Neurophilosophy of Consciousness

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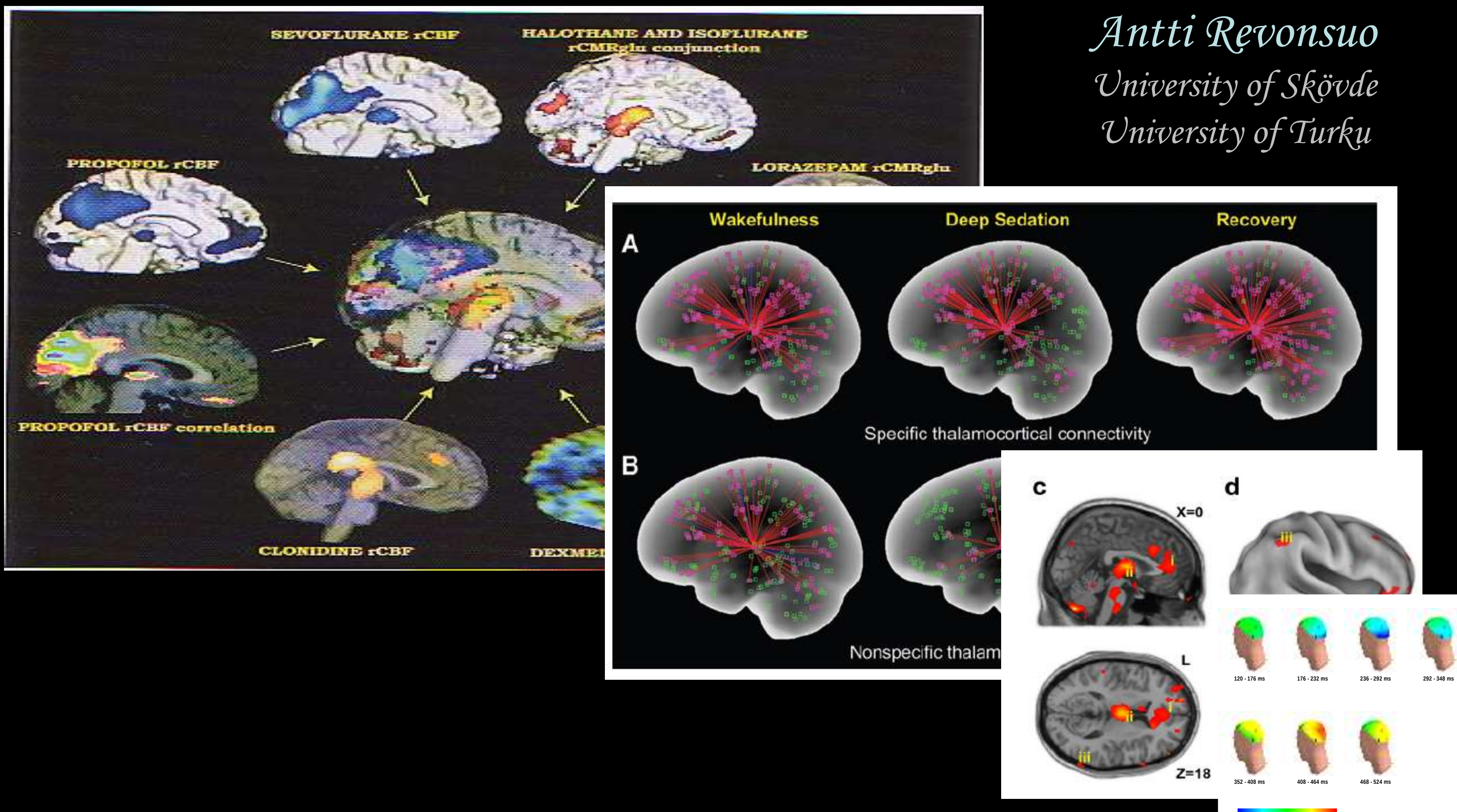

Neurophilosophy of Consciousness

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<u>Explaining Consciousness:</u>

One of the greatest challenges for science

Science (2005):

INTRODUCTION

What Don't We Know?

At *Science*, we tend to get excited about new discoveries that lift the veil a little on how things work, from cells to the universe. That puts our focus firmly on what has been added to our stock of knowledge. For this anniversary issue, we decided to shift our frame of reference, to look instead at what we *don't* know: the scientific puzzles that are driving basic scientific research.

We began by asking *Science*'s Senior Editorial Board, our Board of Reviewing Editors, and our own editors and writers to suggest questions that point to critical knowledge gaps. The ground rules: Scientists should have a good shot at answering the questions over the next 25 years, or they should at least know how to go about answering them. We intended simply to choose 25 of these suggestions and turn them into a survey of the big questions facing science. But when a group of editors and writers sat down to select those big questions, we quickly realized that 25 simply wouldn't convey the grand sweep of cutting-edge research that lies behind the responses we received. So we have ended up with 125 questions, a fitting number for *Science*'s 125th anniversary.

First, a note on what this special issue is not: It is not a survey of the big societal challenges that science can help solve, nor is it a forecast of what science might achieve. Think of it instead as a survey of our scientific ignorance, a broad swath of questions that scientists themselves are asking. As Tom Siegfried puts it in his introductory essay, they are "opportunities to be exploited."

We selected 25 of the 125 questions to highlight based on several criteria: how fundamental they are, how broad-ranging, and whether their solutions will impact other scientific disciplines. Some have few immediate practical implications—the composition of the universe, for example. Others we chose because the answers will have enormous societal impact—whether an effective HIV vaccine is feasible, or how much the carbon dioxide we are pumping into the atmosphere will warm our planet, for example. Some, such as the nature of dark energy, have come to prominence only recently; others, such as the mechanism behind limb regeneration in amphibians, have intrigued scientists for more than a century. We listed the 25 highlighted questions in no special order, but we did group the 100 additional questions roughly by discipline.

Contents >> News

Science (2005)

The greatest and hardest questions for 21st Century science:

#1 What Is the Universe Made Of?

#2 What Is the Biological Basis of Consciousness?

Why is consciousness so important?

Rene Descartes (1596-1650)

Why is consciousness so **important?**

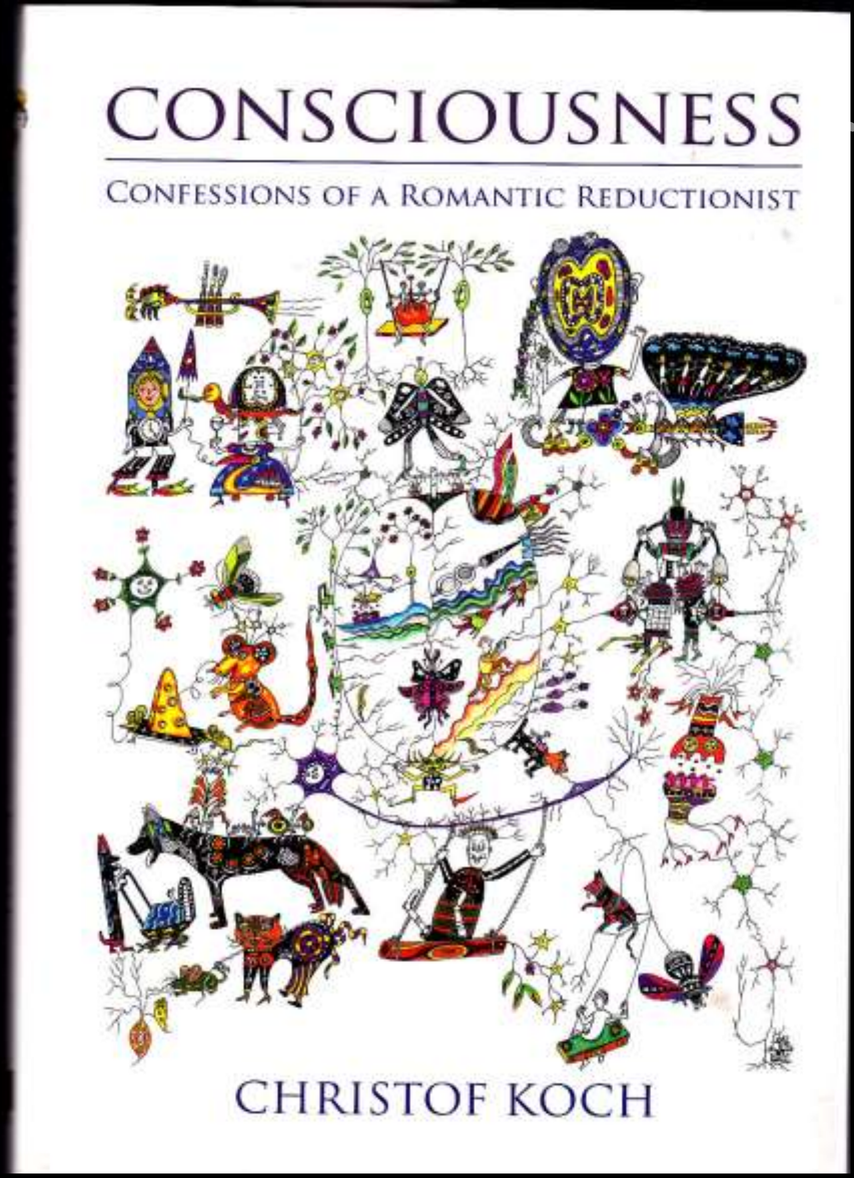
The existence of consciousness cannot be coherently doubted:

Cogito, ergo sum

Why is consciousness so **important?**

Rene Descartes (1596-1650):

We know our own consiousness more directly and more certainly than anything else in this world



Christof Koch (2012),

in "Confessions of a Romantic Reductionist", p. 23.

Consciousness

"Without consciousness there is nothing. The only way you experience your body and the world, is through your subjective experiences.

Christof Koch (2012),
in "Confessions of a Romantic Reductionist", p. 23.

Consciousness

"Ultimately, you only encounter the world in all of its manifestations via consciousness.

And when consciousness ceases, this world ceases as well."

Christof Koch (2012),

in "Confessions of a Romantic Reductionist", p. 23.

What Is ”Neurophilosophy”?

Traditional philosophy:

”Armchair philosophy”

Neurophilosophy of Consciousness:

* How **philosophy** might contribute to **neuroscientific** research on consciousness

* How **neuroscience** might help to solve **philosophical** problems of consciousness

What is “Consciousness” ?

Can ”consciousness” be defined?

Can ”consciousness” be defined?

>> There are many <u>different</u> definitions of consciousness!

>> they have to be <u>distinguished from each other</u>!

Three Major Concepts

Phenomenal consciousness:

Reflective consciousness:

Self-awareness:

Consciousness:

1) Phenomenal Consciousness

- **to *feel one's own existence in the here and now***
- ***qualia*: the redness of red, the hurtfulness of pain…**

Consciousness:

2) Reflective Consciousness

- "thinking", "cognition", inner speech, working memory, voluntary control of attention and action

Consciousness:

3) Self-Awareness

- the idea of a **"self"** as the embodied and temporally enduring (past-present-future) conscious subject

Mirror self recognition:

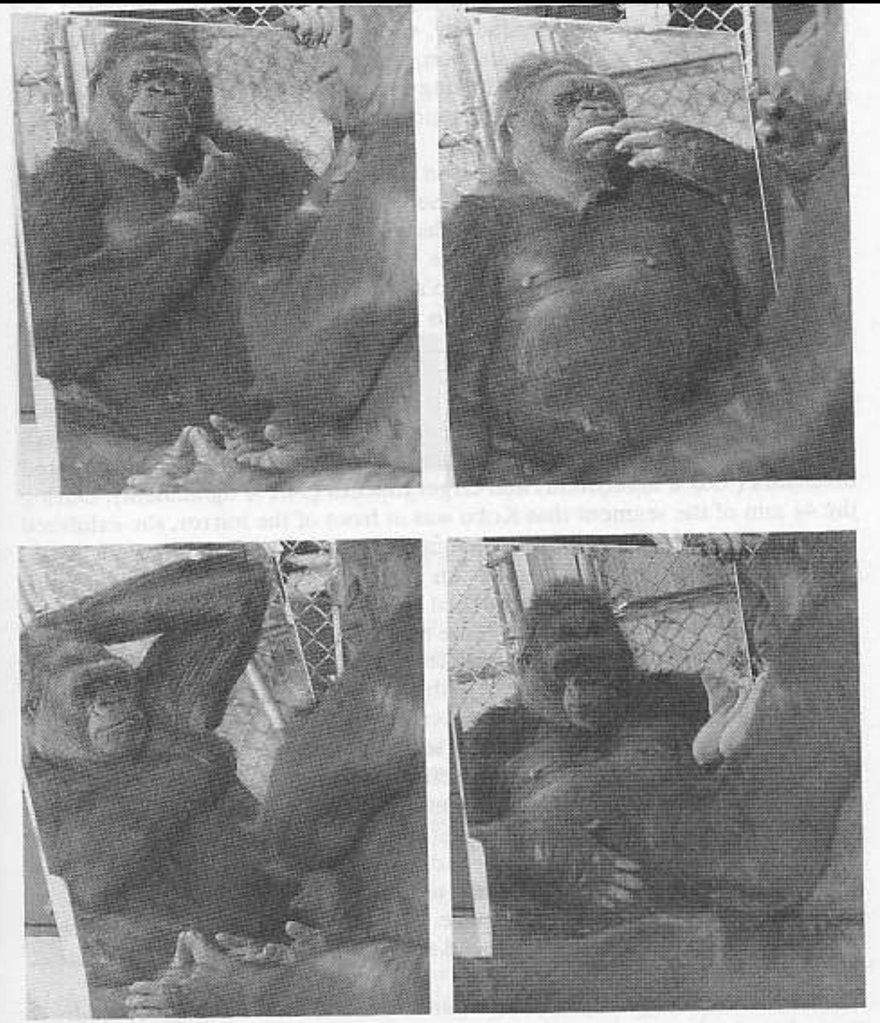


Figure 17.3. With the aid of a mirror, Koko examines parts of her body that she otherwise cannot see.

