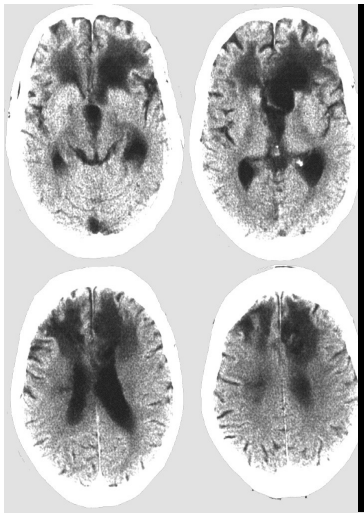
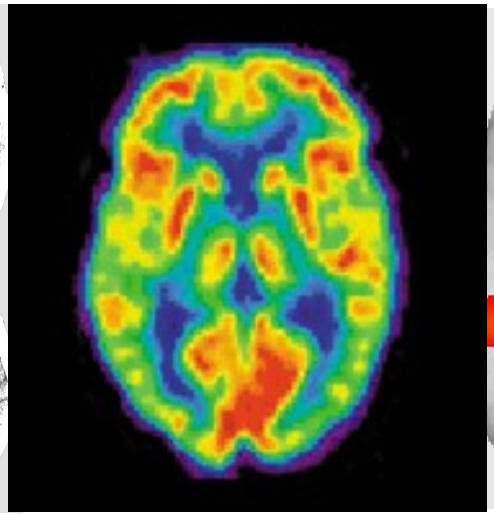
The Cognitive Neuroscientist's Toolkit

Jesse Rissman

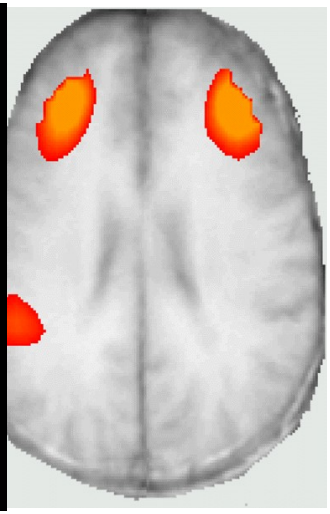
CS 182 Guest Lecture, 2/1/07



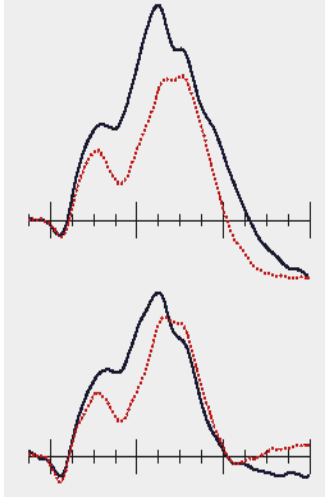
LESION



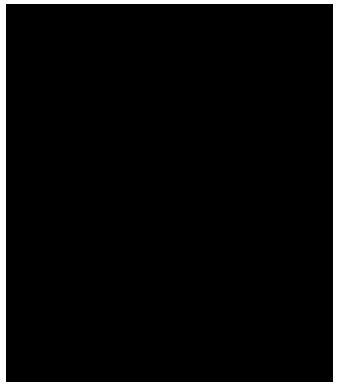
PET



fMRI

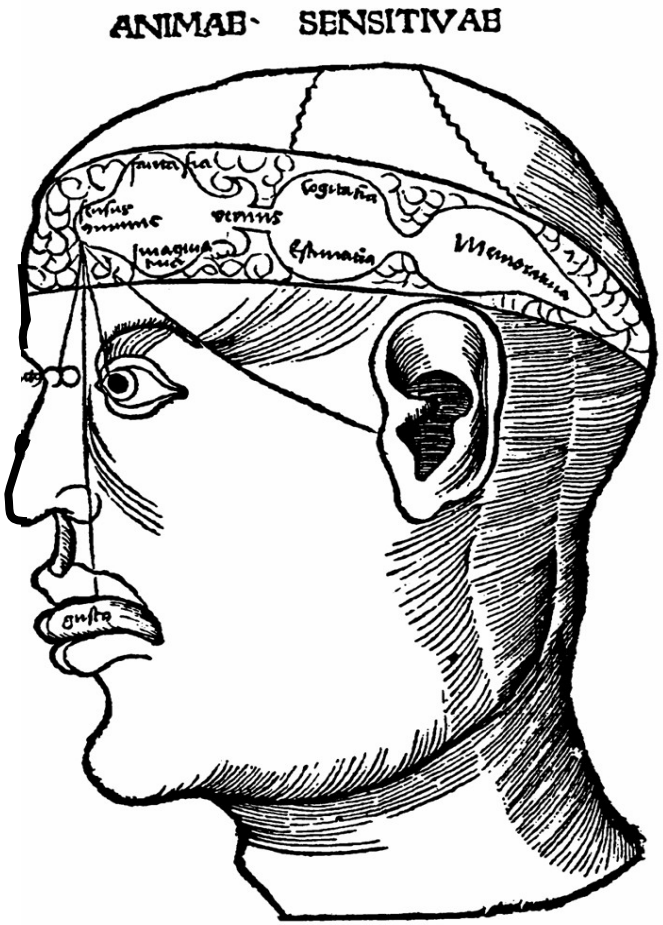


EEG/MEG



TMS

A little history…



Galen (129-200 AD)

Ventricular theory of brain function

* Anterior ventricle controls perception
* Middle ventricle controls cognition
* Posterior ventricle controls memory

Could he have been right?

This is your brain on…love

Yes, it's possible to *see* that head-over-heels feeling. Anthropologist Helen Fisher, Ph.D., scanned the brains of 17 people who'd been in love for an average of seven months. As they stared at photos of their beloved, certain neural areas lit up on-screen. Says Fisher, "The brain in love reacts in a specific way. It's hard to control." Bottom line: You may think you're following your heart, but it's all in your head. —JO PIAZZA

When you're in love, blood flow increases to a region of the brain that's responsible for motivation. It's illuminated here.

someone else doesn't diminish your marriage; acting on that attraction does.

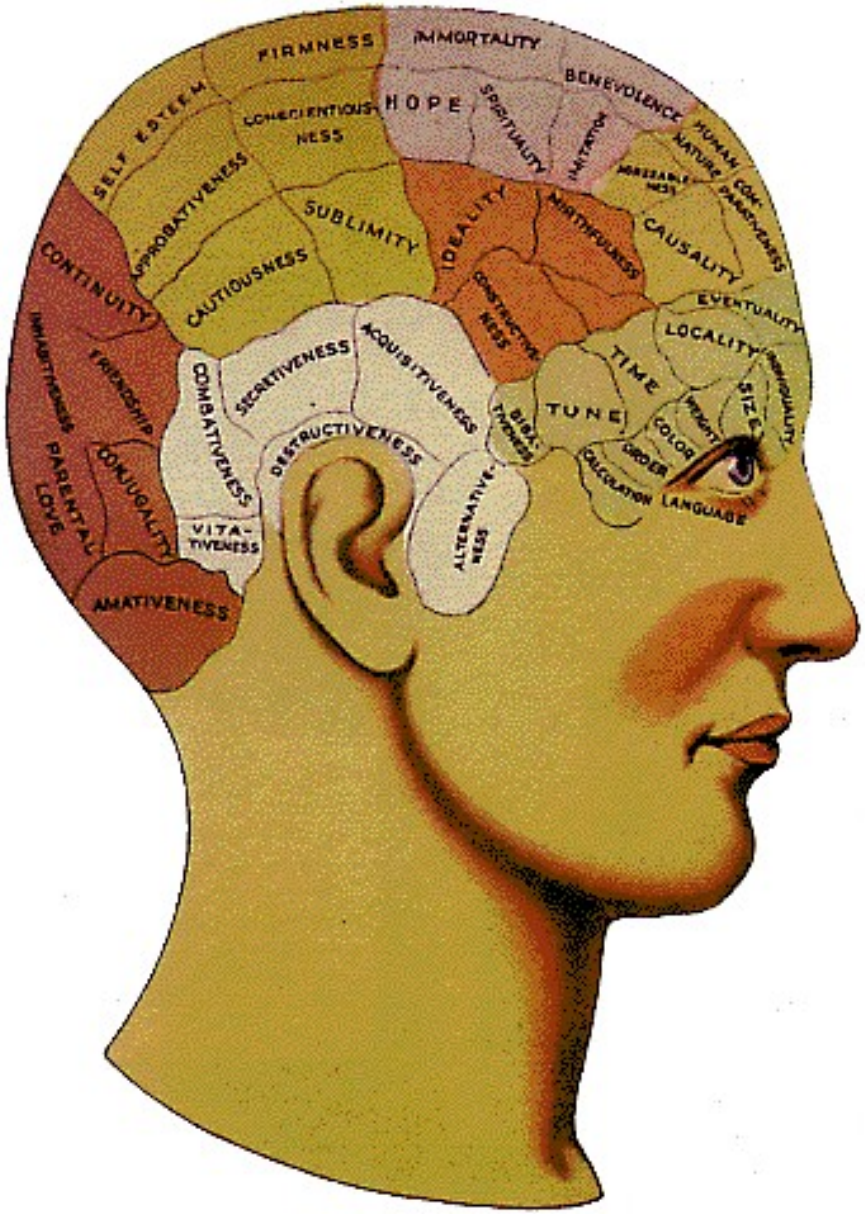
6. If your partner thinks something is important, it is!

love quickie Is commitmentphobia dead? 75% of single women *and* men are "seriously looking" for a mate.

Don't believe everything you read in Glamour Magazine!

Phrenology: the start of localizationism

Franz Joseph Gall
(1758-1828)



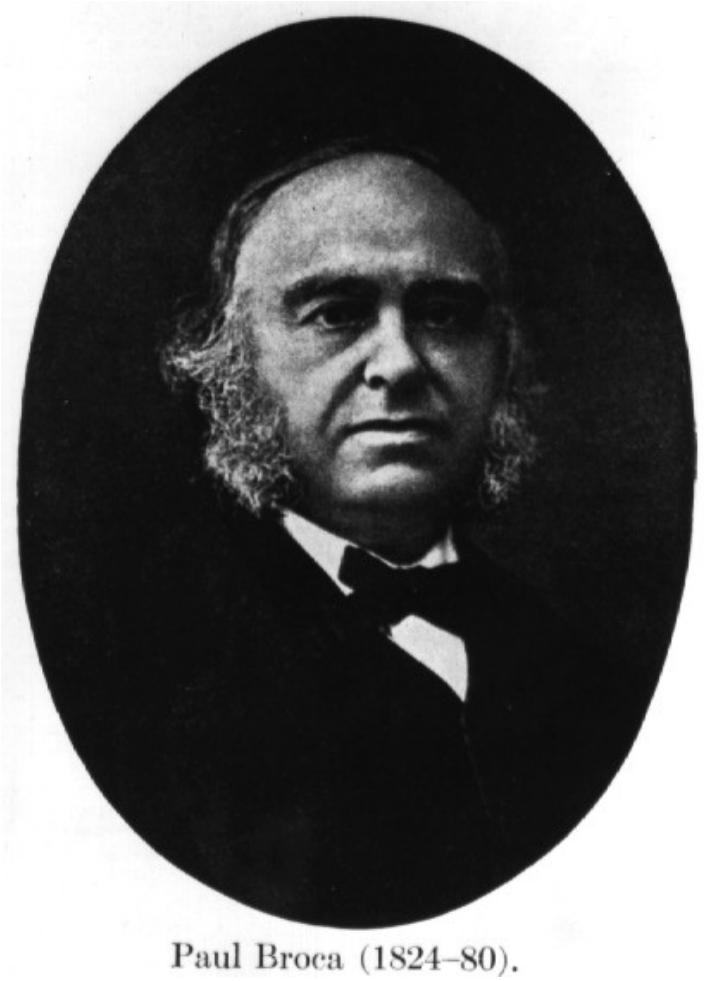
Some people still believe in phrenology to this day.

Mr. Burns: Who could forget such a monstrous visage? She has the sloping brow and cranial bumpage of the career criminal.”

Smithers: "Uh, Sir? Phrenology was dismissed as quackery 160 years ago.”

Mr. Burns: (measuring Smithers' head) "Of course you'd say that... you have the brainpan of a stagecoach tilter!"

Lesions as tool to gain insight into brain function



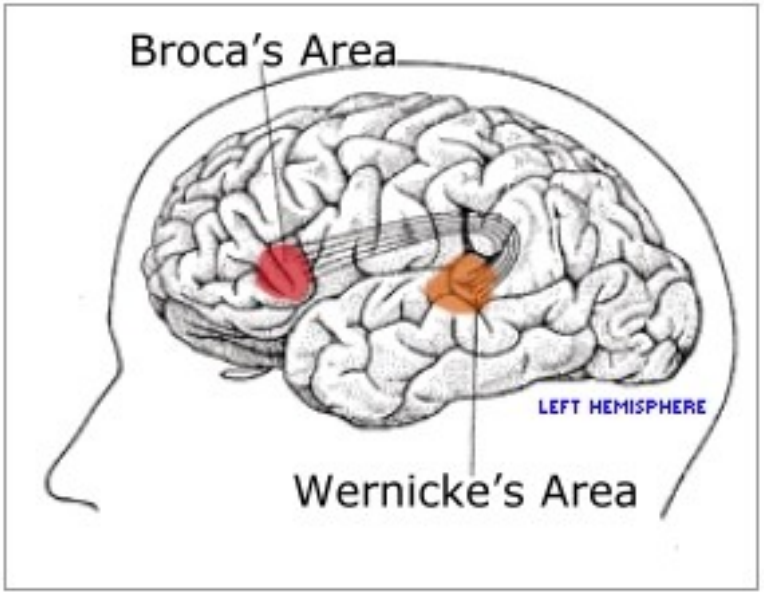
Paul Broca (1824–80).

The brain of patient “tan”

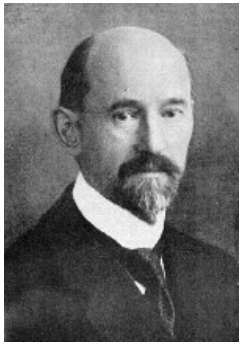
Broca’s Area

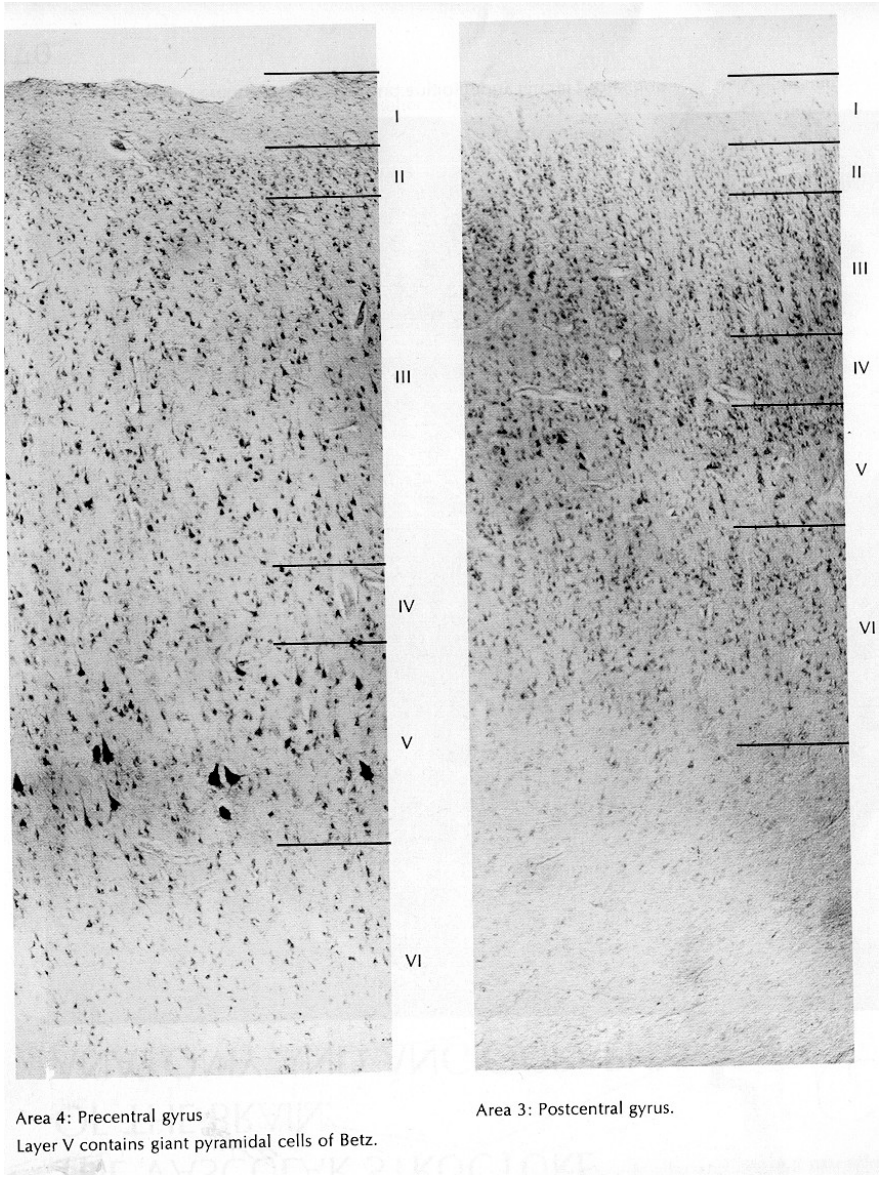
Another landmark case

Carl Wernicke
(1848-1904)



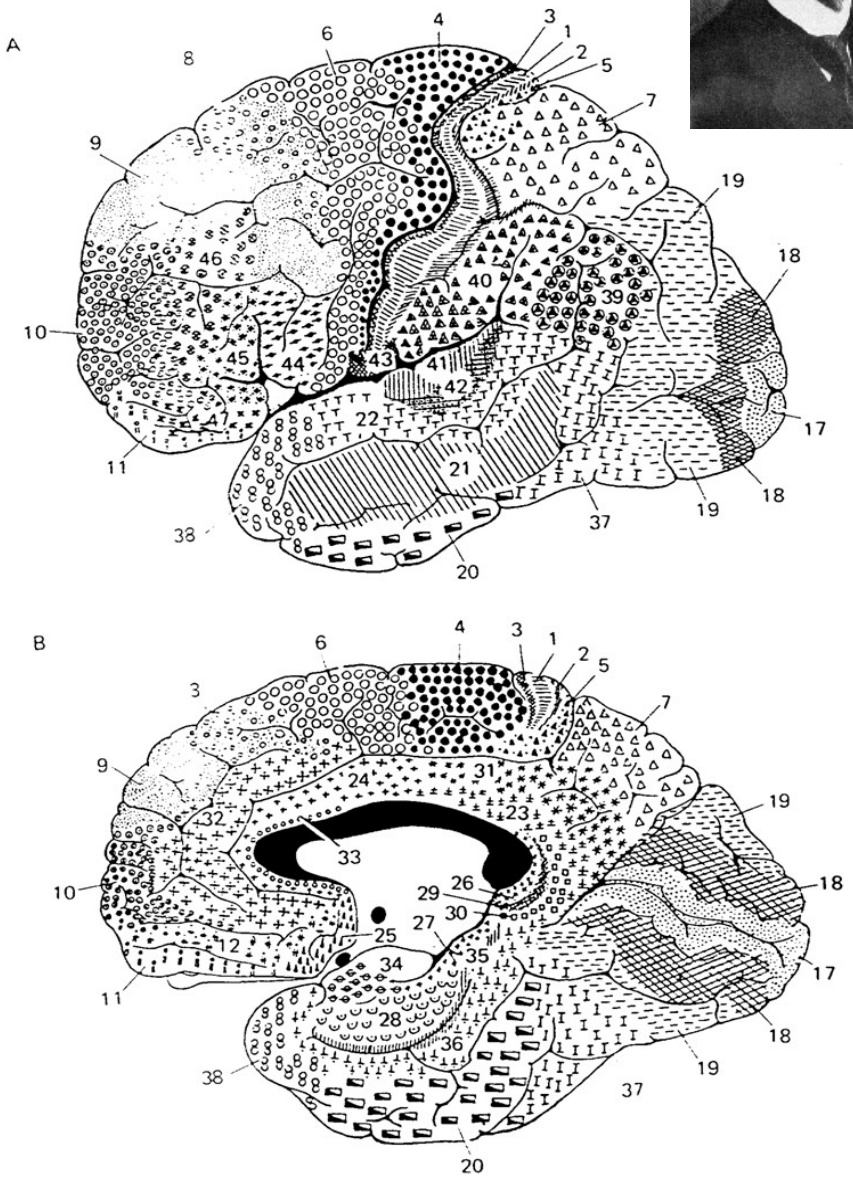
Cytoarchitectonic Areas (Brodmann, early 1900s)





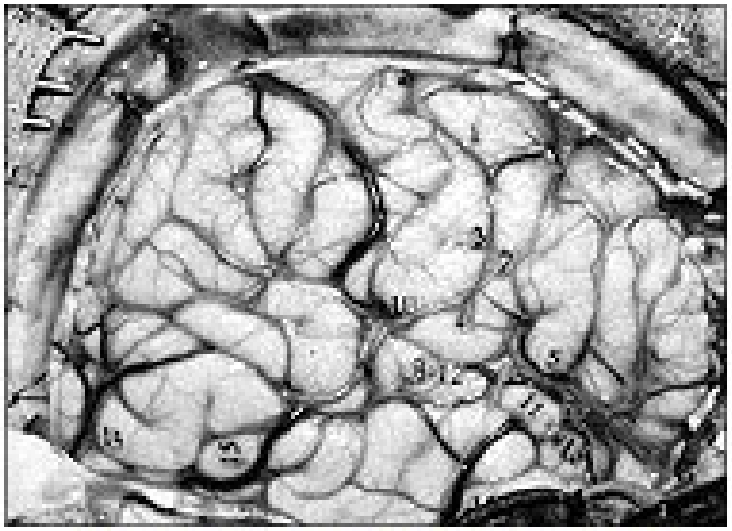
Area 4: Precentral gyrus
Layer V contains giant pyramidal cells of Betz.

