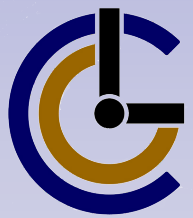
LUND UNIVERSITY



Cognition, Communciation
and Learning

# Internal Simulation as a Key to Cognitive Function

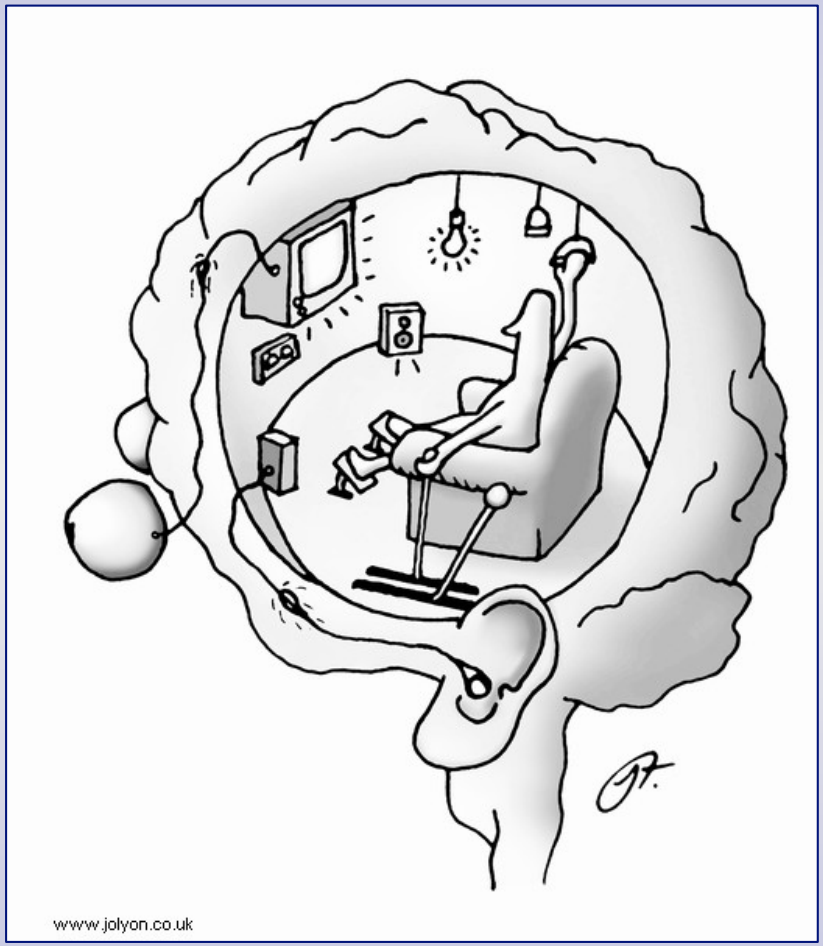
Lund, 2012

Germund Hesslow

# Problems of the inner world

- How does the inner world arise?
- What are mental objects?
- What is the function of the inner world?
- Can animals and robots have inner worlds?

# Cognitivism vs associationism




Homunculus

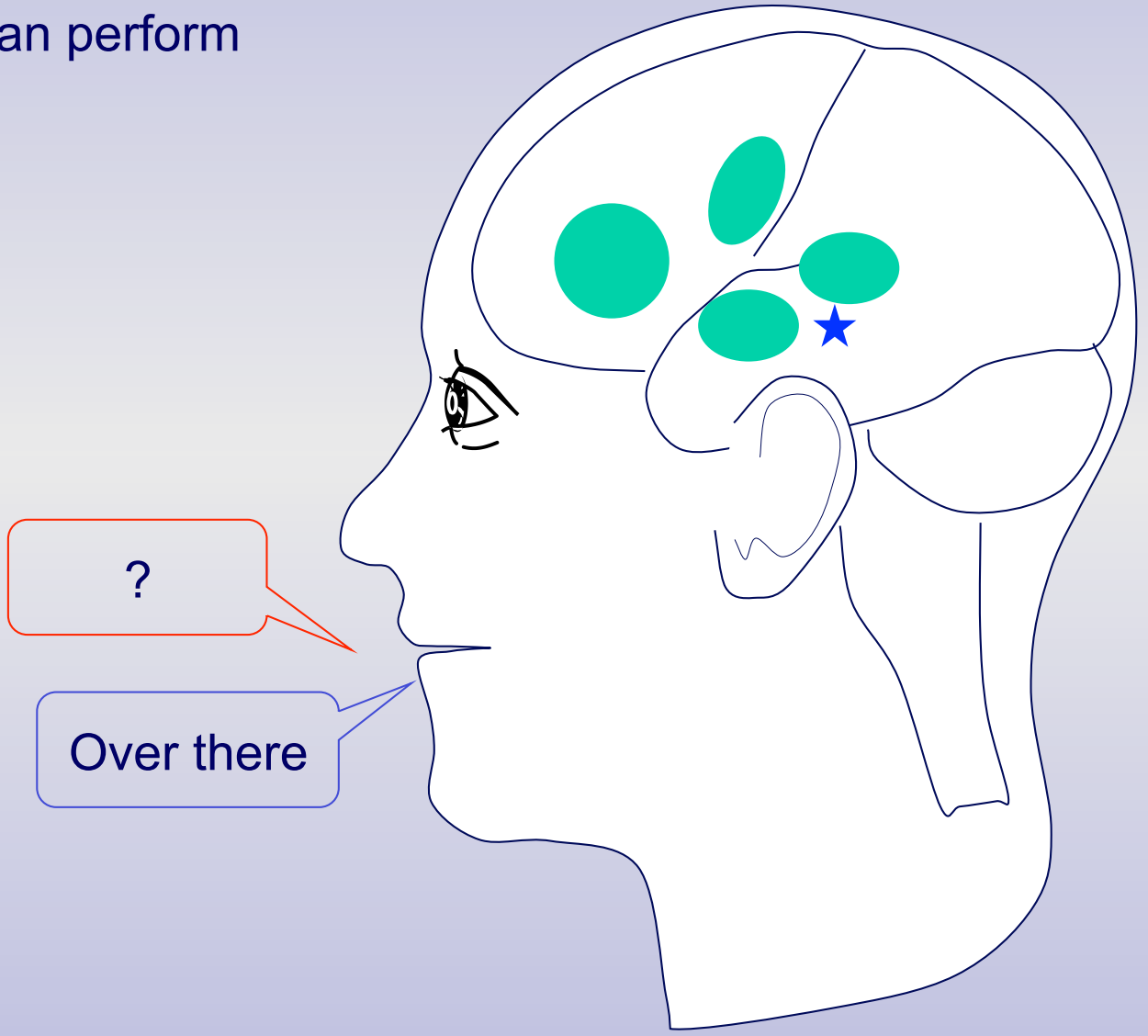
*Cognitivism*:

Representations
Internal models of the world
Knowledge
Information storage
Theory of mind
Understanding

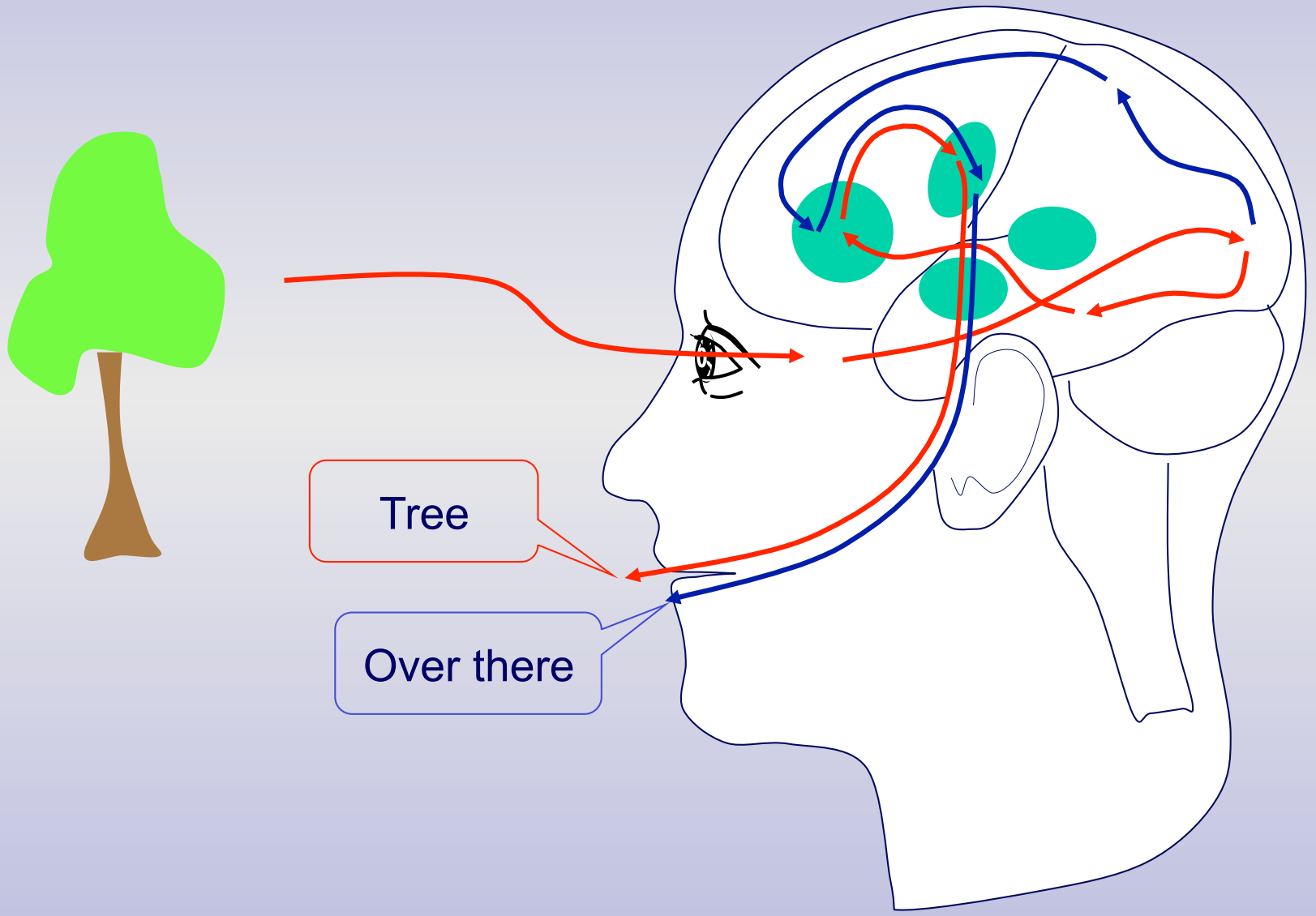
*In short:*
Homunculus theories in a new guise

# Example: how to explain anomia?

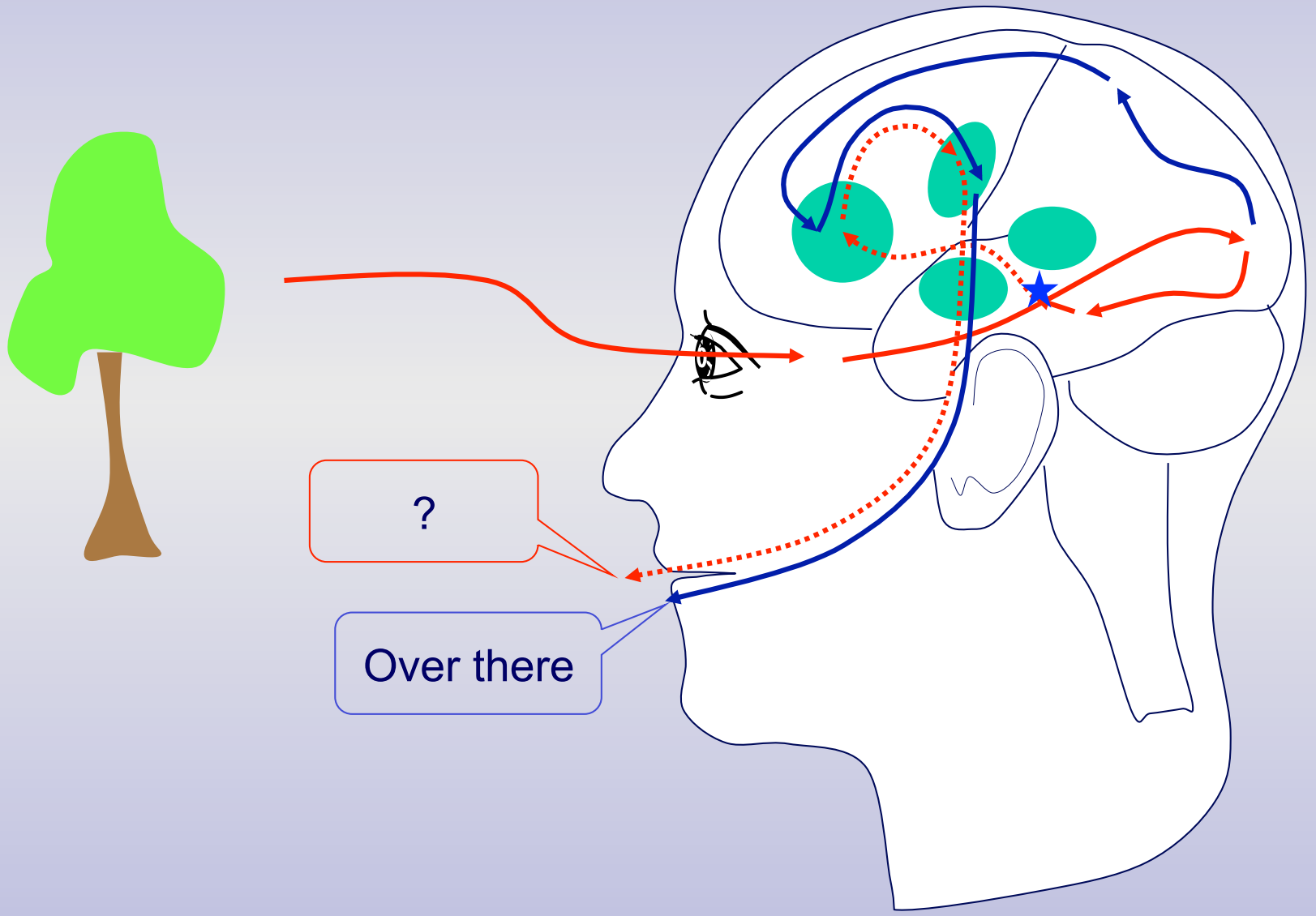
Lesion at ★ patient cannot name object but can perform appropriate action



# Example: how to explain anomia?



# Example: how to explain anomia?

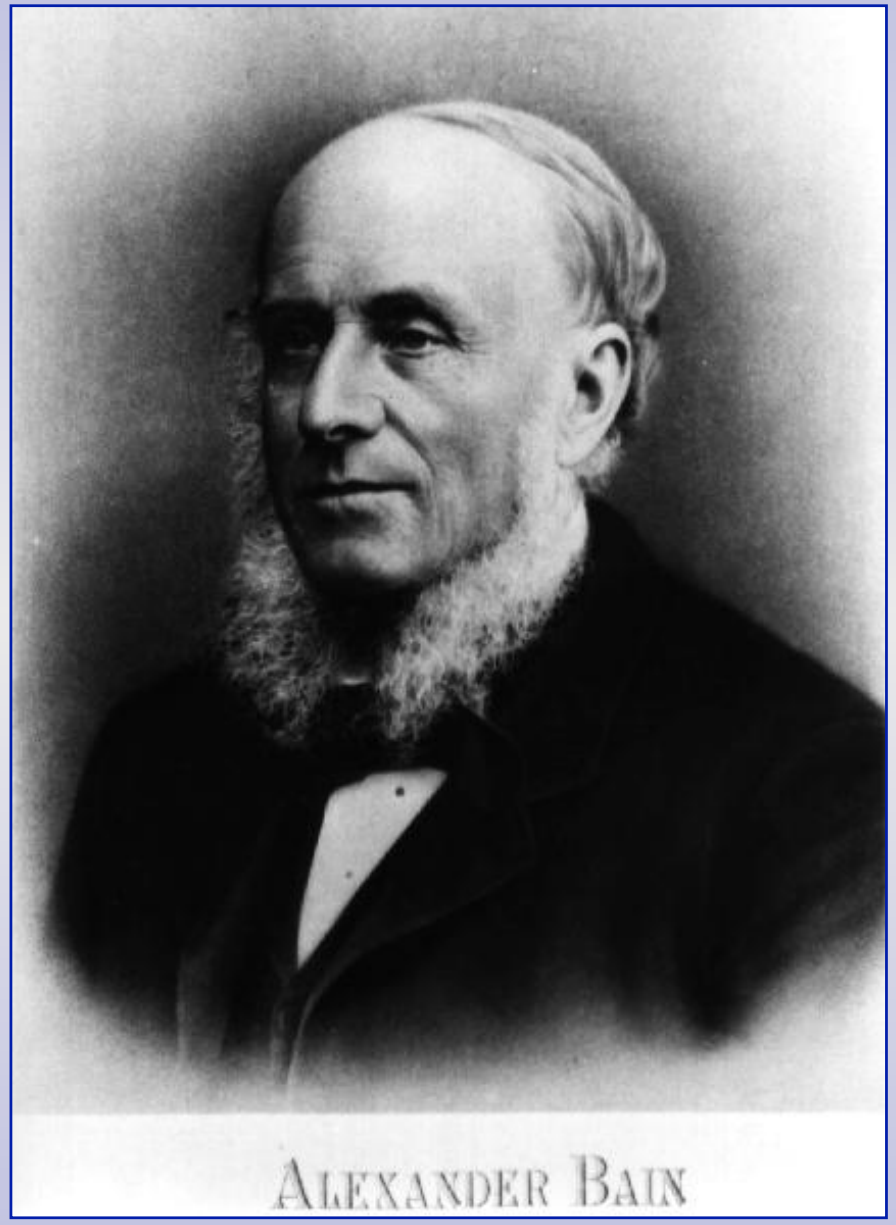


# The Simulation Hypothesis

1) *Behavioural simulation:* early stages of an action can occur without causing overt movement.

2) *Perceptual simulation:* perceptual activity can be elicited within the brain without an external stimulus.

3) *Anticipation:* simulated perception can be elicited by (simulated) behaviour.