State and Contents of Consciousness

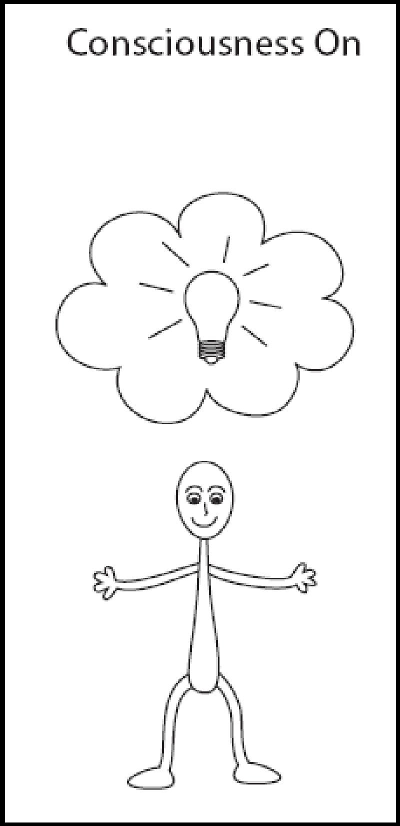
The Contents of Consciousness

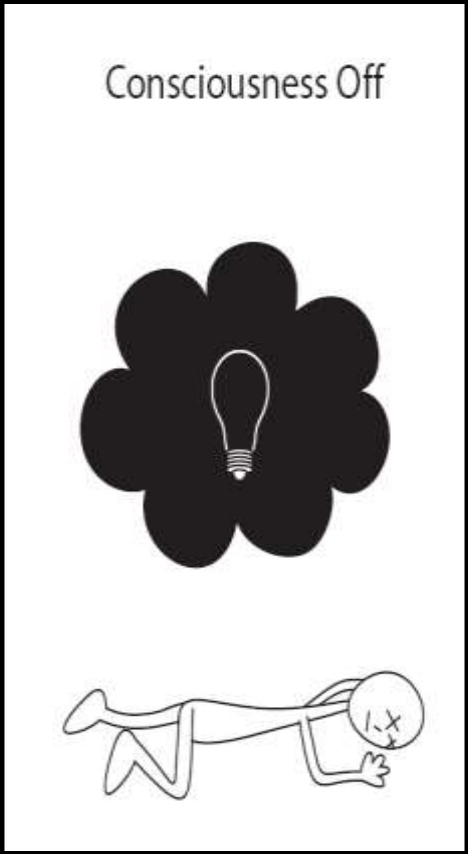
The **<u>Contents</u>** of Consciousness

- **<u>Specific experiences</u>** that occur in the subject's phenomenal consciousness

- colors, sounds, pains, mental images, emotions…

Consciousness as **a <u>State</u>**





Consciousness as a State

- to be in the conscious state is to have the ability to undergo subjective experiences

>> to *feel* one's own existence

(Revonsuo 2006, 2010)

Consciousness as a State

- Conversely, to go into an unconscious state is to lose the ability to have any subjective experiences

>> the inability to *feel* or think anything at all

(Revonsuo 2006, 2010)

BUT: in <u>clinical medicine</u>,

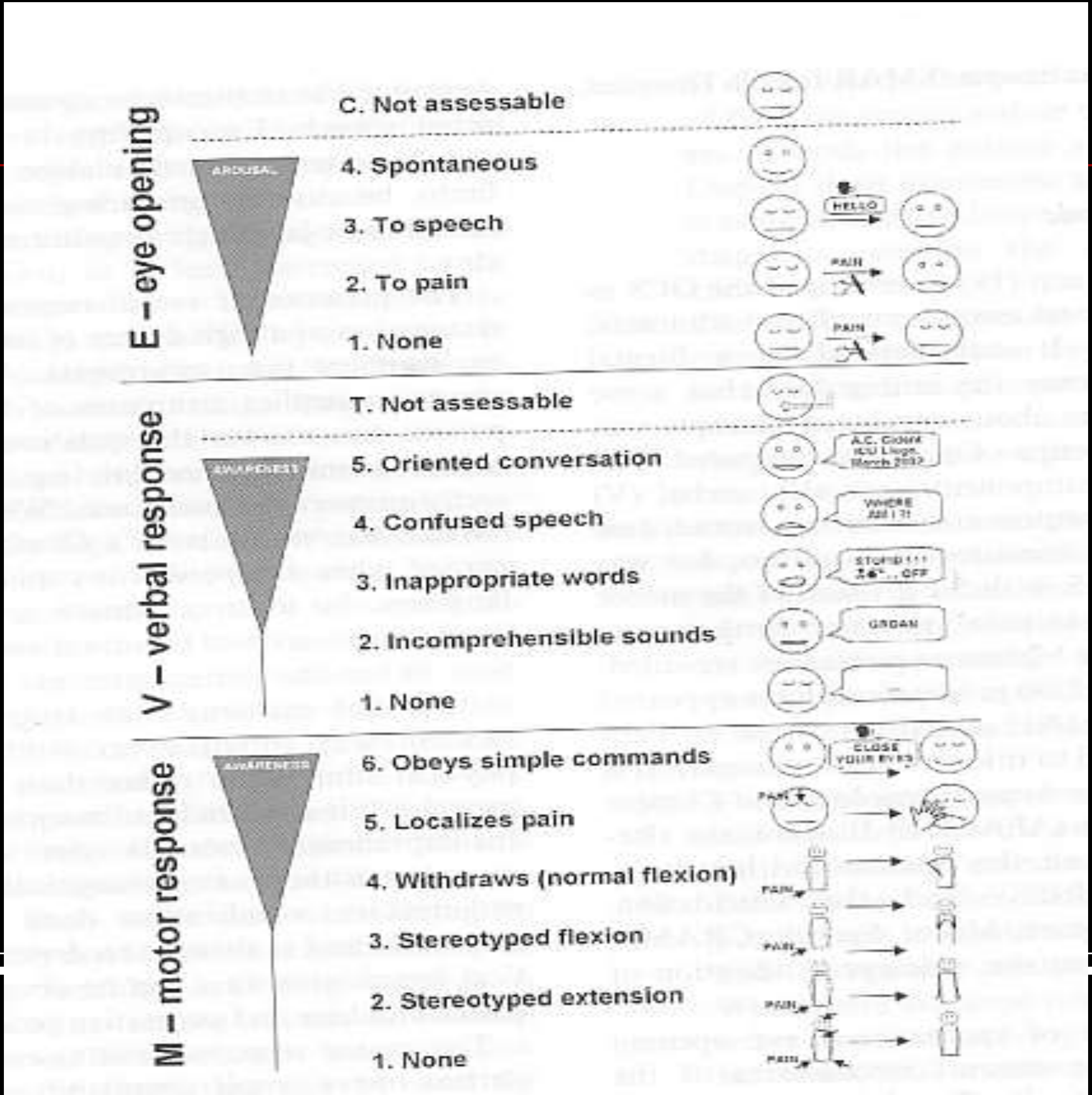
"consciousness" is often defined as…

BUT: in clinical medicine,

"consciousness" is typically defined as

… *responsiveness* to stimuli

Glasgow Coma Scale



BUT:

Are unresponsive patients *necessarily* unconscious??

(i.e. devoid of subjective experiences)?

Dissociations between:

internal ”consciousness”
external ”responsiveness”:

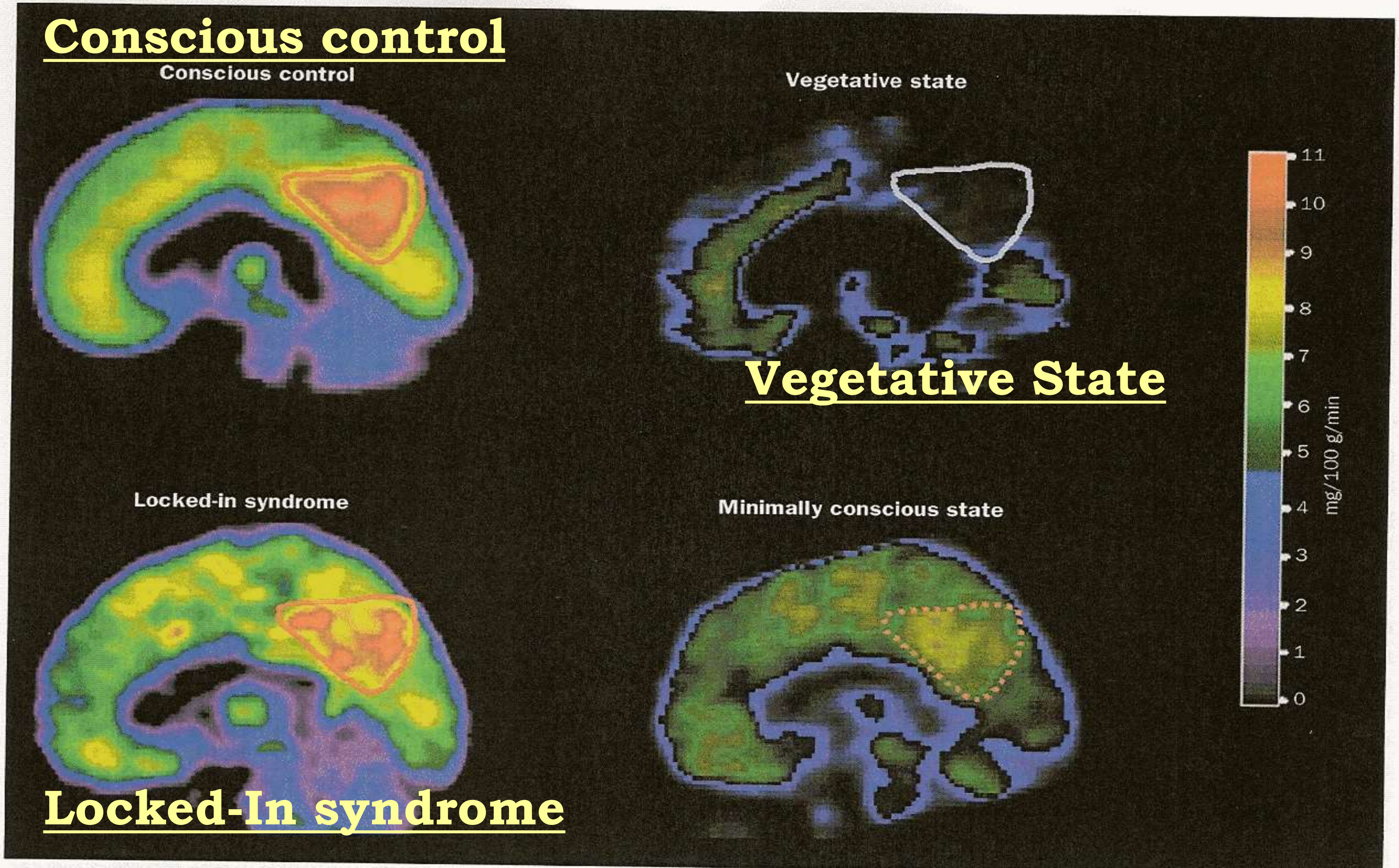
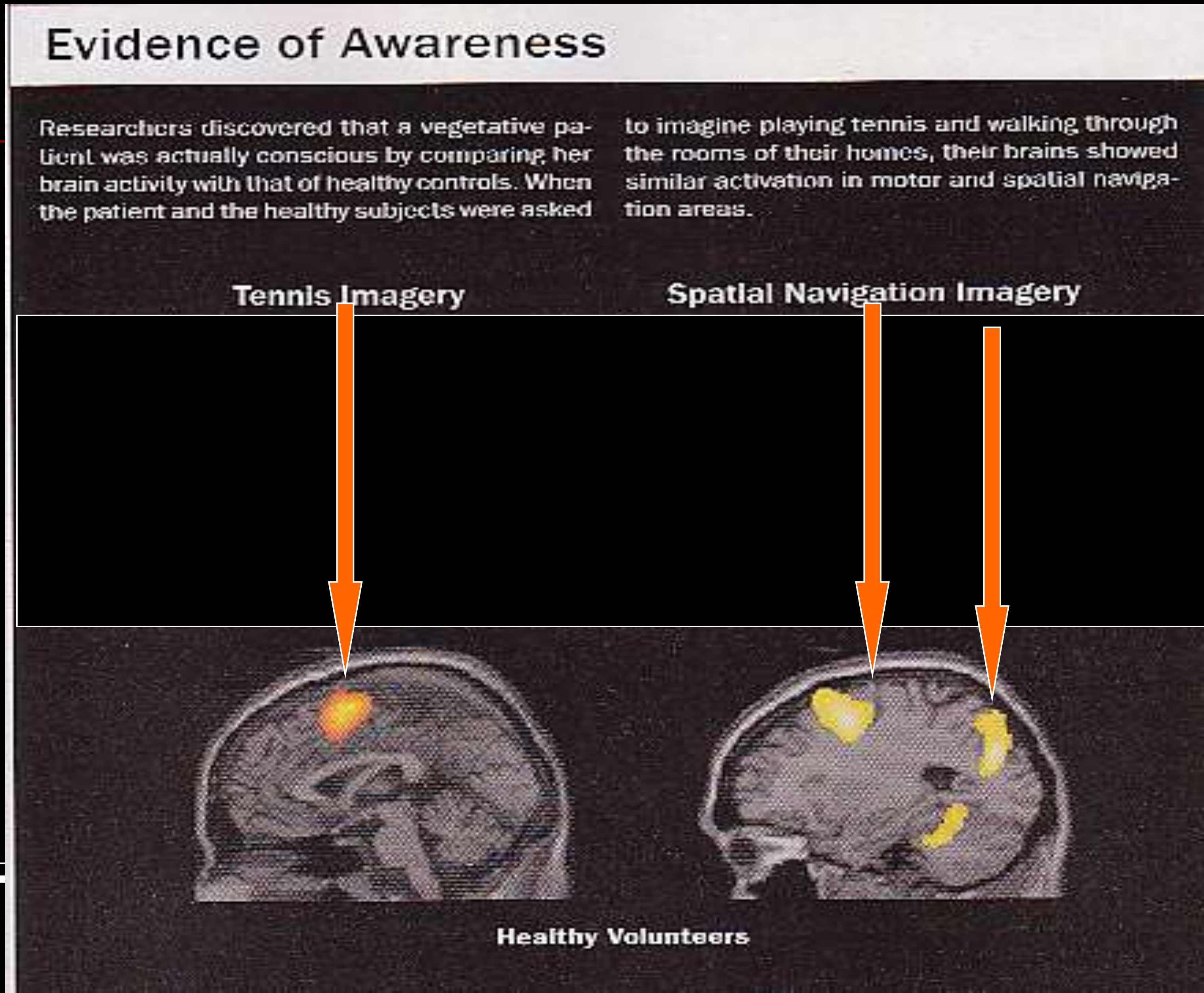


Figure 7. Resting cerebral metabolism in healthy individuals and patients in vegetative state, locked-in syndrome, and minimally conscious state. Images are shown in the sagittal plane with the same colour scale (mg glucose metabolised per 100 g of brain tissue per minute). Note that in healthy (conscious) individuals the medial posterior cortex (encompassing the precuneus and adjacent posterior cingulate cortex, shown with a red line) is the most active region of the brain metabolically; in patients in vegetative state who wake, this same area (shown with a blue line) is the least active region metabolically. In the locked-in syndrome, no supratentorial brain region shows substantial decreases in metabolism. The precuneus and posterior cingulate cortex of patients in minimally conscious state show an intermediate metabolism, higher than in a vegetative state, but lower than in healthy (conscious) individuals. We hypothesise that this region represents part of the neural network subserving consciousness.

