Brain, Consciousness and free will

Idan Segev

Ascolot lecture #6 – June 2014

1. The issue of consciousness and its Neural Correlates (NCC)
2. Methods for studying the NCC
3. Free will? The classical study of

Consciousness in the Primate Brain – Methods, Neural Correlates and Implications for Machine Consciousness

The neural correlates of consciousness

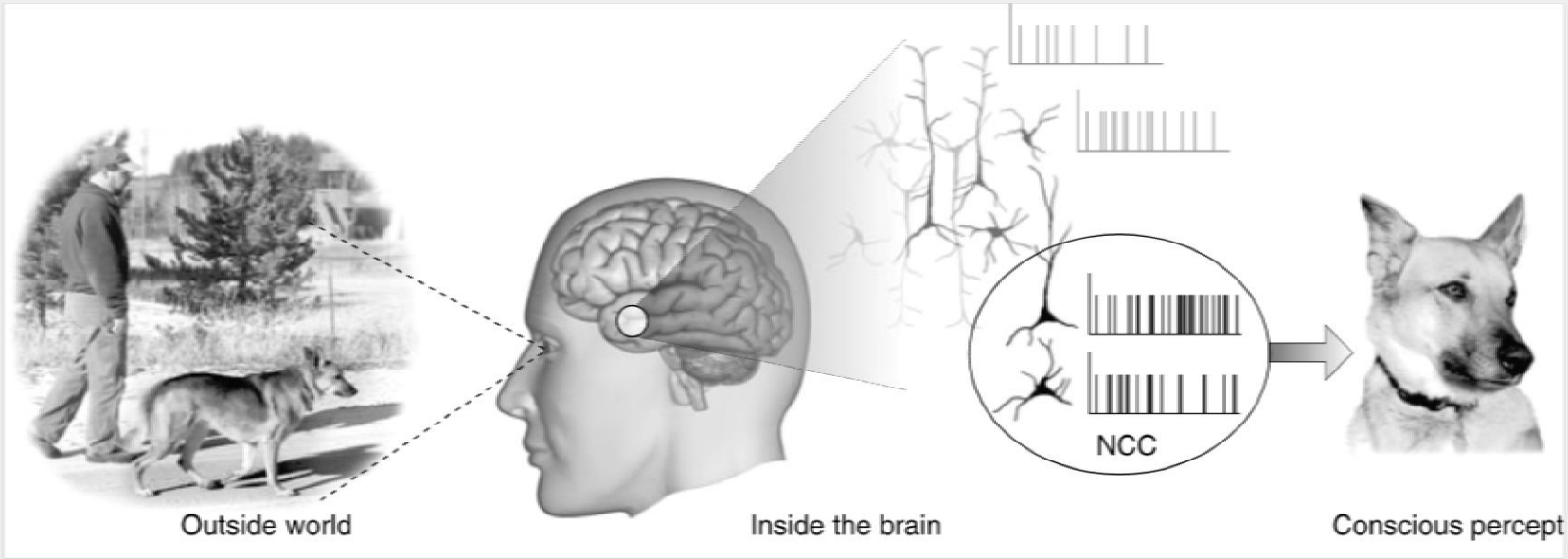
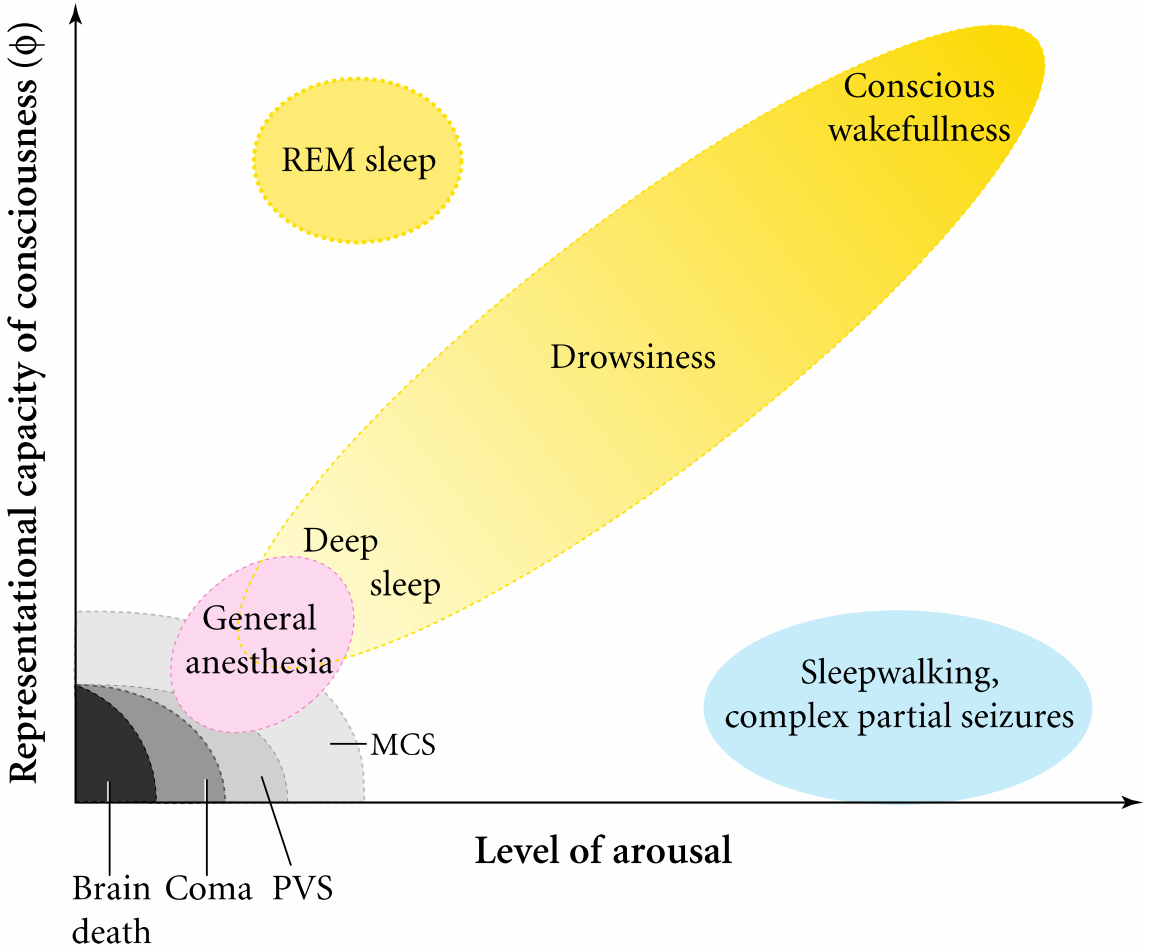
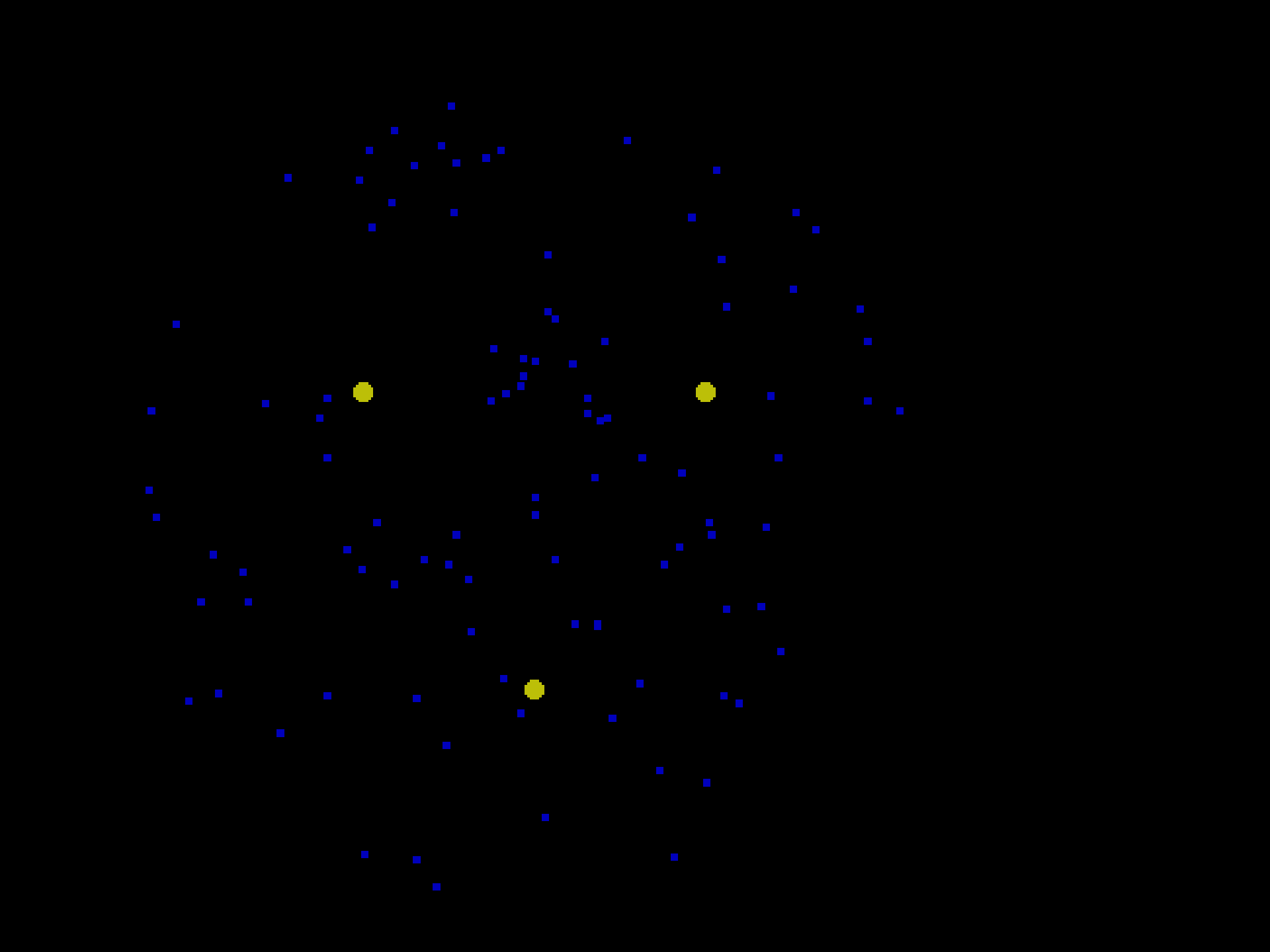


FIGURE 53.3 The neuronal correlates of consciousness (NCC) are the minimal set of neural events and structures—here synchronized action potentials in neocortical pyramidal neurons—sufficient for a specific conscious percept or memory. From Koch (2004).

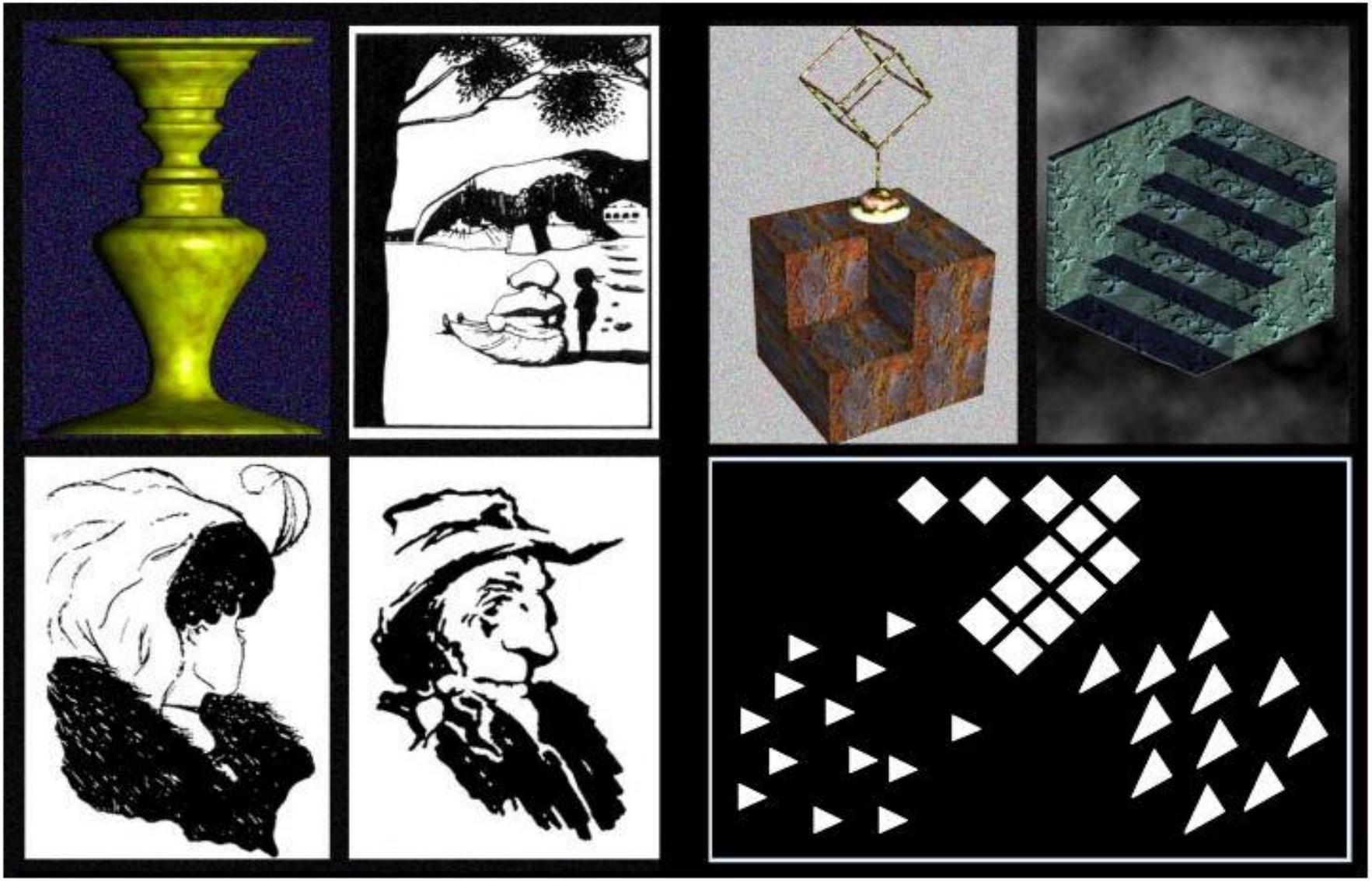
The different levels of consciousness and related behavior



How much of what happens are we conscious of?



Rivalry in conscious perception



At any given moment, only a limited amount of information is consciously accessed and defines the current conscious content, which is reportable verbally or by an intended gesture. At the same time, many other processing streams co-occur but remain nonconscious.

General remarks

- Assume qualia or subjective feelings as given. How can they arise from a non-stationary physical system---brains---that contain about $2 \cdot 10^{10}$ neurons switching at the 1 msec level?

- Physicalism: any change in a subjective state must be caused by a change in brain states.

- The various forms of consciousness (visual C, auditory C, self C and so on) are related.

- Most neuroscientists assume some animal species share key aspects of consciousness (as a corollary, it follows that language is not required).

