# C83MAB: Mind and Brain

## Neuroscience of Consciousness II

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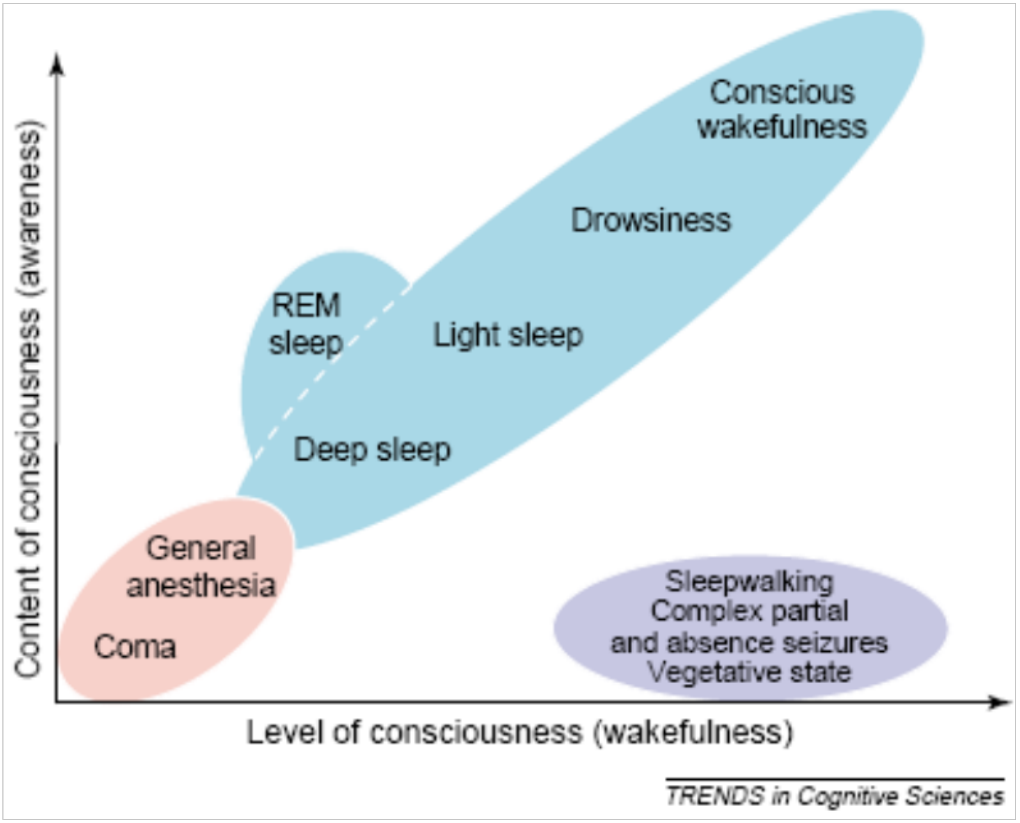
UNITED KINGDOM · CHINA · MALAYSIA

# Consciousness

- **State of consciousness - Being awake/alert/attentive/responsive**

- **Contents of consciousness ('consciousness of . . .') – particular (reportable) experience at a certain level of consciousness**




Laureys (2005) Trends in Cogn. Sci. 9:556-559

# Specific contents of consciousness

- **Specific conscious percepts (example visual percepts)**
- **Conscious (i.e., declarative) memory**
- **Conscious goals / deliberate actions**

# Experimental strategy to identify the neural correlates of (contents of) consciousness



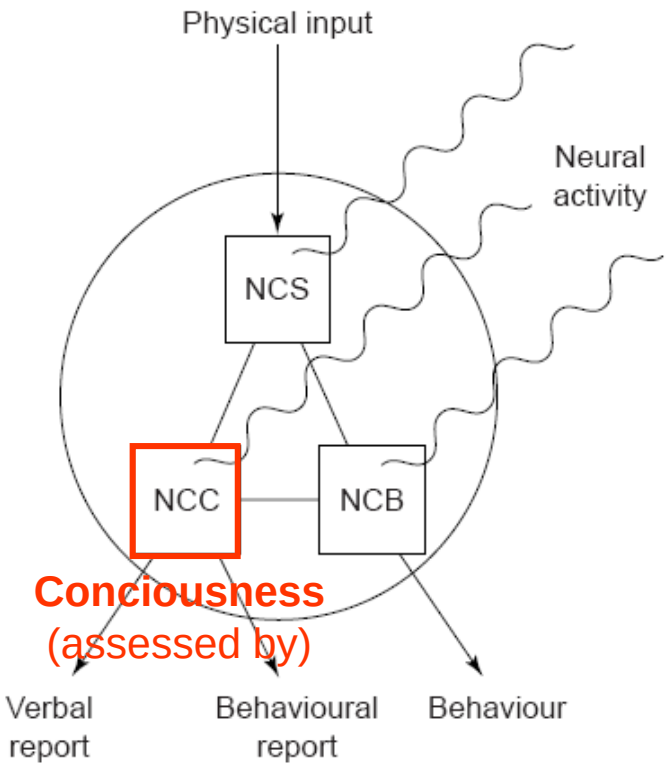



**Fig. 1. Schematic illustration of the three neural correlates that must be contrasted in order to specify the neural correlates of consciousness.** NCS: neural correlates of sensory stimulation. NCB: neural correlates of behaviour. NCC: neural correlates of consciousness. The three different classes of activity need not be spatially segregated in discrete brain regions.

**General strategy to disentangle different NCs**:

Study situations where changes in subjective experience are dissociated from changes in sensory stimulation or behaviour.

**Table 1. Experimental paradigms for studying the neural correlates of consciousness in normal states**

| | Perception | Memory | Action |
|---|---|---|---|
| Subjective experience changes, stimulation and/or behaviour remains constant | Neural correlates of binocular rivalry[23] | Neural correlates of episodic recall[43] | Neural correlates of the awareness of intention[30] |
| Stimulation changes, subjective experience remains constant | Neural correlates of changes in stimulation without awareness[41] | Neural correlates of unrecognised old items[43] | Neural correlates of stimuli eliciting action without awareness[15] |
| Behaviour changes, subjective experience remains constant | Neural correlates of correct guessing without awareness[42] | Neural correlates of implicit learning[44] | Neural correlates of implicit motor behaviour[45] |

*In each category one example is given of an experimental paradigm that has been or could be used to identify neural correlates of consciousness, sensory stimulation or behaviour.*

