality

- Adaptivity has the structure of an **act** (Langer, 1967): onset (sensing negative tendency), acceleration (activation of adaptive mechanism), consummation (satisfaction), cadence (de-activation of adaptive response)
- Adaptivity has **temporal direction**. Autopoiesis has not.
- There's a **minimal time span** in this analysis, which is that of individual acts of regulation.
- Adaptive acts are self-extinguishing by definition, but their collective action and precariousness of metabolism, makes them also self-renewing leading to **rhythms of tension and satisfaction**.
- A **historical dimension** is so established, which is neither the reflection of external events nor the following of an internal plan.

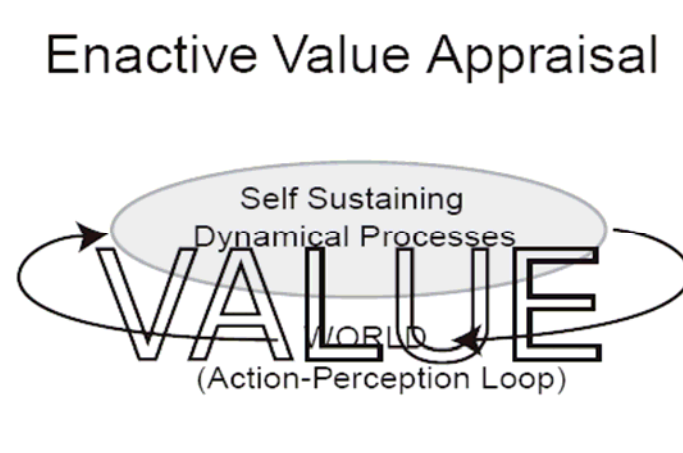
value

values

lues

What is value?

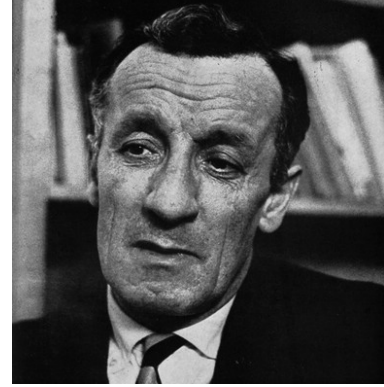
- A value is **the extent to which a situation affects the viability of a self-sustaining and precarious process of identity generation.**
- No more or less than what is at the root of all sense-making.



Irrevocable transitions

- The development of the dimension of concern from metabolism to human projects is marked by transitions where the freedom gained by the primordial processes of life is occupied with novel ways of generating value.
- From the point of view of metabolism, these transitions are of doubtful gain.
- But for Jonas, these transitions cannot go back. Therefore, they must be enabled by **new forms of life**.
- An oak-tree might have some concern for his own being, but it cannot be afraid, nor can an ant be embarrassed.

Non-metabolic values



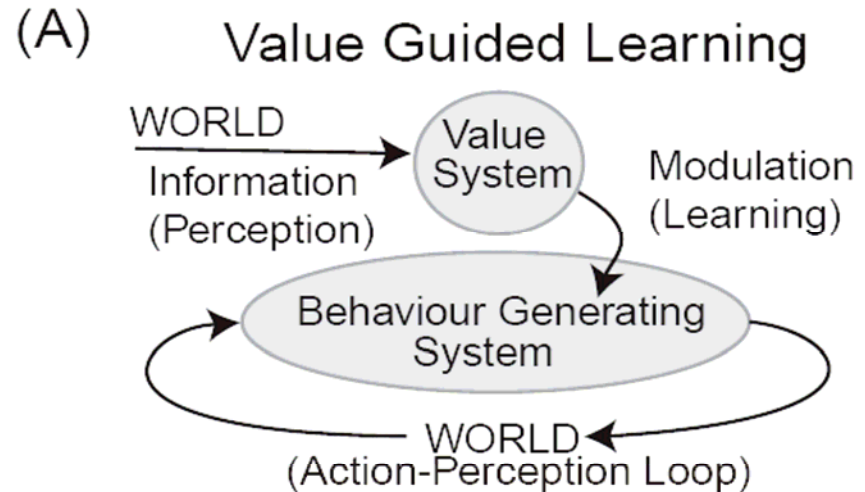
- Animal action has an **organization** of its own, underdetermined by metabolism. It is enough to posit a similar kind of self-sustaining dynamic form in neural and bodily activity to see how value can also be generated at this level.
- Merleau-Ponty's concept of motor intentionality is the most direct 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**

Value-generating activity

- New values arise each time activity becomes self-affirming, a self-sustaining dynamic form.
- This is enabled by metabolism but need not subserve it.
- **Habits** may work against organismic viability (Dewey, Goldstein, etc).
- Re-habilitation of embodied patterns, re-adaptation to novel habits, are difficult, and prolonged processes, not always successful.
- Herein lies one of the greatest challenges for cognitive science: a dynamical theory of value-generating activity.

Traditional values

- Values are explained in cognitivism as built-in modules capable of evaluating whether a situation is good or bad.
- These are pre-designed by a history of natural selection.
- The rest of the cognitive system is therefore value-agnostic.
- Many theories (TNGS) use such boxes to drive learning processes, eg, processes of plastic change to the rest of the cognitive system.



Problems

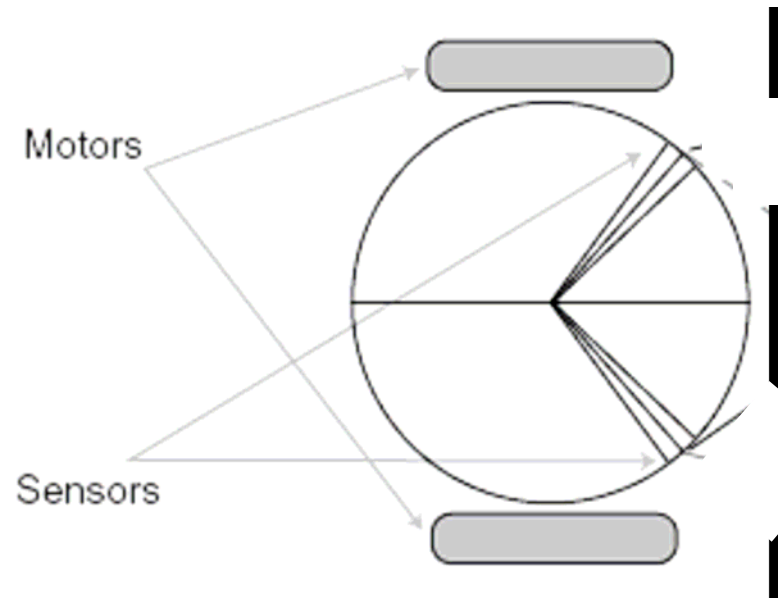
- Value belongs to the emergent level of sense-making. It's a relation between the process of identity generation and the interactions with the world.
- Value-appraisal must be disembodied in order to be general. It mustn't rely on how sensorimotor coordination is achieved since it is meant to modify it.
- This view misses how the organismic dynamics generates value.
- The “poison is good” argument.

