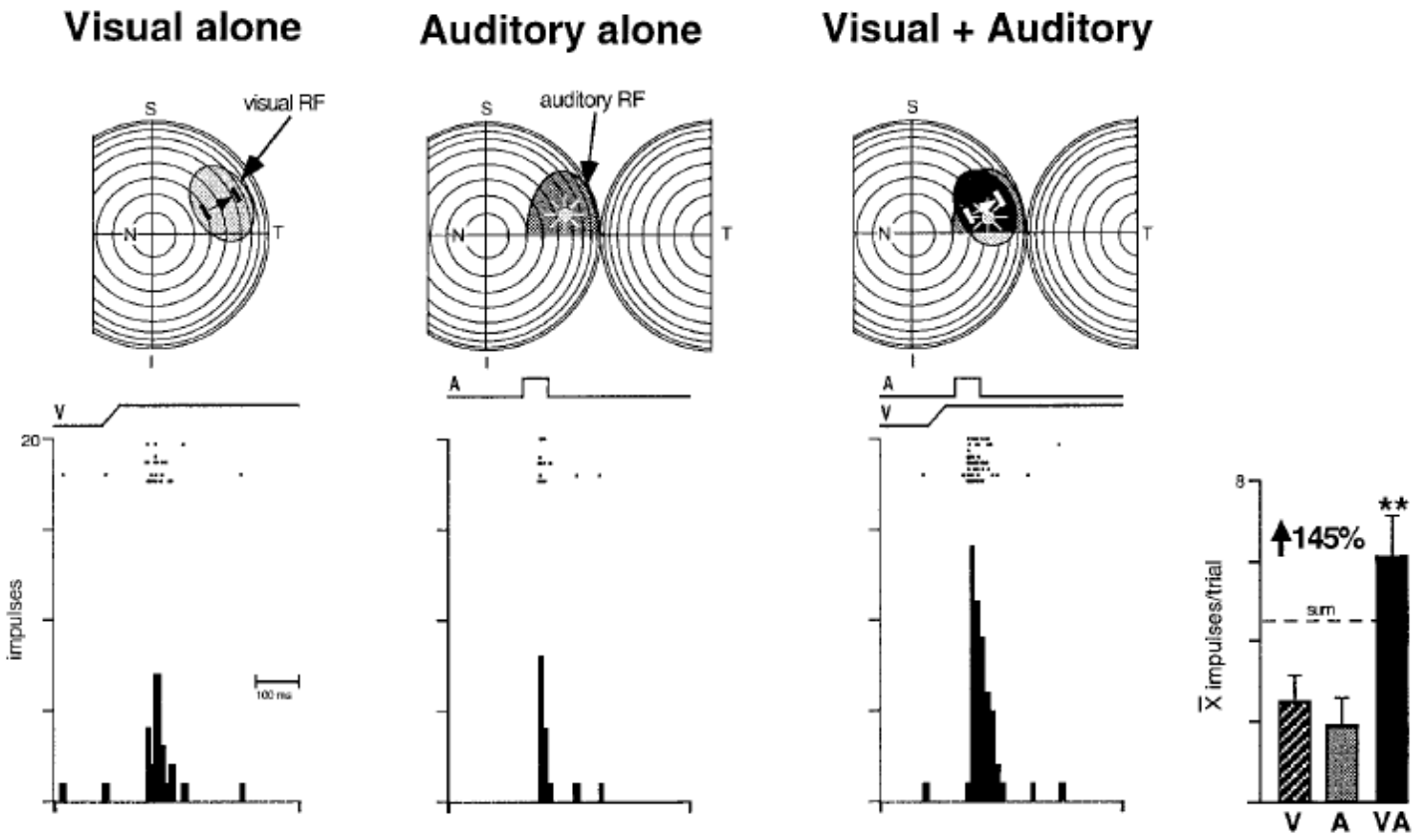
Cogs500/CmpE489: Cognitive Science

Embodiment

Slides adapted from Albert Ali Salah

Multisensory enhancement



Wallace and Stein, 1996

Principle of information fusion

- Why should we fuse?
  - To increase robustness
  - To improve accuracy
  - To cope with missing information
  - To speed up processing
  - To transfer knowledge across modalities