**Table 2. Experimental paradigms for studying the neural correlates of consciousness in abnormal states**

| | Perception | Memory | Action |
|---|---|---|---|
| Subjective experience changes, stimulation and/or behaviour remains constant | Neural correlates of hallucinations[24] | Neural correlates of confabulation[40] | Neural correlates of abnormal intentions (delusions of control)[49] |
| Stimulation changes, subjective experience remains constant | Neural correlates of stimulation of the blind field in blindsight[14] | Neural correlates of unrecognised items in amnesia[47] | Neural correlates of stimuli eliciting unintended actions[50] |
| Behaviour changes, subjective experience remains constant | Neural correlates of correct reaching in form agnosia[46] | Implicit learning in amnesia[48] | Neural correlates of unintended actions[33] |

*In each category one example is given of an experimental paradigm that has been or could be used to identify neural correlates of consciousness, sensory stimulation or behaviour.*

Frith et al. (1999) *Trends Cogn. Sci.* 3:105-114

# Specific contents of consciousness

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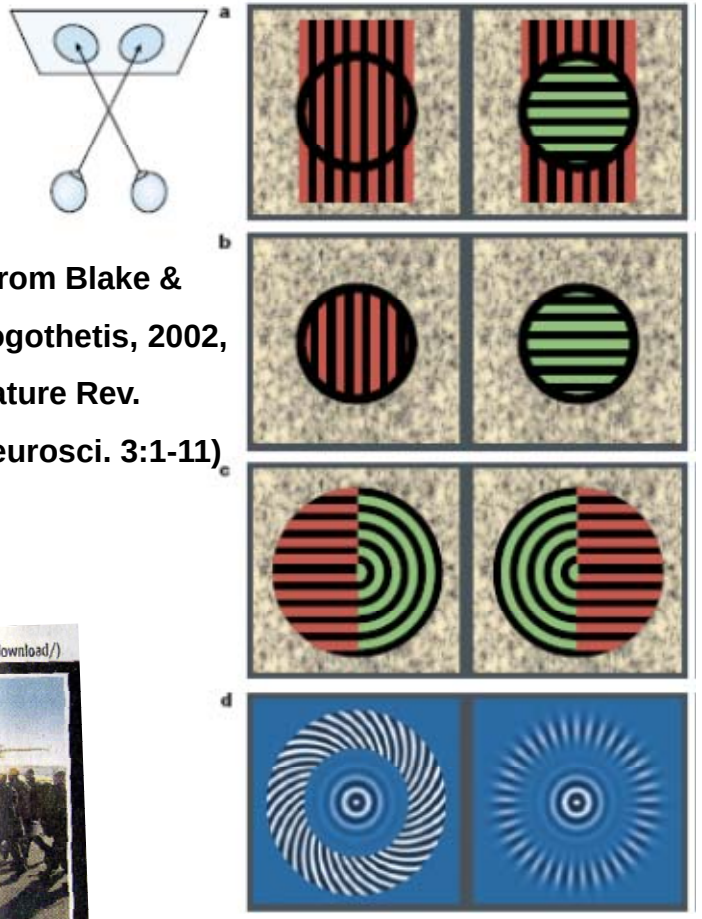
# Changes in conscious visual percepts with constant visual stimulation – tools to study the neural correlates of visual consciousness

## Ambiguous figures

E.g., Kleinschmidt et al., 1998, *Proc. R. Soc. London B* 265:2427-2433

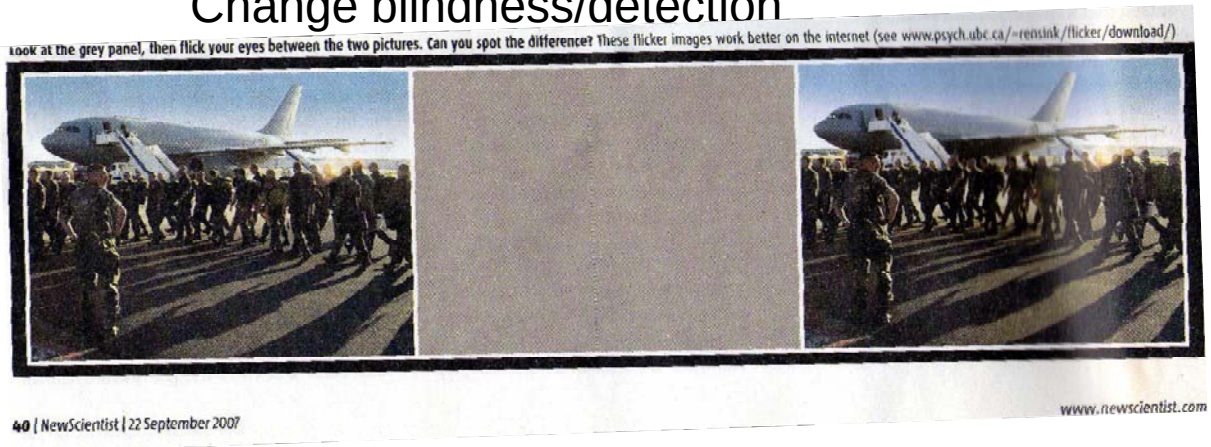
## Binocular rivalry




(From Blake & Logothetis, 2002, Nature Rev. Neurosci. 3:1-11)

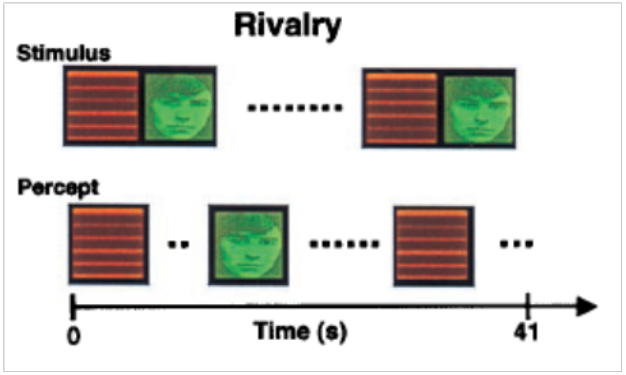
E.g., Lumer et al. (1998) *Science* 280:1930-1934; Lumer & Rees (1999) Proc. Nat. Acad. Sci. USA 96:1669-1673

## Change blindness/detection

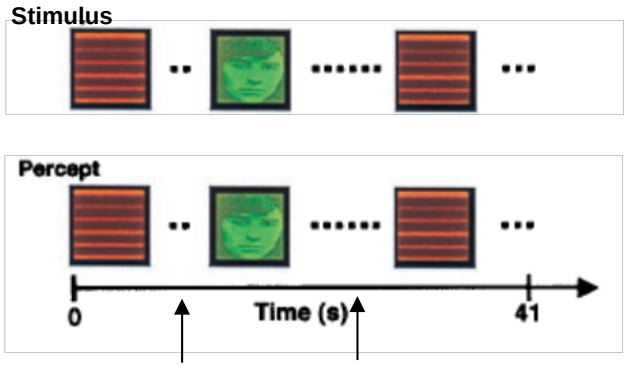



E.g., Beck et al. (2001) *Nature Neurosci.* 4:645-650; Beck et al. (2006) *Cereb. Cortex* 16:712-717