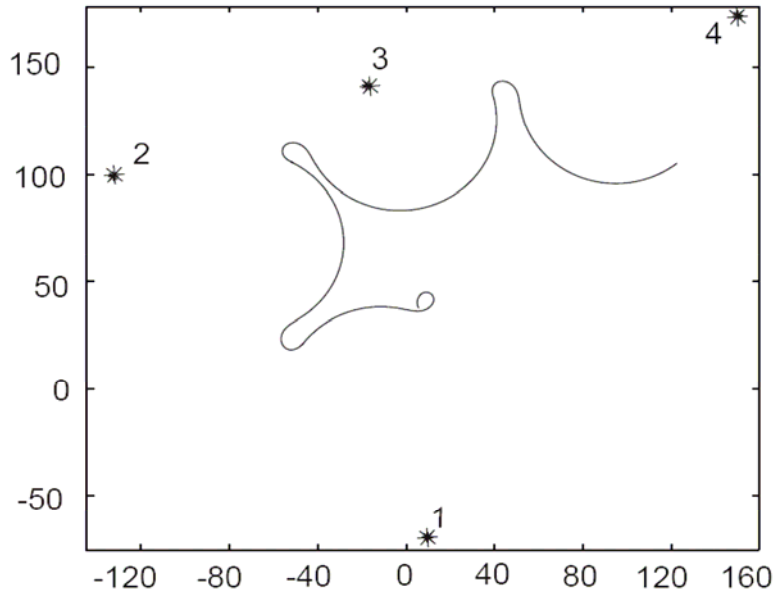
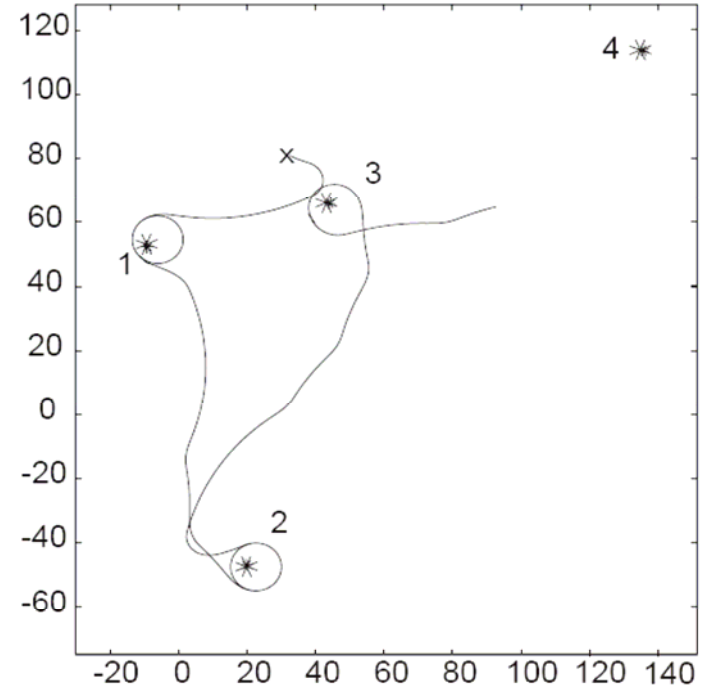
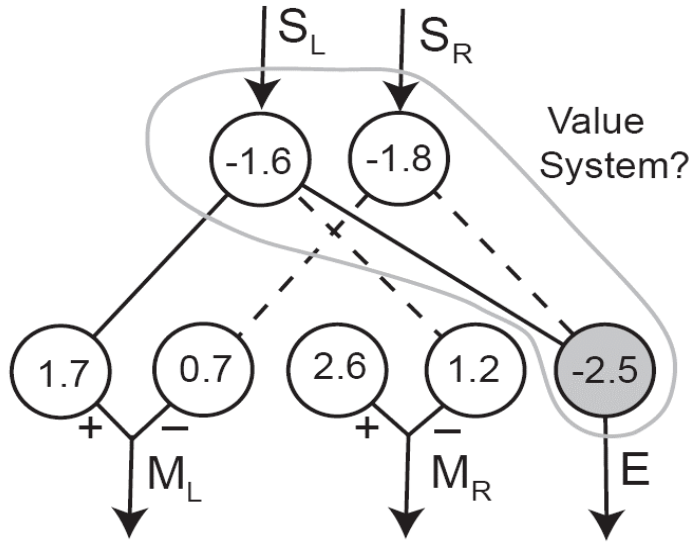
Changing values

- Inbuilt value modules have **a priori semantics**. They cannot modify themselves (only through some other similar module). How to account for values that change?
- Imagine a patient given a dangerous drug in increasing dosages. After some time, he will be taking doses that are fatal for the average human being. Moreover, his metabolism may now depend on the drug to keep going.
- The drug has altered its value from fatal to vital. But only because the organism as a whole has undergone the corresponding change. (Rohde)

A conceptual model

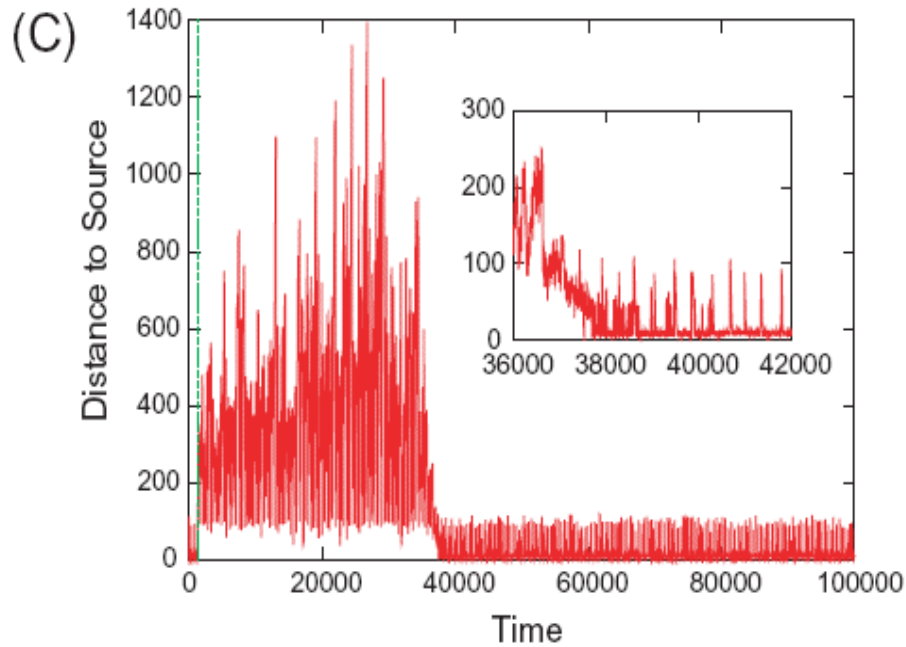
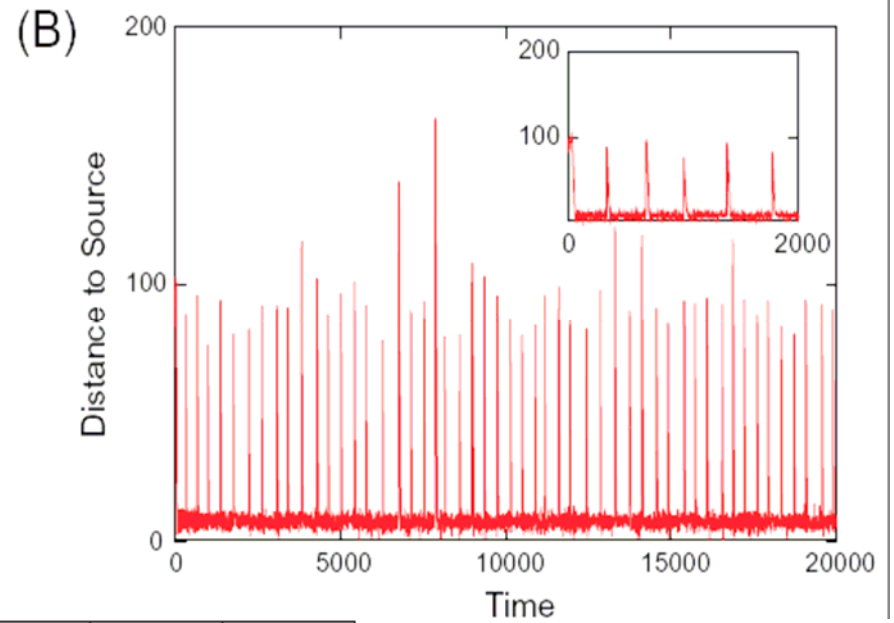
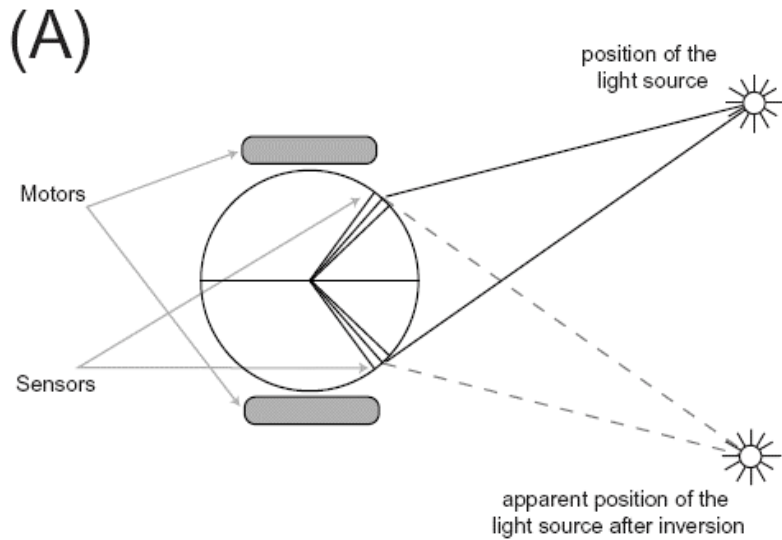
- Let's try to evolve a robot capable of value appraisal.
- Let's see whether the resulting value system behaves as expected.
- Let's try it in a minimal model of a phototactic robot controlled by a very simple neural network, (Rohde & Di Paolo, 2006).