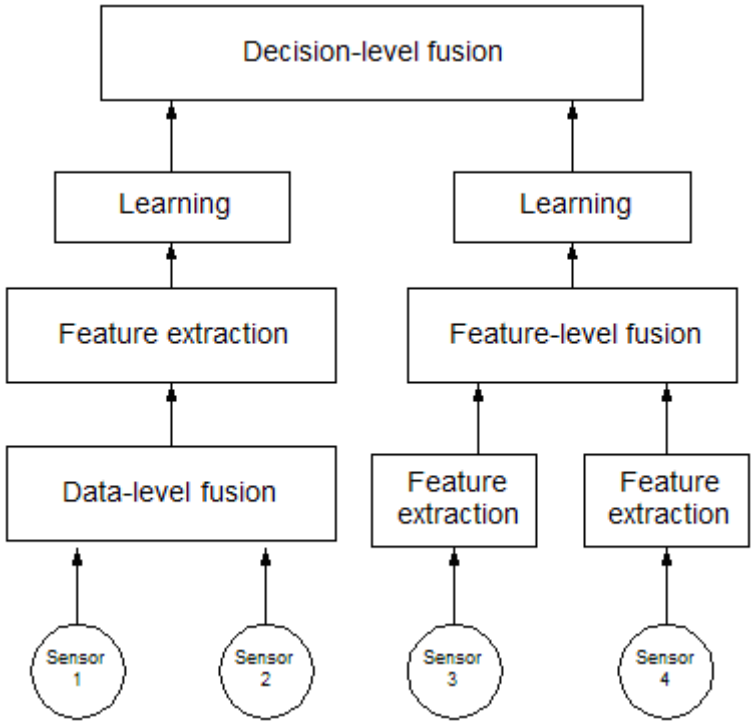
Multiple sensor systems

- *Complementary sensors*:
  - Operate independently, and produce complementary information.
  - The eye and the ear are complementary sensors.
- *Competitive sensors*:
  - Measure the same phenomenon
  - Fusing the output lowers *expected measurement error*.
  - Pressure sensors closely placed in a finger are an example
- *Cooperative sensors*:
  - Sometimes, a single sensor is not enough to measure a phenomenon
  - Depth perception is achieved with two eyes.

Perceptual processing in computers

- Perceptual function
- Perceptual learning
- Models
  - Parametric models
  - Non-parametric models
- Noise resilience

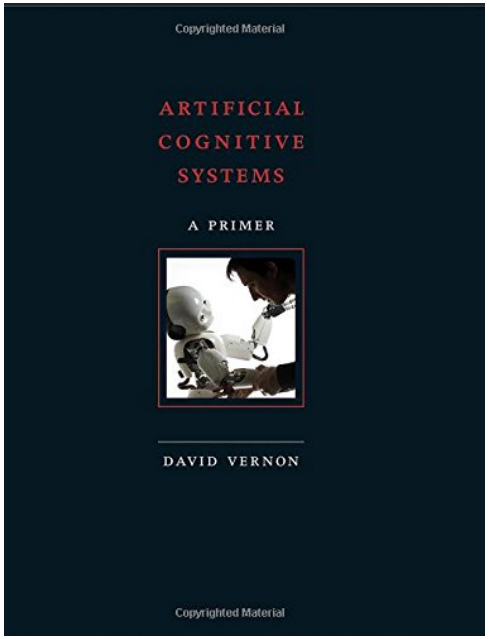
Information fusion



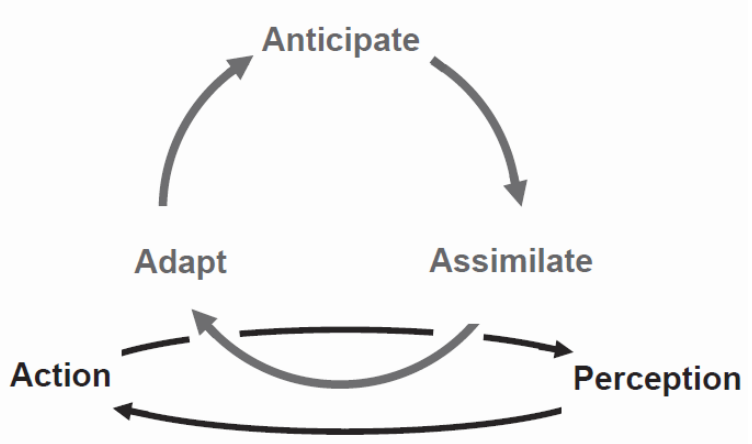
- Feature normalization
- Multidimensionality
- Feature extraction vs selection
- Curse of dimensionality
- Diversity

Cognition

Cognition “can be viewed as a process by which the system achieves robust, adaptive, anticipatory, autonomous behavior, entailing embodied perception and action.” (Vernon et al. 2007)



Cognition is the process by which an autonomous system perceives its environment, learns from experience, anticipates the outcome of events, acts to pursue goals, and adapts to changing circumstances (2014)



Good old fashioned AI (GOFAI)

- Physical symbol systems hypothesis (Newell, Simon, 1972)
  - Thinking is symbol manipulation
  - Machines can be intelligent
- What is a symbol system?
  - Logic
  - Algebra
  - Languages

Problems of GOFAI

- The commonsense knowledge problem (Dreyfus 1991)
  - Today was Jack's birthday. Penny and Janet went to the store. They were going to get presents. Janet decided to get a kite. "Don't do that," said Penny. "Jack has a kite. He will make you take *it* back."
- The frame problem (McCarthy & Hayes 1969)
- The symbol grounding problem (Harnad 1990)

The Frame Problem

- Initially: The problem of expressing a dynamical domain in logic without explicitly specifying which conditions *are not* affected by an action. (McCarthy and Hayes)
- Later: The problem of limiting the beliefs that have to be updated in response to actions.

The Symbol Grounding Problem

- How do words get their meanings?

- ...
- What IS meaning?