Strategy

- Focus on the Neuronal Correlates of Consciousness (NCC) as the minimal neuronal mechanism necessary for a specific conscious percept, memory or event to occur. Different percepts are caused by different NCCs.

- For any NCC to occur, a number of enabling factors are necessary (e.g., ascending reticular activating system).

- We seek to explain why under one set of conditions you "see" a red flower while under different conditions your visual system responds without any conscious perception.

- In the long-term, a complete theory of consciousness is necessary.

Unconscious Processing

Many--if not most--behaviors occur in the absence of conscious sensations, or consciousness occurs after the fact:

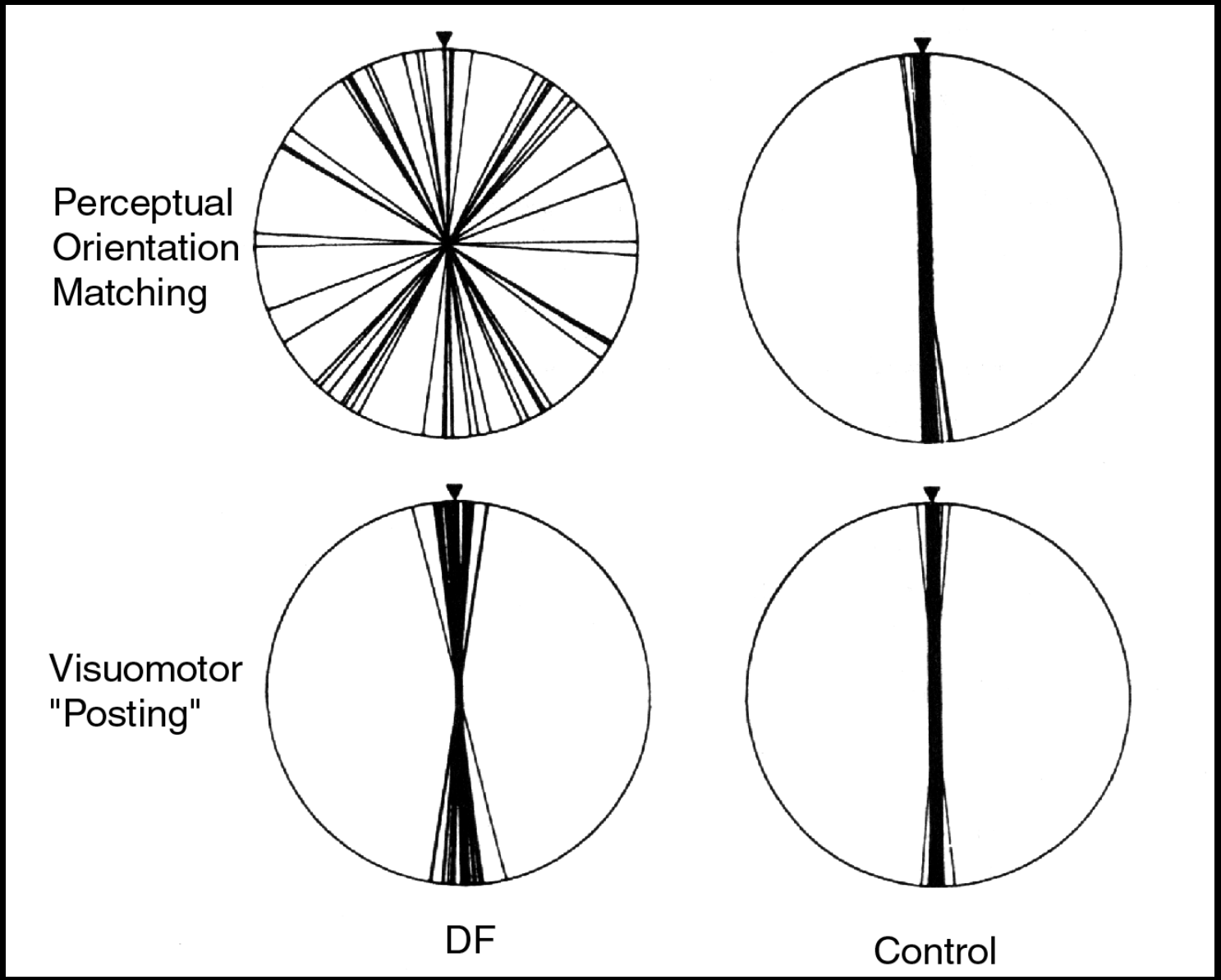
- enteric nervous system
- reflexes
- posture adjustments
- estimating steepness of hills
- reaching and grabbing
- any overtrained ability (driving, rock-climbing, dancing…)
- generating speech
- dissociation between what the eyes see and conscious perception
- high-level decision making (à la Freud?)
- ...

We call these on-line or zombie systems

On-Line or Zombie Systems in Patients

- Dissociation in visual agnosia patient DF between vision-for-perception and vision for action

The puzzle of Visual versus "motor" (action) Consciousness



Milner and Goodale (1995)

Current experimental approaches manipulate the relationship between physical stimulus and percept in a quantitative manner

- Masking
- Binocular Rivalry
- Imagery
- Focal Attention
- Anesthesia

Binocular Rivalry

- Constant stimulus but bistable percept

- Can be used to track the footsteps of the NCC in the brain

- Exploration of perceptual response along the ventral pathway of the macaque monkey using electrophysiology by Logothetis *et al.* (Leopold & Logothetis, 1996; Logothetis, 1998)

- Involvement of similar brain areas in humans via functional brain imaging (Lumer, Friston & Rees, 1998; Polonsky, Blake, Braun & Heeger, *2000*)

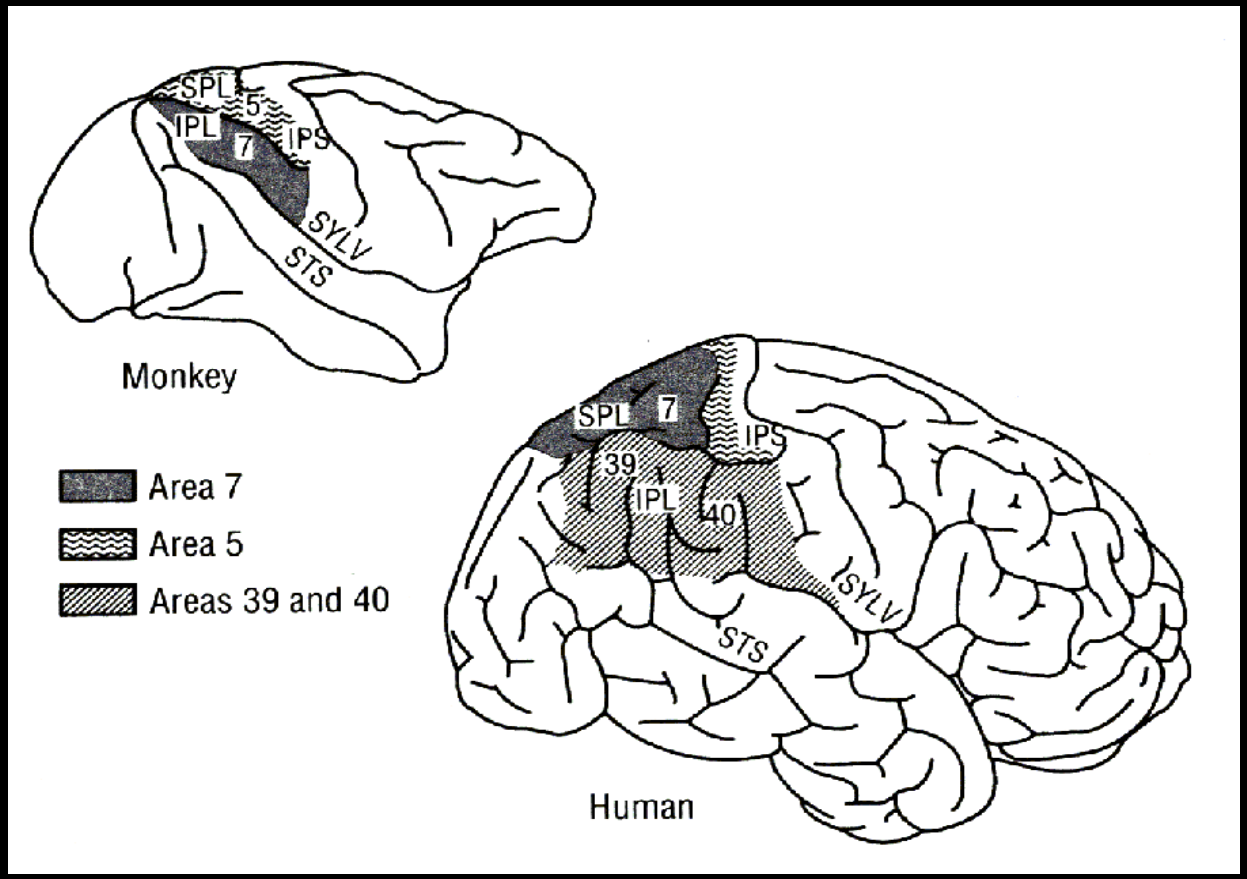
macaca mulatta or rhesus monkey

Macaque or Rhesus Monkey

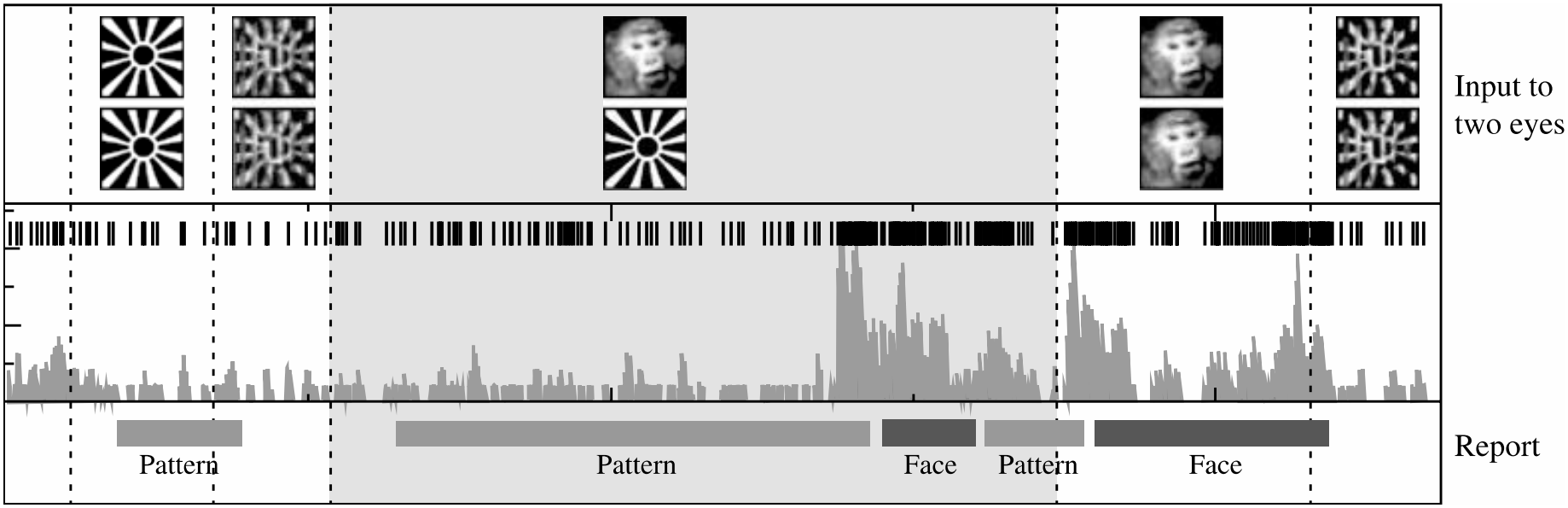
Its brain is quite similar to ours (x10 smaller in area)

It's very difficult to tell 1 mm^3 of macaque cortex from human cortex

Monkeys can be trained to behave similar to humans for simple behaviors



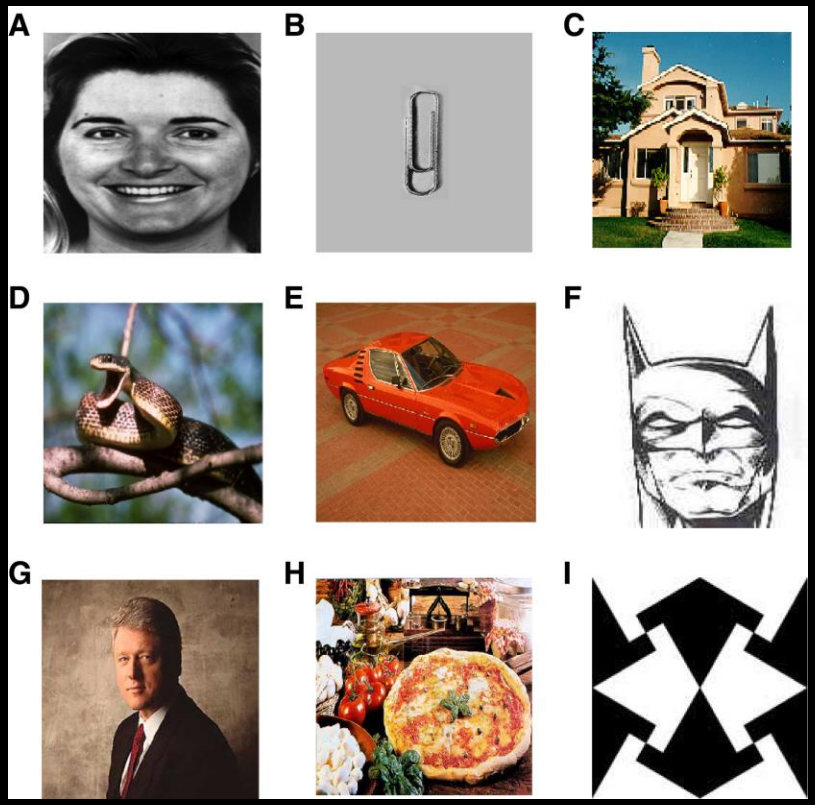
A fraction of a minute in the life of a typical IT cell while a monkey experiences binocular rivalry.