More “enactively”

- Homeostatic adaptation. Creating a robot with “needs”.
- Neurons behave homeostatically, otherwise they change their connections to other neurons.
- After evolution, phototactic behaviour and internal homeostasis are “linked” so that the latter depends on the former.
- Test the robot under new situations involving body disruptions.
- Watch for value-generation at work...



nactive

enactive social cognition

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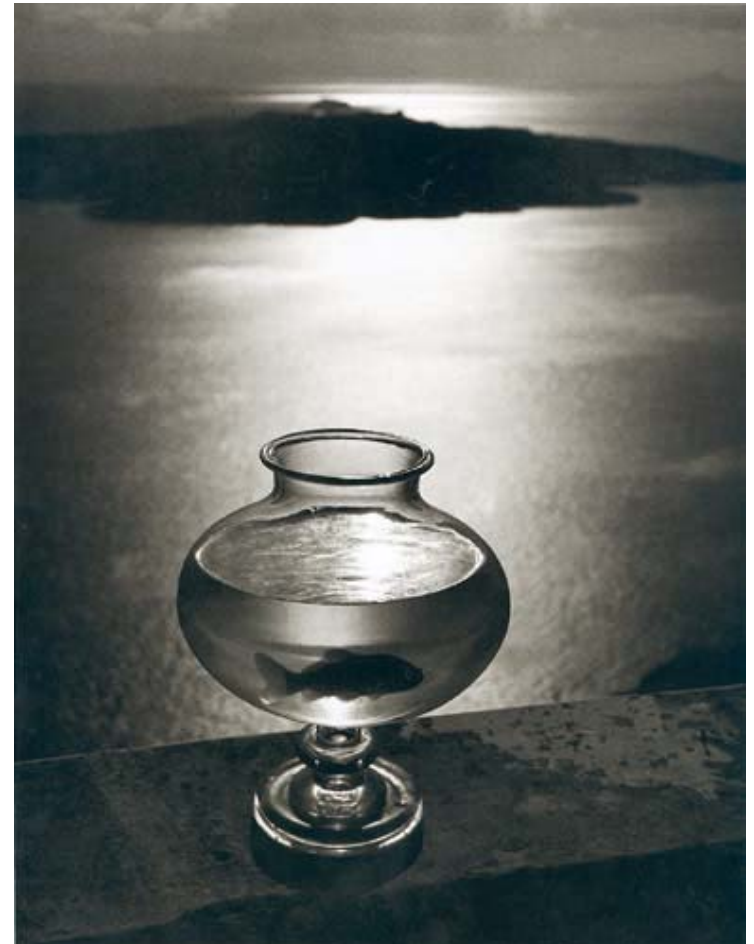
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A clear-cut separation

If we take cognizers to be separate from their surroundings, we take an **individualistic** approach to cognition.

Cognition is about how a cognizer gathers enough **information** so as to solve a problem and act accordingly.

Coupling with the environment, even when continuous, is seen as having conceptually **discrete** and **separate** phases of action and perception.



Individualism in social cognition

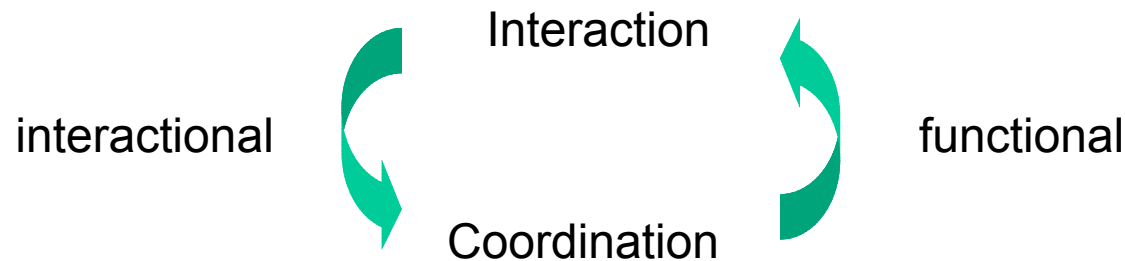
- Individualism is manifested as a stance that looks for **individual capabilities** for solving a particularly complex kind of problem. This view implies that everything that happens in an interaction must be within the realm of **individual competence**.
- Methodological individualism does not see the interaction as a process with its own properties corresponding to a level beyond individual competences.
- Even some embodied approaches pay little attention to interaction as a process (De Jaegher, 2006, De Jaegher, Wood, Di Paolo, 2006).

What makes it social?

- **Coupling** describes the mutual perturbation between a system and its environment.
- Social interaction occurs when coupling leads to **coordination**, i.e., coherence *beyond* that implied by the mode of coupling.
- Sustained coordination implies mutual **attunement** through a history of breakdowns. When interaction becomes self-sustaining, this is a sense-generating and value-transforming process of **co-adaptation**.
- Social performance is greater than the sum of individual competences.
- **Social acts engender social acts.**

Coordination and timing

- Fluid interaction is often marked by measurable degrees of synchrony or other kinds of temporal coordination, indicating some level of attunement between the participants.