# Alexander Bain (1818-1903)

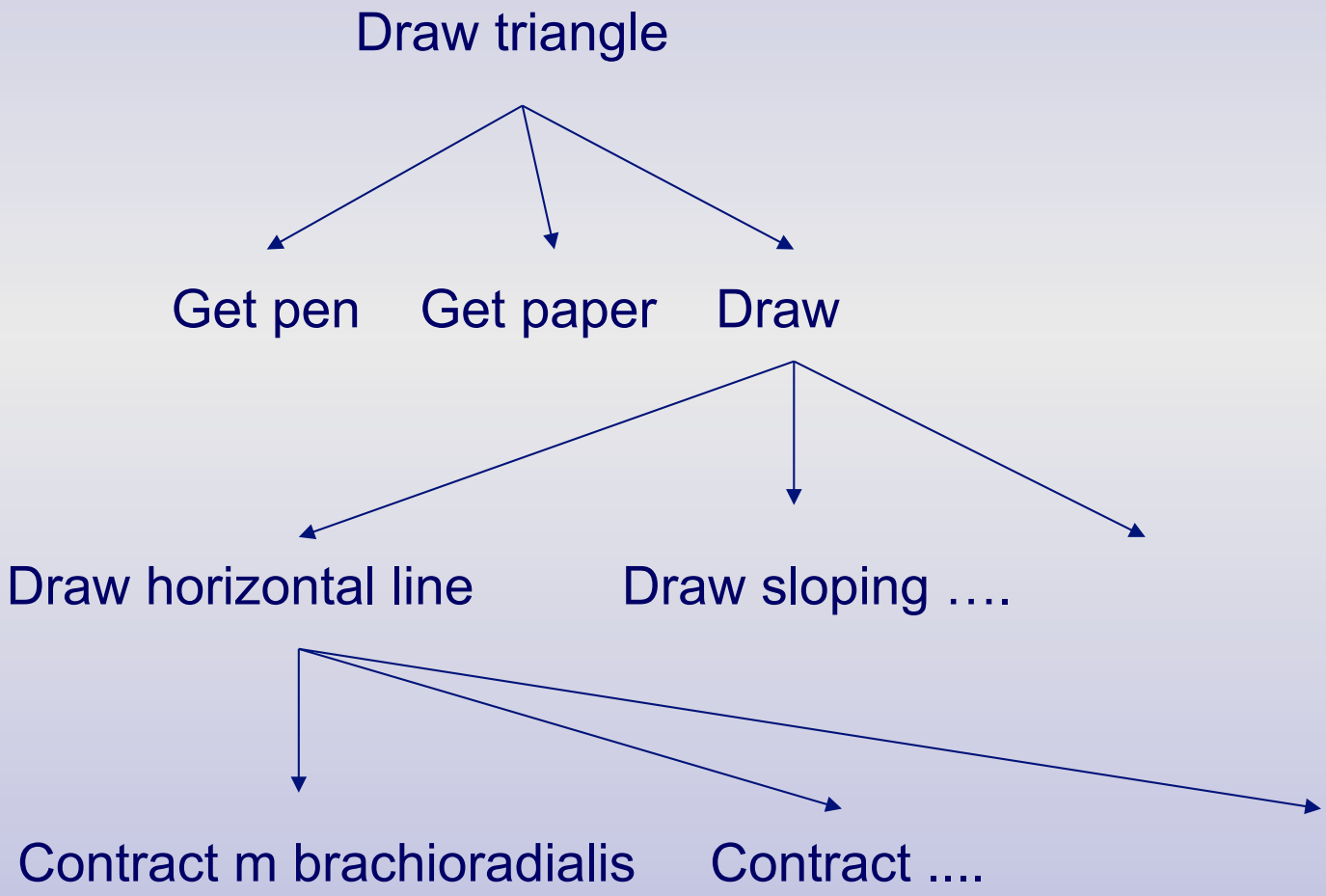
The Senses and the Intellect, 1868

# Simulation of behaviour: covert, incipient behaviour

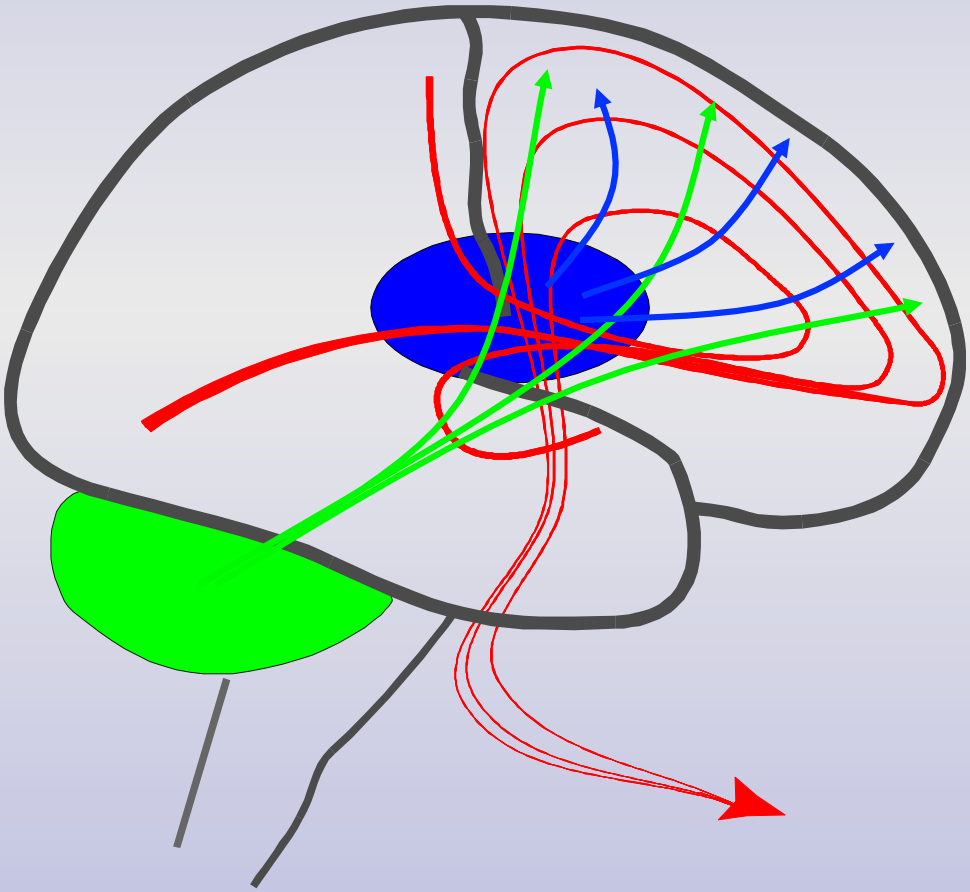
’The tendency of the idea of an action to produce the fact, shows that the idea is already the fact in a weaker form. Thinking is restrained speaking or acting.’ (Bain, 1868 p 340)

*Analogues*:
Have the radio on but the volume turned down.
Have the car engine running but with no clutch

# Hierarchical organisation of action



# Main signal flow



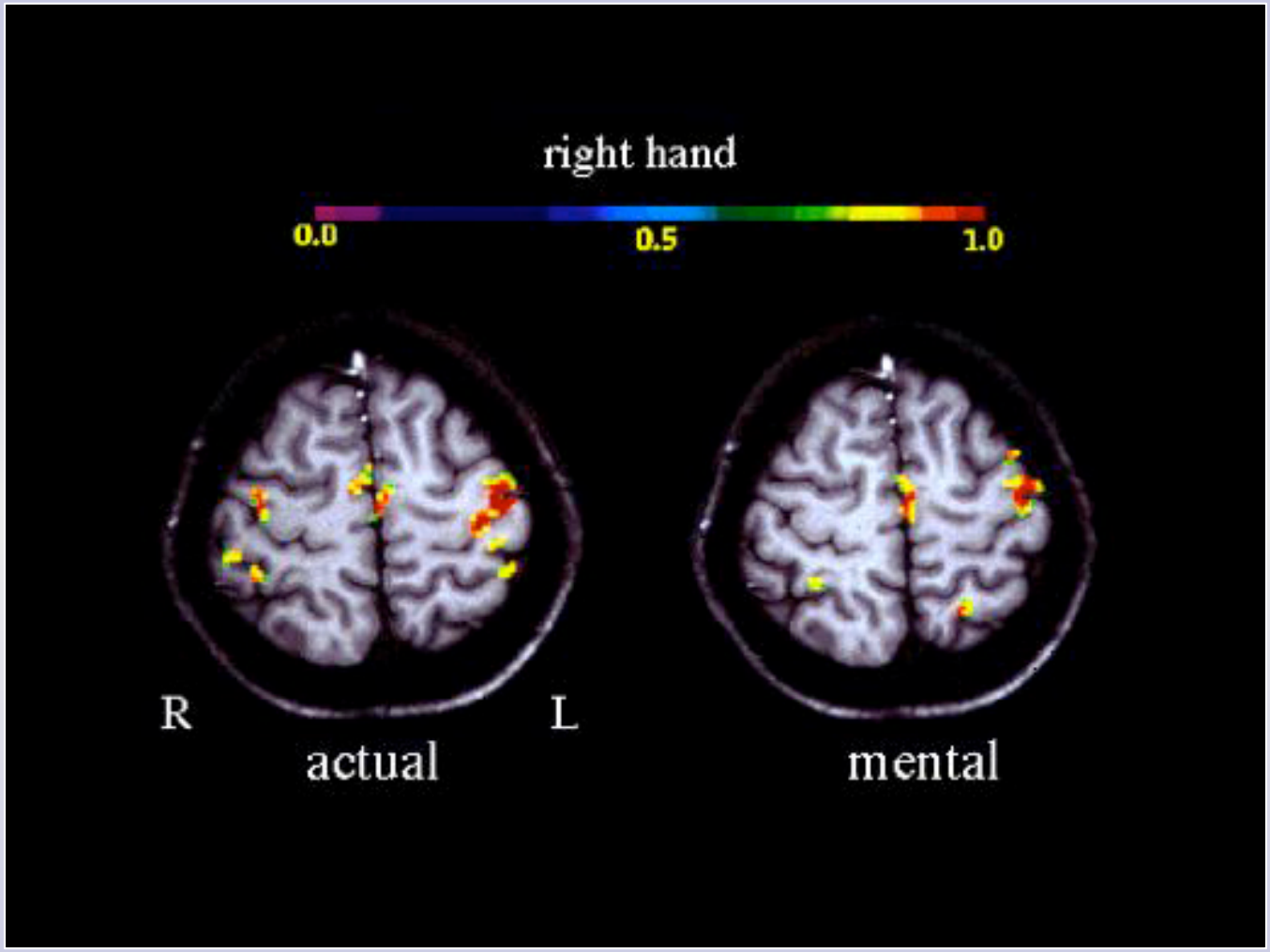
# Evidence for covert behaviour

Behavioural experiments

Imaging studies

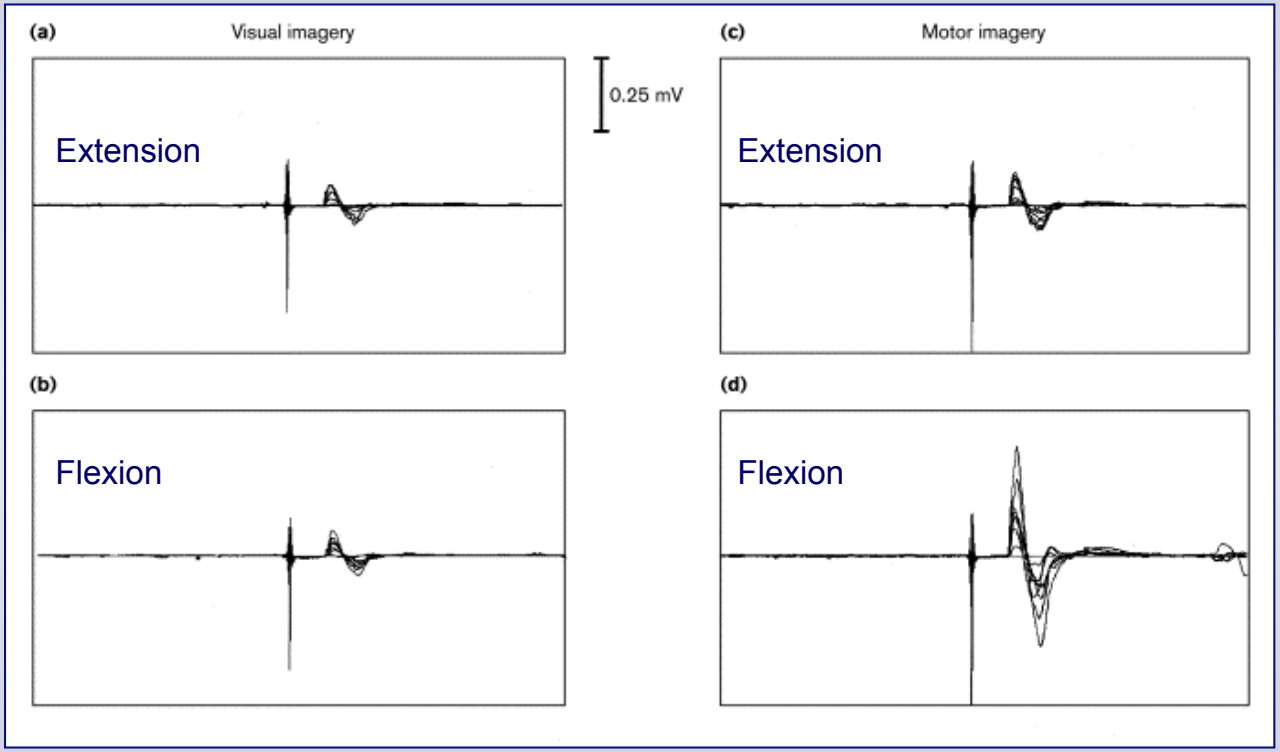
Electrophysiology

# Imaging evidence for covert behaviour




Activation in motor cortex during motor imagery about 30 % of level observed during actual performance; Roth M, Decety J et al. (1996). NeuroRep 7:1280-1284

# Covert behaviour – primary motor cortex




Subjects were instructed to imagine forearm flexion– extension movements with their right arm. TMS was applied to the motor cortex on one side, and the MEPs were recorded from the contralateral flexor muscle (biceps brachialis).

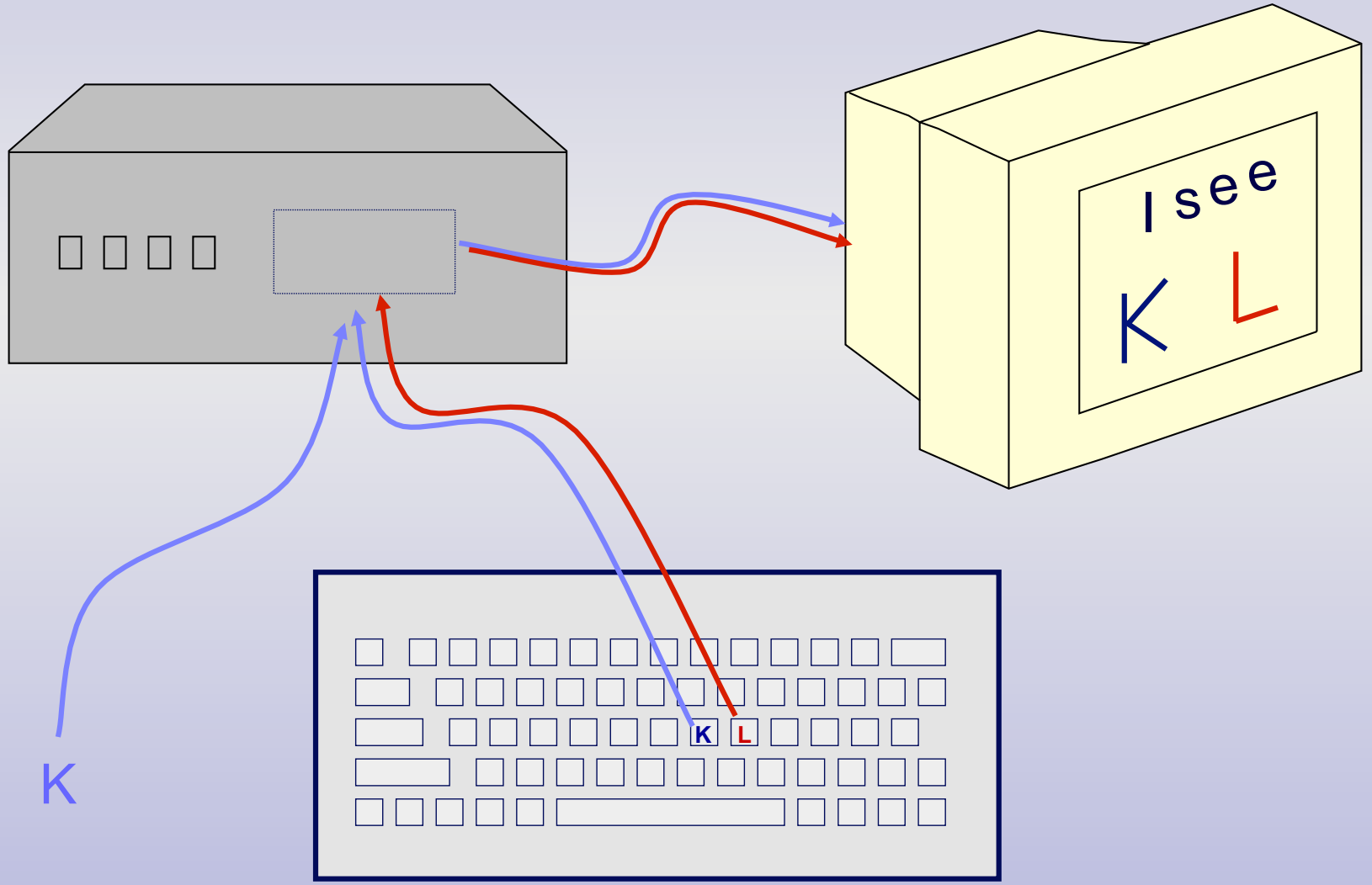
Fadiga et al. *Neuropsychologia*, 37:147-158, 1999