# Neural correlates of perceptual rivalry

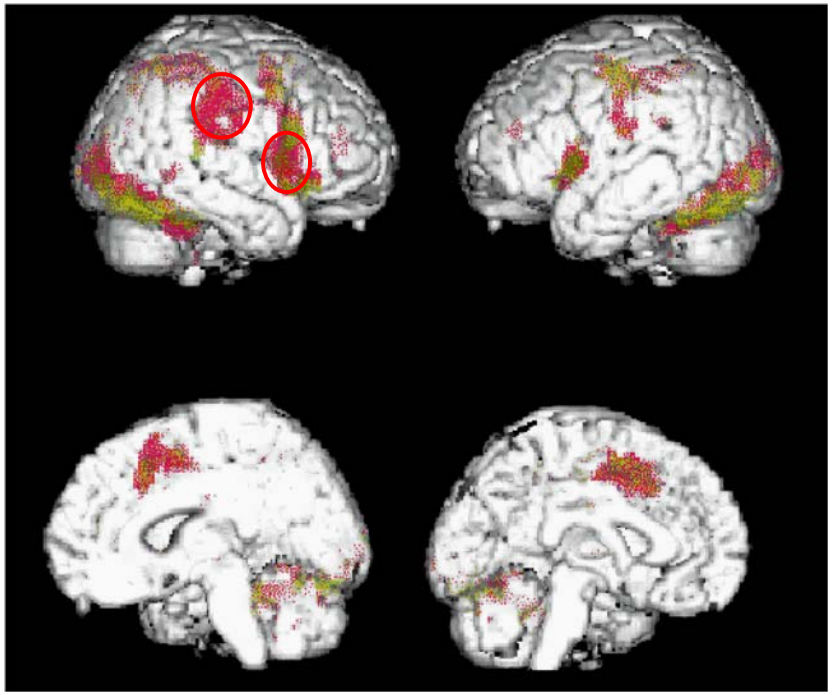



**Replay**




**Transition time points:**
**Physical blends of face and grating**

**Activity (fMRI signal changes) related to perceptual transitions during rivalry and replay conditions**



•Perceptual transitions in both replay and rivalry conditions involve activation of fronto-parietal and visual association (extrastriate) areas (note: not primary visual cortex!).

•Activity in fronto-parietal regions was specifically associated with rivalry condition, leading the authors to suggest that these areas give rise to the “switches” in conscious perception (note: some rivalry-related activation was also found in extrastriate areas).

Lumer et al. (1998) *Science* 280:1930-1934

# Functional-imaging correlates of visual consciousness



•Fronto-parietal substrates

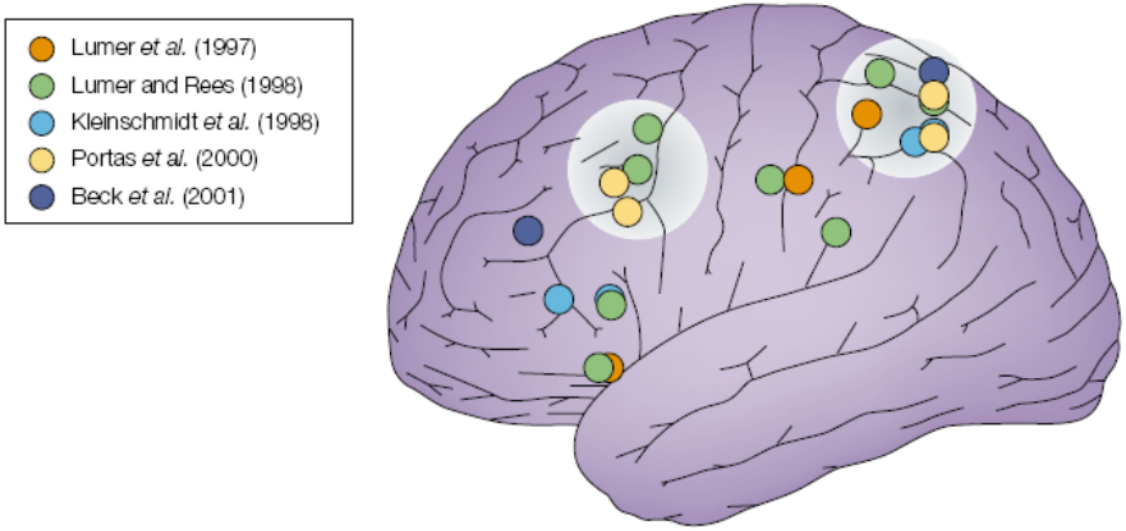



Figure 5 | **Parietal and prefrontal correlates of consciousness.** Areas of parietal and prefrontal cortex that show activation correlated with changes in visual awareness (REFS 85–87,91,92) are plotted on a standardized brain. Each coloured circle is placed at the centre of a cluster of activation, with different colours representing different studies; overlapping loci from the same study are omitted for clarity. There is prominent clustering of activations in superior parietal and dorsolateral prefrontal cortex, highlighted by large, light circles.

•Activity in visual association (extrastriate) cortex also correlates well with aspects of visual consciousness, whereas primary visual cortex activity shows less clear correlates.

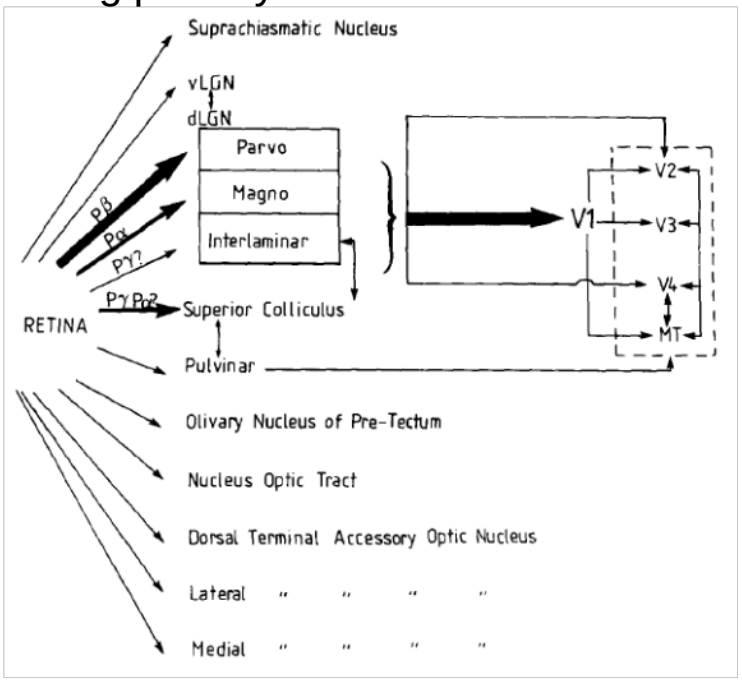
•Neural activity in a brain area may not be the only correlate of consciousness – synchronisation of activity in several distributed brain areas may also be a mechanism underlying (visual) consciousness (Engel & Singer, 2001, *Trends Cogn. Sci.* 5:16-25).