Area 3: Postcentral gyrus.

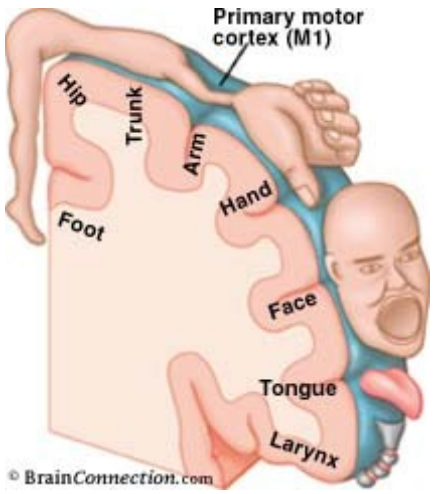


Electrocortical Stimulation Mapping

DR. WILDER PENFIELD

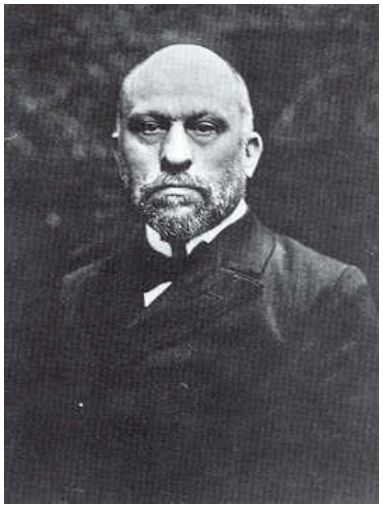


BRAIN MARKED WITH STIMULATION POINTS



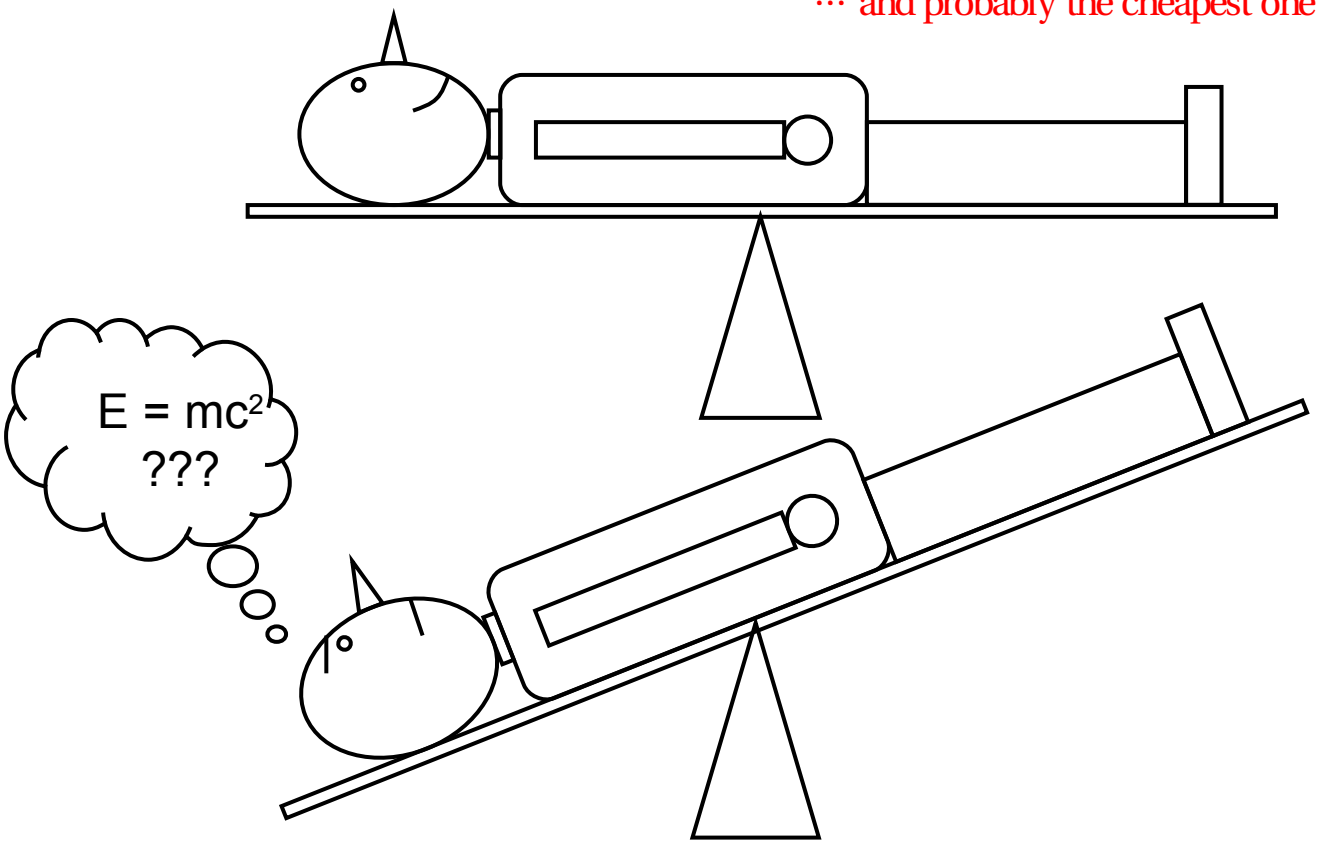
the motor homunculus

The First "Brain Imaging" Experiment



Angelo Mosso
Italian physiologist
(1846-1910)

… and probably the cheapest one too!

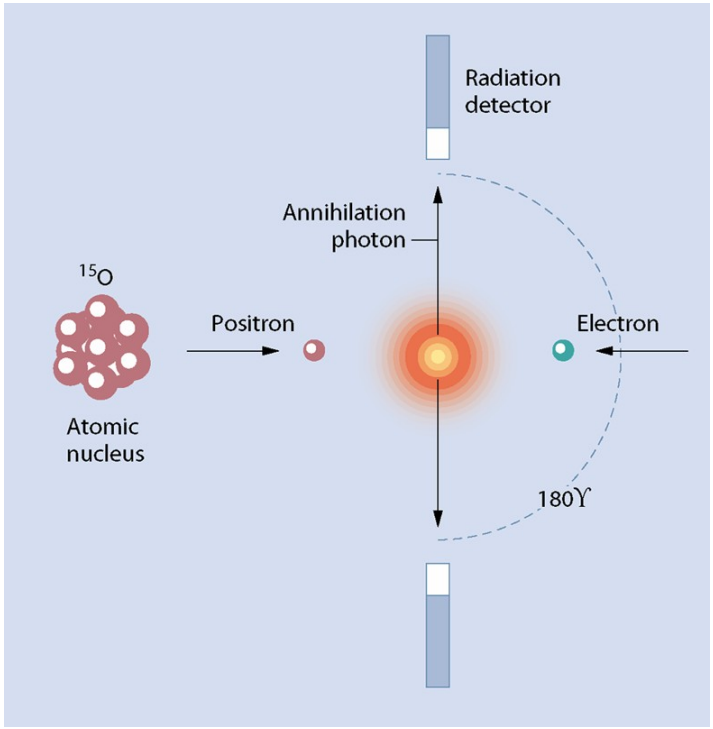


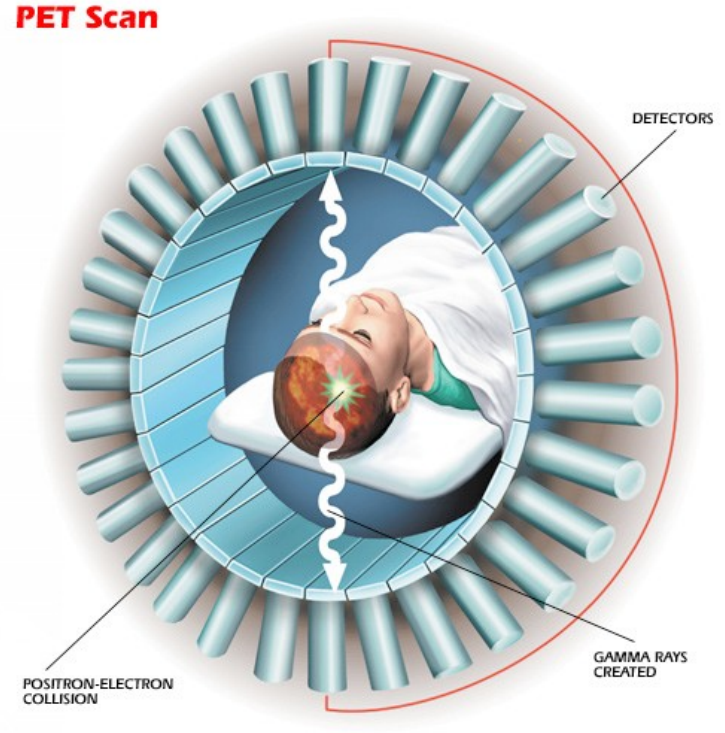
"[In Mosso's experiments] the subject to be observed lay on a delicately balanced table which could tip downward either at the head or at the foot if the weight of either end were increased. The moment emotional or intellectual activity began in the subject, down went the balance at the head-end, in consequence of the redistribution of blood in his system."

-- William James, *Principles of Psychology* (1890)

Source: Jody Culham's fMRI for Dummies web site

Positron Emission Tomography (PET)

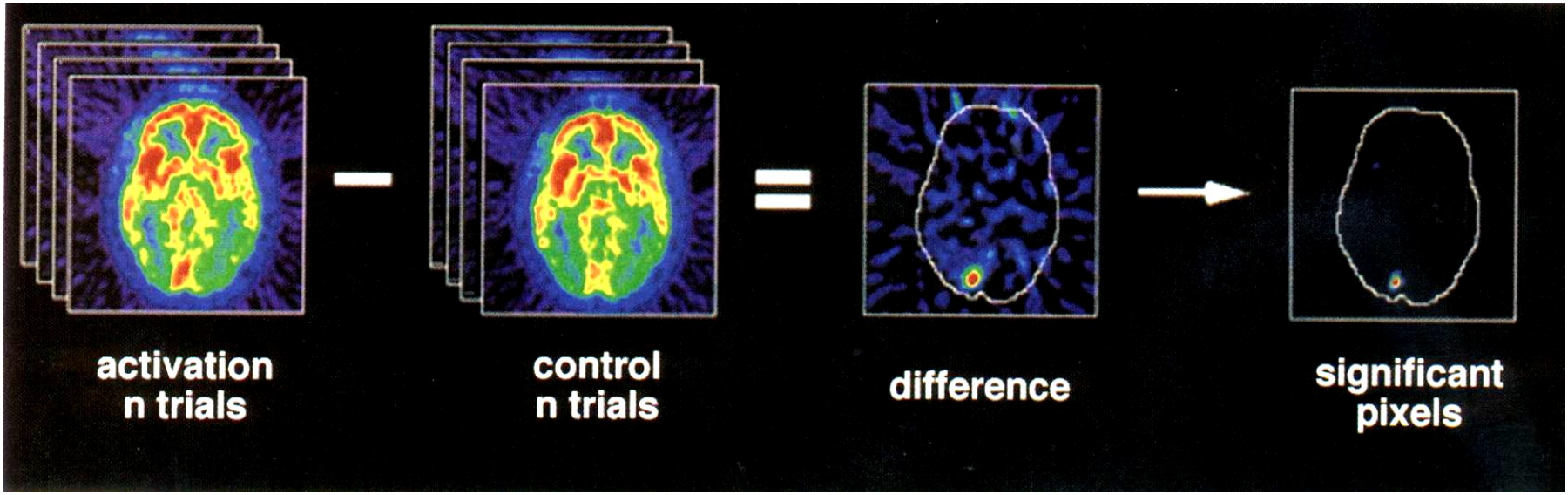




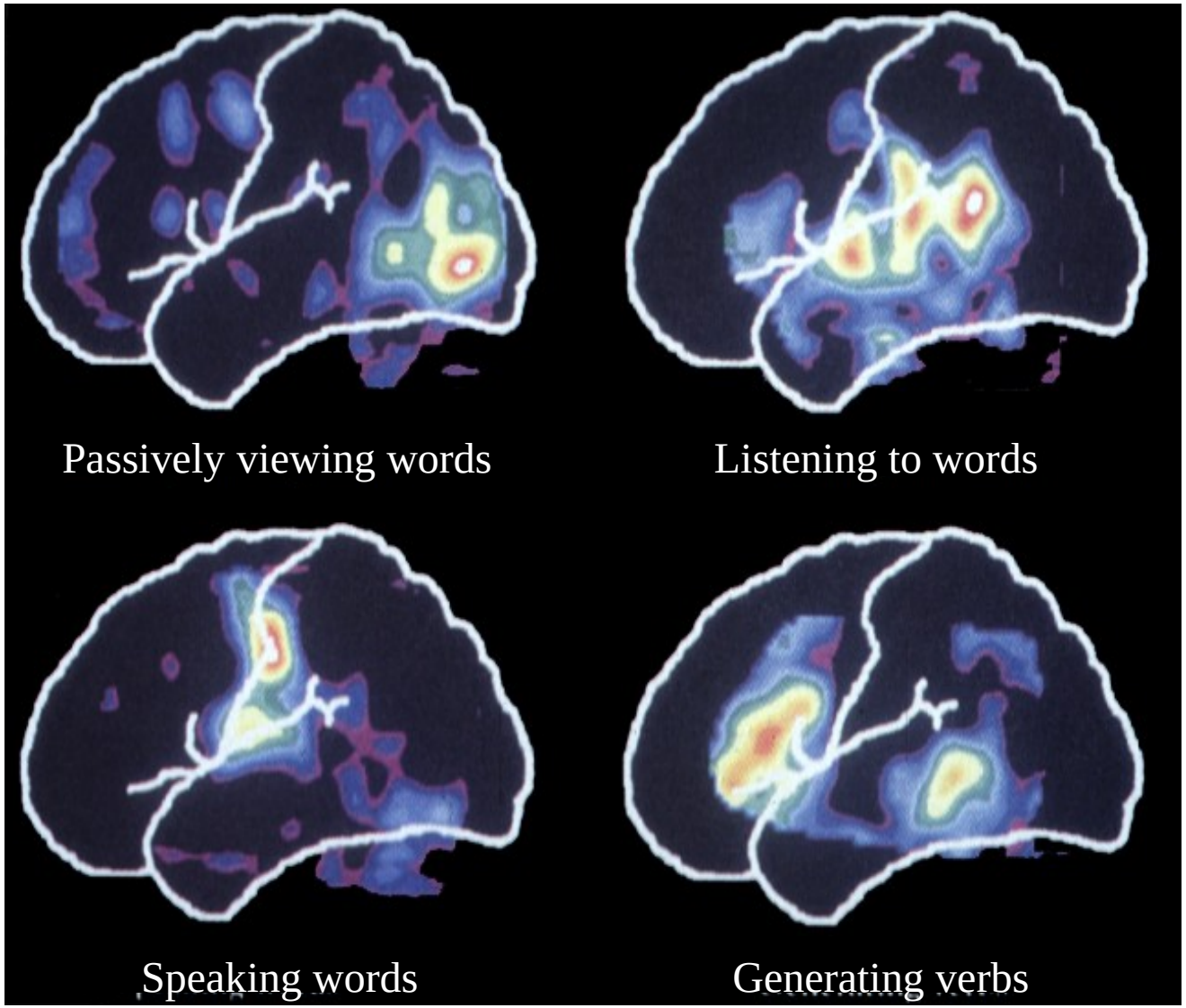
- Subjects injected with radioactive isotope, which emits positrons
- Positrons collide with electrons, emitting two photons (gamma rays) in opposite directions
- Detectors surrounding brain register simultaneous photons and compute likely source
- Neural activity ==> increased metabolic demand ==> local increase in blood flow the active region

PET

- Compares regional cerebral blood flow (rCBF) between cognitive states (experimental conditions)
- Integrates signal over 45-60 sec
- Need to wait a number of half-lives before next injection

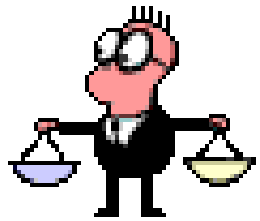


The first cognitive PET study



Petersen et al. (1988). Positron emission tomographic studies of the cortical anatomy of single-word processing. *Nature.*

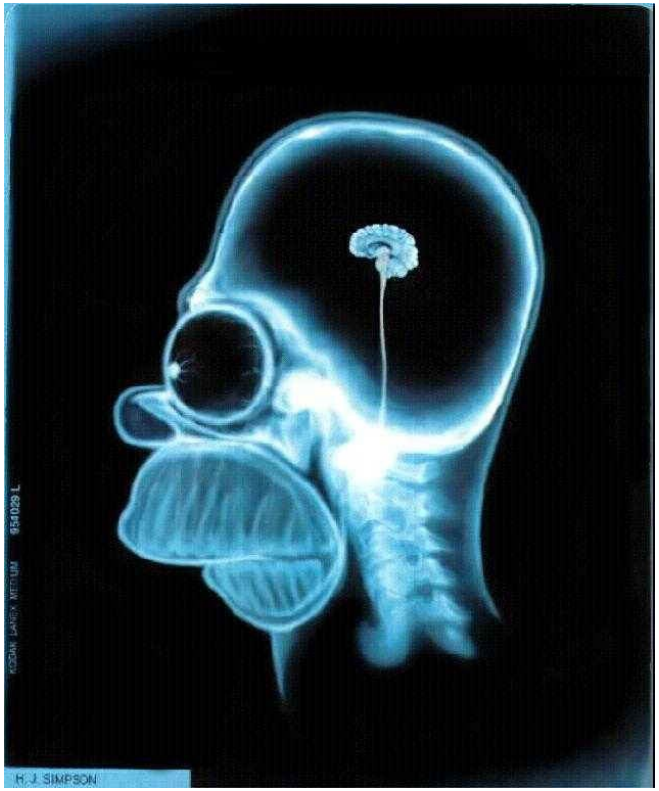
PET: Pros and Cons



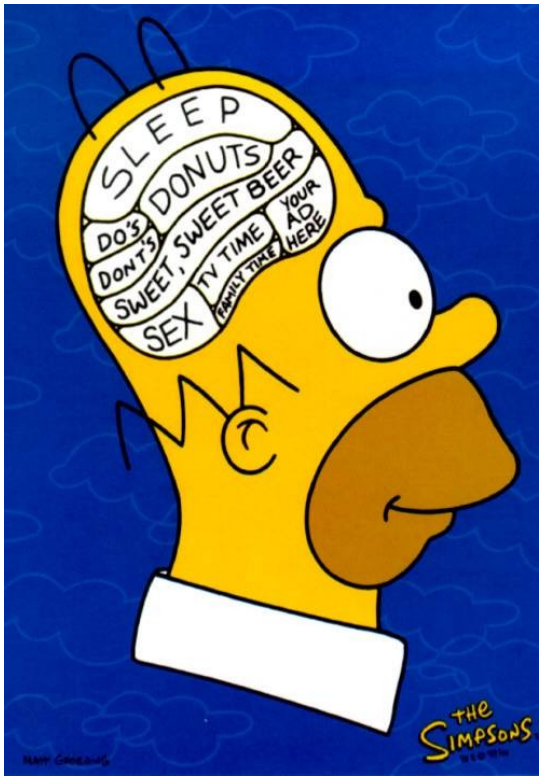
- **PROs**
  - **Decent spatial resolution (5-10mm^3)**
  - **Can also measure neurotransmitter metabolism.**
  - **Can be used as a tool to aid in early diagnosis of disorders such as Alzheimer's disease**
- **CONs**
  - **Invasive (radioactive injection)**
  - **Very expensive**
  - **Poor temporal resolution**
  - **Cannot detect the neural response to discrete cognitive events.**

MRI vs. fMRI

MRI studies brain <u>anatomy</u>.