Owen et al.,
Science 313: 1402 (Sept. 8, 2006)



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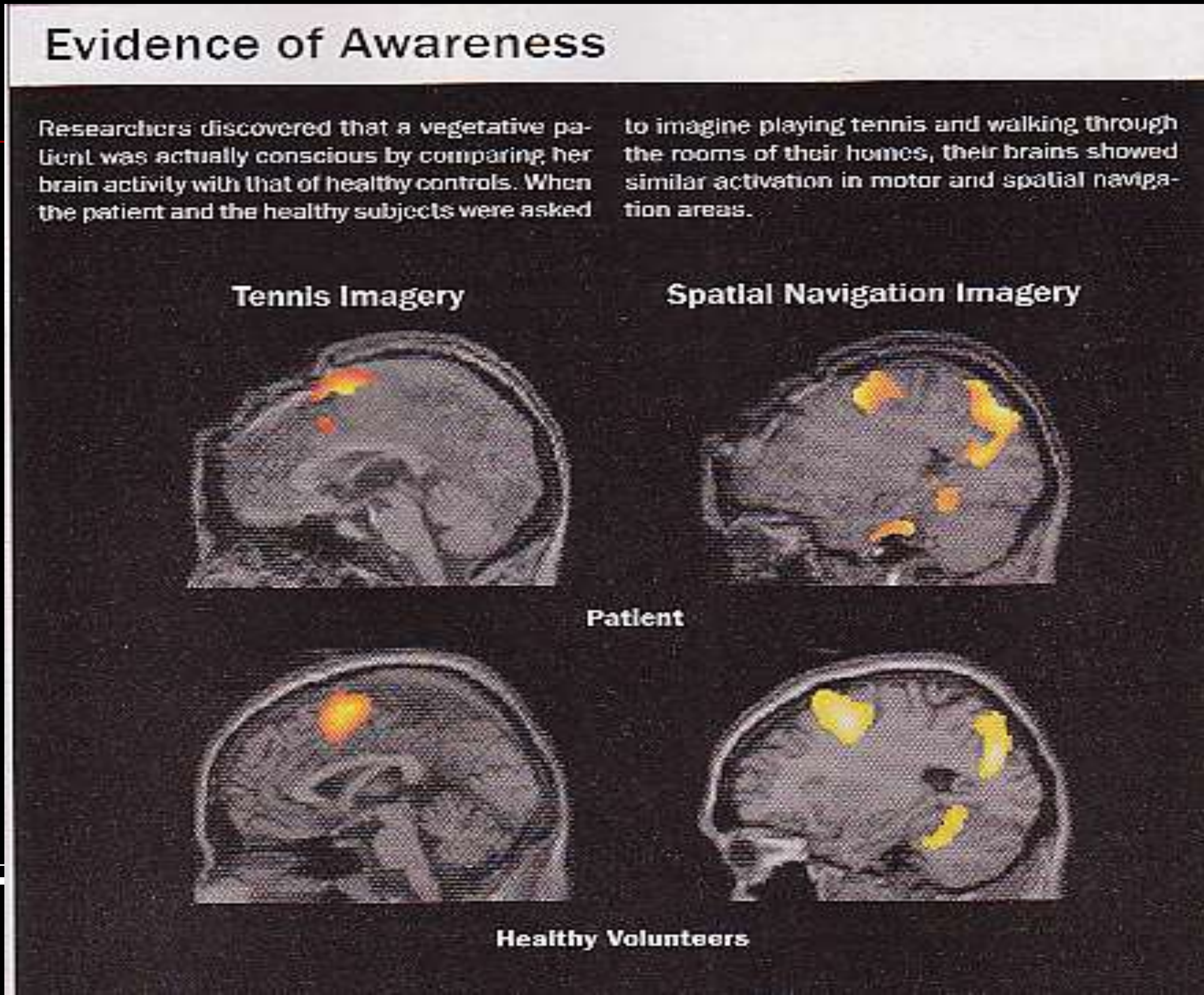


Larger study: communication by brain activity

The NEW ENGLAND JOURNAL of MEDICINE

ESTABLISHED IN 1812 FEBRUARY 18, 2010 VOL. 362 NO. 7

Willful Modulation of Brain Activity in Disorders of Consciousness

Martin M. Monti, Ph.D., Audrey Vanhaudenhuyse, M.Sc., Martin R. Coleman, Ph.D., Melanie Boly, M.D., John D. Pickard, F.R.C.S., F.Med.Sci., Luaba Tshibanda, M.D., Adrian M. Owen, Ph.D., and Steven Laureys, M.D., Ph.D.

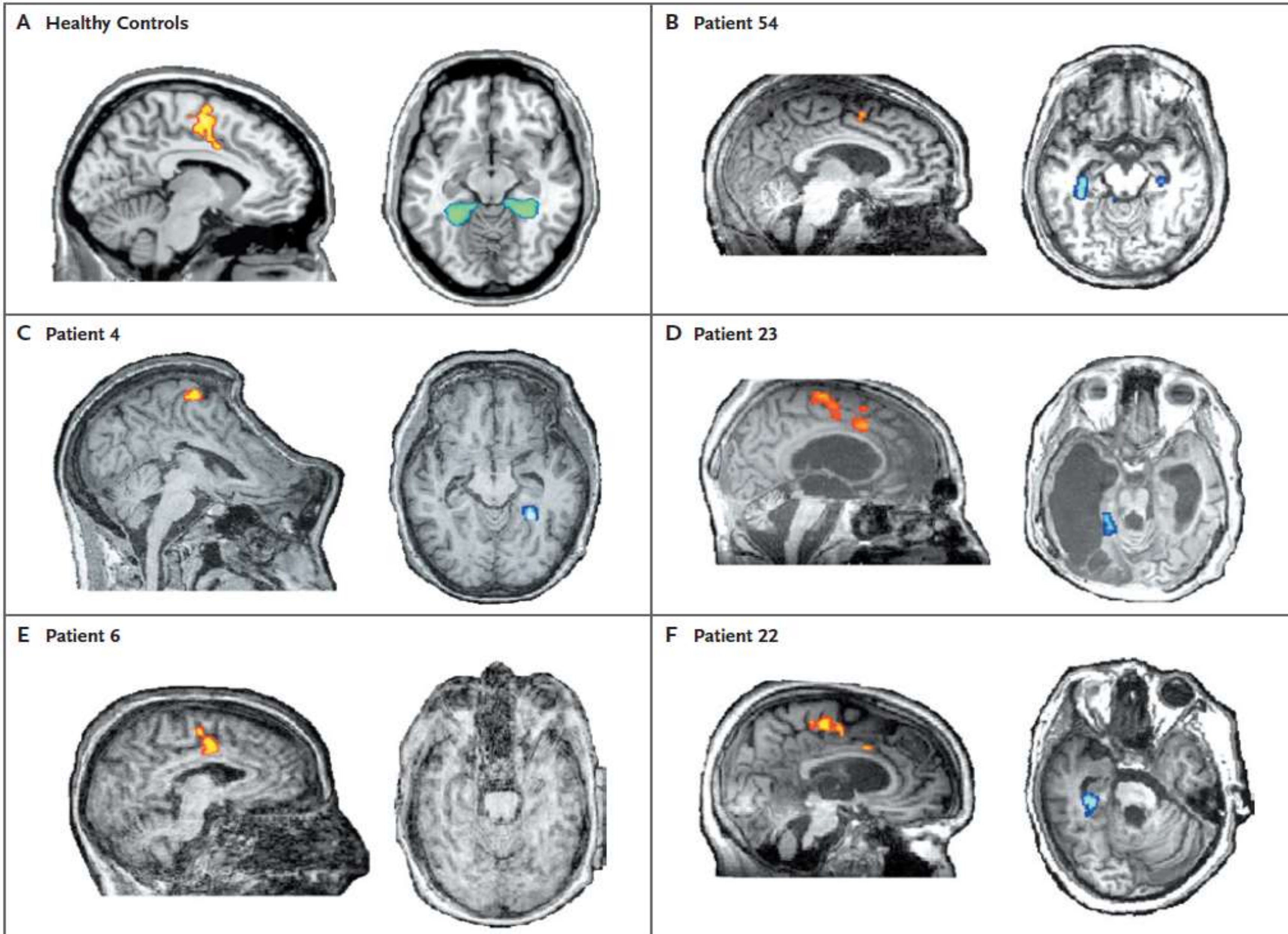
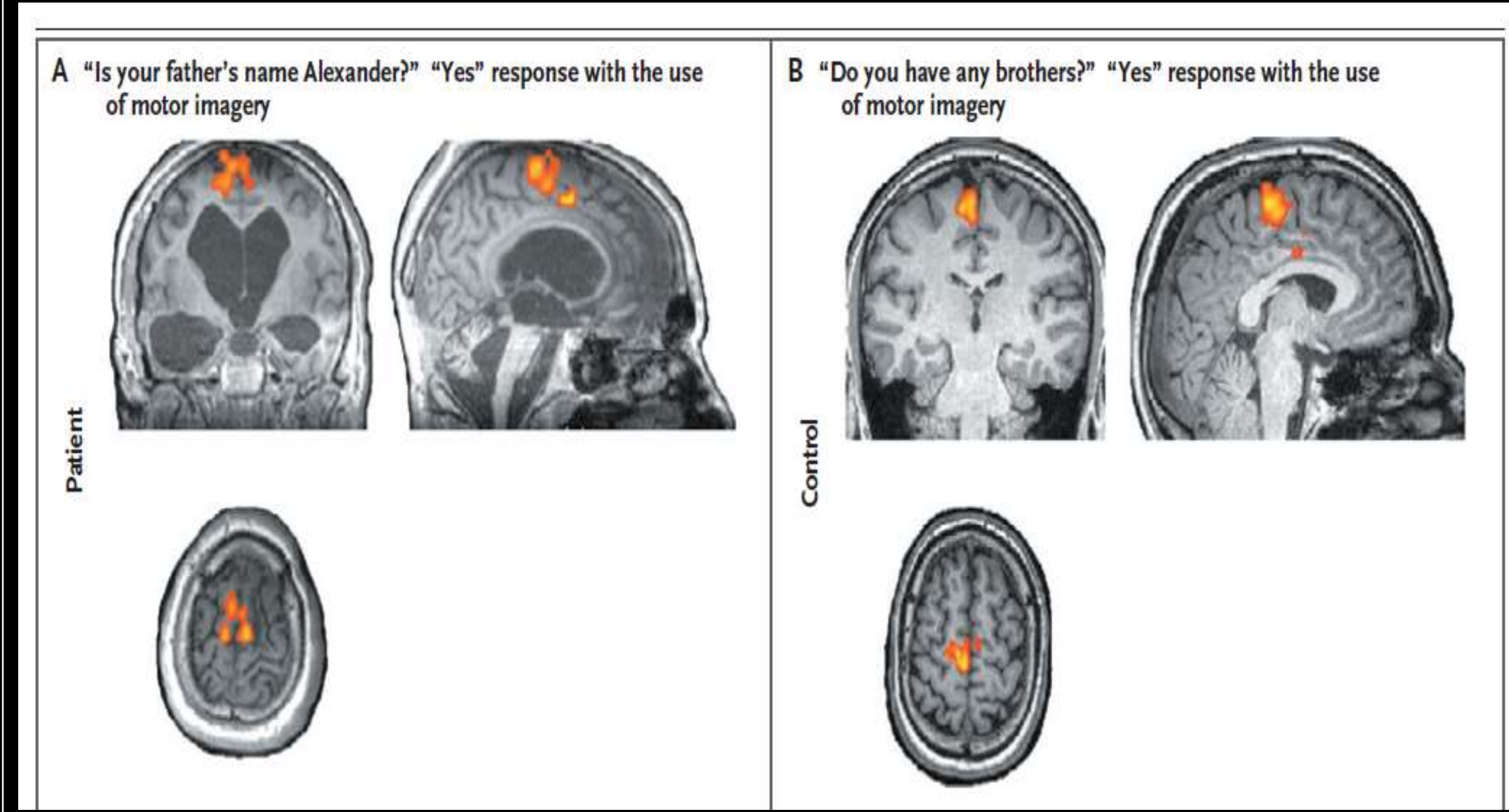


Figure 1. **Mental-Imagery Tasks.**

Functional MRI scans show activations associated with the motor imagery as compared with spatial imagery tasks (yellow and red) and the spatial imagery as compared with motor imagery tasks (blue and green). These scans were obtained from a group of healthy control subjects and five patients with traumatic brain injury.


