Artificial Cognitive Systems

Module 5: Embodiment

Lecture 2: types of embodiment; off-line embodied cognition; interaction within; from situation cognition to distributed cognition.

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Types of Embodiment

Three assumptions:

1. Cognition involves some level of **conceptual** understanding of the world with which it interacts

2. Concepts are **represented** in some way by the cognitive system

3. Cognition involves a capacity for **learning** and **adapting**

Types of Embodiment

The representational framework needs to fulfill two criteria

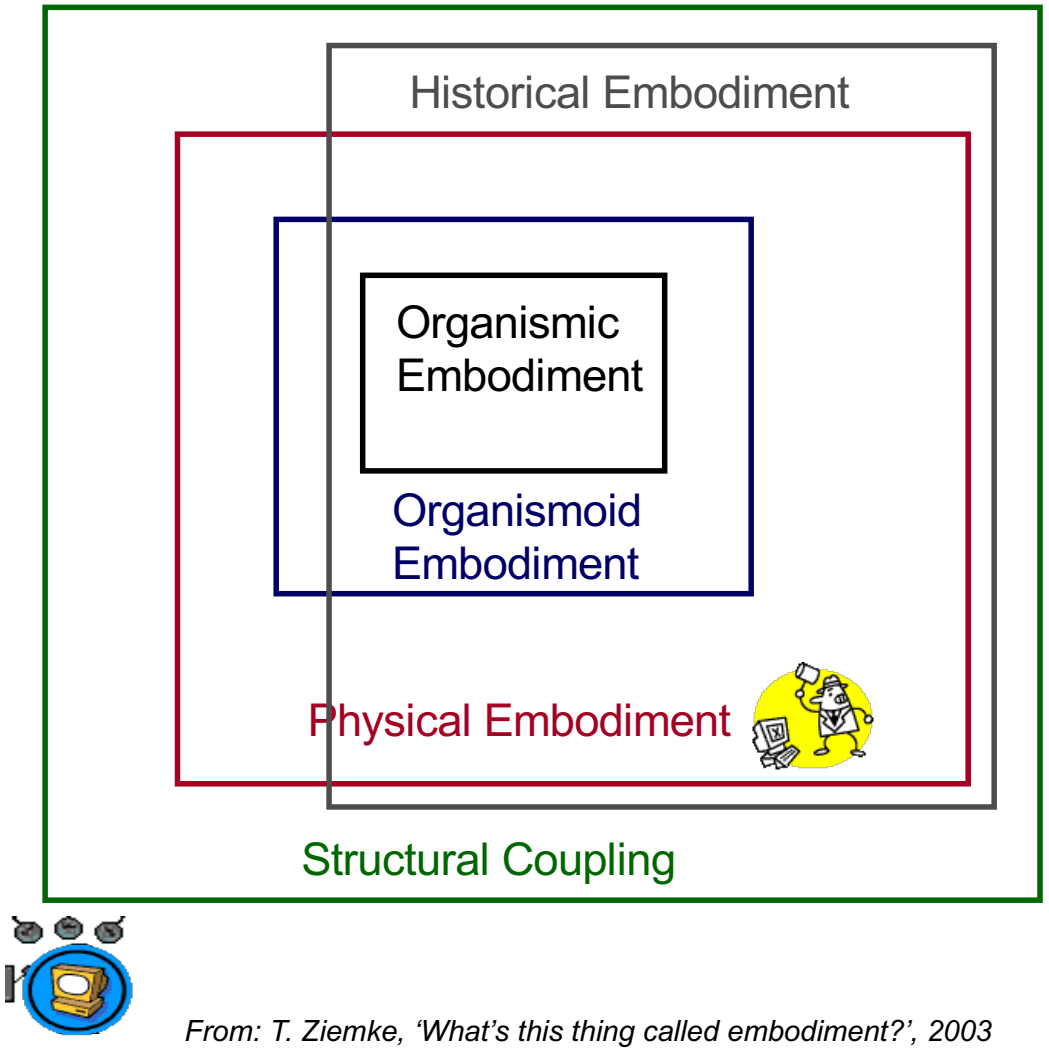
1. Allow for the possibility that the representation is in **error**
2. **Compare** the representation with what is being represented

Types of Embodiment

A minimal form of embodiment is required to satisfy these two criteria:

1. Be capable of “full” interaction – the interaction must have an impact on both the the world and the agent itself

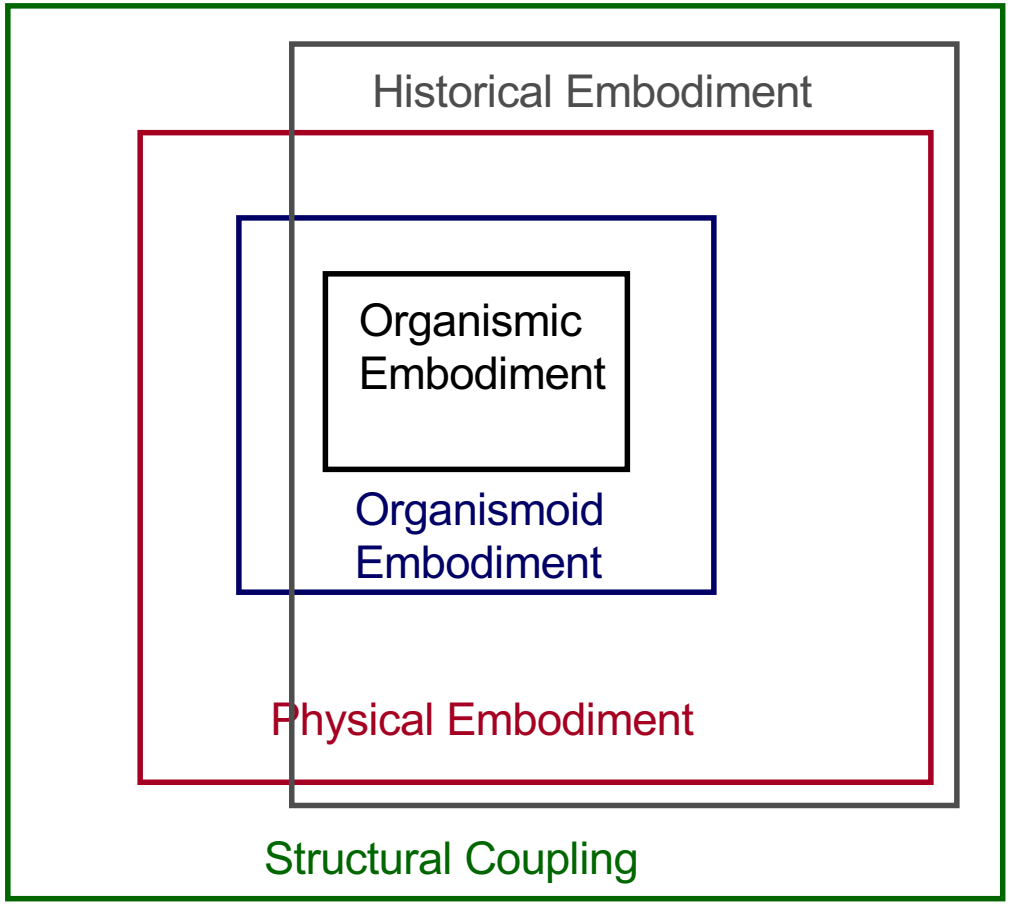
2. The agent’s actions must have a causal impact on the agent’s percepts of the world