<u>Functional</u> MRI (fMRI) studies brain <u>function</u>.



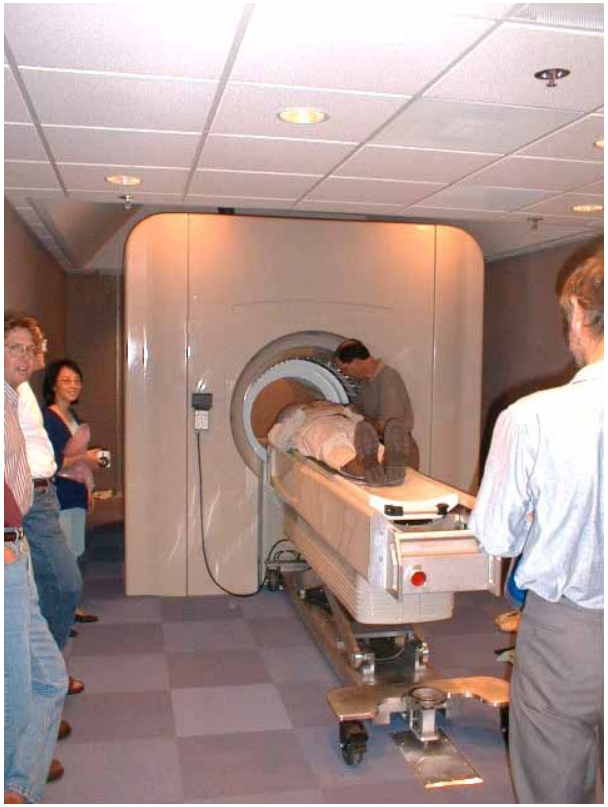
Source: Jody Culham's fMRI for Dummies web site

Berkeley's 4 Tesla Magnet

1 Tesla (T) = 10,000 Gauss

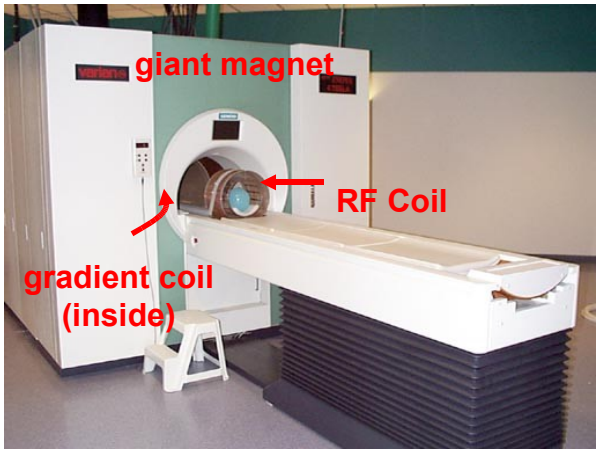
Earth's magnetic field = 0.5 Gauss

4 Tesla = 4 x 10,000 ÷ 0.5 = 80,000 X Earth's magnetic field



Magnets attract metal objects

Necessary Equipment



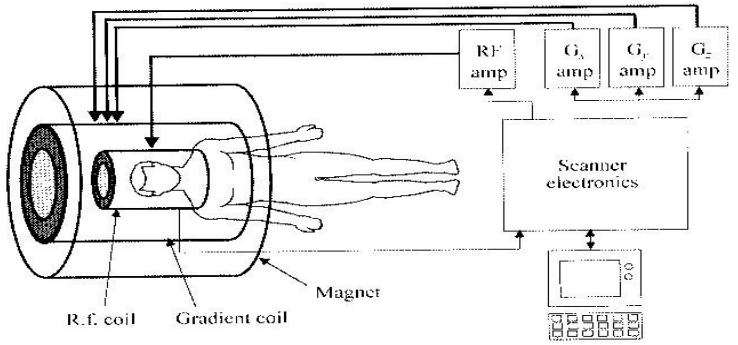
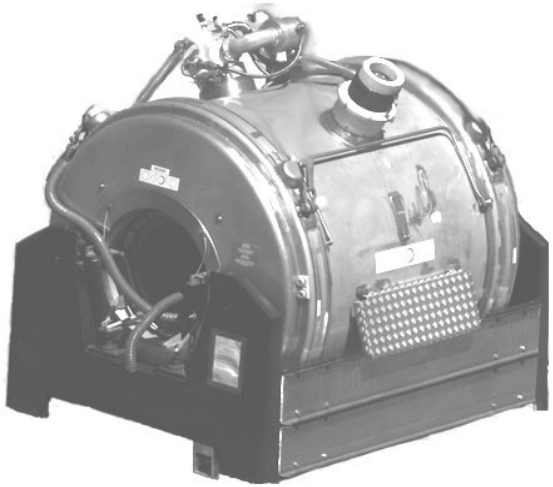


Fig. 3.13 Block diagram of an MRI scanner. The scanner electronics produce signals that are amplified before being sent to the gradient or RF coils. The detected signal is then digitized for processing by the computer.

Magnet

- very strong magnetic field

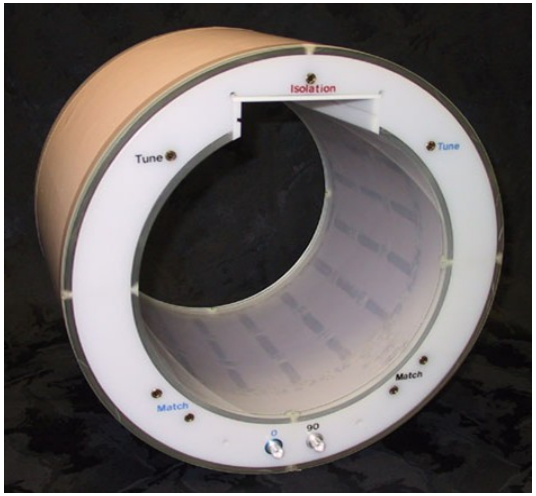


Gradient Coil

- enables spatial encoding

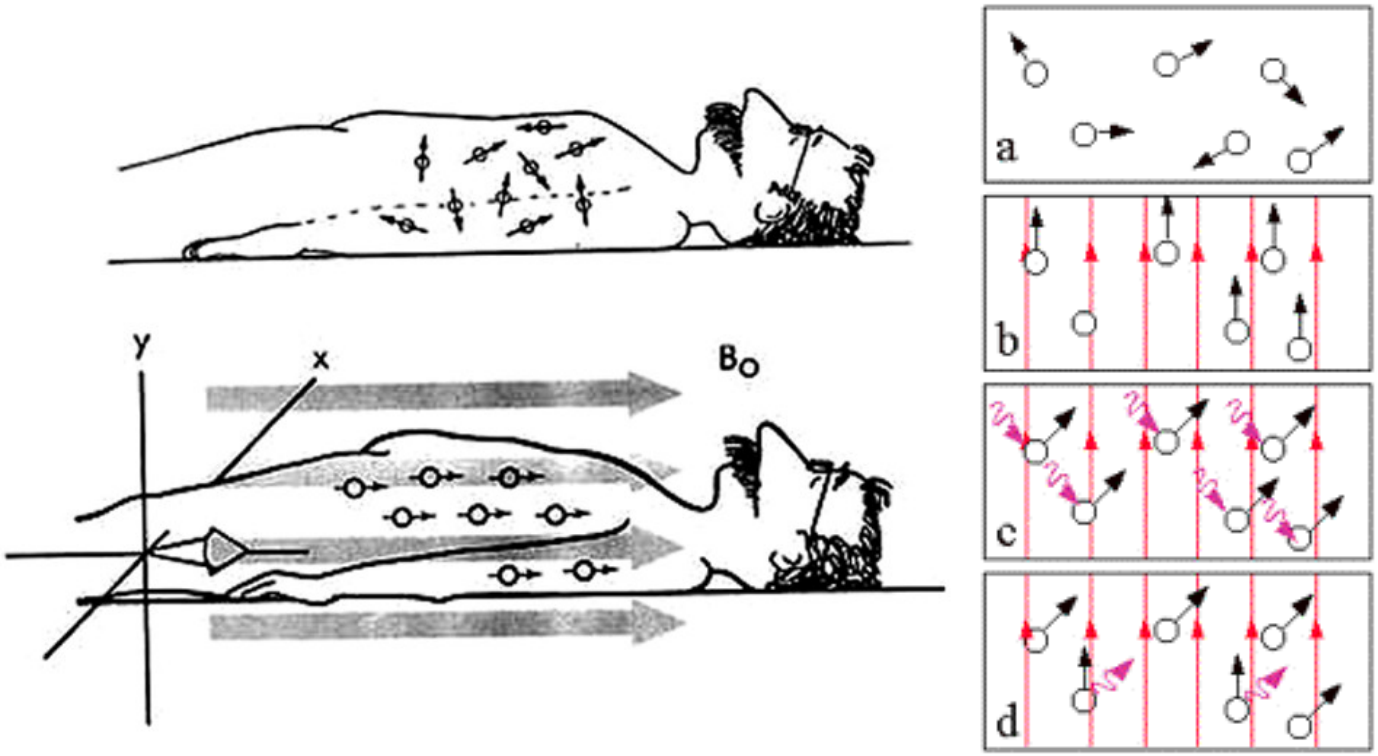
Radio Frequency Coil

- receives and transmits radio frequencies

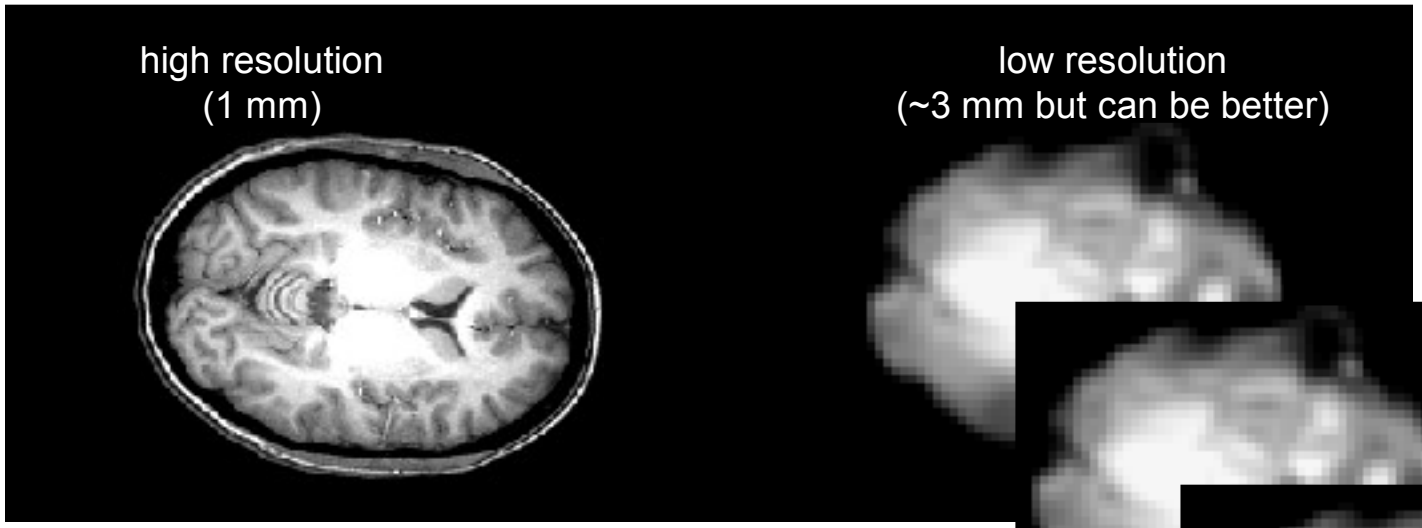


Source for Photos: Joe Gati

Very Basic MRI Physics



MRI vs. fMRI



one image

many images
(e.g., every 2 sec for 20-60 mins)

...

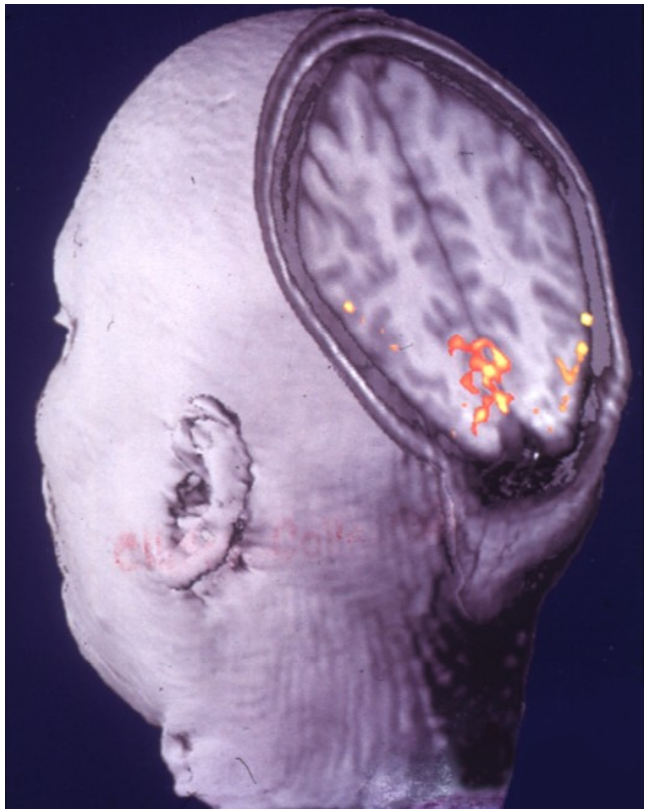
fMRI

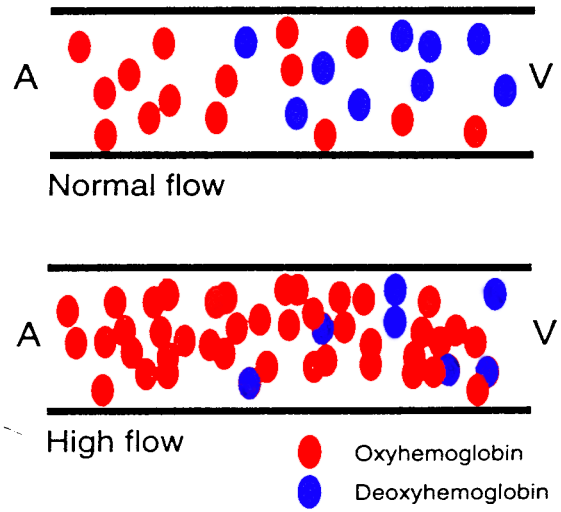
Blood Oxygenation Level Dependent (BOLD) signal

indirect measure of neural activity

↑ neural activity ➔ ↑ blood oxygen ➔ ↑ fMRI signal

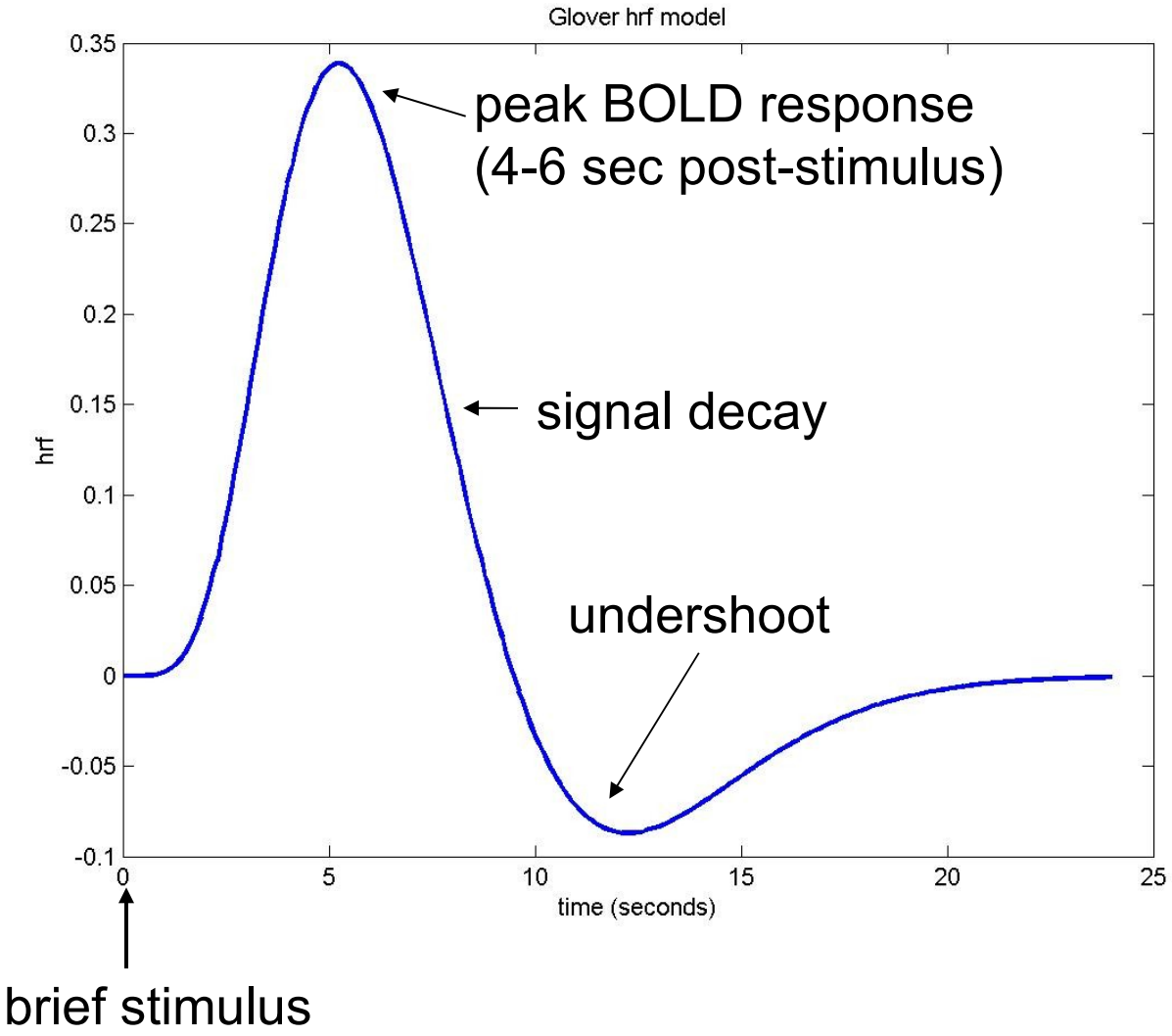
Source: Jody Culham's fMRI for Dummies web site



