Artificial Cognitive Systems

Module 5: Embodiment

Lecture 1: Cognitivist and emergent perspective on embodiment; three hypotheses on embodiment; evidence for the embodied stance.

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What role does a body play in cognition?

(Not everyone thinks it does play a role)

If it does, we refer to embodied cognition

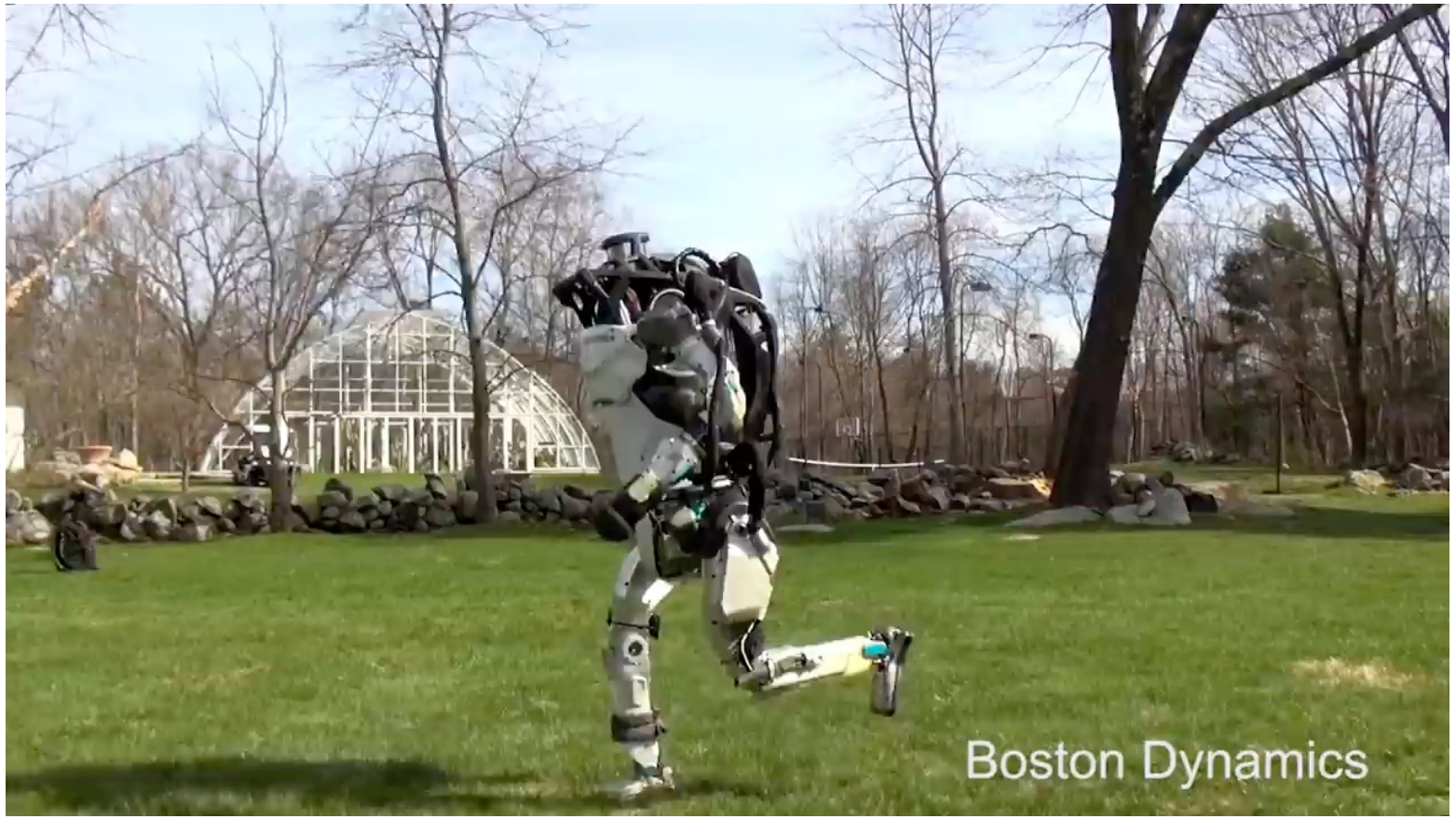
Consider this ...

Walking

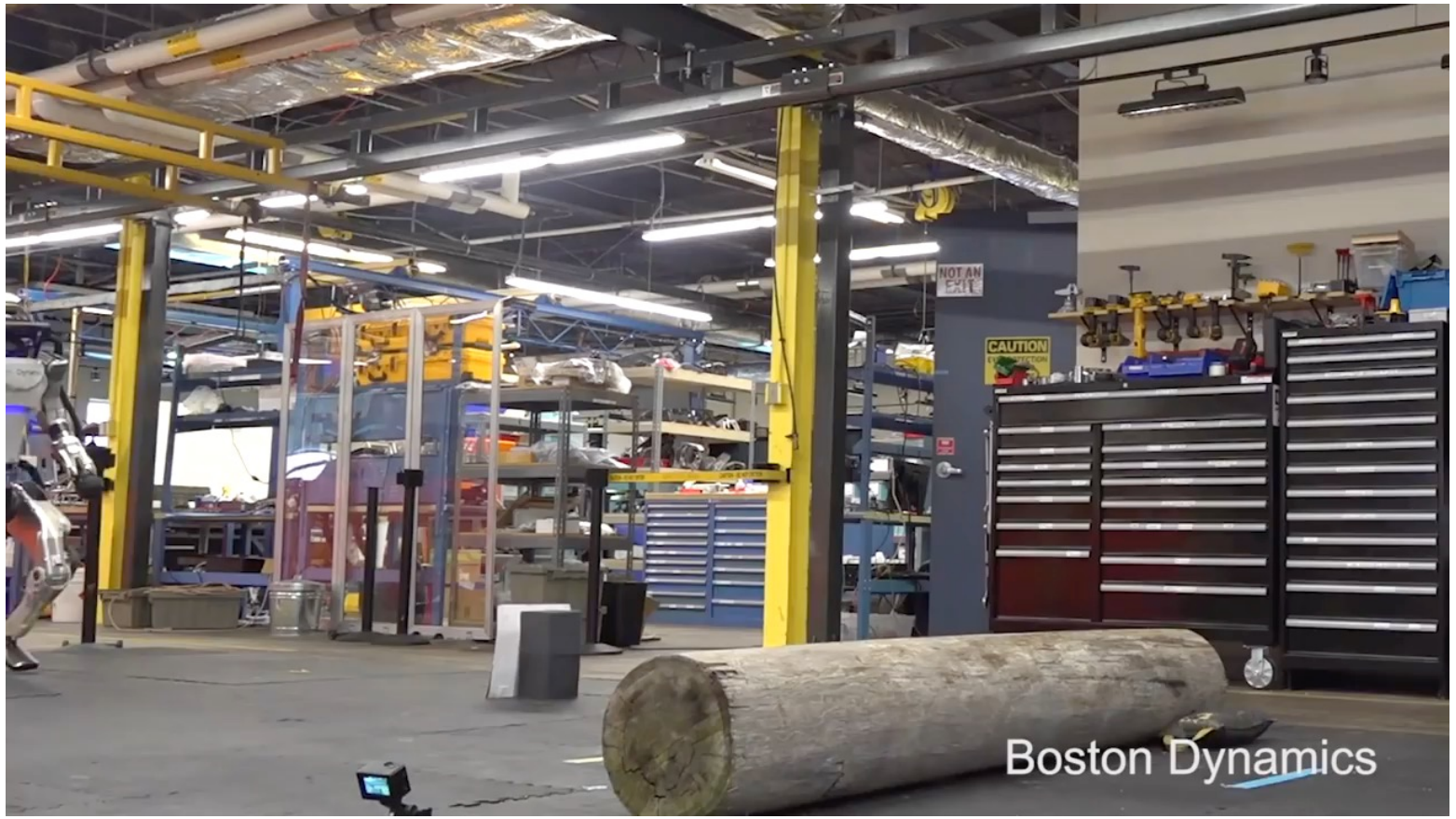
(New) Asimo

Passive Dynamic Walker (Ruina)

Consider this ...