From: T. Ziemke, 'What's this thing called embodiment?', 2003

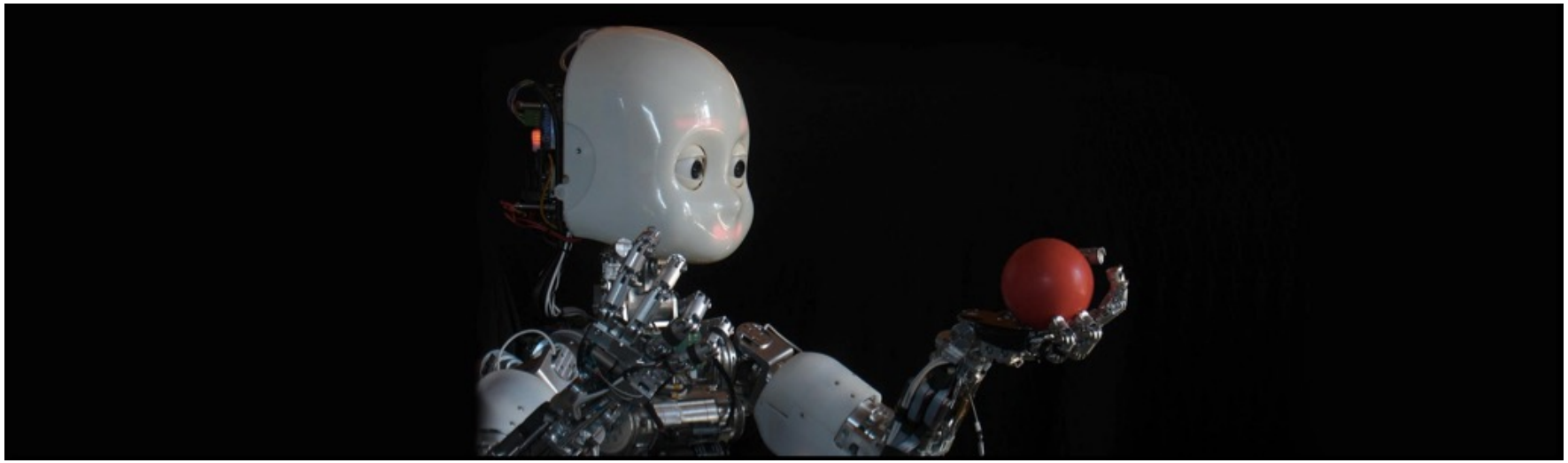
Embodiment

- Structural coupling
  - System can be perturbed by the environment
  - System can perturb the environment
- Historical embodiment
  - History of structural coupling
- Physical embodiment
  - Forcible action (excluded software agents)
- Organismoid embodiment
  - Organism-like bodily form (e.g. humanoid robots)
- Organismic embodiment
  - Autopoietic living systems



Embodiment

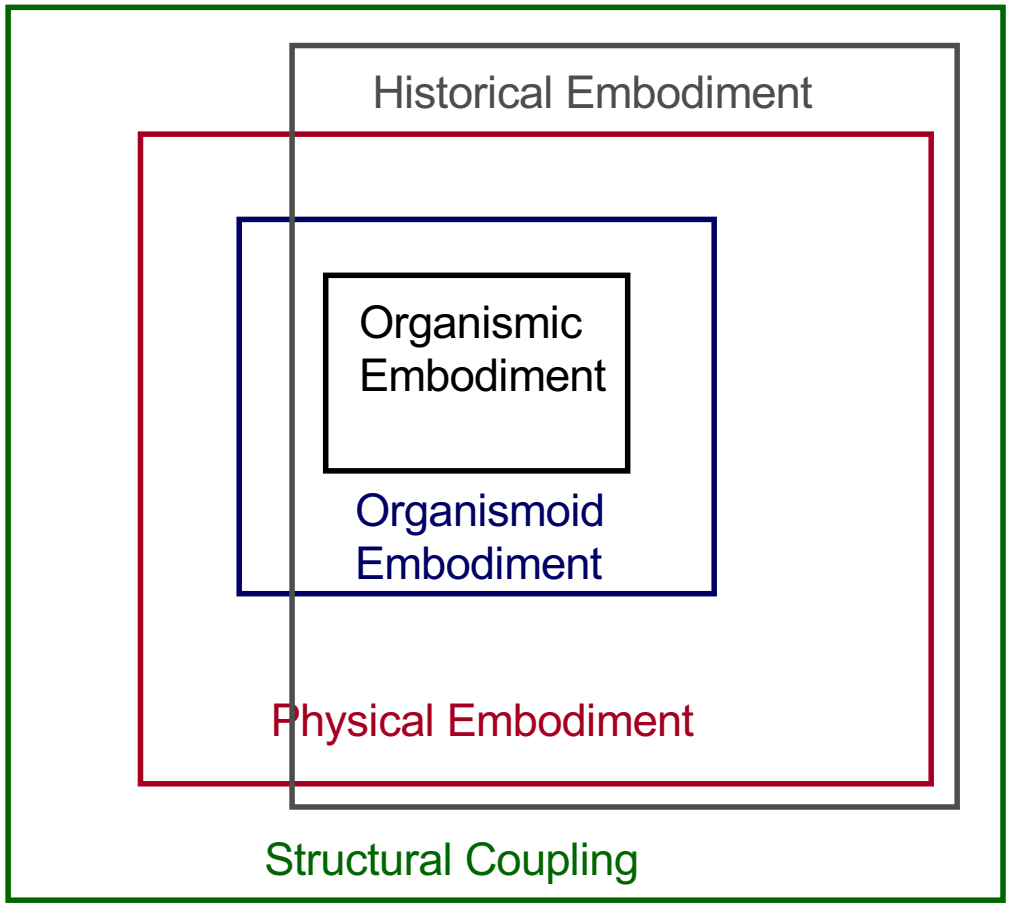
Humanoid robots occupy a special niche in the spectrum of intelligent machines