# Simulation of Perception: sensory reactivation

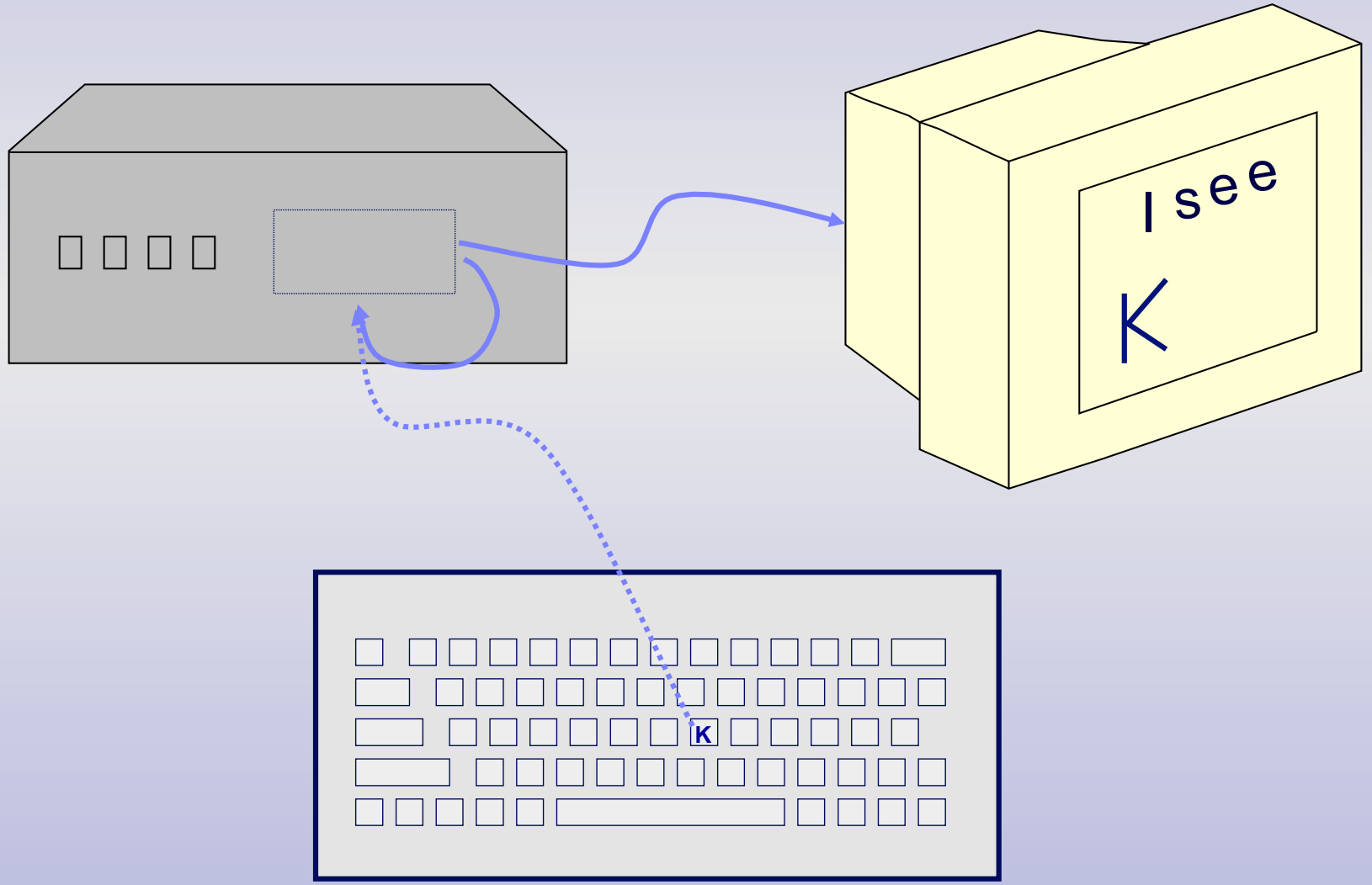
‘What is the manner of occupation of the brain with a resuscitated feeling of resistance, a smell or a sound? There is only one answer that seems admissible. *The renewed feeling occupies the very same parts, and in the same manner, as the original feeling, and no other parts, nor in any other assignable manner.* ‘
(Bain, 1868, p. 338)

*Analogues:*
Short-circuiting measurement instruments

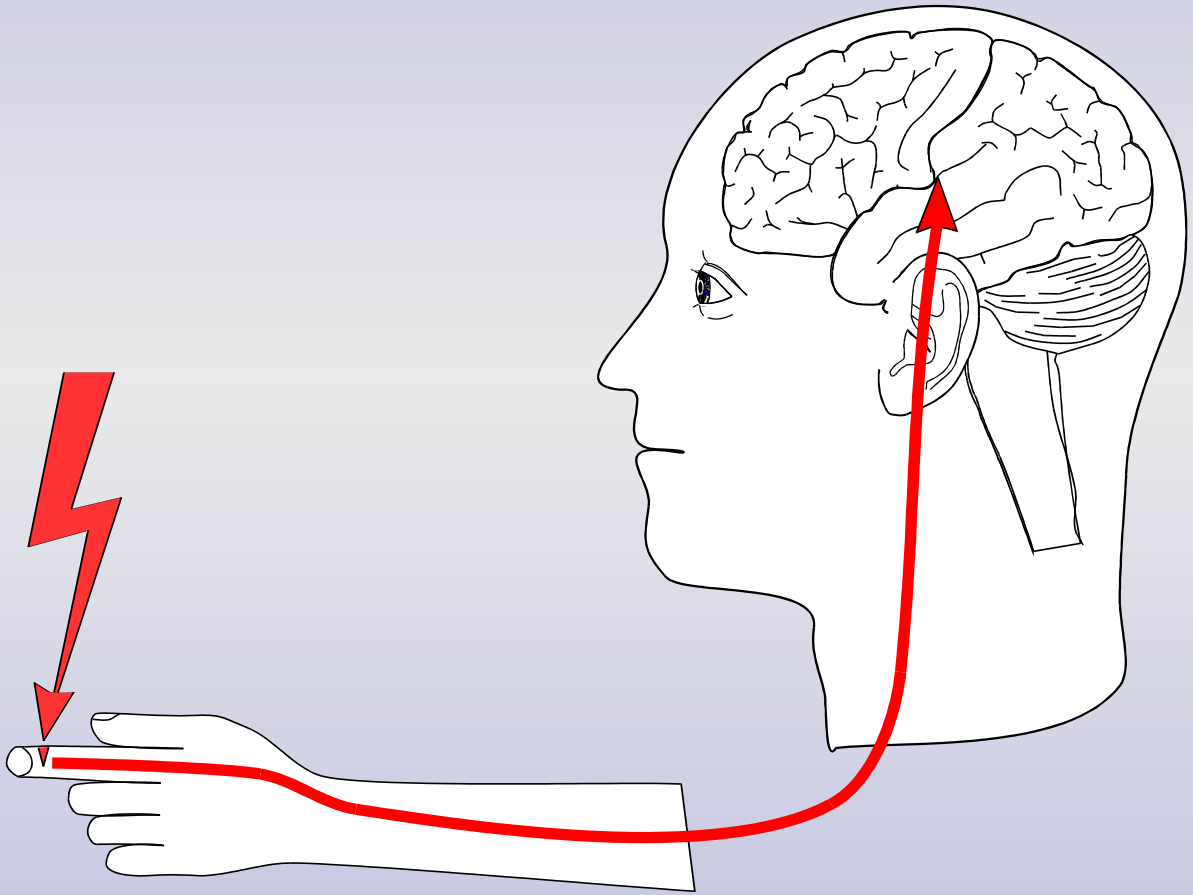
# Perceiving a keypress



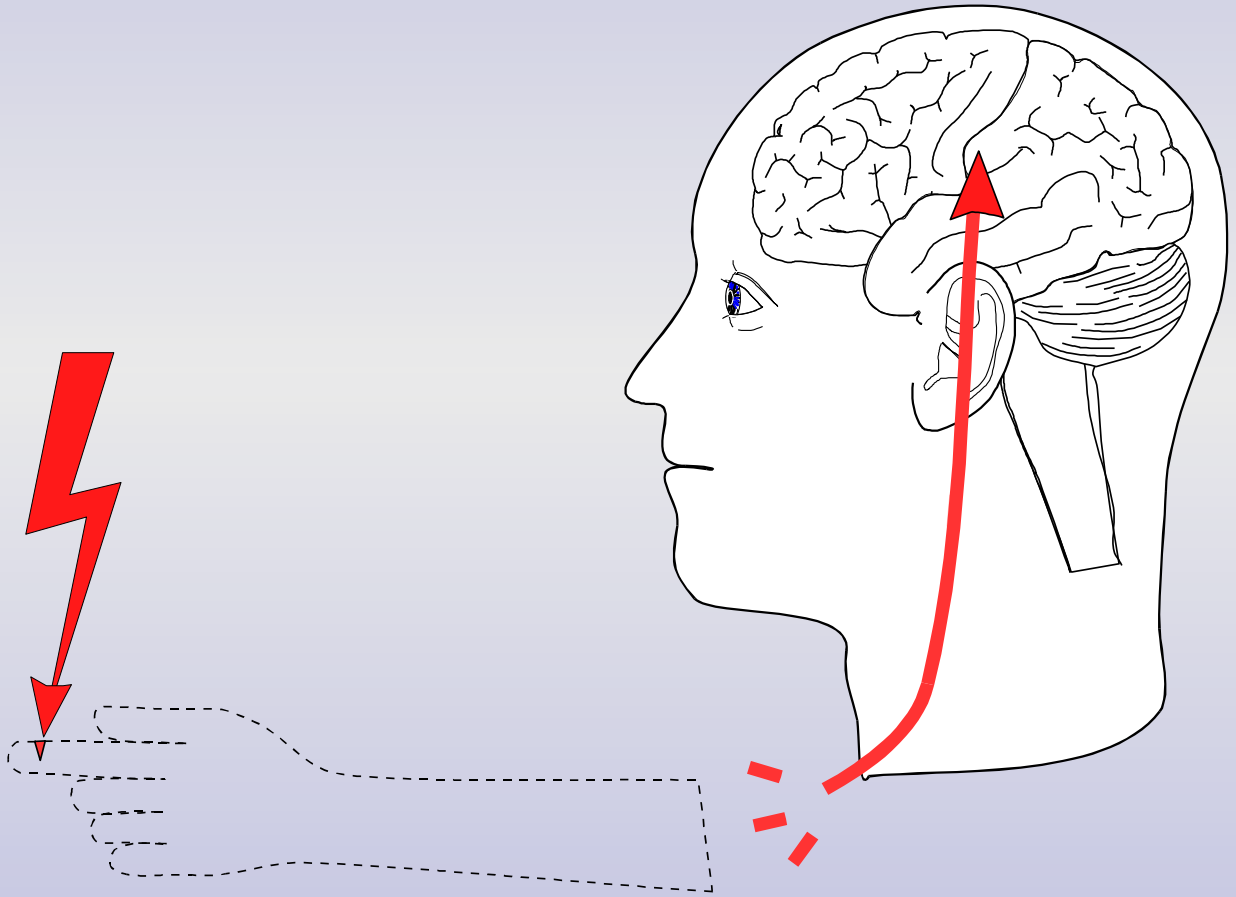
# Imagining a keypress



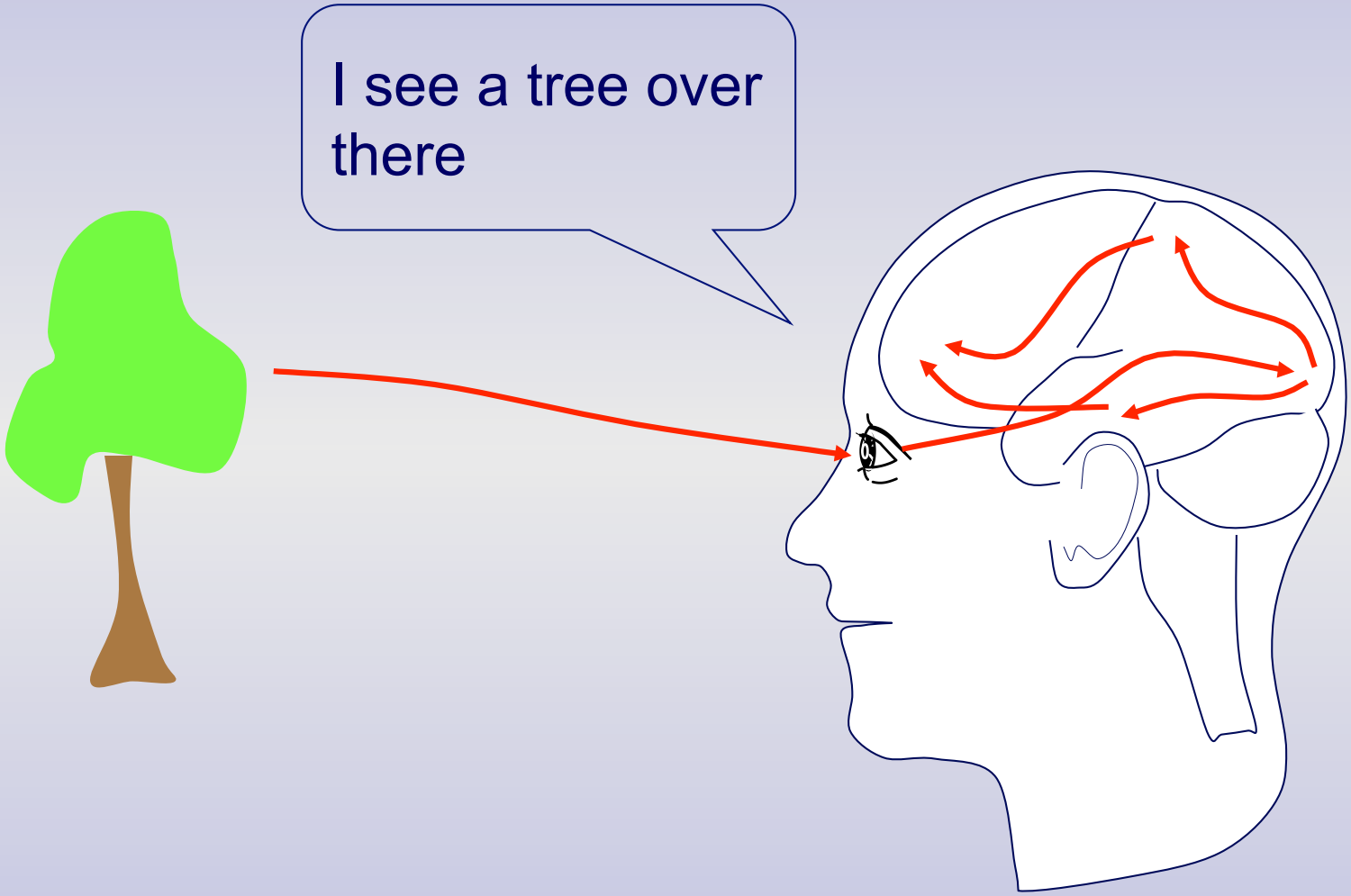
# Damage Perception - Pain



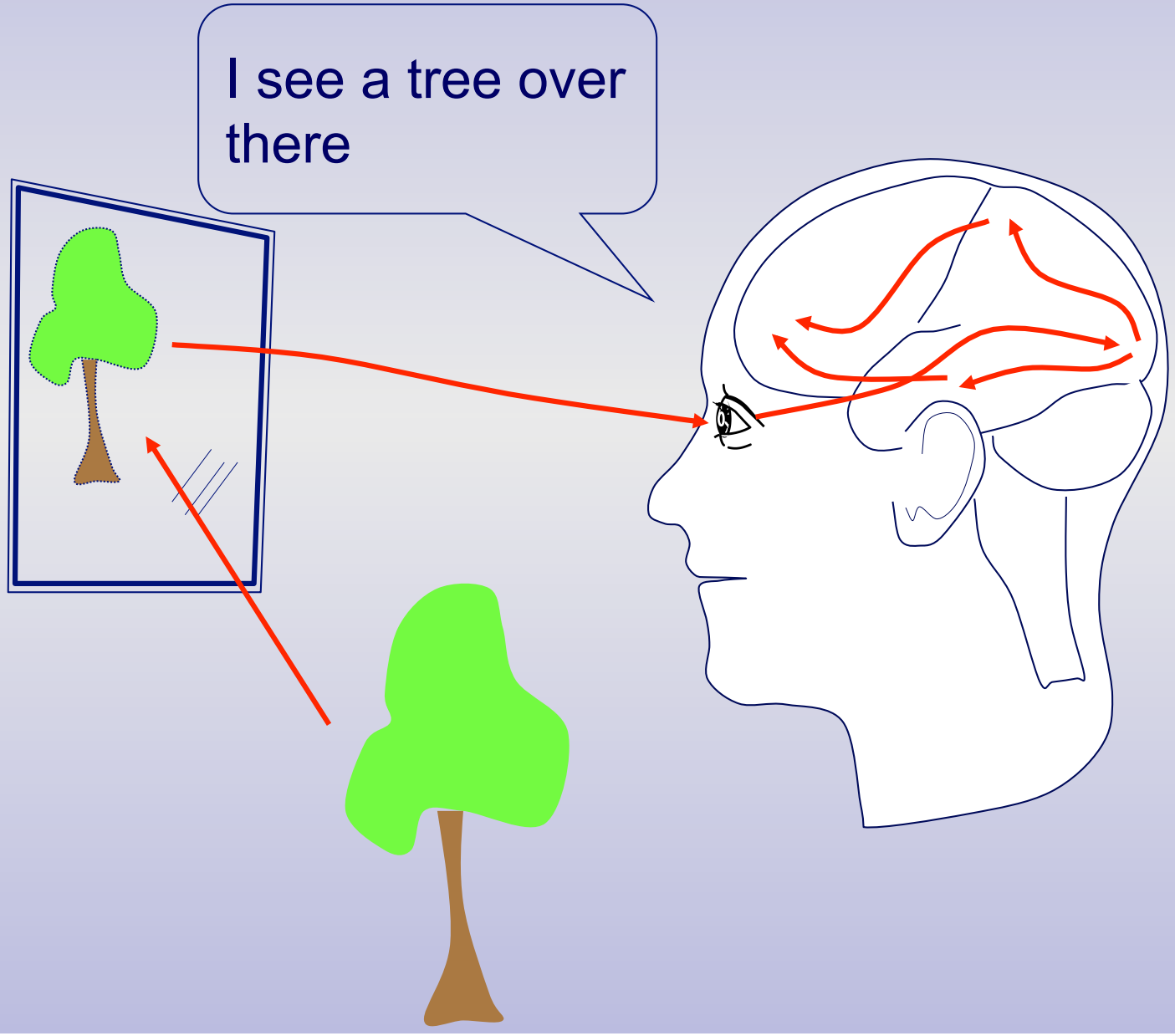
# Phantom pain



# Seeing



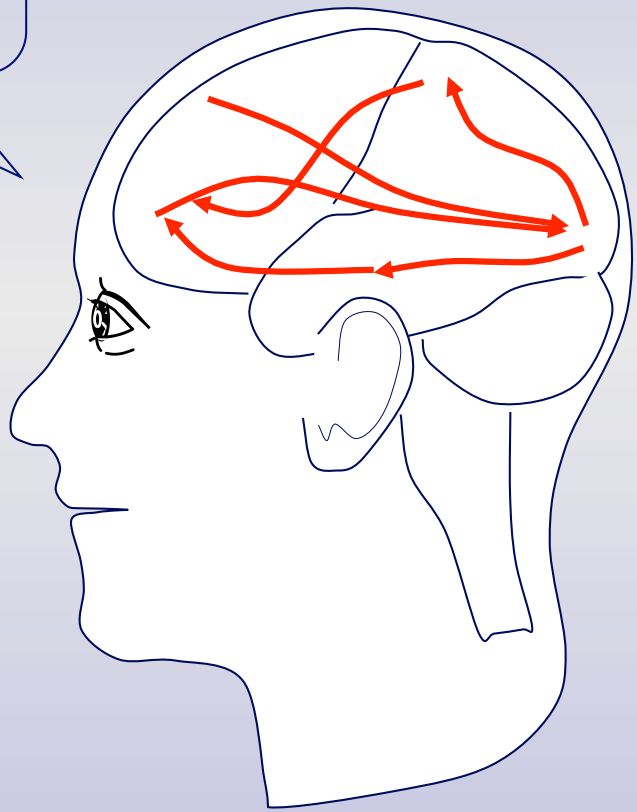
# Seeing virtual tree?