Embodied Cognition

- The only way to understand the mind, and how it works is to consider the body and what helps the body and mind to function
- Tools and work materials are not just stimuli for a cognitive system, but at times, they become part of the system itself
  - A blind person's cane is part of his/her world
  - A cell biologist's microscope is a central part of the way they view the world
- A tool can be integrated in the way people think, see, and control activities and part of the distributed system of cognitive control

Comprehension affects the dynamics of control

- Language comprehension in that word meaning is hypothesized to be grounded in sensorimotor systems
- Predict interaction between concurrent motor and language tasks when the two draw on the same sensorimotor representations.
- Most research in this domain tests this prediction.
- Experiment?

Comprehension affects the dynamics of control

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- Most research in this domain tests this prediction.
- Glenberg and Kaschak (2002)
  - Judgements about the plausibility of sentences that implied a direction of movement with respect to themselves (e.g., Liz told you the story; You told Liz the story).
  - Responses required participants to move their hands either toward or away from their bodies.
  - Movements were initiated more quickly when the direction of movement implied by the sentence matched the response direction than when it did not.

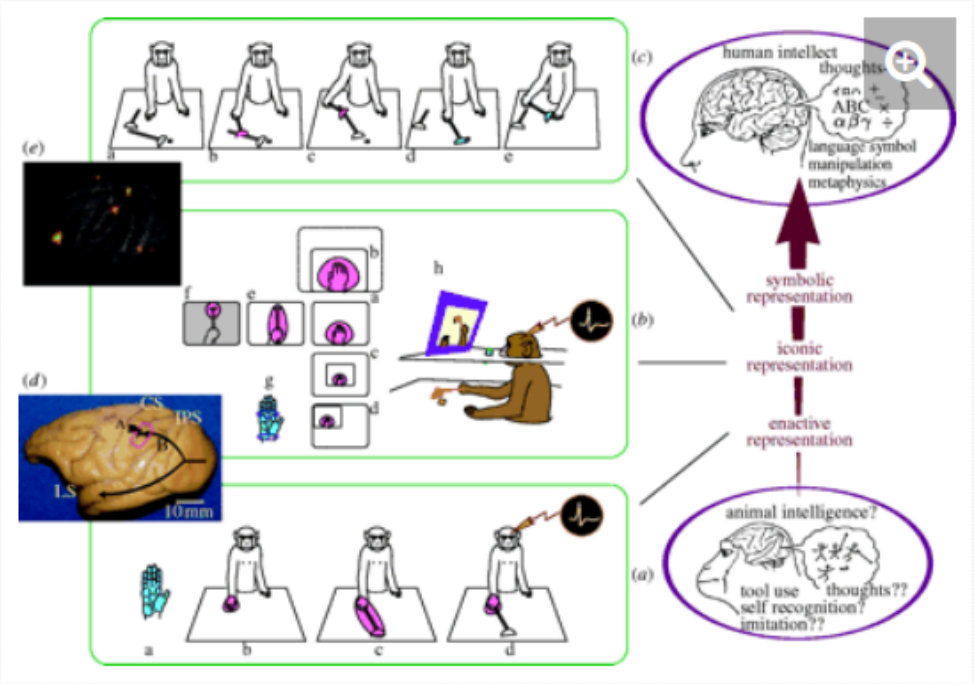


Figure 1

(*a*–*c*) Various modes of cortical body image codings, corresponding to putative hierarchy of internal representations (on the right, see also text). (*a*) When monkeys use a rake to retrieve distant food, the visual receptive field (b), encompassing the somatosensory receptive field (a), of a representative intraparietal bimodal neuron extended along the rake (c) when using, but did not (d) when not using it. (*b*) When monkeys use a monitor (experimental set-up shown in h), a visual receptive field of representative intraparietal bimodal neuron was formed around the hand in the monitor (a) encompassing its somatosensory receptive field (g). The visual receptive field altered to match the modified appearance of the hand in the monitor (b–d), extended along the rake when used under the monitor (e), and was confined around the tip of the rake once the image was blotted out except for the tip (f). (*c*) Combinatory usages (sequentially from a to e) of short and long rakes. (*d*) The left hemisphere of a monkey brain, with arrows A and B indicating somatosensory and spatial visual processing pathways that merge at the intraparietal area indicated by the red square where neurons were recorded. CS, central sulcus; IPS, intraparietal sulcus; LS, lateral sulcus. (*e*) Brain activation pattern for sequential combinatory tool usages, showing prefrontal in addition to parietal activation. (*a*–*c* and *e*, Adapted with permission from **Maravita & Iriki 2004**).