**Rees et al. (2002) *Nature Rev. Neurosci.* 3:261-270.**

# Disorders of visual consciousness

## Blindsight

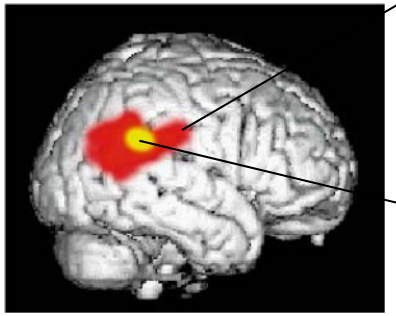
- Behavioural responses to visual stimuli despite absence of visual consciousness (apart from some awareness of moving stimuli) following damage to primary visual cortex.
- Highlights importance of primary visual cortex and subsequent cortical processing for visual consciousness.
- Blindsight is likely mediated by visual pathways bypassing primary visual cortex.

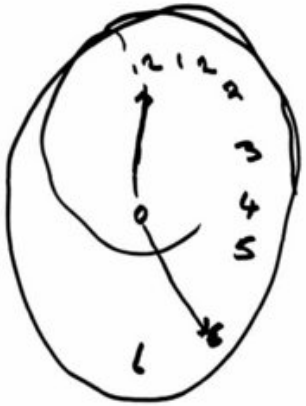



Weiskrantz (2007) Scholarpedia 2(4):3047 (http://www.scholarpedia.org/article/Blindsight); Cowey & Stoerig (1991) *Trends Neurosci.* 14:140-145.

## Hemineglect

Deficient awareness of visual stimuli on contra-lesional side of space (usually left side) following unilateral (usually right-sided) parietal damage.



Husain (2008) Scholarpedia 3(2):3681 (http://www.scholarpedia.org/article/Hemineglect); Driver & Mattingley (1998) *Nature Neurosci.* 1:17-22.

# Specific contents of consciousness

- Specific conscious percepts (example visual percepts)
- **Conscious (i.e., declarative) memory**
- Conscious goals / deliberate actions

# Conscious and unconscious memory

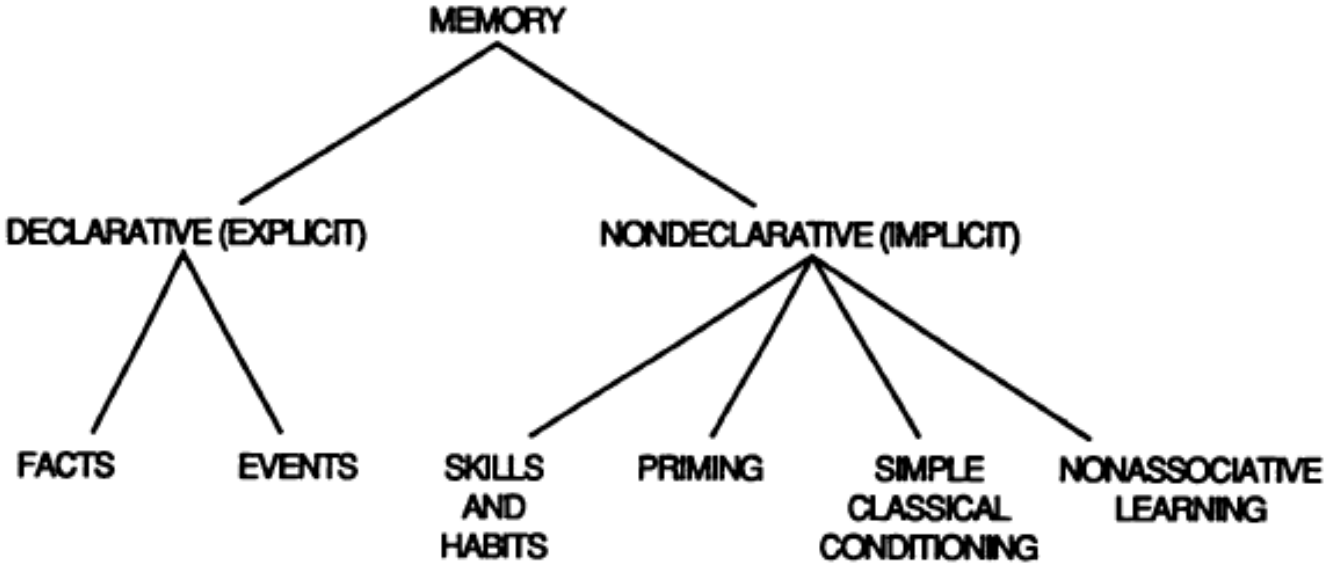
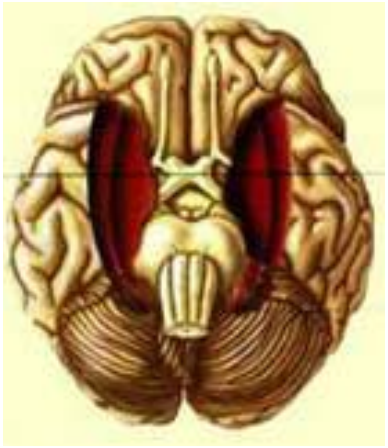


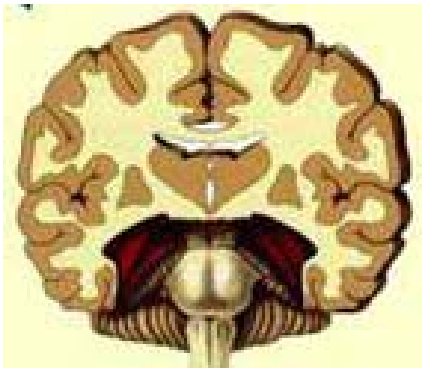

**Fig. 3.** Classification of memory. Declarative (explicit) memory refers to conscious recollections of facts and events and depends on the integrity of the medial temporal lobe (see text). Nondeclarative (implicit) memory refers to a collection of abilities and is independent of the medial temporal lobe (*60*). Nonassociative learning includes habituation and sensitization. In the case of nondeclarative memory, experience alters behavior nonconsciously without providing access to any memory content (*19, 20*).