# Imagination, recall

I see a tree over there





# Evidence for perceptual simulation

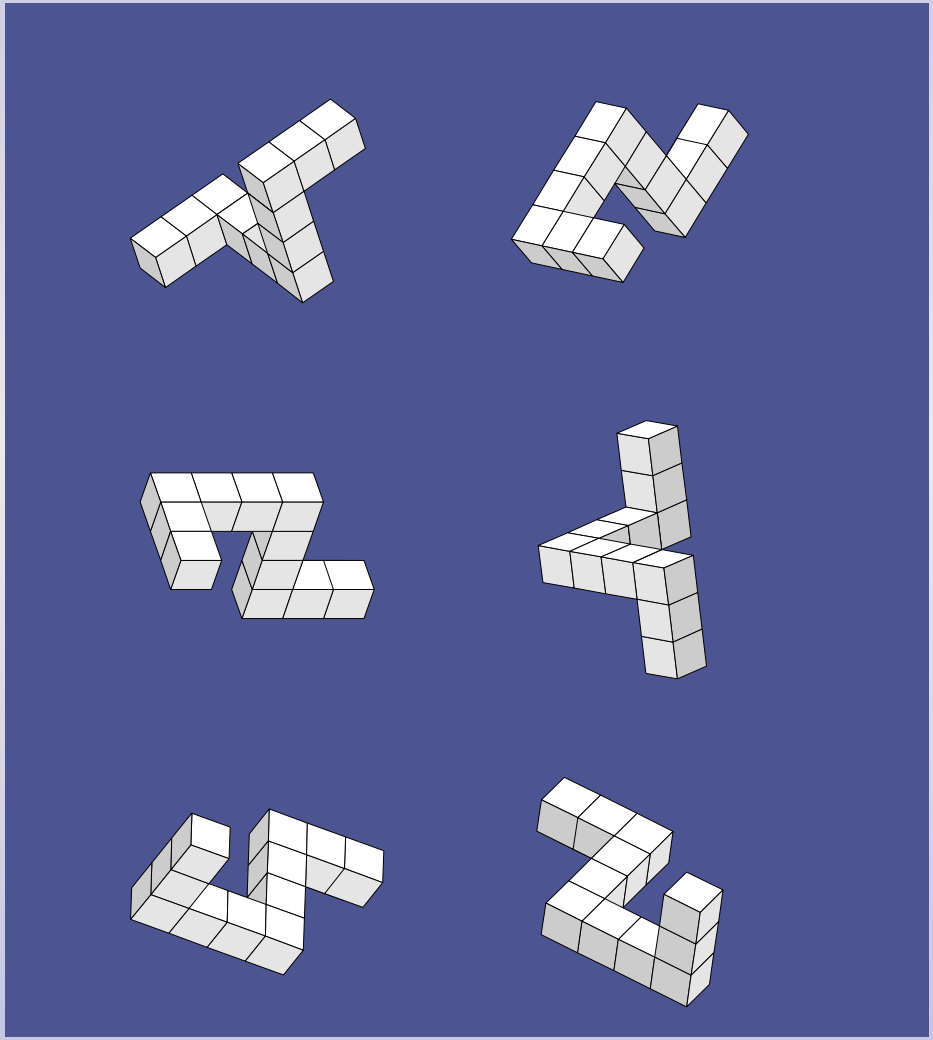
Behavioural experiments

Electrophysiology

Lesion studies

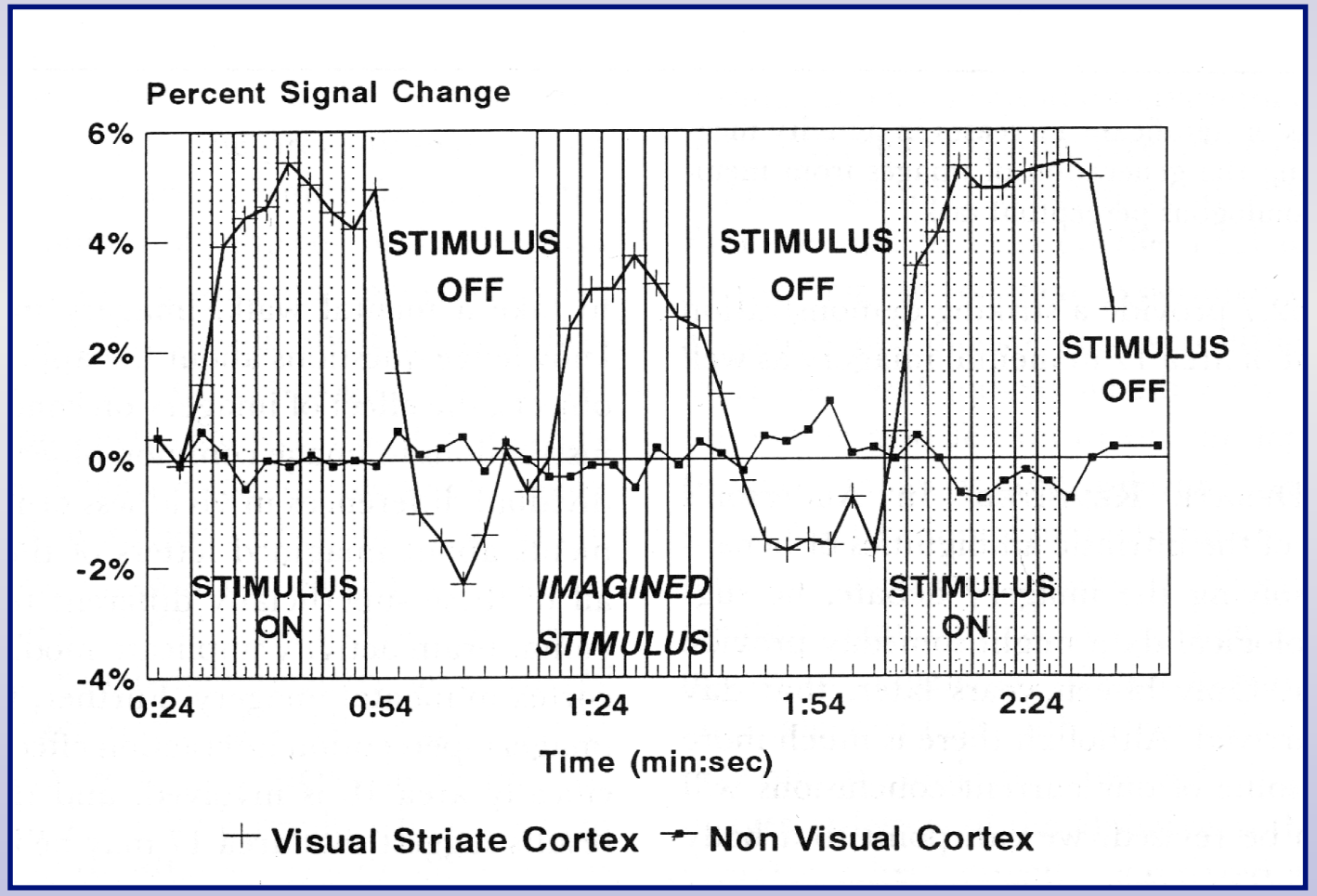
Imaging studies

# Mental rotation



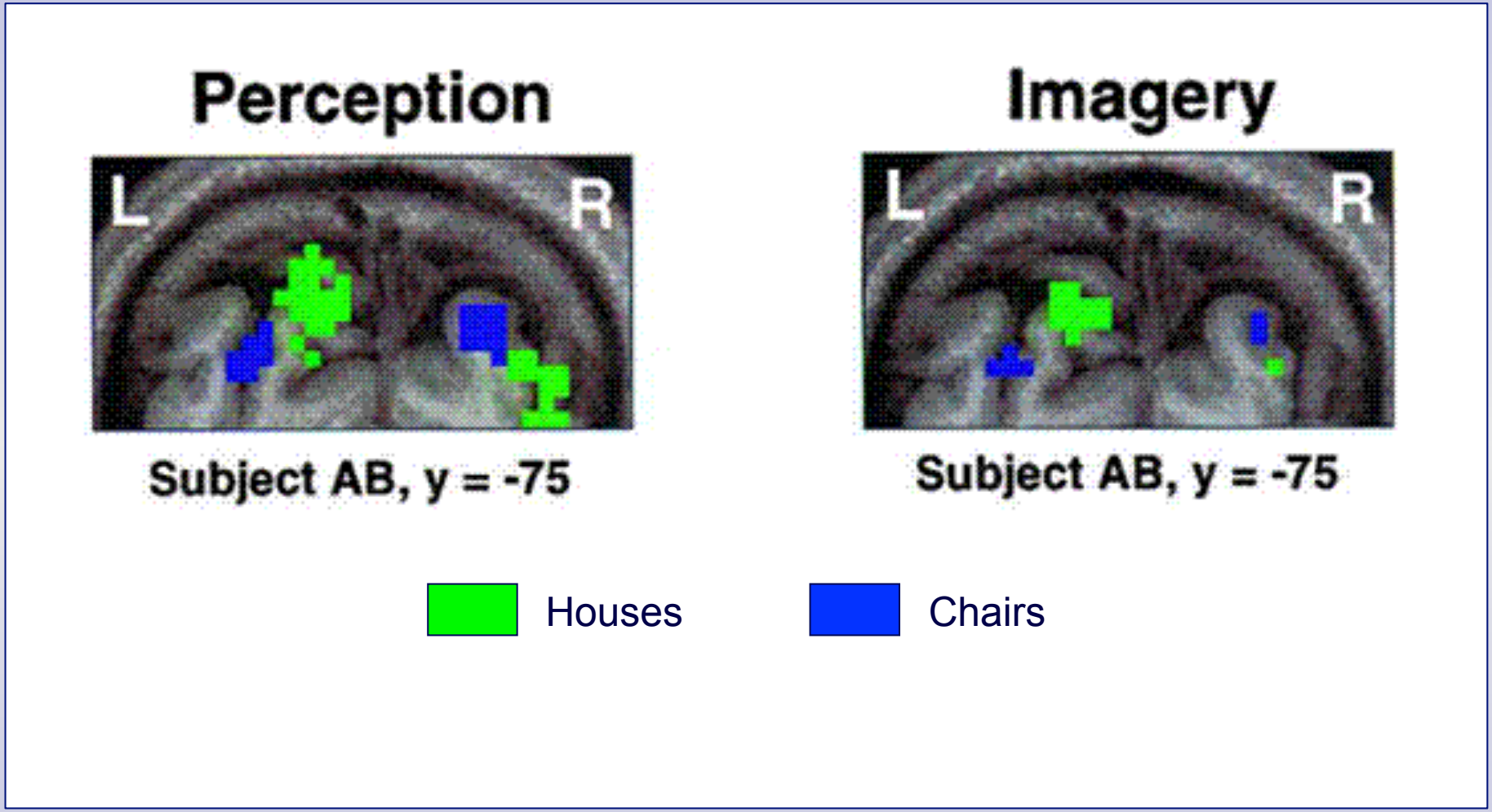
Shepard & Metzler (1971) *Science* 171, 701–703

# MRI signal intensity in visual cortex during external vs imagined stimulus




Le Bihan et al. PNAS 90:11802-11805, 1993

# fMRI dorsal occipital cortex during perception vs imagery




Ishai, Ungerleider, Haxby (2000) *Neuron*, 28, 979-990

# I am NOT suggesting

That the brain creates an *image or* a *representation* of the sensory input

# I AM suggesting

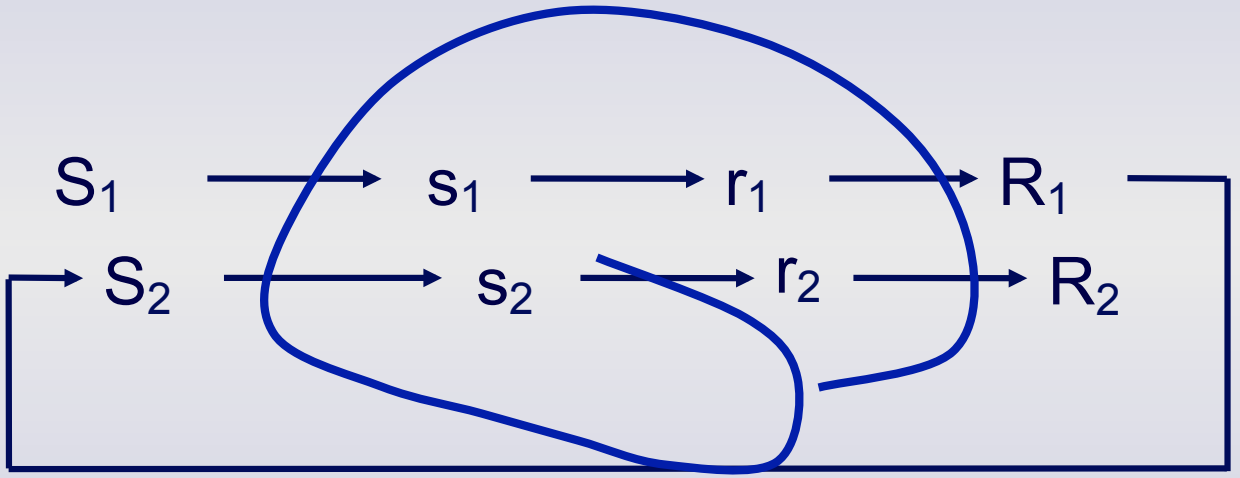
That a complex stimulus can elicit many different behaviours, such as describing the stimulus, pointing towards it, reaching for it, drawing it…

The same is true about an internally generated stimulus.

# Anticipation: action-sensation associations

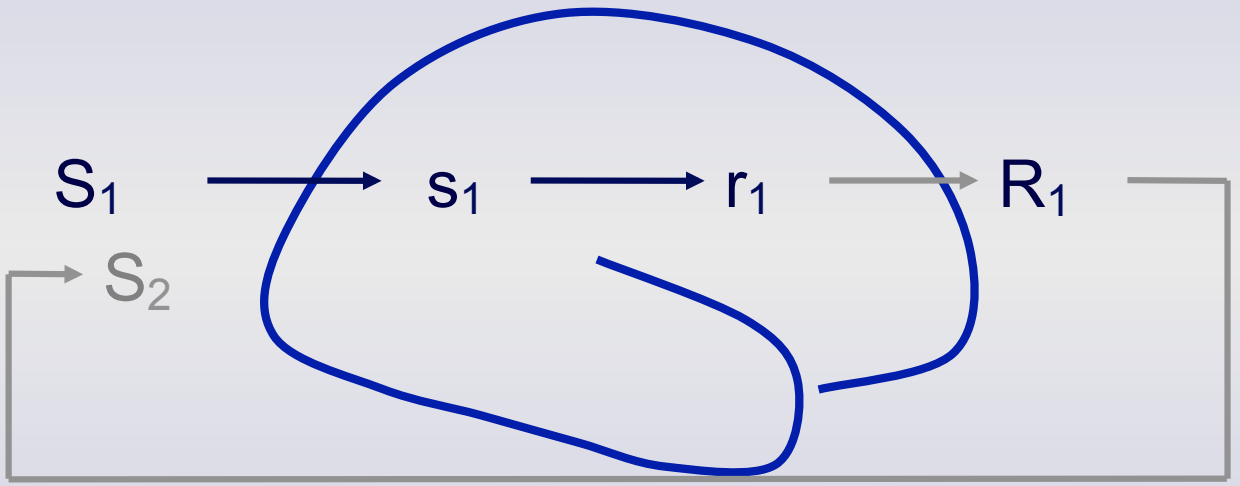
'The succession designated as *cause and effect*, are fixed in the mind by Contiguity. The simplest activity is where our own activity is the cause. We strike a blow, and there comes a noise and a fracture. … Hardly any bond of association arrives sooner at maturity, than the bond between our own actions and the sensible effects that follow from them.' (Bain, 1868, p. 427)