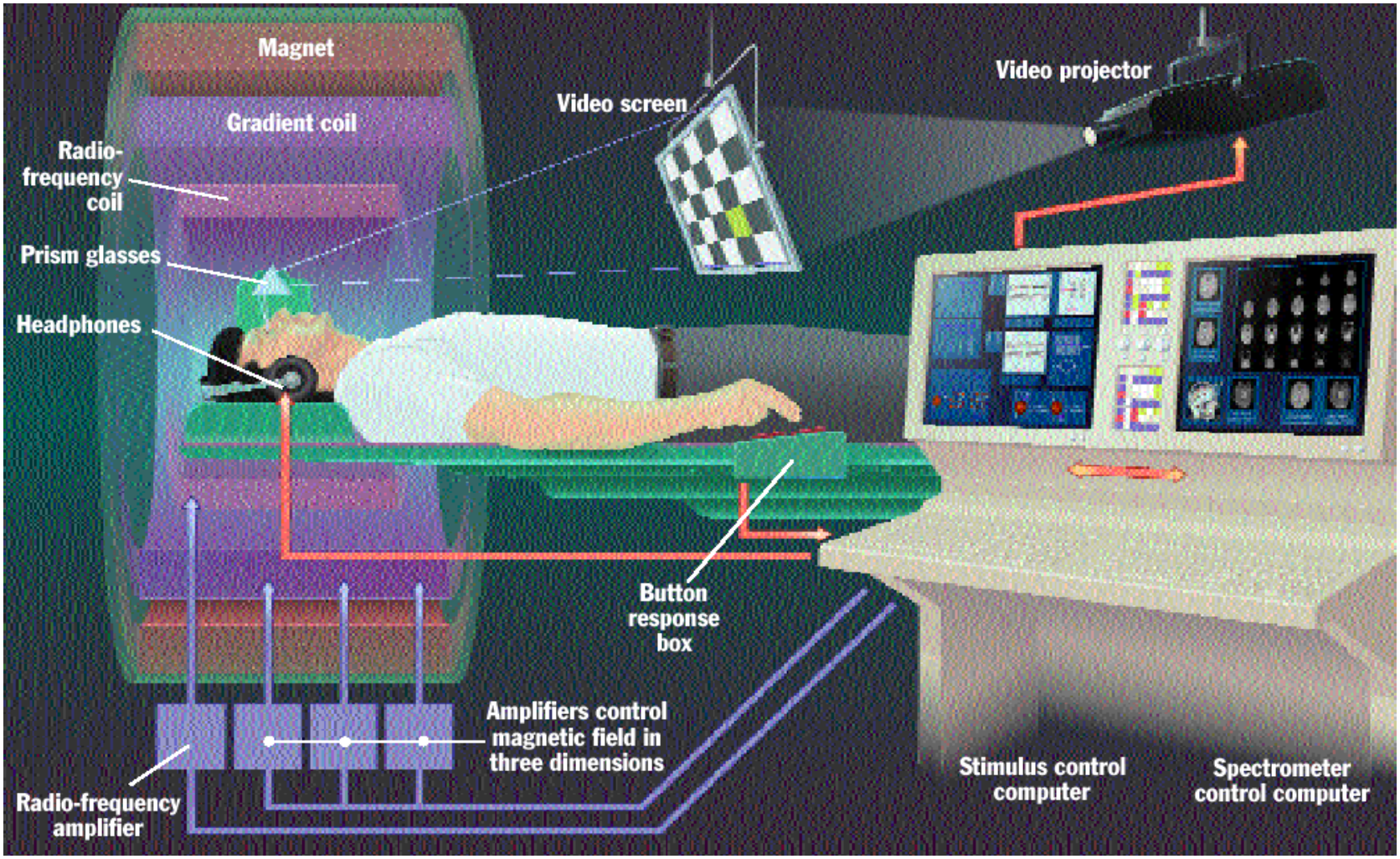


As the ratio of oxygenated to deoxygenated hemoglobin increased, BOLD fMRI signal increases

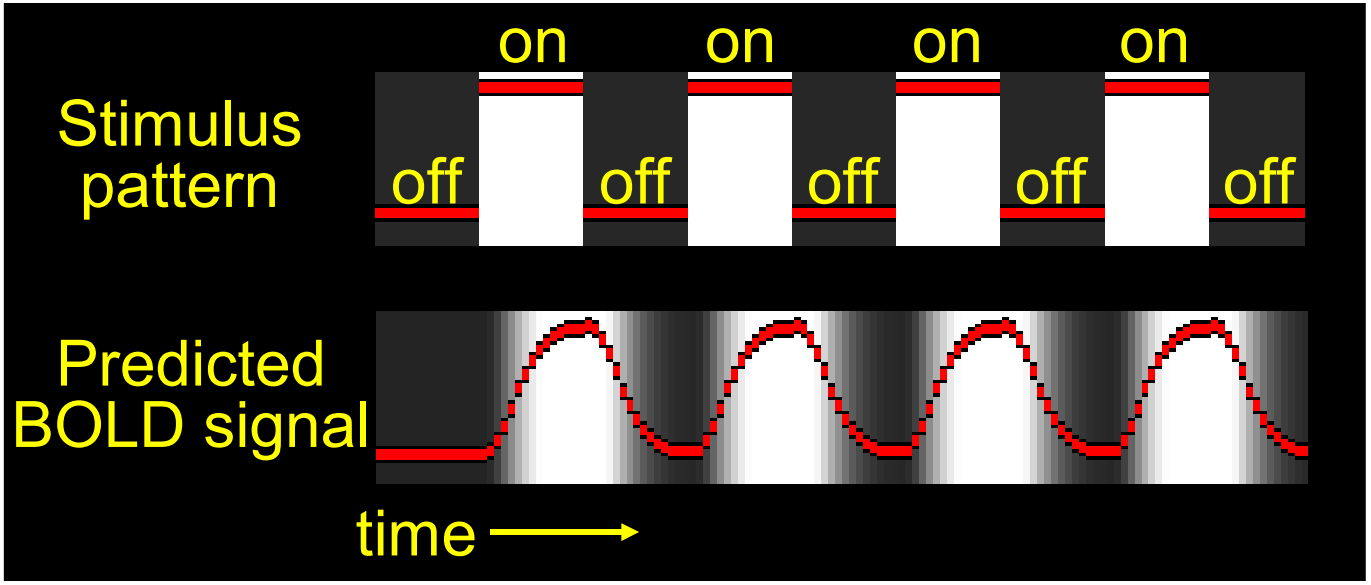
Hemodynamic Response Function (HRF)



fMRI Setup

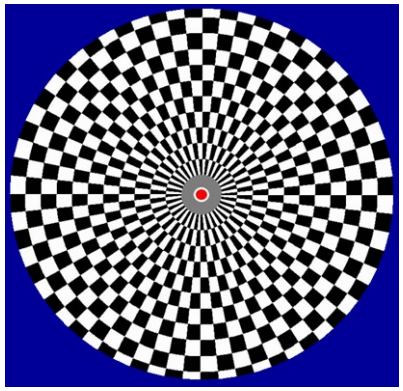

Magnet
Gradient coil
Radio-frequency coil
Prism glasses
Headphones
Video screen
Video projector
Button response box
Amplifiers control magnetic field in three dimensions
Radio-frequency amplifier
Stimulus control computer
Spectrometer control computer

A basic fMRI experimental design



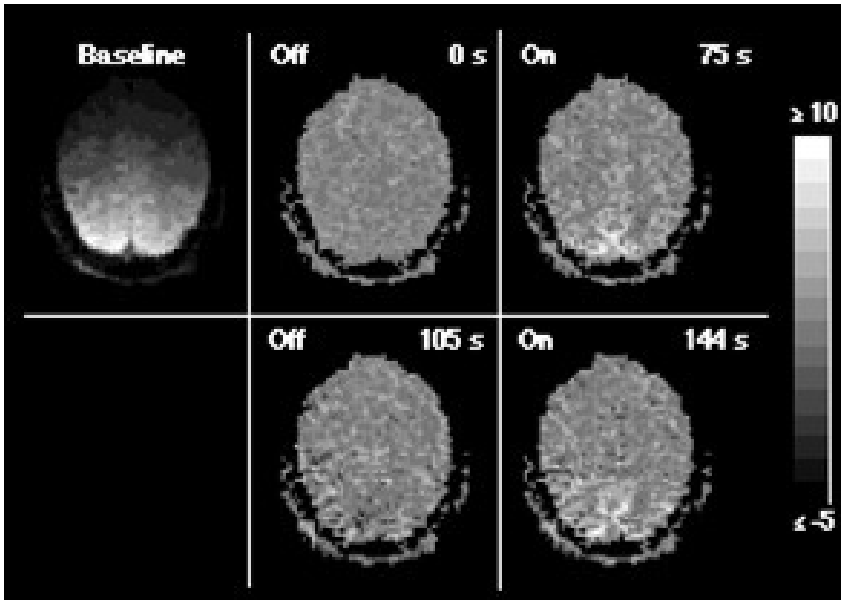
- Subject is given sensory stimulation or task, interleaved with control or rest condition
- Acquire BOLD-sensitive MRI images during stimulation
- Analyze image timeseries to determine where signal changed in response to stimulation

The first fMRI Experiment

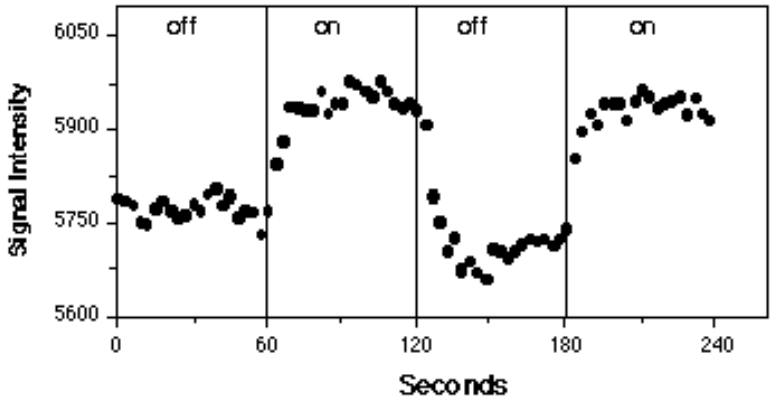


Flickering Checkerboard

OFF (60 s) - ON (60 s) -OFF (60 s) - ON (60 s) - OFF (60 s)