Zola-Morgan & Squire (1991) *Science* 253:1380-1386.

# Patient HM: severe disruption of declarative memory following medial temporal lobe resection

**Henry G. Molaison**
**1926-2008**





**Surgical resection of medial temporal lobe, mainly hippocampus, to stop epileptic seizures**


HM's obituary: http://www.nytimes.com/2008/12/05/us/05hm.html

Following surgery, HM showed striking deficits in the memory of new and recent experiences, facts, and places (memories which in humans are typically subject to conscious recall), whereas other cognitive functions, including procedural learning, were relatively intact.

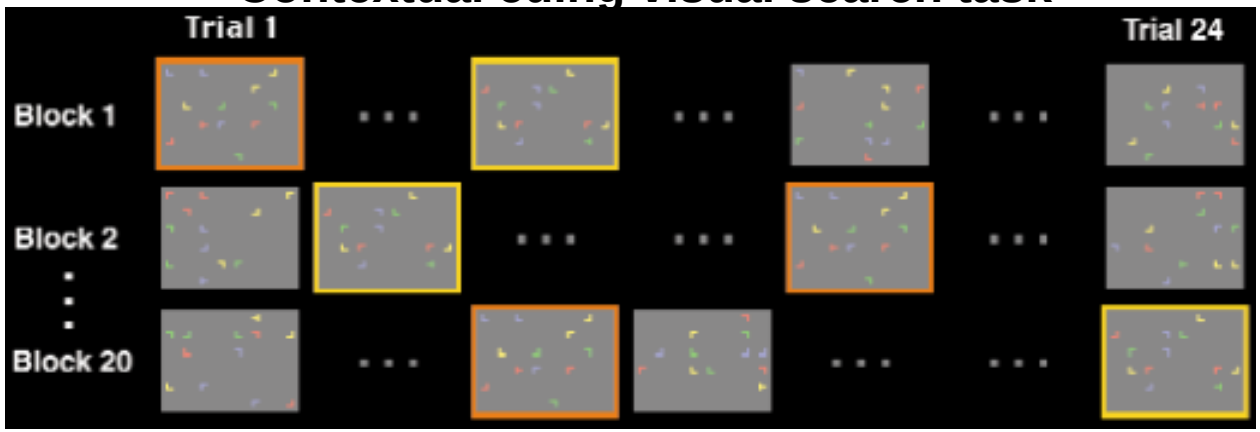
**For detailed overview, see: Corkin S (2002) *Nature Rev. Neurosci.* 3:153-160.**

**So, does MTL/hippocampus mediate consciousness of memories?! Alternatively, MTL/hippocampus may not contribute to consciousness of memories per se, but mediate a specific type of memory that is typically consciously recalled.**

# Impaired implicit contextual memory in patients with hippocampal damage

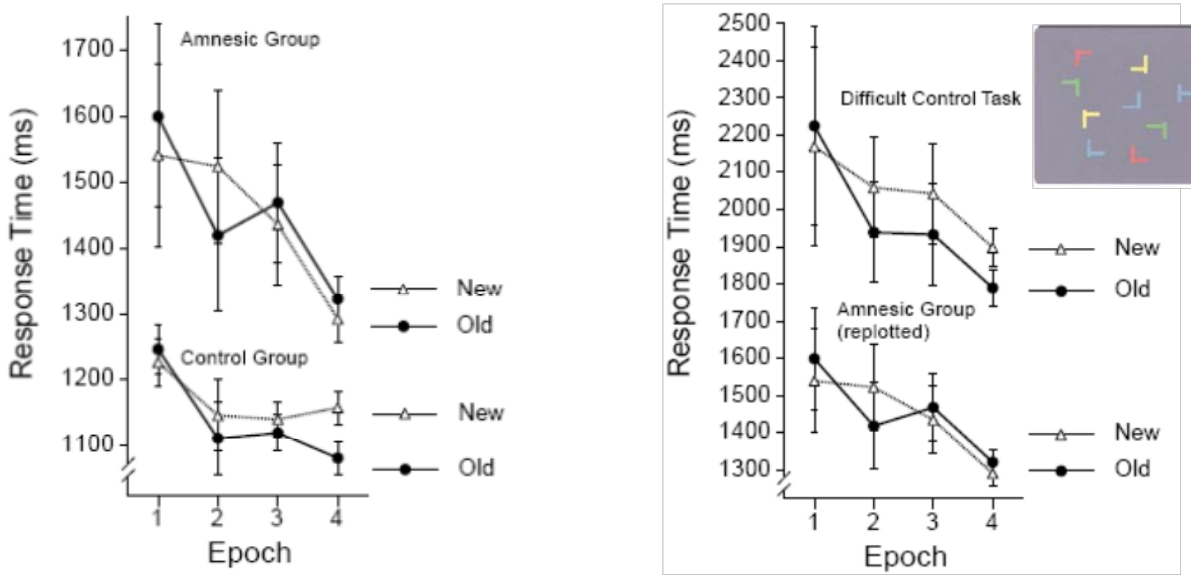


## Contextual cuing visual search task




- Across trials, identification of target (T) gets faster, reflecting perceptual skill learning.
- On later trials, target identification is faster in old vs. new displays, reflecting memory of visuo-spatial context which guides attention to target location.
- Memory of old displays is unconscious (i.e., subjects cannot explicitly discriminate old from new).