Embodiment

Their physical appearance and human-like structure serve a specific purpose: to allow them to be used in situations where they can

- co-exist with humans on human terms
- integrating seamlessly into the human environment
- performing human tasks in the same way humans do
- handling everyday objects with the same ease as a human
- using the tools that humans use
- interacting with humans using human-like gestures



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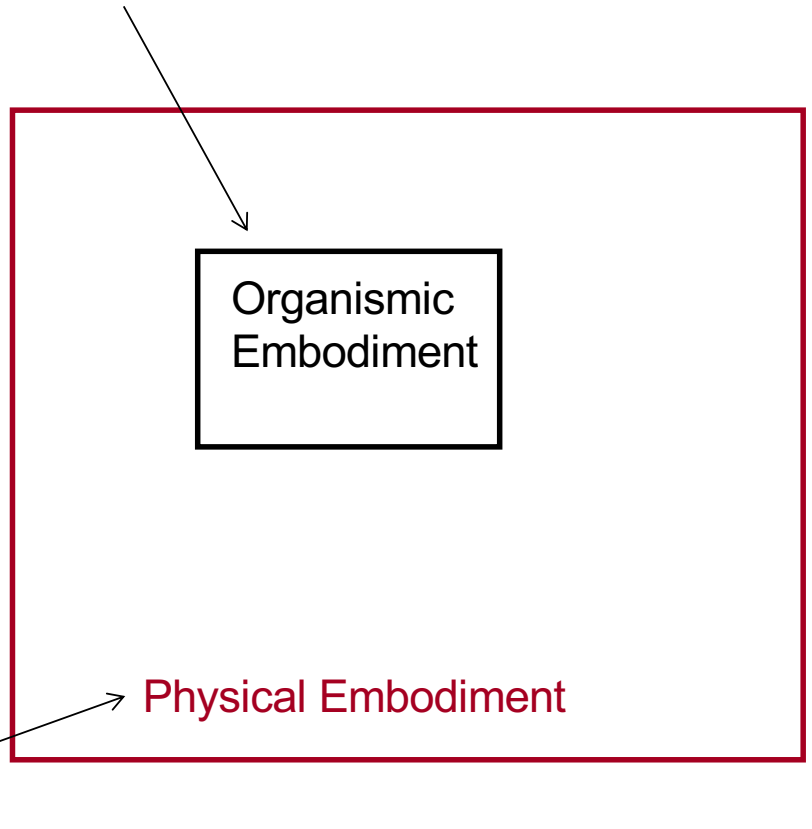
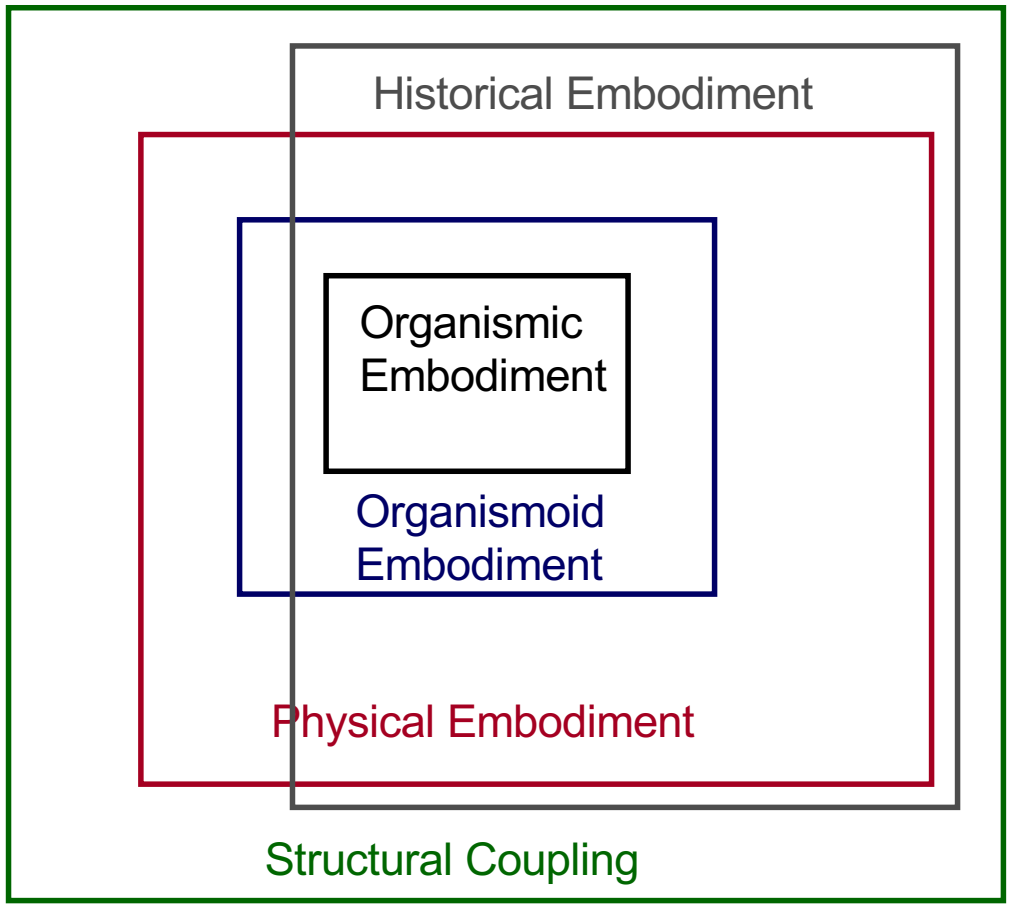
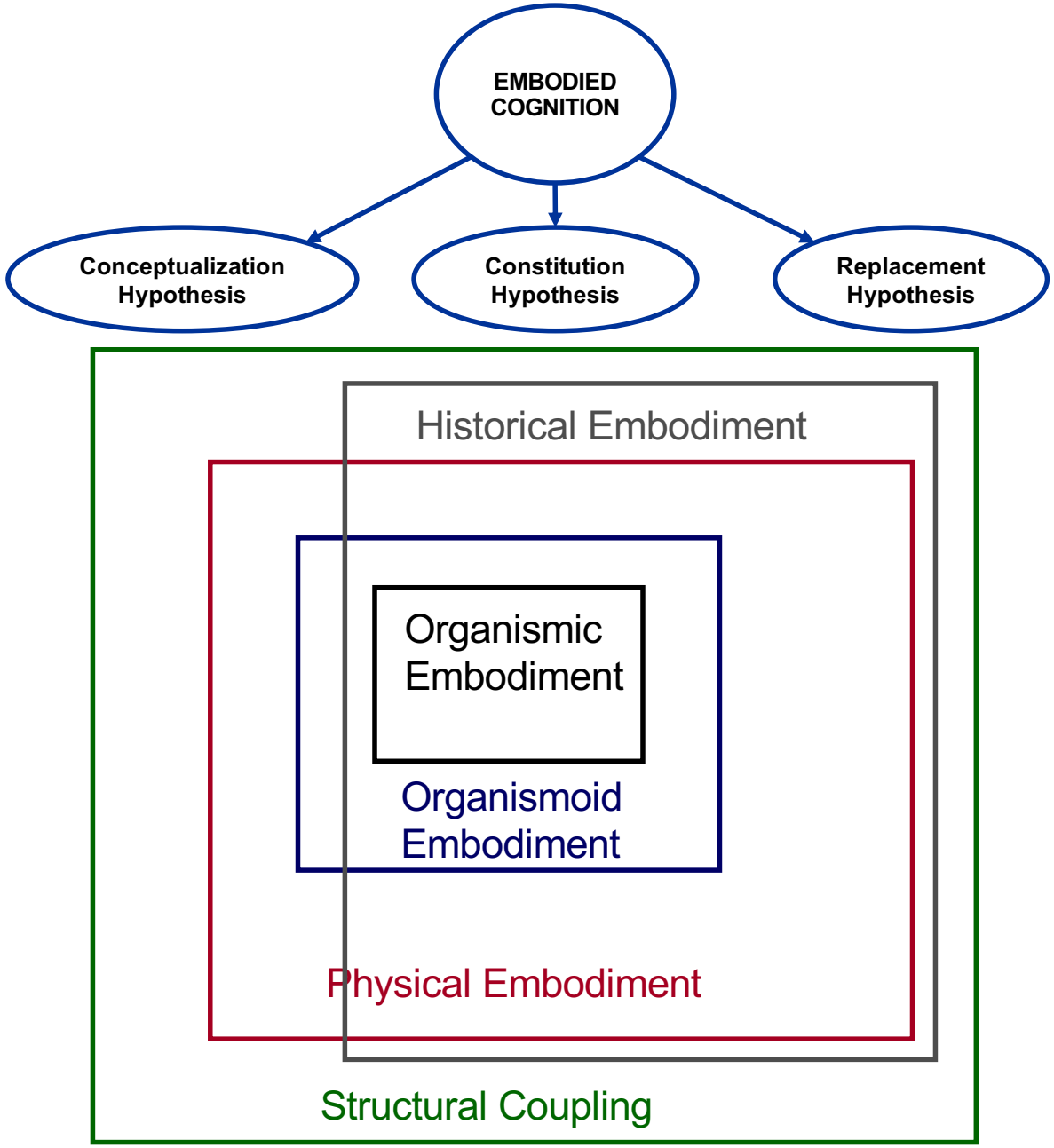
Phenomenal Embodiment
Embodied cognition is uniquely reserved to living entities that exist in some environmental niche and have a subjective experience of that environment