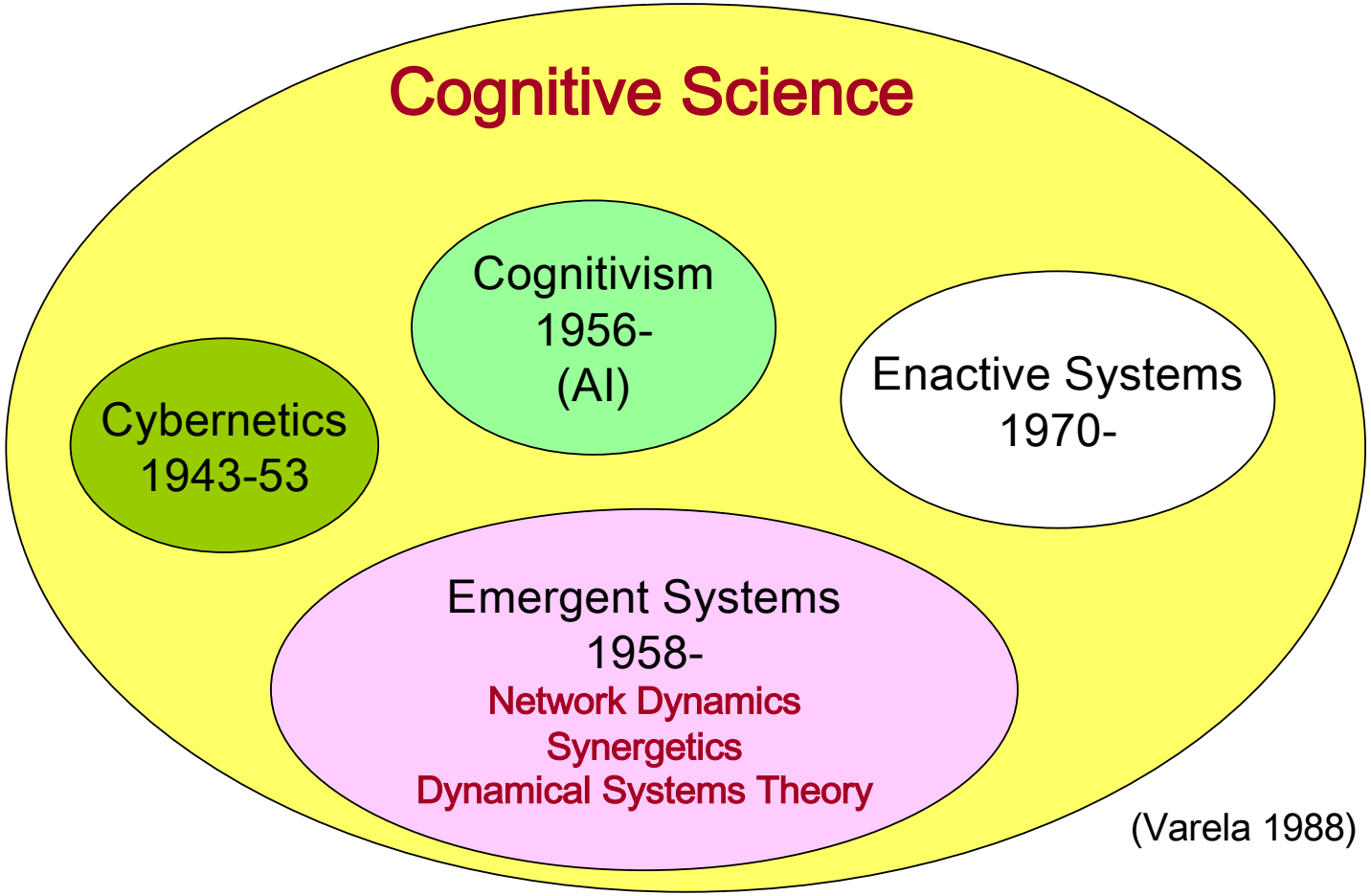


Consider this …

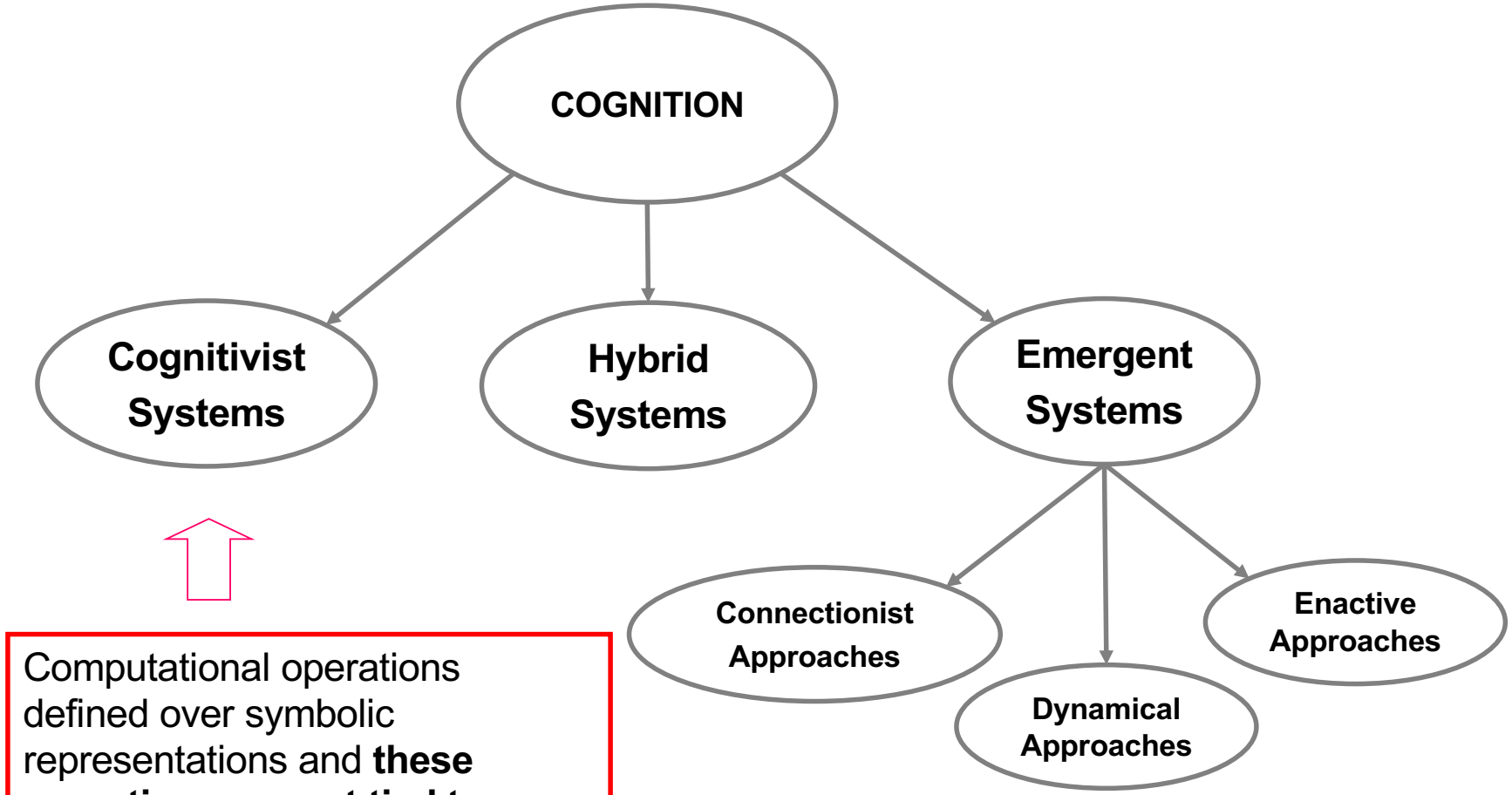


https://robots.ieee.org/robots/atlas2016/

Cognitivist and Emergent Perspectives on Embodiment


Cognitive Science
Cognitivism
1956-
(AI)
Cybernetics
1943-53
Enactive Systems
1970-
Emergent Systems
1958-
Network Dynamics
Synergetics
Dynamical Systems Theory

(Varela 1988)



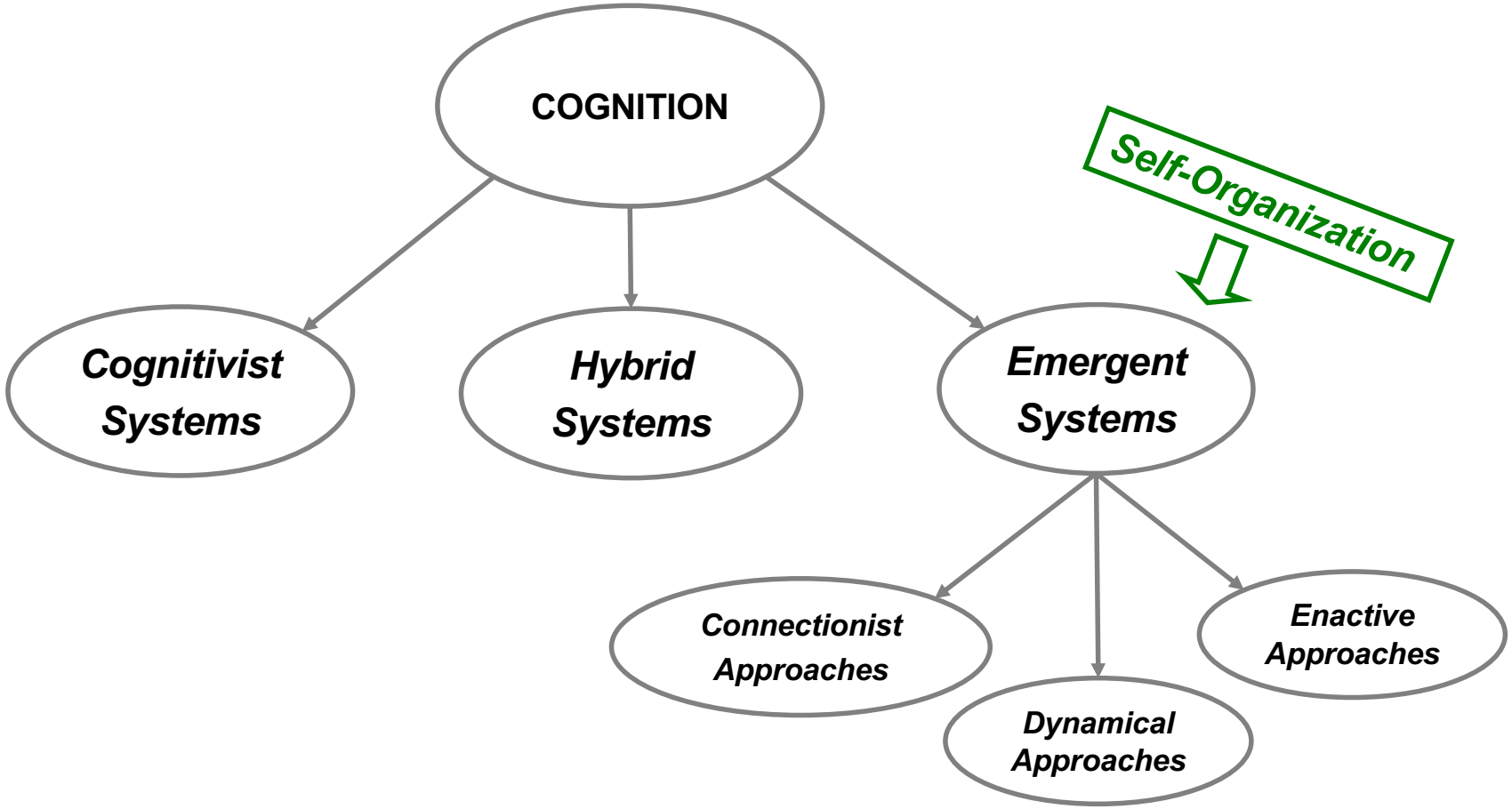
Computational operations defined over symbolic representations and **these operations are not tied to any given instantiation**