Embodied Cognition – Embodied AI systems

Conceptions of embodied cognition

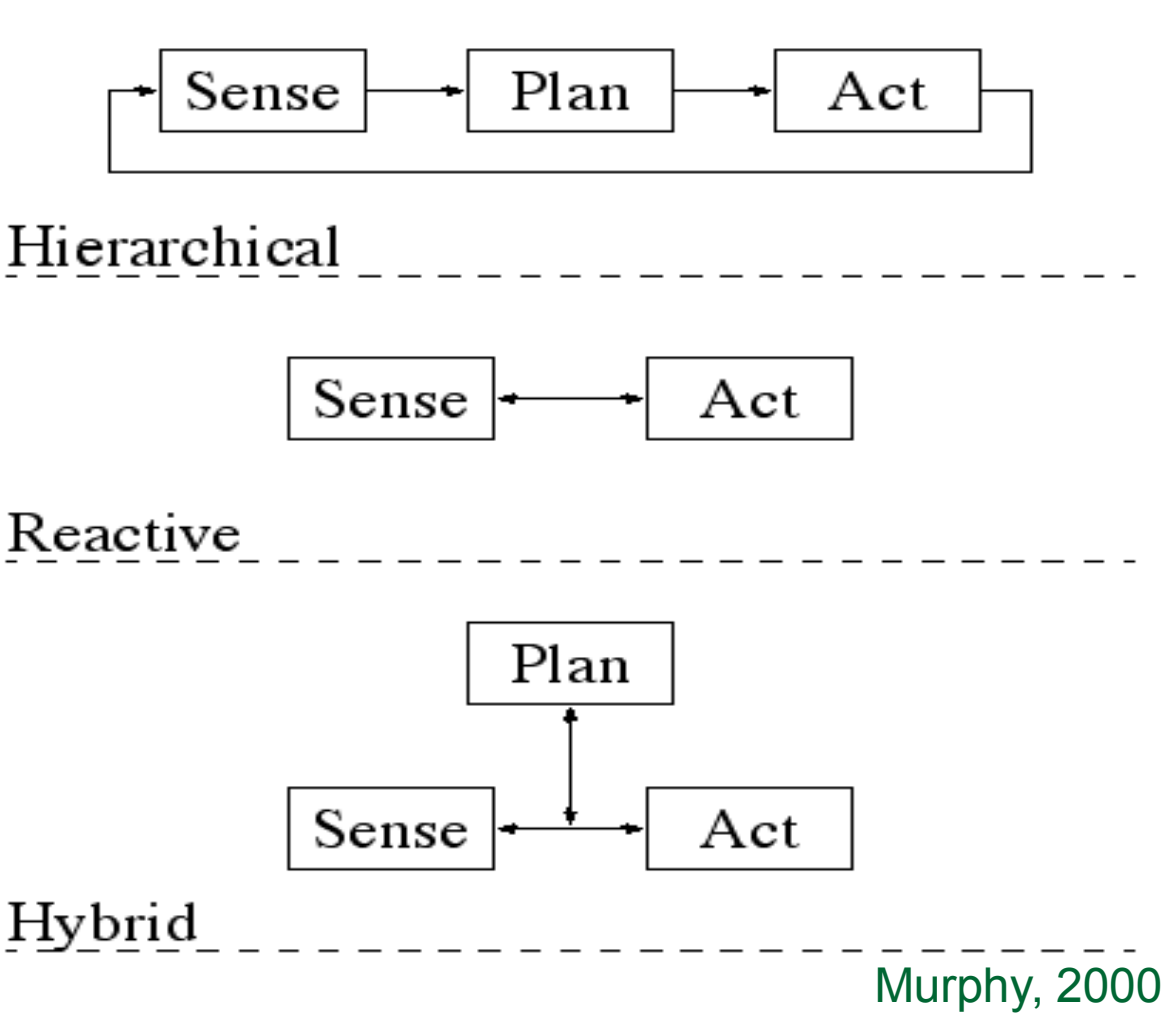
- Structural coupling (Maturana & Varela)
  - coupled relationship between agent and environment
- Historical embodiment (Varela, Thompson, Rosch)
  - a history of structural coupling
- Physical embodiment (Brooks)
  - physical instantiation
- “Organismoid” embodiment (Lakoff & Johnson)
  - an organism-like body
- Organismic embodiment (von Uexküll, Maturana & Varela)
  - only biological living(!) bodies