# Predictable consequence

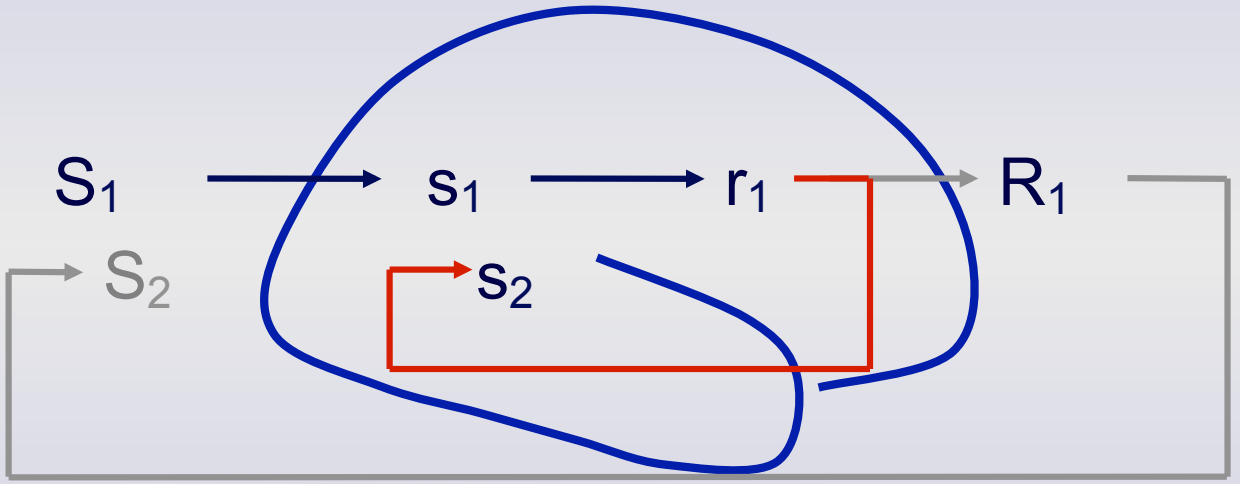



$r_1$ will be associted with $s_2$

# Anticipation

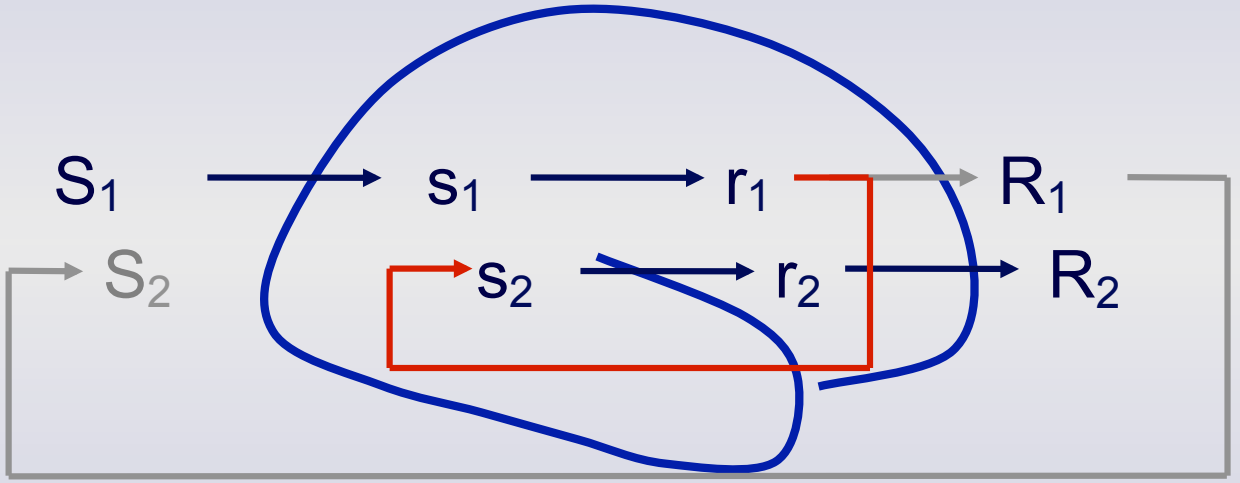


# Anticipation

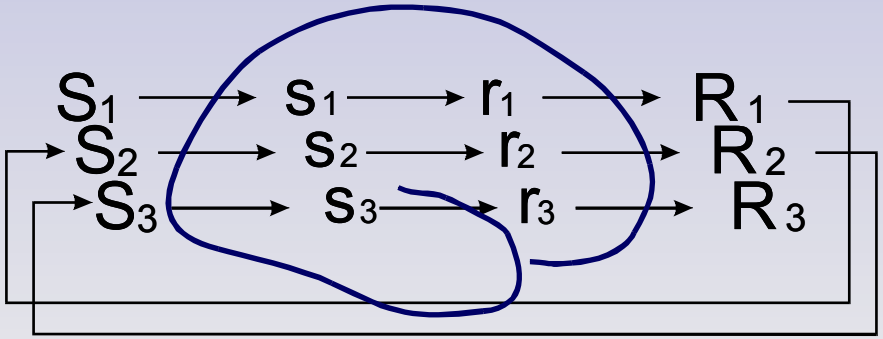



$r_1$ will be associted with $s_2$

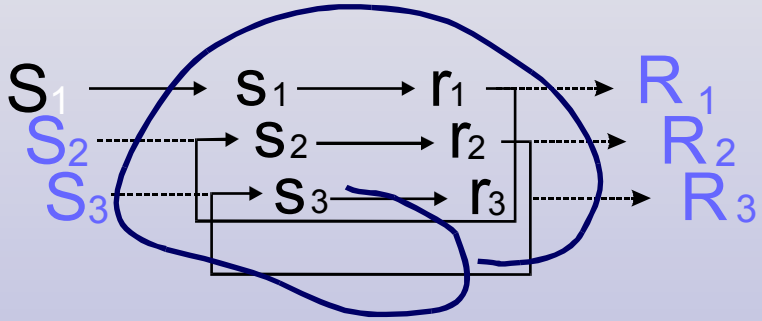
# Anticipation



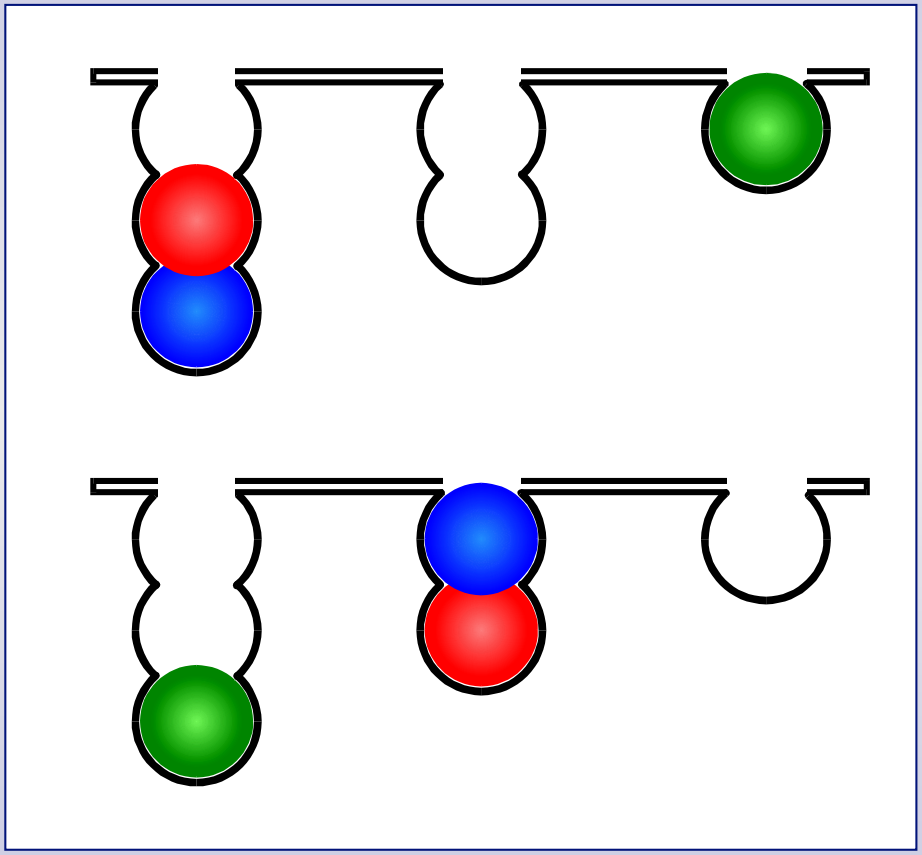
# Behavioural chain

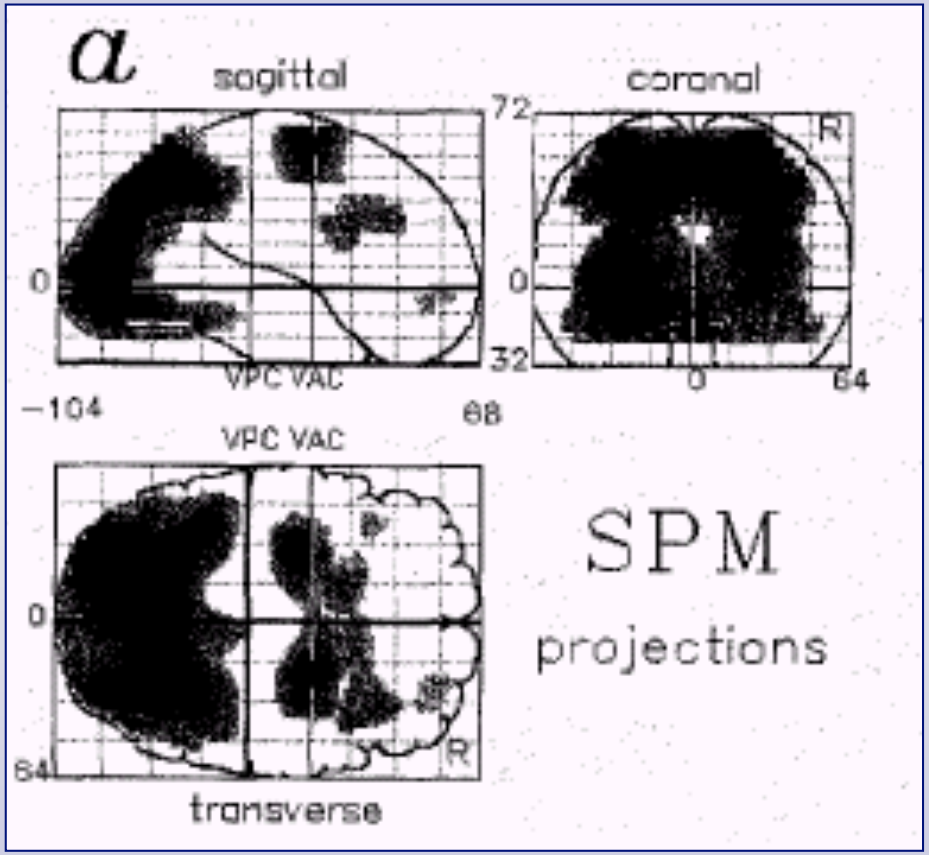



# Simulation of behavioural chain



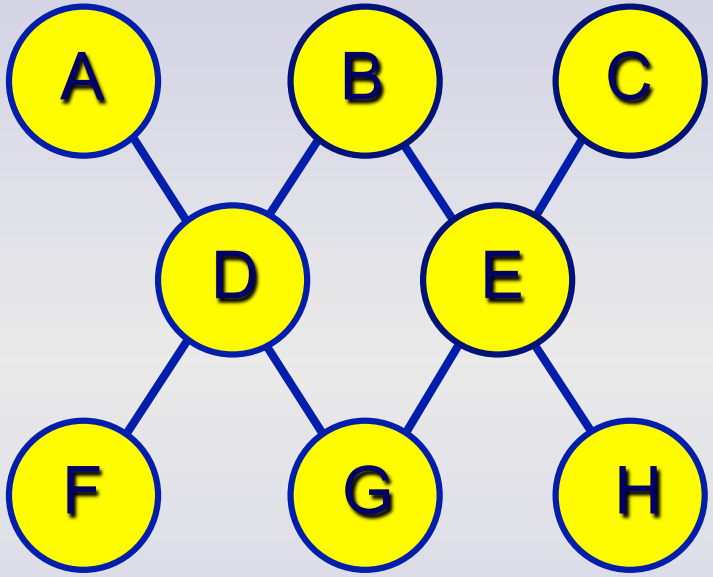
# rCBF during Tower of London task






Baker et el., *Neuropsychologia*. 34:515-26, 1996

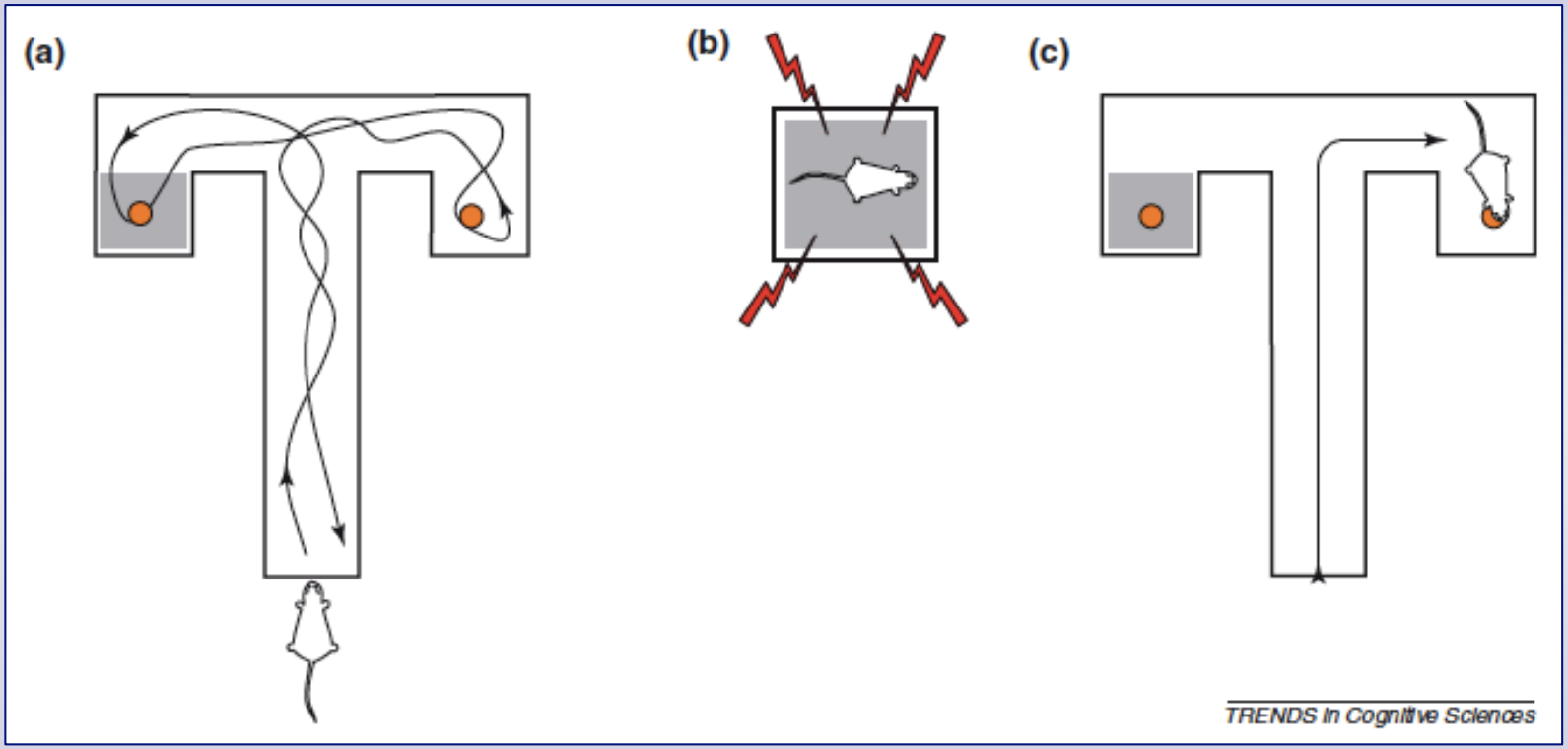
# Do we need cognitive maps?




LF(G) ⟶ D

RF(G) ⟶ E

# Anticipation – no maps




Hesslow (2002) *Trends Cogn Sci* based on
Tolman & Gleitman (1949) *J Exp Psych* **39:** 810-819.

# Declarative Memory – Recall Activated by Actions

Can we account for episodic memory with associative mechanisms?