## Patients with hippocampal damage show no implicit contextual memory

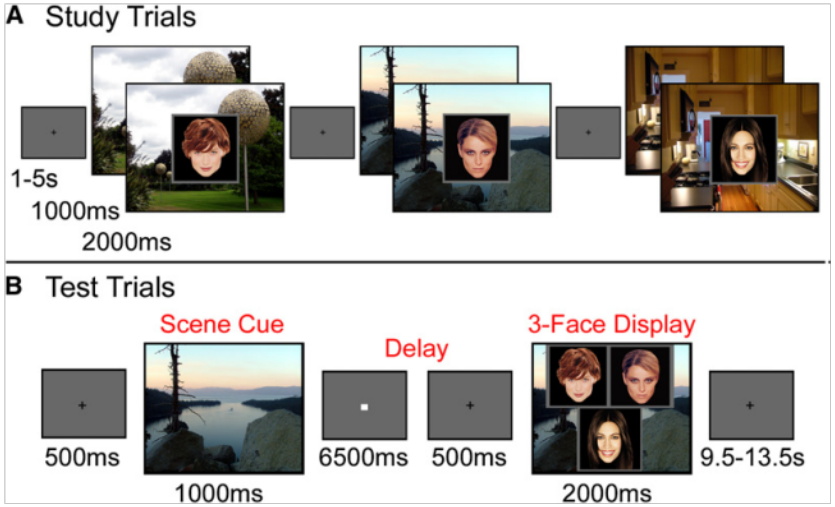



**Deficit may be due to extra-hippocampal MTL damage (see Manns & Squire, 2001, Hippocampus 11:776-782)!**

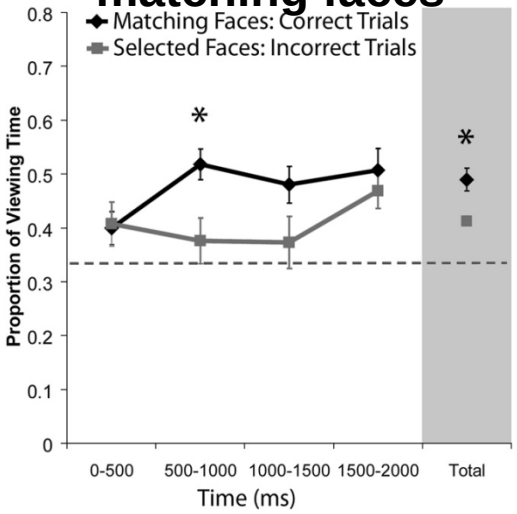
Chun & Phelps (1999) *Nature Neurosci.* 2:844-847

# Hippocampal activity predicts implicit relational memory, despite failure in conscious retrieval

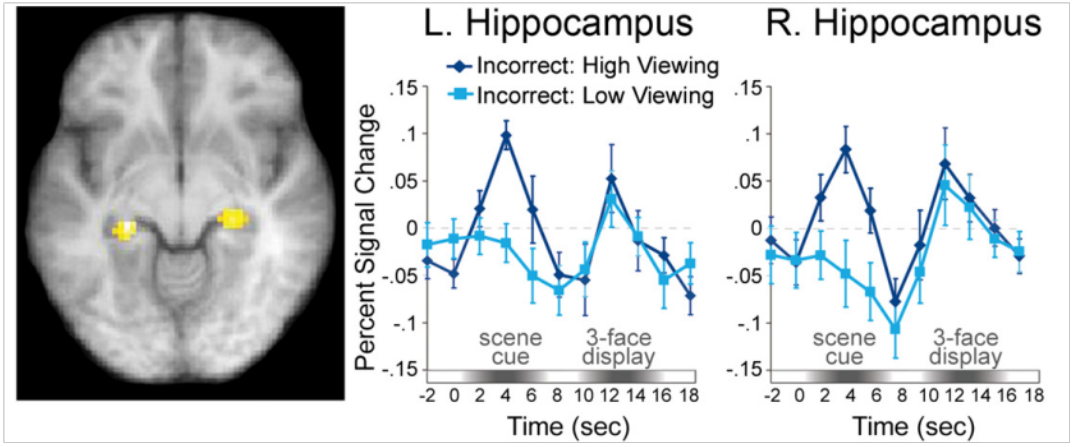
## Face-scene paired associates learning




## Increased viewing time for matching faces




## Hippocampal activity in response to scene cue predicts high viewing of correct face (implicit memory) on trials with incorrect explicit recognition judgments




**. . . but correct explicit recognition was related to increased lateral prefrontal activity and hippocampal interactions with this region.**

Hannula & Ranganath (2009) *Neuron* 63:592-599

# Brain network involved in conscious memory

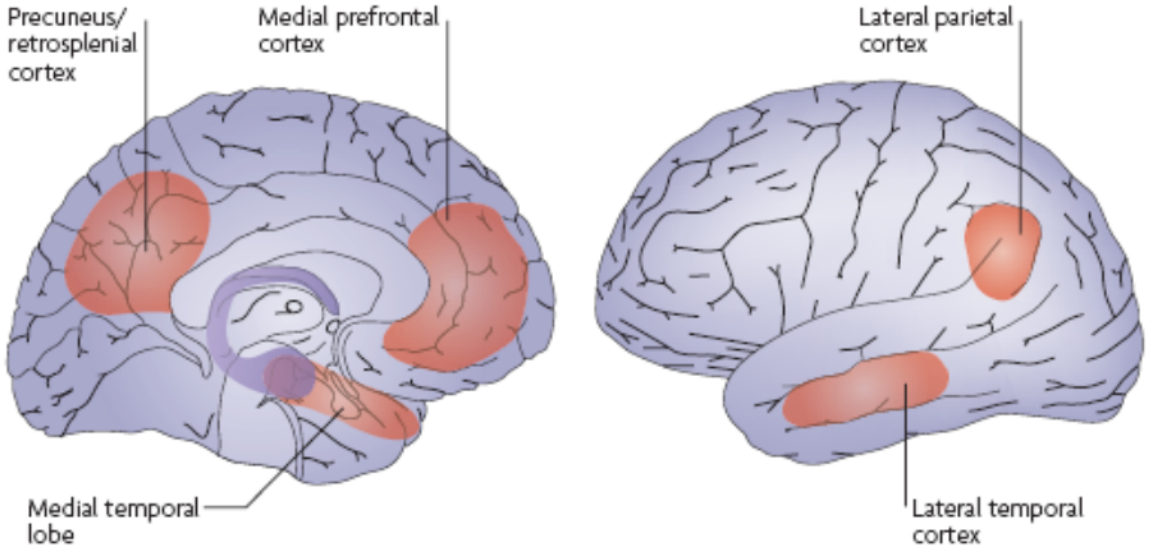



Figure 1 | **The core brain system that mediates past and future thinking.** The core brain system that is consistently activated while remembering the past[30,31,33], envisioning the future[26–28] and during related forms of mental simulation[32] is illustrated schematically. Prominent components of this network include medial prefrontal regions, posterior regions in the medial and lateral parietal cortex (extending into the precuneus and the retrosplenial cortex), the lateral temporal cortex and the medial temporal lobe. Moreover, regions within this core brain system are functionally correlated with each other and, prominently, with the hippocampal formation[34,35]. We suggest that this core brain system functions adaptively to integrate information about relationships and associations from past experiences, in order to construct mental simulations about possible future events.

**Schacter et al (2007) *Nature Rev. Neurosci.* 8:657-661;**
**also see Wheeler & Buckner (2001) *Nature Rev. Neurosci.* 2:624-634**

# Specific contents of consciousness

- Specific conscious percepts (example visual percepts)
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# Brain correlates of conscious ‘deliberate’ action

Consciousness of our acts diminishes as these become habits or skills.