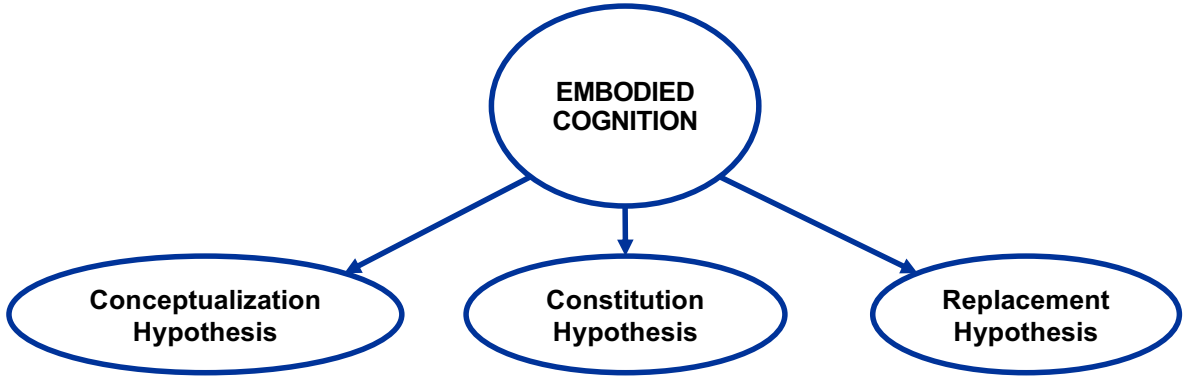


Mechanistic Embodiment:
Everything you need for cognitive activity is there in the physical mechanism

(cf. Replacement Hypothesis)


Historical Embodiment
Organismic
Embodiment
Organismoid
Embodiment
Physical Embodiment
Structural Coupling


