Studying the Human Brain

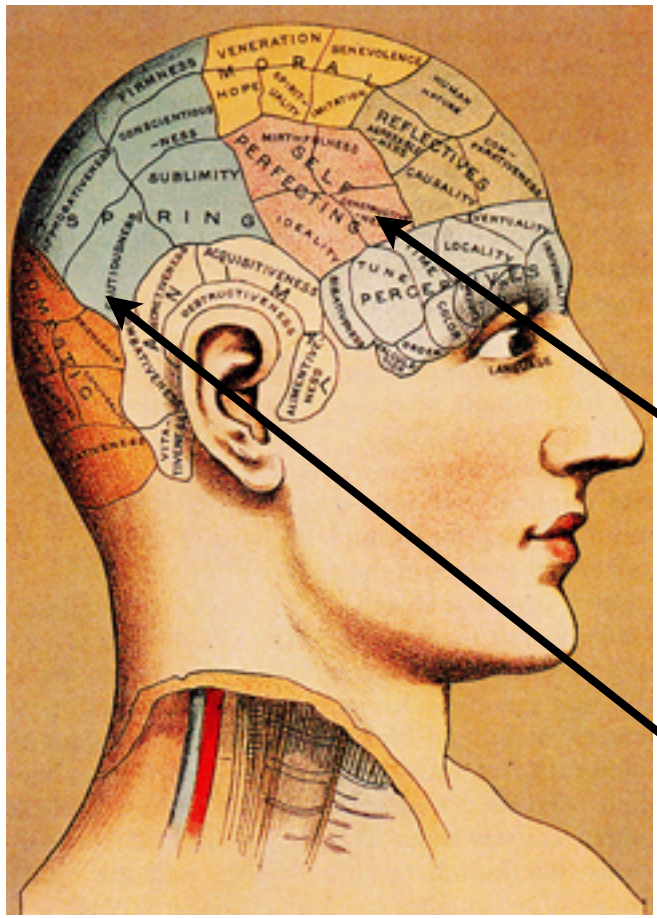
The wet stuff.....

Q: What do we expect to find when studying brains?

How do we find out stuff about the brain?

- Pathology (syndromes, lesions)
- Animal experiments
- Imaging (and similar)
- Behavioral studies

Phrenology (not respectable!)



Franz Josef Gall, ca. 1800

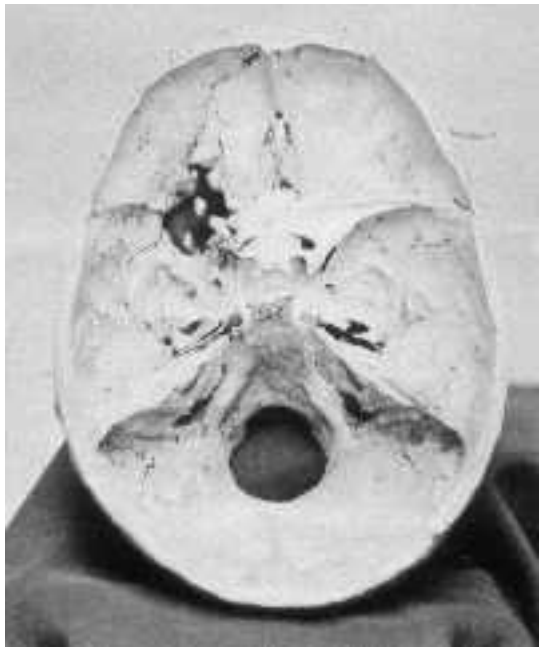
Believed the brain consisted of 27 distinct organs

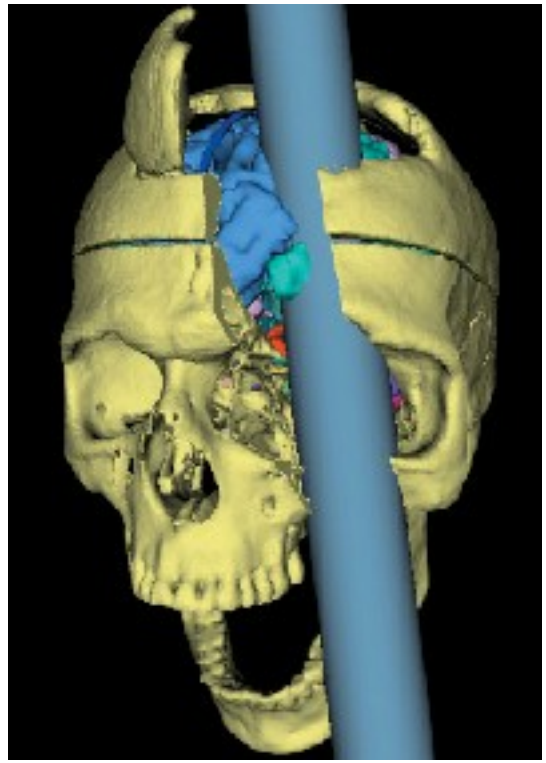
The carnivorous instinct

The poetical talent

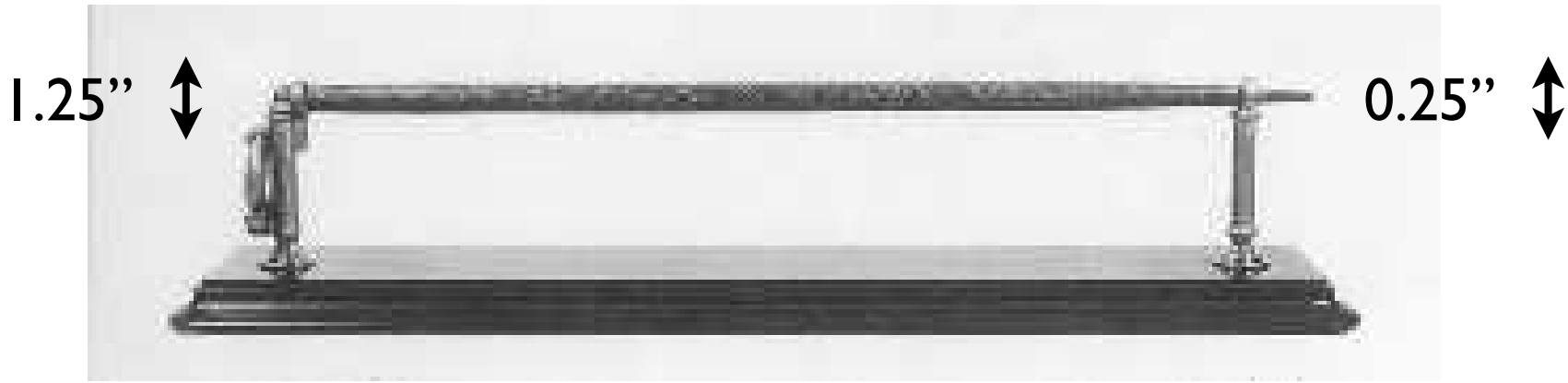
Case study 1: Phineas Gage

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 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. He returned home 10 weeks later.

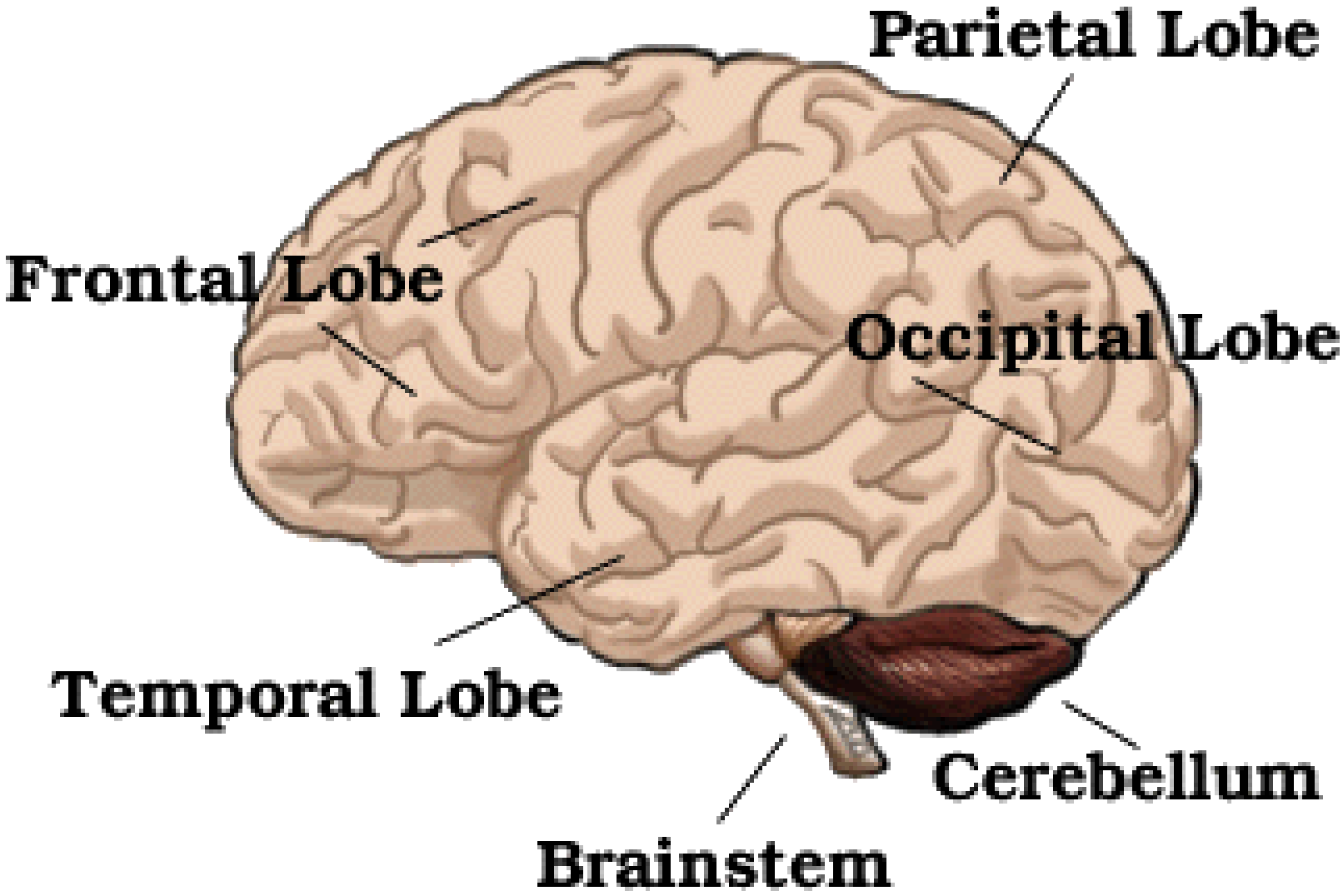


Some months after the accident, probably in about the middle of 1849, Phineas felt strong enough to resume work. But because his personality had changed so much, the contractors who had employed him would not give him his place again. Before the accident he had been their most capable and efficient foreman, 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."