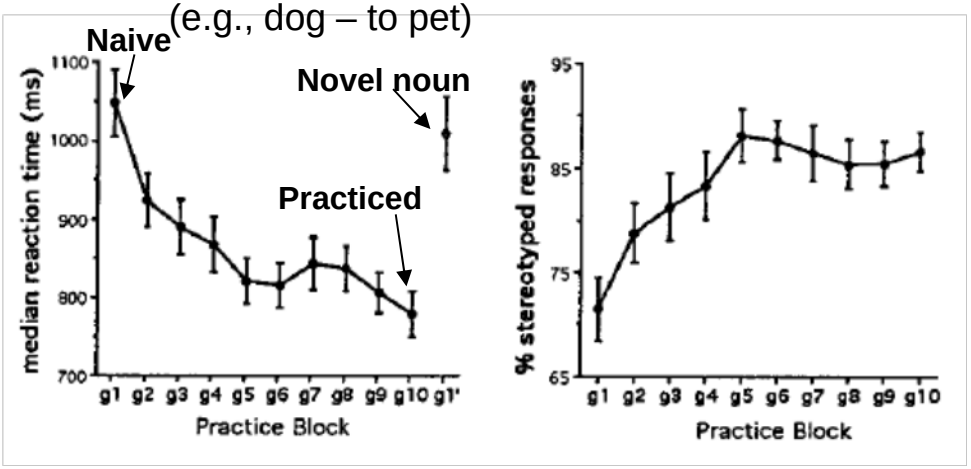
Contrasting brain correlates of naïve performance with those of habitual and skilled behaviour should identify candidate brain substrates of conscious action.

Raichle (1998) *Phil. Trans. R. Soc. Lond.* B 353:1889-1901.

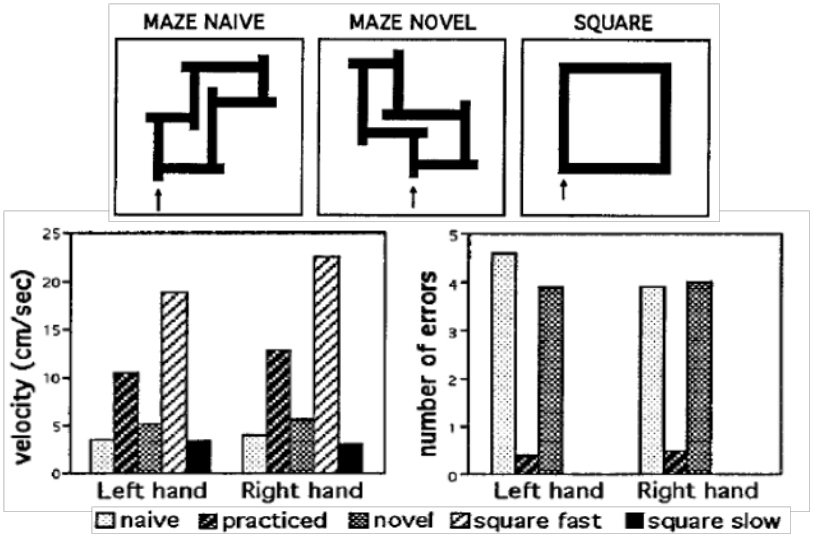
# Functional imaging during skill learning

## Verb generation task

Say appropriate verb for each presented noun (e.g., dog – to pet)

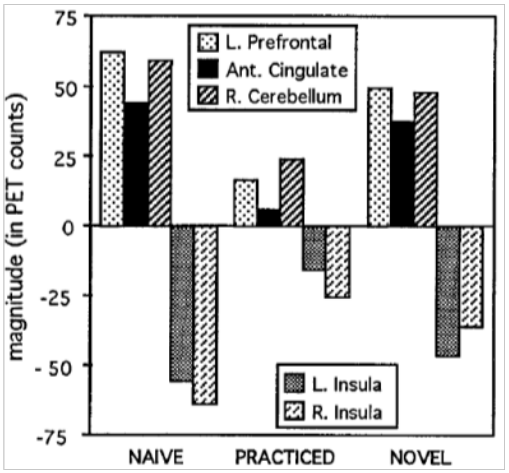



## Maze tracing task



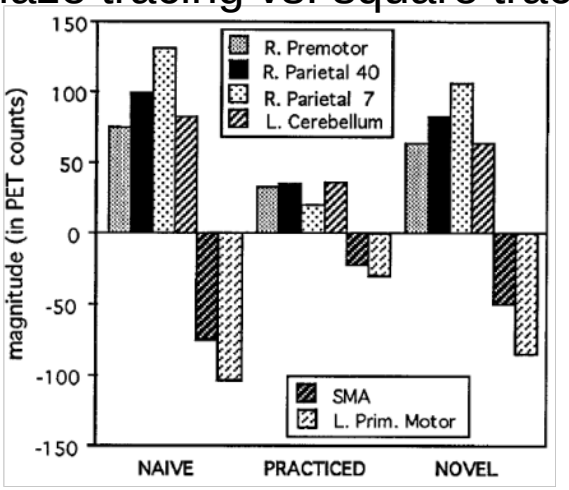

## Areas whose activation changes with practice

### Verb generation vs. reading




Note: Different brain areas!

### Maze tracing vs. square tracing

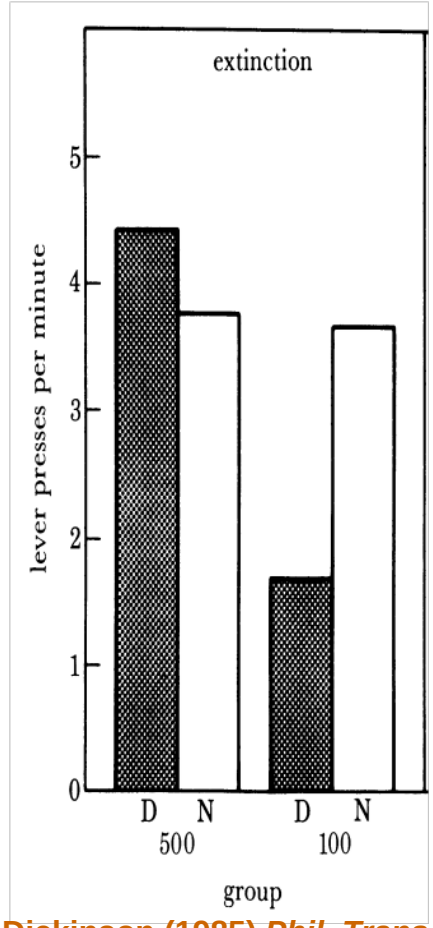



Petersen et al. (1998) *Proc. Nat. Acad. Sci. USA* 95:853-860;
also compare: Raichle (1998) *Phil. Trans. R. Soc. Lond.* B 353:1889-1901.