Recording Single Neurons in the Human Medial Temporal Lobe

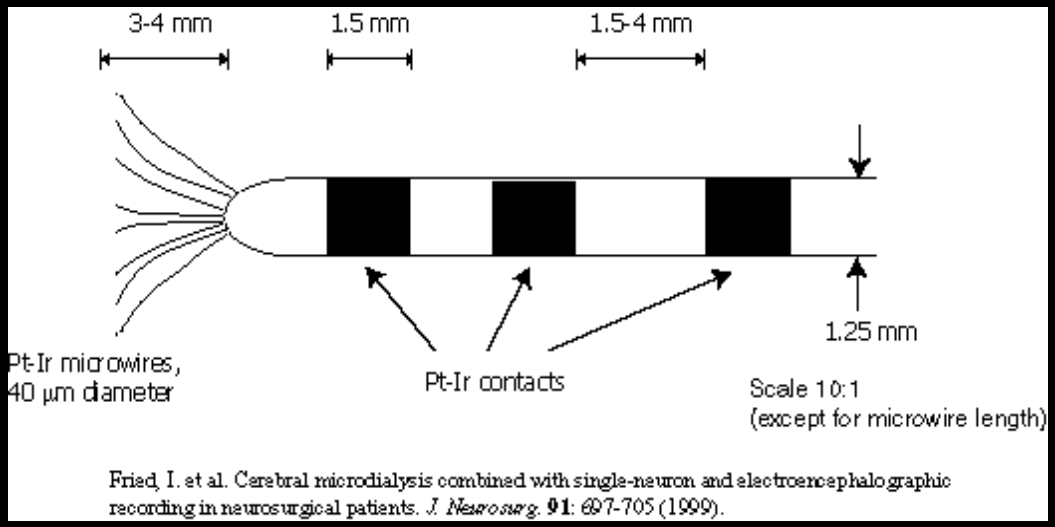
G. Kreiman, C. Koch and I. Fried[‡]

[‡]Division of Neurosurgery. University of California at Los Angeles, School of Medicine

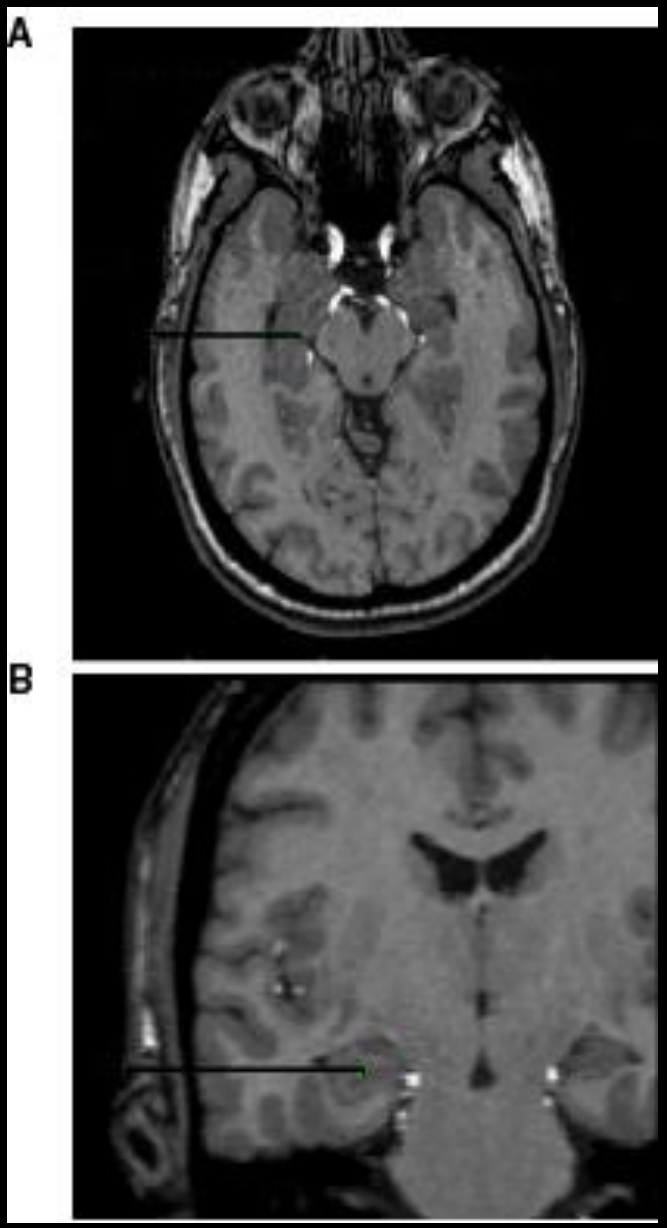


Technique pioneered by Crandell & Engel, UCLA

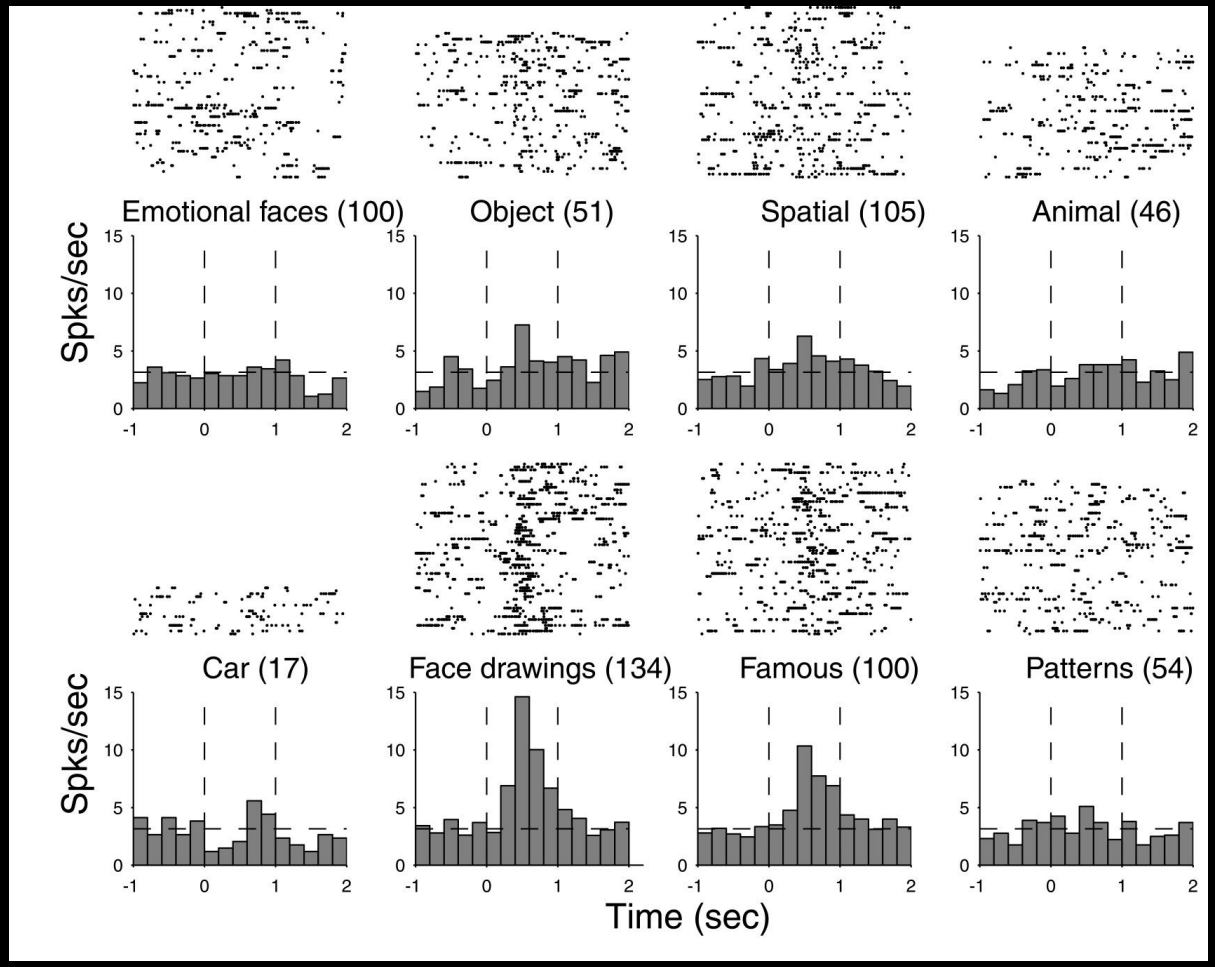
Surgery carried out by I. Fried



Fried, I. et al. Cerebral microdialysis combined with single-neuron and electroencephalographic recording in neurosurgical patients. *J. Neurosurg.* **91**: 697-705 (1999).