*Predictions:*

Declarative (episodic) memory

a) Stored in sensory cortex – disrupted by lesions, activated during recall
b) Activated by pequires prefrontal cortex
c) Similarities between memory recall and imagining future

aps
ASSOCIATION FOR PSYCHOLOGICAL SCIENCE

# Episodic Future Thought: An Emerging Concept

Perspectives on Psychological Science
5(2) 142-162

DOI: 10.1177/1745691610362350
http://pps.sagepub.com
SAGE

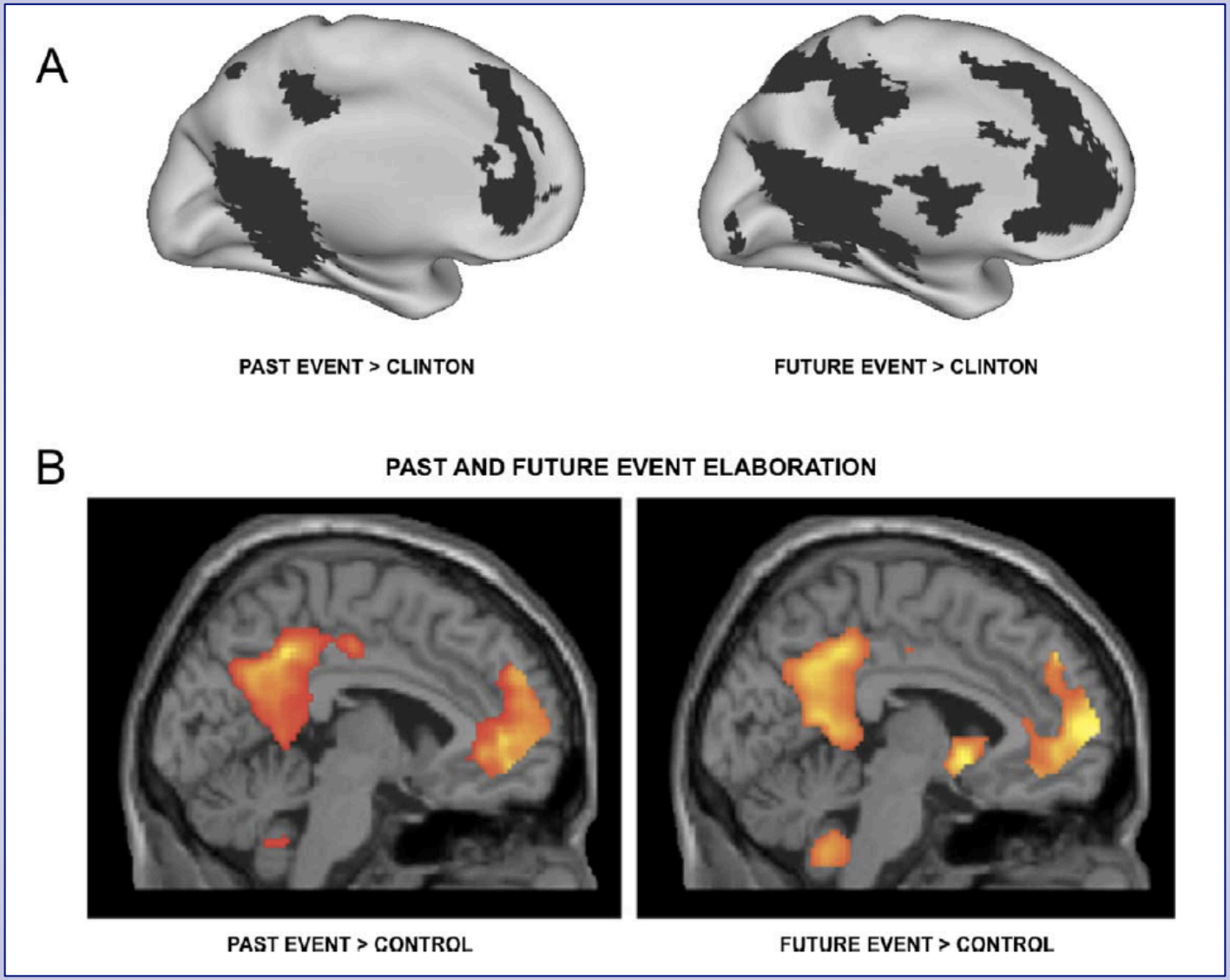
**Karl K. Szpunar**
Department of Psychology, Washington University, St. Louis, MO

**Abstract**

The ability to mentally simulate hypothetical scenarios is a rapidly growing area of research in both psychology and neuroscience. *Episodic future thought*, or the ability to simulate specific personal episodes that may potentially occur in the future, represents one facet of this general capacity that continues to garner a considerable amount of interest. The purpose of this article is to elucidate current knowledge and identify a number of unresolved issues regarding this specific mental ability. In particular, this article focuses on recent research findings from neuroimaging, neuropsychology, and clinical psychology that have demonstrated a close relation between episodic future thought and the ability to remember personal episodes from one's past. On the other hand, considerations of the role of abstracted (semantic) representations in episodic future thought have been noticeably absent in the literature. The final section of this article proposes that both episodic and semantic memory play an important role in the construction of episodic future thoughts and that their interaction in this process may be determined by the relative accessibility of information in memory.

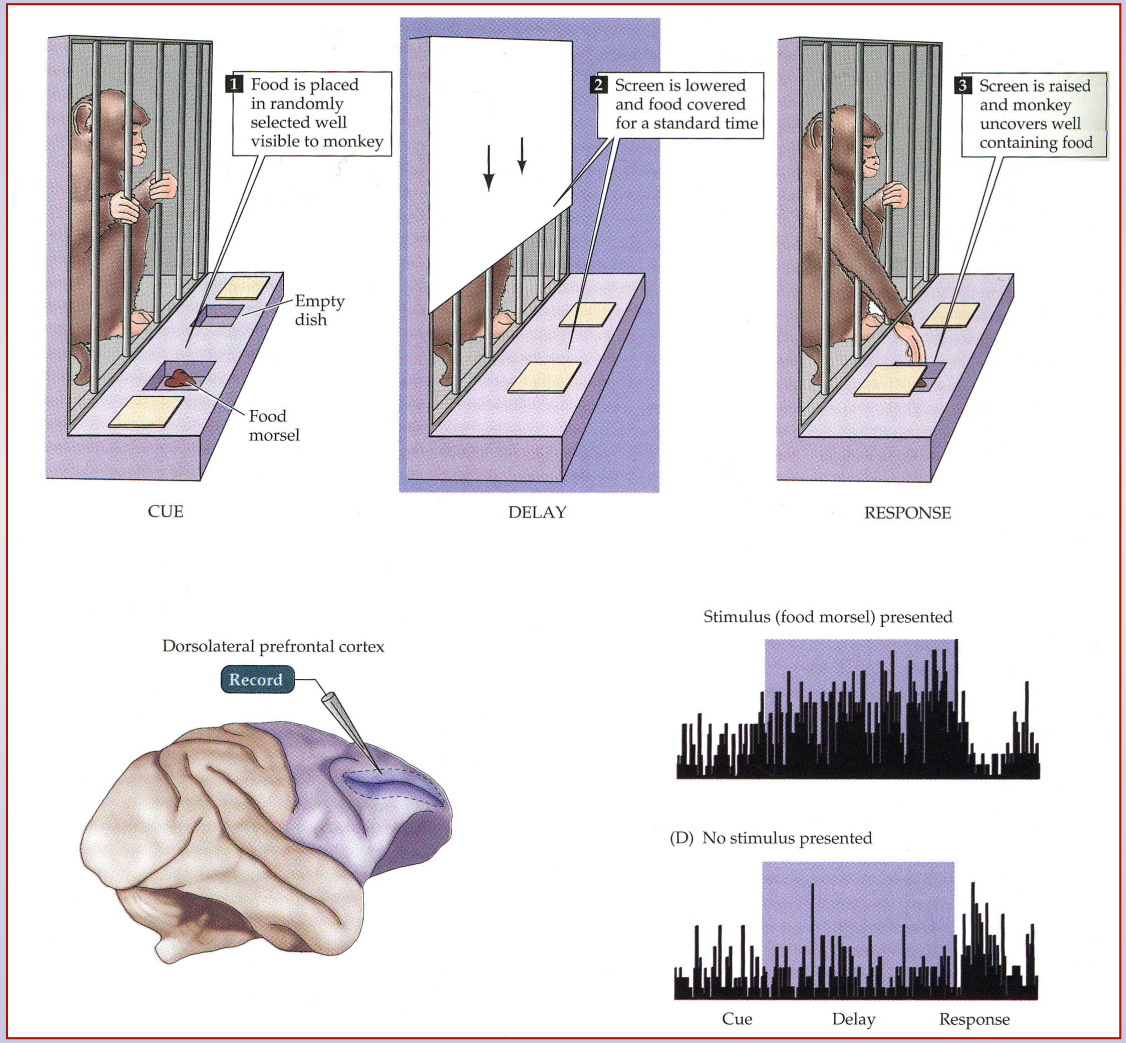
Szpunar, K (2010) Perspectives on Psychological Science 5:142

# Similarity memory recall – imagining future

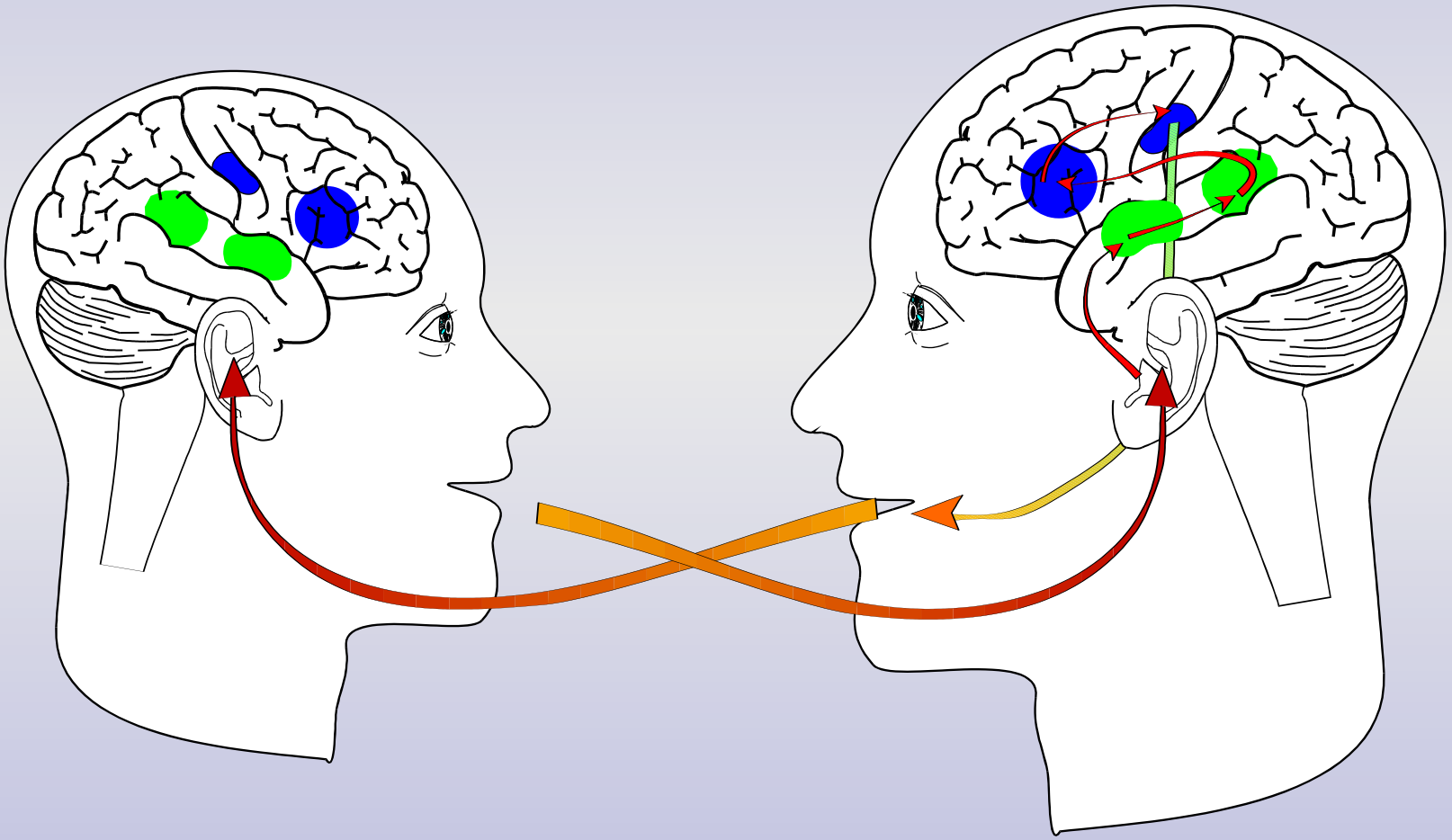



Szpunar, K (2010) Perspectives on Psychological Science 5:142

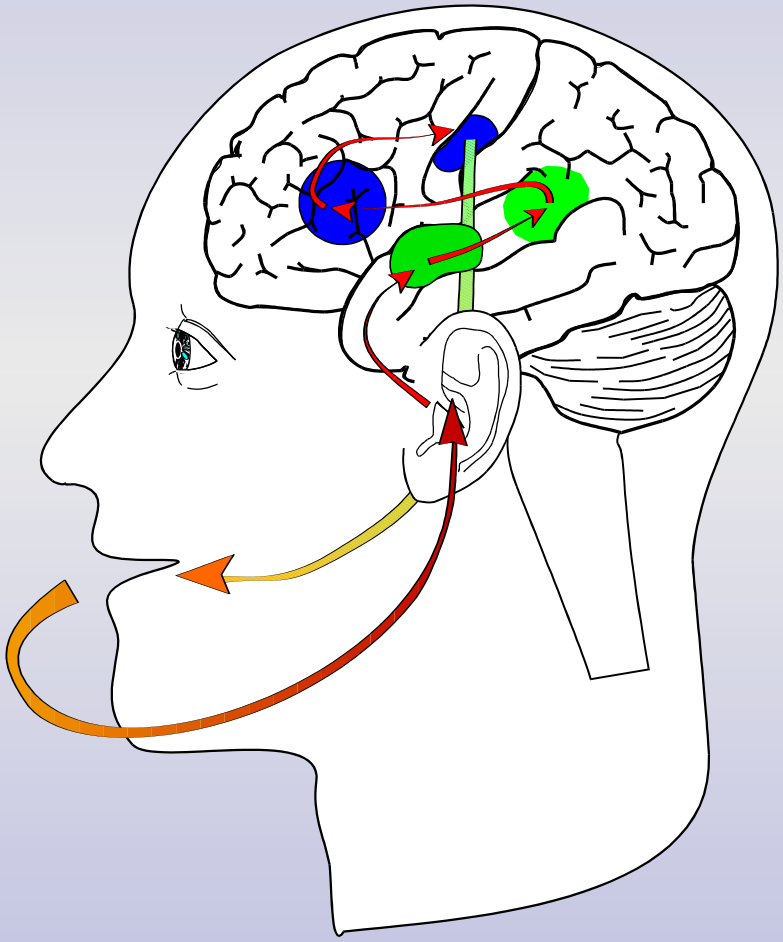
# Working memory – stored information?



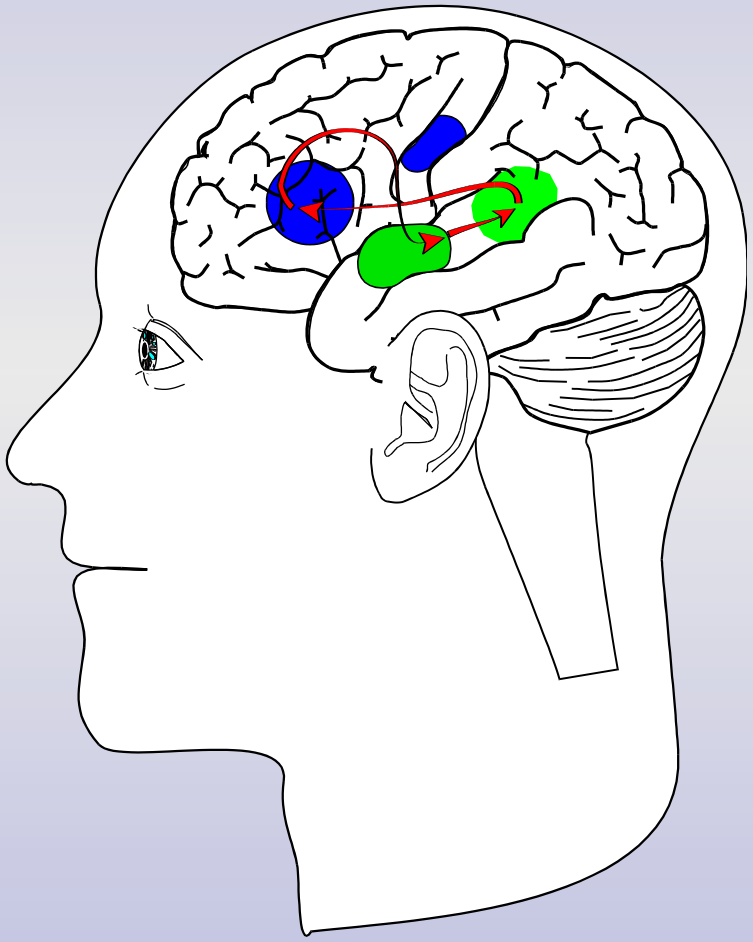
# Conversation



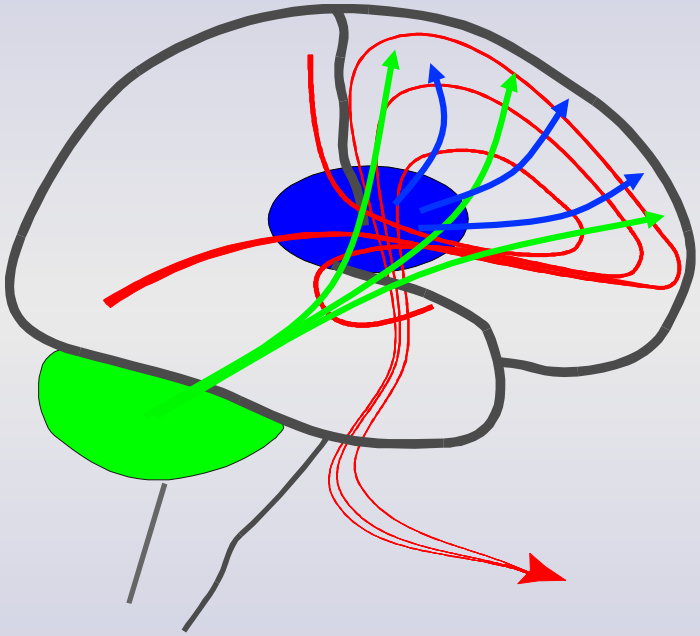
# Talking to oneself



# Simulating conversation



# Why do motor structures participate in cognitive functions ?



a) Thinking is covert movement
b) Abstract actions need same auxiliary systems

# Working Memory as Covert Actions Extended in Time

*Predictions:*

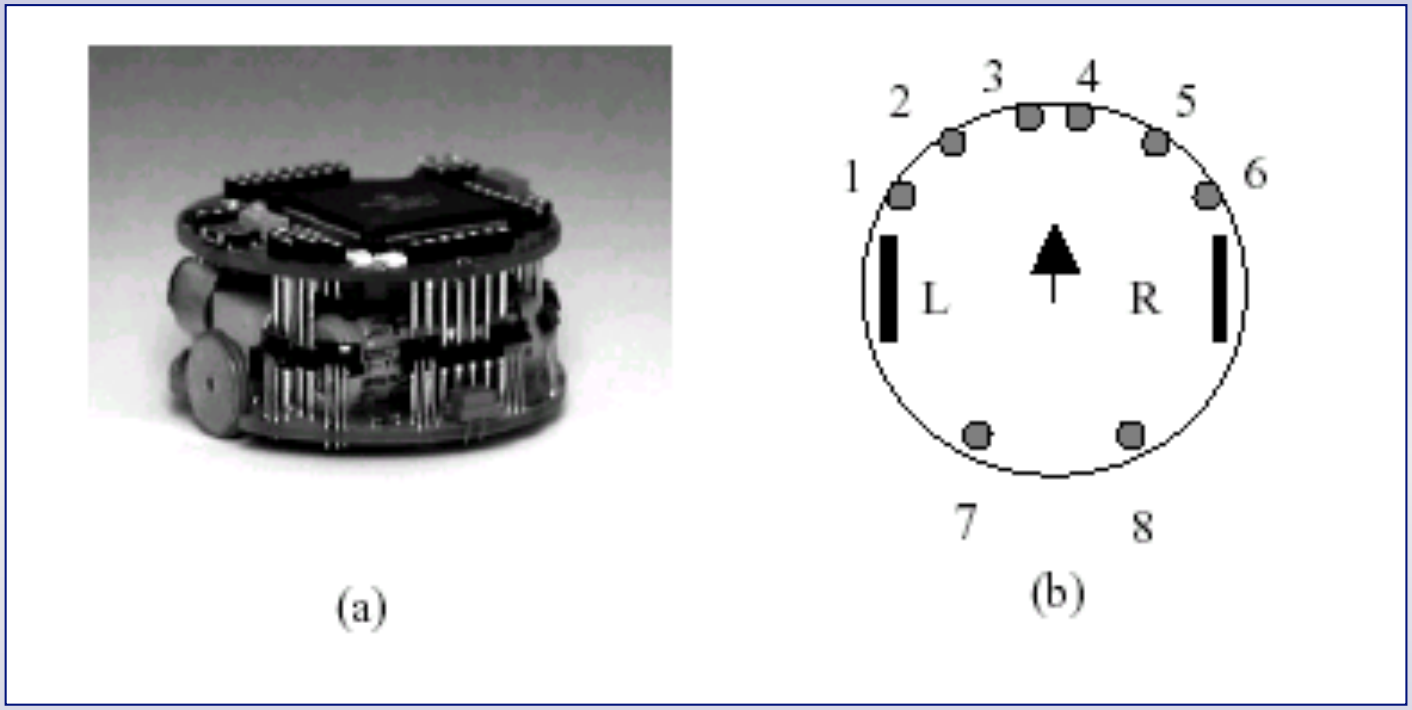
Working memory

a) involves prefrontal and posterior (sensory) cortex
b) utilises the same circuitry as long-term memory
c) is modality and feature specific