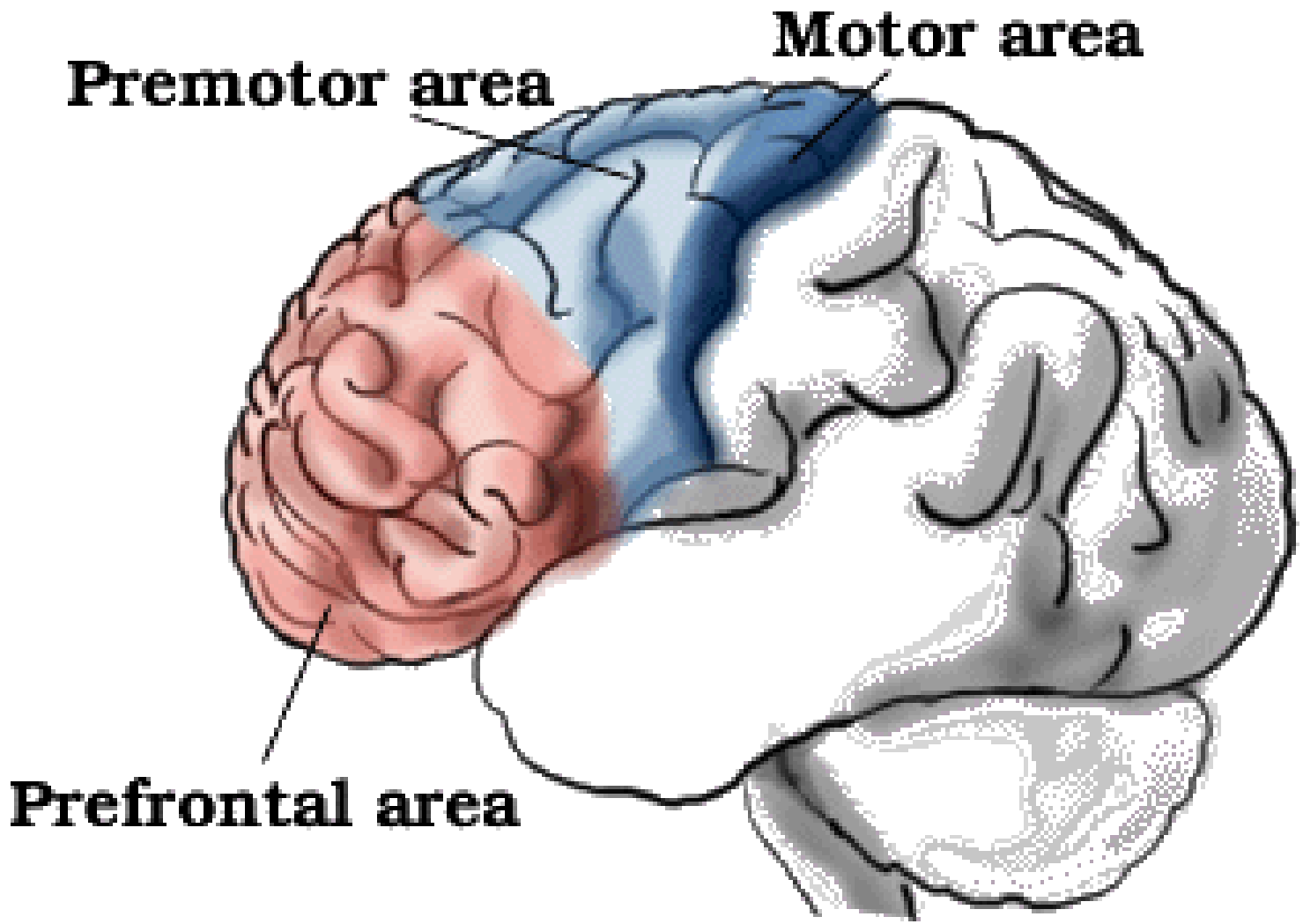
- Gage was one of the first well-documented cases in which specific brain lesions could be linked to specific observable symptoms

- It contributed to medical approaches which sought local causes for overt behavior in the brain (and which found its worst excess in lobotomy, or psychosurgery)

- Partly as a result of Gage, the frontal lobes are often regarded as the seat of higher cognitive functions (reason, deliberation) and personality.

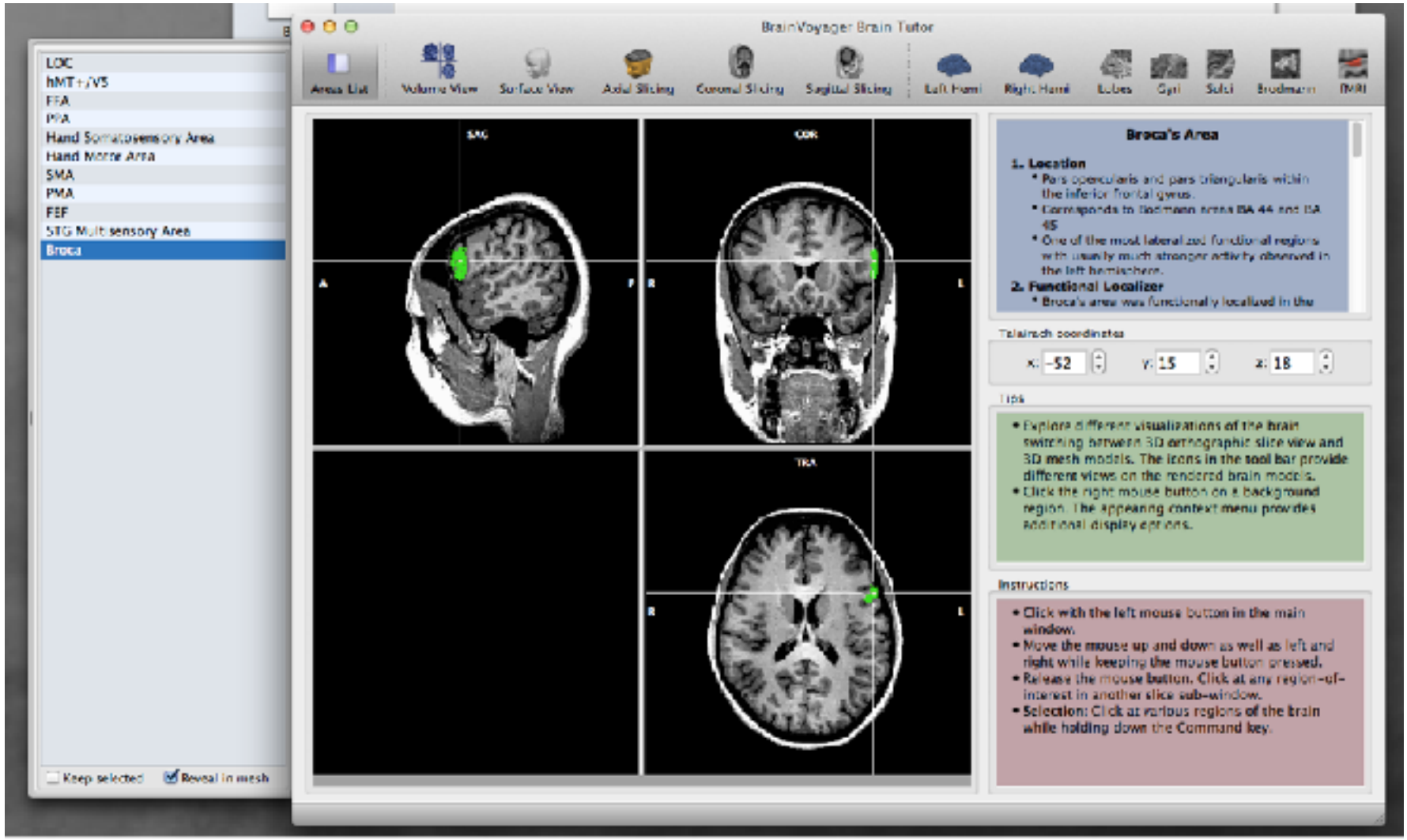

Parietal Lobe
Frontal Lobe
Occipital Lobe
Temporal Lobe
Cerebellum
Brainstem

Frontal Lobe:



Explore the brain yourself!

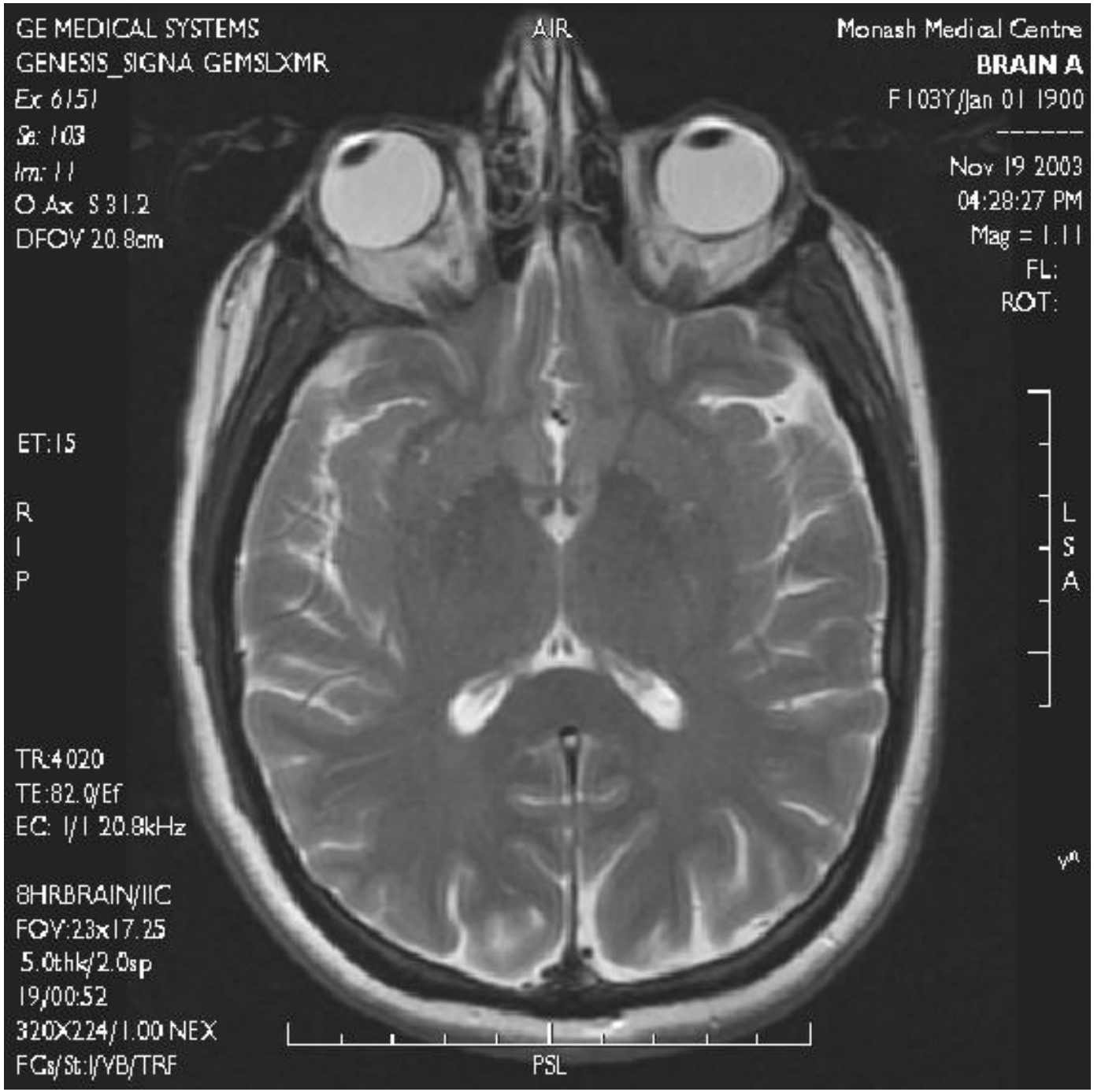
http://www.brainvoyager.com/products/braintutor.html