Ziemke, 2003

Robots

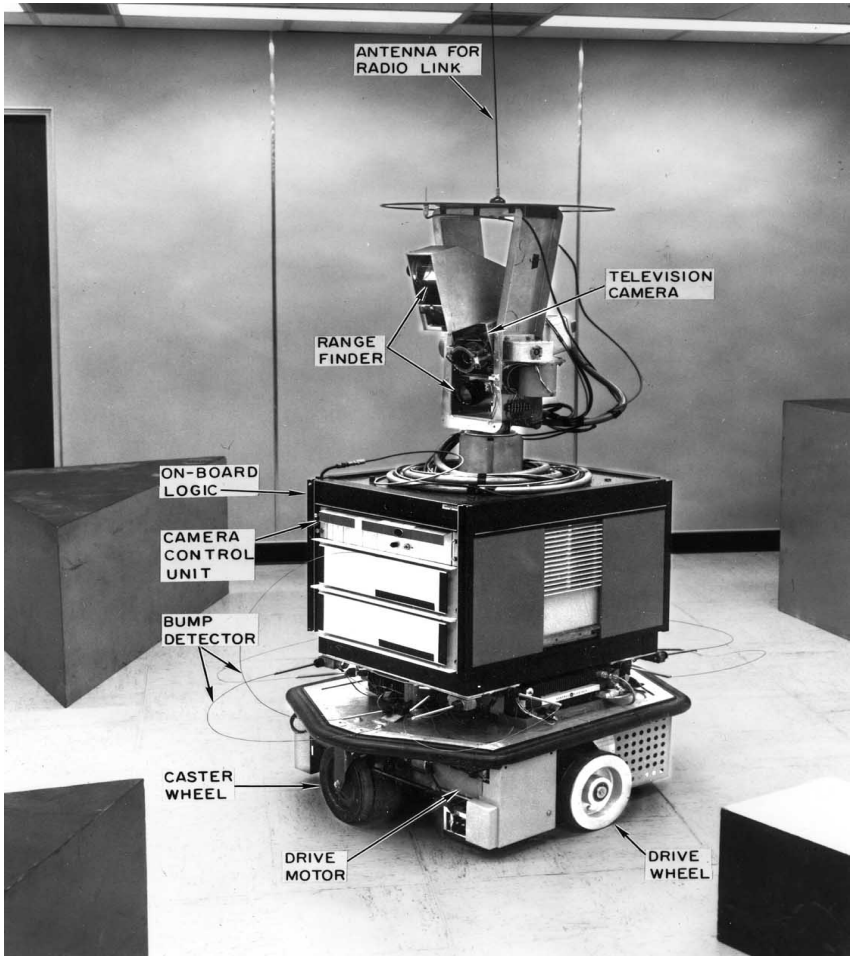
- Definition: “A machine capable of carrying out a complex series of **actions automatically**.“
- Sensors
- Actuators
  - Joints (DoF)
  - Limbs
- Mobile robots
- Planning & action selection