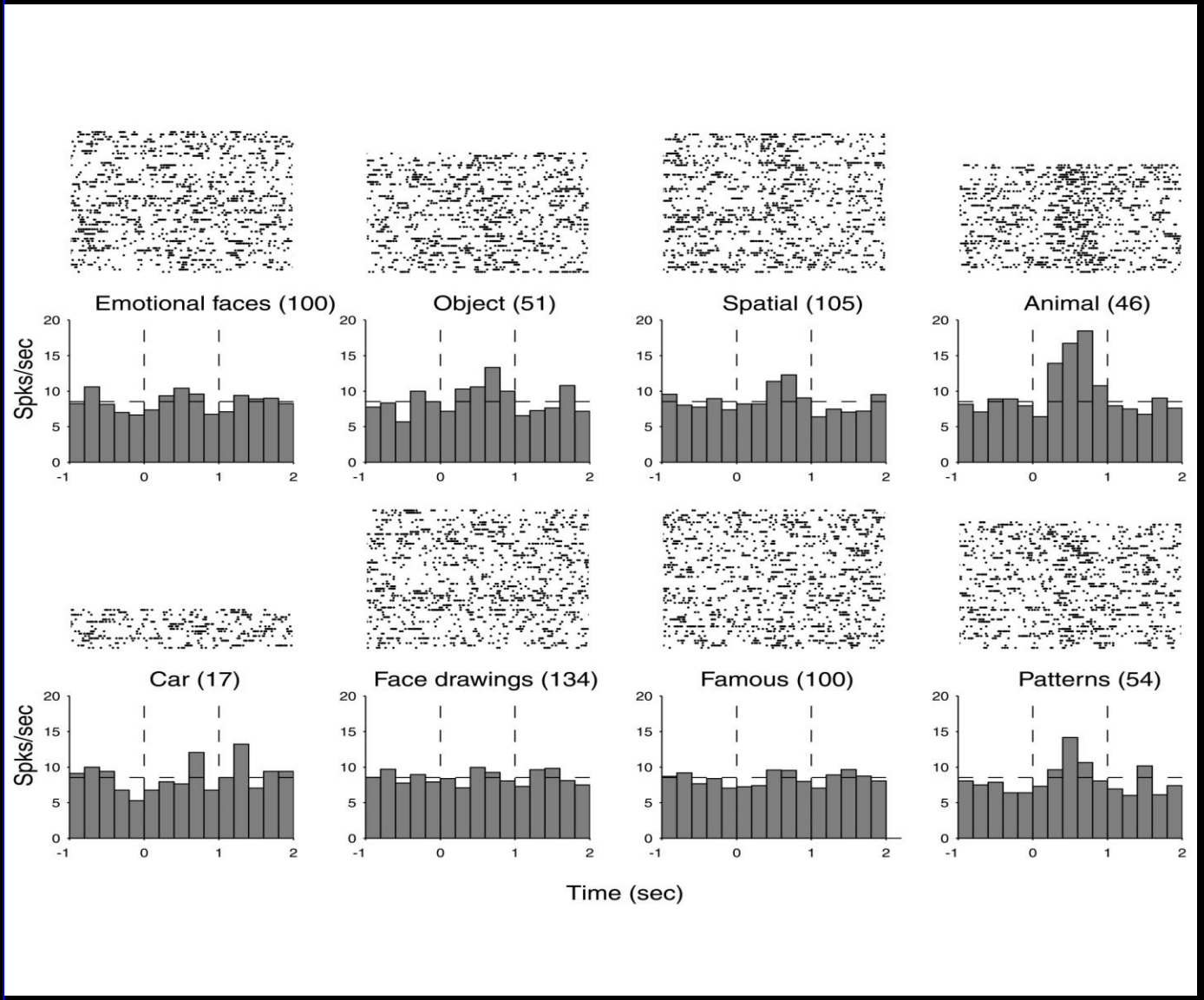


Right Anterior Hippocampus Neuron

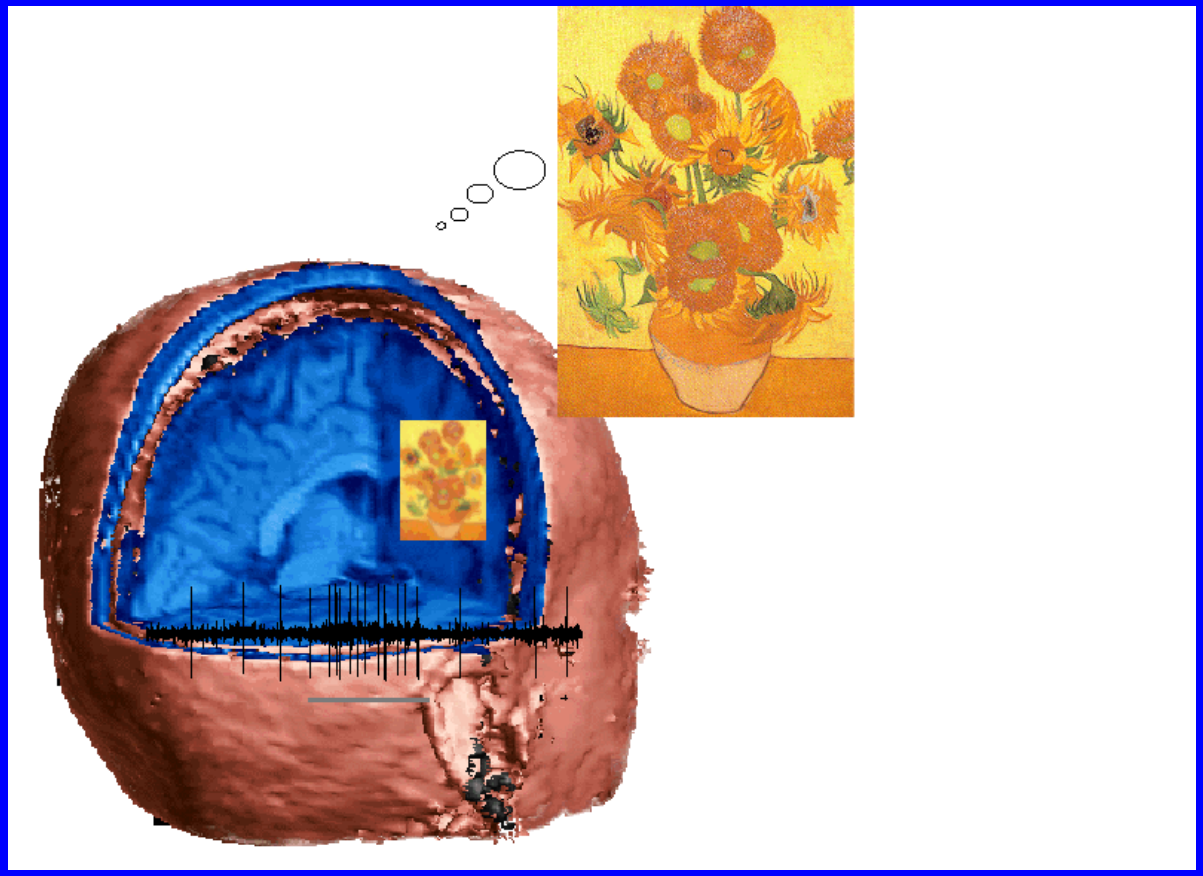


0 msecs

Entorhinal Cortex Neuron

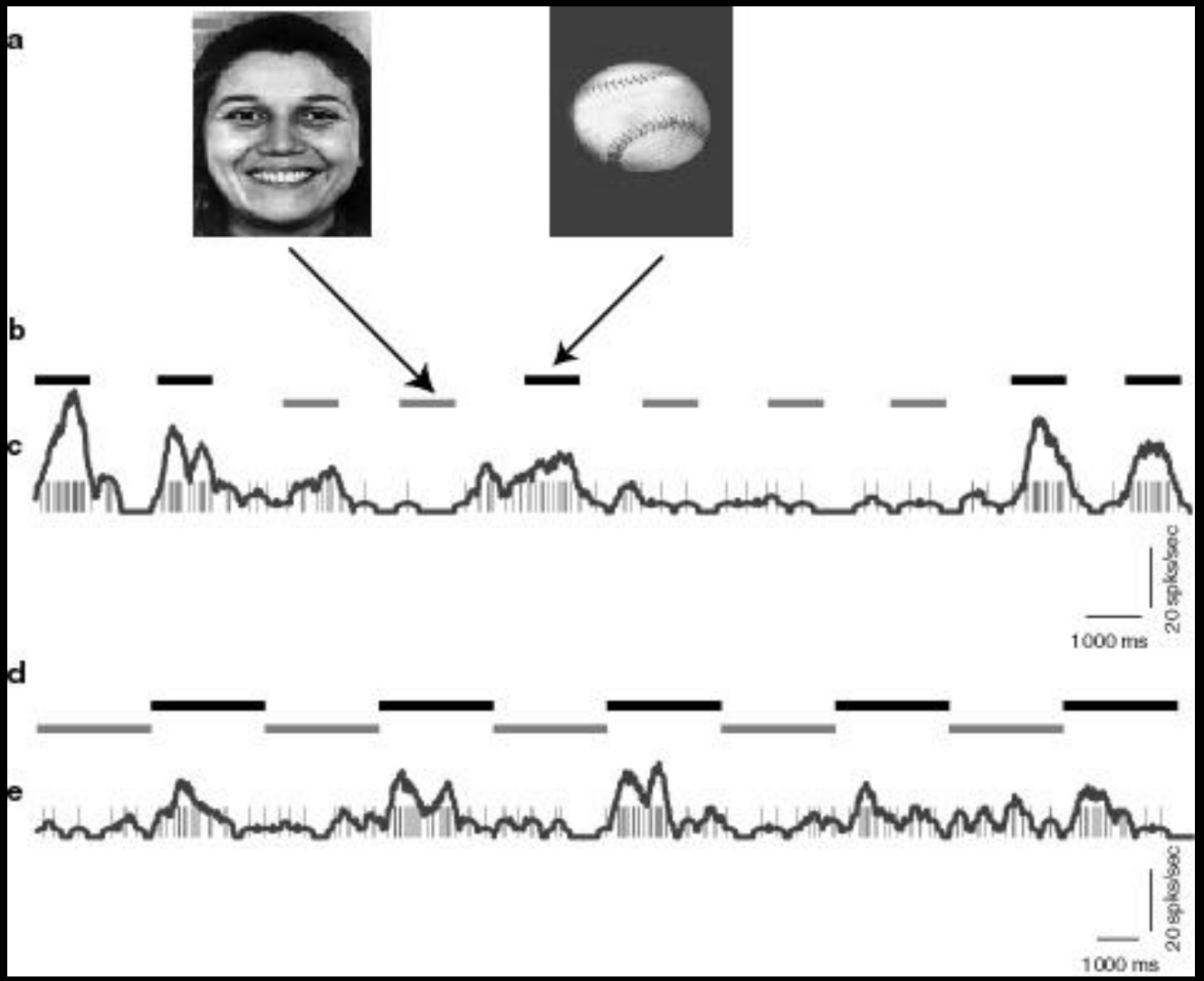


Imagery Neurons in the Human Brain



Visual Stimulation

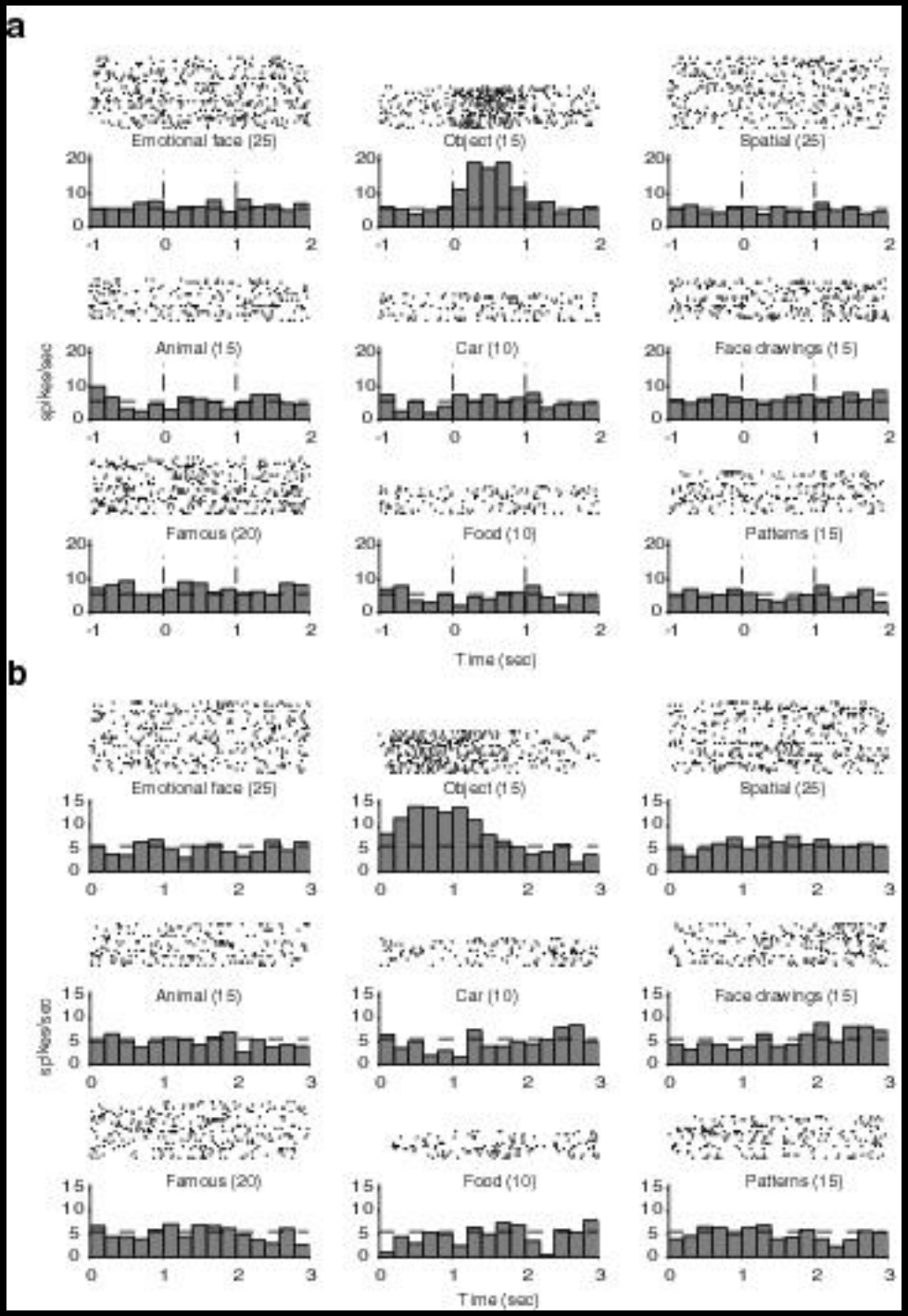
Imagery

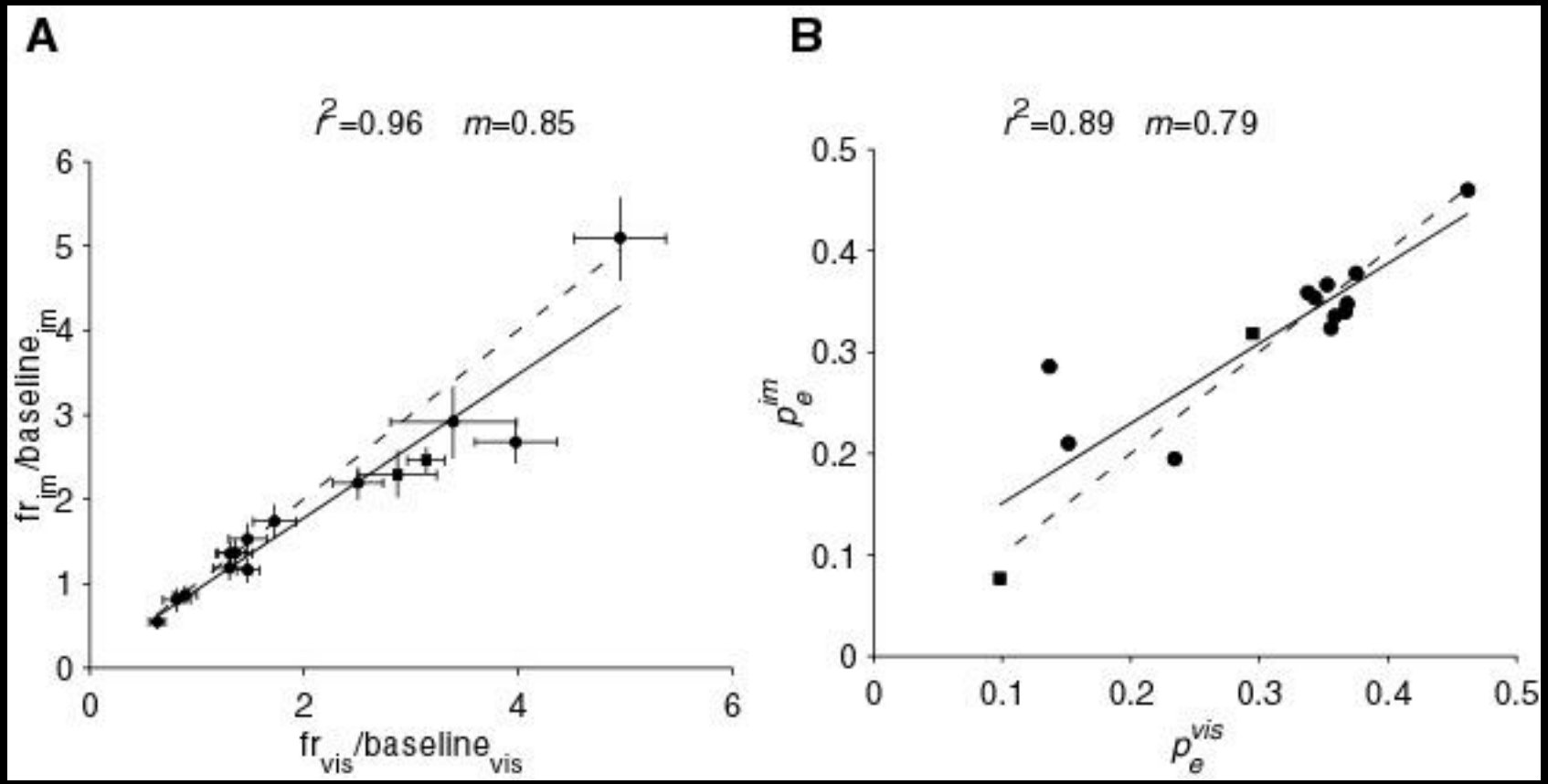


Kreiman, Koch and Fried (2000b)

Visual selectivity of entorhinal neuron

Imagery selectivity of entorhinal neuron




A
r^2=0.96 m=0.85
fr_{im}/$baseline_{im}$
fr_{vis}/$baseline_{vis}$
0
1
2
3
4
5
6
B
r^2=0.89 m=0.79
p_e^{im}
p_e^{vis}
0
0.1
0.2
0.3
0.4
0.5

Summary I

- 44 neurons (16%) selective to vision (latency: 282+/-191 ms)
- 23 neurons (8%) selective to imagery (latency: 409+/-291 ms)
    - 7 neurons (30%) exclusively activated during imagery
    - 16 neurons (70%) activated during vision and imagery

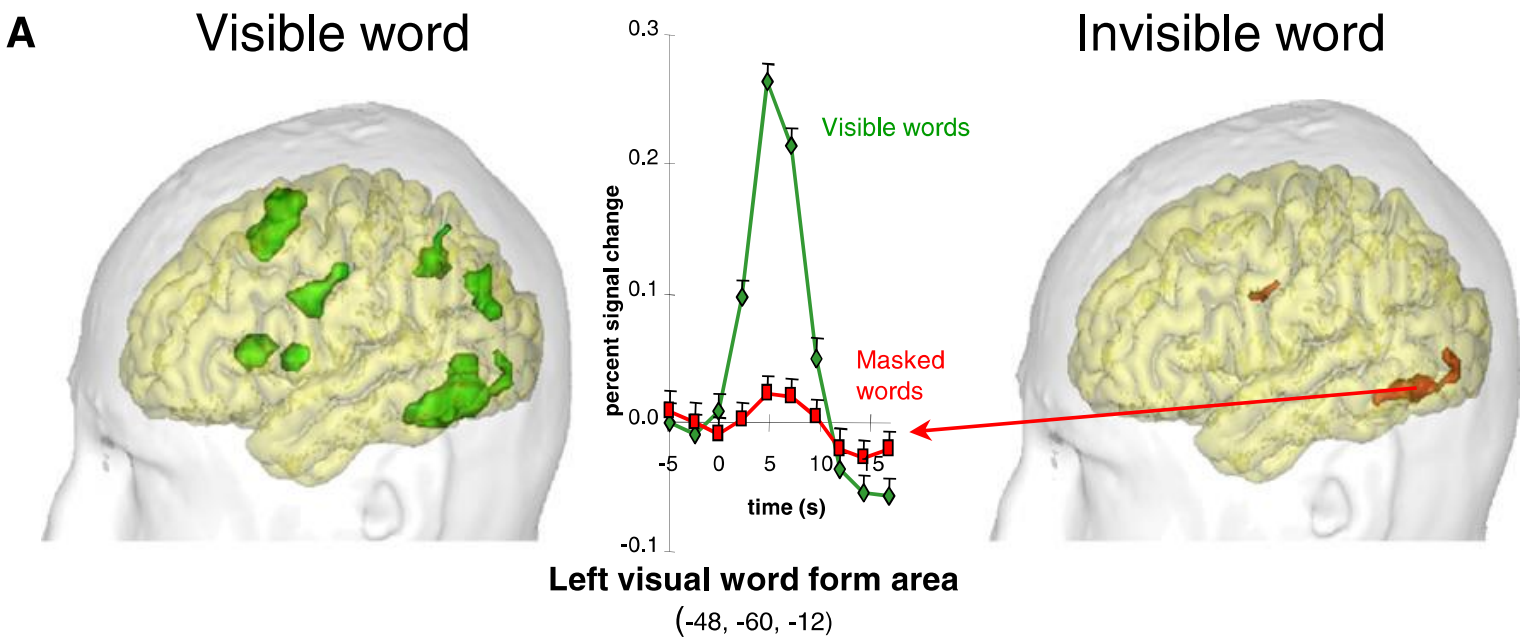
        Of these, 14 (88%) showed the same selectivity. This is expected to occur once in 90,000 cells by chance