EMBODIED COGNITION
Conceptualization Hypothesis
Constitution Hypothesis
Replacement Hypothesis
Historical Embodiment
Organismic Embodiment
Organismoid Embodiment
Physical Embodiment
Structural Coupling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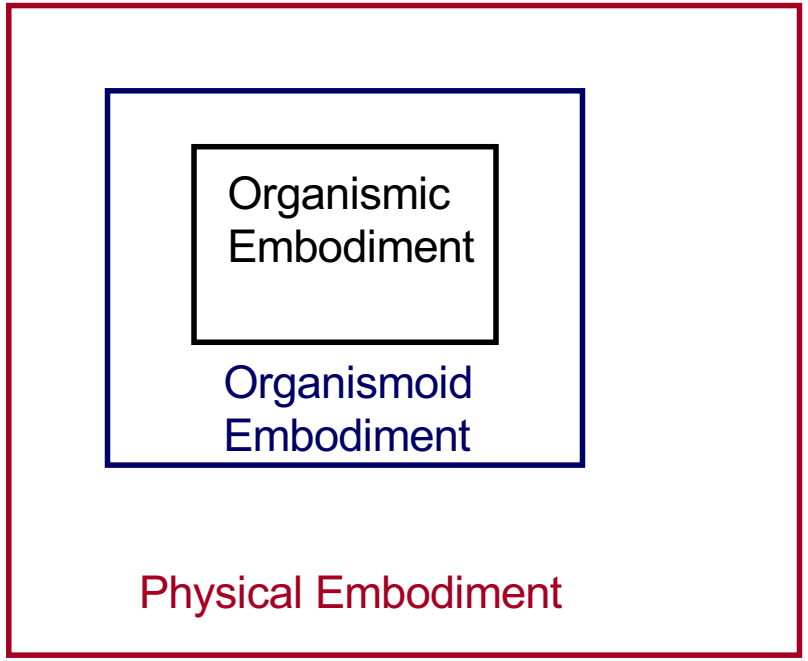

Organismic Embodiment
Organismoid Embodiment
Physical Embodiment

Inward-looking Aspects of Embodiment

1. Off-line Embodied Cognition (Internal Simulation)
2. Internal Interaction

Off-line Embodied Cognition

- Cognition is primarily concerned with action
- And with preparing for action:
  offline cognition / internal simulation
- Multiple options for action
- Choosing on the basis of internal attention
- Based on flow of perceptions

Off-line Embodied Cognition

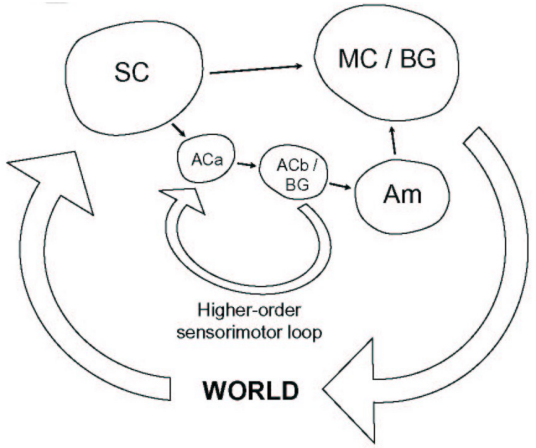
- Cognitive system as a whole is the simulator
- HAMMER architecture
  - Multiple inverse models
    - Input current state and goals, output motor commands
  - Multiple forward models
    - Input motor commands, output predicted outcome

Y. Demiris and B. Khadhouri. Hierarchical attentive multiple models for execution and recognition (HAMMER). Robotics and Autonomous Systems, 54:361–369, 2006.

Off-line Embodied Cognition

- **Off-line cognition is still body-based**

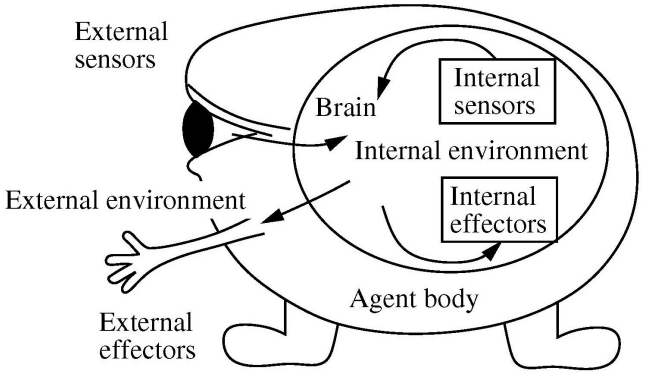
- The cognitive activity is still grounded in the mechanisms of sensory processing and motor control



[Shanahan06,ShanahanBaars06,Shanahan05a,Shanahan05b]

Internal Interaction

- Interaction between the agent and its own internal body
- Interaction with the CNS:

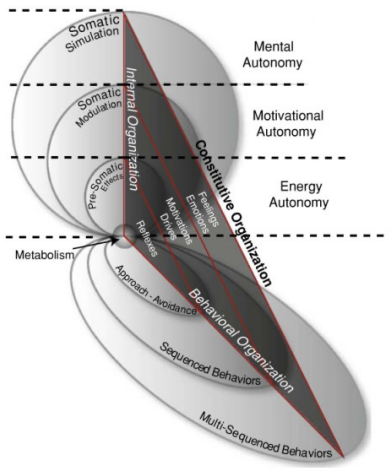


Self-aware self-effecting (SASE) agent

[Weng et al. 01, Weng 02, Weng & Zhang 02, Weng 04a, Weng 04b]

Internal Interaction

- Interaction between the agent and its own internal body
- Interaction with the affective system & metabolism



A. Morse, R. Lowe, and T. Ziemke. 2008.

The Cognitive-Affective Architecture Schematic

Internal Interaction

- Cognition >> memory, attention, and reasoning
- Cognition >> co-dependence of action and perception
- Cognition: **internal constitution of the embodied agent**
  - Homeostatic processes
  - Affective processes that provide the **internal value systems** which influence the goals of autonomous cognitive agents