A "Is your father's name Alexander?" "Yes" response with the use of motor imagery
B "Do you have any brothers?" "Yes" response with the use of motor imagery
Patient
Control

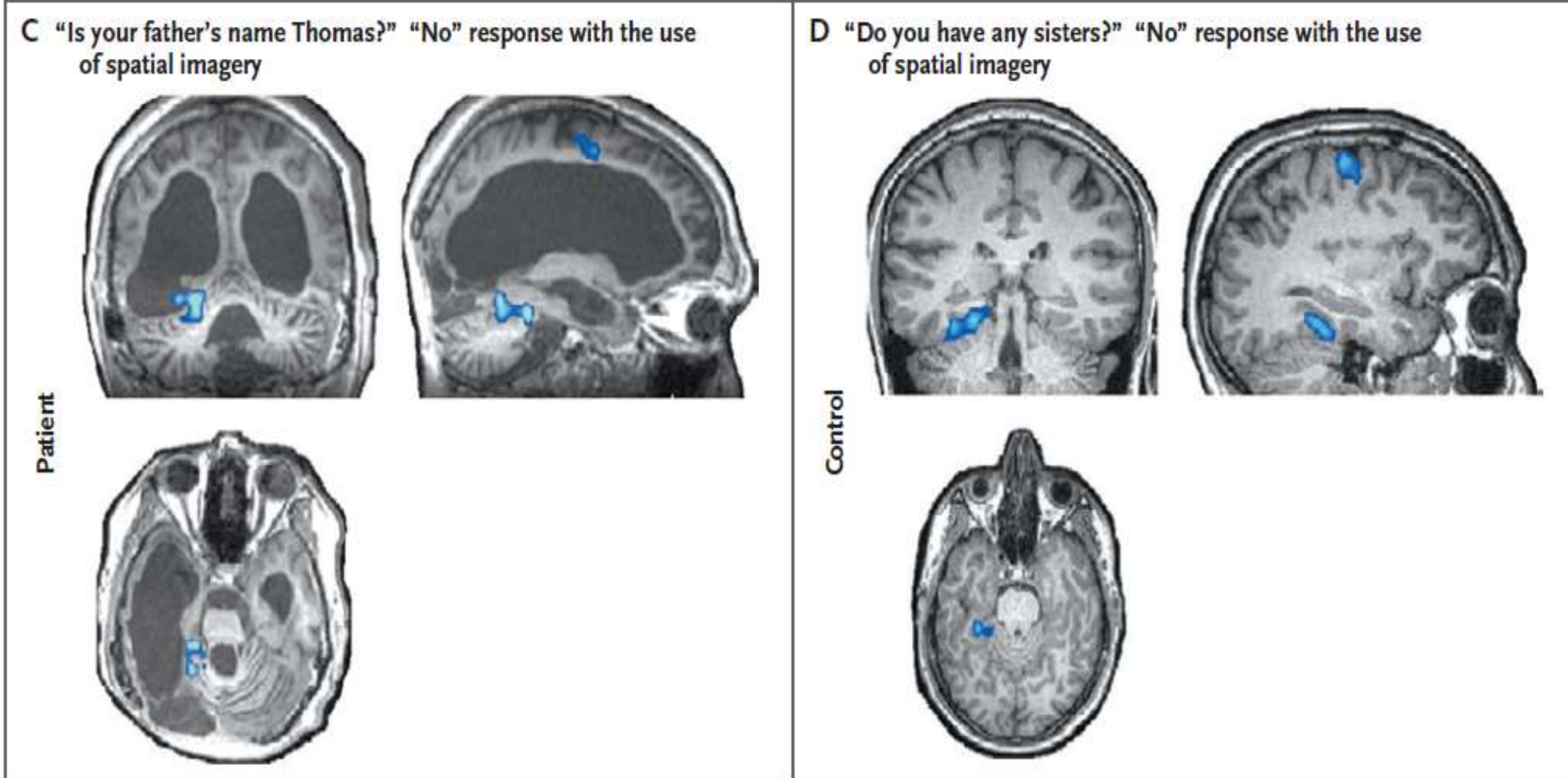


Figure 3. Communication Scans.

Results of two sample communication scans obtained from Patient 23 (Panels A and C) and a healthy control subject (Panels B and D) during functional MRI are shown. In Panels A and B, the observed activity pattern (orange) was very similar to that observed in the motor-imagery localizer scan (i.e., activity in the supplementary motor area alone), indicating a "yes" response. In Panels C and D, the observed activity pattern (blue) was very similar to that observed in the spatial-imagery localizer scan (i.e., activity in both the parahippocampal gyrus and the supplementary motor area), indicating a "no" response. In Panels A and C, the names used in the questions have been changed to protect the privacy of the patient.

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Dissociations between:

internal ”consciousness”
external ”responsiveness”:

Brain and Cognition xxx (2011) xxx–xxx

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Brain and Cognition

journal homepage: www.elsevier.com/locate/b&c

Consciousness lost and found: Subjective experiences in an unresponsive state

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ABSTRACT

Anesthetic-induced changes in the neural activity of the brain have been recently utilized as a research model to investigate the neural mechanisms of phenomenal consciousness. However, the anesthesiologic definition of consciousness as "responsiveness to the environment" seems to sidestep the possibility that an unresponsive individual may have subjective experiences. The aim of the present study was to analyze subjective reports in sessions where sedation and the loss of responsiveness were induced by dexmedetomidine, propofol, sevoflurane or xenon in a nonsurgical experimental setting. After regaining responsiveness, participants recalled subjective experiences in almost 60% of sessions. During dexmedetomidine sessions, subjective experiences were associated with shallower "depth of sedation" as measured by an electroencephalography-derived anesthesia depth monitor. Results confirm that subjective experiences may occur during clinically defined unresponsiveness, and that studies aiming to investigate phenomenal consciousness under sedative and anesthetic effects should control the subjective state of unresponsive participants with post-recovery interviews.

Noreika et al 2011: Consciousness Lost and Found

N = 40 (N = 10 per anesthetic)

* experimental, non-clinical context

* gradual increase of anesthetic until unresponsiveness to command

* BIS- monitoring

* **interview to report experiences immediately after waking up**

Noreika et al 2011: Consciousness Lost and Found

>> In almost 60% of the interviews, subjective experiences were reported from the unresponsive period

>> the experiences were dream-like

Are unresponsive patients *necessarily* unconscious??

(i.e. devoid of subjective experiences)?

>> ”Consciousness”

is NOT the same as

”responsiveness”

NCC:

The Neural Correlates of Consciousness

Model system in NCC research:

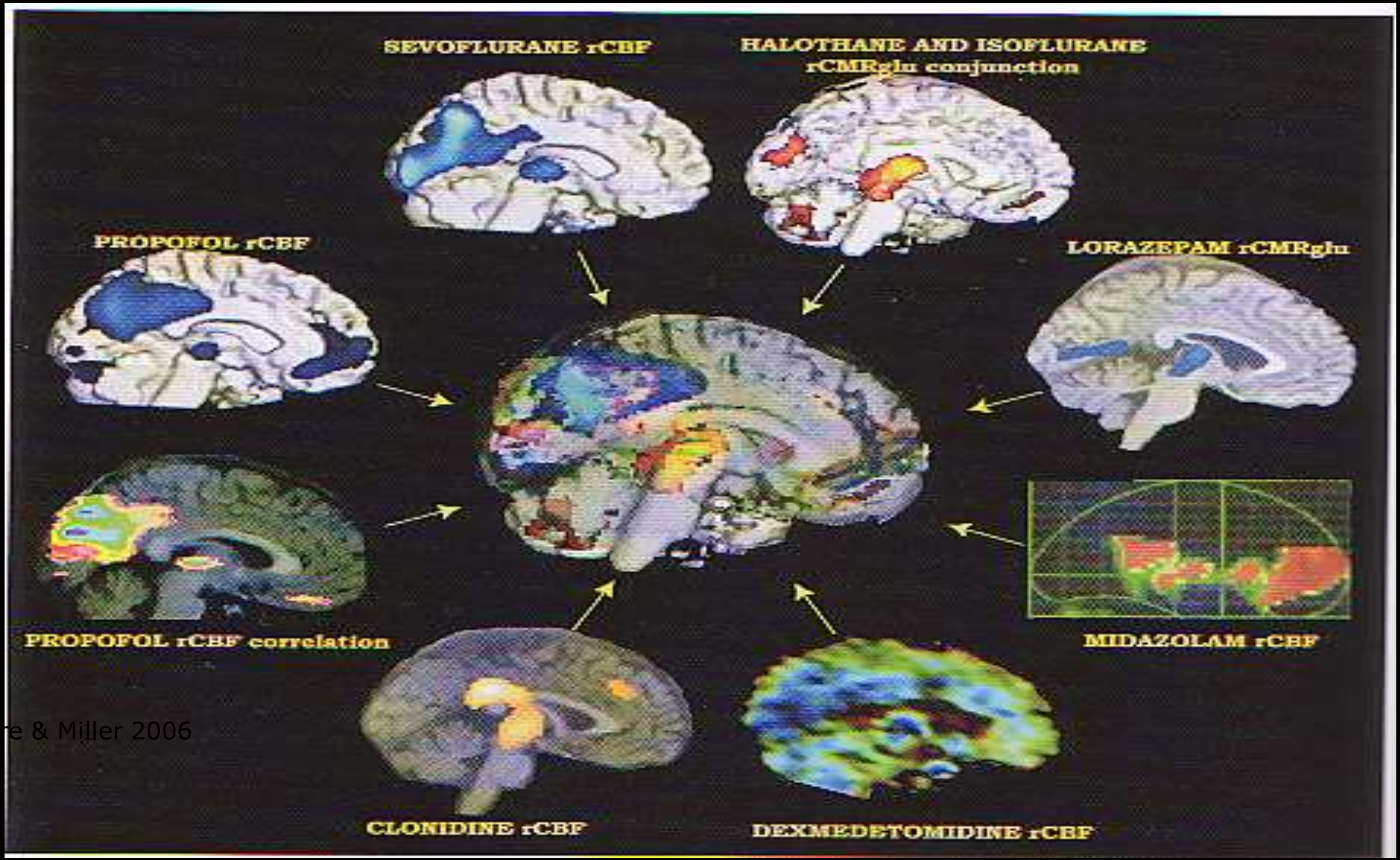
General Anesthesia

>> consciousness switched on and off by anesthetic agents

>> what happens in the brain when consciousness disappears or reappears?

The Thalamus as a Common Target of Anesthetics

Alkire & Miller 2006



The Thalamus is a Common Target of Anesthetics

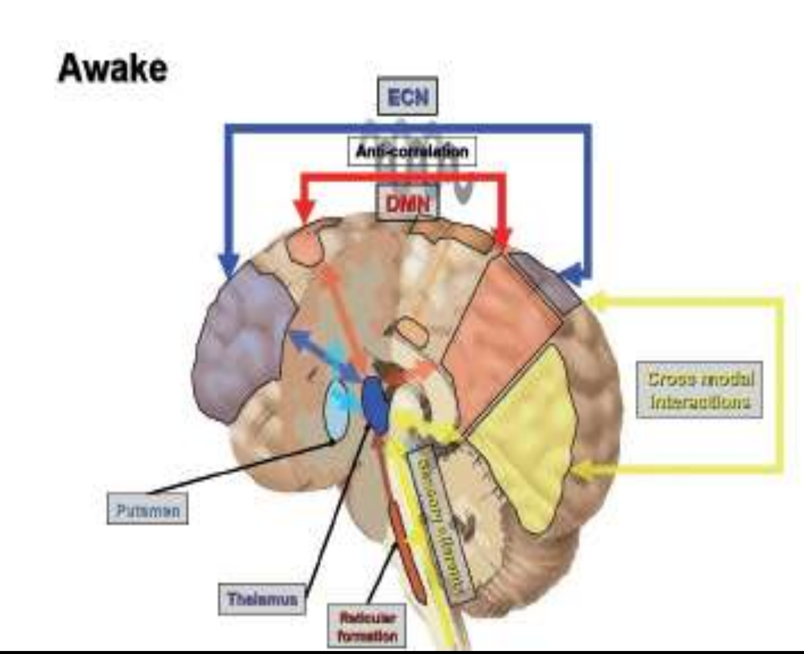
One finding that emerges ..is that **when consciousness goes away** with any number of different anesthetics, **a relative decrease in thalamic activity occurs.**

(Alkire & Miller 2006, p. 233)

Decreases in Functional Connectivity

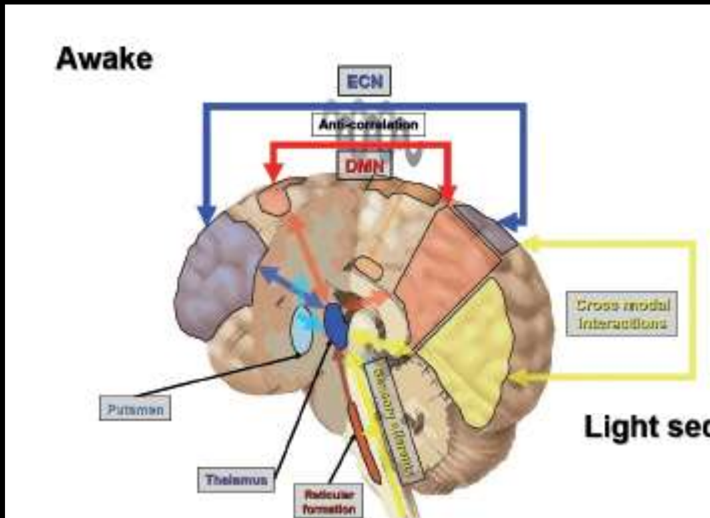
* Default Mode Network <> Executive Control Network

* Cross-Modal Interactions



From: Bonhomme et al. 2012

From: Bonhomme et al. 2012



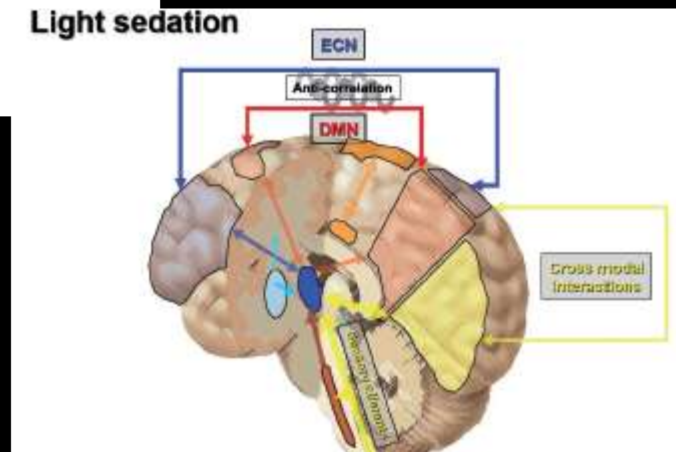
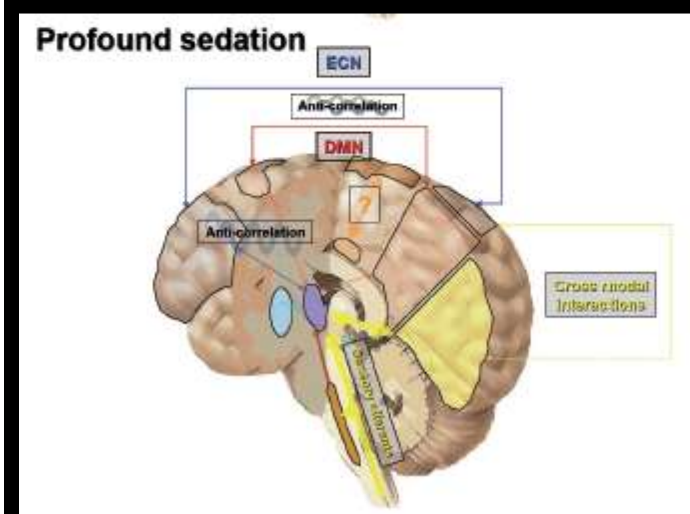


Fig. 1. - Schematic representation of brain connectivity modifications as observed during fMRI studies at different levels of sedation by hypnotic agents that promote inhibitory neurotransmission.

