Grounded cognition

Motor cognition and mental simulation

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Guiding questions

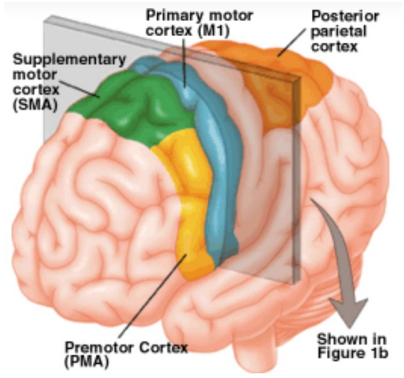
1. What is the nature of motor cognition?
2. What is a mental simulation of action?
3. Why and how do we reproduce the actions of others?
4. What is the role of motor cognition in perception?

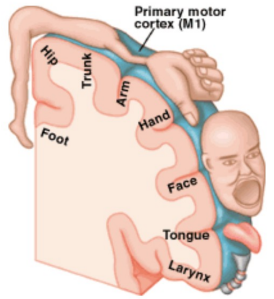
Smith A.H. (2006) Motor cognition and mental simulation. Chapter in Smith E. & Kosslyn S. (eds.): *Cognitive Psychology: Mind and Brain*, Prentice Hall, pp. 451-481.

1. What is the nature of motor cognition?

- **Motor cognition** is mental processing in which the motor system draws on stored information to plan and produce our own actions, as well as to anticipate, predict, and interpret the actions of others.
- Movement vs action
- Perception-action cycle (coupling) – shared representation
- Concept of **shared motor representations** refers to our ability to mentally represent actions made by other people.

Brain areas involved in motor cognition





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M1 – fine motor control (+cerebellum), PM – setting up programs for specific sequences of actions (to M1), SMA – setting up and executing action plans. Highly overlapping, rather than sequential.

2. Mental simulation of action

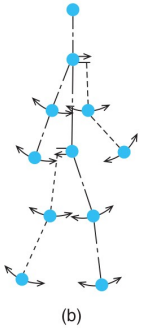
- Motor imagery – highly overlaps with motor execution
  - has a positive effect on subsequently performing that action (Feltz & Landers, 1983).
- Motor priming
  - the effect whereby watching a movement or an action facilitates making a similar motor response oneself.
  - evidence: e.g. discs (Kerzel et al., 2000); hand/robotic actions (Castiello et al., 2002)
- Motor program, motor anticipation, readiness potential (in SMA)
- relationship between imagining own actions and anticipating seeing someone else's actions (Ruby & Decety, 2001): shared + self-other distinctive activations found

3. Imitation

- Mimicry vs imitation
- Inborn and learned components (Piaget, 1953; Meltzoff and Moore, 1977), including emotions
  - What can infants imitate?
- Humans can imitate both meaningful or meaningless actions, different circuits used
  - top-down component (purpose of observing)
  - difference in apraxia
- Simulation theories of action understanding (debate)
  - neural correlates of self-other distinction, forward models
- Mirror neurons and self–other mapping

4. Biological motion

- Perception of biological motion – via kinematic patterns
- Motor knowledge guides mental simulations (exper. with infants)
- STS involved (Grèzes et al., 2001; Grossman & Blake, 2001)
- Apparent motion (relies on tacit motor knowledge)



(b)

Neural simulation of action theory

(Jeannerod, 2001)

- Covert and overt actions – differences
- Simulation theory: covert actions are actions, not executed
- Covert actions are neurally simulated actions
- Imagined actions – retain the same temporal characteristics as the corresponding real action when it comes to execution (Decety et al., 1989).
- Observed actions – putting oneself "in the shoes of the agent."
- S-states – "mental" states with action content
- Activation of the motor system is a prerequisite for simulation theory
  - Areas involved: primary motor cortex, premotor cortex, corticospinal pathway, basal ganglia, cerebellum

Taxonomy of S-states

Type of S-state	Degree of awareness
Intended action	Conscious/nonconscious
Imagined action	Conscious
Prospective action judgements	Nonconscious
Perceptually based decisions	Nonconscious
Observation of graspable objects	Nonconscious
Observation of actions performed by others	Conscious/nonconscious
Action in dreams	Conscious