[Vernon, Metta, Sandini 2007]

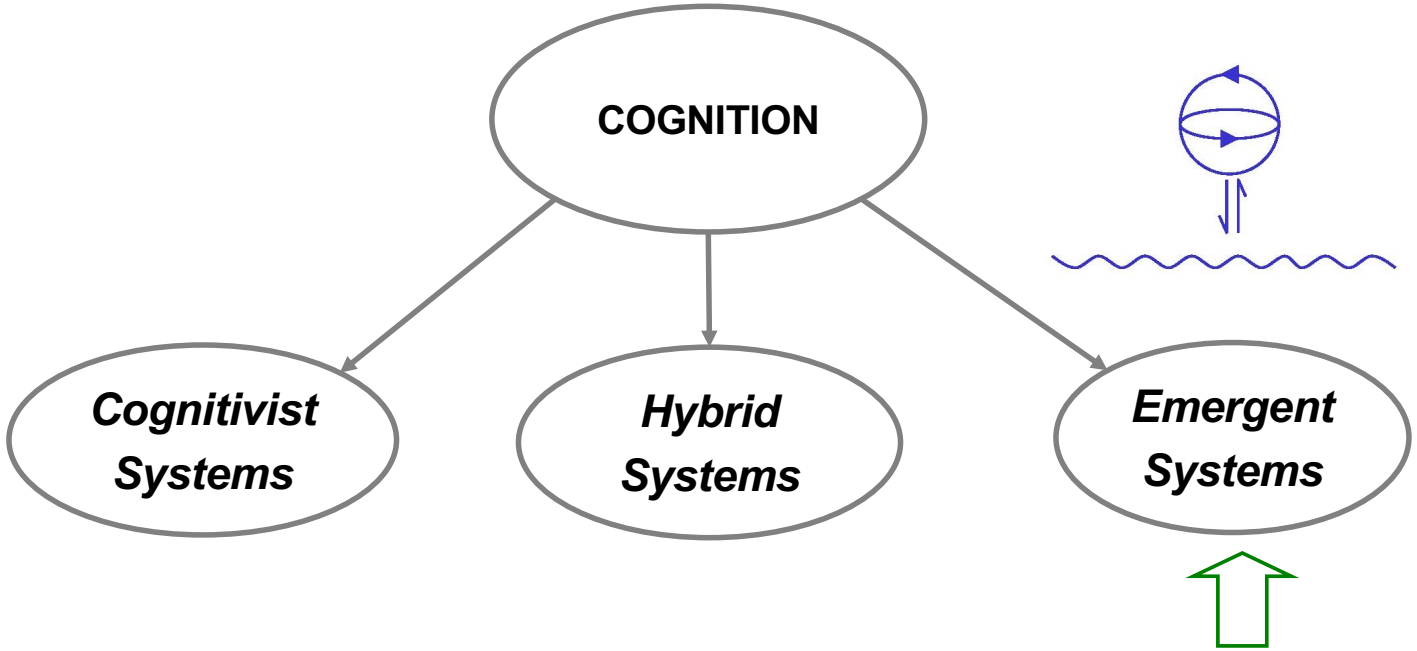
Physical symbol system hypothesis – **computational functionalism**

Symbolic knowledge can be programmed in directly

There is no need for embodiment
(Embodiment may be useful, but it's not necessary)

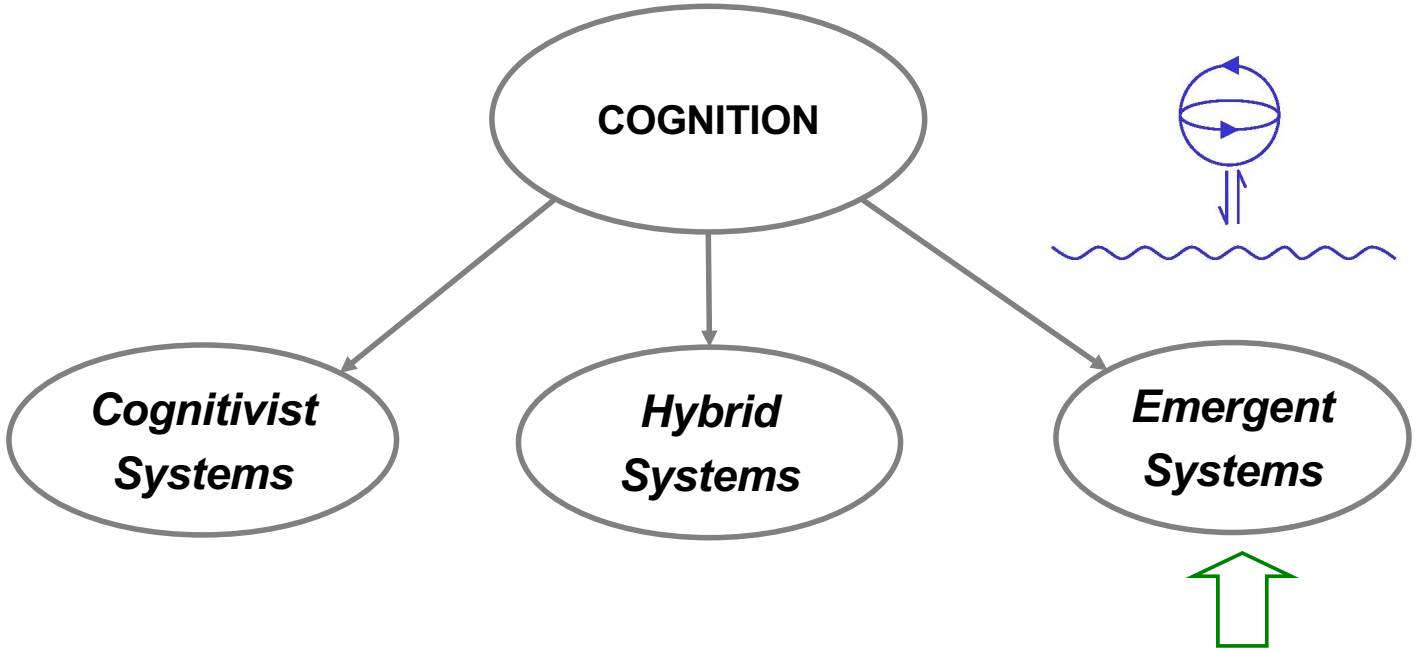


[Vernon, Metta, Sandini 2007]

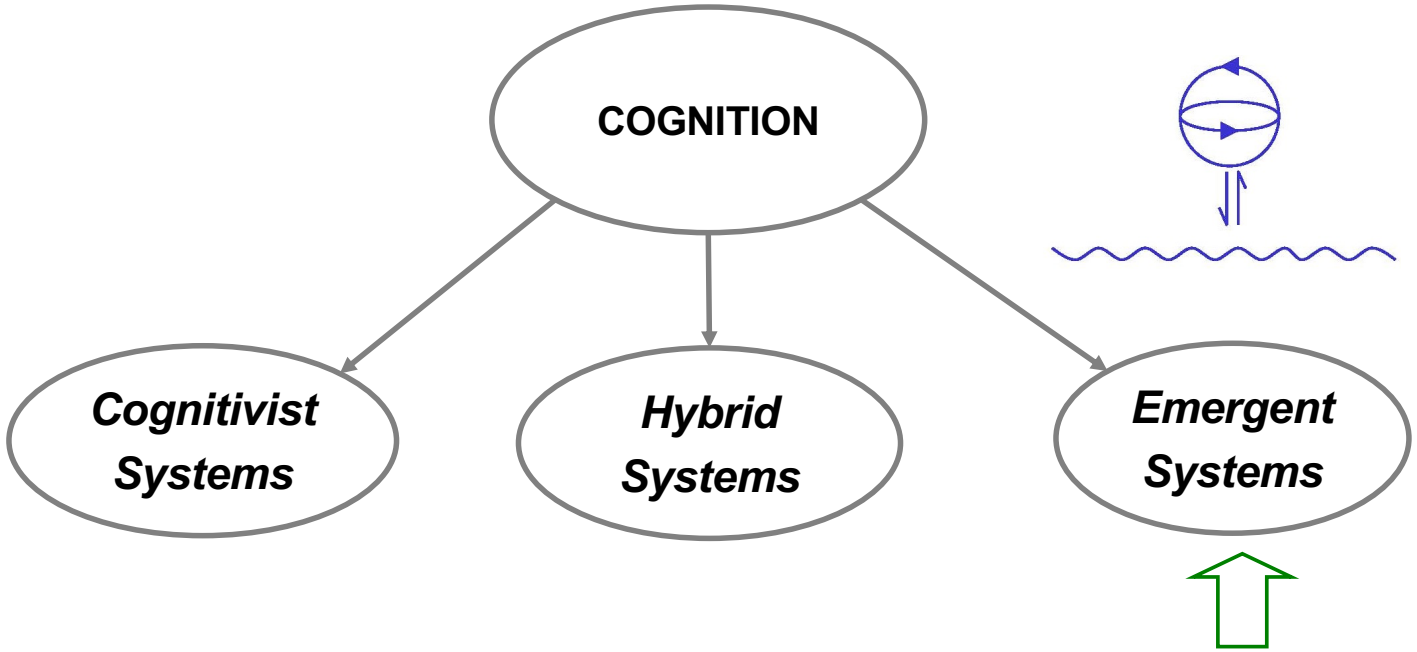


Developing through real-time interaction with the environment
Self-organization
Structural coupling with the environment