Robot architectures



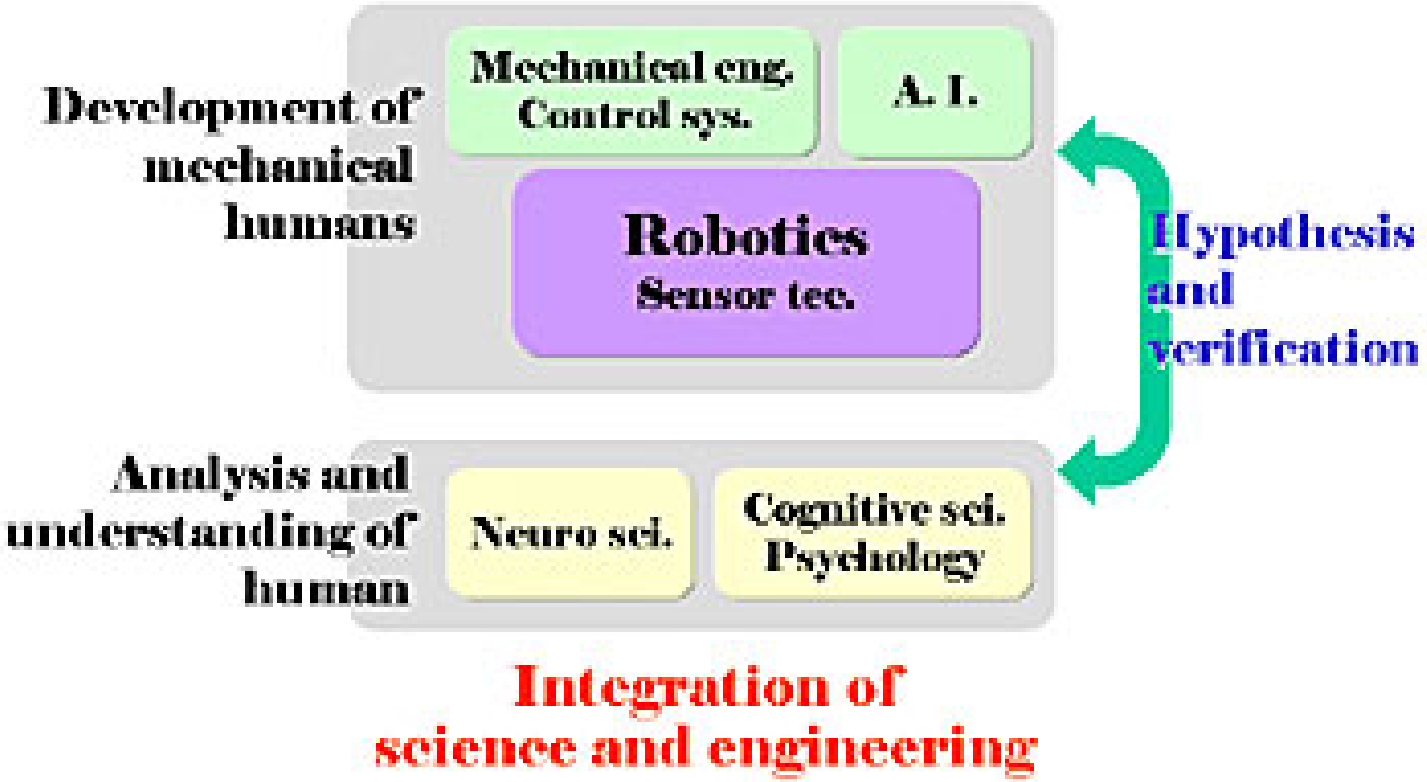
Murphy, 2000

SRI's Shakey



http://www.ai.sri.com/shakey/

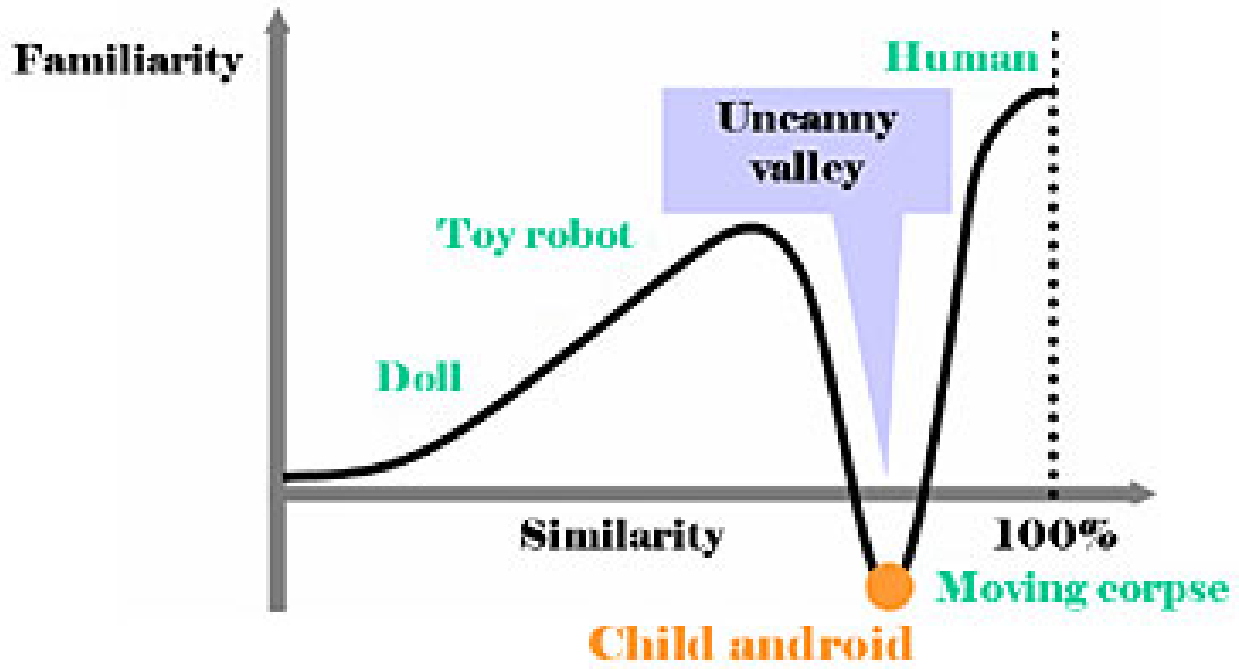
Swarm systems



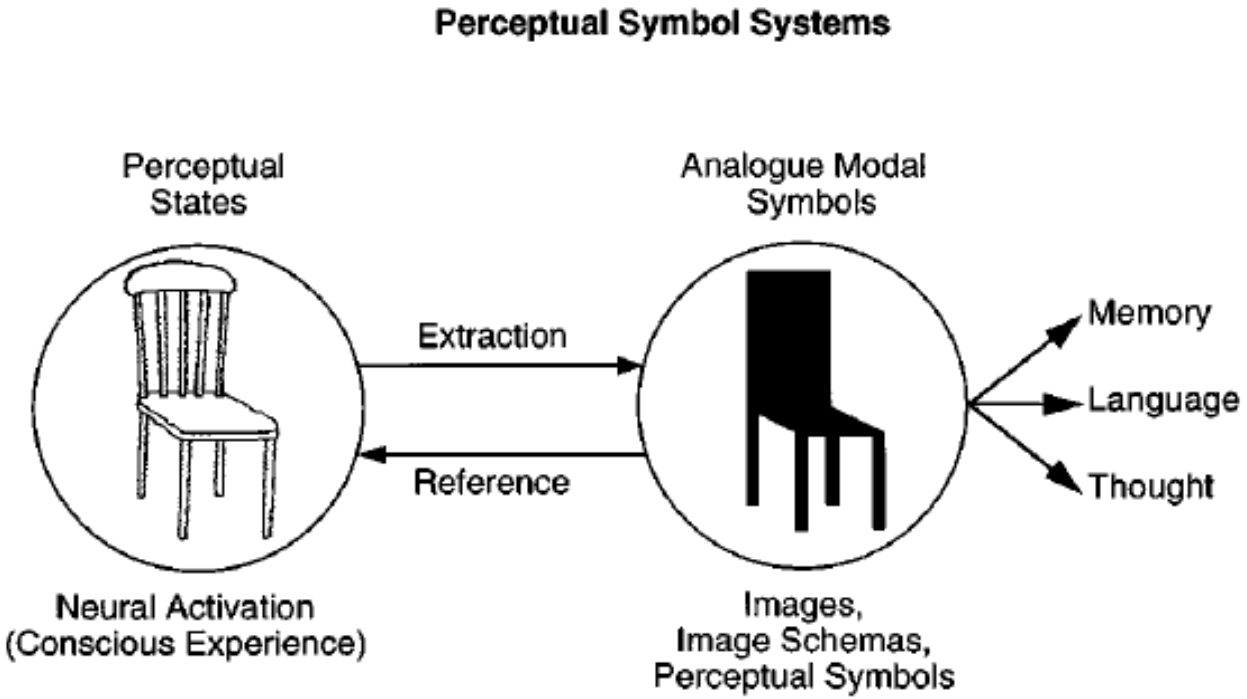
Do androids dream of electric sheep?