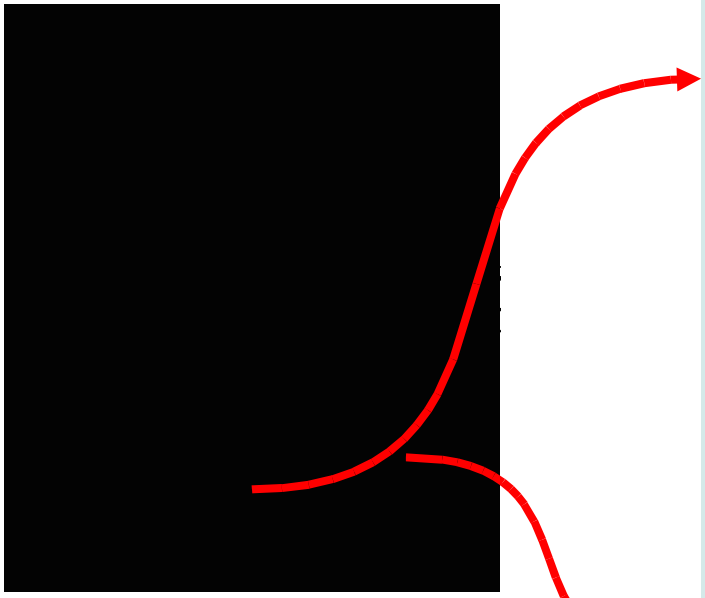
Brain Activity

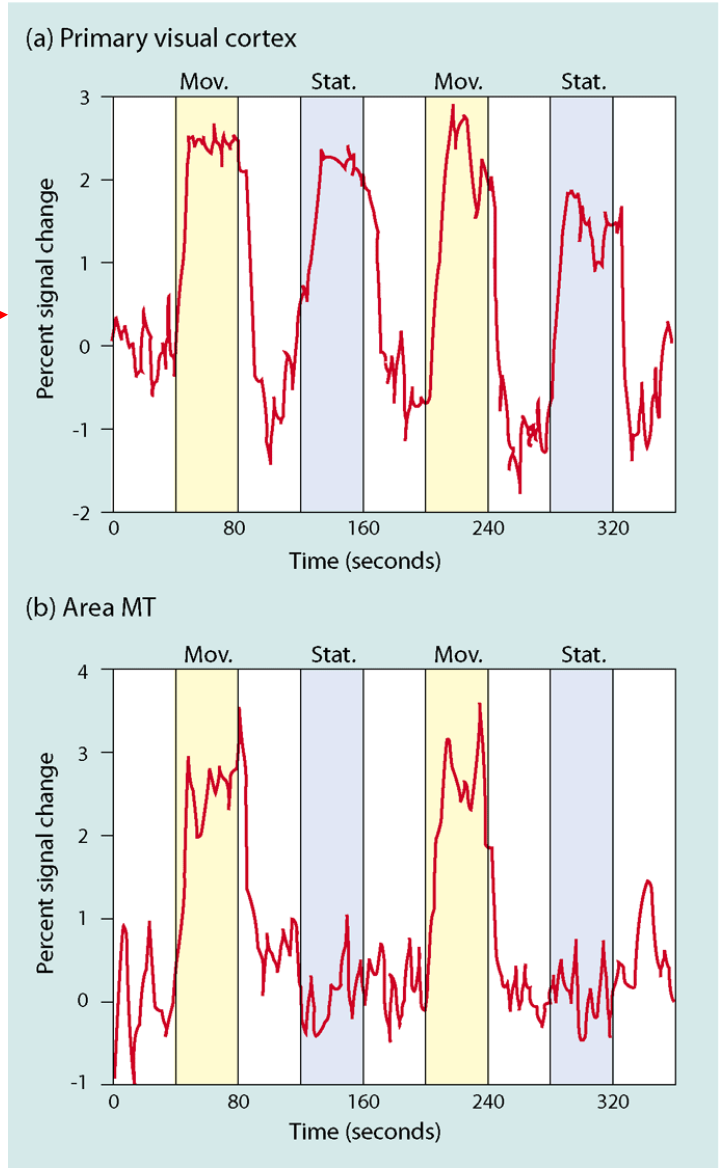


Time ⇨

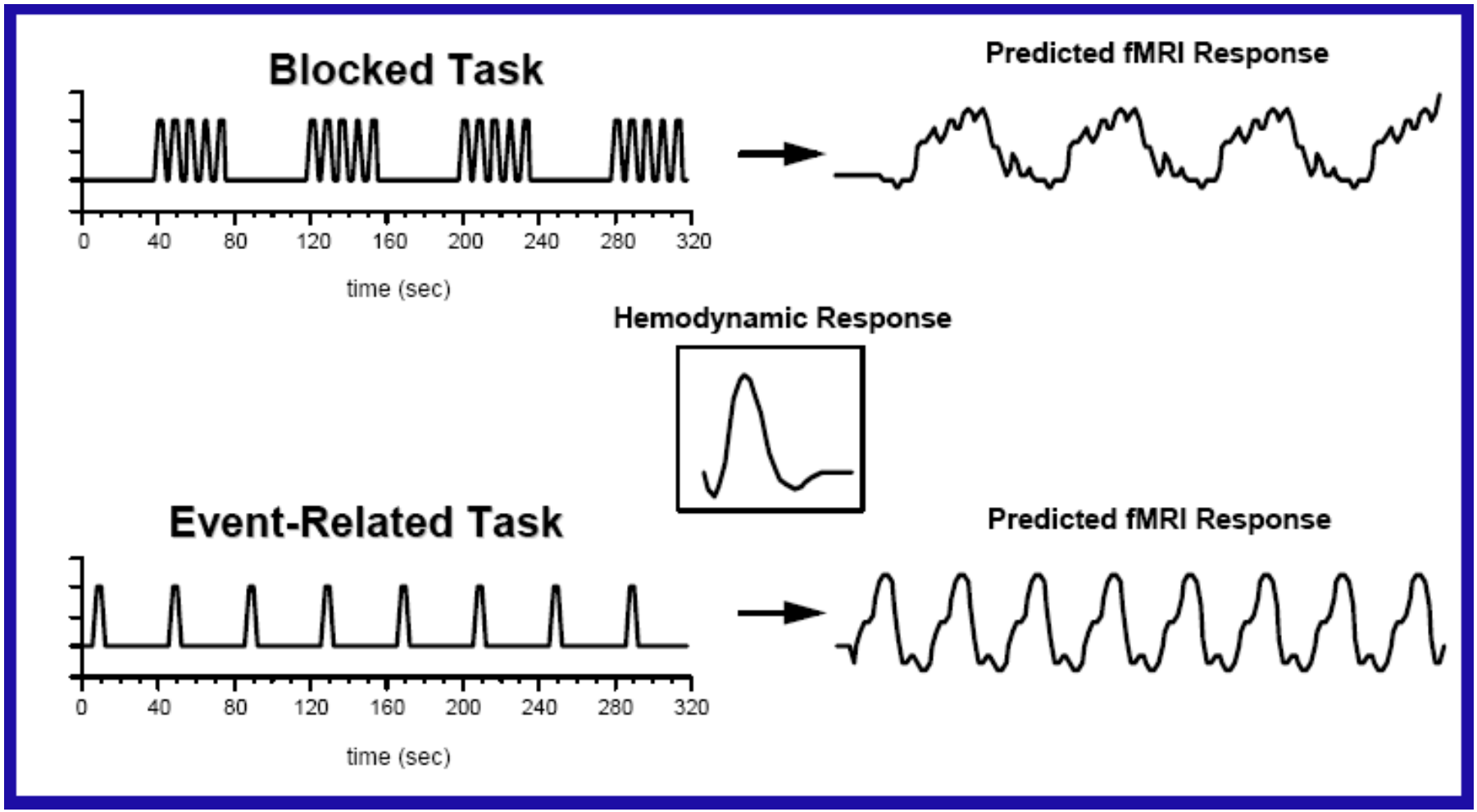
Source: Kwong et al., 1992

BOLD signal change during presentation of static and moving visual stimuli



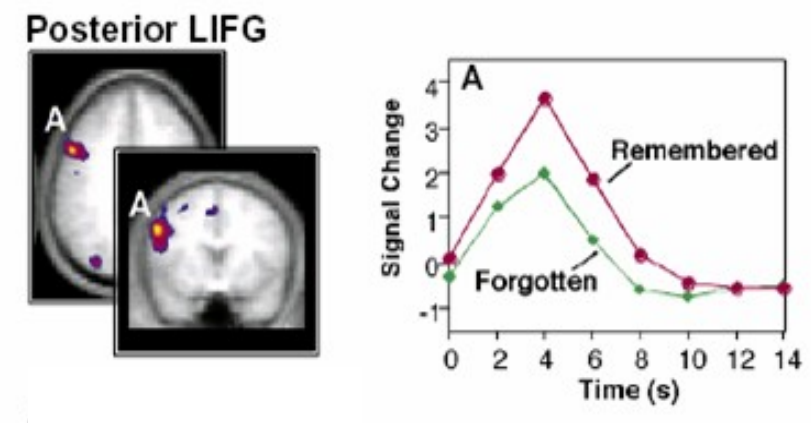


Blocked vs. Event-Related Designs

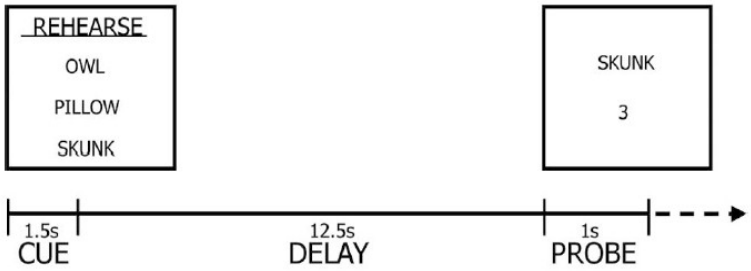


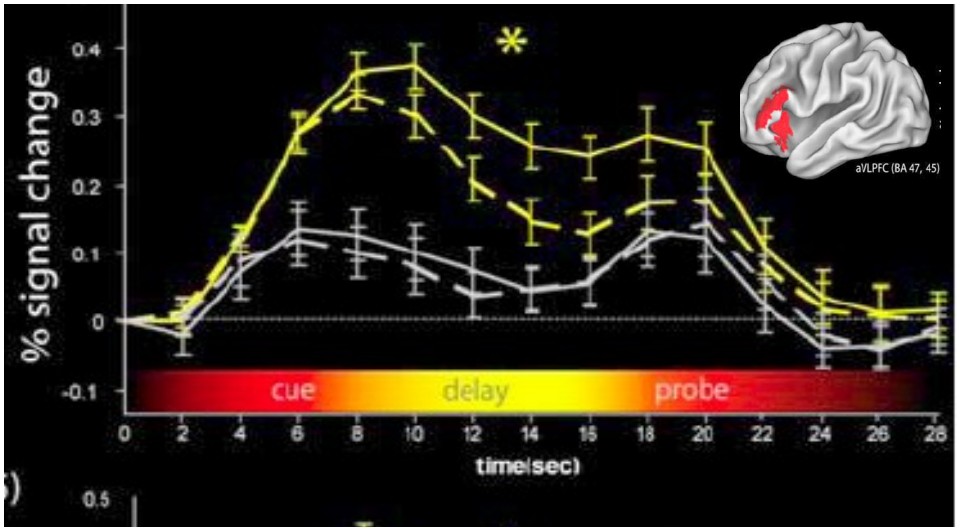
Advantages of event-related designs

Characterize individual trials after-the-fact, based on the subject's behavioral response



Wagner et al., 1998, Science

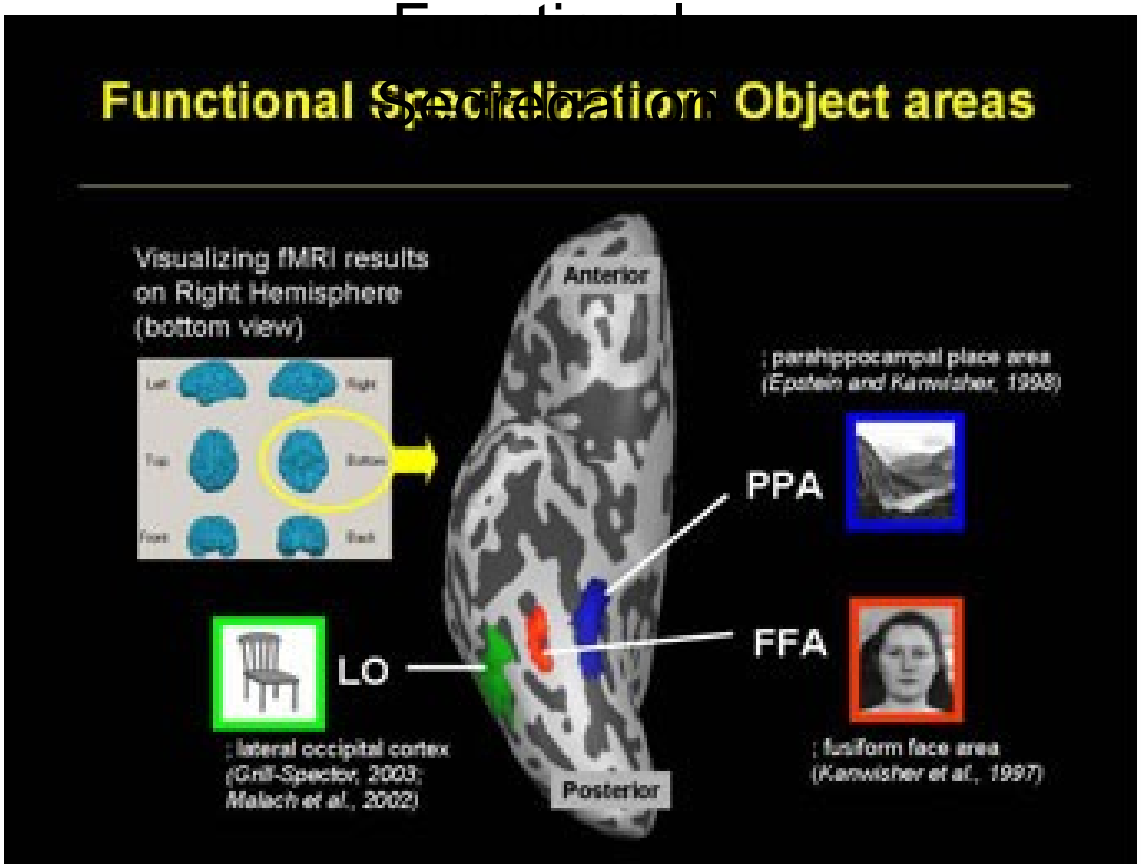




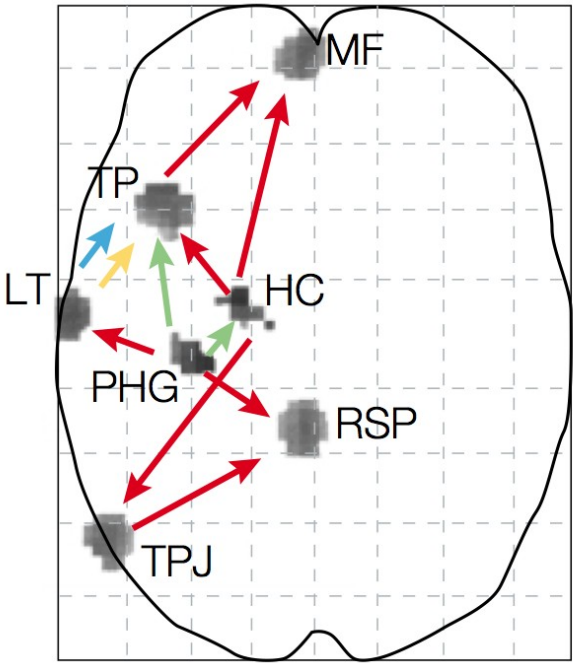
Correct trials vs. Incorrect trials

Blumenfeld et al., 2006 J Neuroscience

Modularity vs. Networks



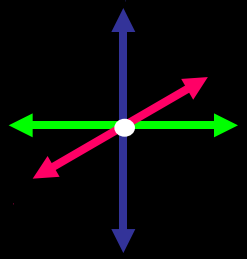
Functional Integration

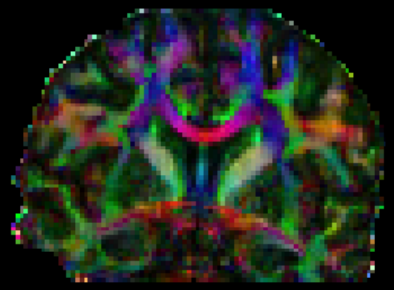


Localization of category-specific visual processing regions

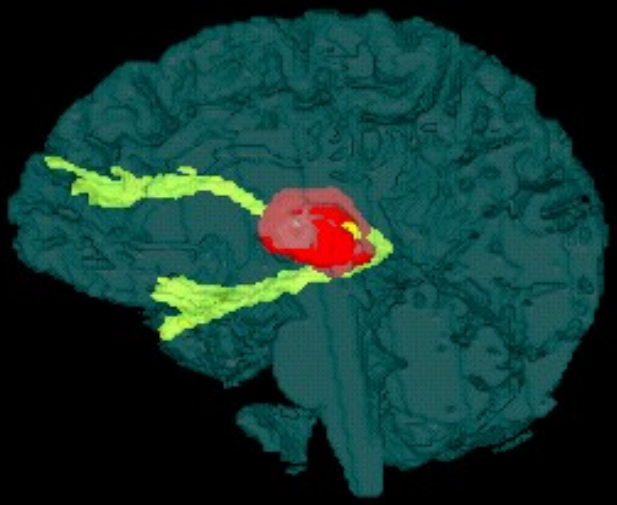
Statistical modeling of functional interactions between brain regions

Diffusion Tensor Imaging (DTI)

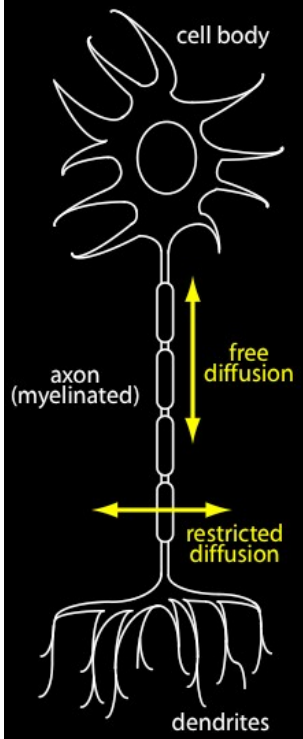


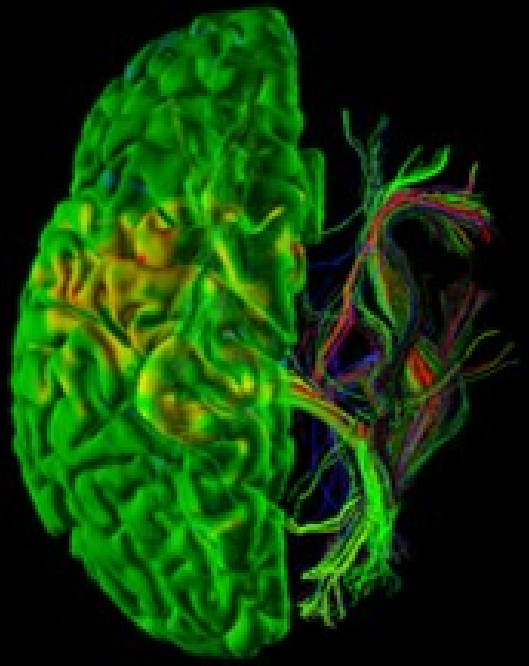


Color-coded directions



Tract-based connectivity





- Water diffusion restricted along white matter pathways
- Tractography: tracing white matter pathways between gray matter regions

Can fMRI read your mind?

NO LIE MRI

Home | Product | Customers | Investors | Test Centers | Publications | About Us

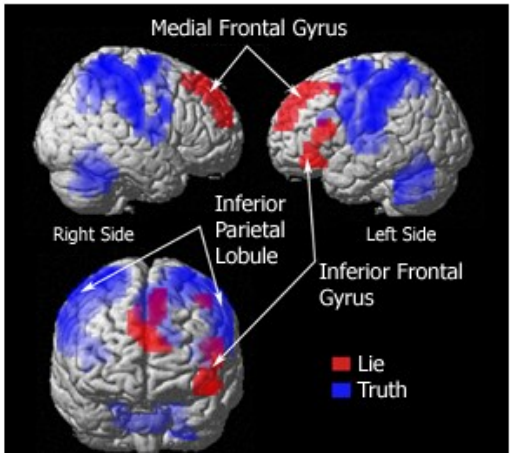
New Truth Verification Technology

No Lie MRI, Inc. provides unbiased methods for the detection of deception and other information stored in the brain.

The technology used by No Lie MRI represents the first and only direct measure of truth verification and lie detection in human history!

No Lie MRI uses techniques that:

- **Bypass conscious cognitive processing**
- **Measure the activity of the central nervous system (brain and spinal cord) rather than the peripheral nervous system (as polygraph testing does).**



To help identify the information of most interest to you, please let us know who you are.

- Individual Customers
- Lawyers / Law Firms
- Corporate Customers
- Government Customers
- Prospective Test Centers
- Prospective Investors

The Era of Neuromarketing Has Begun

The science of human choice

- Home
- Who We Are
- Case Studies
- Super Bowl XLI Ad Rankings
- Frequently Asked Questions
- Ethics
- Recent Coverage of FKF
- Contact Info

Super Bowl XLI Ad Rankings

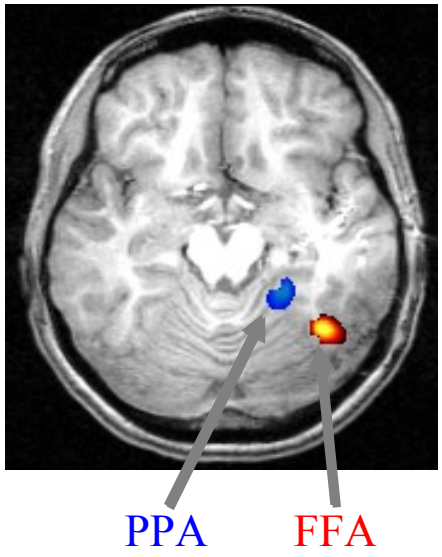
SUPER BOWL XLI
SOUTH FLORIDA
02.04.07

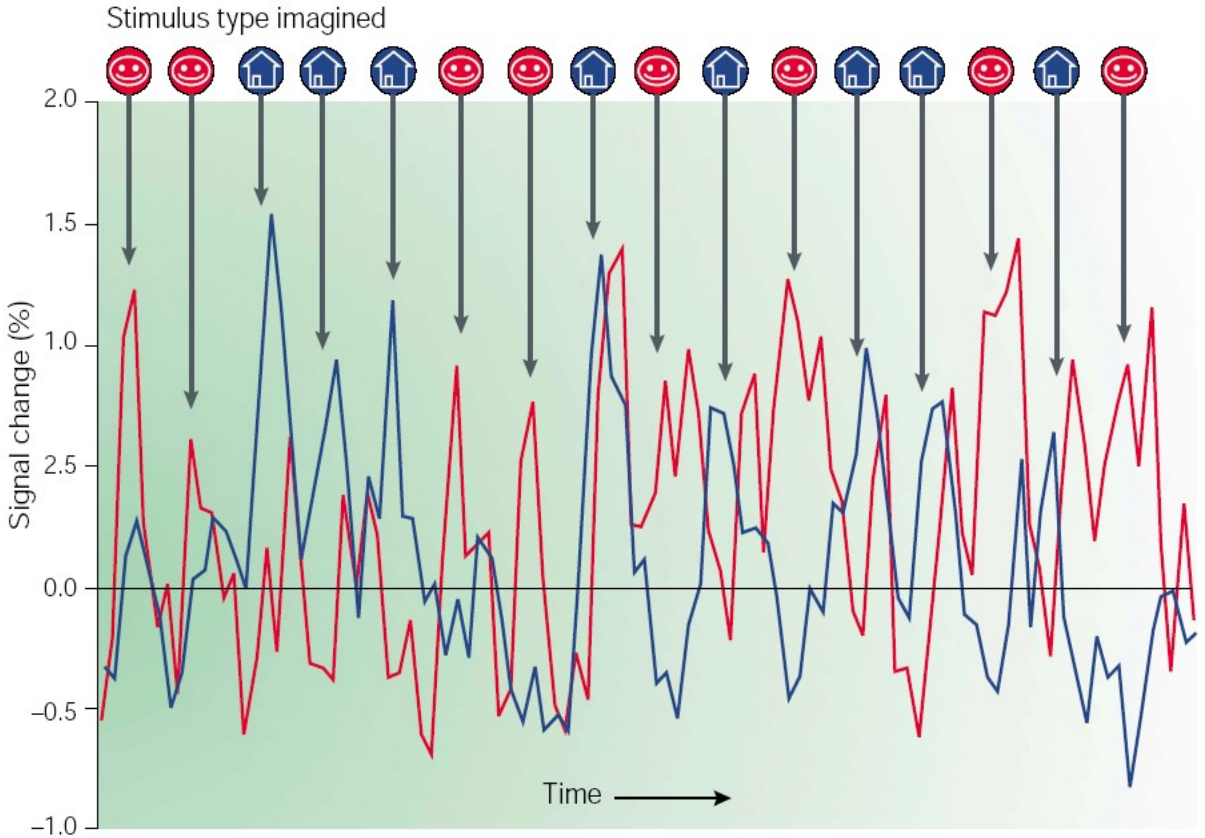
Welcome to the Second Annual FKF Applied Research Super Bowl Ad Rank.

In conjunction with the Ahmanson Lovelace Brain Mapping Center at UCLA, we measure the effect of many of the Super Bowl ads by using fMRI technology. We track the ads on a host of dimensions by looking for activity in key parts of the brain areas that are known to be involved in wanting, choosing, sexual arousal, fear, indecision and reward.

Please check back with us after the Super Bowl for our results on the most and least engaging Super Bowl XLI commercials.