        Strength of firing during imagery 85%

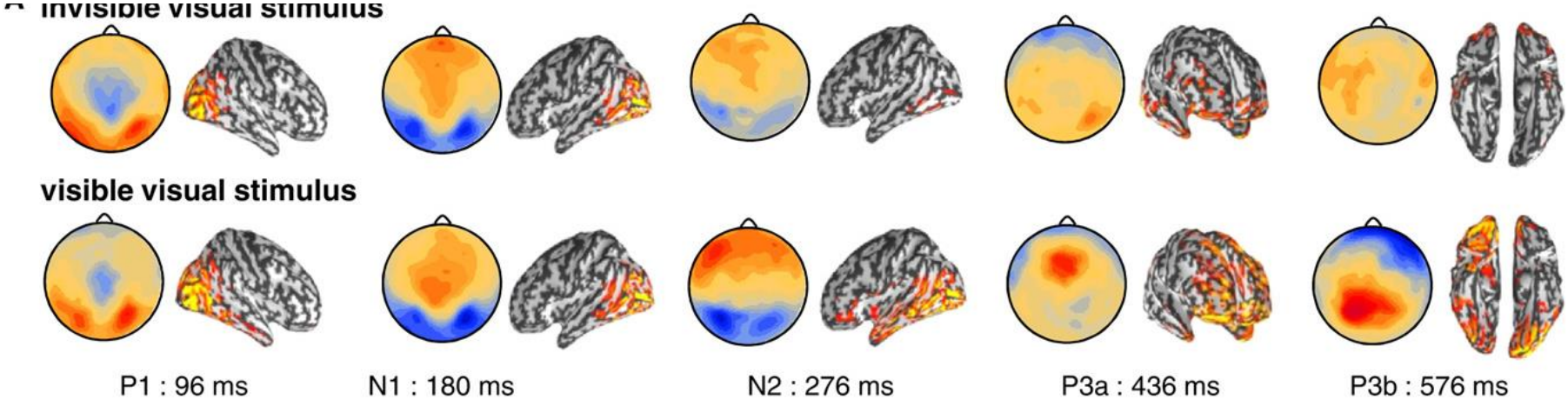
Manipulating Visual Awareness Via Attention

- Subjects can be blind to very large changes in the image: we only see a small fraction of the scene around us. This is illustrated in *Change Blindness (*Rensink, O'Regan and Clark, 1997).

fMRI Measures of Conscious Access (using masking)

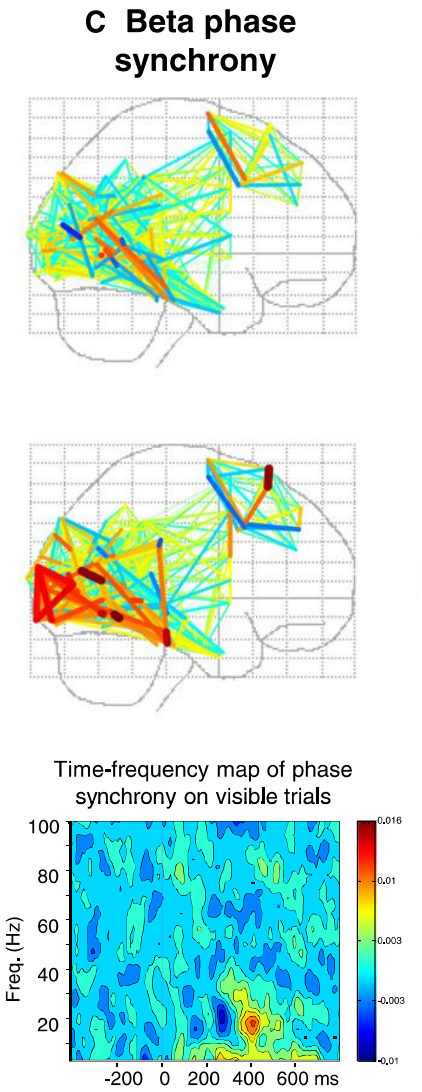


Time Course (using Electro- and Magneto-encephalography) of Conscious vs. Unconscious Access



Intracranial Potentials during Conscious in ten epileptic patients implanted with deep intracortical electrodes

Phase synchrony increased for visible words in a late time window (300–500 ms) in the beta frequency range (13–30 Hz)



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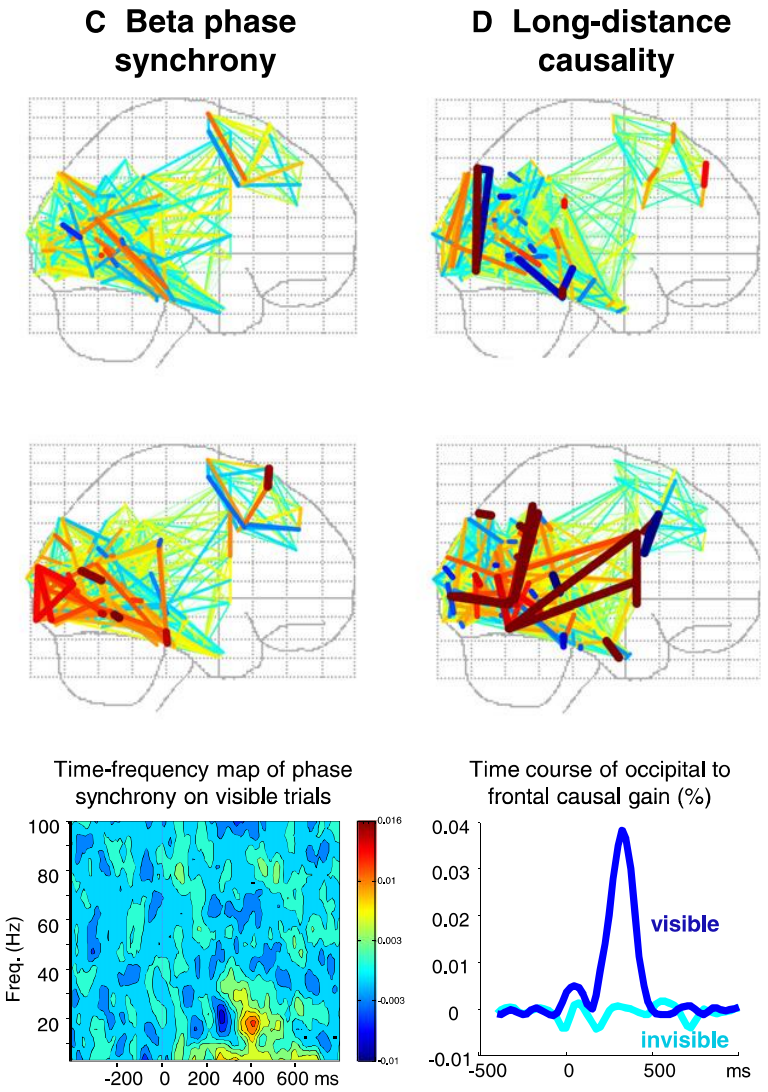
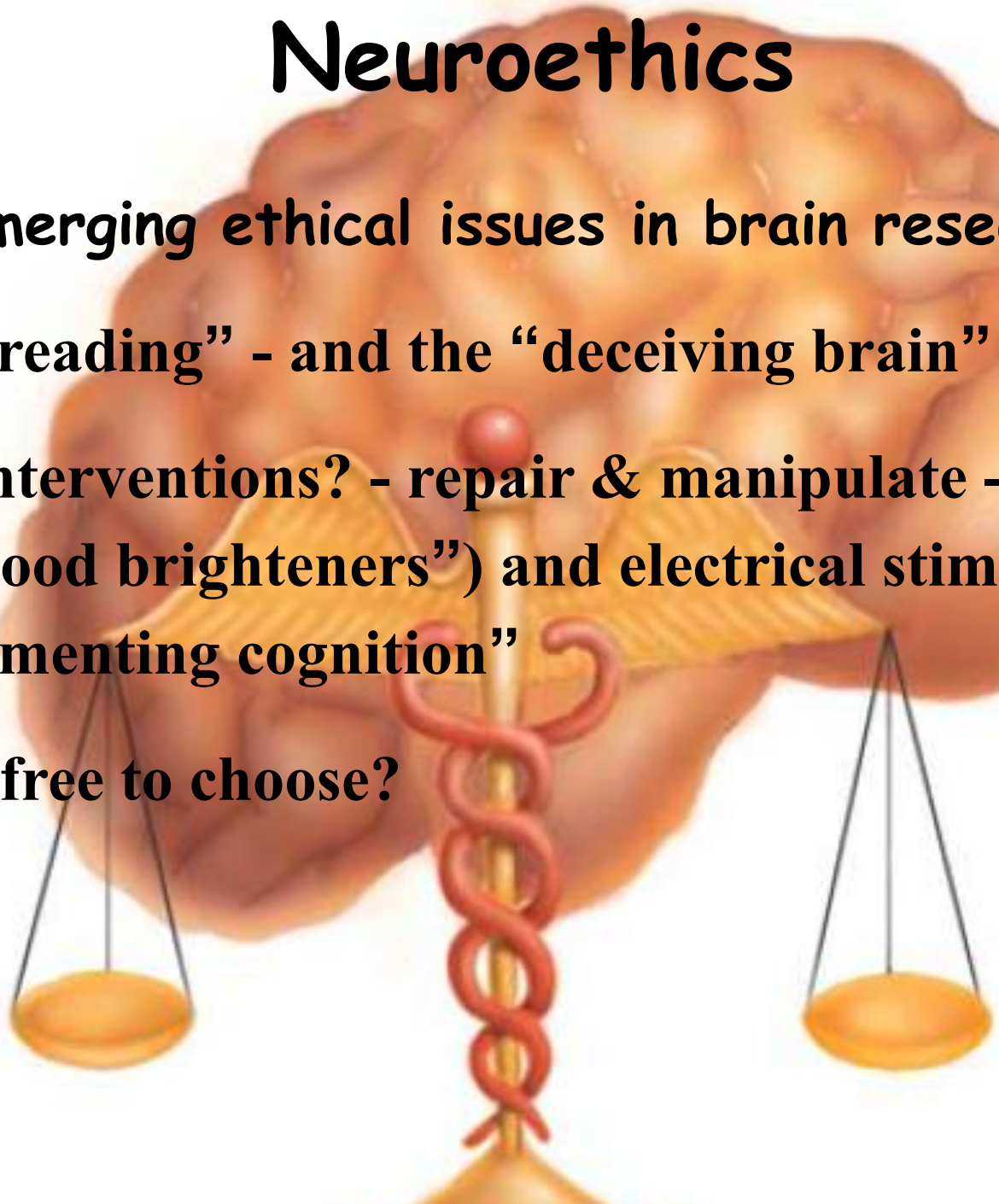


Causal relations across distant electrodes increased massively during the same time window.
Increases were bidirectional but dominant in the occipital-to-frontal direction.

Biological and Machine Consciousness

- We know that humans are conscious (except some philosophers).
- Based on similarity in neuroanatomy, physiology, architecture and behavior, as well as on grounds of evolutionary continuity, we assume that mammals share many aspects of consciousness with us, in particular many aspects of sensory consciousness.
- At this point in time, any hypothesis regarding machine consciousness must be based on analogies with biological consciousness.

Neuroethics



Emerging ethical issues in brain research

- **Brain "reading" - and the "deceiving brain"**
- **Brain interventions? - repair & manipulate - drugs (e.g., "mood brighteners") and electrical stimulations for "augmenting cognition"**
- **Are we free to choose?**

1. Gazzaniga et al., *Neuroscience and the law* (DANA Press)
2. Laurence Tancredi *Hardwired behavior: What neuroscience reveals about morality* (Cambridge Univ. Press, 2005)
3. Martha J. Farah, *Emerging ethical issues in neuroscience* (Nat. Neurosci. 2005)
4. Wolf Singer *“I’m an not guilty - but my brain is”* (Guardian, Aug. 12, 2004)
5. Special report: *Lie detectors spooks ethicists* (Nature, June 2006)
6. Mobbs et al,. *Law, responsibility and the brain* (PLoS Biology (2007)
7. *The DANA Neuroscience Progress Report* (2007)

In an fMRI study designed to simulate the investigation of a shooting inside a hospital, Feroze Mohamed and colleagues identified eight brain areas that showed significantly more activity during the act of deception than in a neutral situation, and two areas that showed significantly more activity during truth-telling than in a neutral situation. They published their work in *Radiology*.[3]

To date, most neuroscientists are reserving their opinions, but an editorial in *Nature* urges the neuroscience community to voice its doubts loudly and clearly, as well as to get ready for a long public debate on the ethical implications of this technology and on the nature of privacy itself.[4]

The field of neuroethics took on a more explicit form in 2006 with the establishment of the Neuroethics Society. Founded by eminent scientists, lawyers, and ethicists, the society hosts a Web site, www.neuroethicssociety.org, and two "partner" publications, the *American Journal of Bioethics* and the *Journal of Cognitive Neuroscience*.

1. “Reading thoughts”?

   Privacy

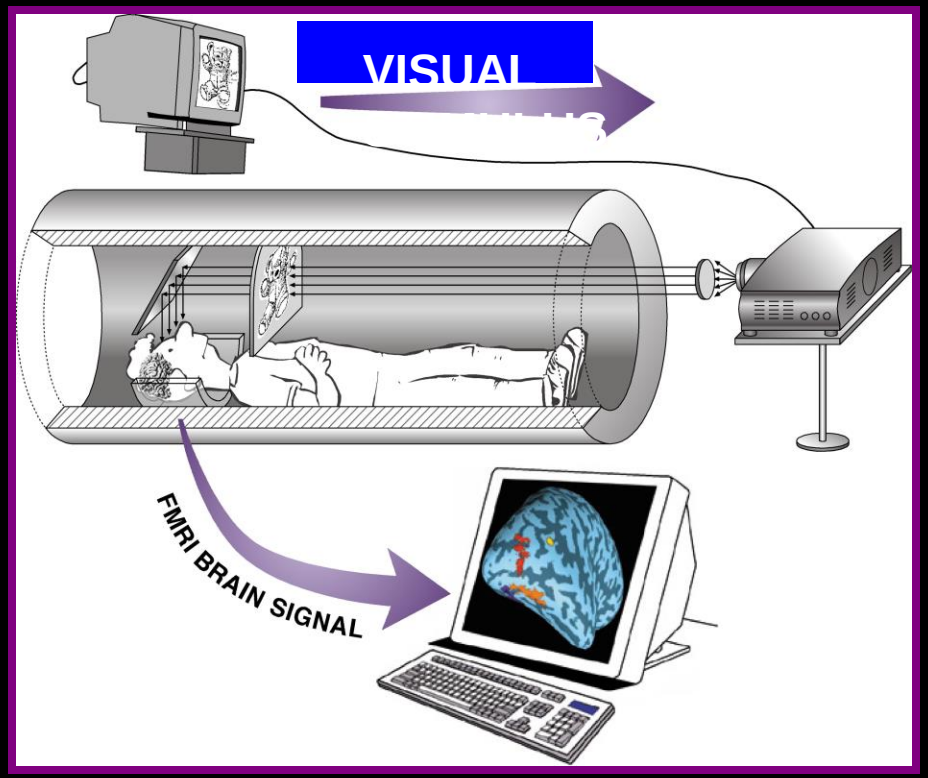
   Reproducibility (accuracy)

   Individuality (how similar/different are our “personal” brain codes?)