Must be embodied



Cognition is **inseparable from bodily action** because, without physical embodied action, a cognitive system cannot develop



Through development, the cognitive system constructs and develops its own understanding of the world in which it is embedded, i.e. its own agent-specific and body- specific knowledge of its world

Embodied Cognition Thesis

The cognitive agent **exists in some ecological niche** and the brain-body system has **evolved to take advantage** of the **particularities** of its environment

Embodied Cognition Thesis

"Many features of cognition are embodied in that they are deeply dependent upon characteristics of the physical body of an agent, such that **the agent's beyond-the-brain body plays a significant causal role**, or physically constitutive role, in that agent's cognitive processing."

R. A. Wilson and L. Foglia. Embodied cognition. In E. N. Zalta, editor, The Stanford Encyclopedia of Philosophy. 2011.

Embodied Cognition Thesis

Embodiment:

1. Physiology
2. Evolutionary history
3. Practical activity
4. Its socio-cultural situation

Rough/smooth depends on tactile sensors

Steep hill depends on physiology & training

Agents with different type of bodies understand the world differently

Embodied Cognition Thesis

Embodiment:

1. Physiology
2. Evolutionary history
3. Practical activity
4. Its socio-cultural situation

Often we recruit older (in evolutionary terms) cognitive capabilities in new ways

Made possible by carrying these mechanisms forward from generation to generation is the agent's embodiment, encoded in its genes

Embodied Cognition Thesis

Embodiment:

1. Physiology
2. Evolutionary history
3. Practical activity
4. Its socio-cultural situation

Solving problems very often relies on physical trial and error

Dependent on your physical capabilities

You develop an understanding of the environment in terms of your embodied action capabilities

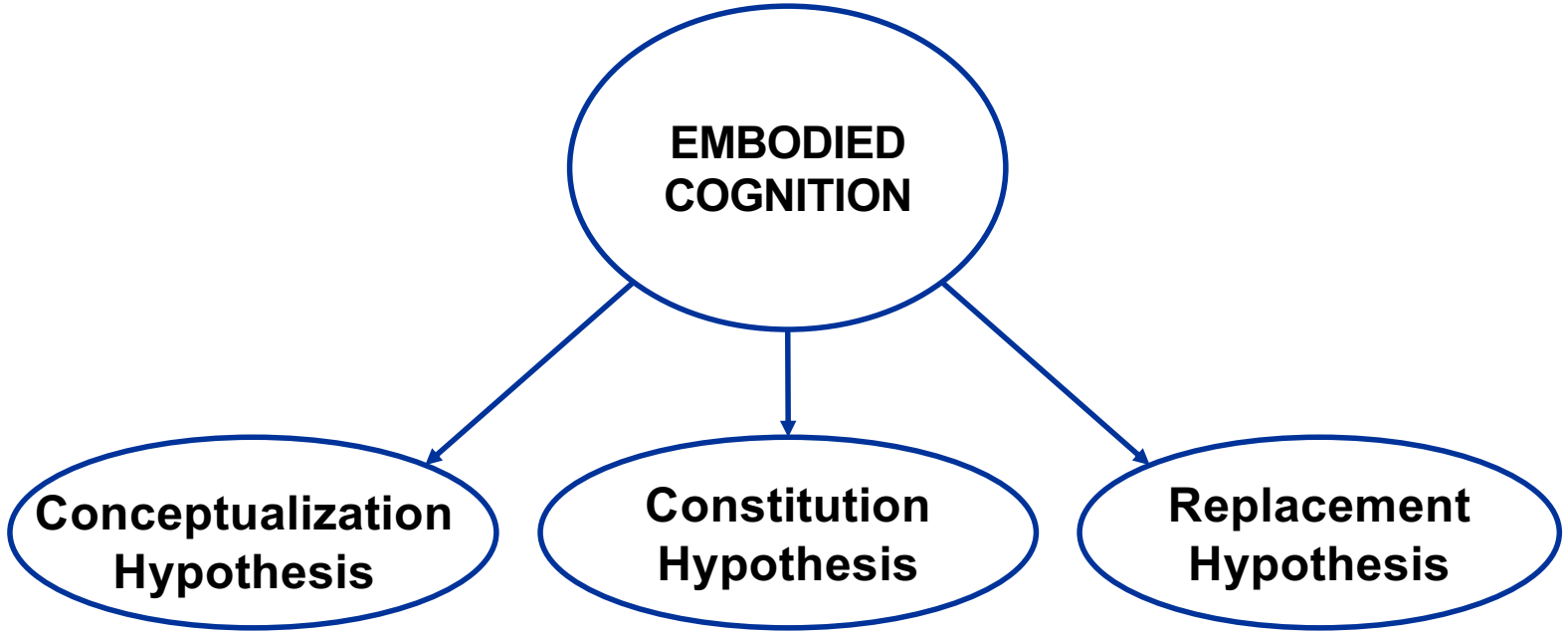
Embodied Cognition Thesis

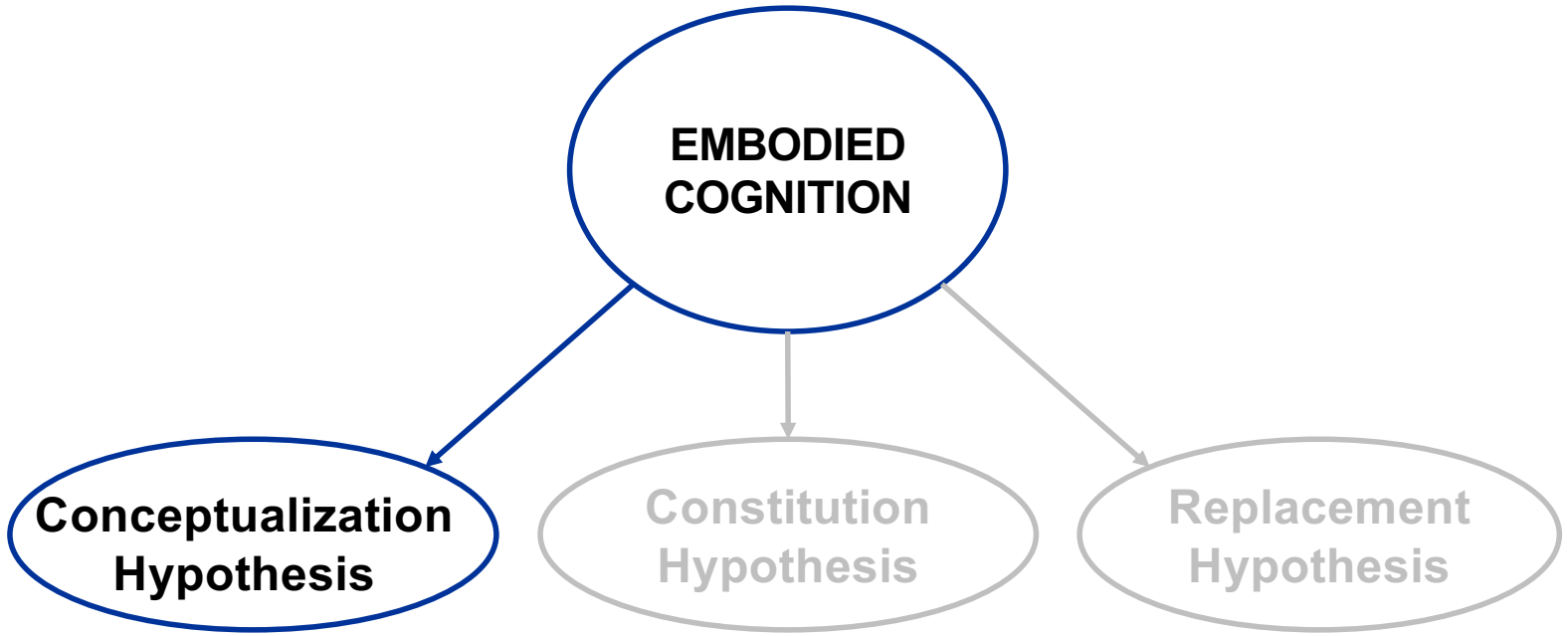
Embodiment:

1. Physiology
2. Evolutionary history
3. Practical activity
4. Its socio-cultural situation

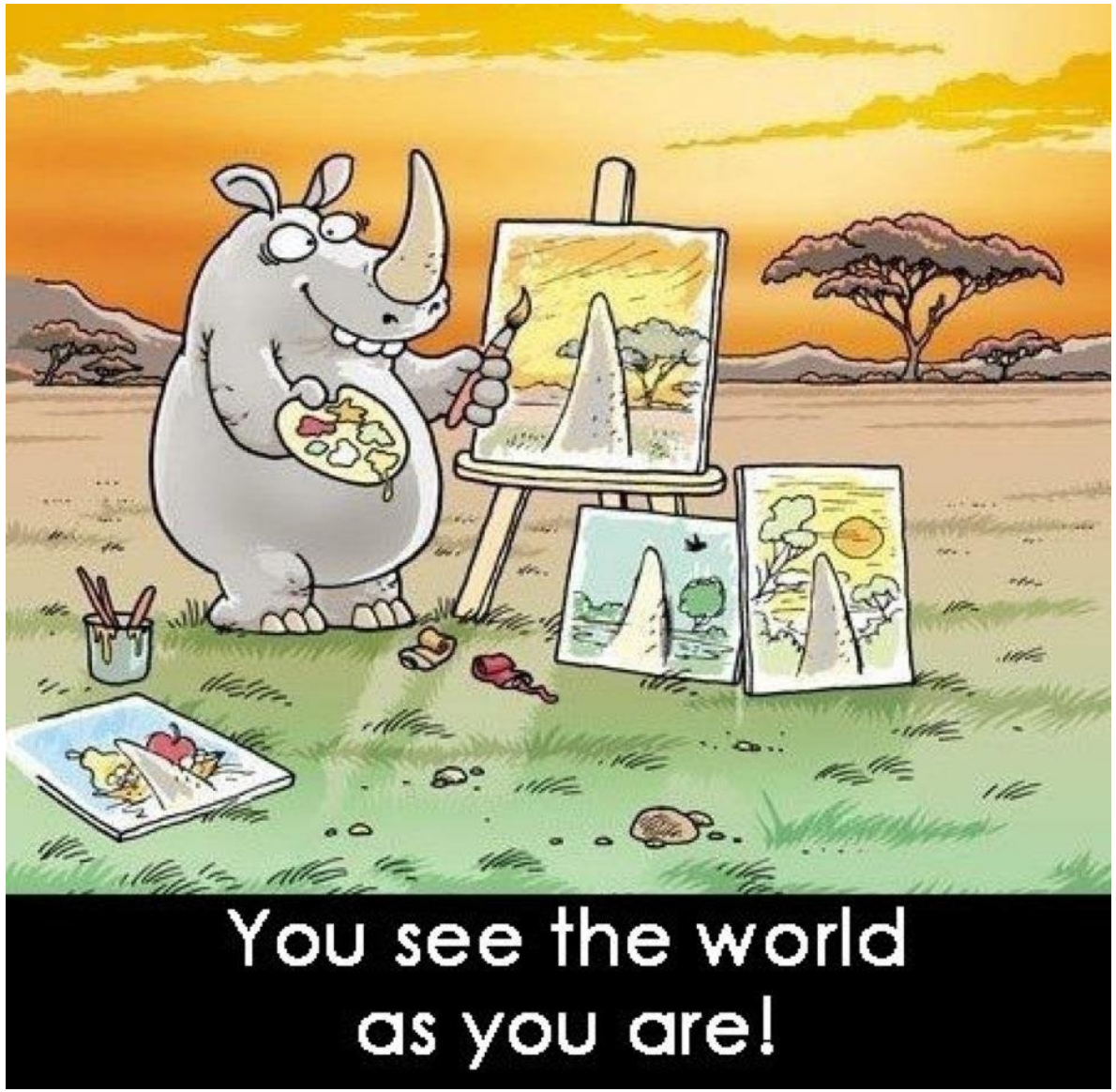
Hand gestures, for example, can have completely different meanings in different cultures

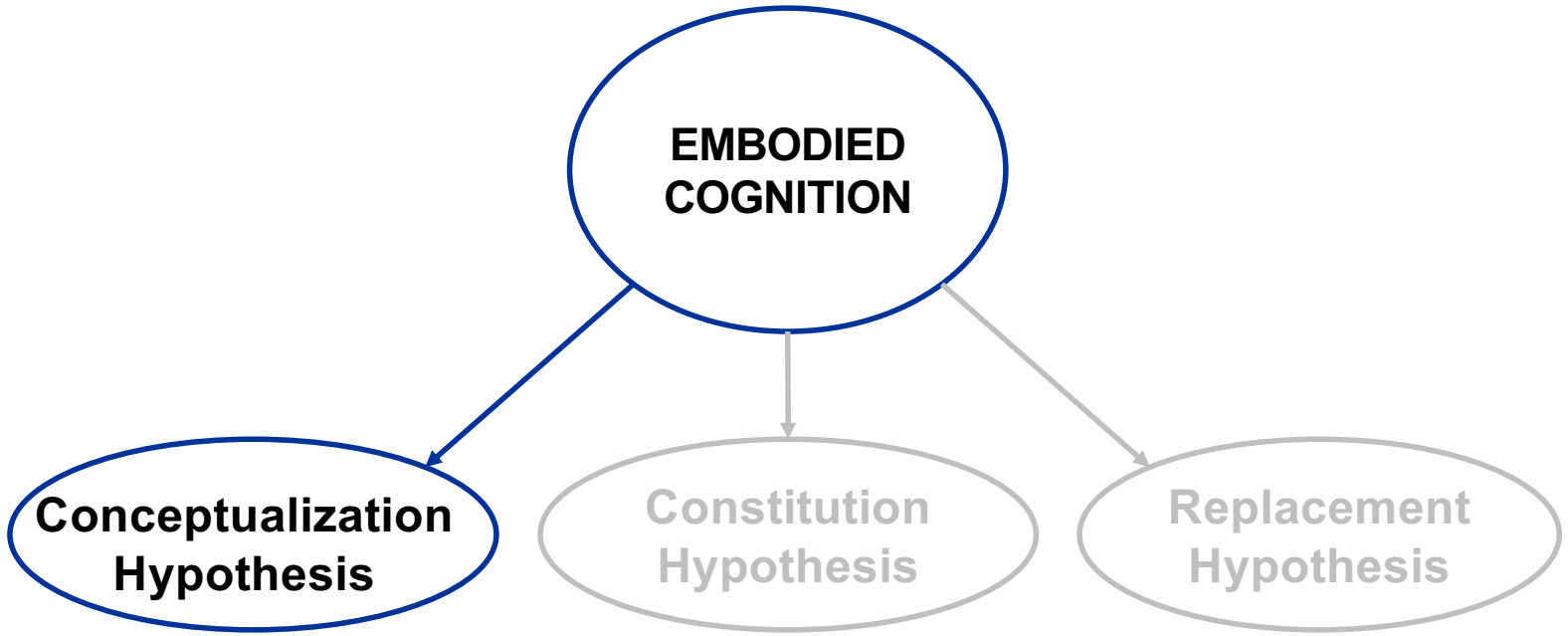
Three Hypotheses on Embodied Cognition


EMBODIED
COGNITION
Conceptualization
Hypothesis
Constitution
Hypothesis
Replacement
Hypothesis

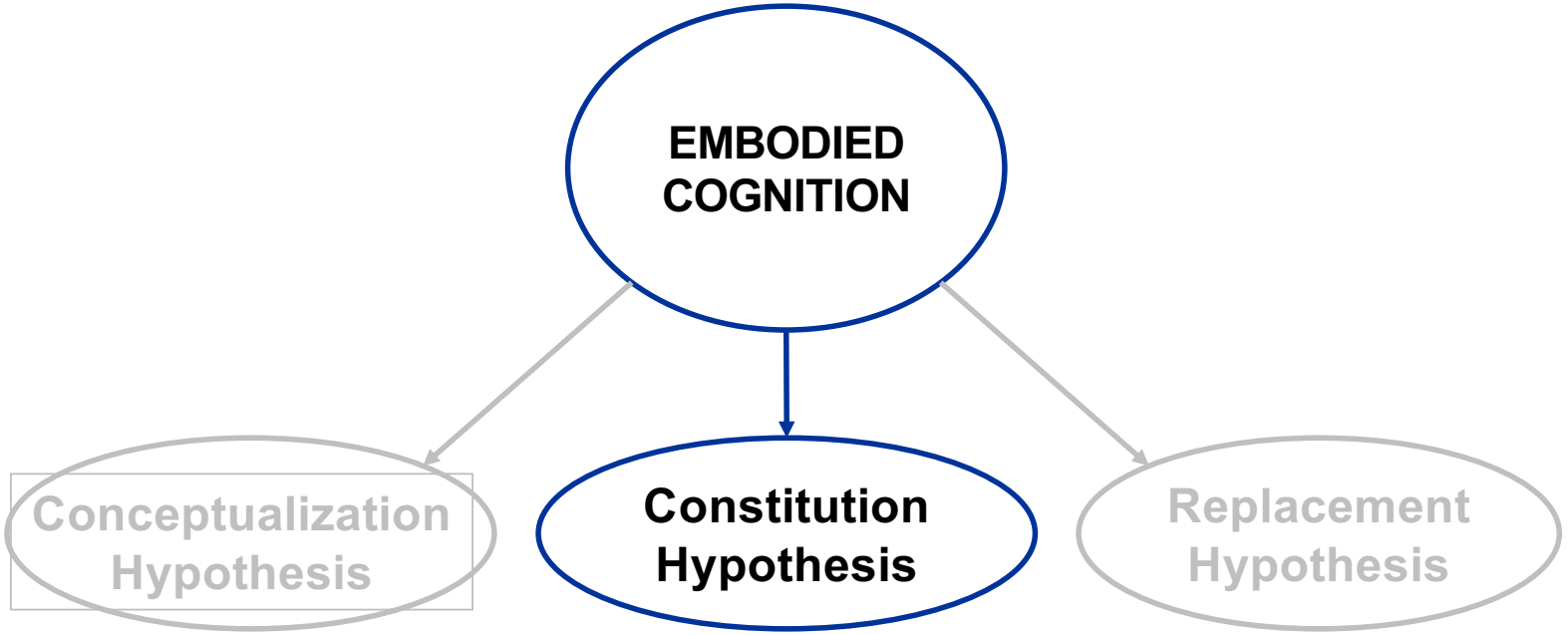


The characteristics of an agent's body determine the concepts an organism can acquire


You see the world
as you are!