- Psychologically, attunement leads to the feel of understanding, even if this understanding is later revealed to be incomplete (e.g., back-channelling)

Flexibility, closure

- Minor breakdowns in coordination (e.g., sudden changes of subject) may be flexibly managed by co-adapting to changing rhythms or changing circumstances during interaction.
- Flexible management of coordination implies the capability of co-adaptation at the whole-system level, which sometimes could mean an individual's capability to adapt but not necessarily.
- Meanings generated during interaction, agreeing on meanings,

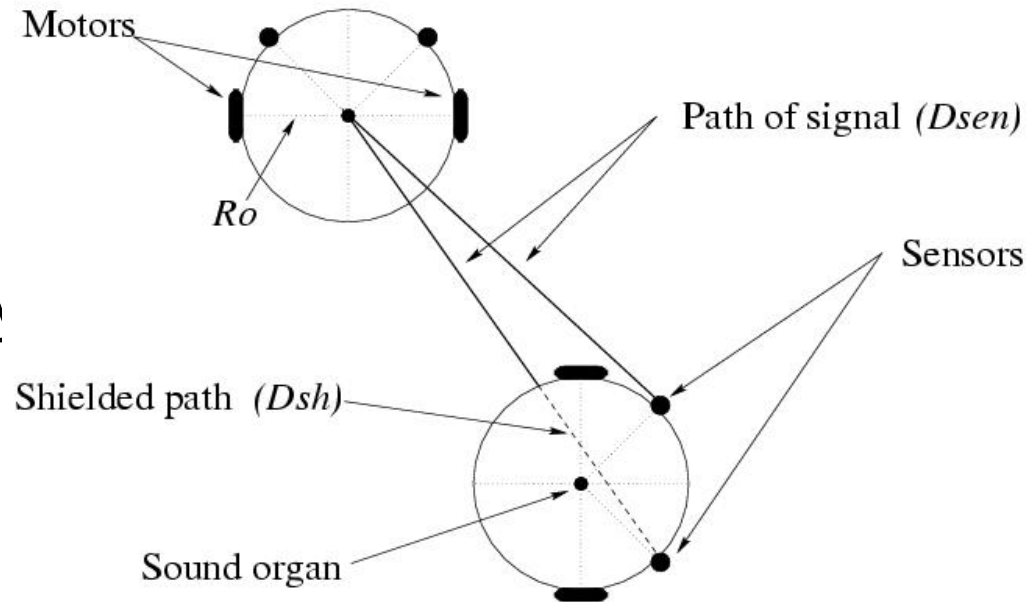
Plasticity, bonding

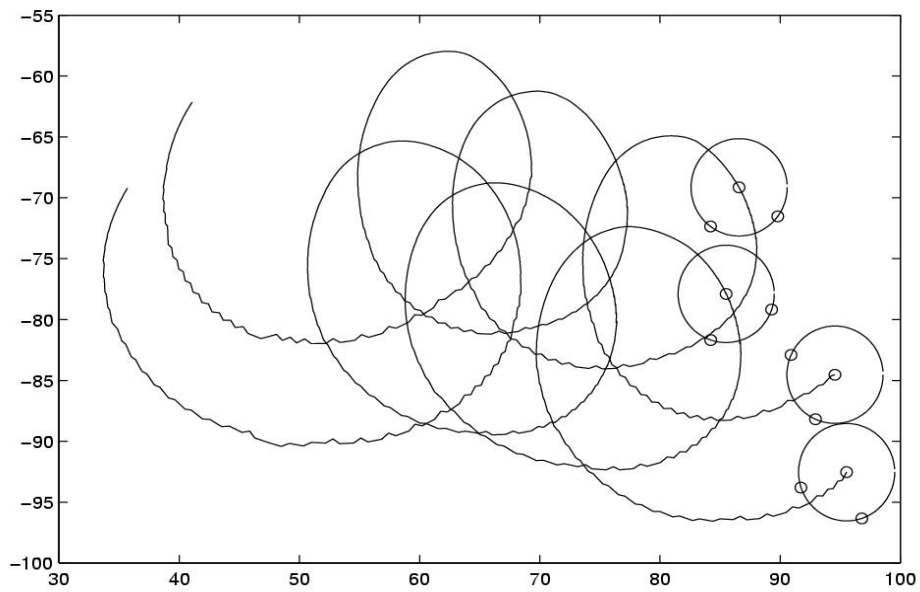
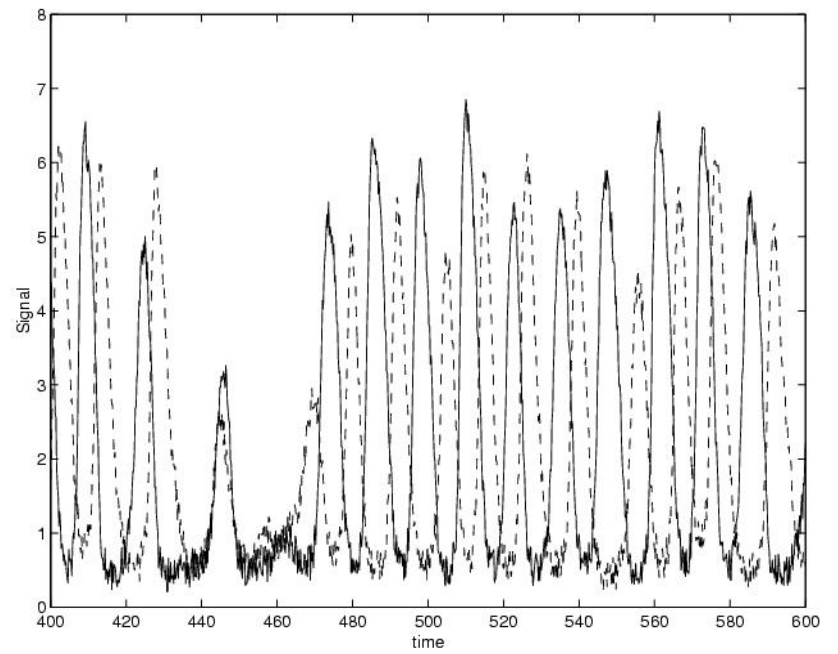
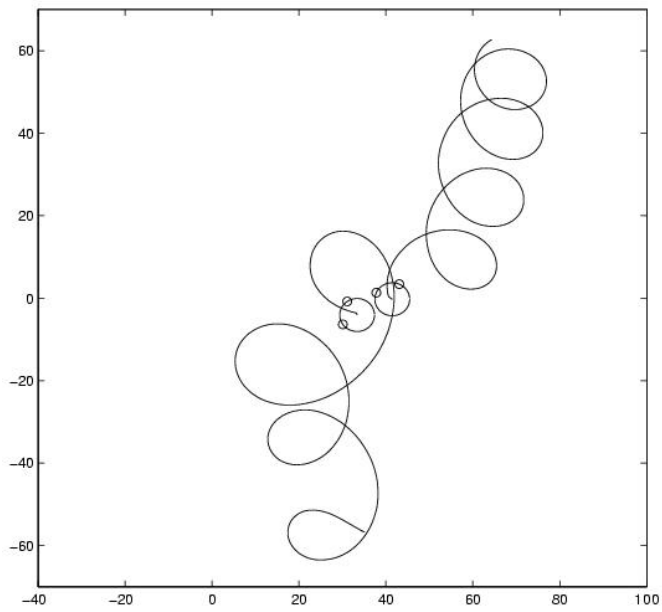
- History of breakdowns changes partners in a way that either facilitates further interaction or it doesn't. A sustained re-occurrence of interaction between the same partners implies a joint history of structural changes in them.
- Relationship/recognition
- Established shared meanings

A model example

- Evolution of acoustic coupling.
- Two blind neuro-controlled robots must find each other using sound.
- They're able to hear themselves and sound intensity is shadowed by their own bodies
- They must remain close to each other in a noisy environment

Di Paolo E. (2000) *Adaptive Behavior*.