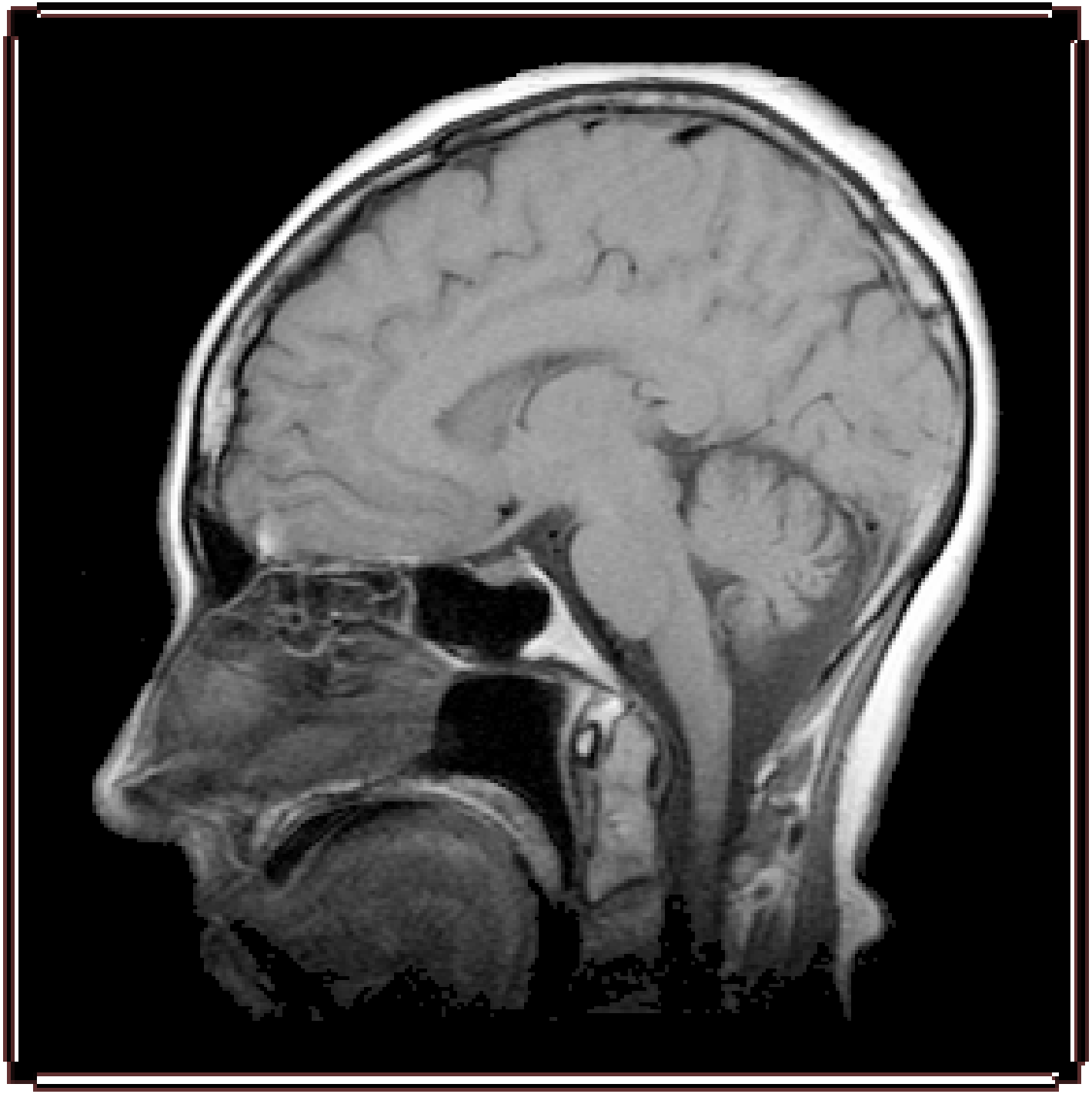
Magnetic Resonance Imaging


PHILIPS

- Not X-rays!!!! Uses very high intensity magnetic field to alter spin of protons
- Typical human strength: 3 tesla. Earth's magnetic field: ca. 50 μT
- Images soft tissue with great accuracy
- Noisy, slow, but non-invasive
- Produces *structural* images



Transverse cross-section



Saggital cross-section

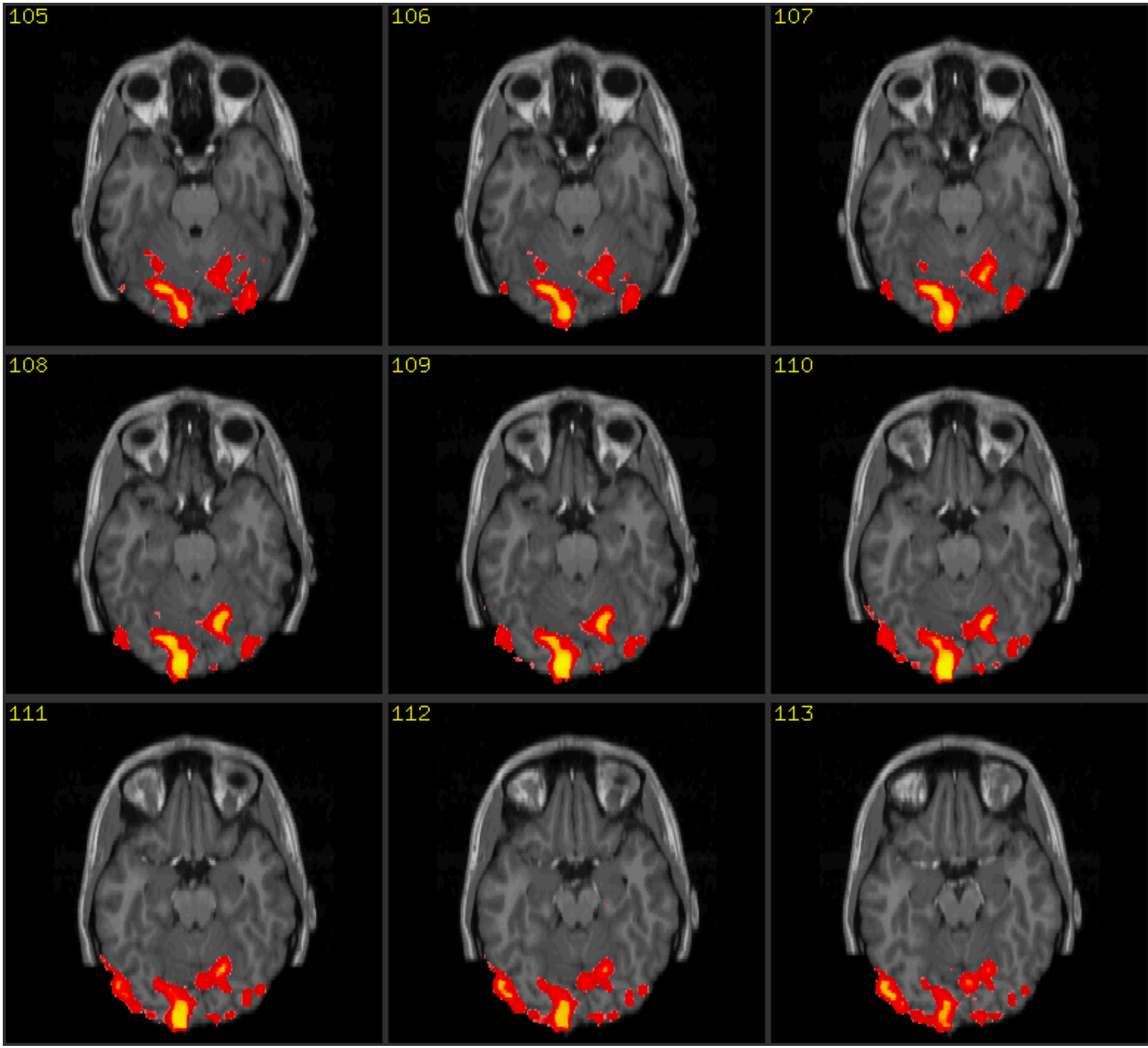
Coronal cross-section

Functional MRI (fMRI)

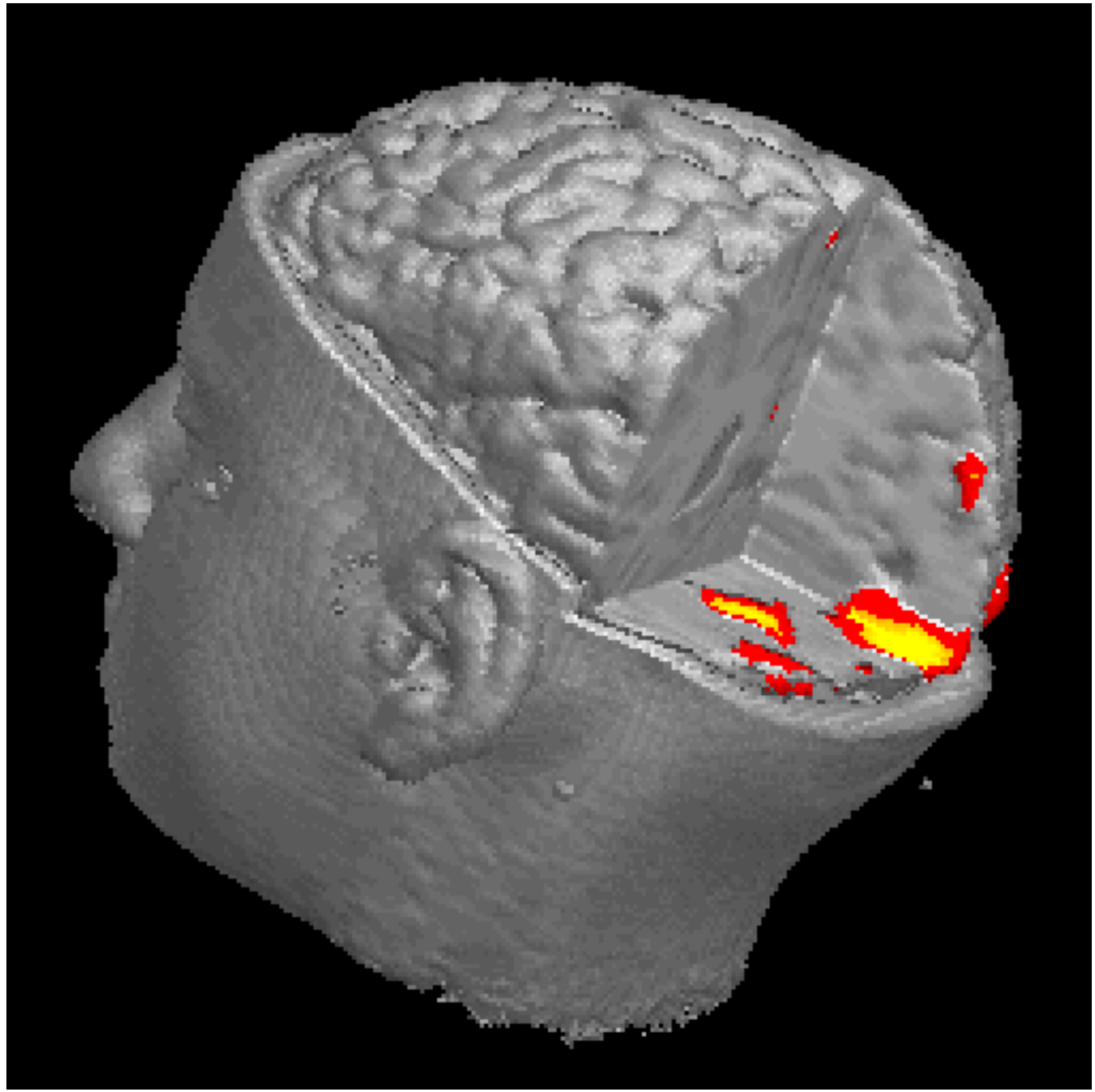
- Same basic principles as MRI
- Sensitive to local blood flow (not to nerve firings directly)
- Blood Oxygen-Level Dependent signal (BOLD)
- Overlaid on structural MRI
- Limited temporal resolution, good spatial resolution