# Animal model of 'deliberate' action vs. habits/skills

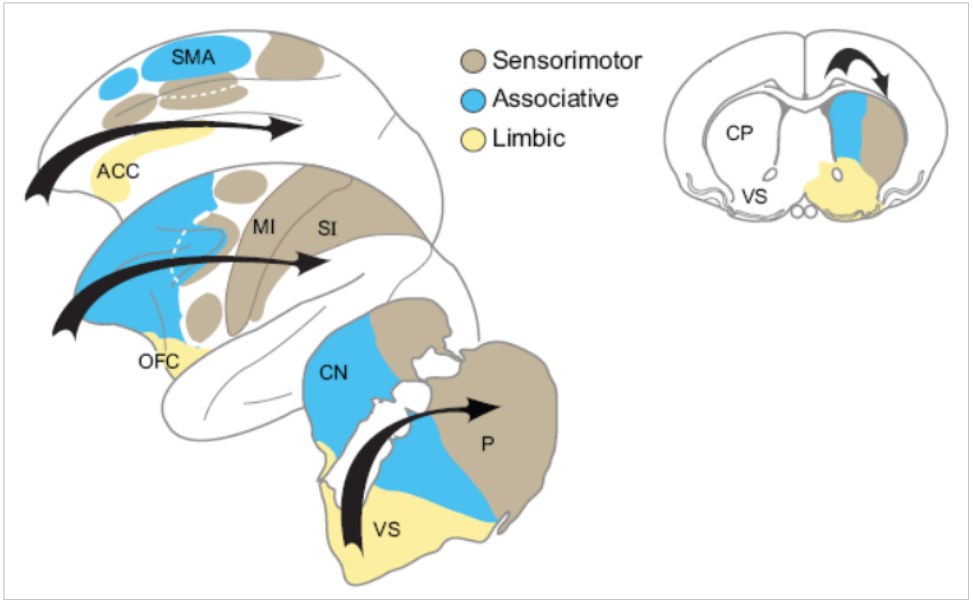
•Deliberate actions are goal-directed, whereas habits are relatively independent of the original goal we had in mind at the beginning of habit formation.

•Goal-directed action vs. habit in animals




Dickinson (1985) *Phil. Trans. R. Soc. Lond.* B 308:67-78.

•Brain substrates of goal-directed action vs. habit as identified by lesion studies in experimental animals




Graybiel (2008) *Ann. Rev. Neurosci.* 31:359-387.

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## Brain substrates?

- **Strategies to identify brain substrates of specific contents of consciousness have been developed.**
- **Several contents of consciousness have been related to brain substrates.**
- **Some brain substrates are content-specific (e.g., visual association cortex) others appear to overlap between different contents (fronto-parietal sites).**
- **If these brain substrates actually mediate phenomenal consciousness or mediate other functions associated with consciousness is often difficult to judge.**

# Problems of consciousness – what is to explain?

- **Difference between wakefulness and sleep**
- **Difference between being responsive and unresponsive**
- **Reportability of our mental states**
- **Integration of information**
- **Ability to access own internal states**
- **Focus of attention**
- **Deliberate control of behaviour (as opposed to automatic behaviour)**

**'Easy' problems**

**The 'hard' problem:**

- **Subjective experience ('phenomenal consciousness', 'qualia')**

How does it arise? What difference does it make?

**Chalmers (1995) "Facing up to the problem of consciousness" Journal of Consciousness Studies 2:200-219**
**http://consc.net/papers/facing.pdf**

# Neuroscience of consciousness II – Selected Reading

***General*:**

Frith C, Perry R, Lumer E (1999) Neural correlates of conscious experience: an experimental framework. Trends Cogn. Sci. 3:106-114.

Dehaene S, Changeux J-P (2011) Experimental and theoretical approaches to conscious processing. Neuron 70:200-227.

***Visual consciousness*:**

Rees G, Kreiman G, Koch C (2002) Neural correlates of consciousness in humans. Nature Rev. Neurosci. 3:261-270.

***Conscious memory*:**

Eichenbaum H (1999) Conscious awareness, memory and the hippocampus. Nature Neurosci. 2:775-776.

Kumaran D, Wagner AD (2009) It's in my eyes, but it doesn't look that way to me. Neuron 63:561-563.

Schacter DL, Addis DR, Buckner RL (2007) Remembering the past to imagine the future: the prospective brain. Nature Rev. Neurosci. 8:657-661.

***Conscious action*:**

Raichle ME (1998) The neural correlates of consciousness: an analysis of cognitive skill learning. Philos. Trans. R. Soc. Lond. B 353:1889-1901.

# Neuroscience of consciousness II – Some questions to guide your revision



- What can be the different contents of our consciousness?

- How can neuroscientists study the substrates that contribute to our contents of consciousness?

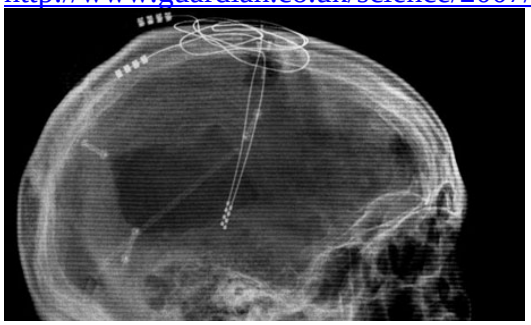
- What problems of consciousness have neuroscientists addressed, perhaps even solved? What problems remain to be addressed or solved?

**Neuroscience of Consciousness Seminar (Tobias Bast) – papers for presentations**

You can propose a paper/text relevant to the neuroscience of consciousness or decision making, and we can see if it is suitable for the seminar!

Alternatively, you can select a paper from the list below.

1. Schiff ND, et al. (2007) Behavioural improvements with thalamic stimulation after severe traumatic brain injury. Nature 448:600-603 (plus supplementary online material). Also see news report in Guardian:
   http://www.guardian.co.uk/science/2007/aug/02/3



2. Owen AM, et al. (2006) Detecting awareness in the vegetative state. Science 313:1402 (plus supporting online materials and comments).
   Also see news report in Guardian:
   http://www.guardian.co.uk/news/2006/sep/08/topstories3.science
3. Beck DM, et al. (2006) Right parietal cortex plays a critical role in change blindness. Cereb. Cortex 16:712-717.
4. Monti MM, et al. (2010) Willful modulation of brain activity in disorders of consciousness. N. Engl. J Med 362:579-589.
5. Dehaene S, Changeux J-P (2011) Experimental and theoretical approaches to conscious processing. Neuron 70:200-227. Review article.
6. Blanke O (2012) Multisensory brain mechanisms of bodily self-consciousness. Nature Rev. Neurosci. 13:556-571.