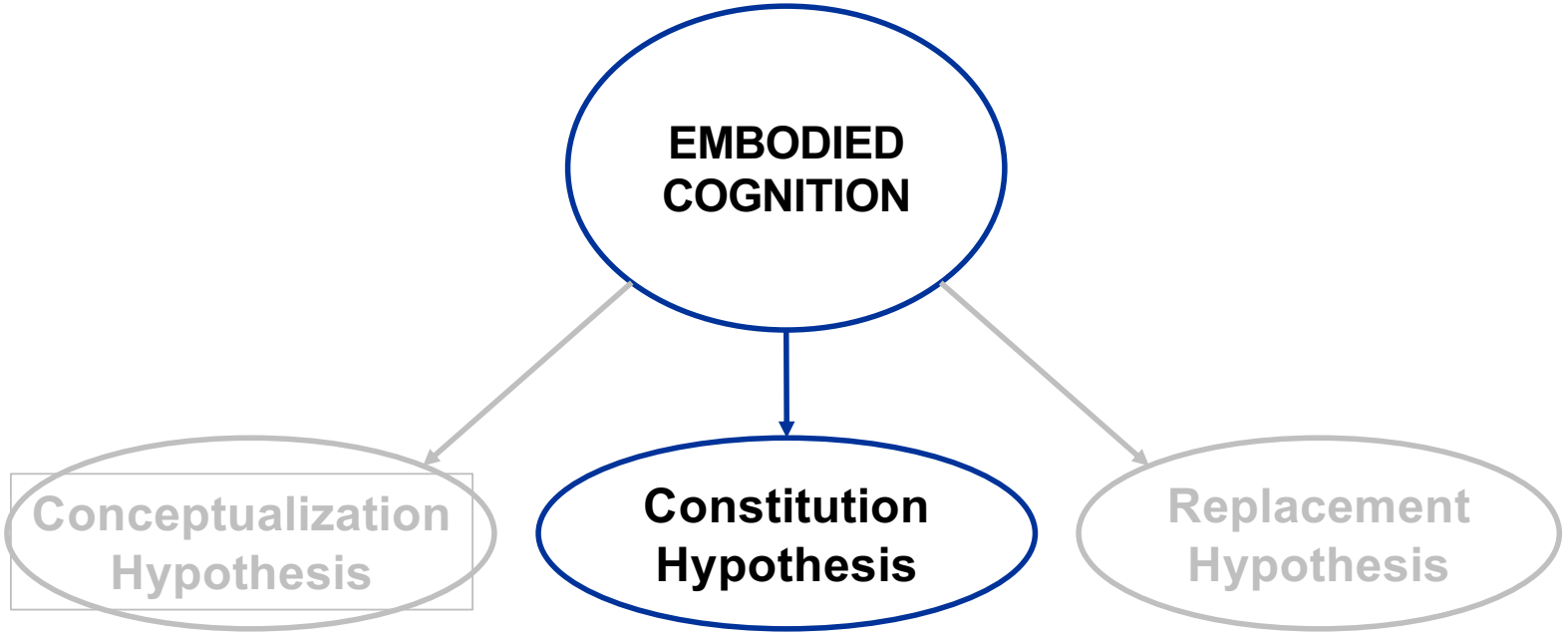


The body conditions / constrains cognition



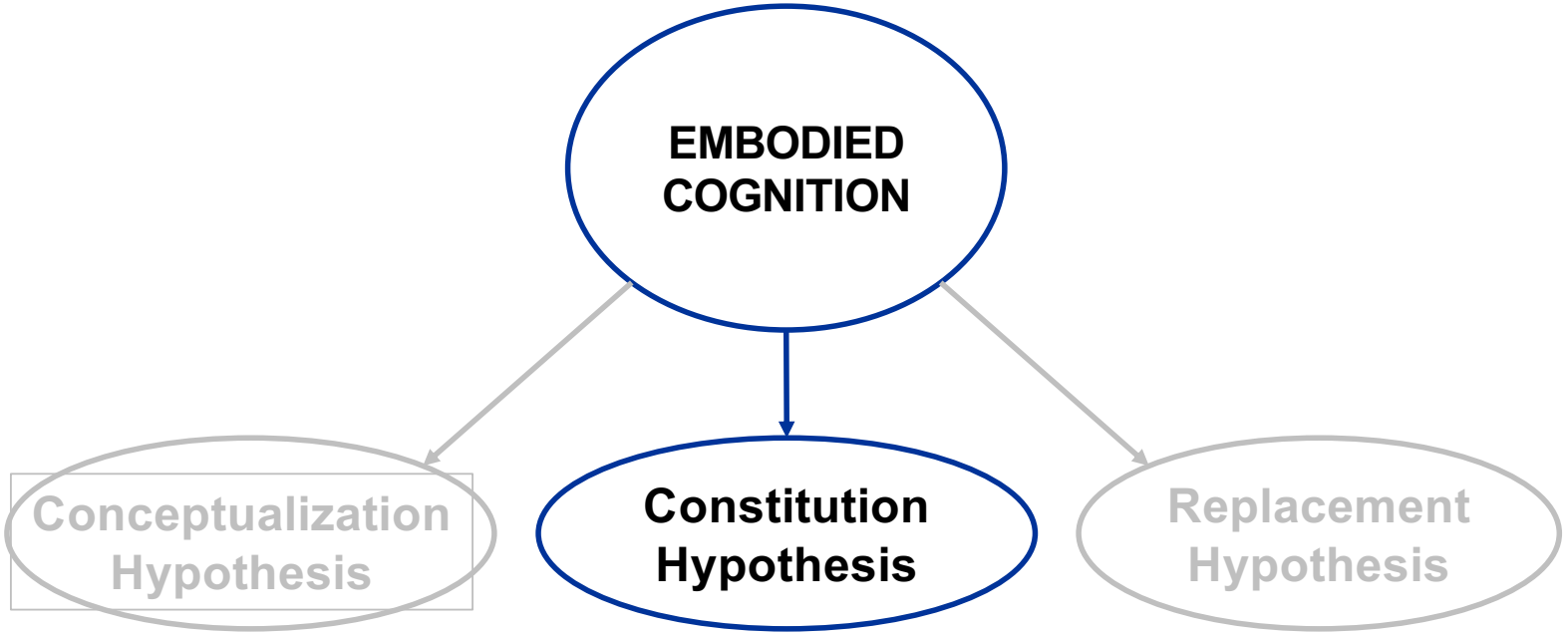
The body is itself an integral part of cognition

The way the body is shaped and moves augments brain-centred neural processing



Cognition is distributed between the neural and the non-neural

The body simplifies what the brain has to do
or takes over responsibility for it completely



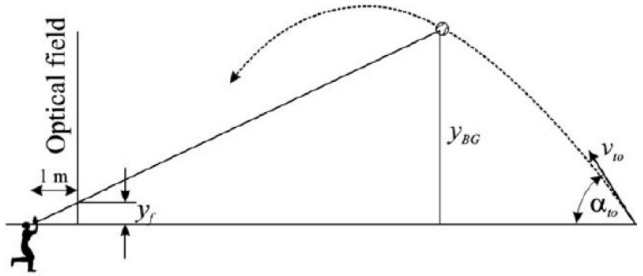
Optical Acceleration Cancellation (OAC)

[Ball coming towards you: run so that ball appears to have constant velocity]

Lateral Optical Trajectory (LOT)

[Ball moving laterally: run so that ball appears to travels in straight line]

[Wilson & Golonka 2013]