Basic transverse MRI

Sequence of BOLD responses from one slice



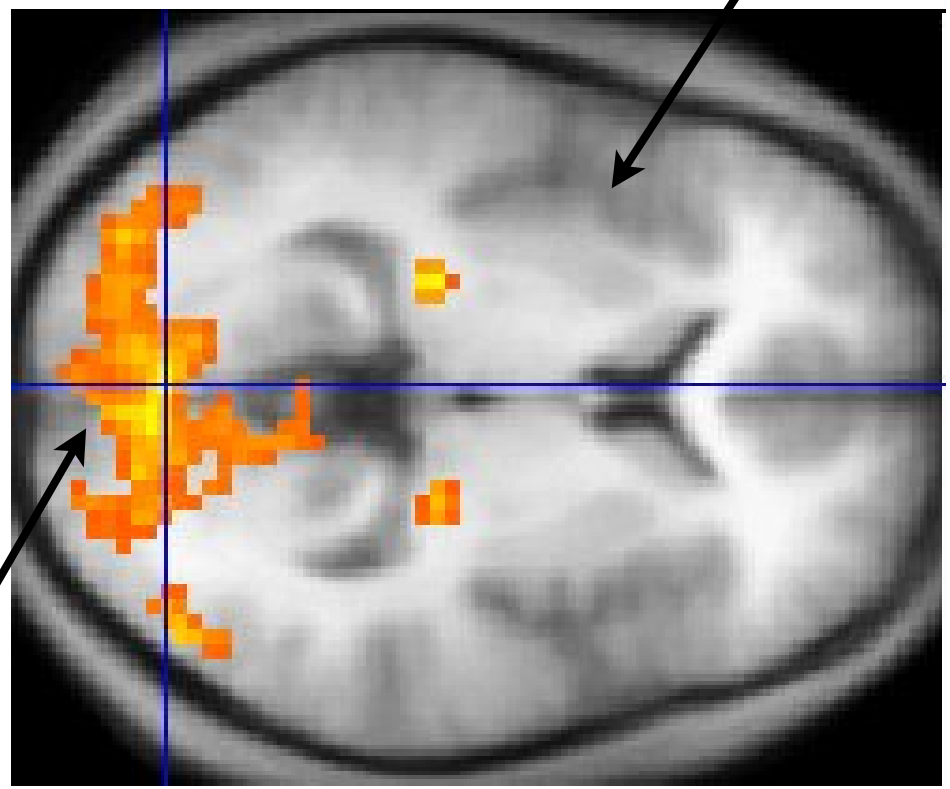
3-D
image
of
brain
activity



Typical procedure

- First, do protracted, hi-res, anatomical MRI scan
- Now do ca 150 lo-res scans of about 5 sec each (half with stimulus, half without)
- Compare activation, voxel by voxel, across the two conditions

Structural average MRI



Subjects viewed a complex moving stimulus or a black screen. Areas more active when viewing the moving stimulus are coloured.

Primary visual cortex

Caveats

- Averaging in time necessary: repeated presentations of stimulus
- Brains differ greatly in their fine structure: averaging among subjects thus inherently fuzzy
- Bloodflow is hard to interpret
- Danger of premature association of ‘function’ with ‘location’

Mapping Brain Connectivity

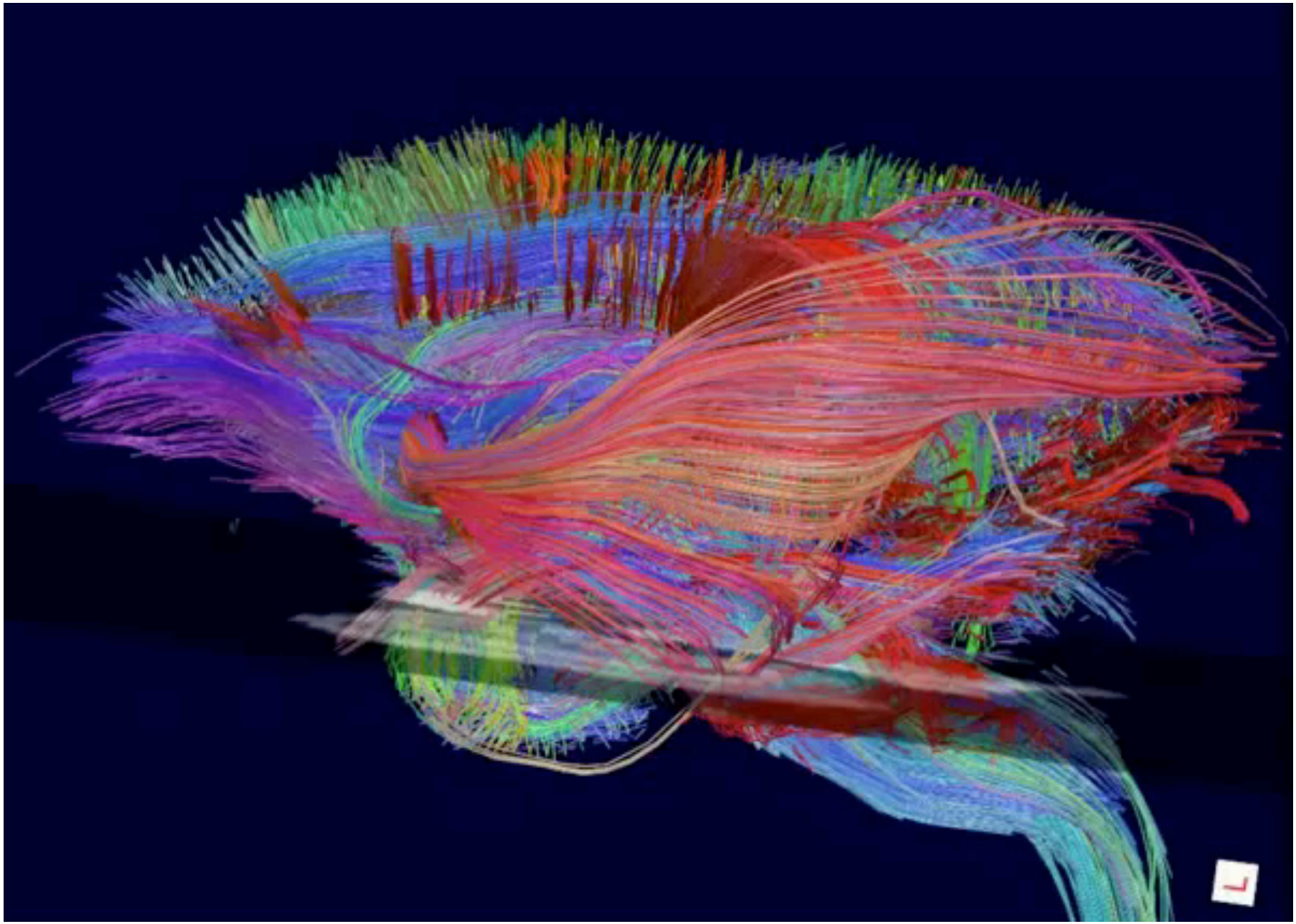
The brain contains massive interconnectivity.

In general, if Area A connects to Area B, then Area B will connect back to Area A

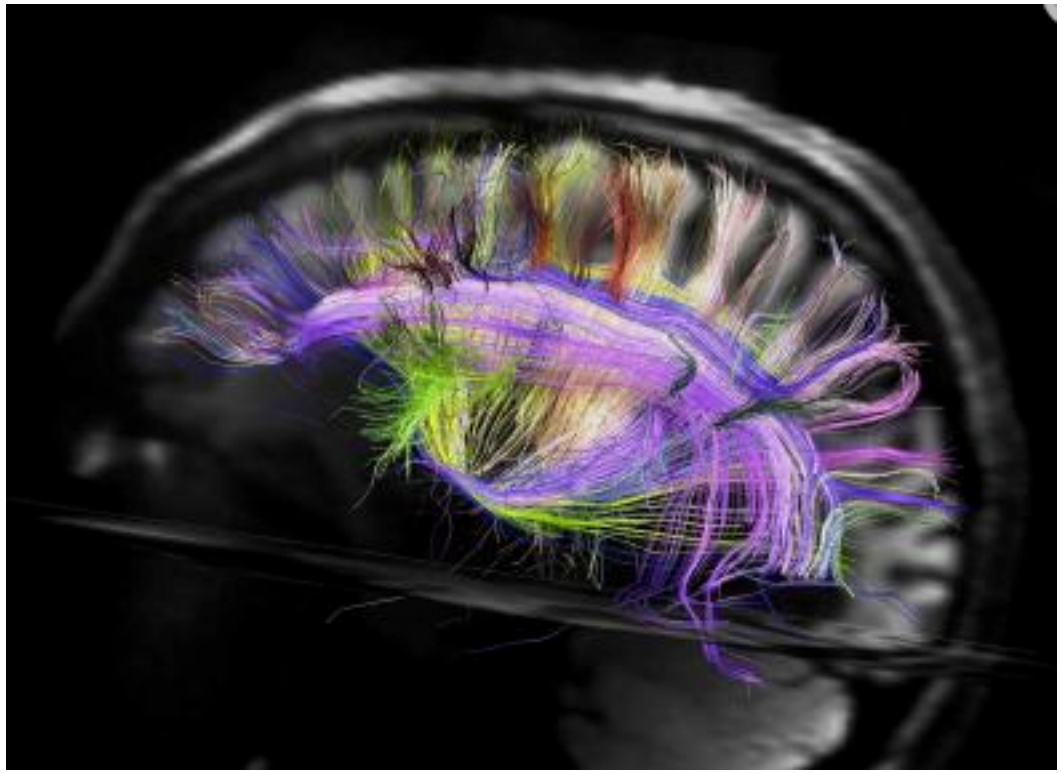
Modern techniques are just uncovering the richness of connectivity

Techniques: Diffusion Tensor Imaging (DTI) and Diffusion Spectrum Imaging (DSI)

Diffusion Tensor Imaging (marmoset brain)



March 2012: Diffusion Spectrum Imaging shows the existence of a fabric or grid like structure in long range connections in the human brain



Advances in neuroimaging have led to several highly questionable new "disciplines". Take your favourite topic related to humans, and stick "Neuro-" in front, and voila:

Neuroaesthetics
Neuroethics
Neuromusicology
Neuroarthistory

Approach such shiny new areas with a great deal of caution!

Part of the reason for this explosion of new "disciplines" is that people are increasingly willing to identify the *person* with the *brain*.

Do you?

Why is this?

Why is it such a popular way to think?

Keep an eye out for this as you read more generally.

Neuromarketing

- Recent studies have attempted to find out how the brain reacts to brands and advertising details
- Why do consumers make the decisions they do?

- 67 subjects were given the blind Coke/Pepsi taste test
- 50% said they preferred Pepsi, 50% chose Coke
- Reward centers light up (dopamine...)
- Nothing tooooo surprising there...

- Repeating the study, this time subjects were told which brand they were trying
- 75% now preferred Coke
- A new area in prefrontal cortex lit up
- Brand awareness?
- What assumptions are the researchers making about brains and people here?

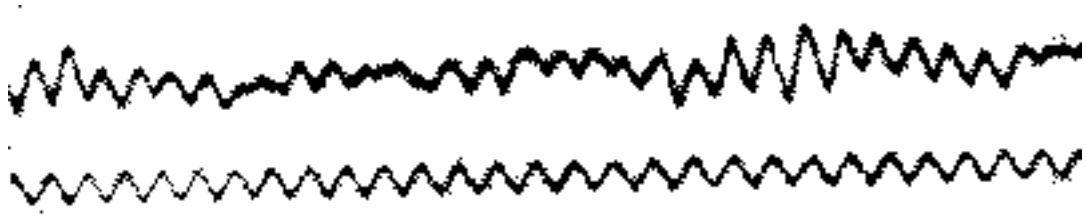
We don't have time or space to debunk the many abuses of neuroscience out there.