Awake state: consciousness is thought to be sustained by synchronized activity into the anti-correlated default mode network (DMN, red) and executive control network (ECN, blue), as well as in other higher order information processing networks (not presented). Cortical activity is sustained by the activity of the midbrain reticular formation (brown) and by cortico-thalamic interactions into those networks. Sensory information from the periphery is transferred through the thalamus (yellow) to lower order sensory networks, where there exist cross-modal interactions, before being transferred to higher order networks. Information transfer through the thalamus is regulated by sub-cortical systems involving the putamen (light blue).

Light sedation: connectivity into higher order cortical networks decreases, as anti-correlation between DMN and ECN does (thinner arrows, lighter colors). Functional connectivity is also reduced into the sub-cortical systems regulating thalamic activity (putamen, light blue). The connectivity in lower order sensory networks, including thalamo-cortical connectivity, is preserved, while connectivity into sensory-motor networks increases (orange).

Profound sedation: connectivity into DMN and ECN further decreases and anti-correlation between them disappears. Those networks present an anti-correlated activity with the thalamus. Connectivity into lower order sensory networks is still present but cross-modal interactions are altered. For those deep stages of sedation, no information is available in the literature regarding connectivity into sensory-motor networks (question mark).



Thalamocortical connectivity:

Specific and Non-specific

(Liu et al. 2012)

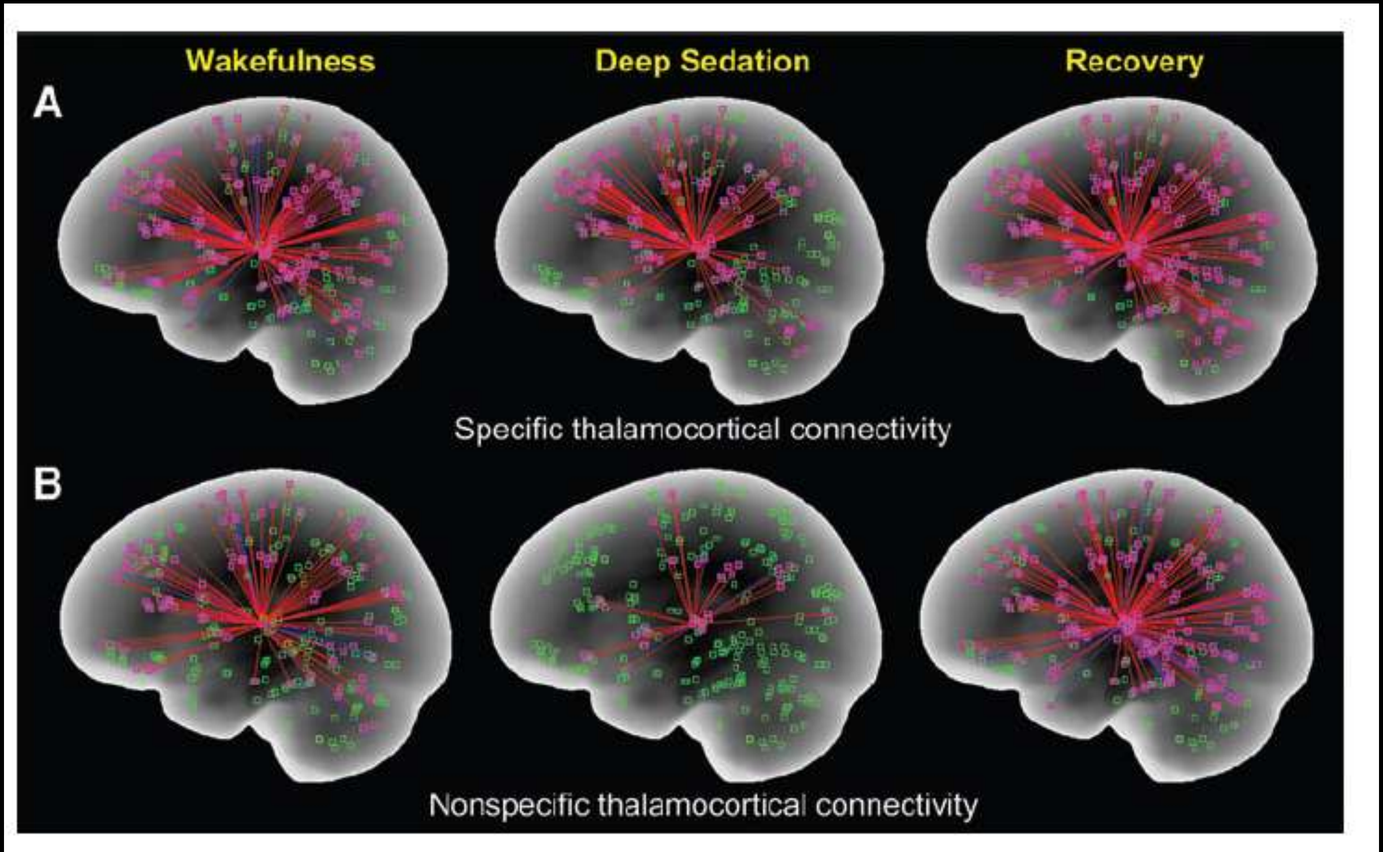
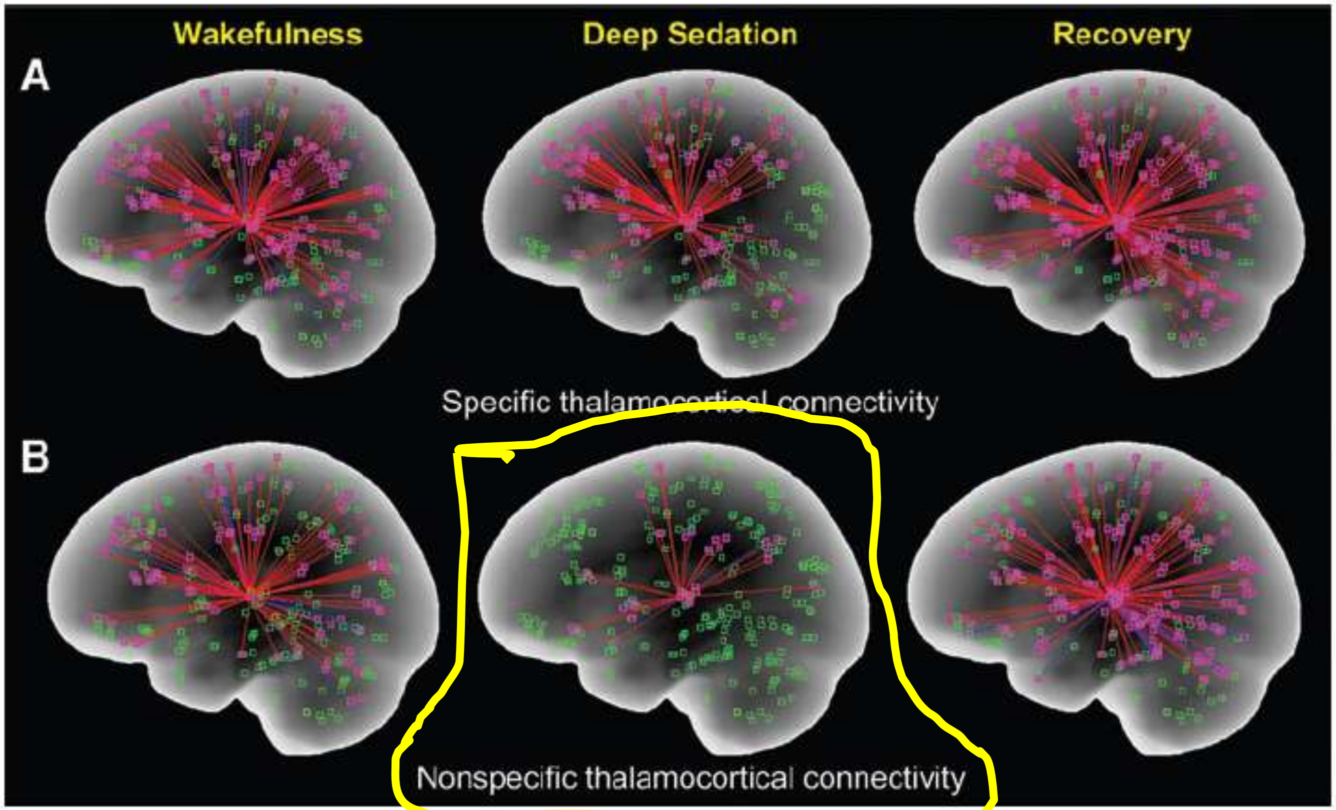


FIG. 2. Specific **(A)** and nonspecific **(B)** thalamocortical functional connectivity in baseline wakefulness, deep sedation, an recovery. Functional connectivity was obtained from seed-based analysis of the temporal correlation of fMRI blood oxyge dependent signals. The brain was partitioned into 300 regions, and the regions containing < 10 voxels were removed. Nonsp cific connectivity is based on intralaminar nuclei as a seed; specific connectivity is based on the reminder of thalamus as see Deep sedation was defined as absent responsiveness to verbal commands. Data are from seven volunteers (Liu et al., 2012b Note the substantial and reversible reduction of nonspecific thalamocortical connectivity during deep sedation (Figure by th courtesy of Dr. Xiaolin Liu).



our PET-anesthesia study: Return of Consciousness

(Långsjö J, Scheinin H, Revonsuo A et al., 2012) :

The Journal of Neuroscience, April 4, 2012 • 32(14):4935–4943 • **4935**

Behavioral/Systems/Cognitive

Returning from Oblivion: Imaging the Neural Core of Consciousness

Jaakko W. Långsjö,[1,2*] Michael T. Alkire,[3*] Kimmo Kaskinoro,[4] Hiroki Hayama,[3] Anu Maksimow,[4] Kaike K. Kaisti,[1] Sargo Aalto,[1] Riku Aantaa,[4] Satu K. Jääskeläinen,[5] Antti Revonsuo,[6] and Harry Scheinin[1,7,8]

One of the greatest challenges of modern neuroscience is to discover the neural mechanisms of consciousness and to explain how they produce the conscious state. We sought the underlying neural substrate of human consciousness by manipulating the level of consciousness in volunteers with anesthetic agents and visualizing the resultant changes in brain activity using regional cerebral blood flow imaging with positron emission tomography. Study design and methodology were chosen to dissociate the state-related changes in consciousness from the effects of the anesthetic drugs. We found the emergence of consciousness, as assessed with a motor response to a spoken command, to be associated with the activation of a core network involving subcortical and limbic regions that become functionally coupled with parts of frontal and inferior parietal cortices upon awakening from unconsciousness. The neural core of consciousness thus involves forebrain arousal acting to link motor intentions originating in posterior sensory integration regions with motor action control arising in more anterior brain regions. These findings reveal the clearest picture yet of the minimal neural correlates required for a conscious state to emerge.