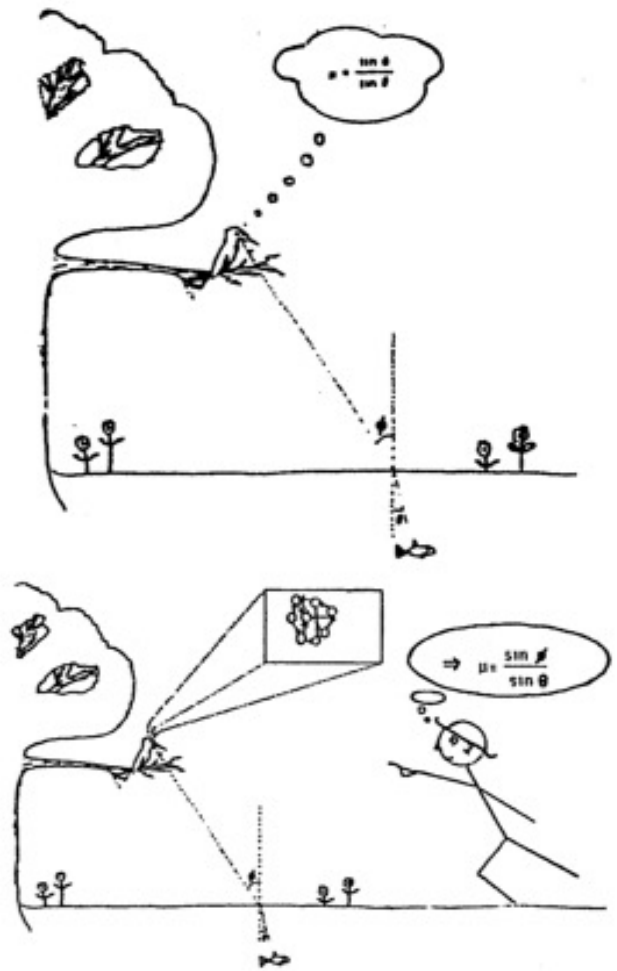
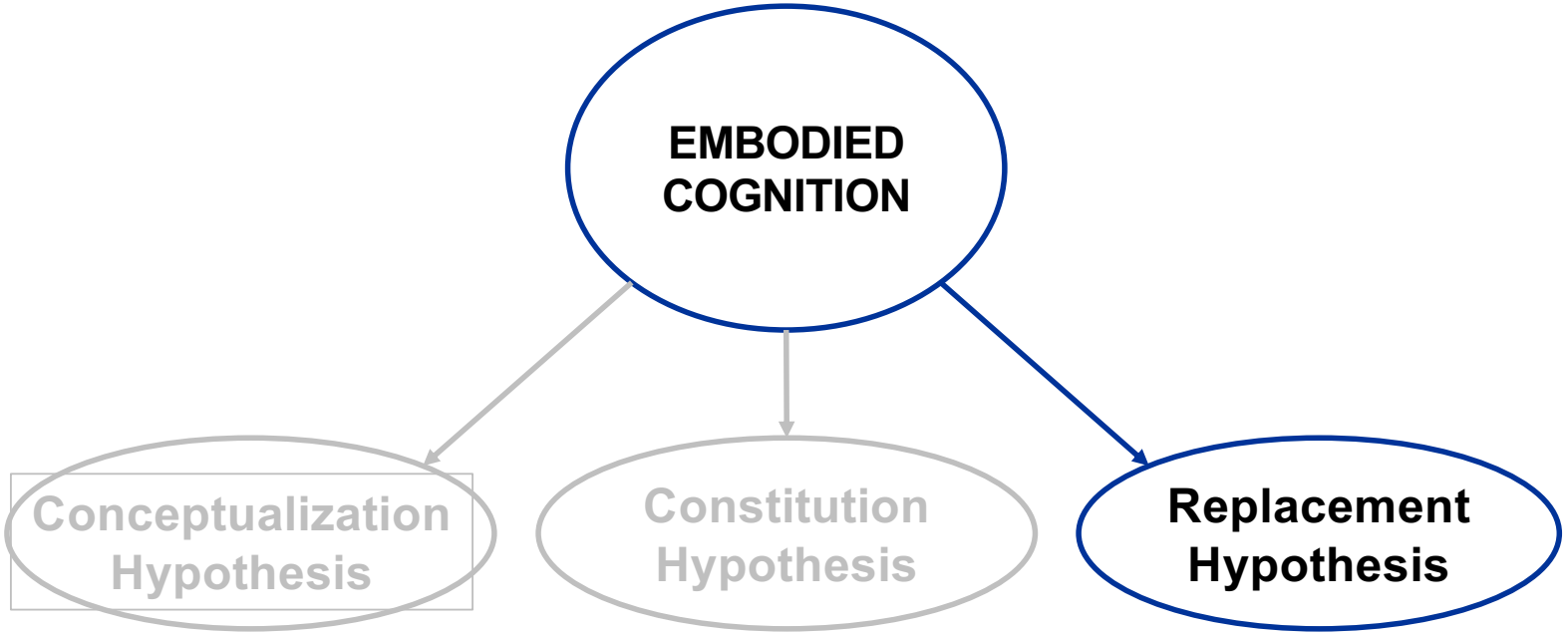
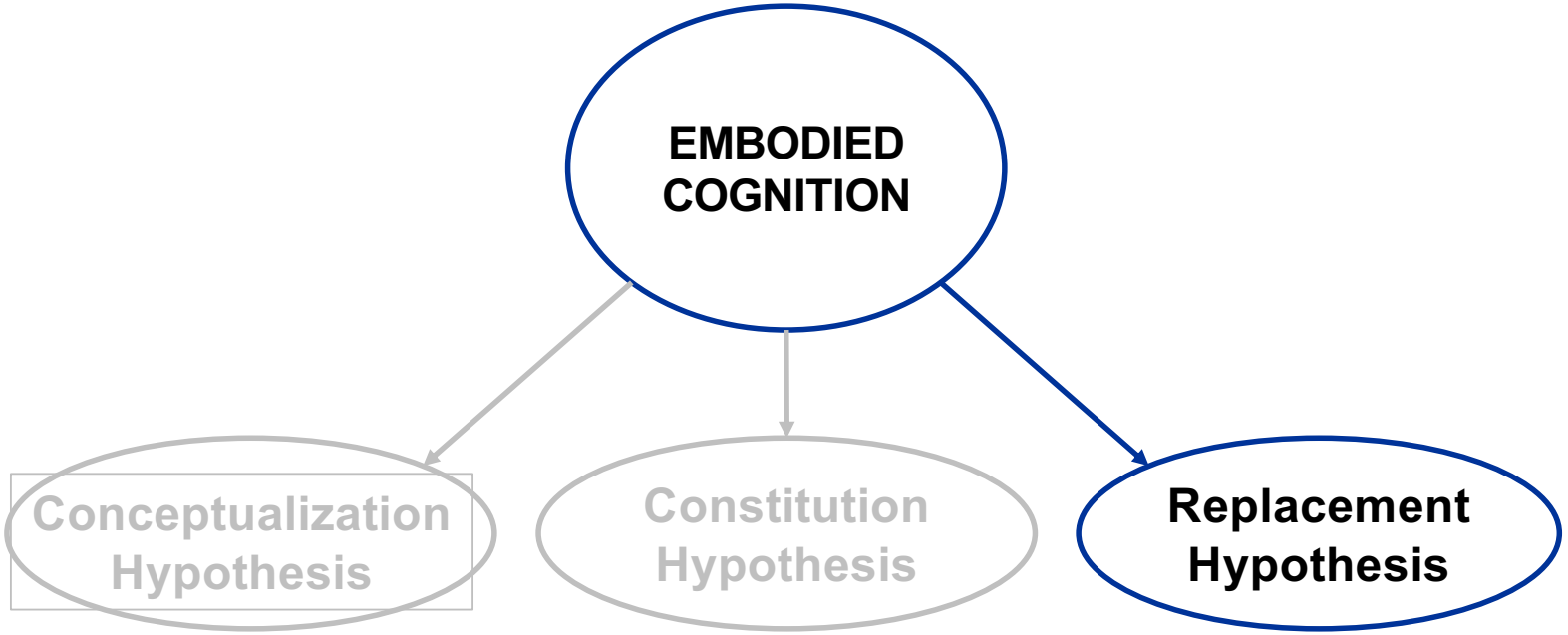


Fig. 1. (a) A *Punch* cartoon that depicts succinctly the cognitivist hypothesis. To catch its prey, this kingfisher has, in its brain, a representation of Snell's law of refraction. (b) Another reading of the cartoon to indicate how the symbolic levels can be seen as arising from the underlying network.



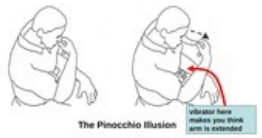
An agent's body in real-time interaction with its environment **replaces** the need for representational processes
(with dynamical-systems-based perception-action couplings)



The body acts as a regulator of cognitive activity

Evidence for the Embodied Stance: the Mutual Dependence of Perception and Action

- Spatial and selective attention
- The Pinocchio effect



- Canonical and mirror visuo-motor neurons in F5

- Affordances

Action-Perception Dependency

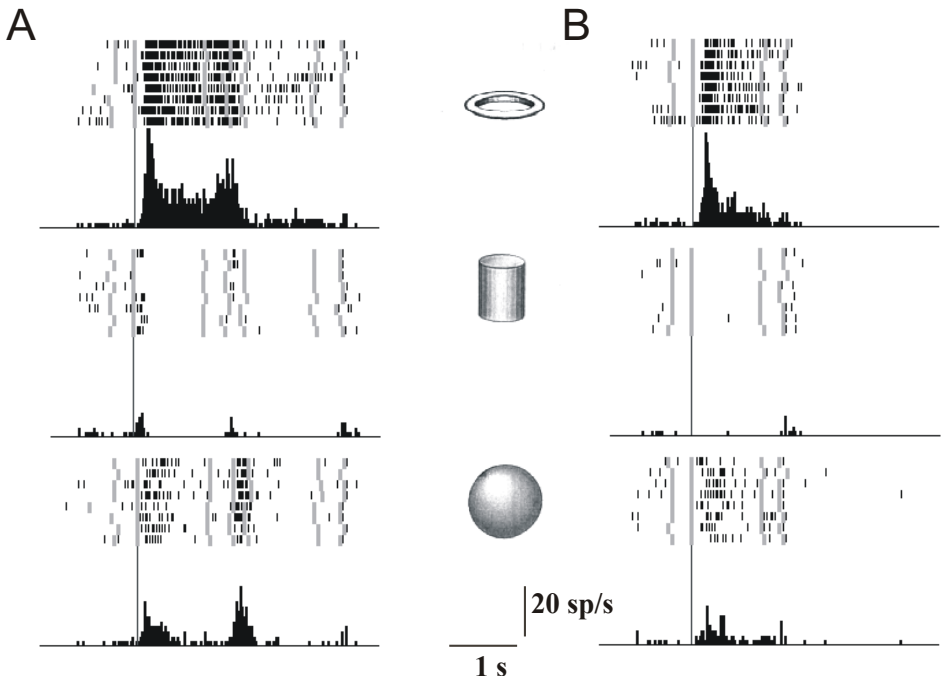
Affordances

Action-Perception Dependency

Affordances

Action-Perception Dependency

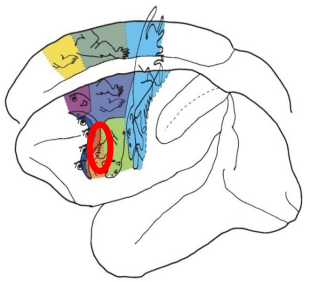
Visuomotor Neurons



Observation + action

Observation only

Active when objects that can be manipulated are presented visually (grasp specific)