A special expression of distaste though ought to be reserved for the misleadingly named *Neuro-Linguistic Programming*, which is not neuroscience, not linguistic science, and not programming science.

More discussion of this, if you are interested, at http://neurobollocks.wordpress.com/ (up to 2015) or from the Neuroskeptic at http://blogs.discovermagazine.com/neuroskeptic

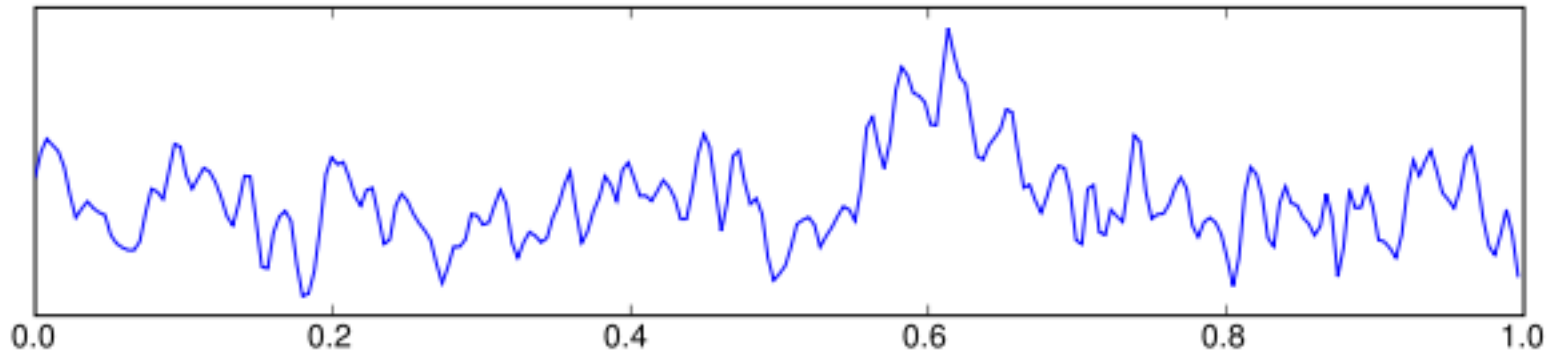
Brain Waves (EEG)

- EEG: Electroencephalography
- Non-invasive technique: uses scalp electrodes
- Excellent temporal resolution/lousy spatial resolution
- Oldest imaging method (Berger, 1924)



One of Hans Berger's original recordings from 1924.

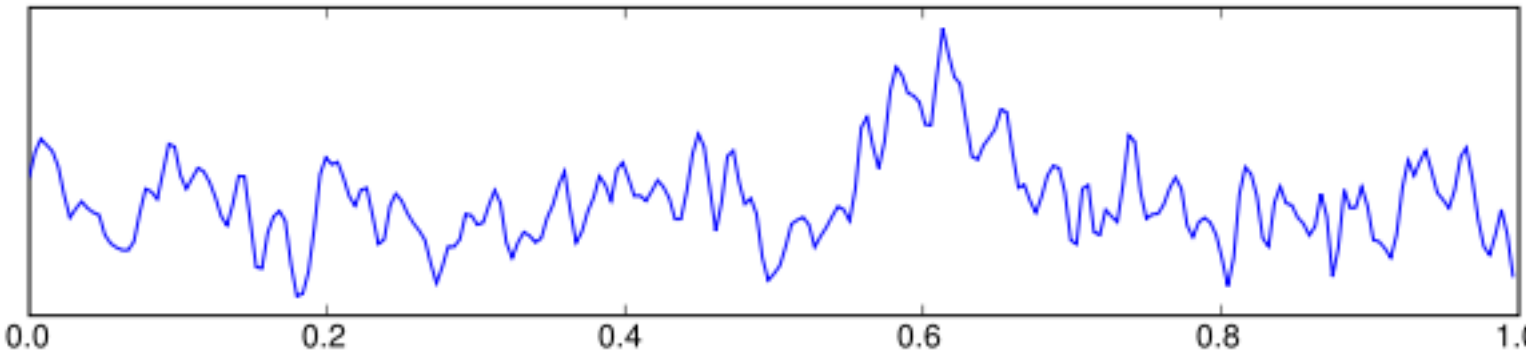
What do you make of it?

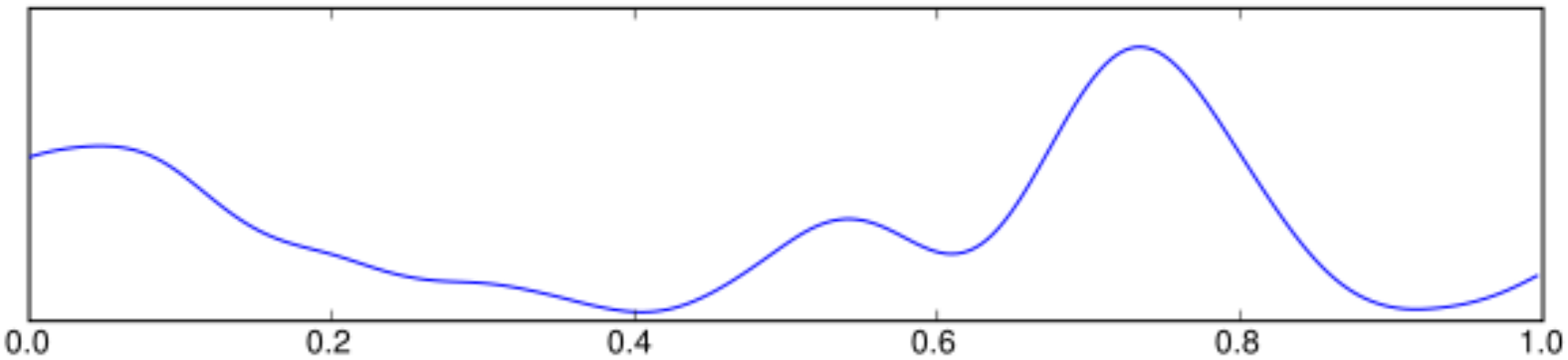


A complex signal recorded at one location may look like this.

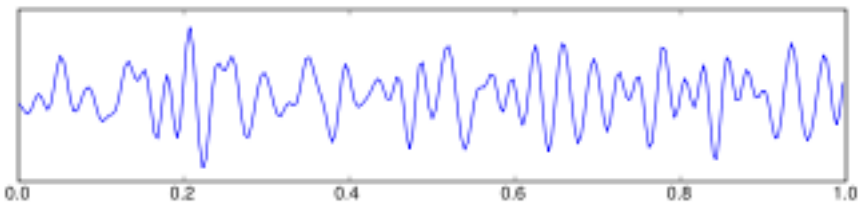
This can be analysed as the sum of a large number of separate signals at different frequencies (much as your audio signal can be thought of as a sum of the bass, middle and treble registers).

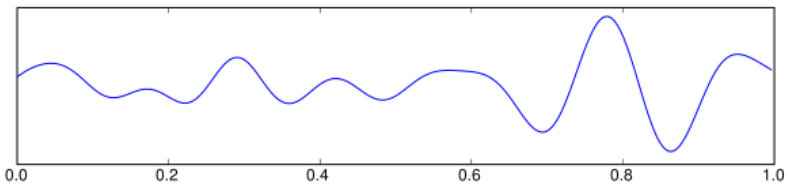
Composite

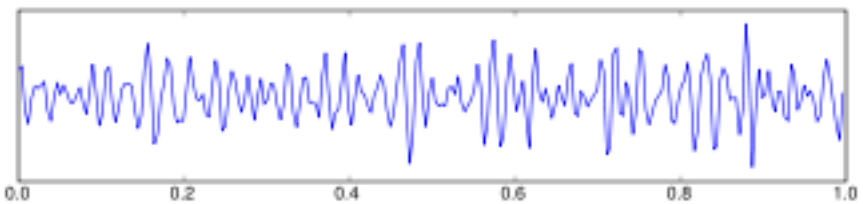




Delta component: some sleep stages; some pathologies; very young subjects







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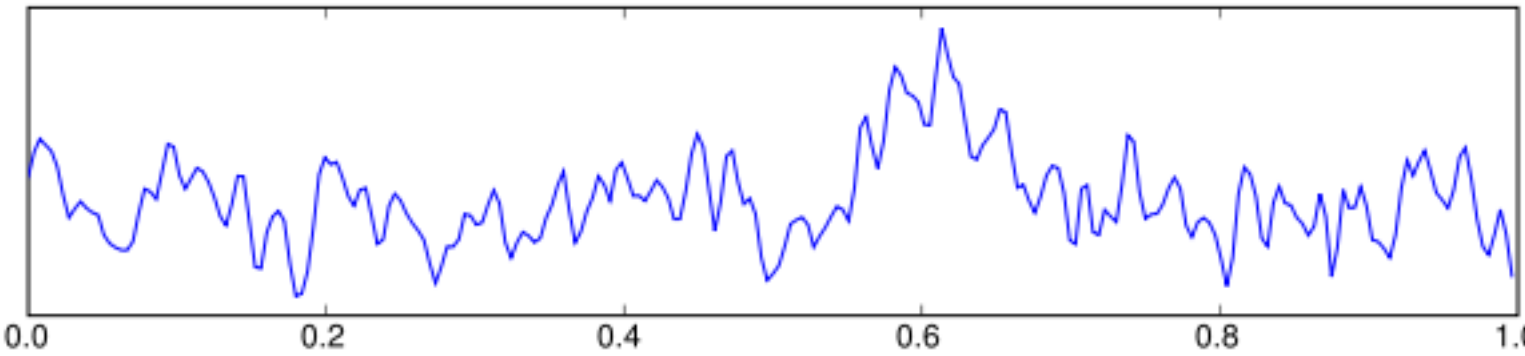
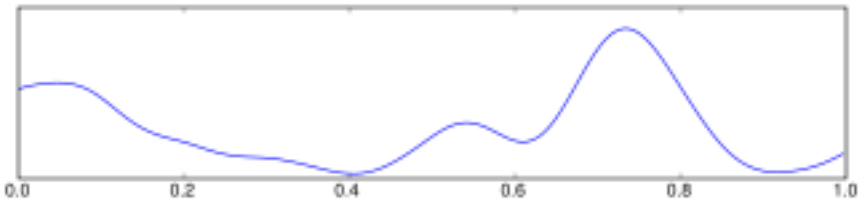
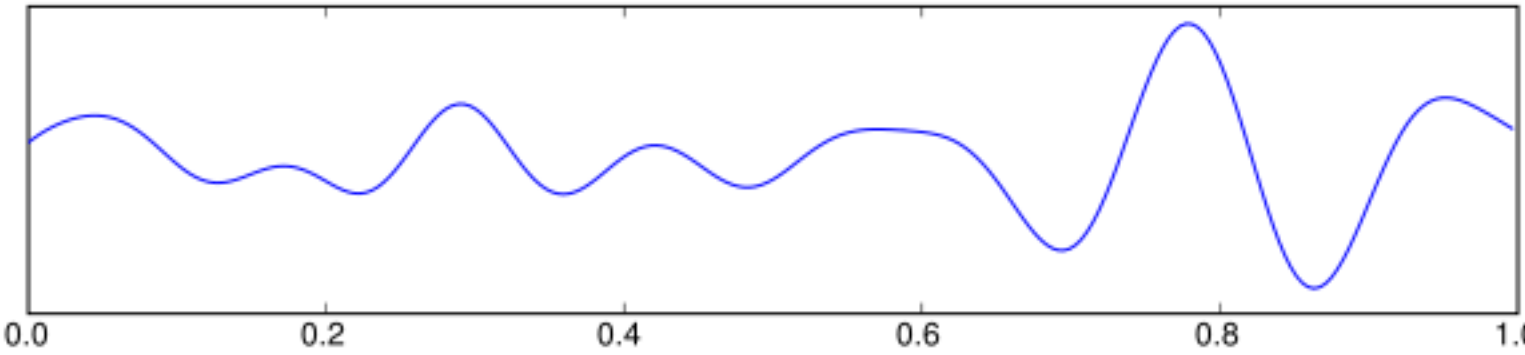
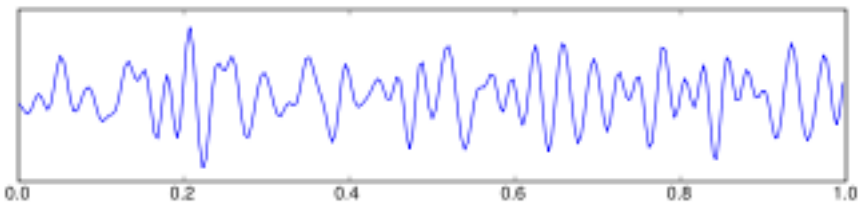
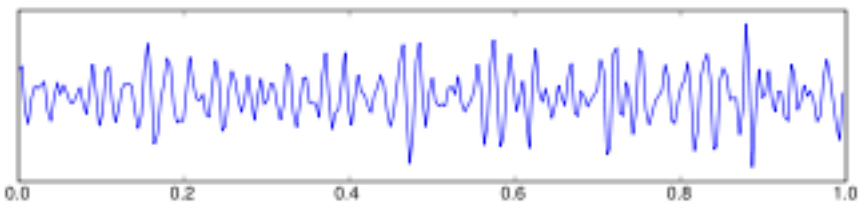