Child android

Uncanny valley



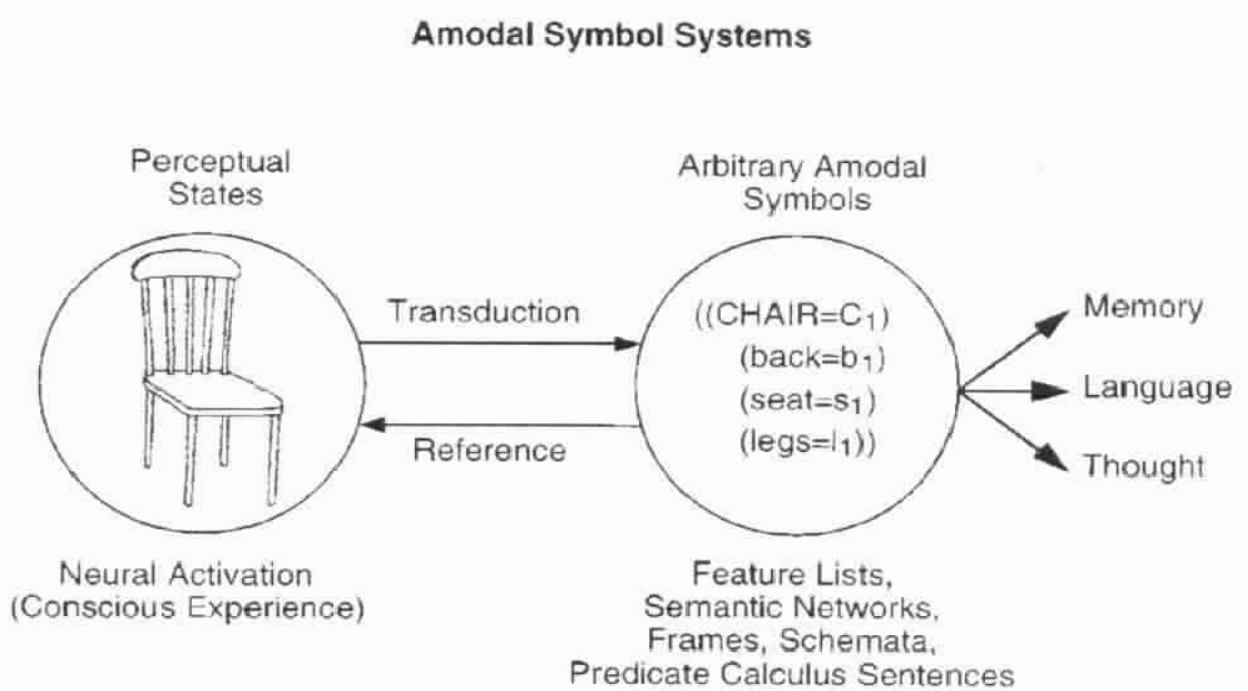
Perceptual symbol systems – Barsalou



Subsets of perceptual states in sensory-motor systems are extracted and stored in long-term memory to function as symbols. As a result, the internal structure of these symbols is modal, and they are analogically related to the perceptual states that produced them.

Barsalau, 1999

Perceptual symbol systems – Barsalou



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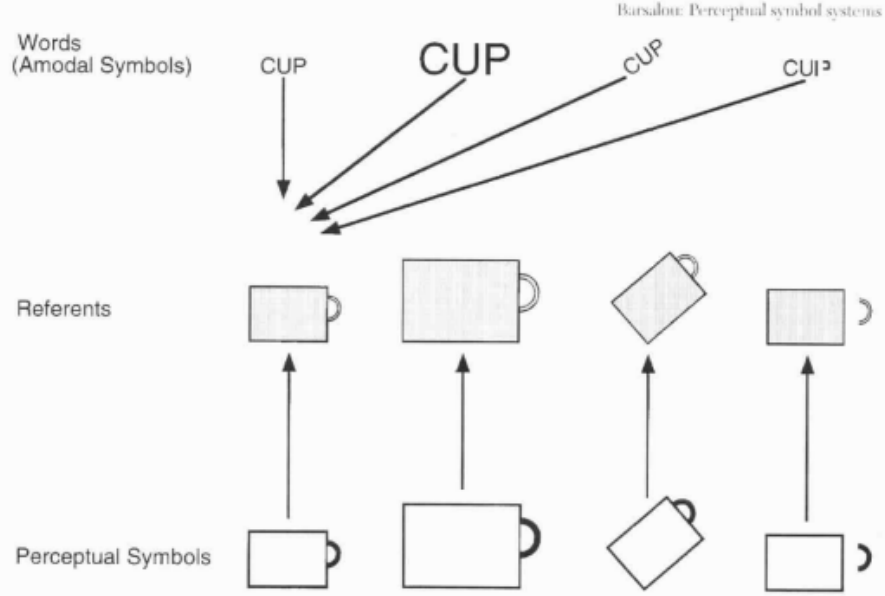