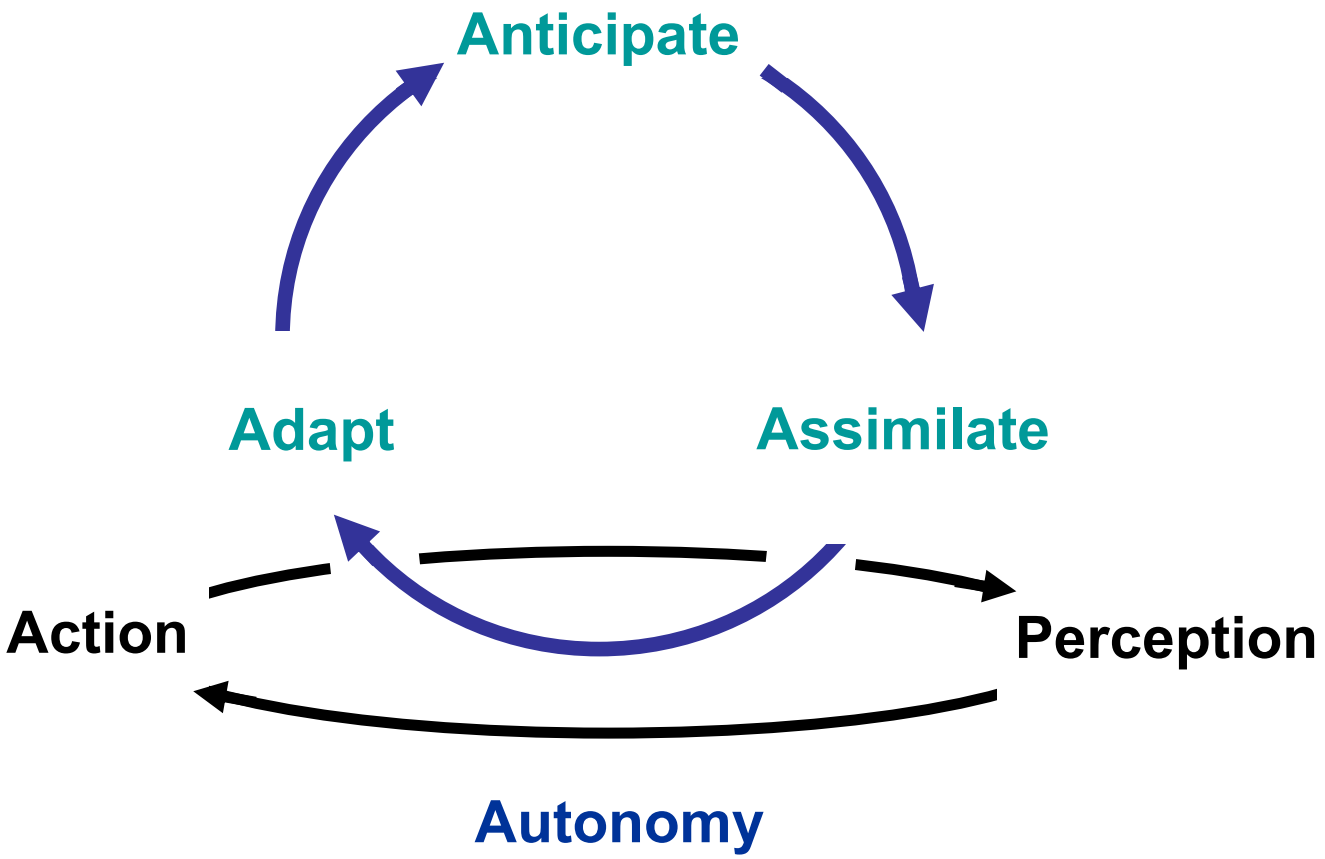
Internal Interaction

- Interoception & Internal Robotics [Parisi 2004]
  - CNS
  - Endocrinal System
- Being "properly embodied" [Mog Stapleton 2013]

D. Parisi. Internal Robotics. Connection Science, 16(4):325– 338, 2004.

M. Stapleton. Steps to a "Properly Embodied" cognitive science. Cognitive Systems Research, 22—23:1–11, 2013.

Brain—Body—Environment Characteristic of Embodied Cognition


Anticipate
Adapt
Assimilate
Action
Perception
Autonomy

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

Two sources of confusion

1. The part played by the environment

2. Some versions of embodiment don’t need a body!

Situated Cognition

On-going real-time interaction with its environment

Structurally-coupled to the environment

Maintain its autonomy despite the precarious circumstances

W. J. Clancey. Situated Cognition: On Human Knowledge and Computer Representations. Cambridge University Press, Cambridge MA, 1997.

Embedded Cognition

Off-load cognitive work onto the environment

Using landmarks to help remember your way home

Modify the environment

(External) Scaffolding

Create sign*s to help with navigation*

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

Grounded Cognition

Less concerned with embodiment,
More concerned with the nature of representations

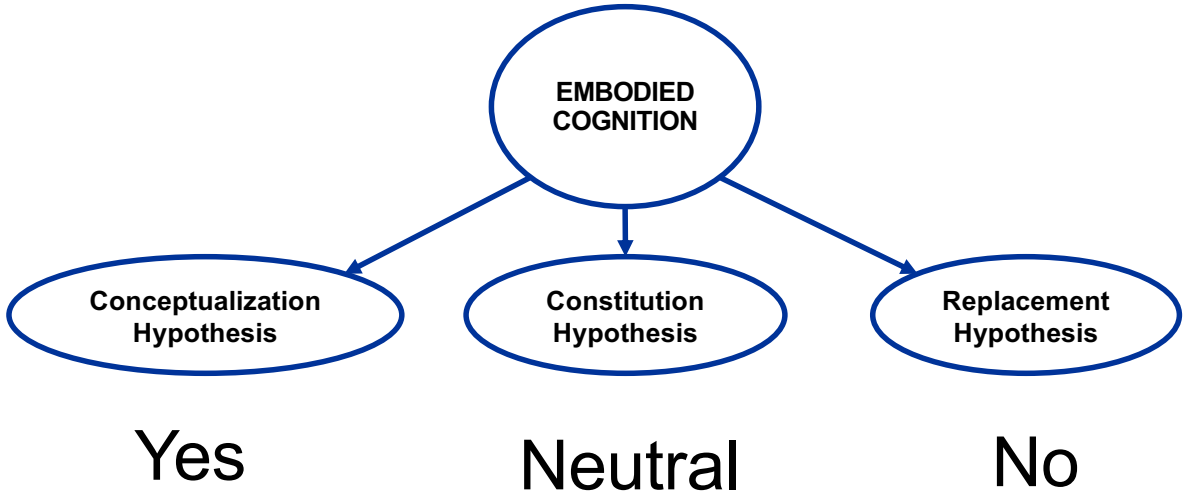
Modal (not amodal) representation

Symbolic but grounded in sensorimotor experience

Internal simulation is key, and is modal
Operates off-line, independently of the body

L. W. Barsalou. Grounded cognition. Annu. Rev. Psychol., 59(11):II.1–II.29, 2008.
L. W. Barsalou. Grounded cognition: Past, present, and future. Topics in Cognitive Science, 2:716–724, 2010.