Theta: drowsiness, hypnosis, light sleep





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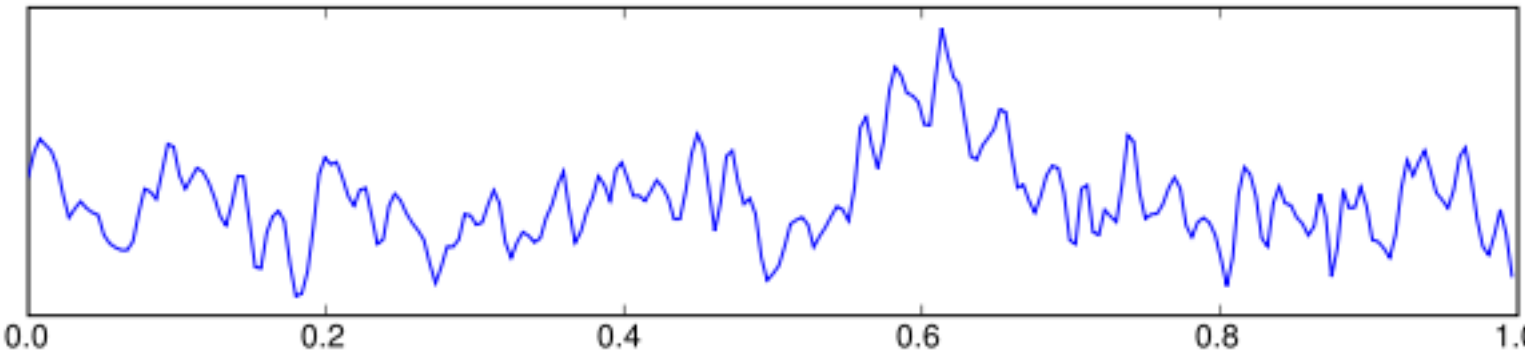
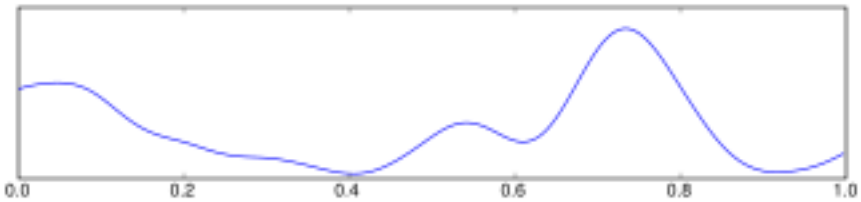
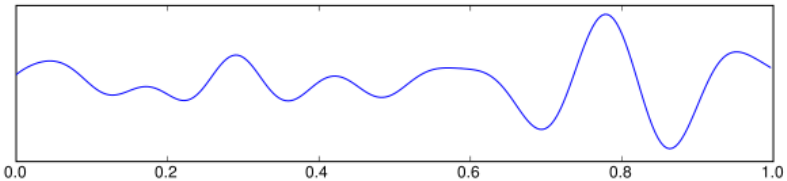
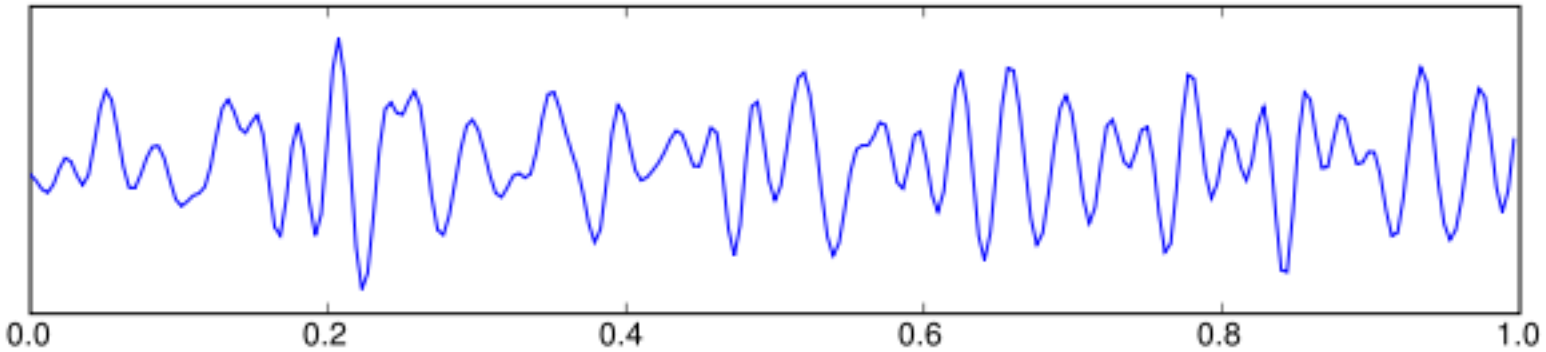
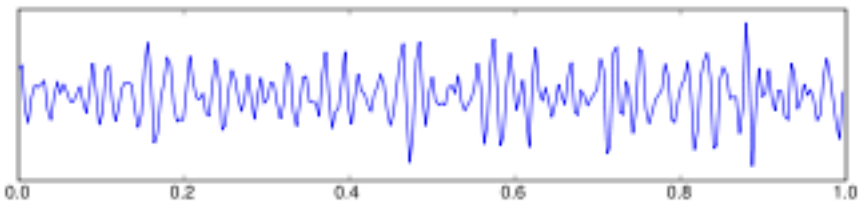






Beta: active concentration, thinking





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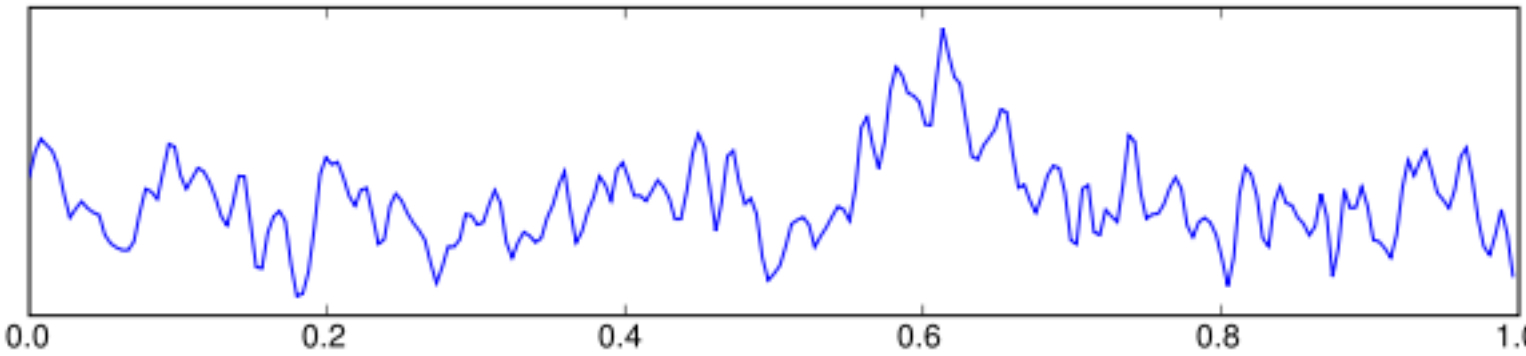
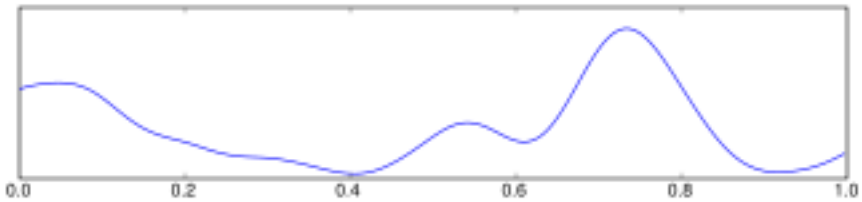
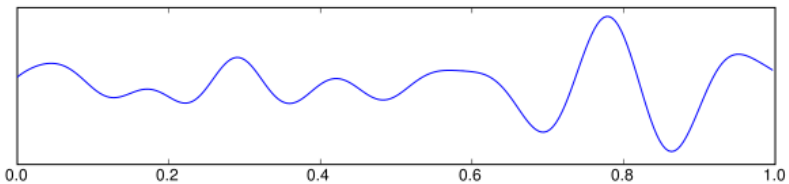
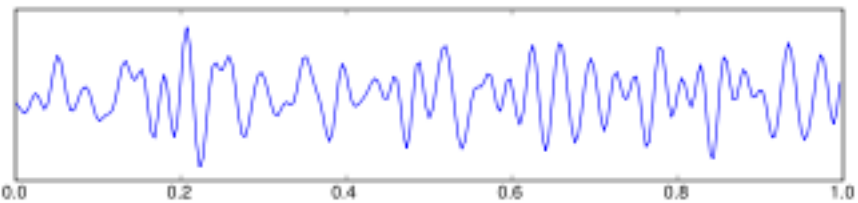
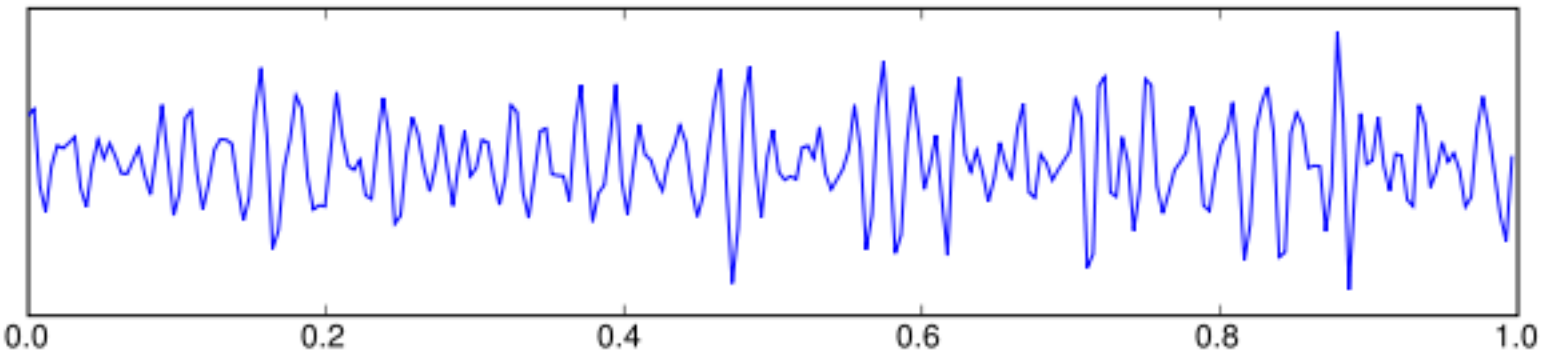








Gamma: intellectual activity? problem solving?