A more reasonable example





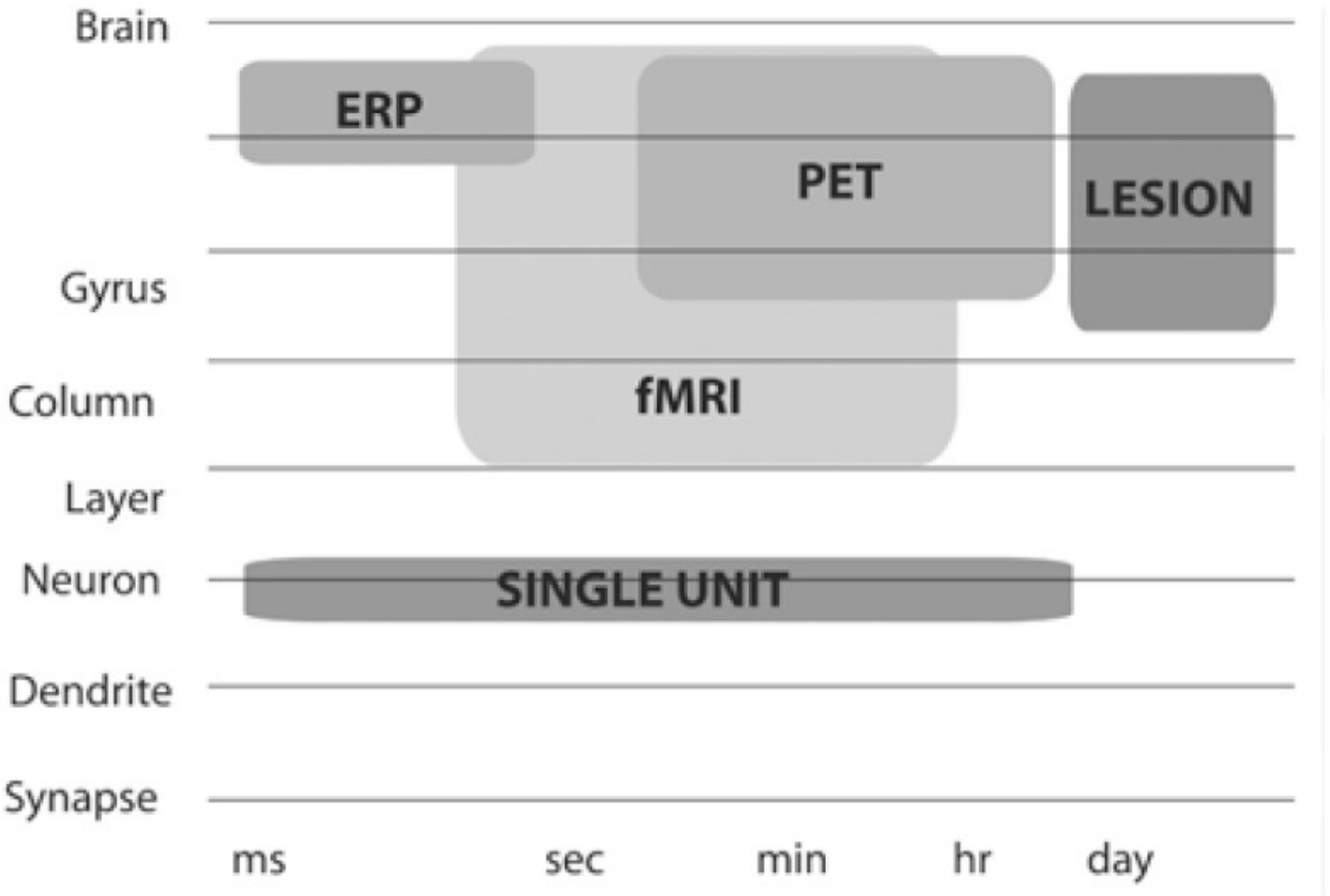
O'Craven & Kanwisher, 2001

FFA- Fusiform Face Area

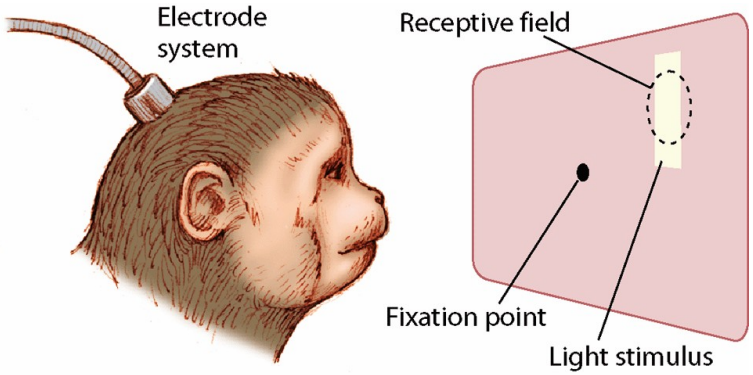
PPA- Parahippocampal Place Area

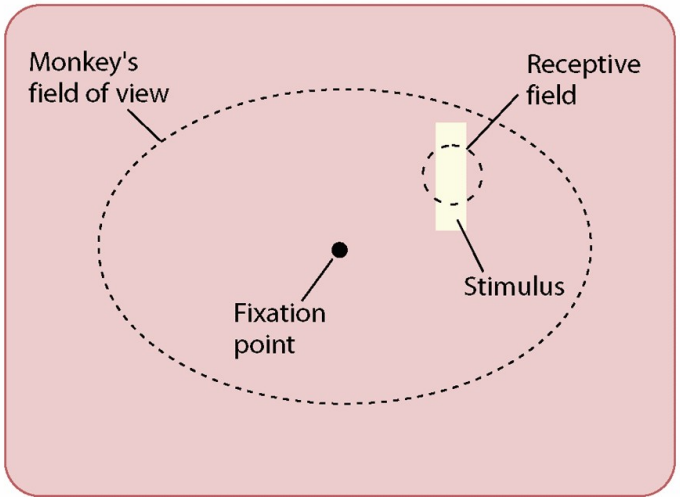
But we still have a long way to go

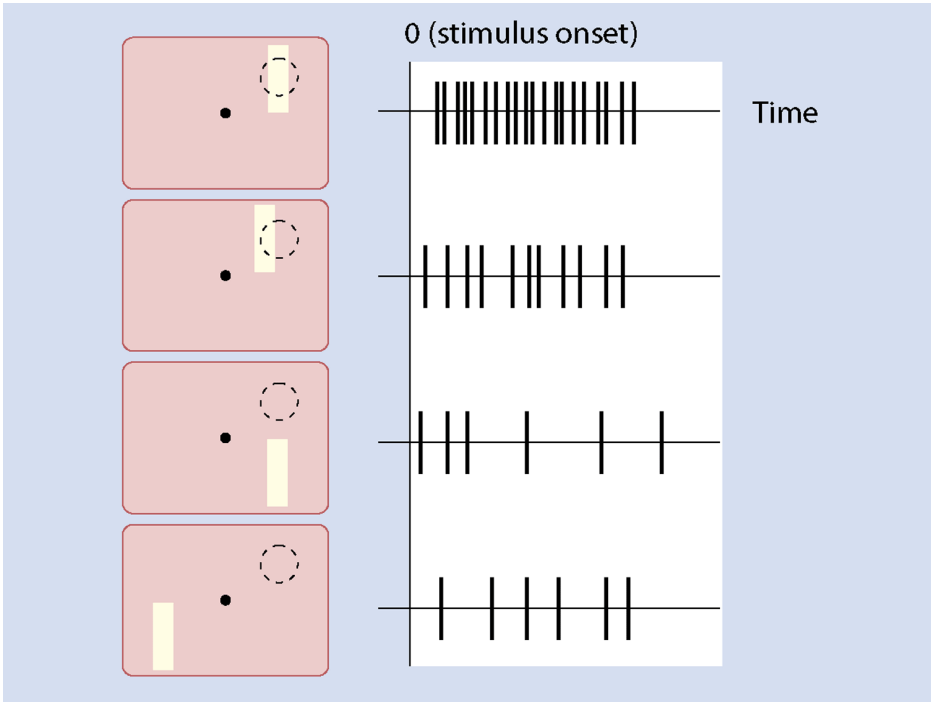
Spatial and Temporal Resolution



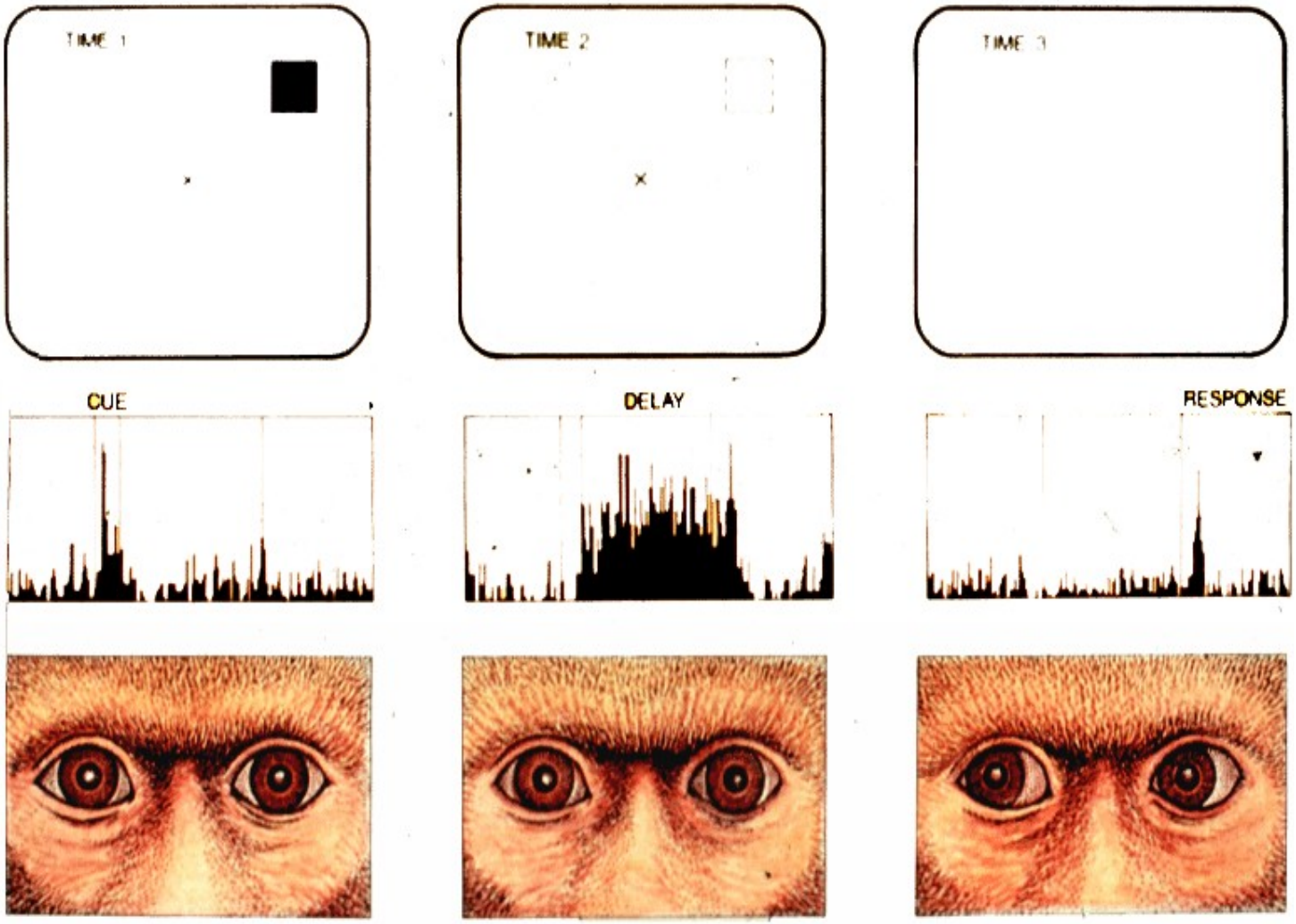
Single-unit recording: Identifying neuronal receptive fields



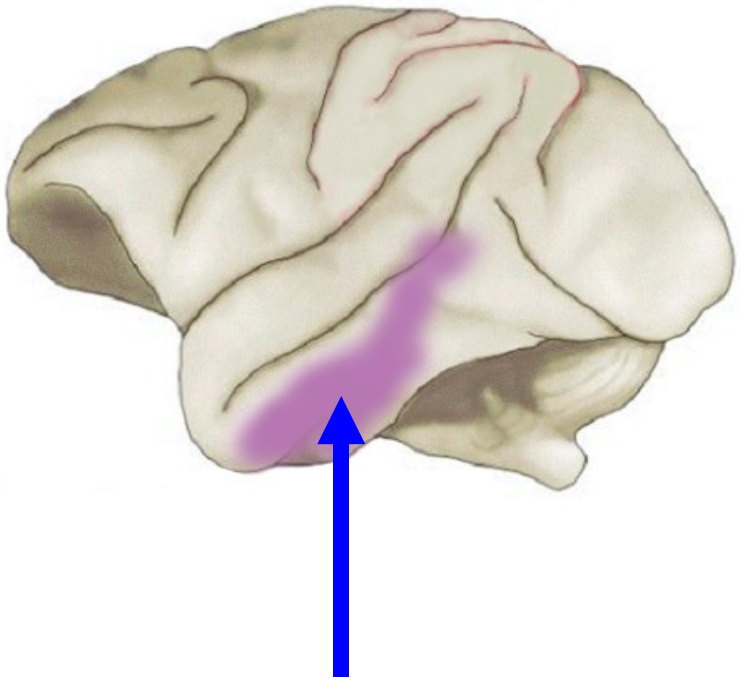




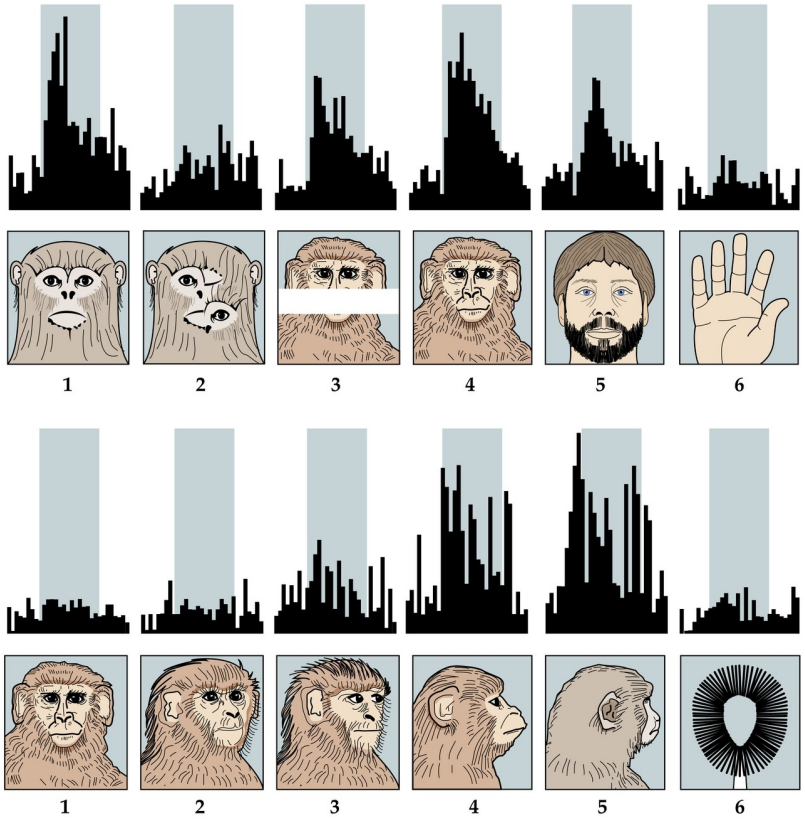
Memory Cells in the Prefrontal Cortex



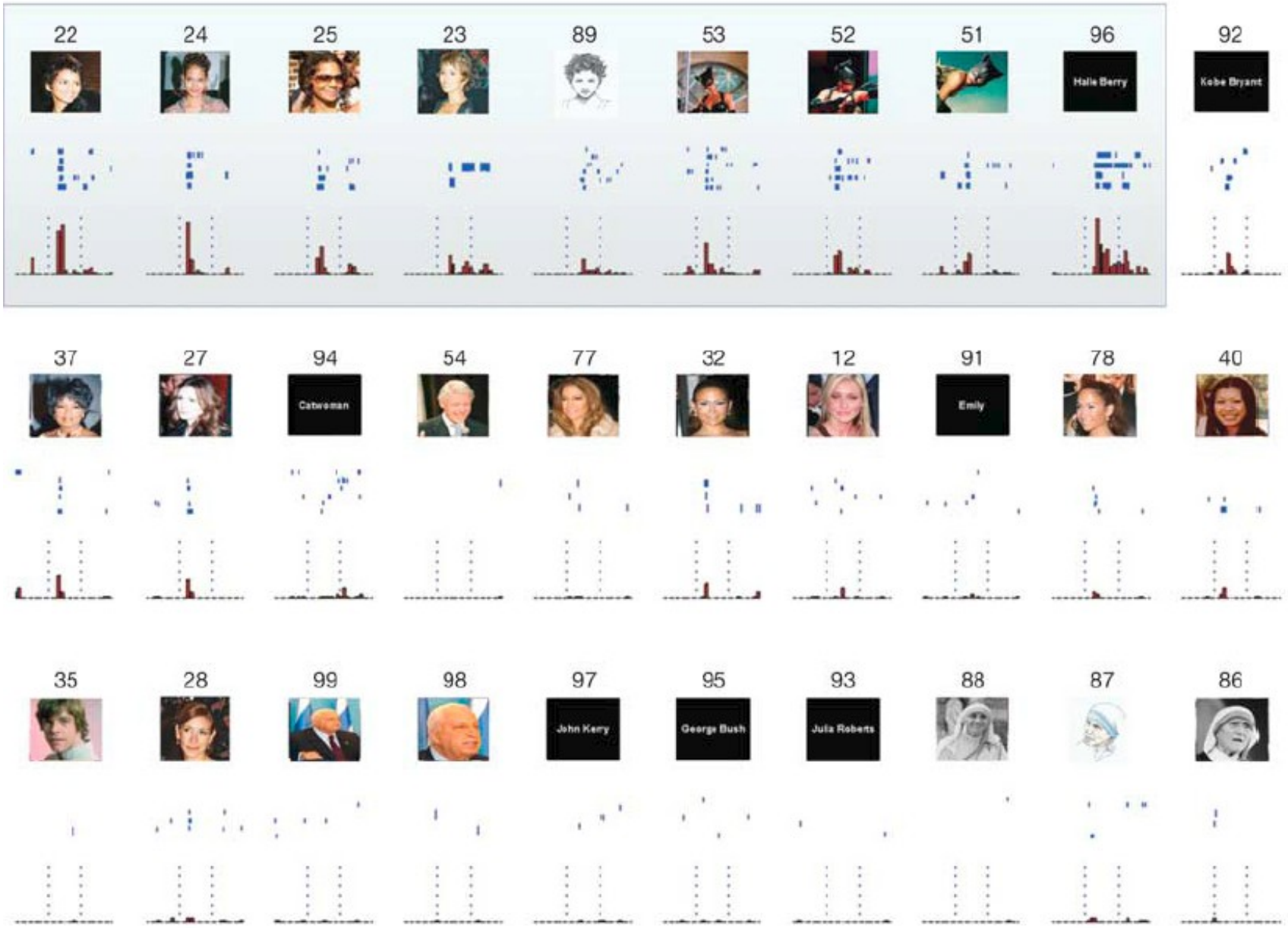
A Face Area in the Monkey Brain



An area of the monkey's brain that responds to faces

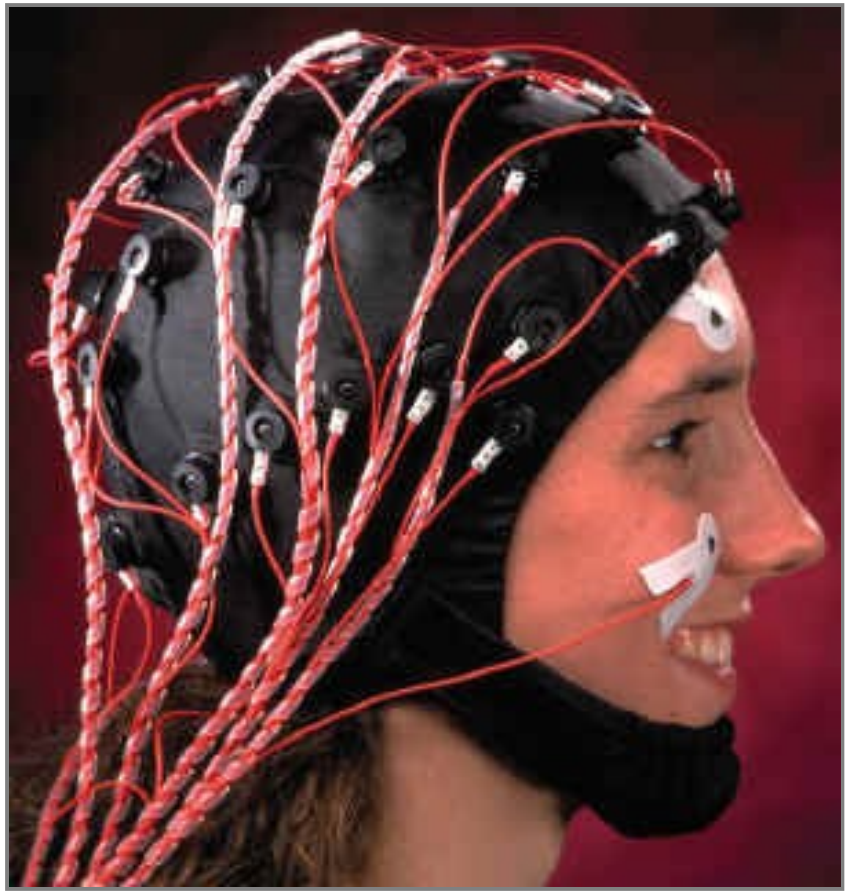


A Halle Berry neuron?