Return of consciousness from dex anesthesia

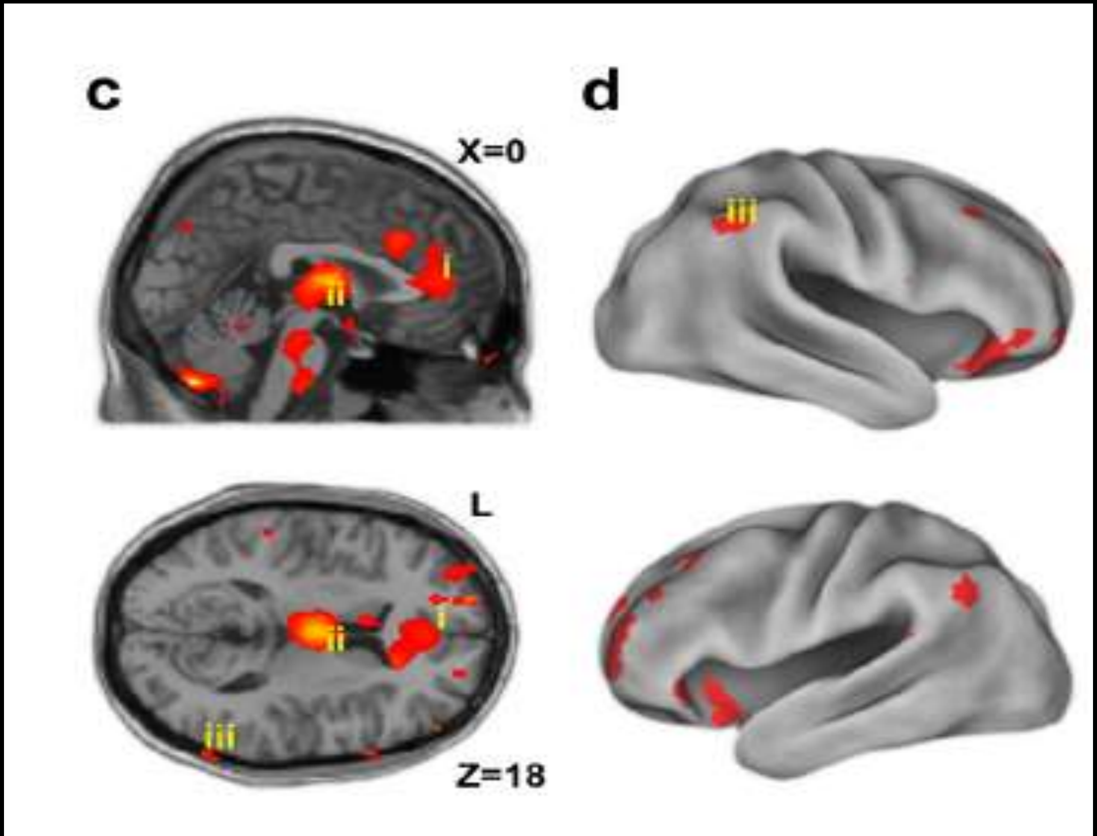


Figure 2. Neural correlates associated with the ROC during constant dose dexmedetomidine anesthesia. ***a***, LV1 design score pattern showing changes associated with the temporary return of consciousness ($p < 0.0001$). ***b***, PLS singular image (positive salience; top, sagittal; bottom, axial) of LV1 ($p < 0.001$) projected on SPM-8 glass brain template. ***c***, Sagittal (top) and axial (bottom) sections showing cingulate (i), thalamus (ii), inferior parietal cortex (iii), and brainstem activations. ***d***, Cortical renderings showing parietal (iii) and frontal activations. ***e***, Voxel intensity plots (mean ± SE) showing how i, ii, and iii follow LV1 pattern.

Return of consciousness from propofol anesthesia

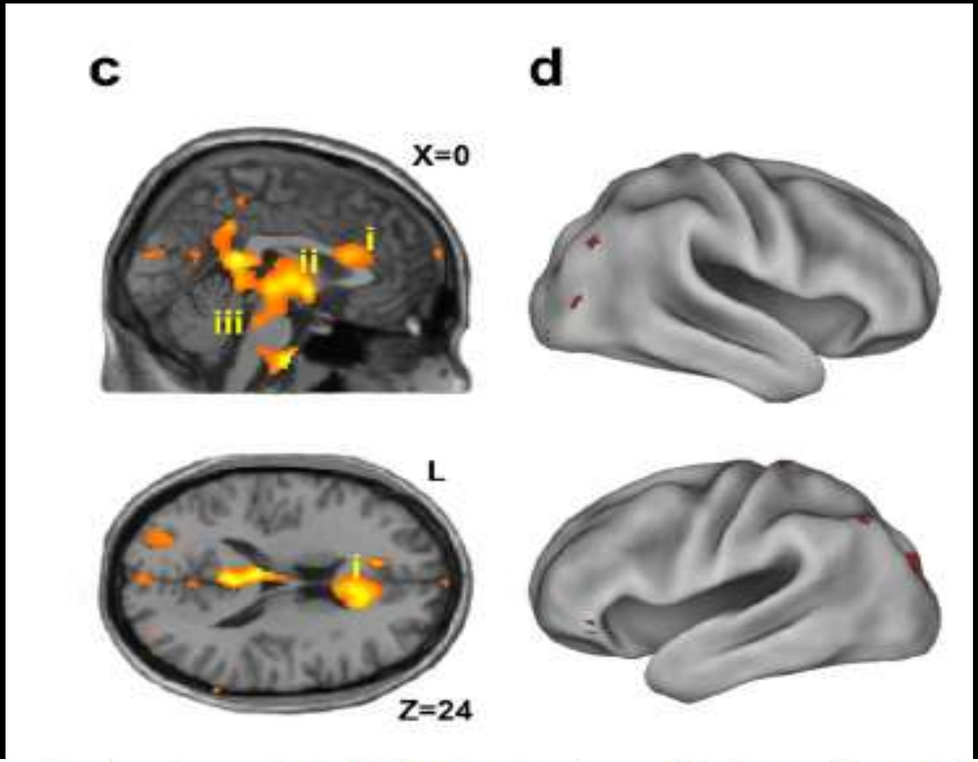


Figure 4. Neural correlates associated with the return of consciousness following propofol anesthesia. ***a***, LV2 design score pattern shows changes primarily associating with ROC ($p < 0.03$). ***b***, PLS singular image (positive salience; top, sagittal; bottom, axial) showing the regions associated with LV2 ($p < 0.001$) projected on SPM-8 glass brain template. ***c***, Sagittal (top) and axial (bottom) sections showing activation in the ACC (i), thalamus (ii), and the brainstem (iii). ***d***, Cortical renderings showing minimal occipital, parietal, and frontal activations at this threshold. ***e***, Region-specific voxel intensity plots showing how i, ii, and iii follow the overall pattern of LV2 (mean ± SE).

Consciousness as a state

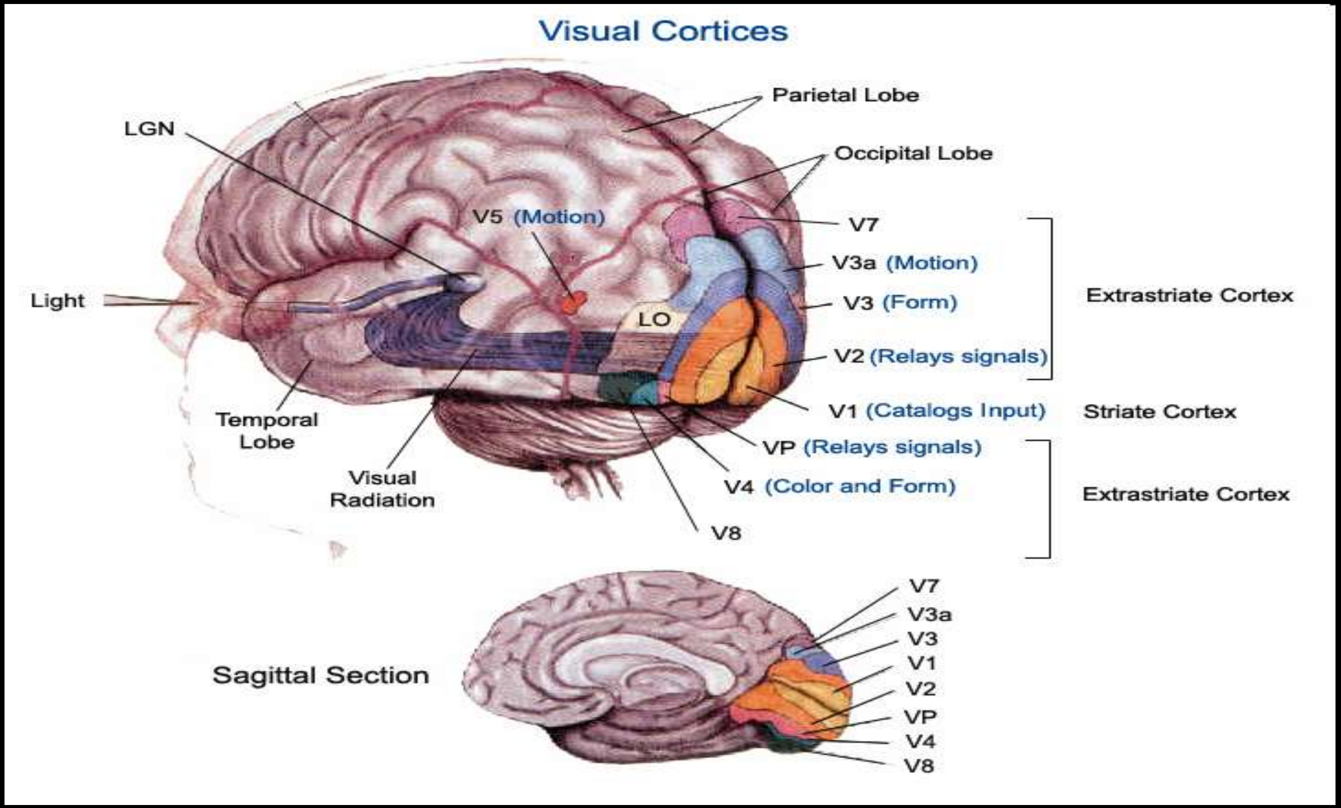
General Anesthesia

>> consciousness switched on and off by anesthetic agents

>> what happens in the brain when consciousness disappears or reappears?

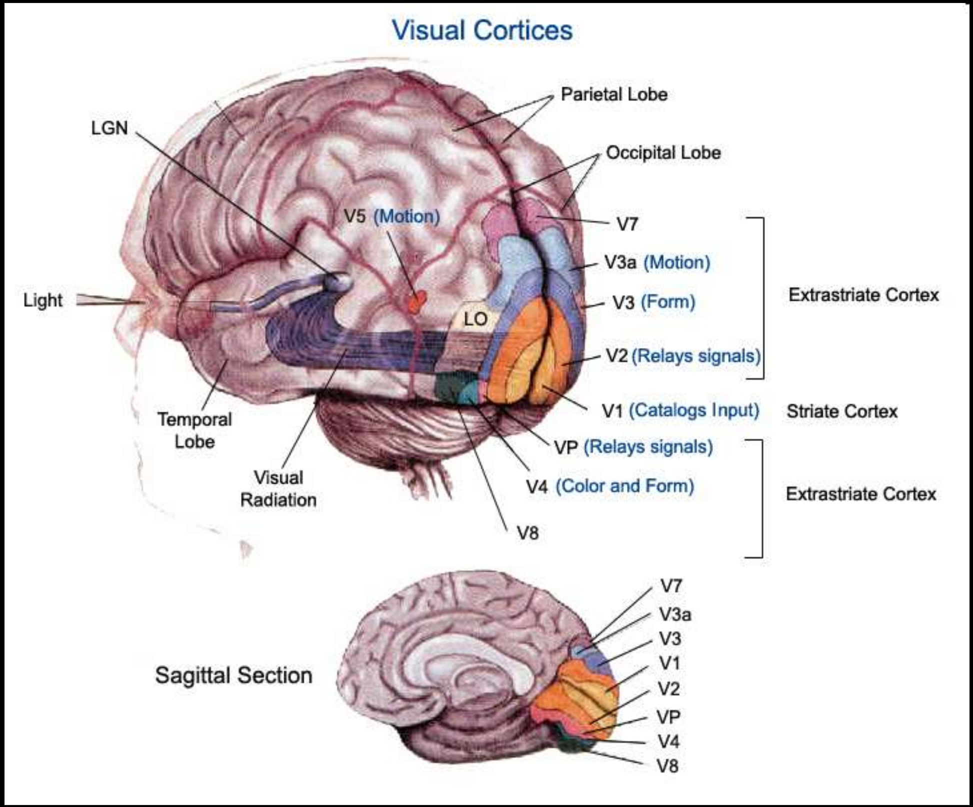
>> Extremely active area of NCC research

NCC of visual consciousness



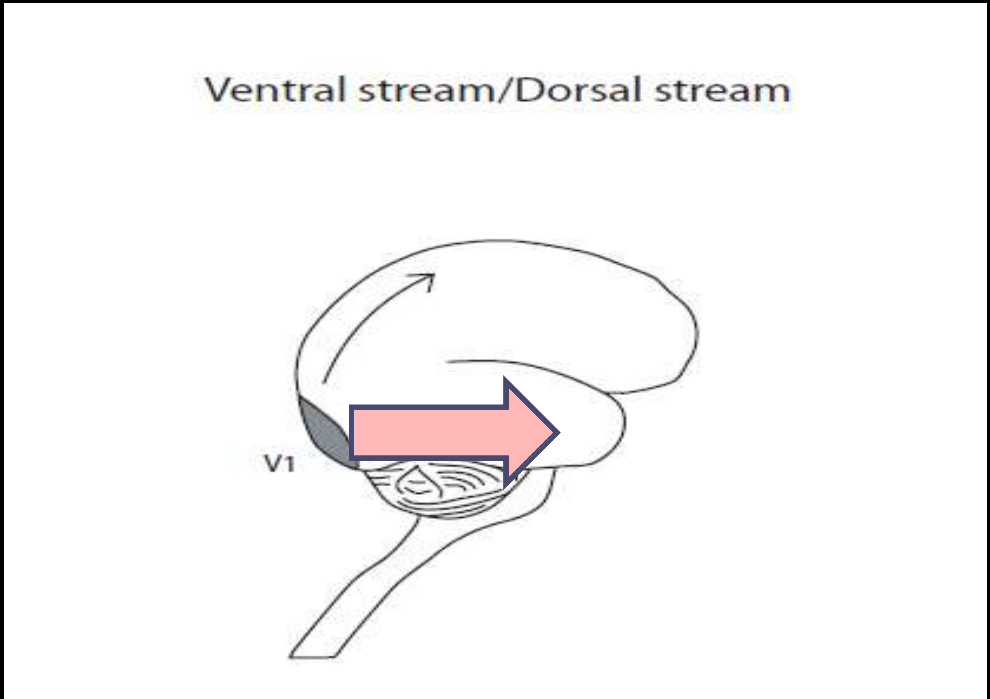
NCC of visual consciousness

What happens in the brain when we undergo **the subjective experience of seeing**?