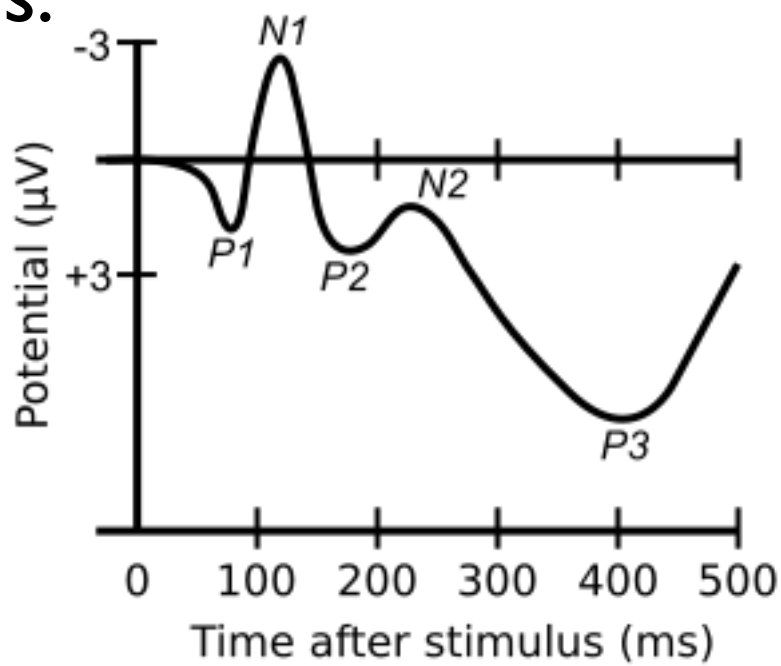


One common technique: Event-Related Potential:

repeated presentation of a stimulus, and averaging of the immediately following EEG signal

Requires very many (often hundreds) of stimulus presentations.

Treats the (endogenously active) brain as if it were merely "responding" to the stimulus.



Weird convention: negative is up, positive is down.

Caveats

- Signal-to-noise ratio is very small (hard to detect anything other than randomness)
- Stronger signals require averaging over many many trials
- Experimental design is complex, and doesn't suit many purposes
- Spatial localization is difficult
- Deep brain activity is not recorded

fMRI

- Measures oxygen in blood flow (BOLD)
- Good spatial resolution
- Poor time resolution

EEG

- Measures electrical activity at the scalp
- Good time resolution
- Poor spatial resolution

Near Infra-Red Spectroscopy: NIRS

Uses light!

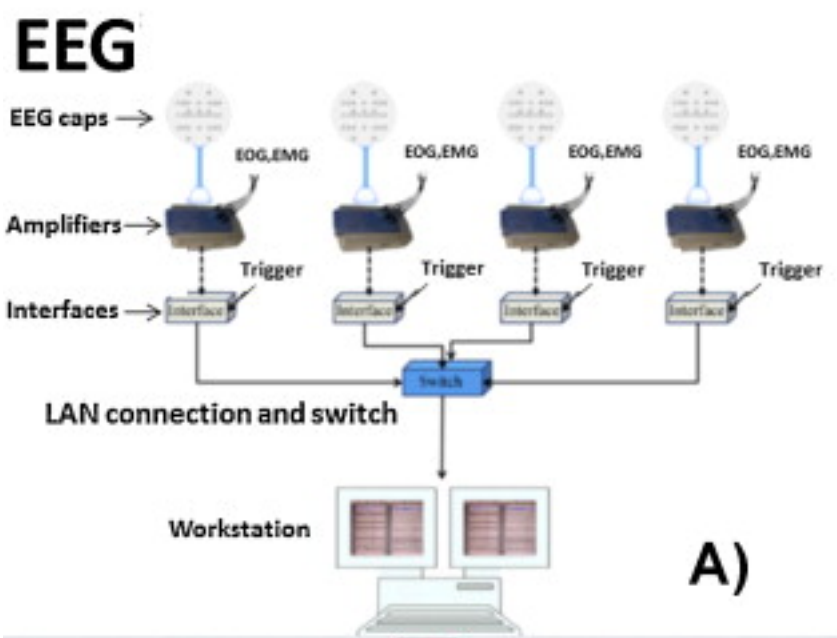
Monitors regional bloodflow (much like fMRI) at the cortical surface.

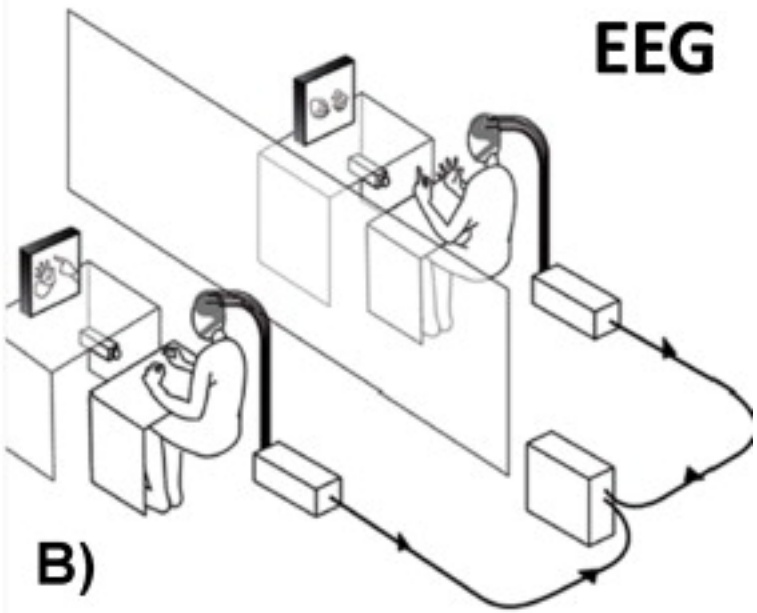
Non-invasive

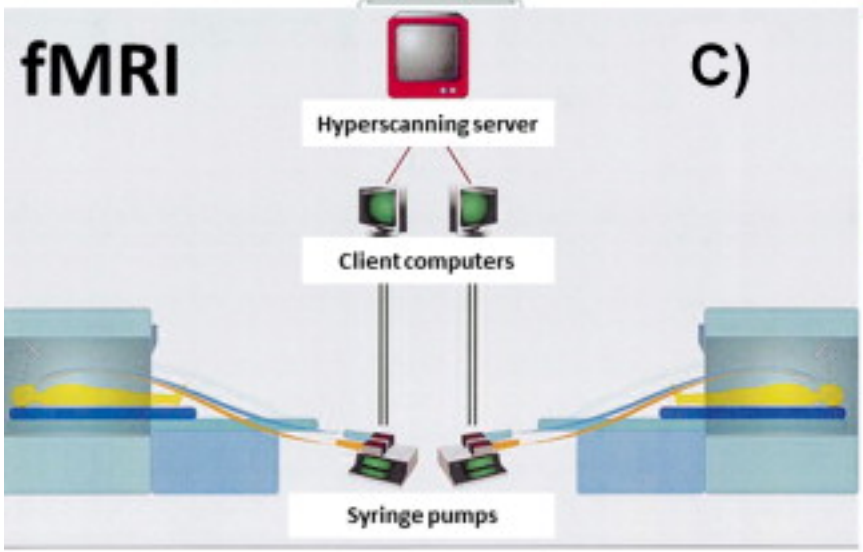
Relative newcomer, but developing rapidly!

Can be combined with EEG (complex!!)

Imaging more than one brain at a time: HYPERSCANNING!







Neuroscience has recently noticed that brain activity is massively different when subjects engage in social interaction.

This has recently been dubbed the "dark matter" of neuroscience

In social interaction, two brains may become coupled!

Challenges of hyperscanning:

fMRI is based on a very slow-changing signal, so tasks cannot involve real-time coordination of movement (which excludes nearly everything)

. . . also, subjects can't move in the scanner as this disrupts the signal.

SO fMRI is only suitable for abstract forms of coordination, e.g. in playing prisoner's dilemma games.

The normal game is shown below:

	Prisoner B stays silent (*cooperates*)	**Prisoner B betrays (*defects*)**
Prisoner A stays silent (*cooperates*)	Each serves 1 year	Prisoner A: 3 years Prisoner B: goes free
Prisoner A betrays (*defects*)	Prisoner A: goes free Prisoner B: 3 years	Each serves 2 years

Source: wikipedia

Challenges of hyperscanning (2):

EEG and NIRS both provide much better temporal resolution, and in each case, subjects are free to move.

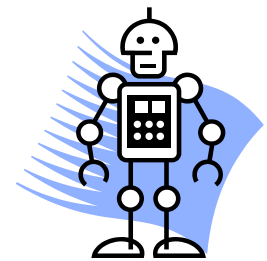
BUT, spatial resolution is lousy, and signals are very very very weak.

Much work is currently focussed on developing ways to combine various methodologies.

Brain-Computer Interfaces

- Communication, e.g. for severely immobilized (ALS)