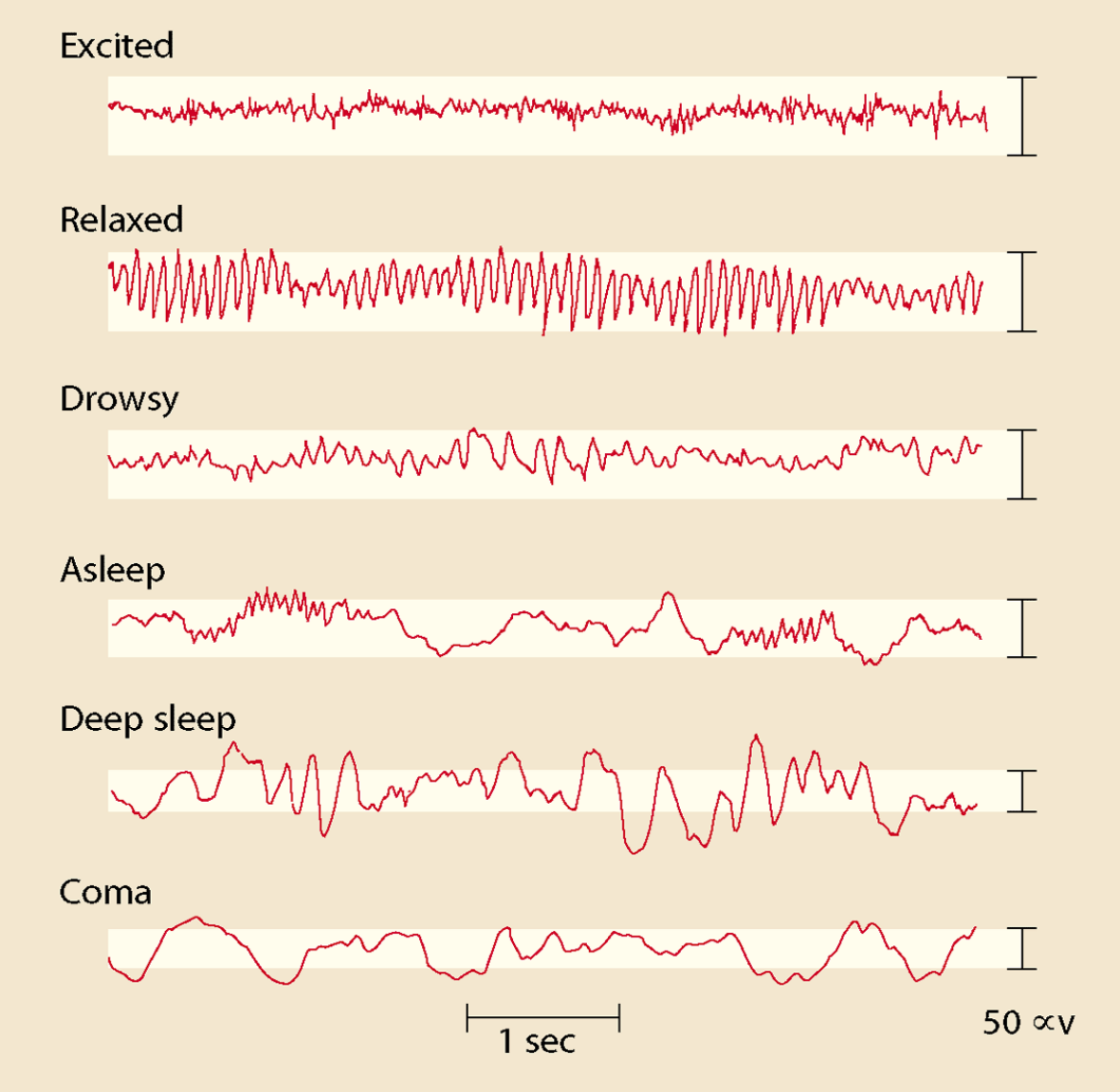
Quiroga et al., 2005, *Nature*

Electroencephalography (EEG)

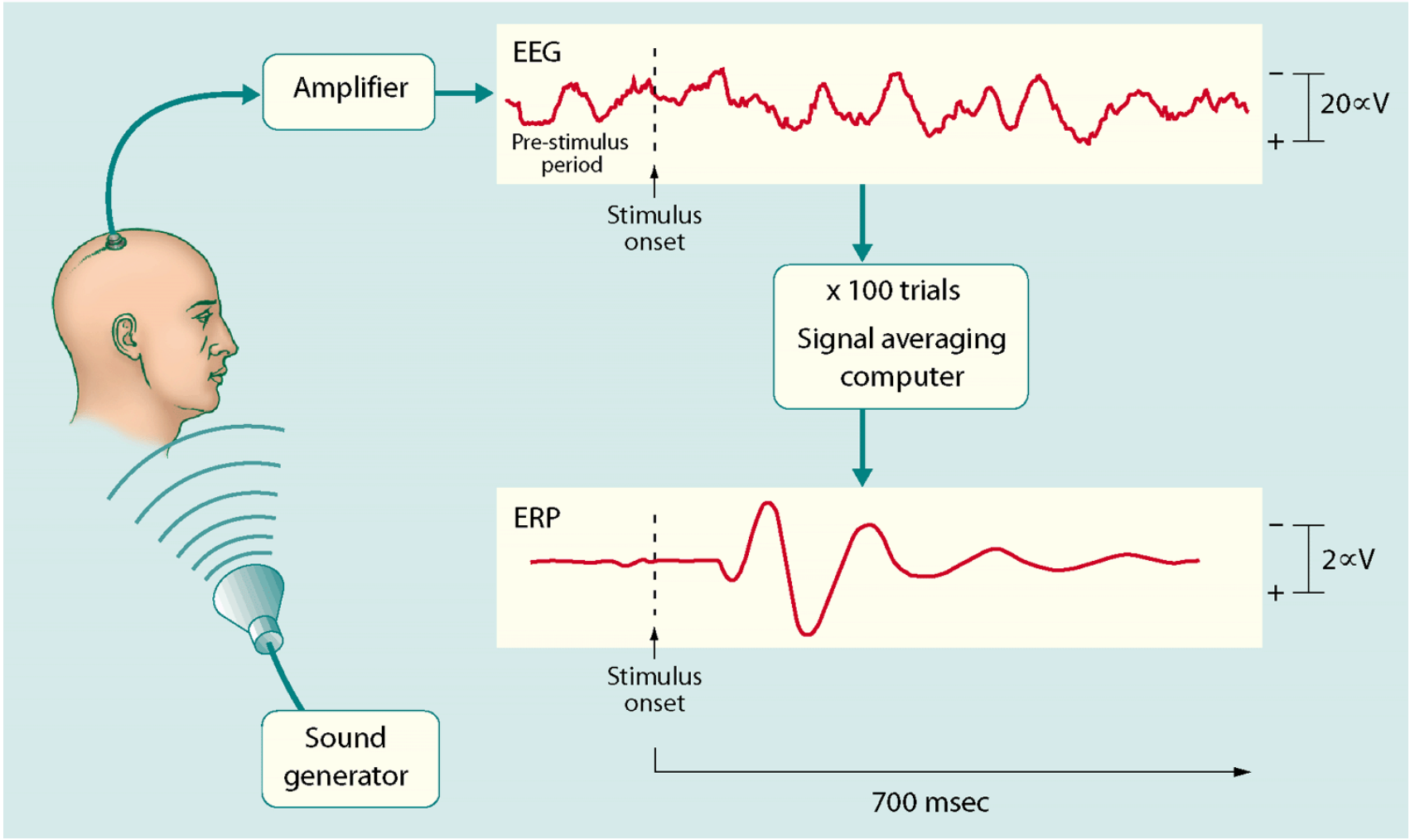


- fMRI does not provide precise info about the timing of neural activity.
- Single-unit recordings can only measure activity in one brain region at a time.
- EEG can record electrical potentials of large populations of simultaneously active neurons at the scalp with millisecond resolution.
- Plus, EEG is a direct measure of neural activity.

Arousal states of the brain:
characteristic waveform patterns

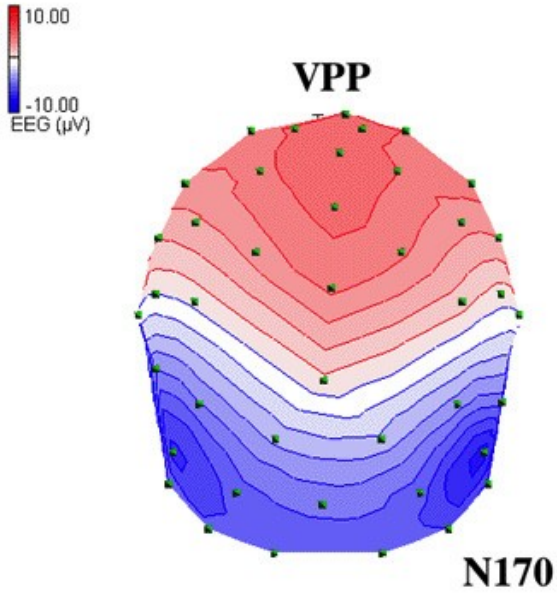


What about electrical activity for specific cognitive events?



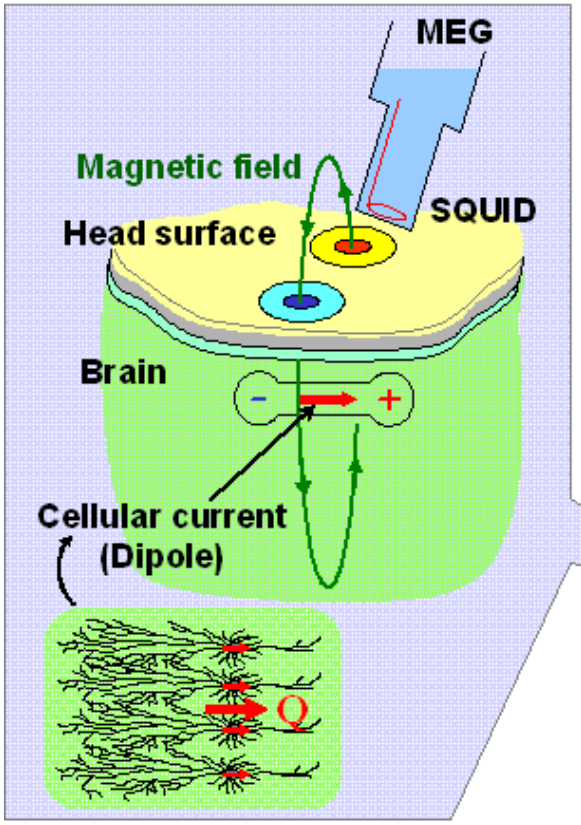
Event-Related Potentials (ERPs)

ERP example:
The face-sensitive N170

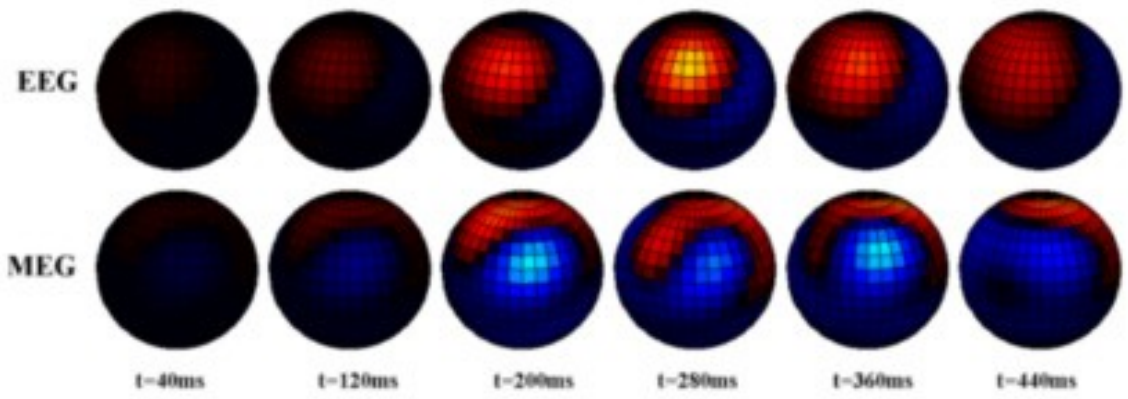


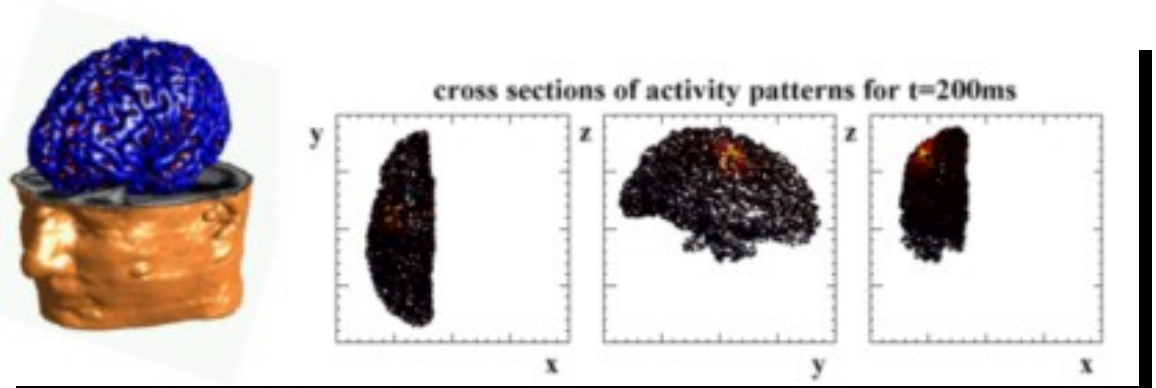
Magnetoencephalography (MEG)

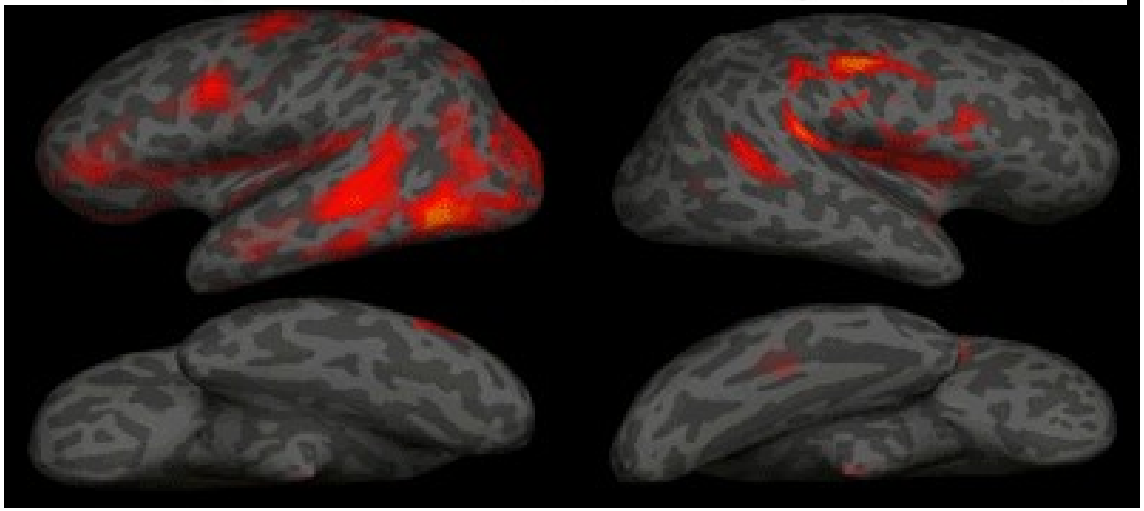
SQUID Array:
64 to 275 Sensing Locations