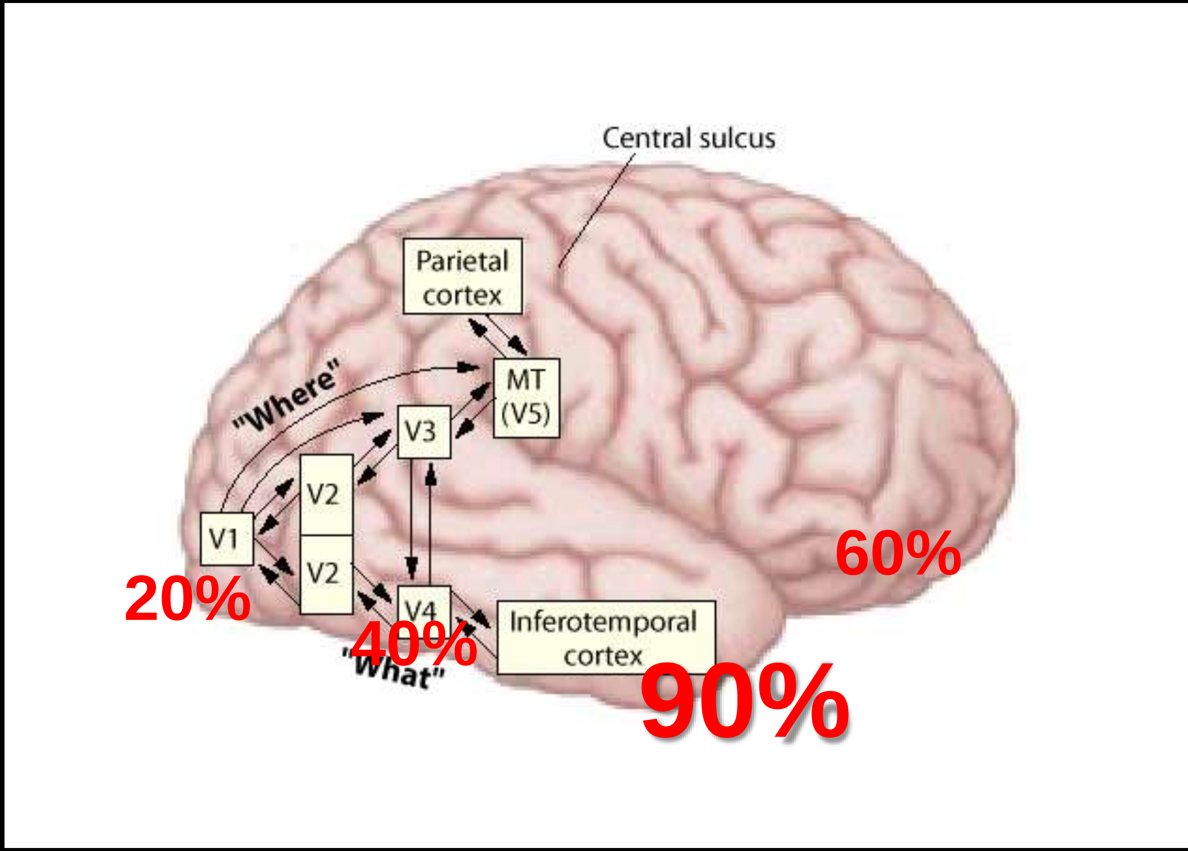


The Ventral Stream Hypothesis:

NCCs of visual consciousness are located in areas along the ventral visual stream



NCC in binocular rivalry in monkeys:
how many % of single cells correlate activity with content of visual consciousness (Logothetis et al.)



Human fMRI studies: faces and places

(Tong et al.)

EEG Correlates of Visual Consciousness

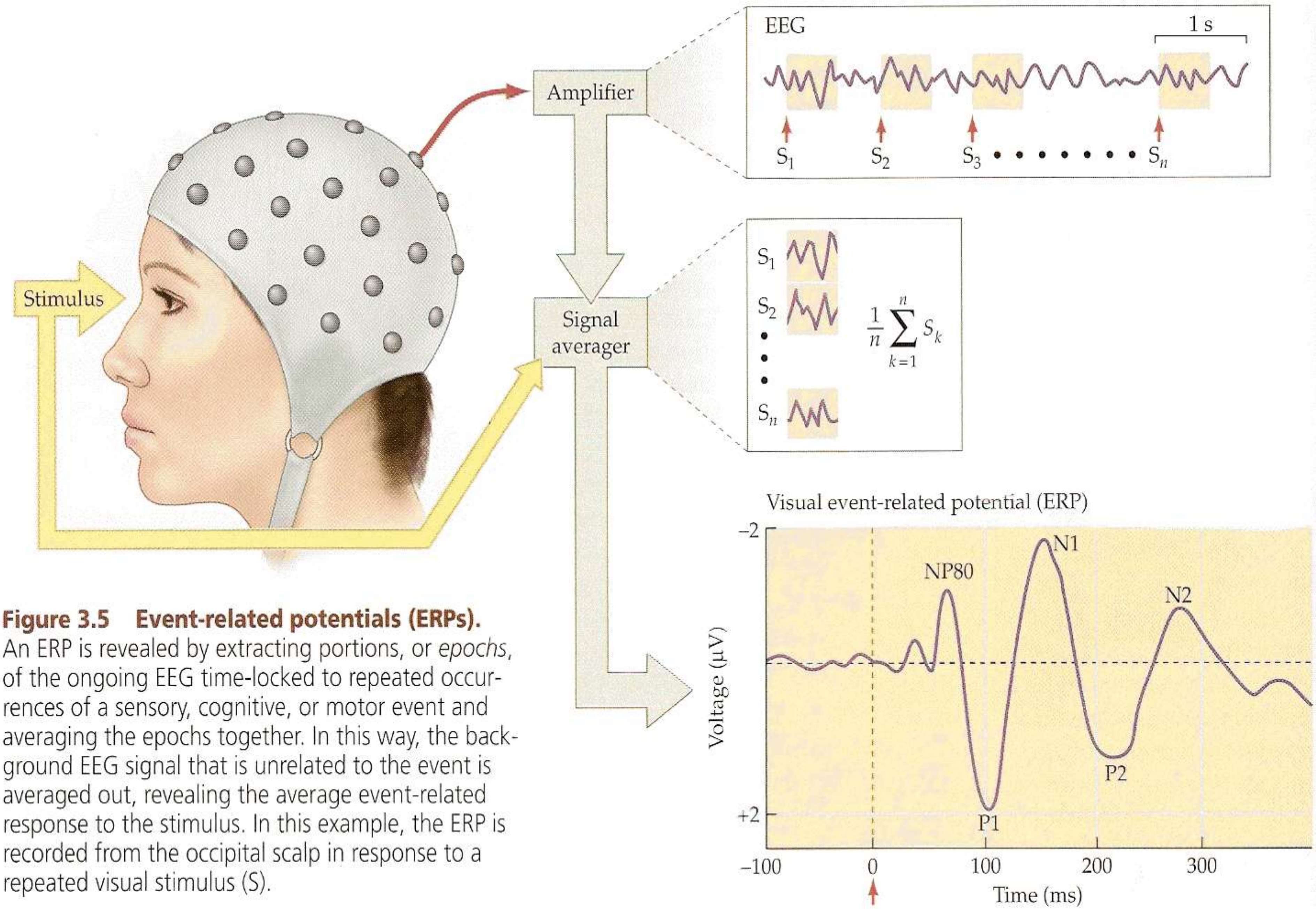
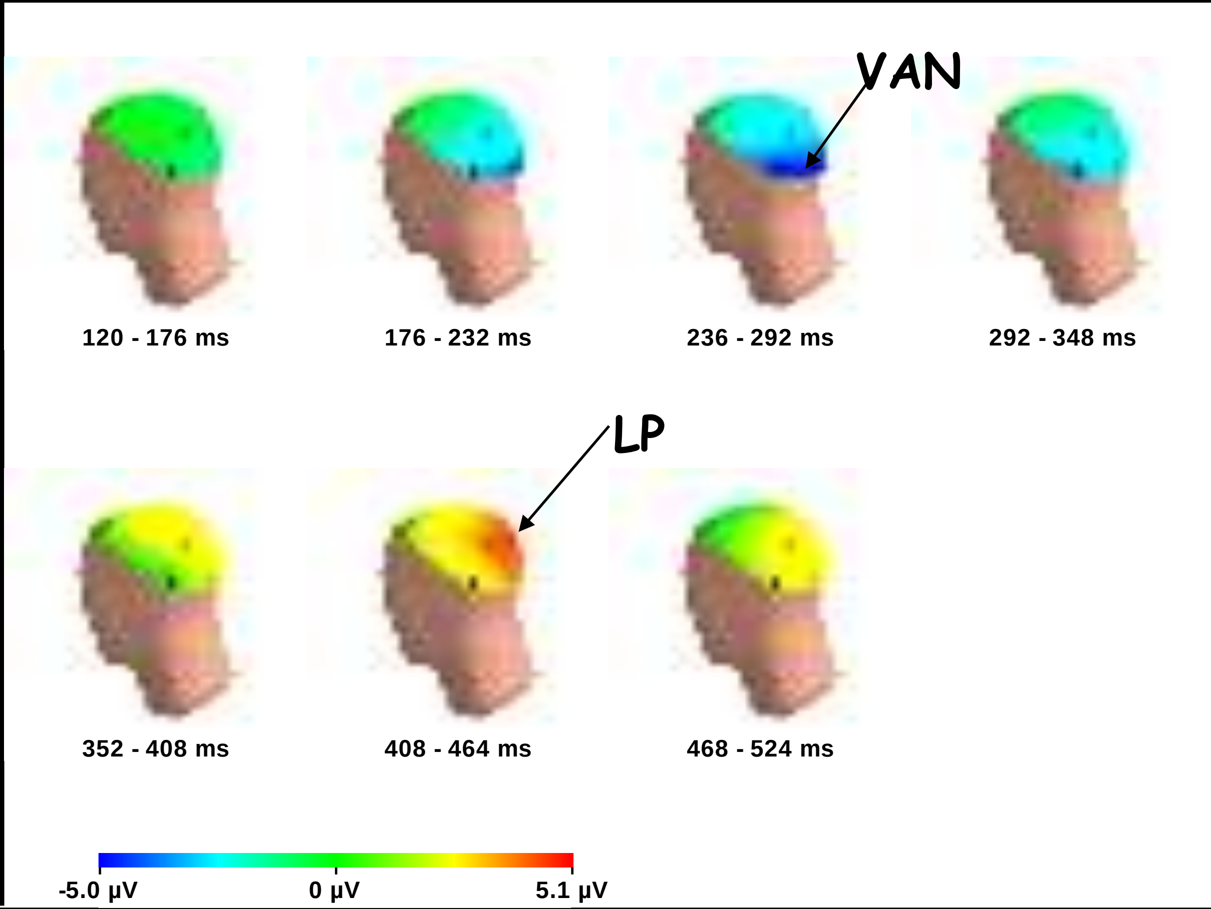


Figure 3.5 Event-related potentials (ERPs). An ERP is revealed by extracting portions, or *epochs*, of the ongoing EEG time-locked to repeated occurrences of a sensory, cognitive, or motor event and averaging the epochs together. In this way, the background EEG signal that is unrelated to the event is averaged out, revealing the average event-related response to the stimulus. In this example, the ERP is recorded from the occipital scalp in response to a repeated visual stimulus (S).

ERP Correlates of Visual Consciousness

-**The DIFFERENCE in ERPs between a stimulus that enters consciousness and a similar stimulus that remains outside consciousness**

Typical topography and time course of VAN & LP

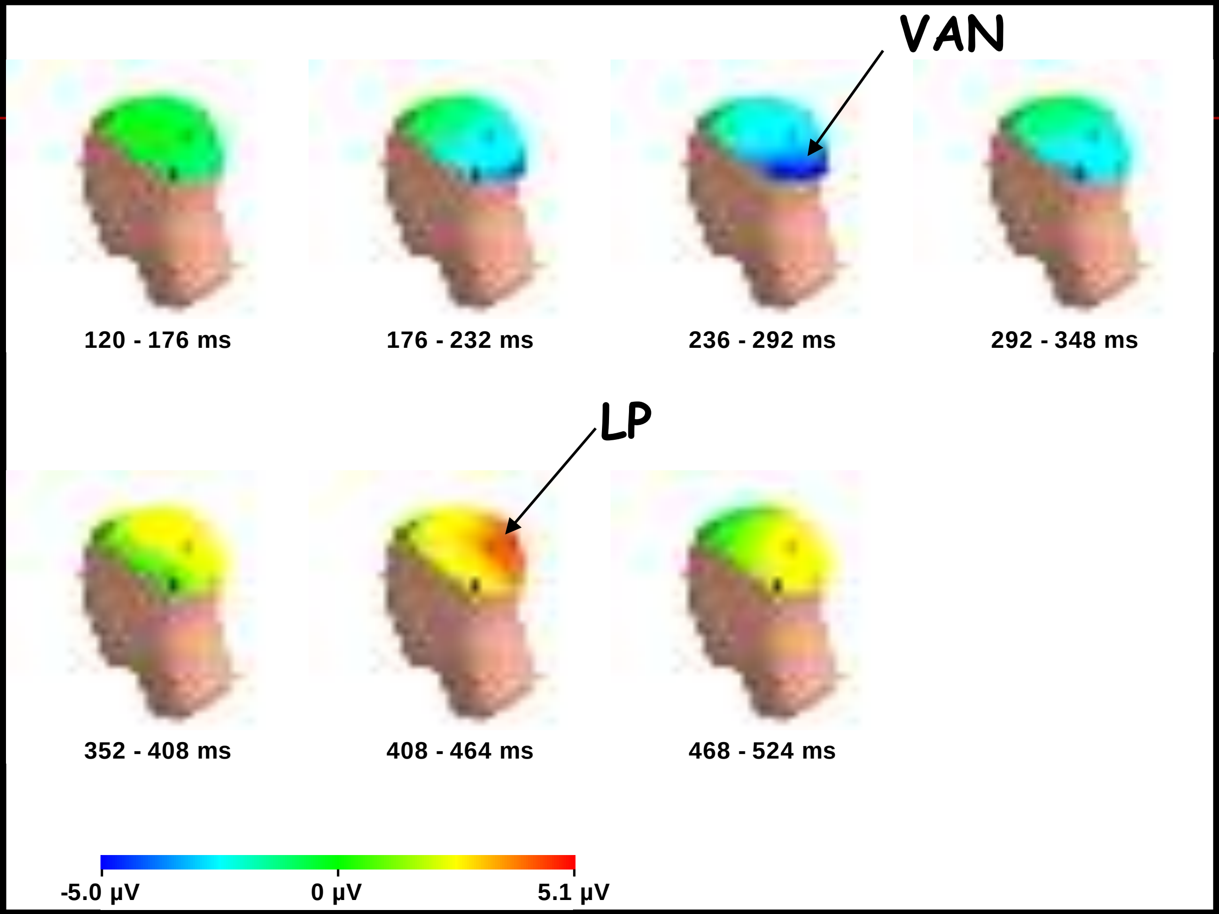


VAN is illustrated as the posterior negativity (blue color), which develops between 100-200 ms and is maximal at occipital and posterior temporal sites around 250 ms. Late postive difference (LP) is demostrated by the parietal postivity (red color) peaking after 400 ms. (The maps have been calculated from the data of Koivisto et al. 2005).