Grounded Cognition



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L. W. Barsalou. Grounded cognition: Past, present, and future. Topics in Cognitive Science, 2:716–724, 2010.

Grounded Cognition

Modal representations can be based on introspective internal simulations

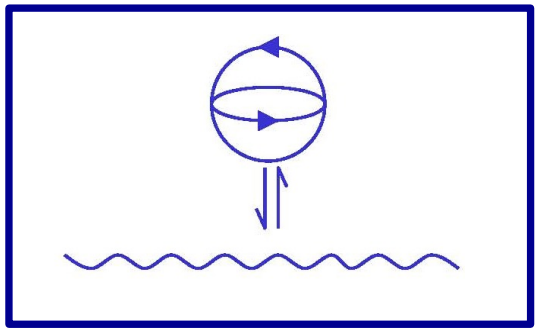
Do not necessarily involve a faithful complete reconstruction of embodied experience

Allows for the inclusion of abstract concepts that are not grounded directly in specific sensorimotor experiences

L. W. Barsalou. Grounded cognition. Annu. Rev. Psychol., 59(11):II.1–II.29, 2008.
L. W. Barsalou. Grounded cognition: Past, present, and future. Topics in Cognitive Science, 2:716–724, 2010.

Extended Cognition

The environment is a constituent component in a bigger brain-body-environment cognitive system



A. Clark and D. Chalmers. The extended mind. Analysis, 58:10–23, 1998.

Extended Cognition

The environment is a constituent component in a bigger brain-body-environment cognitive system

Embodiment and body augmentation

Extendable body schema [Sato, Iizuka, Ikegami 2013]

“Bodies are not constant”
“The interaction defines the body”

Florentin Wörgötter

A. Clark and D. Chalmers. The Extended Mind. Analysis, 58:10–23, 1998.

Distributed Cognition

Cognitive processes can be distributed across
a group of individuals in a social group

It can involve coordinated interaction between those individuals and elements of their environment

Distributed over resources, space, and time

Social organizations are cognitive

E. Hutchins. Cognition in the Wild. MIT Press, Cambridge, MA, 1995.

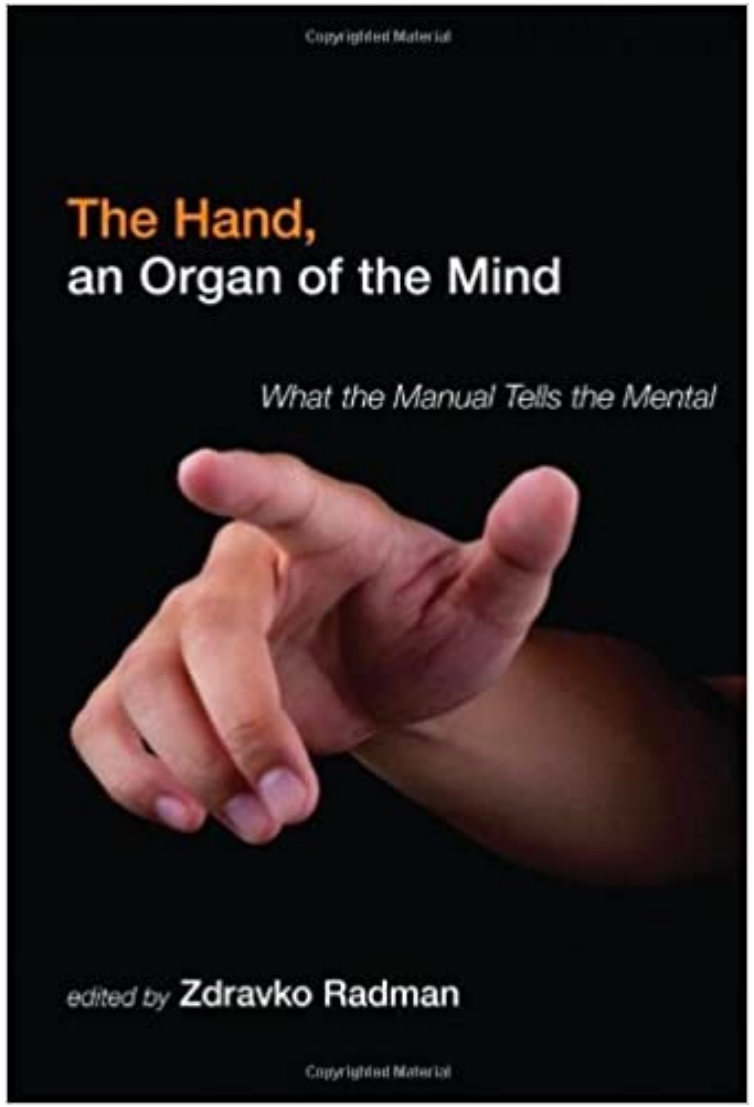
Cognition	Necessary Constituents	Typical Characteristics
Embodied	Depends on interpretation	Body and brain are both constitutive elements of the cognitive process
Situated	Brain	Real-time interaction with the environment
Embedded	Brain, body	Exploit the environment and other agents to assist with cognitive activities
Grounded	Brain and body	Experiential modal representations and internal simulation
Extended	Brain, body, environment	Environment is part of the cognitive system
Distributed	Brain, body, environment	Cognitive systems include environmental systems