Brain areas activated during S-states

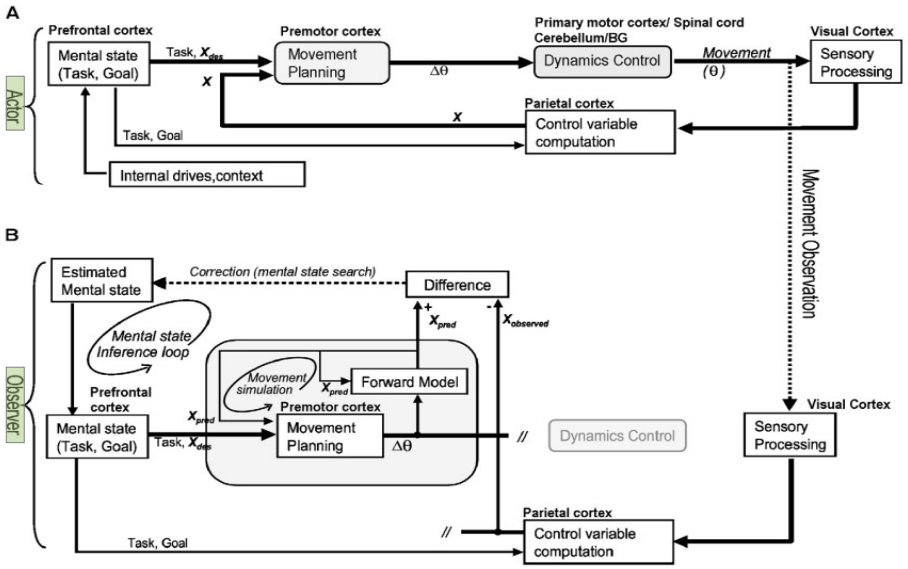
Brain regions and Brodman areas (Ba)	Conditions				
	Execute	Intend	Imagine	Observe actions	Observe objects
Precentral gyrus Ba 4	4, 8, 10, 12, 13		9, 10, 13	15	
Precentral gyrus (dorsal) Ba 6	1, 8, 10, 14		4, 8, 9, 10, 14	5, 9	
Precentral gyrus (ventral) Ba 6	1, 14		4, 14	2, 5	3
SMA (rostral) Ba 6	6, 10, 13		8, 9, 10	5, 9	
Cingular gyrus Ba 24	1, 8, 10, 12, 4	7	4, 8, 10, 14		
Superior frontal gyrus Ba 10			4, 8		
Middle frontal gyrus Ba 9, 46		7	4, 8, 9	5	
Inferior frontal gyrus Ba 44, 45			4, 8, 9	2, 5, 9, 12	11
Inferior parietal lobule Ba 40	1, 6, 10, 12, 14		4, 8, 9, 14	2, 5, 9	3

Note. Brodman areas (Ba) activated during action execution and several different S-states have been listed. Numbers in the table are those of the references listed below. Each time a number appears, it indicates that the authors of the corresponding study have described activation in this particular area during a particular state. 1, Binkofski *et al.* (1999); 2, Buccino *et al.* (2001); 3, Chao and Martin (2000); 4, Decety *et al.* (1994); 5, Decety *et al.* (1997); 6, Faillenot *et al.* (1997); 7, Frith *et al.* (1991); 8, Gerardin *et al.* (2000); 9, Grafton *et al.* (1996); 10, Lotze *et al.* (1999); 11, Perani *et al.* (1995); 12, Rizzolatti *et al.* (1996); 13, Roth *et al.* (1996); 14, Stephan *et al.* (1995); 15, Hari *et al.* (1998).

- Neurophysiological validation of the simulation theory

Mental state inference via visual feedback

Conceptual model - example (Oztop, Wolpert, Kawato, 2005)



Conclusions

- Motor cognition at the core
- The role of simulation in motor cognition:
- S-states at the core of both covert and overt actions
- Self-others distinction possible
- Neural simulation applies not only to one's own actions
- Allowing to predict consequences of actions