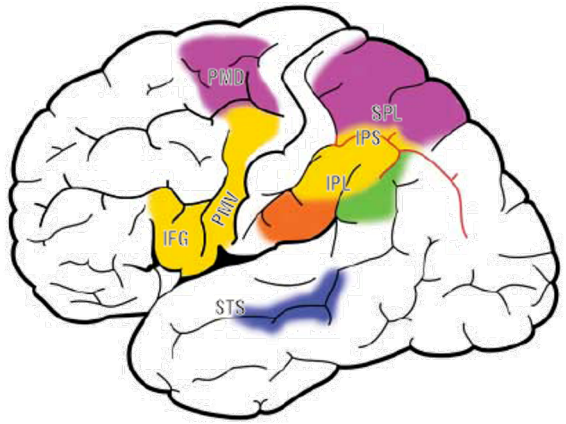
It is not the shape of the object that matters but how you can grasp it

From: Fadiga, L., L. Fogassi, V. Gallese, and G. Rizzolatti, Visuomotor Neurons: ambiguity of the discharge or "motor" Perception? Internation Journal of Psychophysiology, 2000. ***35****: p. 165-177.*

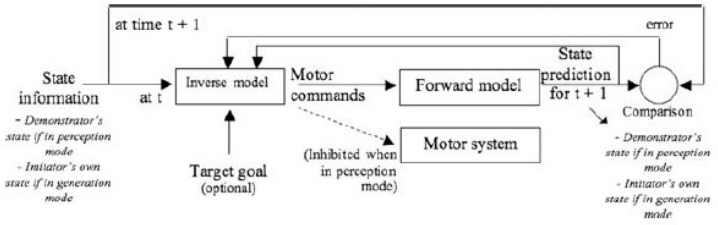
Action-Perception Dependency

Mirror Neuron System

(Rizzolatti et al. 1996 Cogn Brain Res)



Active when a monkey does an action and also when another individual is seen performing the same manipulative gestures

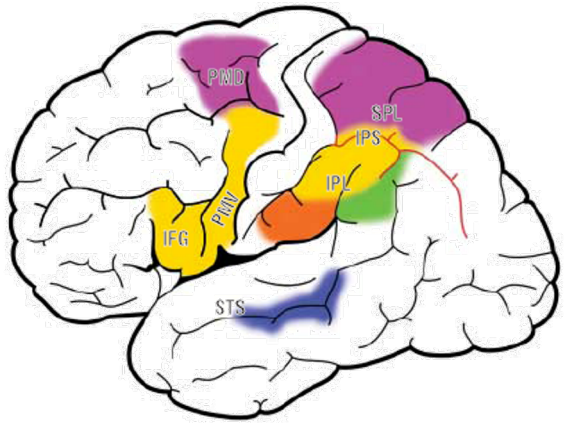


[Demiris 2007 Cognitive Processing]

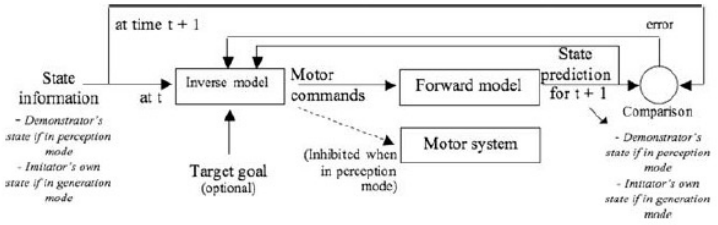
Action-Perception Dependency

Mirror Neuron System

(Rizzolatti et al. 1996 Cogn Brain Res)



Action planning and action understanding share the same internal models



[Demiris 2007 Cognitive Processing]

Examples of human embodied cognition

Much experimental work in the neural and behavioral sciences in the last 20-30 years indicates that in / for human cognition the embodiment implies that **cognitive, affective/emotional, and bodily mechanisms are massively intertwined and largely inseparable**. I'll give a a number of concrete examples here, but only discuss each of them very briefly - see original sources for details.

[From the lecture notes of Tom Ziemke]

Brain responses (1)

Pulvermüller et al. let subjects perform a lexical decision task, using verbs referring to mouth, hand or leg motion (e.g. chew, grab, kick).

They found that the corresponding mouth, hand, leg areas of motor cortex exhibited increased activation, although of course no overt action was required.

Pulvermüller et al. (2001). “Walking or talking?: Behavioral and neurophysiological correlates of action verb processing”, Brain and Language,78, 143-168.

Brain responses (2)

Tettamanti et al. showed, using fMRI brain imaging, that passive listening to action-related sentences describing mouth, hand, leg motions activates the corresponding parts of pre-motor cortex.

Tettamanti et al. (2005). “Listening to action-related sentences activates fronto-parietal motor circuits”, Journal of Cognitive Neuroscience,17, 273-281.

Behavioral responses (1)

Bargh et al. let subjects form sentences from short word lists, either priming them with a social stereotype/trait (e.g. “gray”, “Florida”, “bingo” for an elderly stereotype) or just neutral words.

Primed subjects, after they thought the experiment was over, took longer to walk from the lab to the elevator than the control group.

Bargh et al. (1996). “Automaticity of social behavior: Direct effects of trait construct and stereotype activation on action”, Journal of Personality and Social Psychology, 71, 230-244.

Behavioral responses (2)

In a similar setup, Aarts & Dijsterhuis primed subjects with either fast or slow animals.

Subjects primed with fast animals subsequently took less time walking to another room.

Aarts & Dijsterhuis (2002). "Comparability is in the eye of the beholder: Contrast and assimilation effects of primed animal exemplars on person judgements", British Journal of Social Psychology, 41, 123-138.

Head motion

Tom et al. had subjects nod their heads (vertically) or shake them (horizontally) while listening to music on headphones.

When later offered, by a naïve experimenter, either a pen they had seen or one they had not see, nodding subjects preferred the original pen, head-shaking subjects preferred the new pen.

Tom et al. (1991). "The role of overt head movement in the formation of affect", Basic and Applied Social Psychology, 12, 281-289.

Arm motion

Cacioppo et al. had subjects view neutral Chinese ideographs while either pushing upward on the table surface ("approach") or pushing downward ("avoidance").

In later ratings ideographs seen in "approach" mode were rated more positively than those seen in "avoidance" mode.

Cacioppo et al. (1993). "Rudimentary determination of attitudes: Arm flexion and extension have differential effects on attitudes", Journal of Personality and Social Psychology, 65, 5-17.

Arm movement

Glenberg and Kaschak asked subjects to judge the sensibility of sentences.

Subjects responded faster when their action and the described action were compatible, e.g. when moving the hand towards themselves in response to “open the drawer”.

Glenberg & Kaschak (2002). “Grounding language in action”, Psychonomic Bulletion and Review, 9, 558-565.

Levers

Chen and Bargh asked subjects to respond to positively or negatively valenced words by indicating their valence by pulling a lever towards themselves or pushing it away.

Subjects responded faster to positive words by pulling the lever towards them, and faster to negative words by pushing it away.

Chen & Bargh (1999). "Consequences of automatic evaluation: Immediate behavior predispositions to approach or avoid the stimulus", Personality and Social Psychology, 25, 215-224.

Facial muscle activation

Strack et al. had subjects rate cartoons while holding a pen (with the tip outward), either between their teeth (activating the muscles associated with smiling) or their lips (activating muscles used for frowning).

Subjects holding the pen with their teeth rated the cartoons as funnier than those holding it with their lips.

Strack et al. (1988). “Inhibiting and facilitating conditions of the human smile”, Journal of Personality and Social Psychology, 54, 768-777.

Facial muscle de-activation

In experiments of Havas et al. (2010) with botox:

"temporary paralysis of the facial muscle corrugator supercilli (responsible for producing a frown) *hindered processing*, relative to pre-injection baseline, *for angry and sad sentences, while processing for happy sentences was unaffected*" (emphasis added)

Havas et al. (2010). "Cosmetic Use of Botulinum Toxin-A Affects Processing of Emotional Language". Psychological Science, 21: 895-900.

Incidental Haptic Sensations

Ackerman et al. let passers-by evaluate job candidates by reviewing resumes on either light or heavy clipboards.

Participants using heavy clipboards rated the candidate as better overall and specifically as displaying more serious interest in the position.

Participants using the heavy clipboard also rated their own accuracy on the task higher.

Ackerman et al. (2010). “Incidental Haptic Sensations Influence Social Judgments and Decisions”, Science, 328(5987), 1712-1715.

https://www.youtube.com/watch?v=Ks-_Mh1QhMc

https://www.forbes.com/sites/kimelsesser/2018/04/03/power-posing-is-back-amy-cuddy-successfully-refutes-criticism/#589ca55f3b8e

Recommended Reading

Vernon, D. Artificial Cognitive Systems – A Primer, MIT Press, 2014; Chapter 5.