Examples

Scanning the ("social") brain:
Functional Magnetic Resonance Imaging (fMRI)

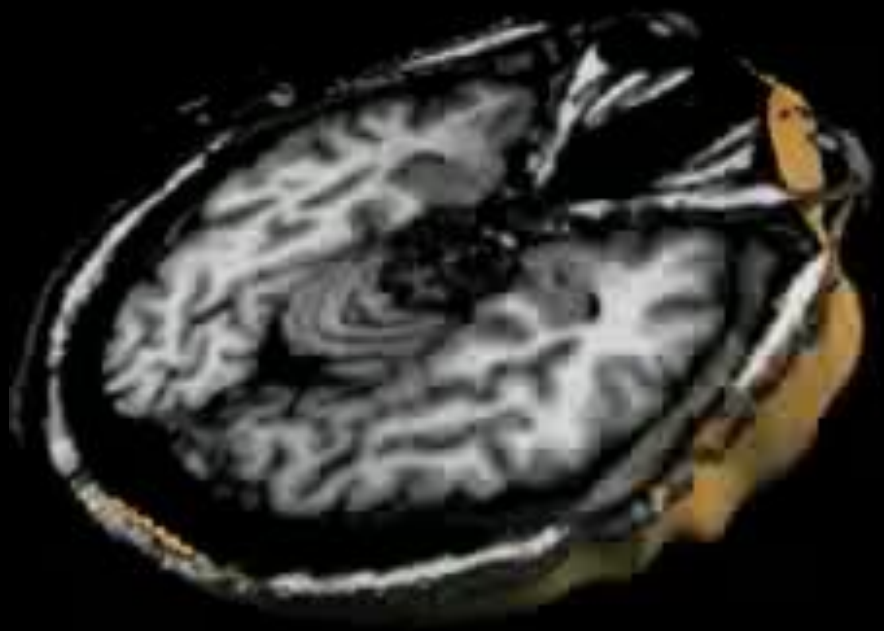
1. Detecting brain functions and diseases
2. Detecting racial tendency (and more?)
3. Communicating with the brain in vegetative states



I. Levy, Hebrew University & R. Malach, Weizmann

The Use of fMRI

Probing Face recognition in the Human Brain (with fMRI)

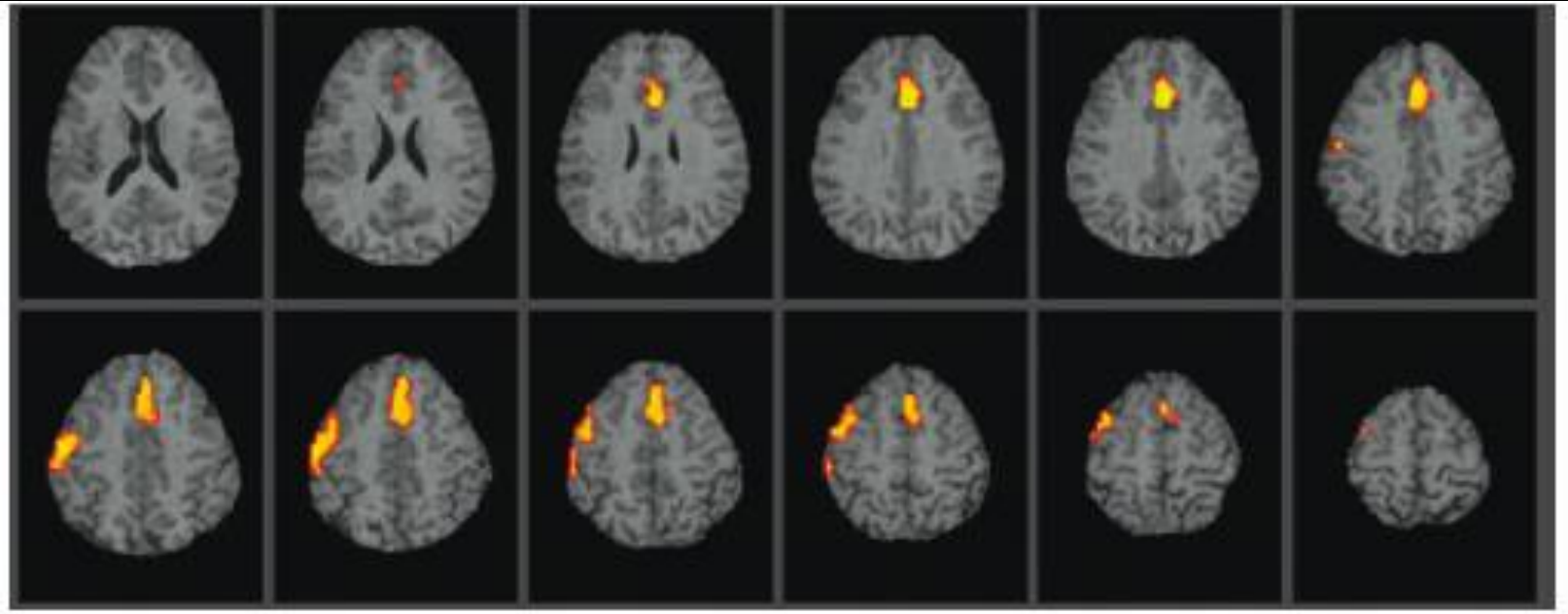


Probing the brain with fMRI for: Lie-detection

"Accessing brain activity goes to the very source of the lie"

No Lie MRI (Philadelphia)

Cephos, (Peppel Mass)

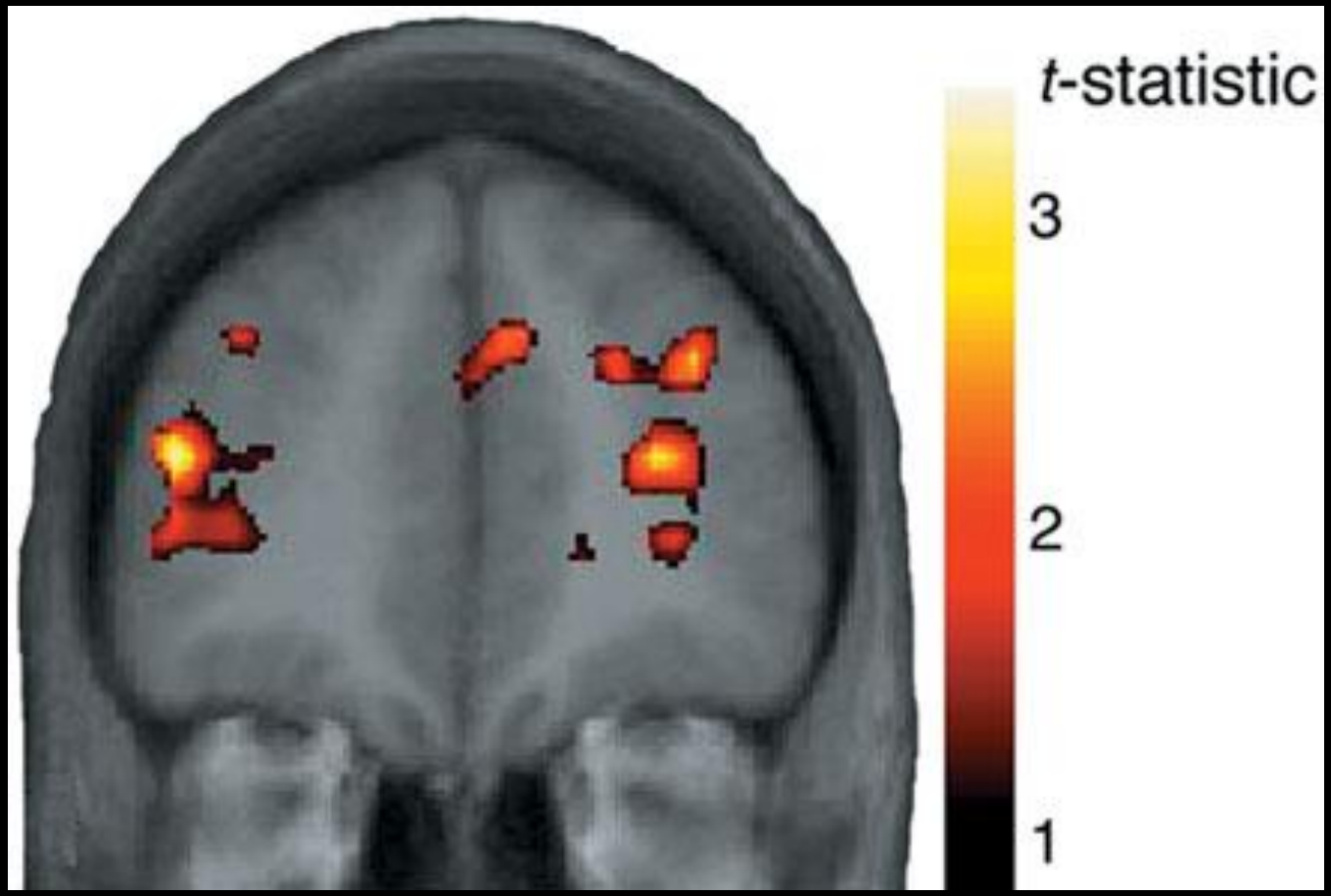


Mind reading: functional MRI scans reveal brain regions that light up only during a lie.

Cards related to money; students try to conceal which card they held

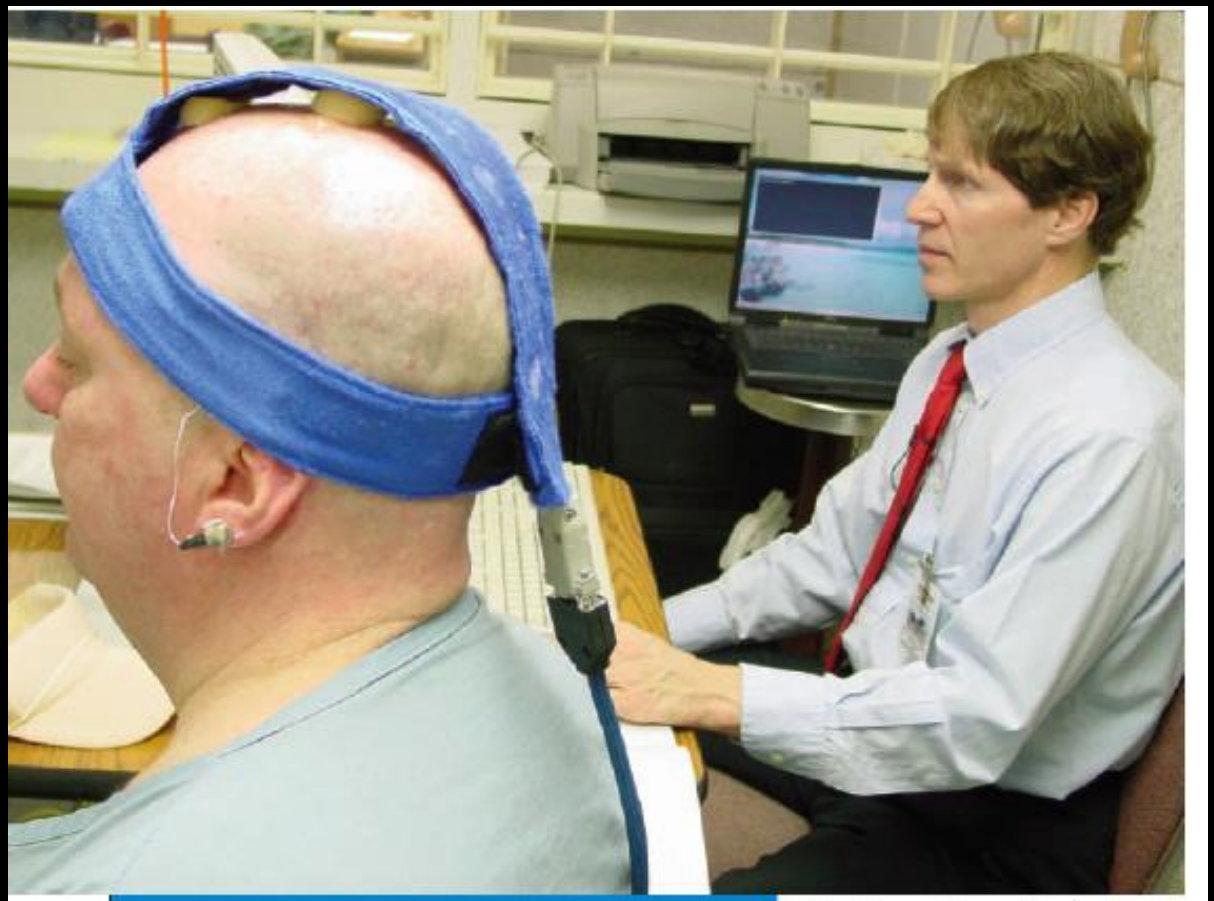
When lying - particular spots at the prefrontal cortex become more active

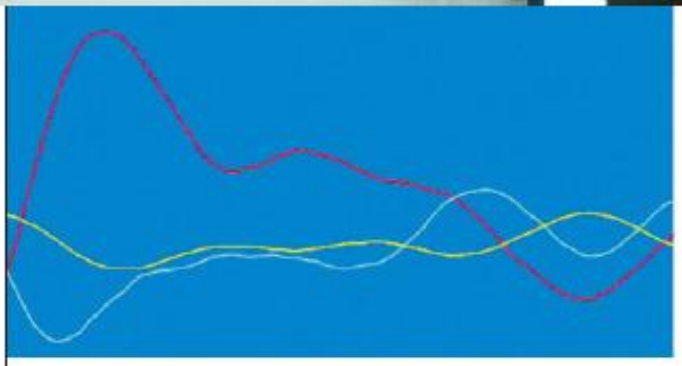
Detecting thoughts and feelings while interacting with someone of a different race.