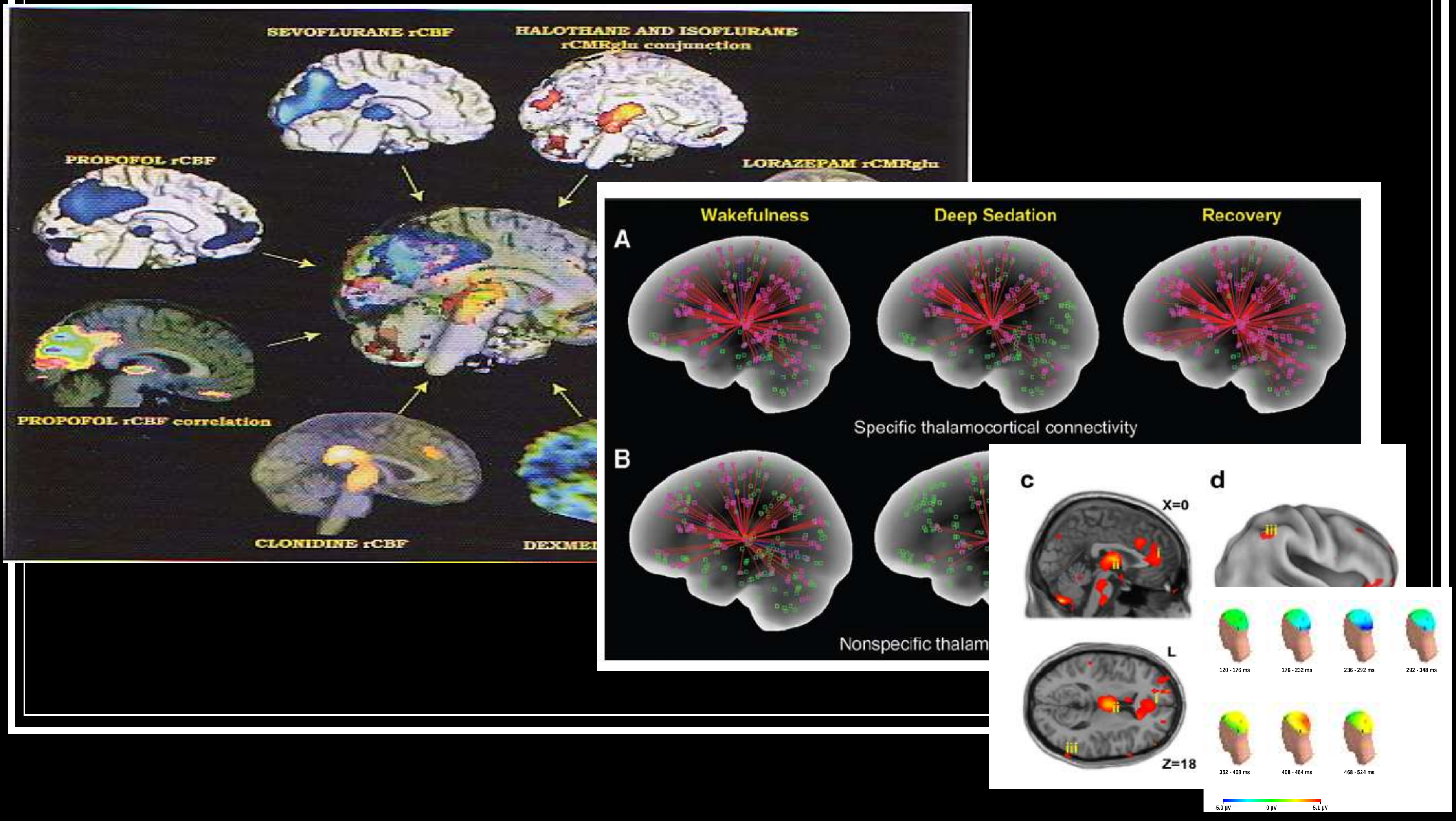
Visual consciousness:
Early vs Late

Does visual consciousness happen <u>early (VAN) or late (LP/P3) ?</u>

- Visual cortex or frontoparietal networks?


VAN
120 - 176 ms
176 - 232 ms
236 - 292 ms
292 - 348 ms
LP
352 - 408 ms
408 - 464 ms
468 - 524 ms
-5.0 µV
0 µV
5.1 µV

Will neuroscience ever solve the Brain-Consciousness –problem?



Will neuroscience ever solve the Brain-Consciousness –problem?

>> we find only neural correlates, not consciousness itself!

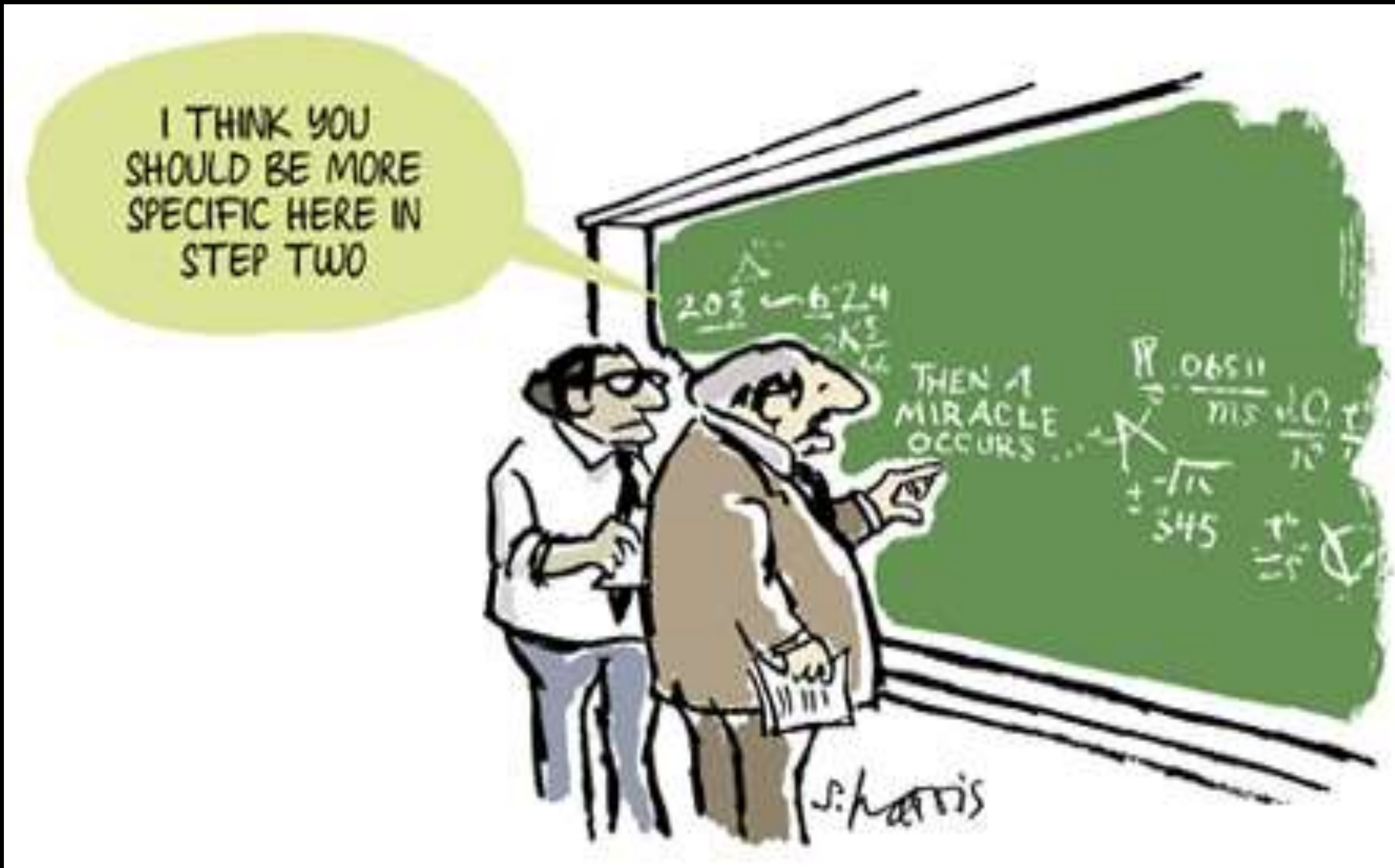
The Explanatory Gap

The Explanatory Gap

J. Levine (1983)

- we cannot even imagine any kind of mechanism that could explain how **subjective** experiences arise from **objective** physical or neural phenomena

brain activity >> consciousness…



Colin McGinn (1989): *Can We Solve the Mind-Body Problem?*

”Somehow, we feel, the **water** of the physical brain **is turned into** the **wine** of consciousness, but we draw a total blank on the nature of this conversion.”

The ”Hard Problem”

(Chalmers 1995)

- **Why does any neural activity in the brain produce any kind of subjective experiences?**

Will neuroscience ever solve the Brain-Consciousness –problem?

For more details, see also:

Current Pharmaceutical Design, 2014, *20*, 000-000

Harnessing Anesthesia and Brain Imaging for the Study of Human Consciousness

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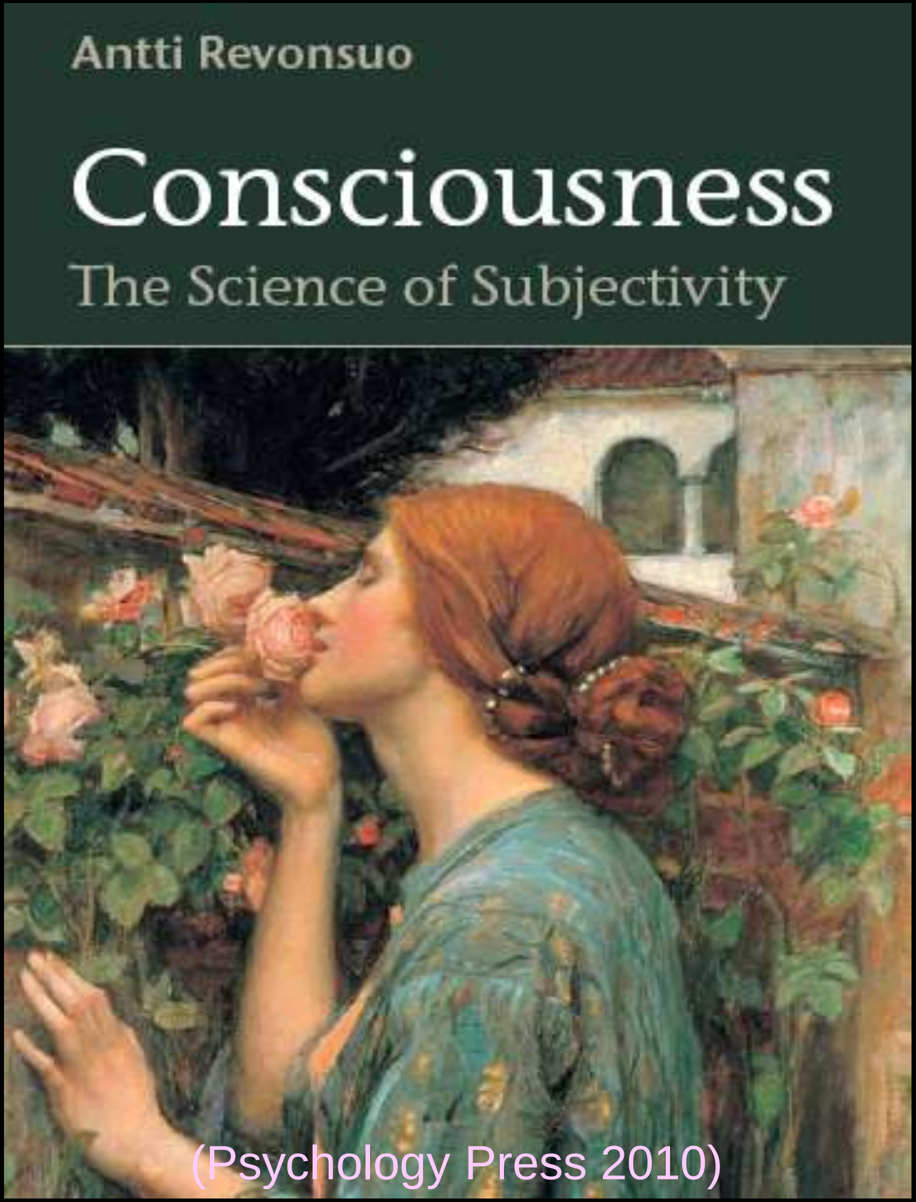
Abstract: Philosophers have been trying to solve the *mind-body problem* for hundreds of years. Consciousness is the core of this problem: How do subjective conscious sensations, perceptions, feelings, and thoughts arise out of objective physical brain activities? How is this subjective conscious world in causal interaction with the objective sensory and motor mechanisms of the brain and the body? Although we witness the seamless interaction of the mental and the physical worlds in our everyday lives, no scientific theory can yet fully describe or explain it. The hard problem of consciousness, the question why and how any brain activity should be accompanied by any subjective experiences at all, remains a mystery and a challenge for modern science. Anesthesia offers a unique and safe way to directly manipulate the state of consciousness and can, thus, be used as a tool in consciousness research. With neuroimaging, such as positron emission tomography (PET) and functional magnetic resonance imaging (fMRI) performed at different states of consciousness, it is possible to visualize the state-related changes and pinpoint the brain structures or neural mechanisms related to changes in consciousness. With these tools, neurosciences now show promise in disentangling the eternal enigma of human consciousness. In this article, we will review the recent advancements in the field.

For more details, see also:



(Psychology Press 2010)