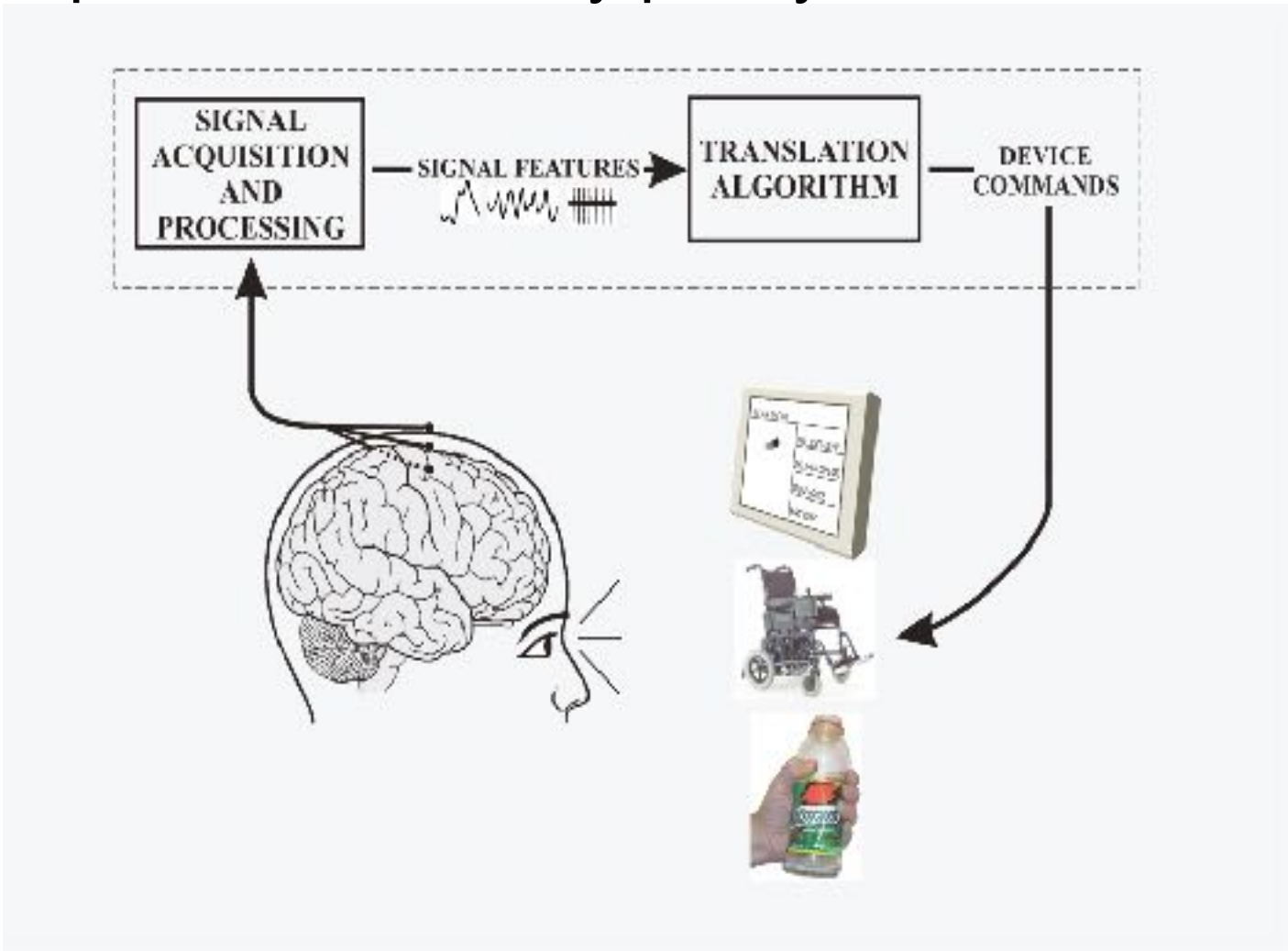
- Mobility

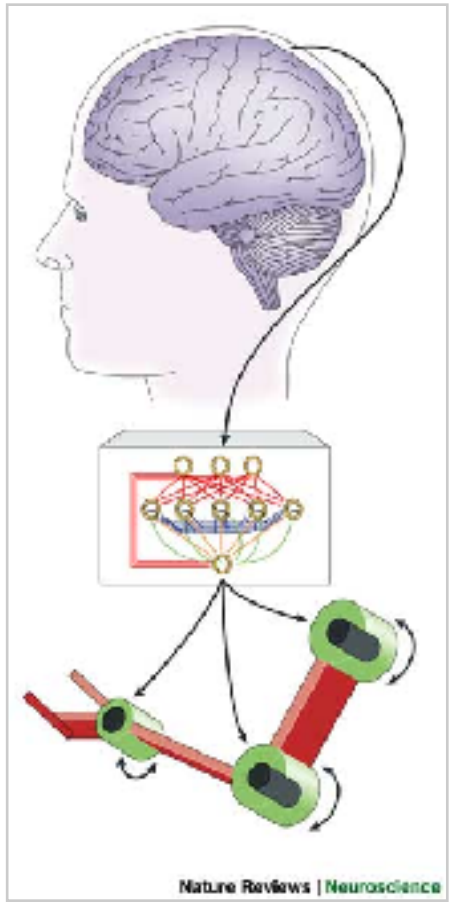


- Neuroprosthetics

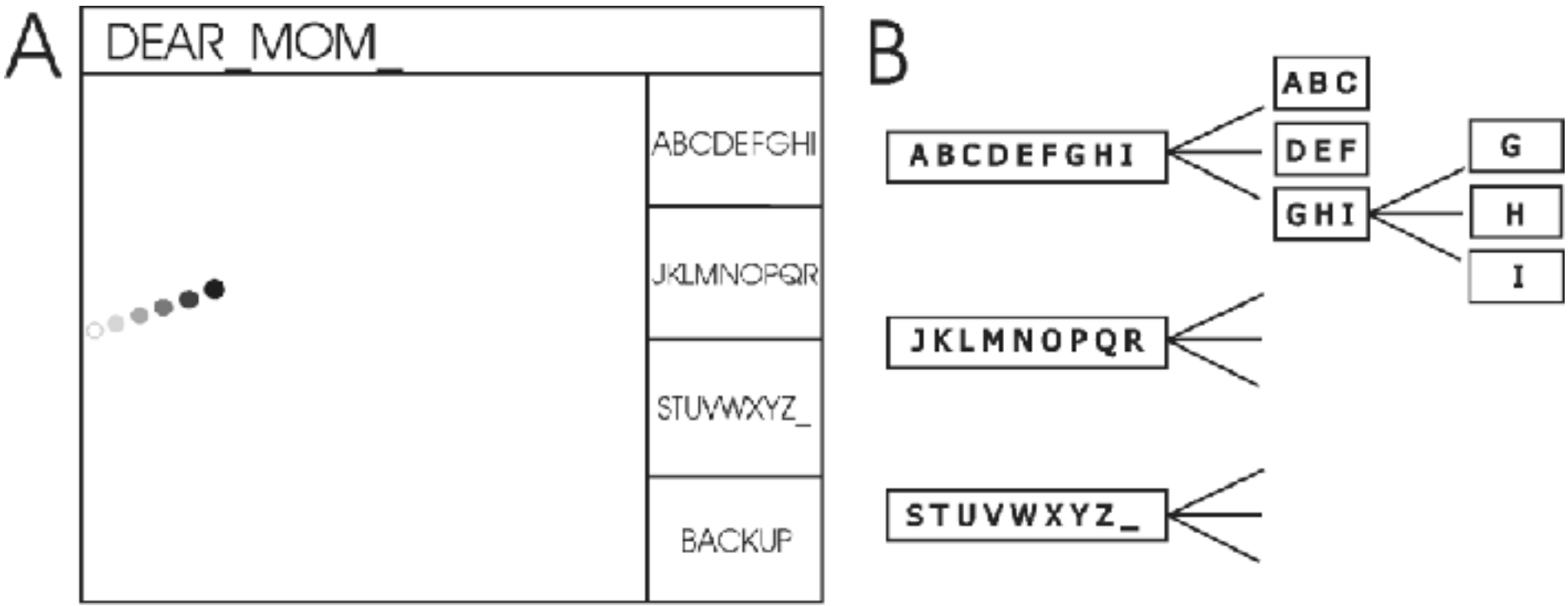
- Entertainment
- Military use

- Uses brain signals to convey intent
- Does not use peripheral nerves or muscles
- Can provide communication and control to people who are totally paralyzed



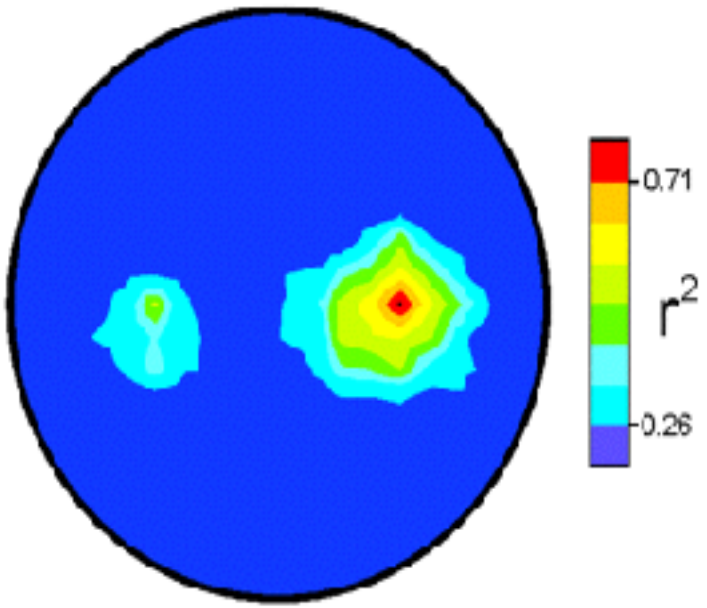


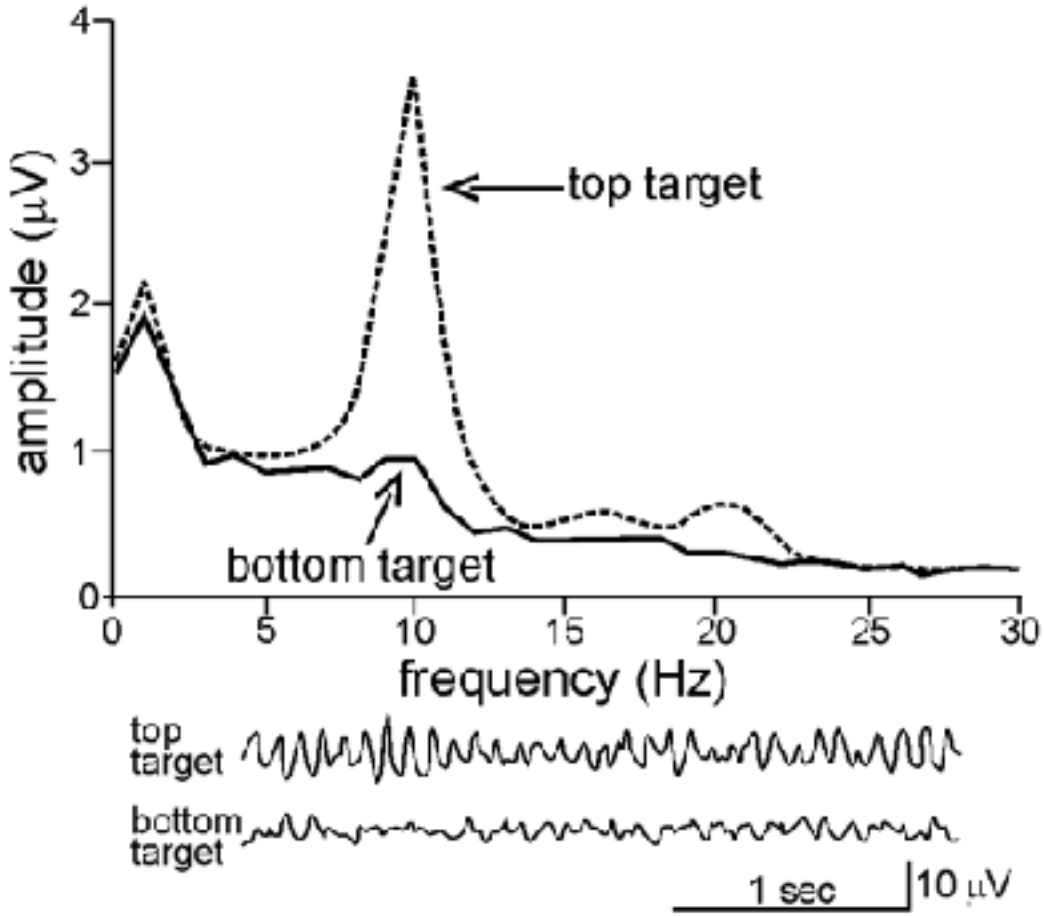
Progress so far...



EEG signals make a 1-bit discrimination: top or bottom target

1-bit communication is sssllllloooooooowwww





- An infant science
- Non-invasive techniques preferred
- The imagination runs much faster than the technology

Things to think about

- We are trying to understand both WHAT the brain does and HOW it does it
- With so much ignorance, convergent evidence is much more satisfying than single study results
- Phrenology made the mistake of over-localizing function in the brain
- We ought not to repeat that mistake!!!