Recommended Reading

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

W. R. Klemm, “Why Writing by Hand Could Make You Smarter”

https://www.psychologytoday.com/intl/blog/memory-medic/201303/why-writing-hand-could-make-you-smarter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The Hand,
an Organ of the Mind
What the Manual Tells the Mental
edited by Zdravko Radman
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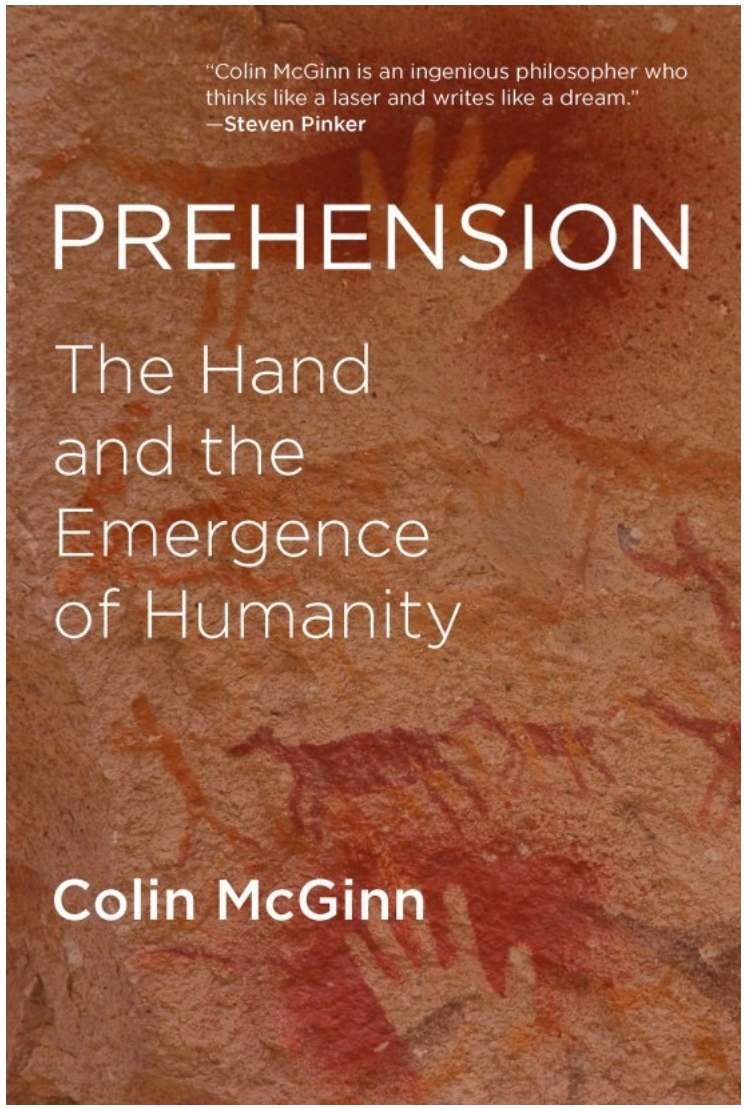
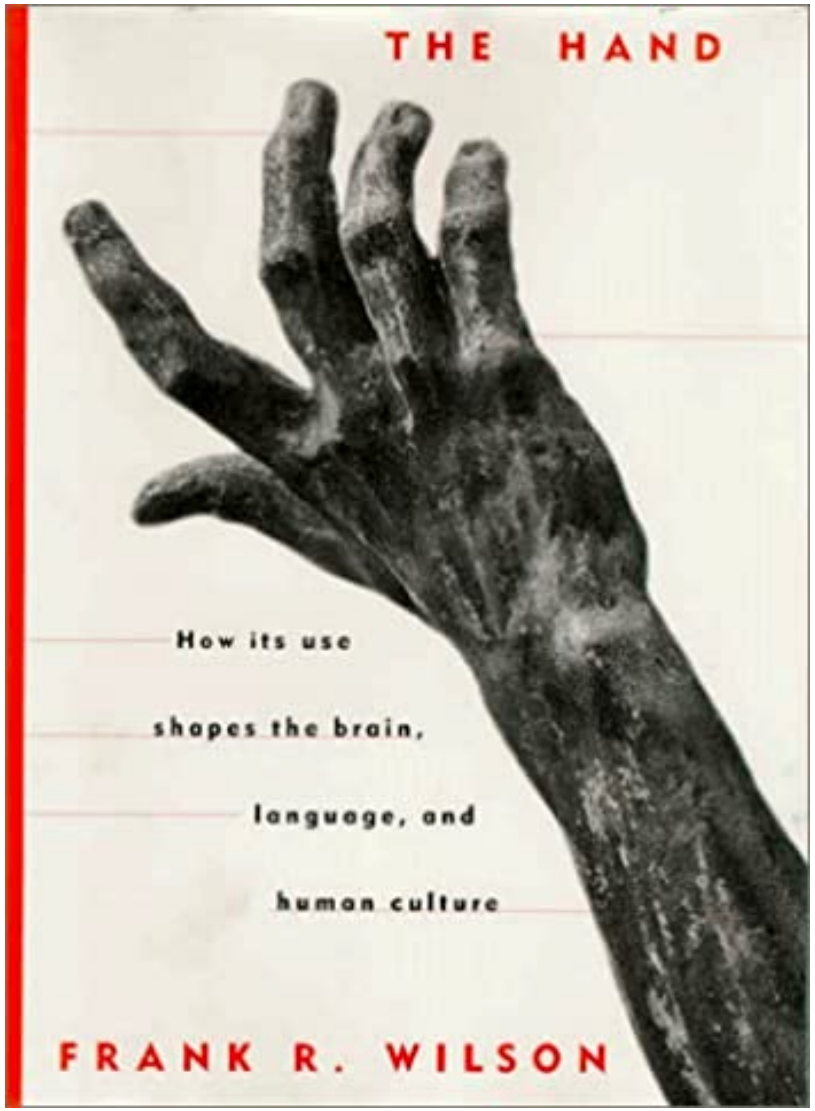

"Colin McGinn is an ingenious philosopher who thinks like a laser and writes like a dream."
—Steven Pinker
PREHENSION
The Hand and the Emergence of Humanity
Colin McGinn


THE HAND
How its use shapes the brain, language, and human culture
FRANK R. WILSON