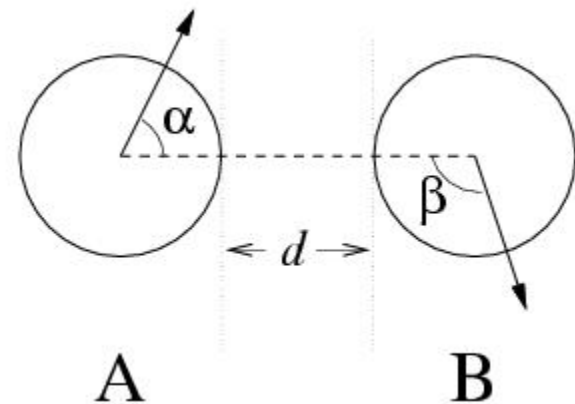
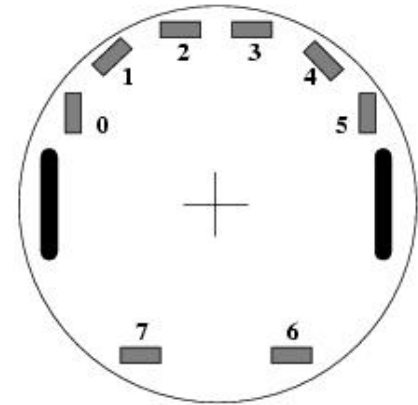


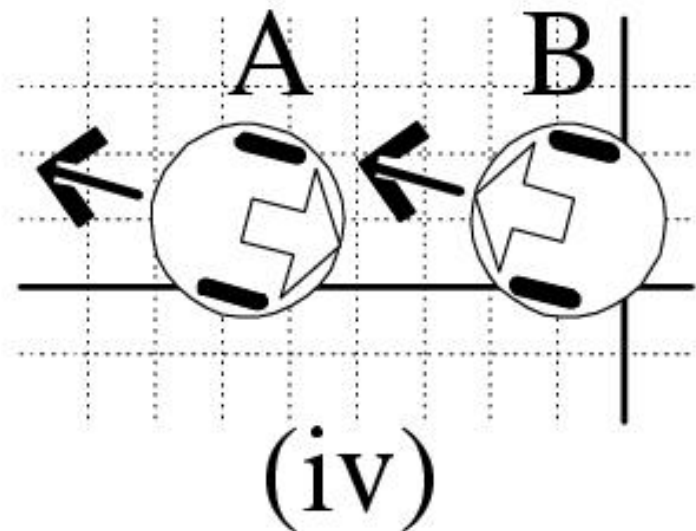
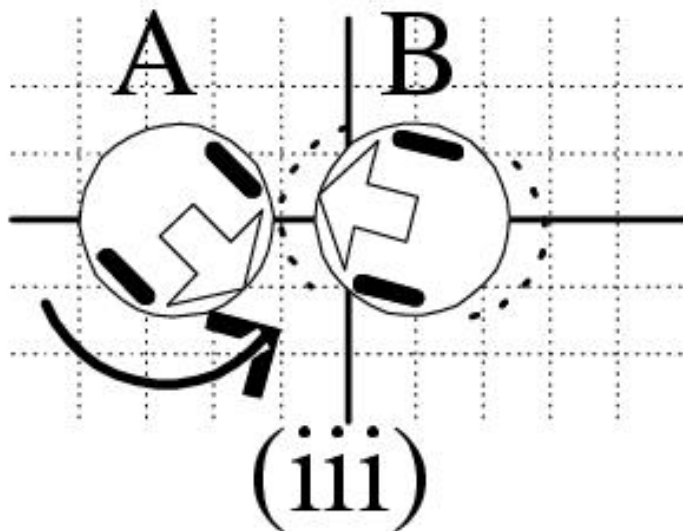
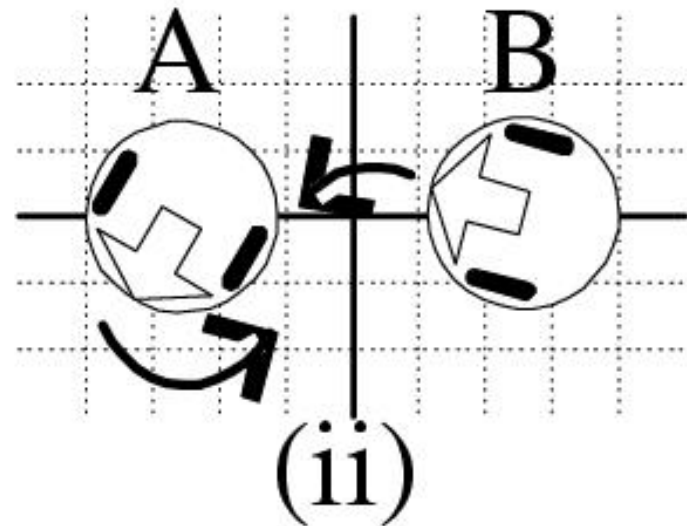
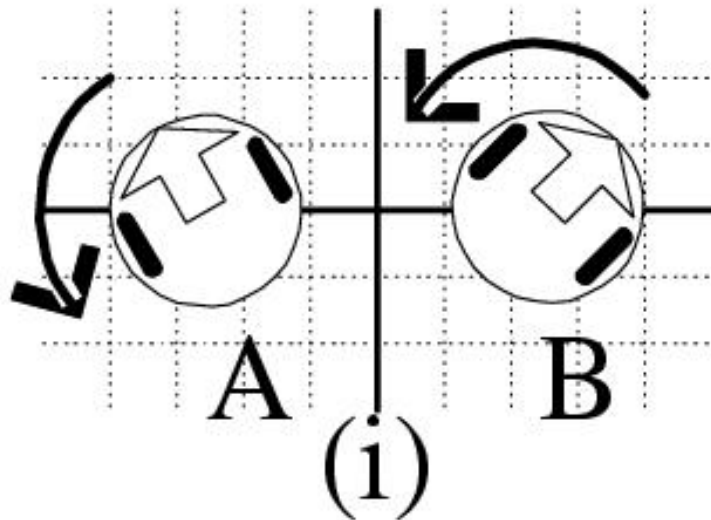


Role allocation and signalling

- Two identical robots using only proximity sensors must coordinate their actions in a role-allocation task.
- Robots start with one of many possible relative orientations.
- They must move **together** in any direction maximizing the distance to the original position.

Matt Quinn (2001).

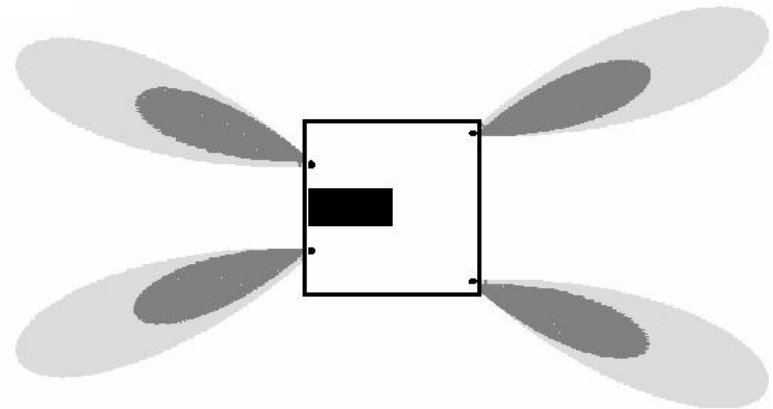
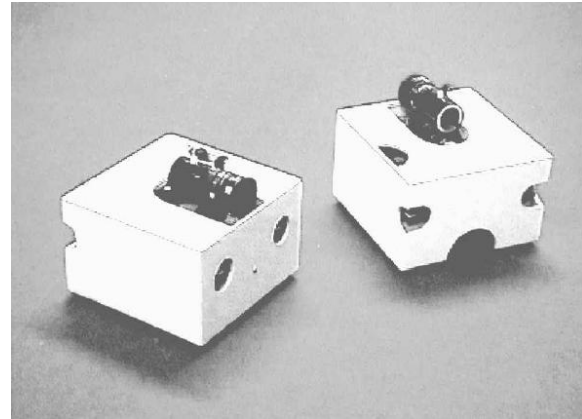




Robot team coordination

- Homogeneous teams of 3 robots interacting via infrared sensors.
- Evolve coordination and role allocation in simulation. Test in real-world.