Cortica activity

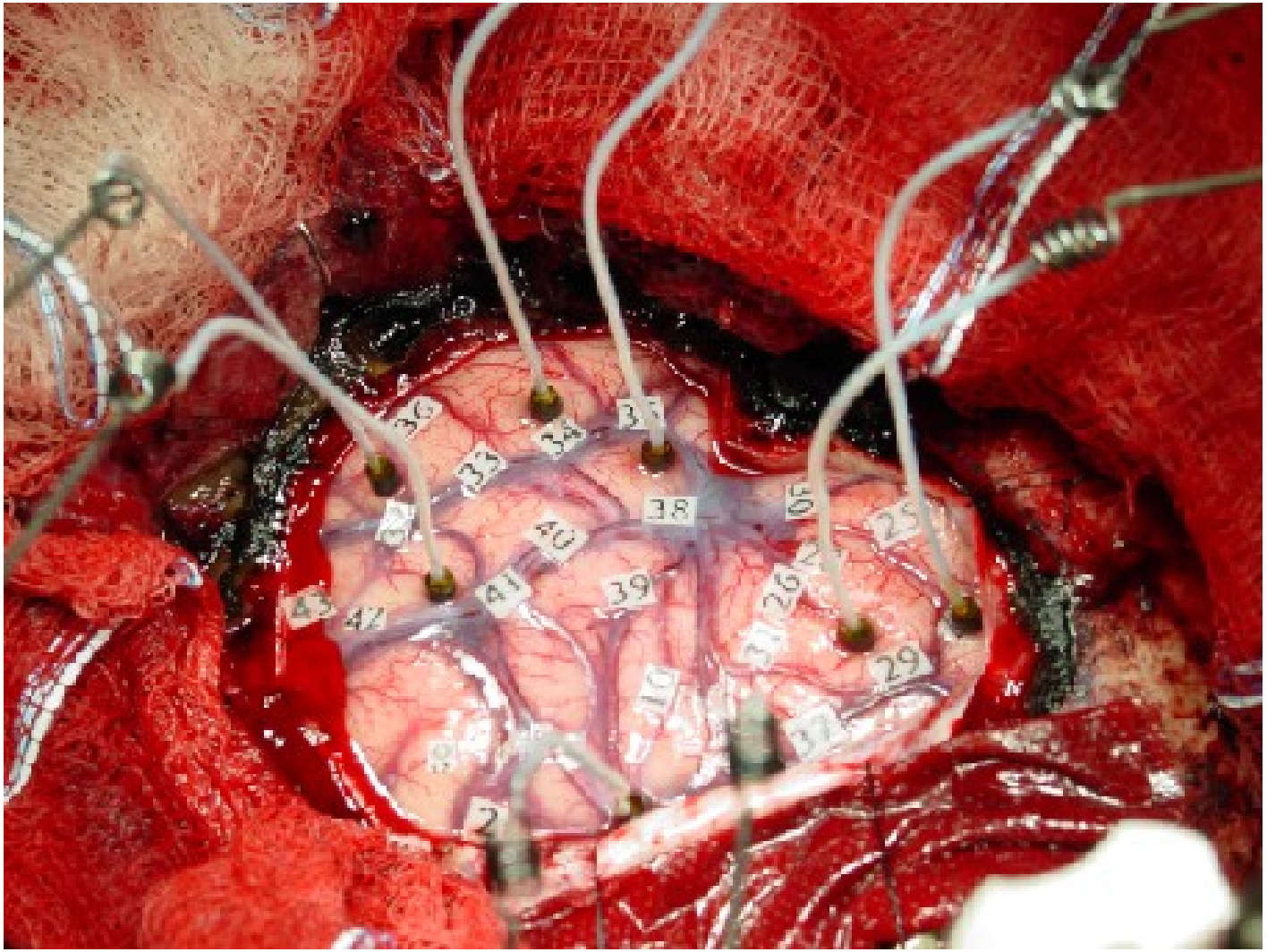






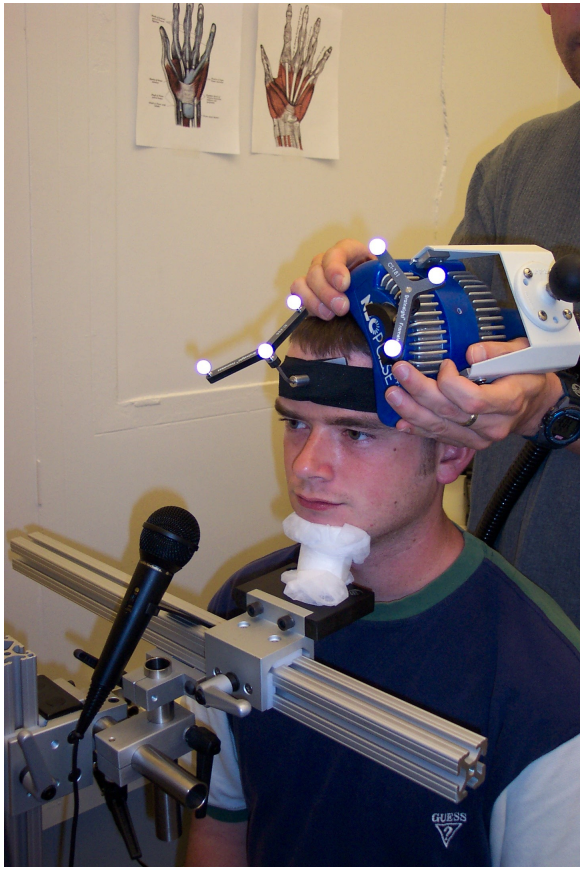
Gonsalves et al. (2005) *Neuron*

Electrocorticography (ECoG): Direct recordings from the cortical surface



Transcranial Magnetic Stimulation (TMS)

- Brief powerful (several thousand amperes) electrical charge is created in coil
- Creates a 1.5-2.0 Tesla magnetic field capable of inducing eddy currents in tissue 1-2 cm deep



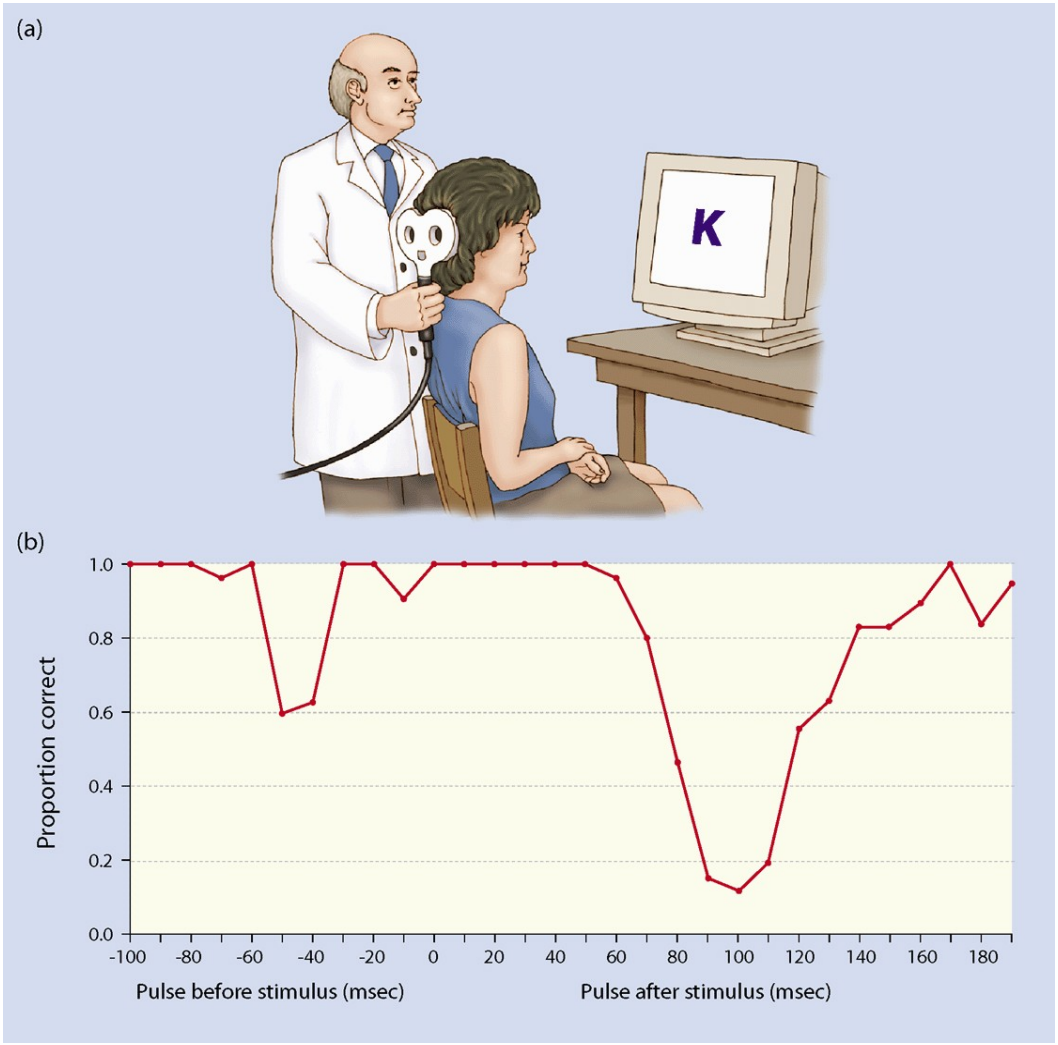
Transcranial Magnetic Stimulation (TMS)

- Disrupts normal neural function by adding noise
- In essence, TMS creates a temporary "virtual patient"
- Unlike fMRI and PET, TMS can assess the causal influence of a region on behavior.
- Unlike naturally-occurring lesions, TMS gives the researcher more control, better temporal resolution, and the ability to create multiple virtual patients in the same individual.

Safety Issues

- Generally thought to be free from harmful effects
- Examination of brain tissue submitted to thousands of TMS pulses has shown no detectable structural changes
- It is possible in unusual circumstances to trigger a seizure in healthy subjects, but using the proper guidelines eliminates this risk

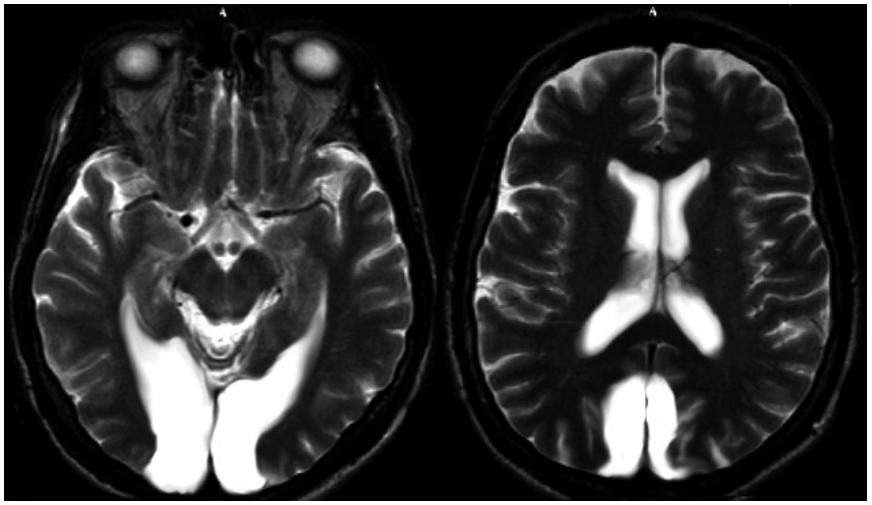
A simple TMS experiment



- Coil placed over target brain region
- Cognitive failures recorded

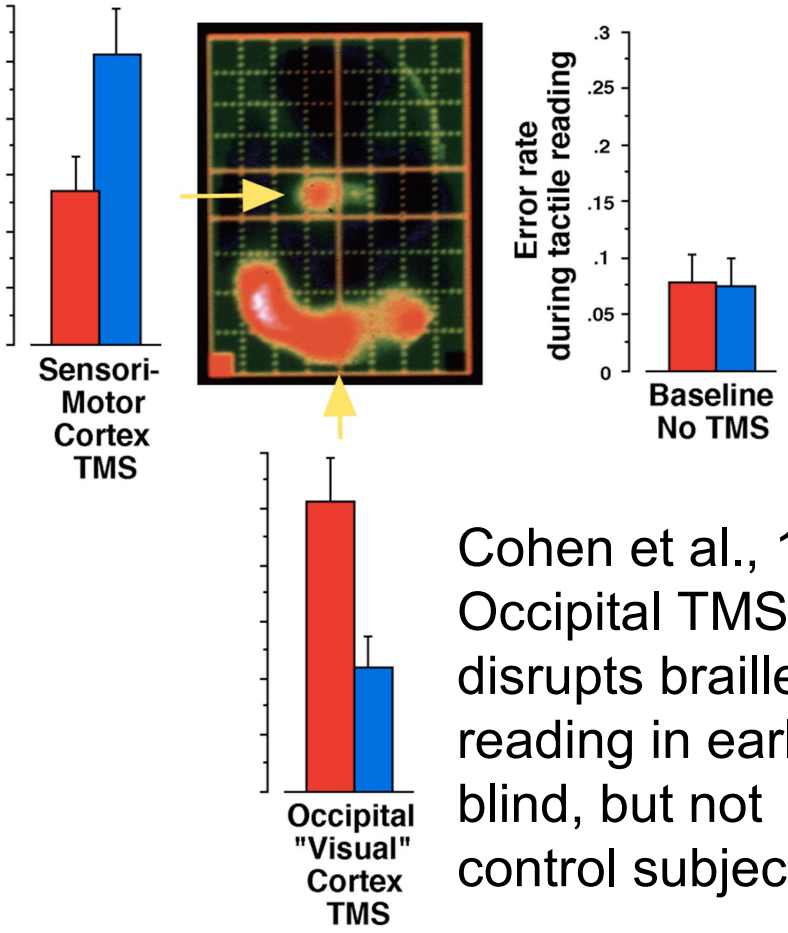
Establishing causal links between brain activity and behavior

Real lesion



Hamilton et al., 2000. Reported case of blind woman who lost ability to read braille following bilateral occipital lesions

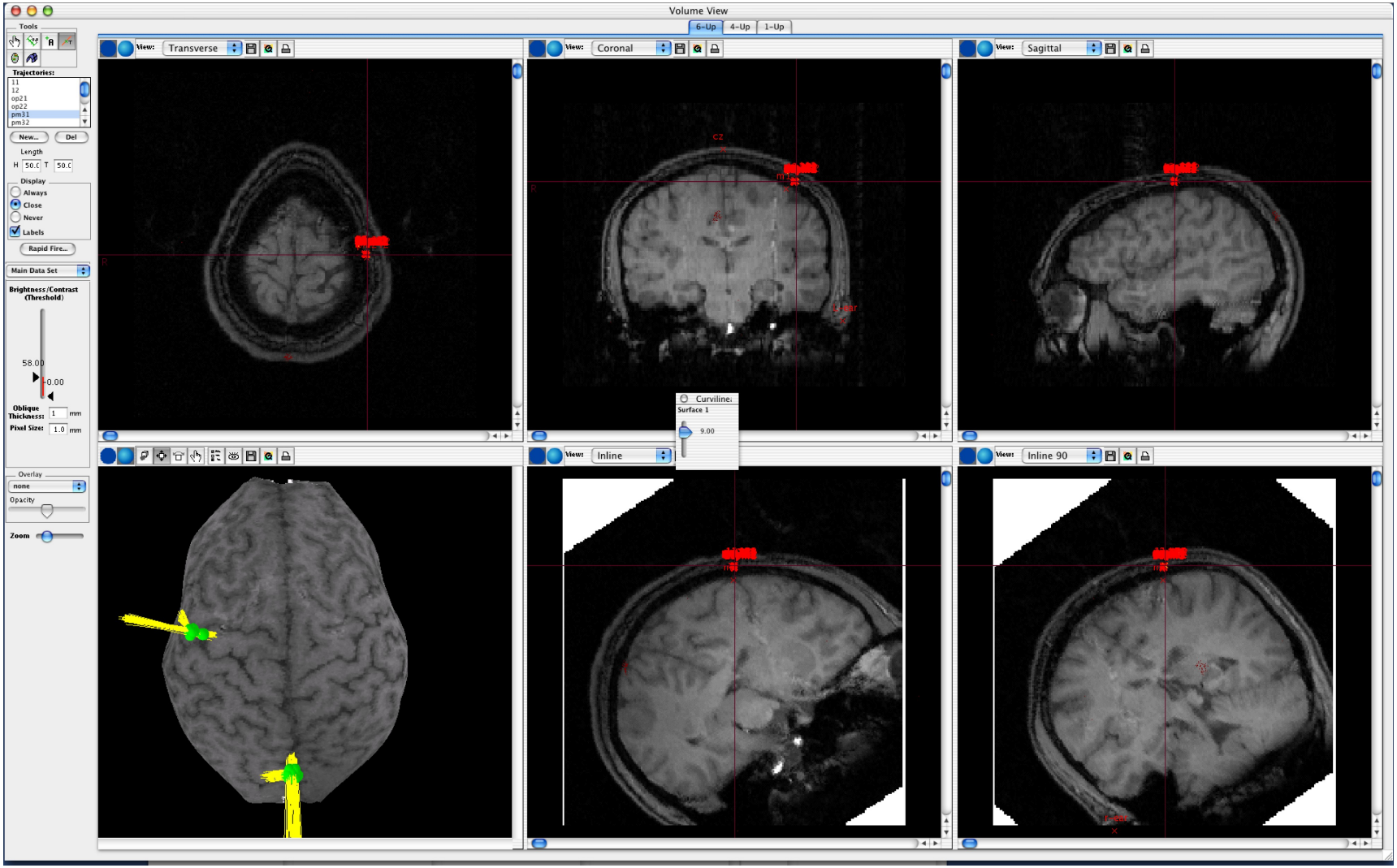
TMS "lesion"



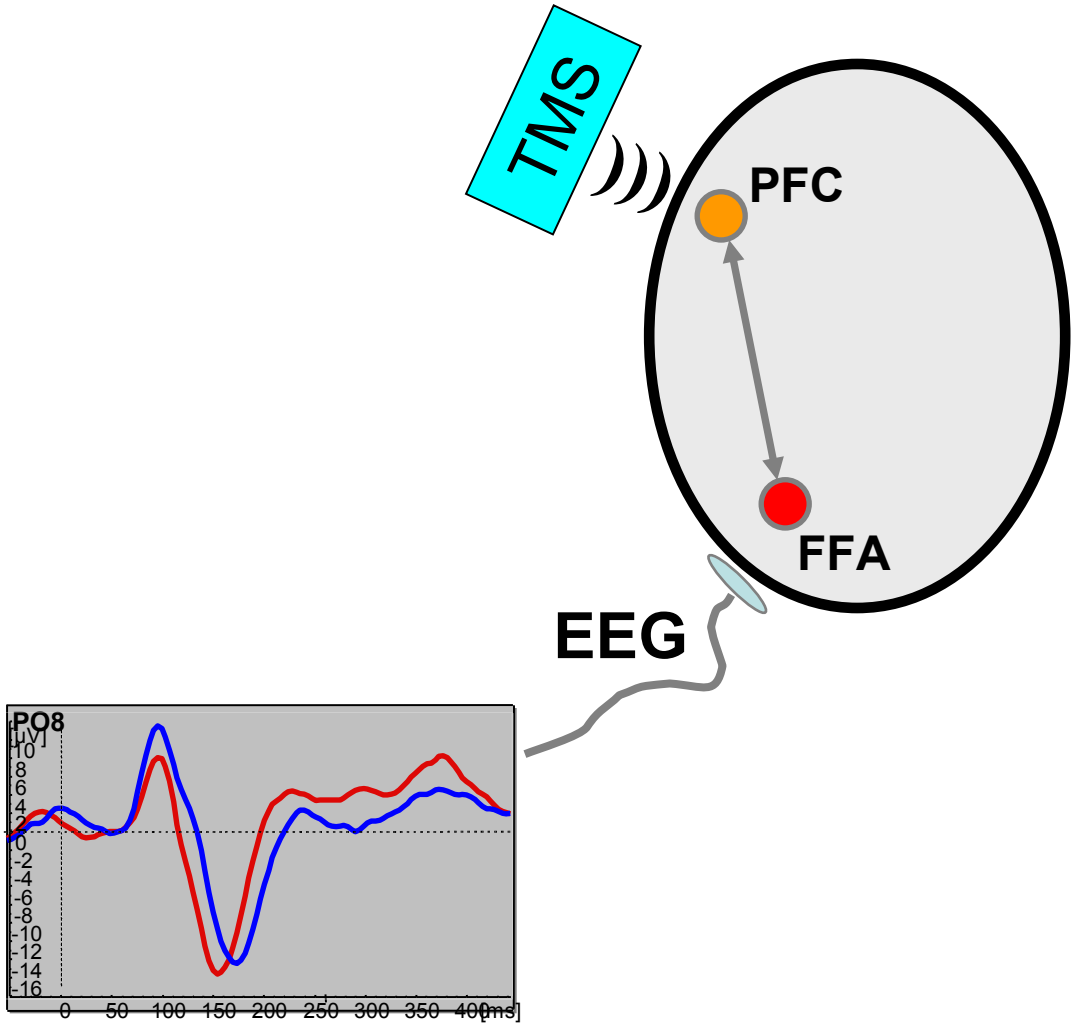
Cohen et al., 1997. Occipital TMS disrupts braille reading in early blind, but not control subjects

Blue = sighted; Red = early blind

fMRI-guided TMS stimulation



Converging Methodolgies: fMRI guided-TMS/ERP



N170 ERP

Thanks for your attention!