Figure 6. An example of how transforming a word or an amodal symbol fails to produce an analogous transformation in reference, whereas transforming a perceptual simulation does.

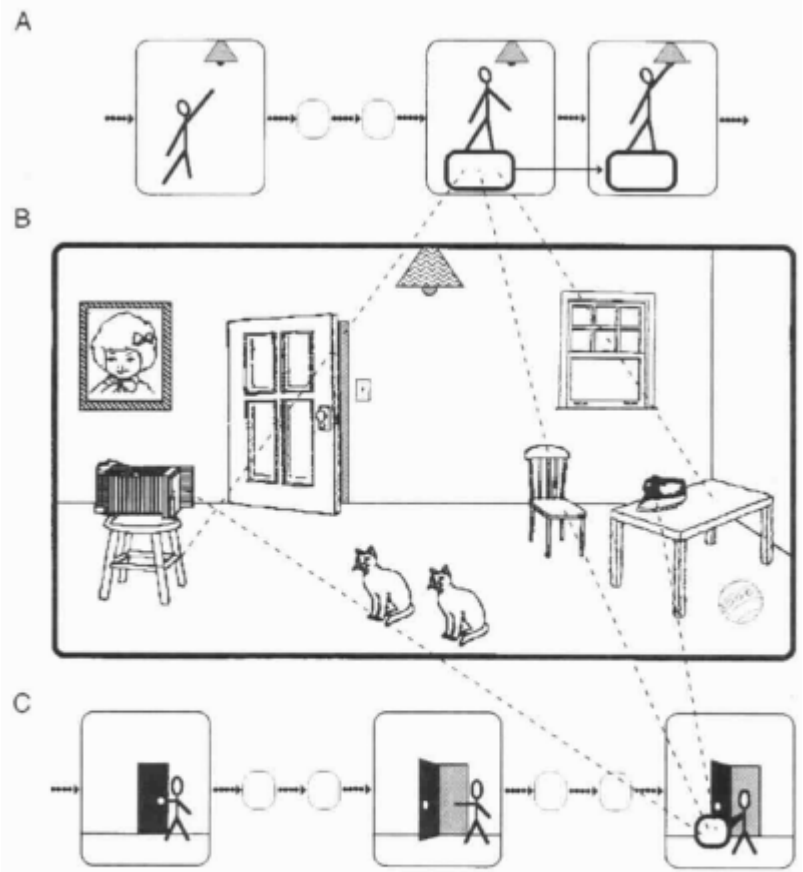

Figure 9. Accounting for the ad hoc categories of *things to stand on to change a light bulb* (A) and *things that could prop a door open* (C), which construe common entities in the same scene differently (B).

Common coding theory

- What is the link between perception and action?
- Sense-plan-act=perception+cognition+action
- Common coding theory:
  - there is a shared representation (a common code) for both perception and action
  - seeing an event activates the action associated with that event,
  - performing an action activates the associated perceptual event.

Mirror neurons

- Canonical neurons:
  - respond to the presentation of an object
- Mirror neurons:
  - respond when the monkey sees object-directed action (Rizzolatti, Craighero, 2004)
- Functional role of mirror neurons:
  - mirror-neuron activity mediates imitation (Jeannerod 1994)
  - mirror neurons are at the basis of action understanding (Rizzolatti et al. 2001)

An experiment in cross-modal classification

- Subjects listened to the sounds of hand actions (e.g. ripping paper) and mouth actions (e.g. crunching food) as well as control sounds (e.g. water dripping)
- The mouth and hand action execution tasks were performed after the auditory task and without prior warning, to avoid subject focus on performing movements while listening to the sounds.
- The ROIs were chosen based on simulation theory-derived hypotheses prior to analysis;

Etzel et al., 2008

An experiment in cross-modal classification (continued)

- SVM classifiers trained, within-subject manner.
- Classifiers are trained on **auditory data,** but tested on **execution data (separating whether the subject executed hand or mouth action)**
- The null hypothesis: there is no relationship between the test data class labels (mouth or hand) and the voxel activity pattern
- Of the ten ROIs, significant (p,0.005) cross-modal classification was possible only using the left and right premotor cortex

Etzel et al., 2008

Selected References

- Ziemke, What's that Thing Called Embodiment? 2003
- Calvo & Gomila, "Handbook of cognitive science", 2008