Matt Quinn et al. 2002/2003



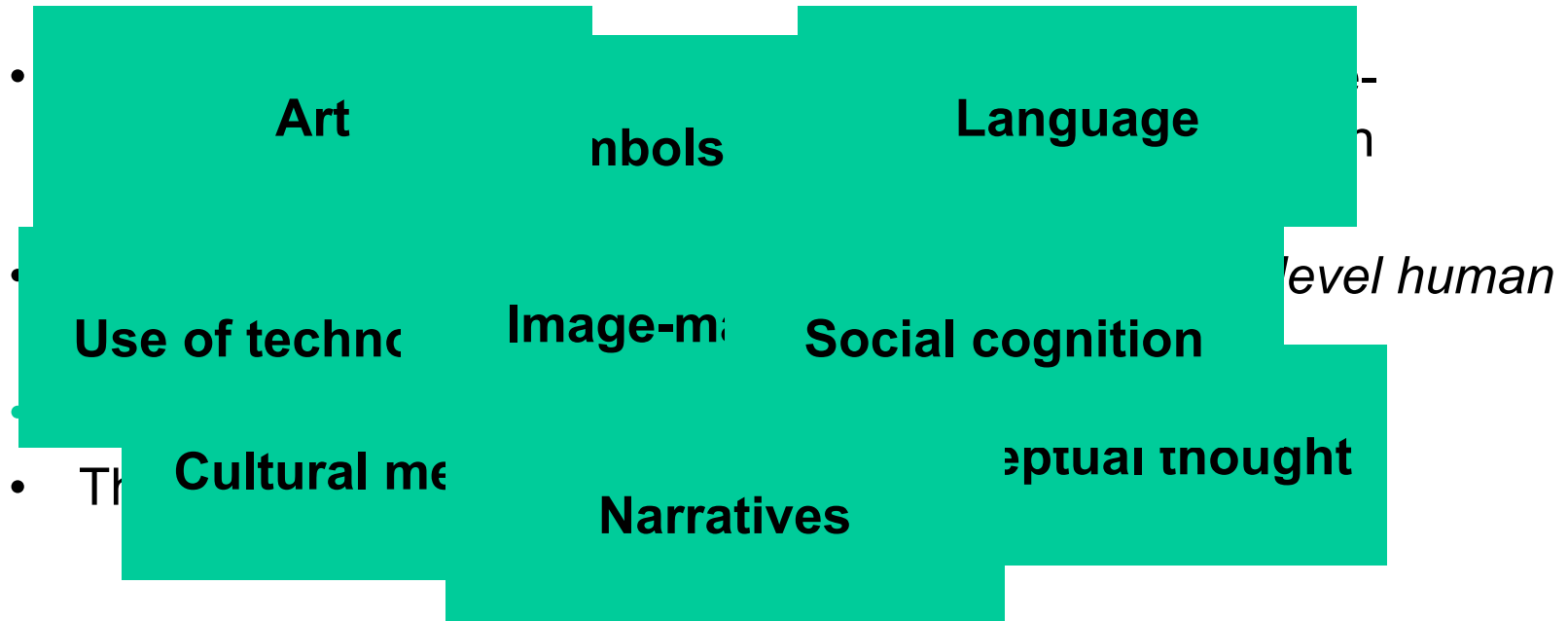
Enacting social meaning

- **Intersubjectivity:** we must move beyond the picture of detached observation of the behaviour of the other towards an interactive situation.
- The rhythm and rhythm capacity of an interaction is the substrate for coordinated activity leading to social understanding (De Jaegher, 2006).
- Behaviour is expressive and we actively make sense of others. But coordination brings a new form of sense-making: **joint construction of meaning** through mutual orientation of individual sense-making.

play

play

What is human cognition?



The “essence” approach ...

What are we after?

- **Active management and transformation of meaning**
- The capacity to “unstick” meanings from situations, “stick” novel ones and generally manipulate values.
- Management of images to guide action.
- Eventually leading to projects, myths and narratives.
- Confusingly described as “decoupling”, “disengagement”, “offline intelligence”.
- Better descriptions: “de-centering”, “sense-creation”, “active worldmaking”.

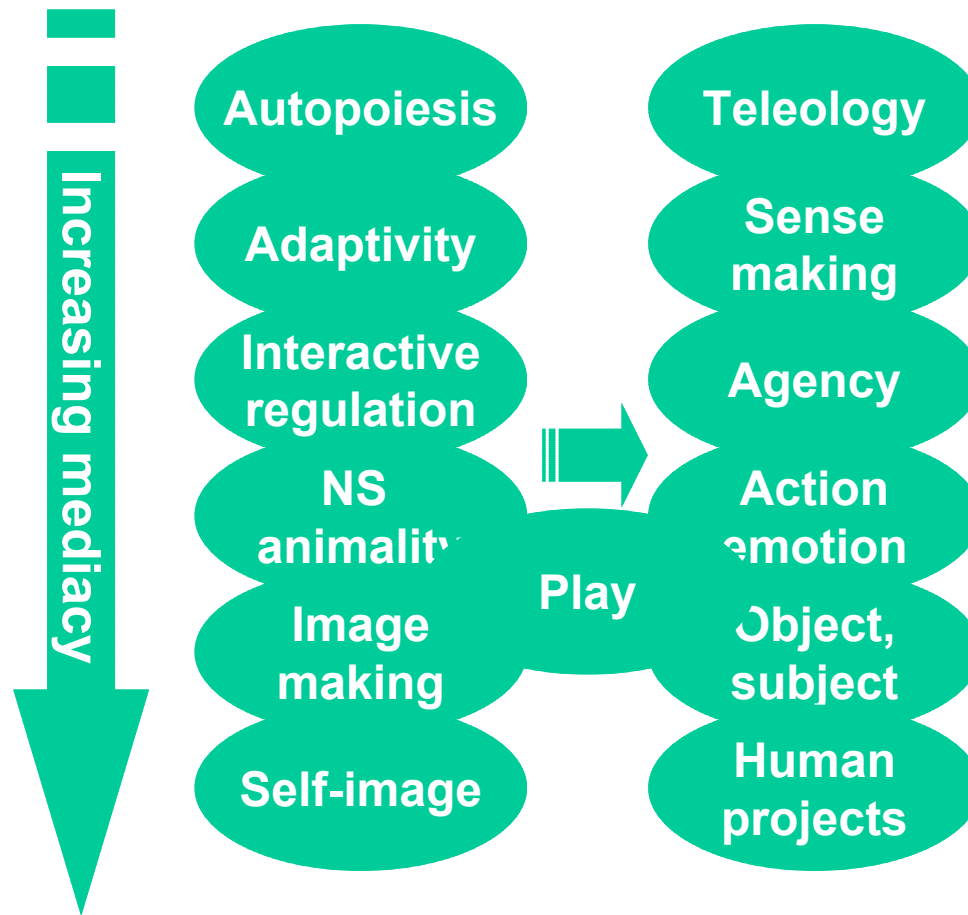
Margaret Donaldson

- Different modes of being a human mind.
- **Point mode:** dealing with the here and now (most animal activity, engaged coping in humans, all of autonomous robotics)
- **Line mode:** dealing with the “there and then”. Events in the past or in the future, maybe not here but somewhere else.
- **Construct mode:** dealing with somewhere-sometime, anywhere-anytime. (generalization, some maths).
- **Transcendent mode:** dealing with nowhere (abstract thought, maths, metaphysics, ethics).