Regions showing greater activity to black faces than to white faces for people with racial bias

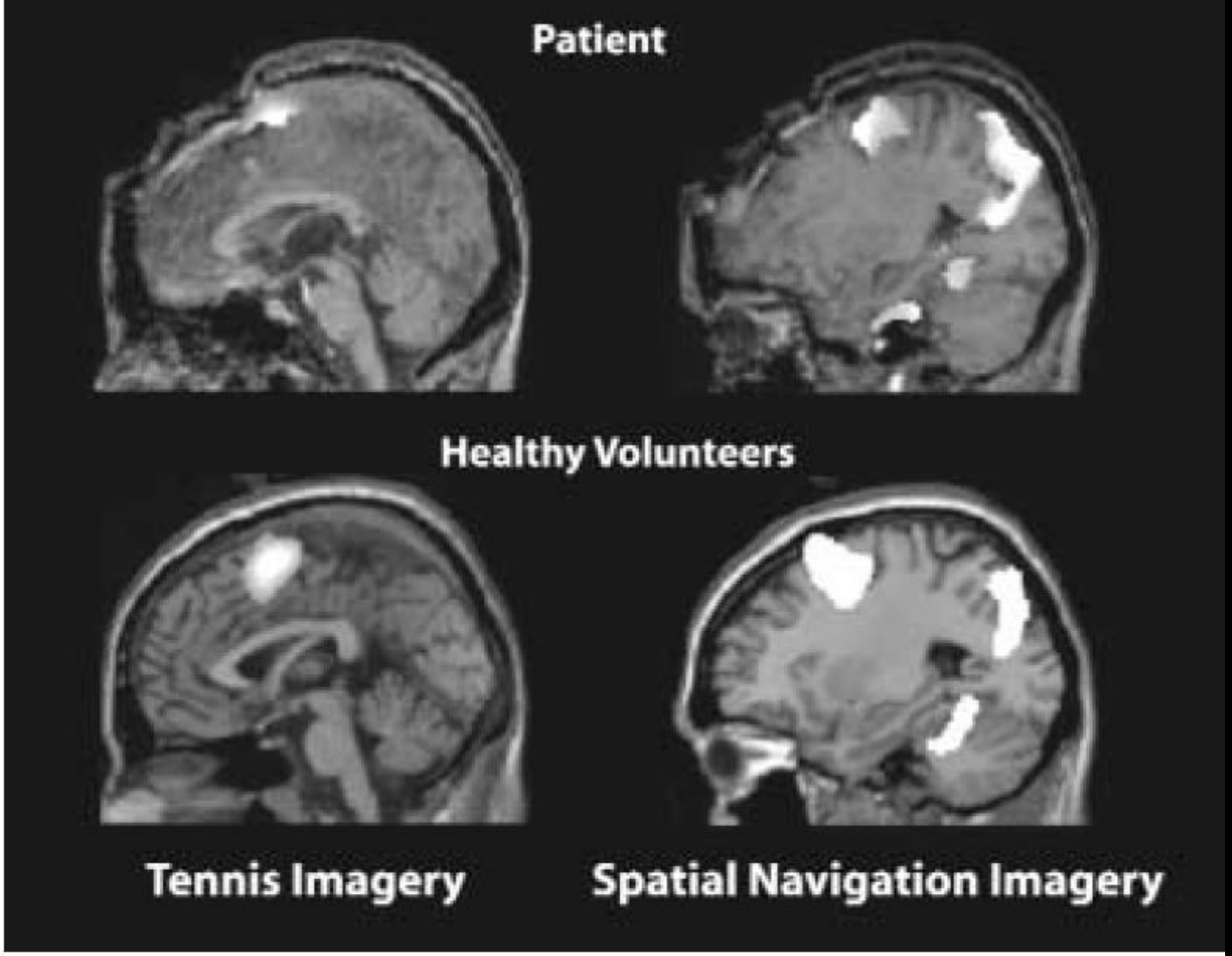
Brain Fingerprinting lab. (L. Farwell, Seatle) - using P300 (EEG) for detecting input that has a special significance (“hidden knowledge”) for the subject





Lies, damned lies, and technology: the accuracy of the polygraph lie detector (facing page) has been attacked. Lawrence Farwell (above, right) thinks measuring the burst of brain activity that occurs when a person recognizes something (left) could provide a reliable alternative. Others fear the technique works better in the lab than in the field.

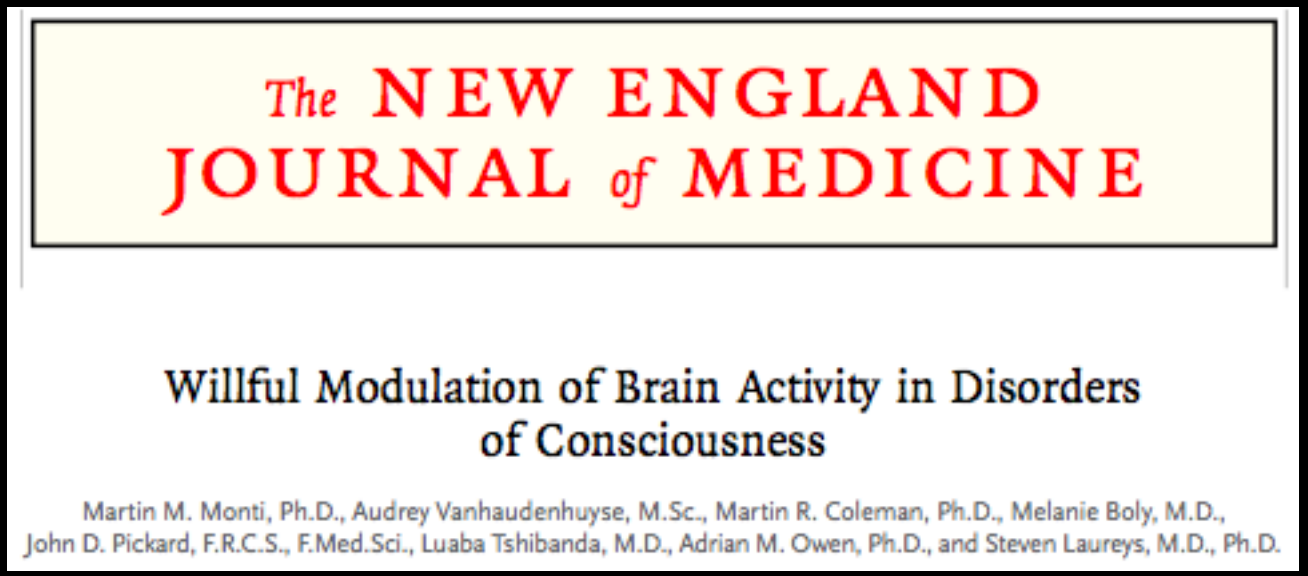
Interacting with the brain in vegetative states



Brain activity in a vegetative state

A patient in a persistent vegetative state showed activity in the same brain areas as healthy volunteers in response to spoken commands to visualize herself playing tennis or moving through her house.

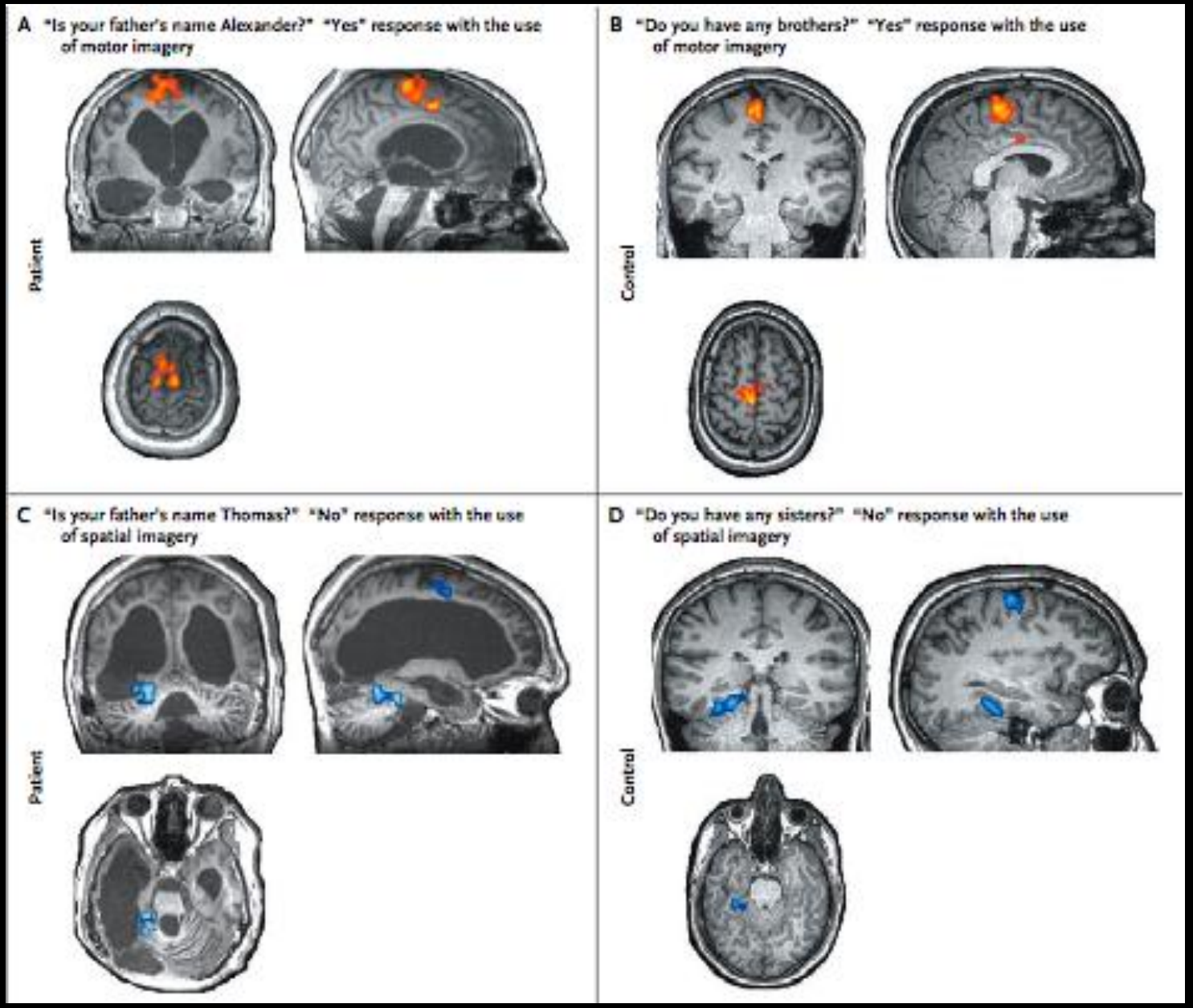
Communication with people in vegetative state



The NEW ENGLAND JOURNAL of MEDICINE

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.


A "Is your father's name Alexander?" "Yes" response with the use of motor imagery
Patient
B "Do you have any brothers?" "Yes" response with the use of motor imagery
Control
C "Is your father's name Thomas?" "No" response with the use of spatial imagery
Patient
D "Do you have any sisters?" "No" response with the use of spatial imagery
Control

Why then not use DBS (or various drugs - antidepressants etc.) in normal people for

- Anti-stress
- Improve capabilities (become more creative?)
- …

What are the limits?

3. How free are we?

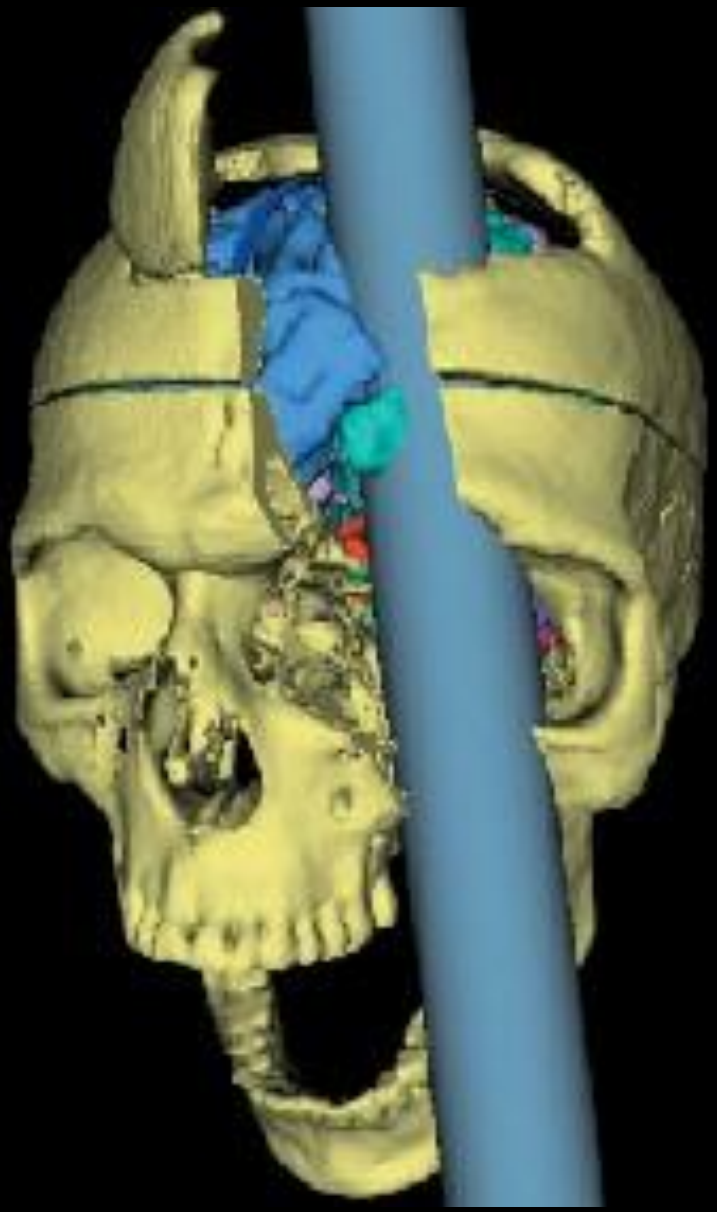
The case of Phineas Gage - Vermont, 1848

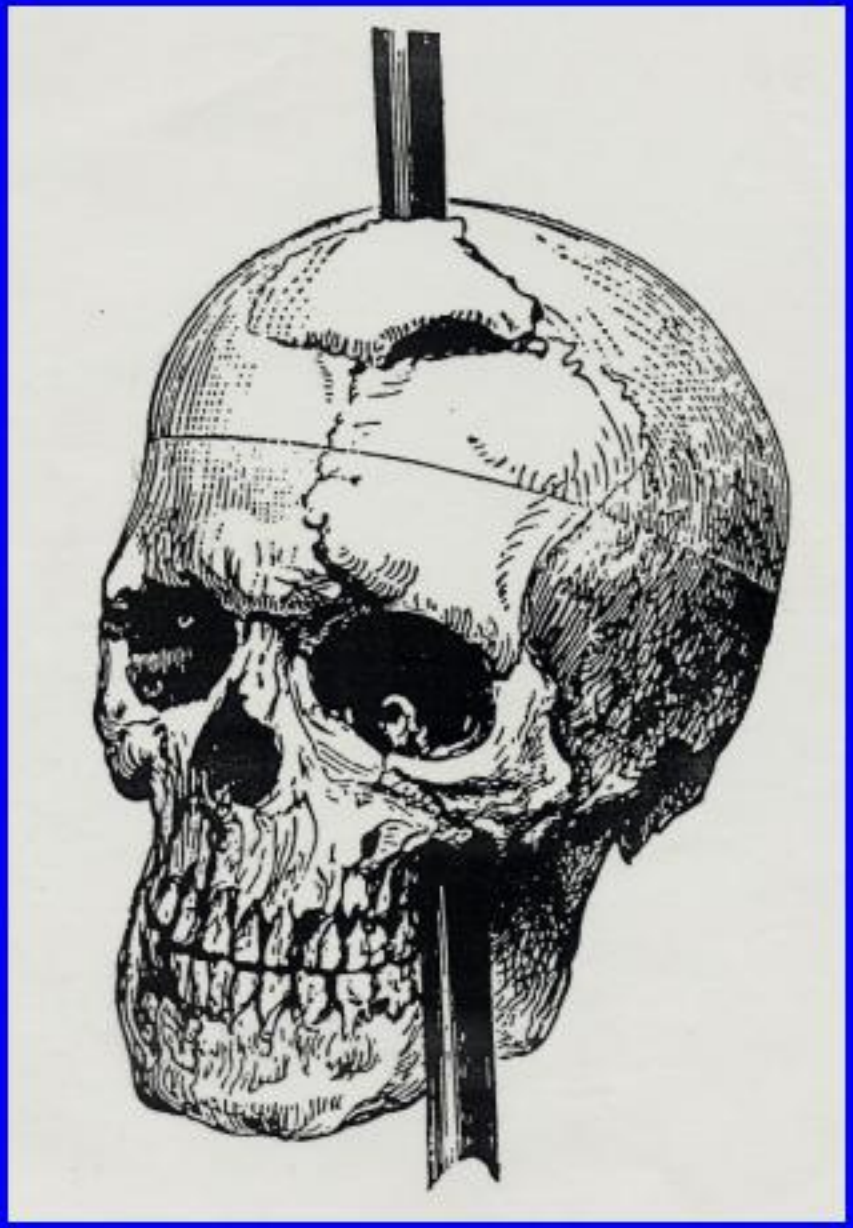
Phineas Gage is probably the most famous patient to have survived severe damage to the brain. He is also the first patient from whom we learned something about the relation between personality and the function of the front parts of the brain.