# Strong points of the simulation hypothesis

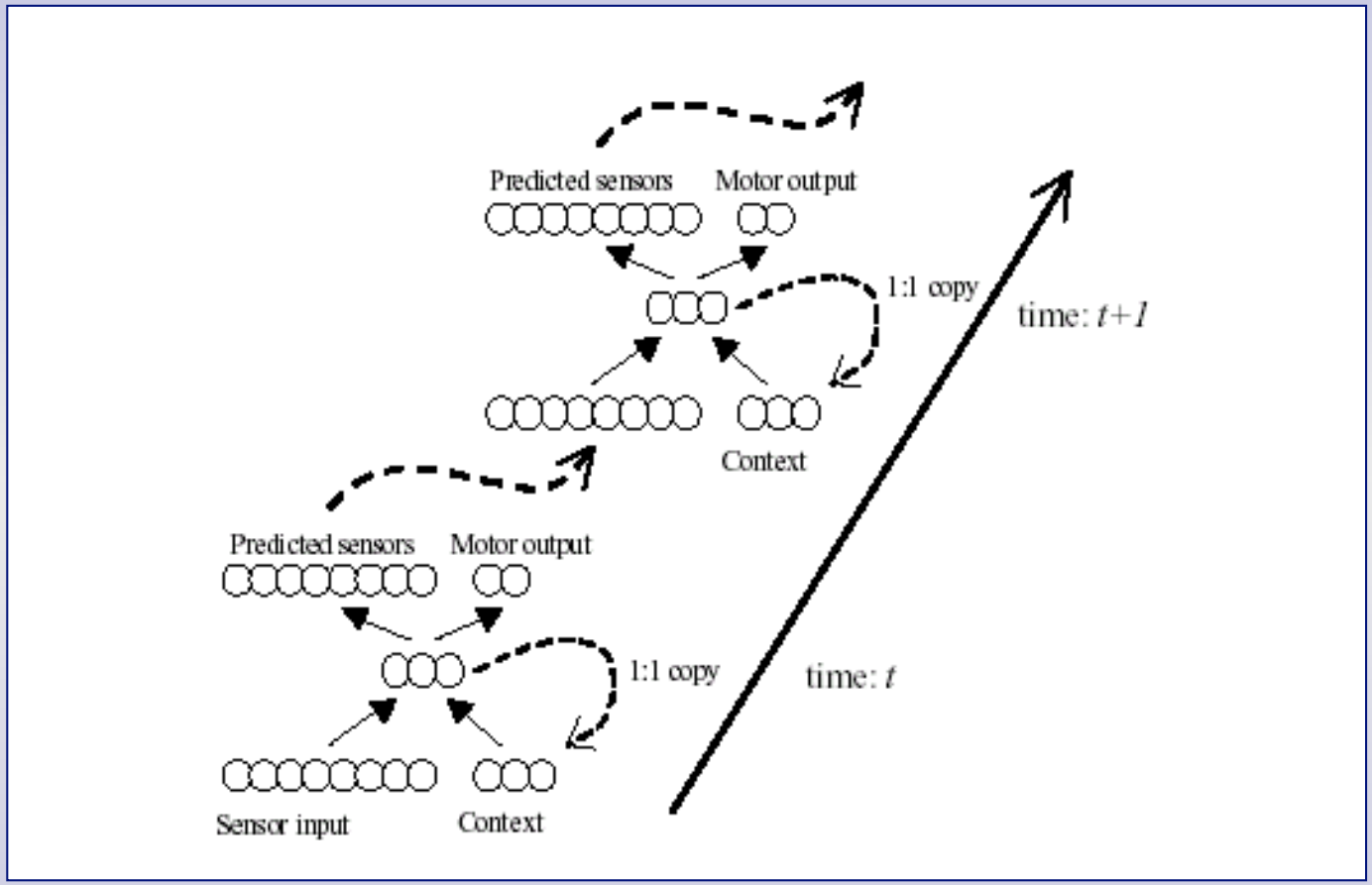
- Ontological parsimony: no representations, images …
- Does not require external agent
- No evolutionary leaps: same structures underlying inner world as are used for perception and movement
- Explains relationship between cognitive and motor function

# Khepera robot



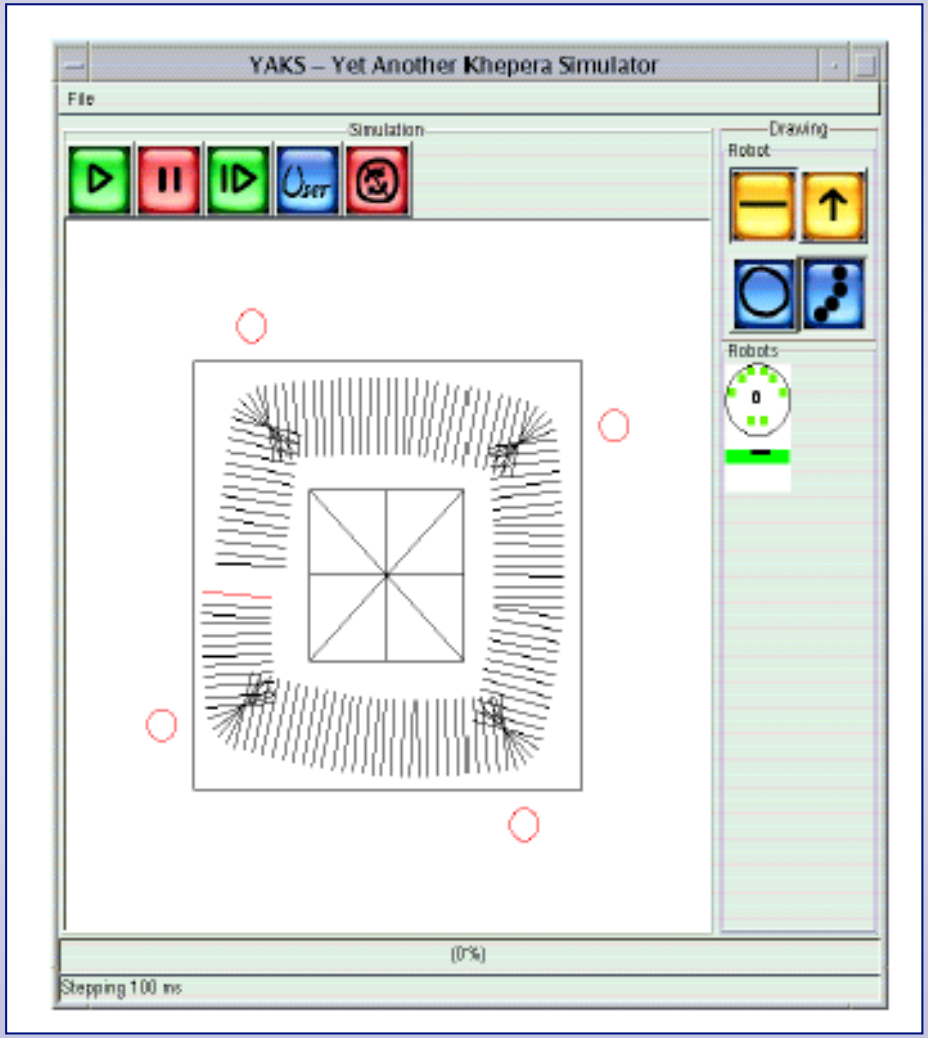

K trained to a) avoid obstacle
b) predict sensor input in next step

# Robot architecture



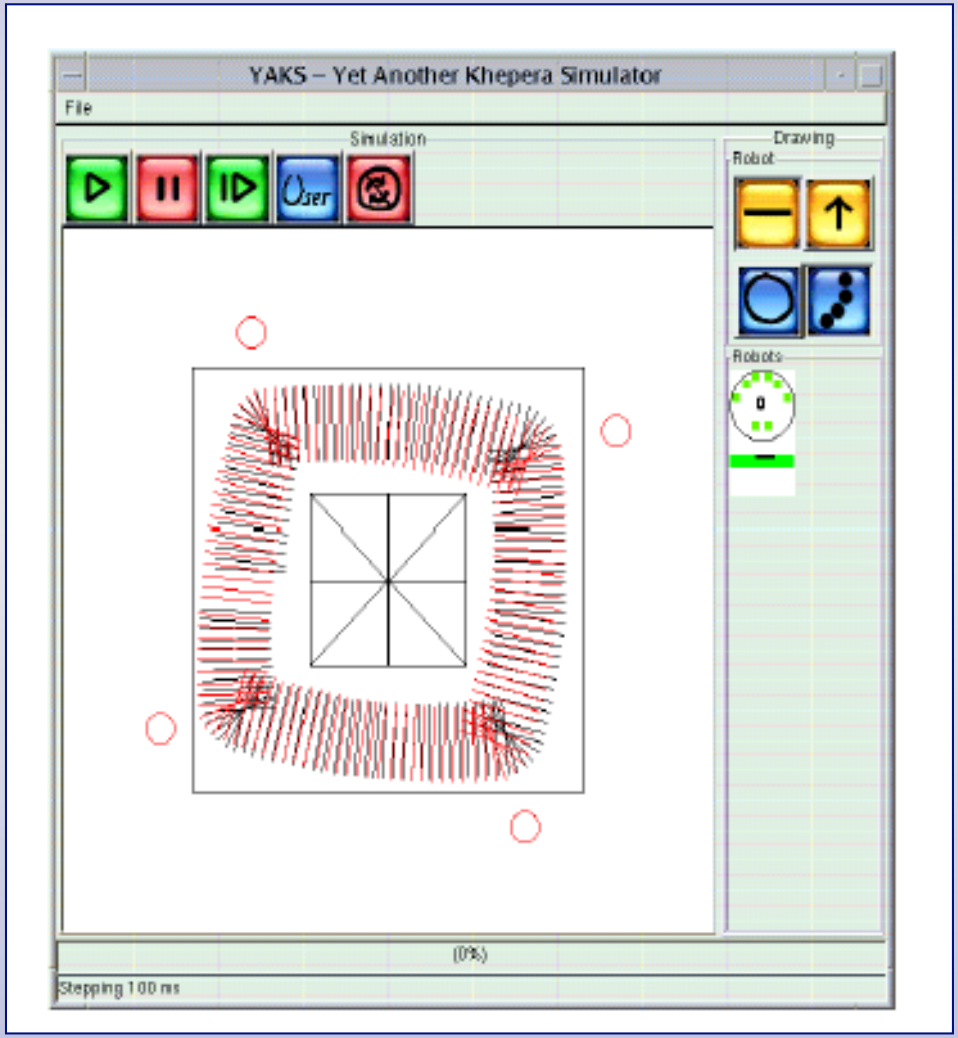

Jirenhed, D.-A. (2001).
Ziemke et al. (2002).

# Sensor guided movement



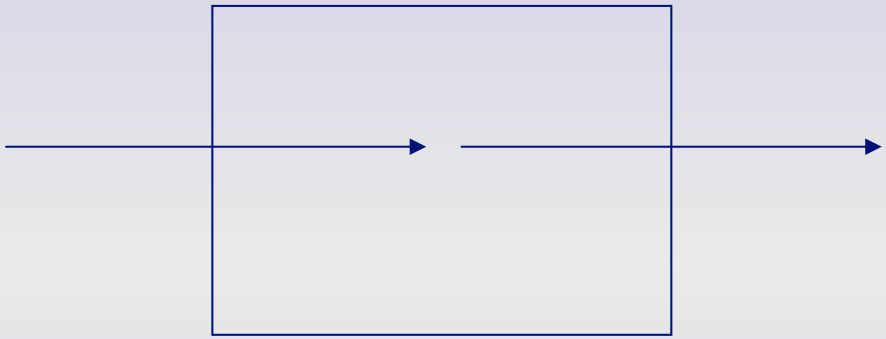

Ziemke et al. (2002).

# Prediction guided movement



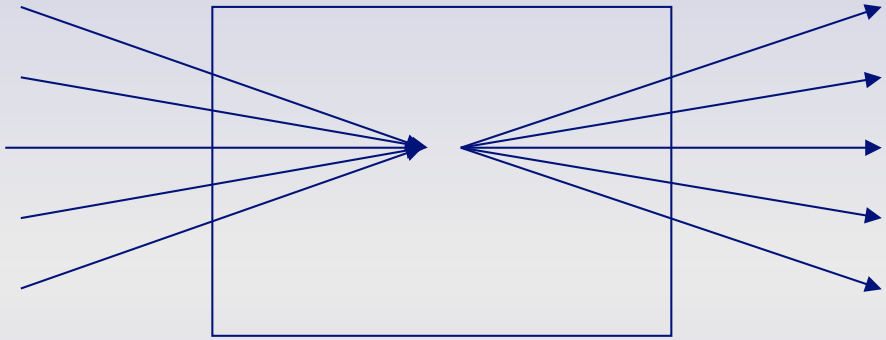

Ziemke et al. (2002).

# Does *K* have an inner world?



- Why is this not merely a causal chain?
- Why do not any internal events count as inner worlds?

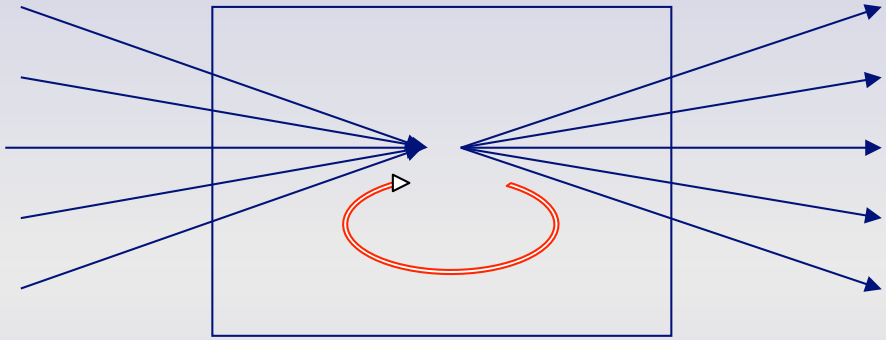
# Does *K* have an inner world?



Suppose that the robot could

- Respond differentially to different inputs
- Respond in many different ways to the same input
  - describing the obstacle verbally
  - draw the obstacle

# Does *K* have an inner world?



Suppose that the robot could

- Respond differentially to different inputs
- Respond in many different ways to the same (simulated) input
  - describing the obstacle verbally
  - draw the obstacle

# Problems of the inner world

- How does the inner world arise?

  By simulation of behaviour and perception

- What are mental objects?

  Source of image is not object but simulated seeing

- What is the function of the inner world?

  Inevitable consequence of simulation

- Can animals and robots have inner worlds?

  Yes, if their ”brains” can generate their own input

## References

*Outline of the simulation hypothesis can be found in*

Hesslow G (2002) Conscious thought as simulation of behaviour and perception. *Trends Cogn Sci,* 6:242-247

Hesslow,G. (2012) Current status of the simulation theory of cognition. *Brain Research* 1428: 71-79.