A (big) challenge to enactivism

- For representational thinking, this is not a major problem. Manipulation of representations to deal with the here-and-now isn't fundamentally different from manipulation of representation to deal with the there-and-then, or with non-temporal, non-spatial concepts (in fact it's harder!).
- Cognitivism is based on non-temporal, non-spatial, unsituated mechanisms!! So, no surprises there.
- But, the enactive approach emphasizes situatedness. In doing so, cognition appears as “glued” to the here-and-now.

Play as “transitional” activity



The transition

- How to explain this transition manifested in image-making? What guides it? Very likely, lots of factors.
- But importantly, it must involve some embodied activity allowing for **ambiguity of meaning** as well as generation of some **novel kind of value**.
- Worst candidates are concrete goal-directed activities. Meaning is well-defined by the situational constraints.
- Best candidates are purpose-generating activities (dance, **play**, collective rituals). Meaning is fluid, made on-the-fly. Such activities generate meaning by themselves, hence providing the first detachments of meaning from the here-and-now. **They extend freedom (and create new needs)**.

Bodily play



Kinetic play



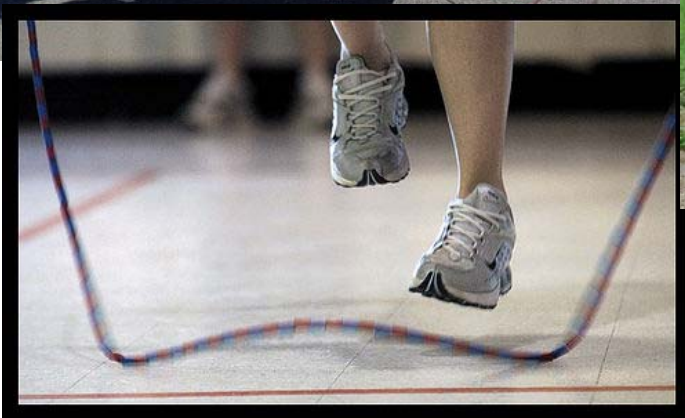
Maxine Sheets-Johnstone

- Understanding bodily play (rough and tumble, locomotor activity, etc.) cannot be fully achieved without an experiential approach.
- Adaptive explanations are useful but limited. You miss an important aspect of bodily play if you don't understand why animals are interested in it.
- Movement generates kinesthetic feeling. The individual explores the dimension of the *I-can* and *I-can-not*.
- The beginnings of **make-believe** situations are already in place. Signals are used to distinguish fake from real aggression. Big individuals flee from smaller ones.

Object play



“Galumphing”



Pretend-play



Mastering make-believe

- Pretend there is a monster coming, ok?
- No, let's don't pretend that.
- Okay, why?
- Cause it's too scary, that's why.

I. Bretherton, 1989

- Stephen, are you a little boy or a little girl?
- I'm a little doggie.
- Come on now, Stephen. Be sensible! Are you a little boy or a little girl?
- Gr-rrr! Woof!!

M. Donaldson, 1992

Of course...

- The picture is one of continuity. There is an element of pretence in animal play-fighting, but not to the extent that it becomes an issue for the animals themselves. (And not all animals play; think tics). You need protected free time! Thus mostly juveniles play.
- Encultured chimpanzees (e.g., Kanzi) are very sophisticated at pretending (e.g., imaginary food, absent characters made present, intentional deception).
- Their use of symbolic communication also gives us a clue to the importance of language as a tool for de-centering and sense creation.

Piaget, Donaldson

- The beginnings of play for Piaget are rooted in the assimilative function. The pillow is copied with using some existing behavioural schemas. As soon as another object (a blanket) is assimilated into the same structures, it becomes a make-believe pillow. The child laughs in the pleasure of the assimilative function.
- Donaldson: If true assimilation is happening, blanket = pillow for the child. No reason to laugh unless there is a simultaneous awareness of the difference between the two objects. Make-believe relies crucially on the *combined similarity and difference* between two situations, one concrete, tied to physical events, the other in terms of meaning being manipulated (possibly consciously) by the child.

Vygotsky

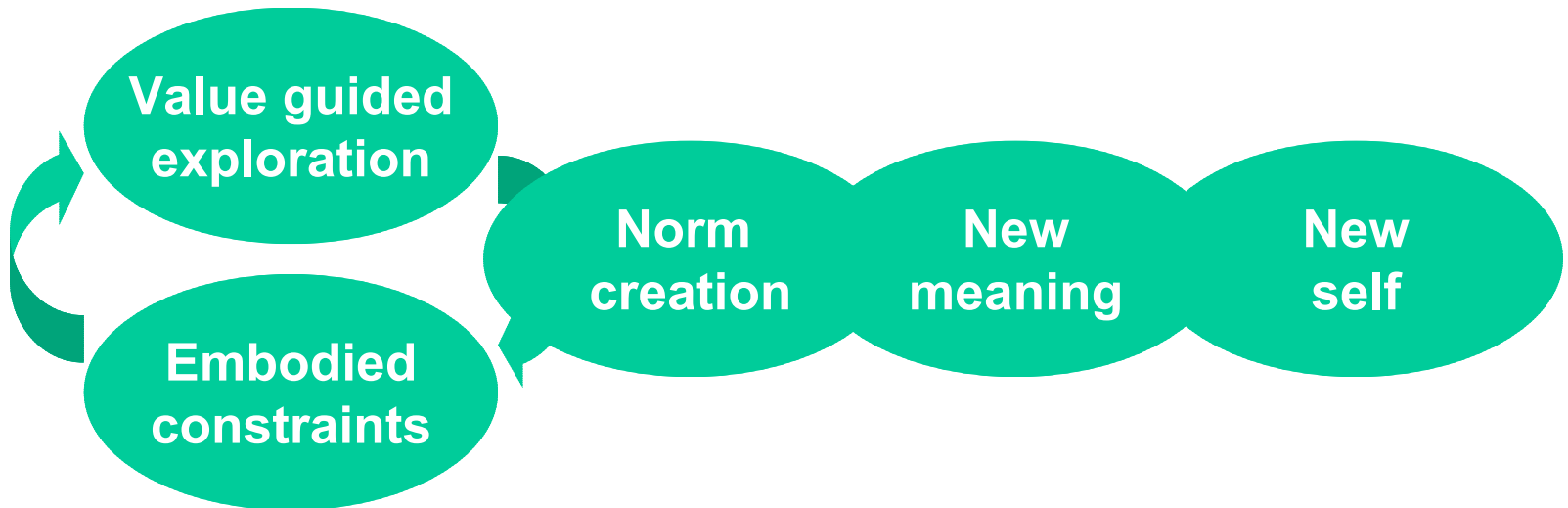
- Play should not be intellectualized. Play begins with the incapacity of satisfying some needs immediately. It becomes a substitution for real satisfaction (not far from Winnicott's transitional objects).
- As in most animals, perception, action and emotion in the child are strongly interlinked and correlate to the current situational constraints.
- In play, the child begins to detach meaning from a situation and to manipulate such meanings. First meaning is detached from objects, later from her own actions.

Vygotsky

- Meaning detachment relies on concrete similarities and on **gestural schemata** applied by the child herself. If something is treated as a horse, if you make it move as a horse, then it allows you accept it as a horse (without forgetting it isn't). This is the ambiguity that can produce laughter, a new kind of freedom, a sort of cheating of reality.
- **The first paradox of play:** the combination of a concrete embodied situation with alienated embodied meaning.
- **The second paradox of play:** The child explores the new freedom by following activities that produce pleasure, but at the same time she learns to generate new rules, new constraints on reality that must be followed strictly (otherwise play becomes random and is boring). A dialectical expansion of freedom and needs.