As the first newspaper account of the accident, that appearing in the Free Soil Union (Ludlow, Vermont) the day after the accident, and here reproduced as it appeared in the Boston Post, reported, Phineas Gage was the foreman of a railway construction gang working for the contractors preparing the bed for the Rutland and Burlington Rail Road near Cavendish, Vermont. On 13th. September 1848, an accidental explosion of a charge he had set blew his tamping iron through his head

The tamping iron was 3 feet 7 inches long and weighed 13 1/2 pounds. It was 1 1/4 inches in diameter at one end and tapered over a distance of about 1-foot to a diameter of 1/4 inch at the other. The tamping iron went in point first under his left cheek bone and completely out through the top of his head, landing about 25 to 30 yards behind him. Phineas was knocked over but may not have lost consciousness even though most of the front part of the left side of his brain was destroyed. Dr. John Martyn Harlow, the young physician of Cavendish, treated him with such success that he returned home to Lebanon, New Hampshire 10 weeks later.

The case of Phineas Gage - Vermont, 1848






B

The case of Phineas Gage - Vermont, 1848

Some months after the accident, probably in about the middle of 1849, Phineas felt strong enough to resume work. But because his personality had changed so much, the contractors who had employed him would not give him his place again. Before the accident he had been their most capable and efficient foreman, one with a well-balanced mind, and who was looked on as a shrewd smart business man. He was now fitful, irreverent, and grossly profane, showing little deference for his fellows. He was also impatient and obstinate, yet capricious and vacillating, unable to settle on any of the plans he devised for future action. His friends said he was "No longer Gage."

Are we completely defined by the deterministic nature of physical laws? Are we essentially sophisticated automatons only, with our conscious feelings and intentions tacked on as epiphenomena with no causal power? (cf. Thomas H.Huxley)

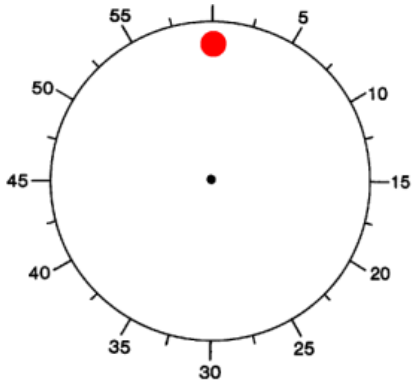
Or do we have some independence in making choices and actions, not completely determined by the known physical laws?

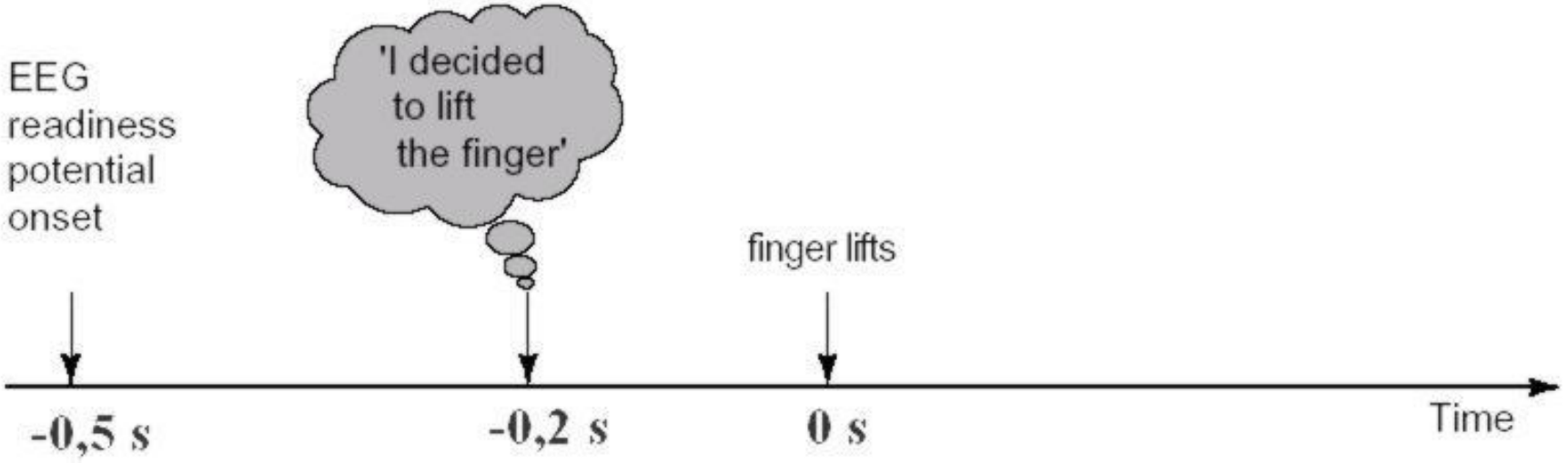
The greatest gift which humanity has received is free choice. It is true that we are limited in our use of free choice but the little free choice we have is such a great gift and is potentially worth so much that for this itself life is worthwhile living. (Isaac Bashevis Singer 1968)

Free Will and the Brain

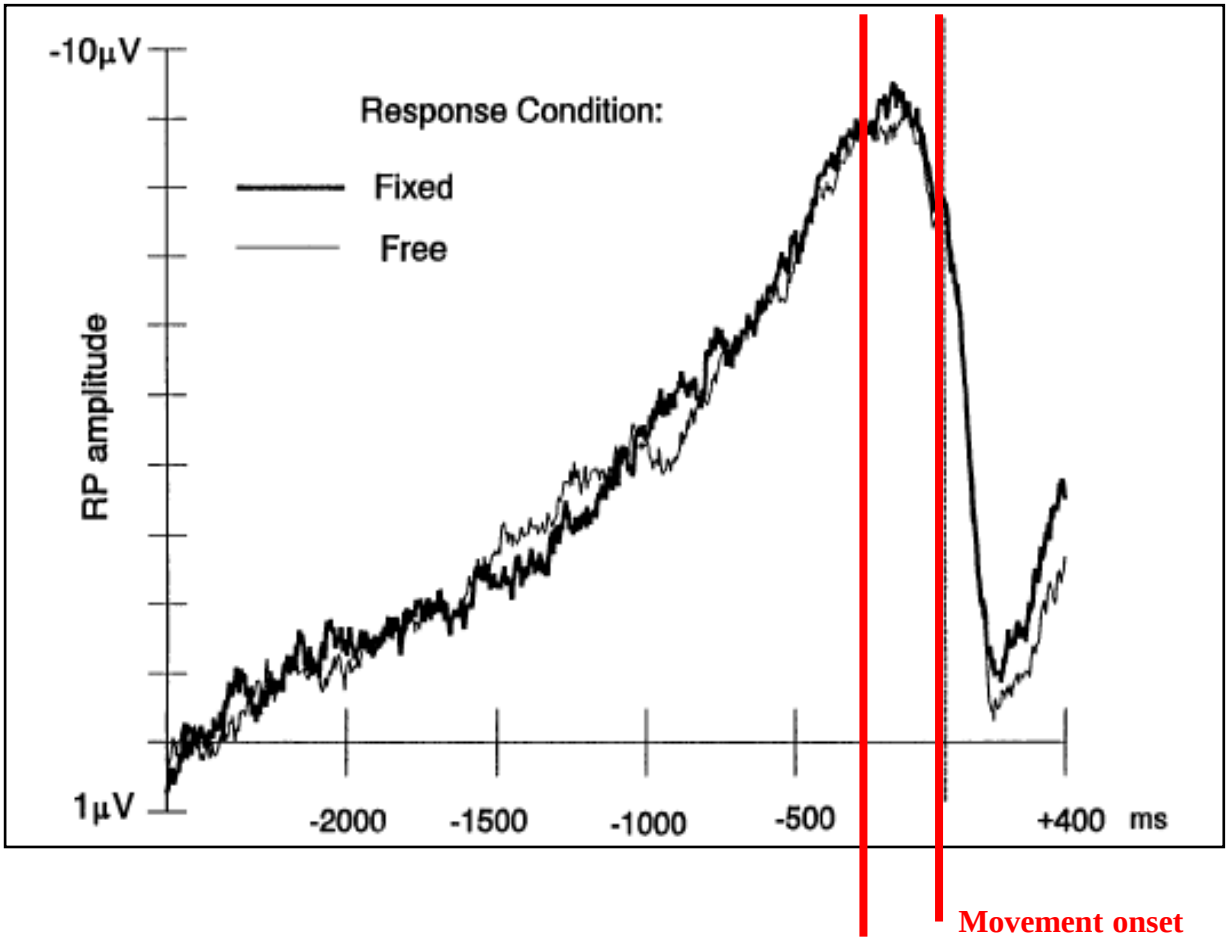
1916 - 2007

Benjamin Libet's experiment





The “readiness potential” – Libet experiments

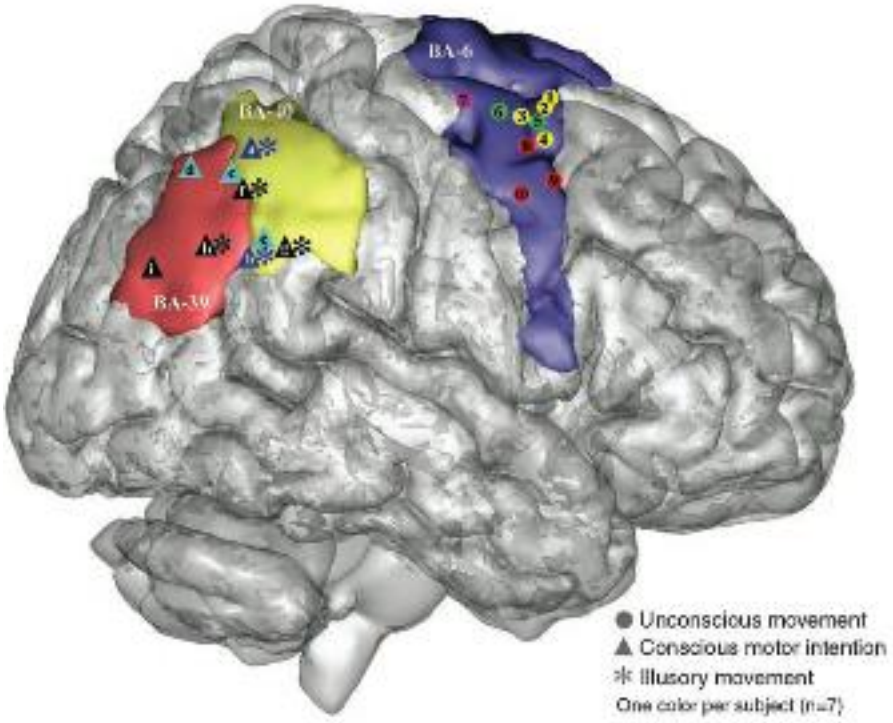


Libet's findings have been widely taken to show that since our brain has already started preparing to flex the wrist before we even become aware of our intention to flex it, our supposedly free will is not free at all. Rather, our brain has decided for us and has started a causal chain leading to the finger-bending, before we become aware of our decision.

Thus, our will appears determined and causally irrelevant.

Movement Intention After Parietal Cortex Stimulation in Humans

Michel Desmurget et al., Science 2009



Left/right inferior parietal regions: **No movement, no EMG BUT**

Low-intensity : "I felt a desire to lick my lips" " (▲ Conscious motor intention)

Higher intensity: "I moved my mouth, I talked, what did I say?"" (✳ Illusory movement)

Premotor regions: Low + strong stimulation**, movement without awareness**

Wolf Singer (dir. MPI - Frankfurt) - 2004

“Crime itself should be taken as evidence of brain abnormality”

“Even if no abnormalities can be found in the brain, criminal should be treated as incapable of having acted otherwise”

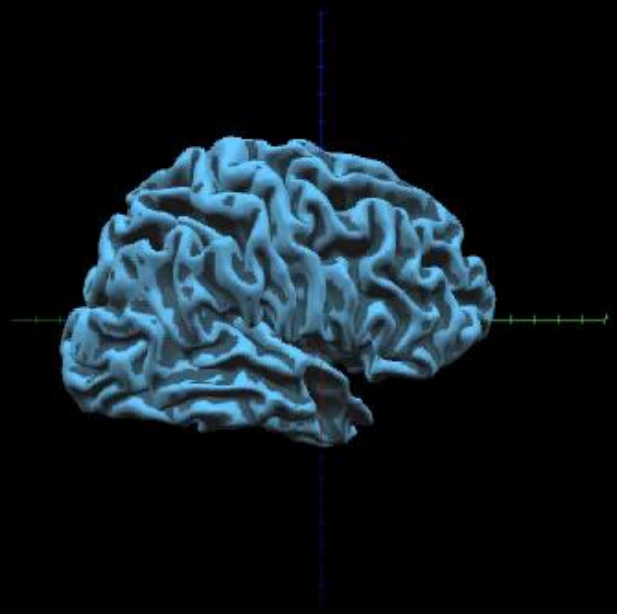
“Most of what we do is at the subconscious level so we are not aware of all the elements that make us behave in a certain way”

“Free will is an illusion

“We need to continue to assign value to our behavior - essential for organizing society”

Are we going to fully understand our own brain in the 21st century:

"The century of the Brain"?



Toda Rabba

To all of you

Machine Consciousness

- Does the system (computer, world-wide web etc) display non-stereotyped behaviors making use of memory (zombie test)?

- Can it extract correlations? That is, does it encode meaning?

He paused, then murmured slowly: "I wonder---I wonder if your computers may not have consciousness. If they might not have---minds."

"Don't get fantastic," snorted the scientist.

"But how do you know?" persisted the visitor. "Look, your feedback arrangement is closely analogous to a human nervous system. How do you know that your individual computers, even if they are constrained by the group linkage, don't have individual personalities? How do you know that their electronic senses don't interpret the game as, oh, as an interplay of free will and necessity; how do you know that they don't receive the data of the moves as their own equivalent of blood, sweat, and tears?" He shuddered a little.

From "*The Immortal Game*" by Poul Anderson