*For empirical evidence for covert behaviour, see papers by Jeannerod, e.g.*

Jeannerod M (1994) The representing brain: Neural correlates of motor intention and imagery. *Behav Brain Sci* 17: 187-245

*Evidence for simulation of perception is reviewed in*

Kosslyn,S.M., Ganis,G., & Thompson,W.L. (2001) Neural Foundations of Imagery. *Nature Rev Neurosci* 2: 635-42

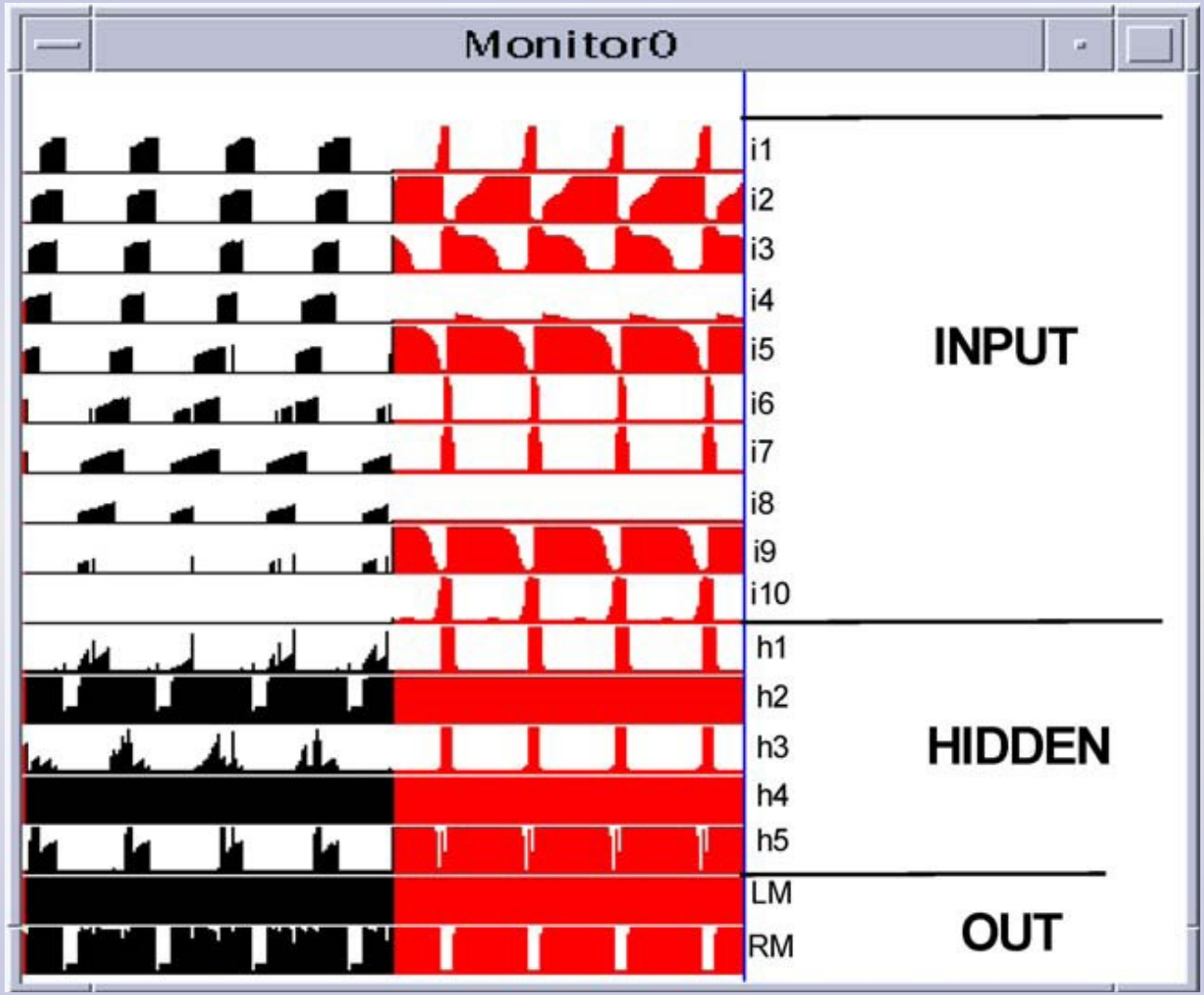
*Robot simulation:*

Ziemke T, Jirenhed D-A, Hesslow G (2005) Internal Simulation of Perception: A Minimal Neuro-Robotic Model. *Neurocomputing. 28:85-104*

Hesslow G and Jirenhed D-A (2007) The inner world of a simple robot. *J Consc Stud* 14:85-96

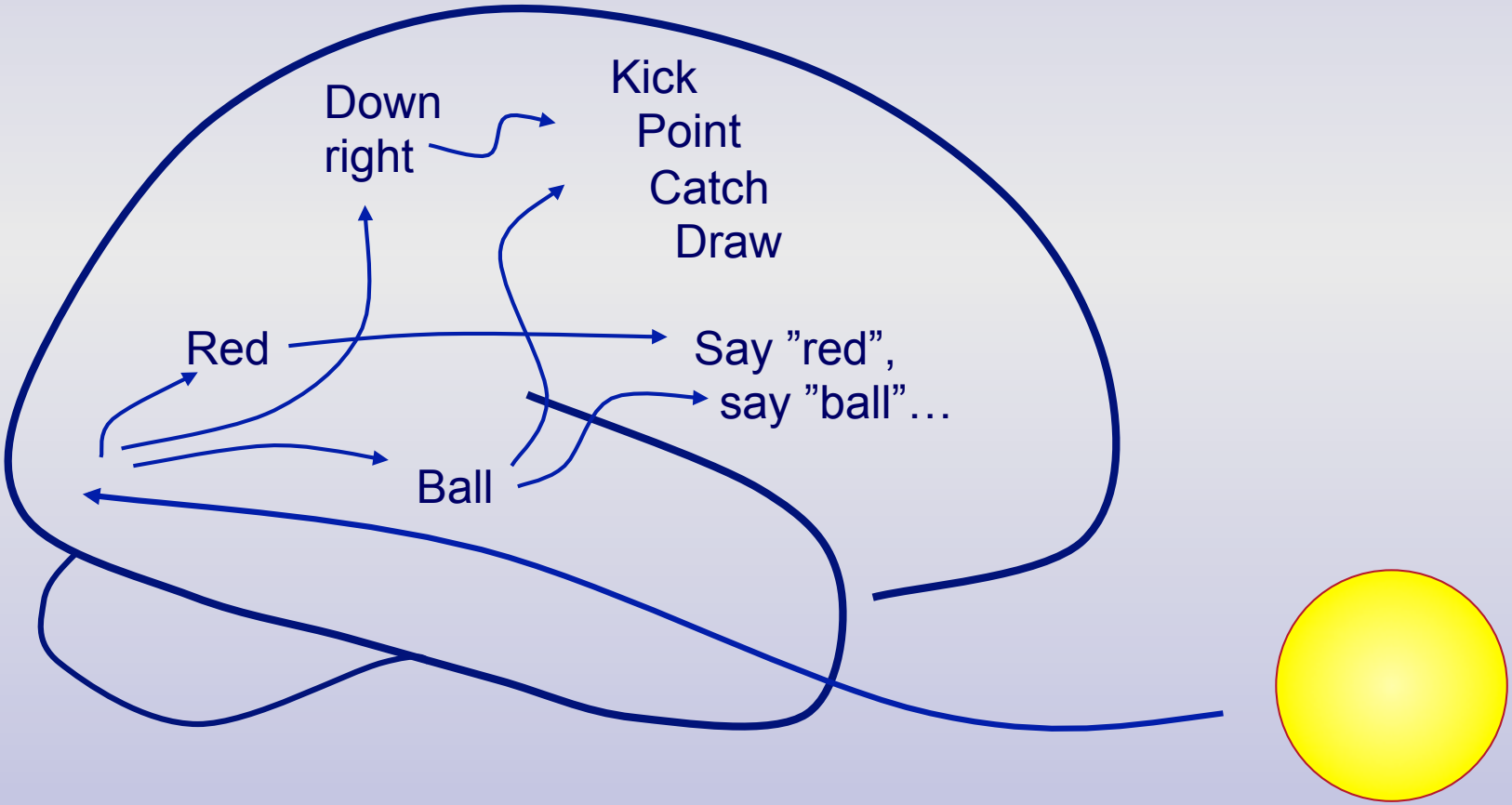
Thank you for listening!

# External vs internal sensor activation

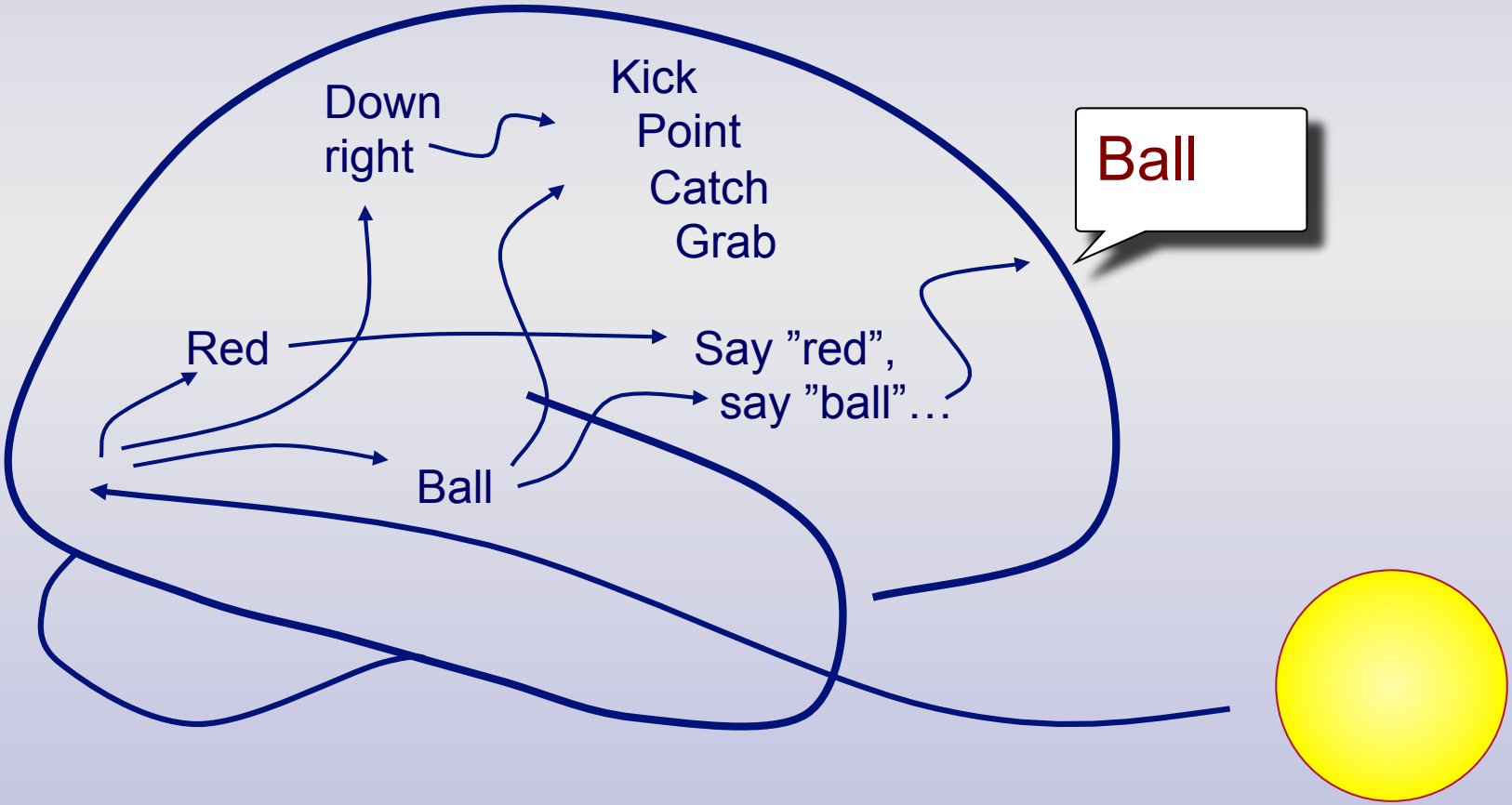



Ziemke, Jirenhed & Hesslow (2005) *Neurocomputing*

# Stimulus prepares many responses

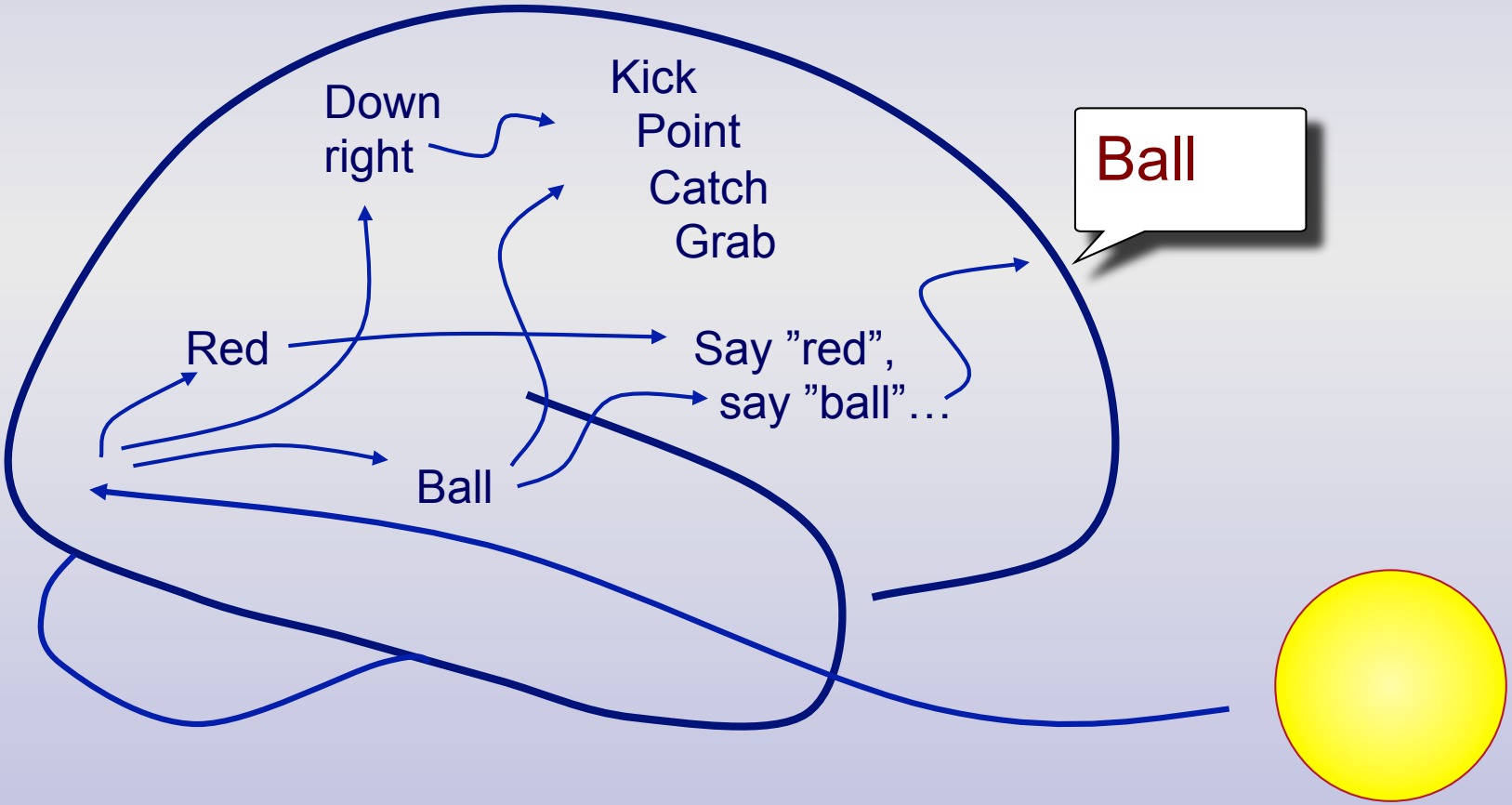


# One response ”wins”.



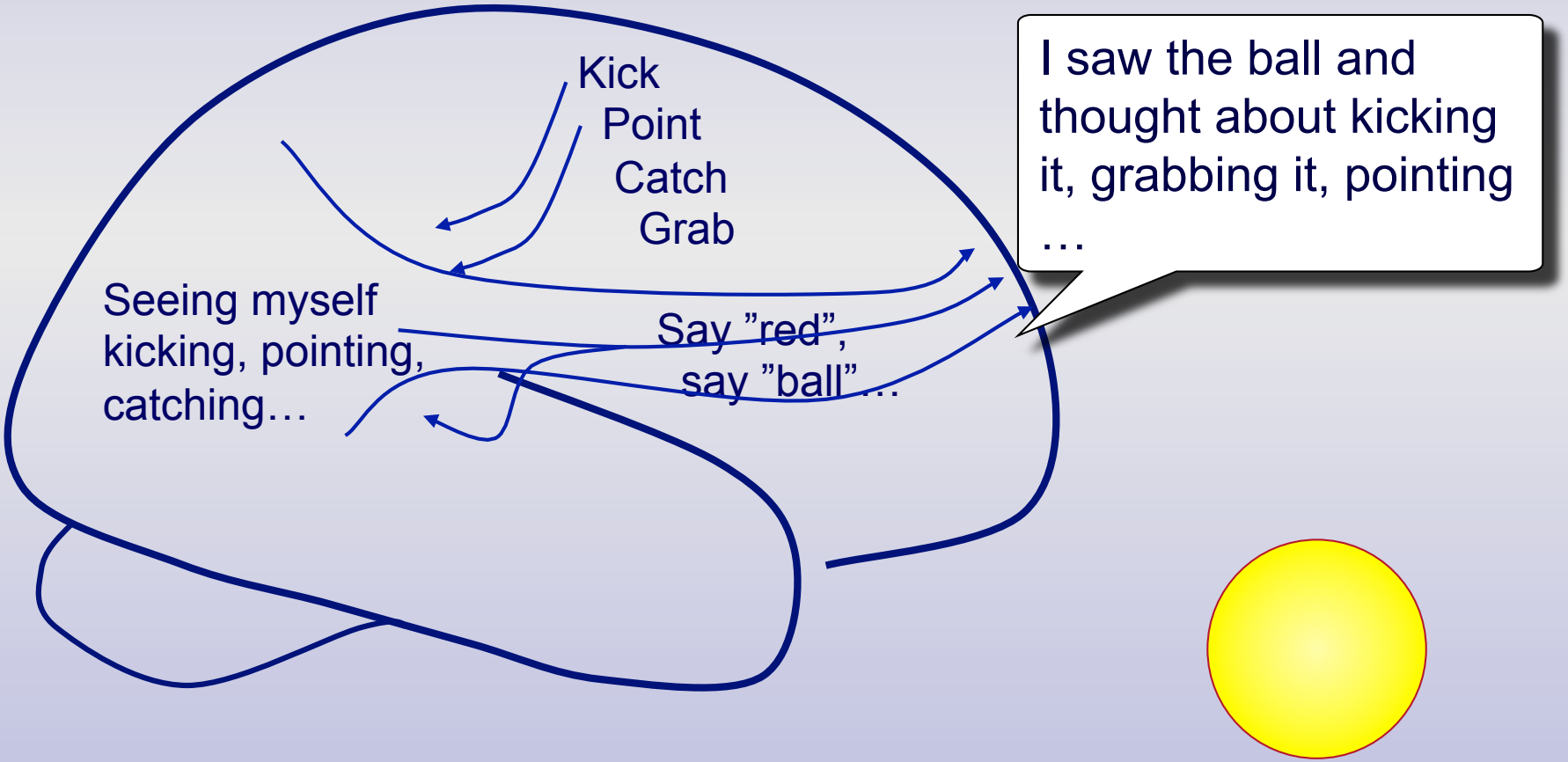
# At what point did subject become conscious?

## It didn't!



# Responses elicit simulated perceptions

Both overt and abortive responses elicit simulated perceptions – *these can be reported.*



# The echo in the brain