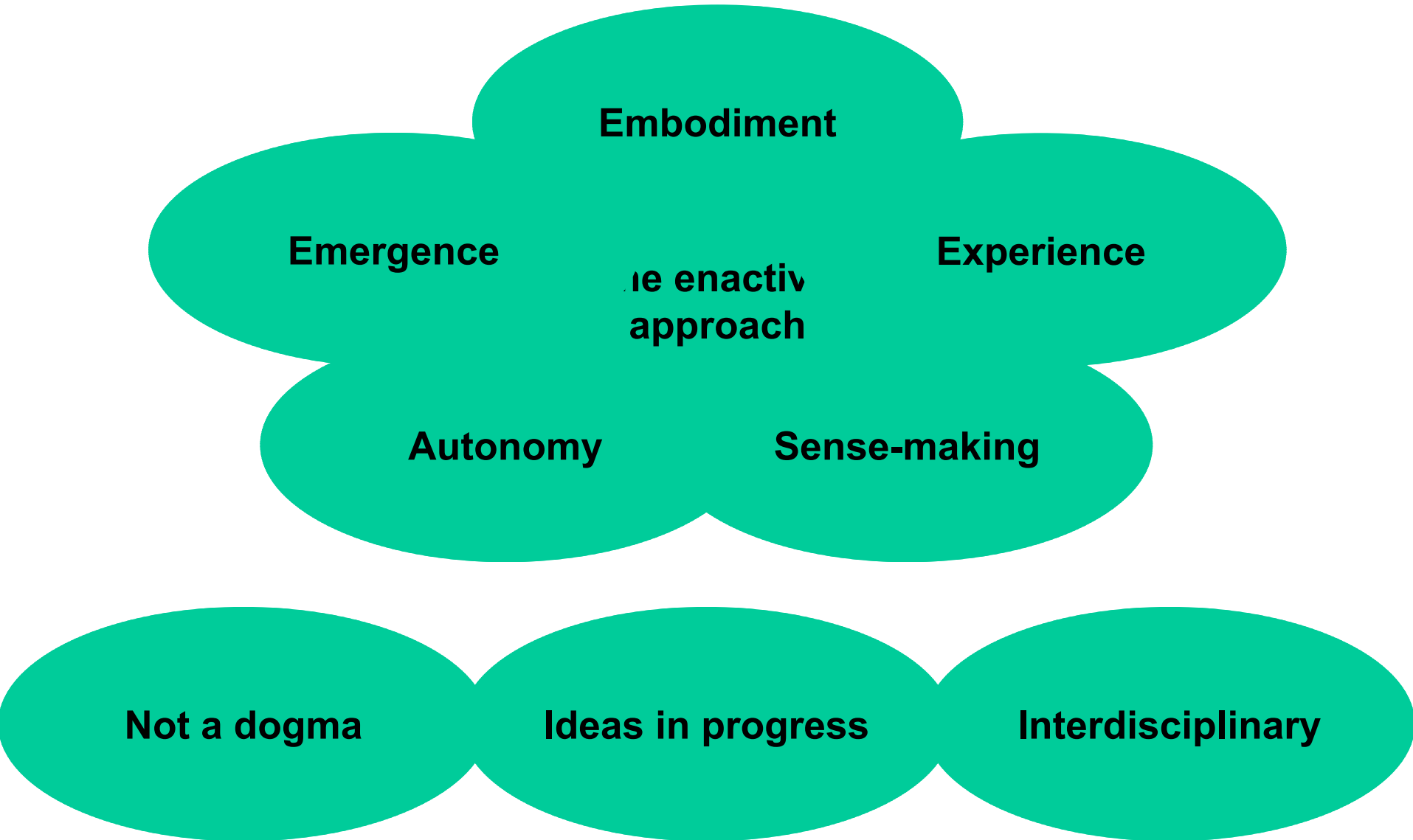
Play as a form of life

- An enactive view on the expansion of cognitive autonomy. The emergence of the socio-linguistic self.
- A precarious, self-sustaining creation of norms and activities that follow and alter those norms.
- Being able to do this is nothing less than the beginning of higher-level cognition.



conclusion

conclusion



Embodiment

Emergence

Experience

**the enactiv
approach**

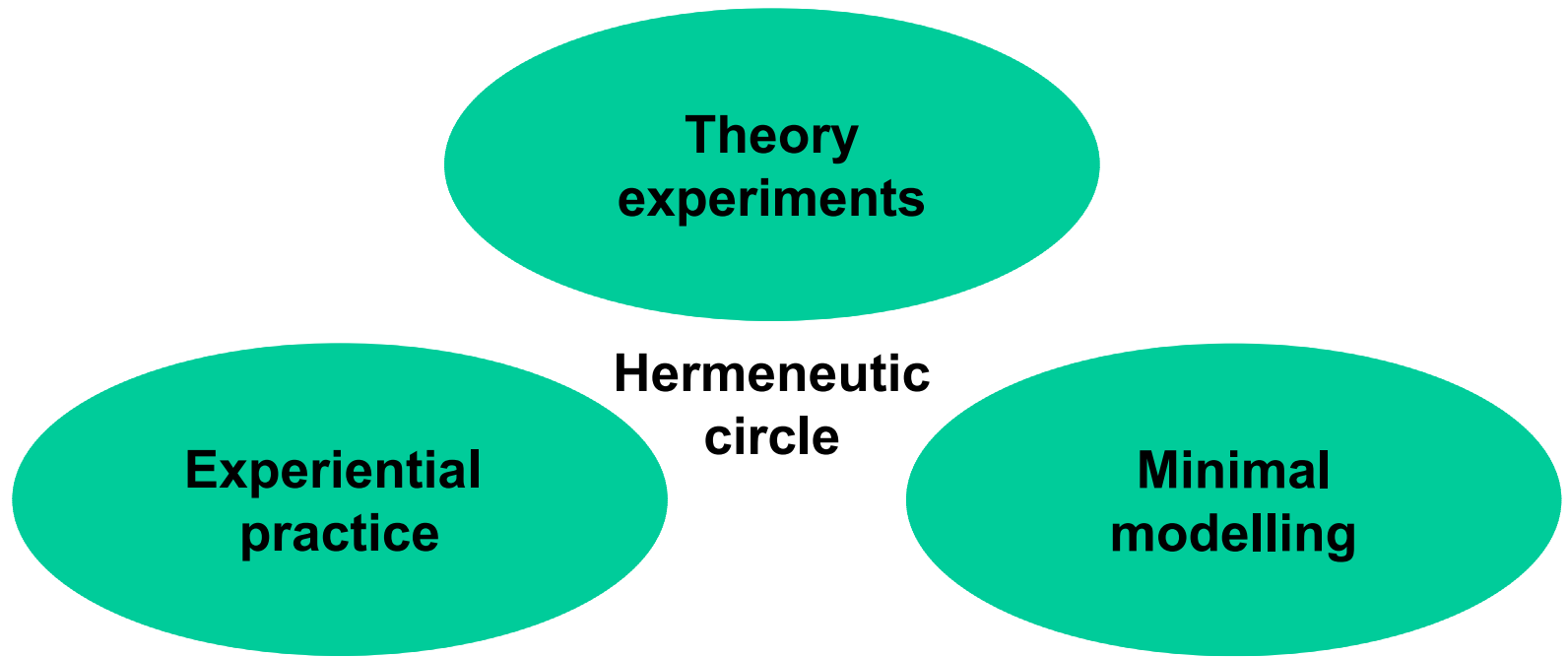
Autonomy

Sense-making

Not a dogma

Ideas in progress

Interdisciplinary



Value

Social understanding

Play



Not in a box

**Interaction
rhythms**

Re-creation

ank

thank you

you