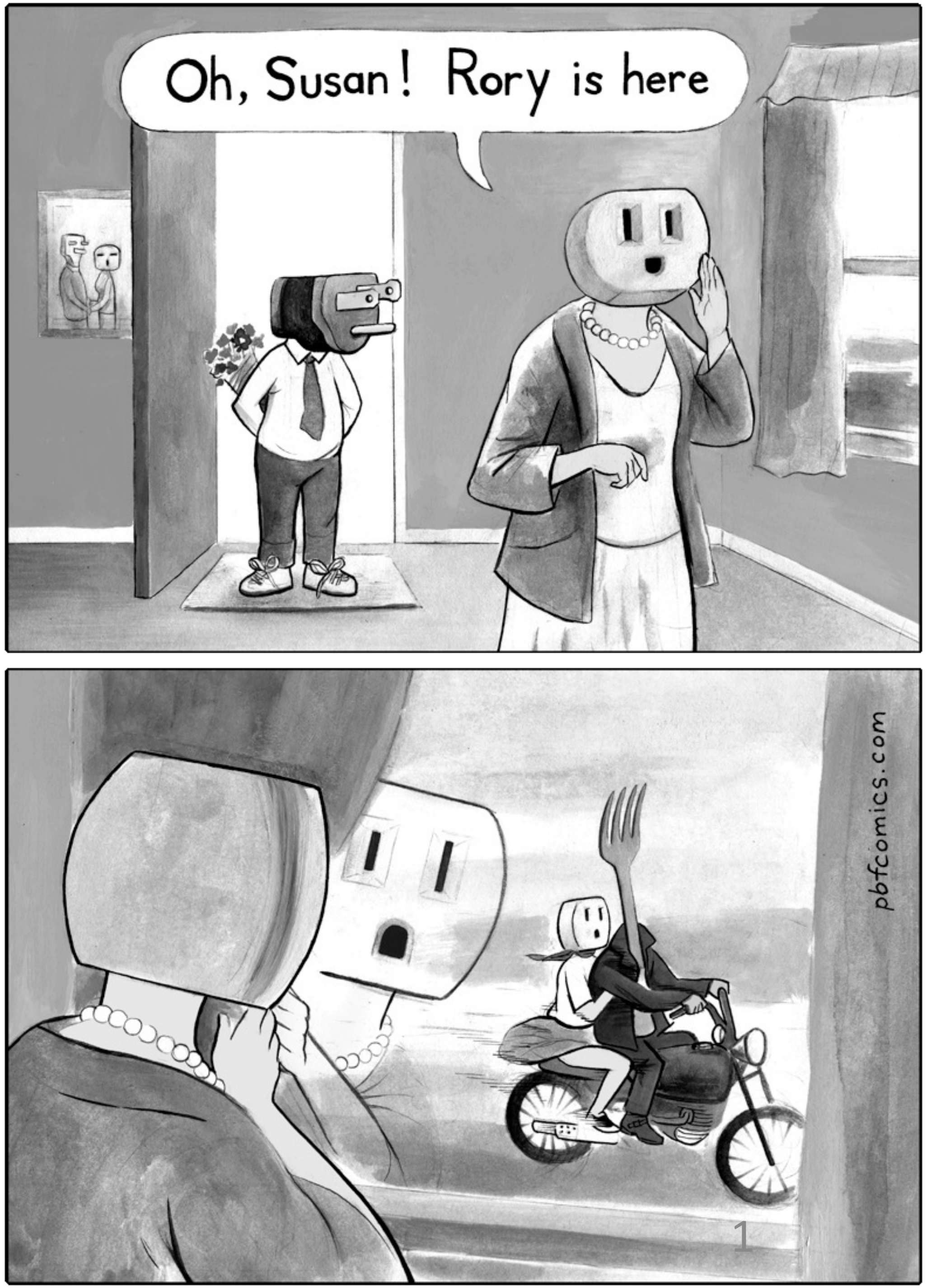
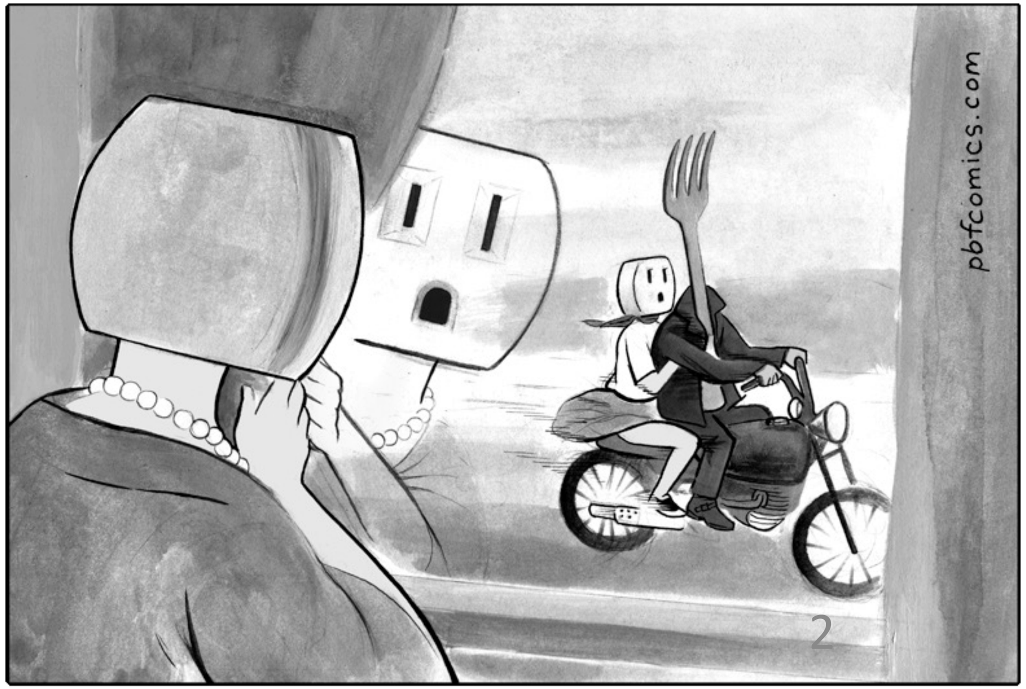
PSYC301: Neuroimaging (structural and functional)

Jay Hosking, PhD

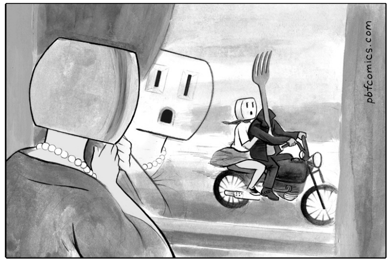


Overview

A. Structural brain imaging
B. Functional brain imaging
C. Thinking critically about functional brain imaging



Learning objectives



1. Describe the fundamental difference between structural and functional neuroimaging. What sorts of research questions can be addressed with structural neuroimaging? What sorts of research questions can be addressed with functional neuroimaging?
2. Describe and compare the different methods of structural brain imaging that are listed in this lecture.
3. Explain how an MRI machine works.
4. Describe and compare the different methods of functional brain imaging that are listed in this lecture.
5. Explain how PET and fMRI work.
6. In a single sentence, be able to discuss each of the many challenges involved in interpreting functional brain imaging data.
7. (Required) Read the paper by Owen (2014) posted on the main course page. It is a pop-science article, so I expect you to understand all of the material. Critically, though: Identify and describe the patient population in this article. Describe the methodological approach by Owen to solve these patients' dilemma. Describe the results of these studies.

X-Ray

Seeing through a living body is the stuff of science fiction!

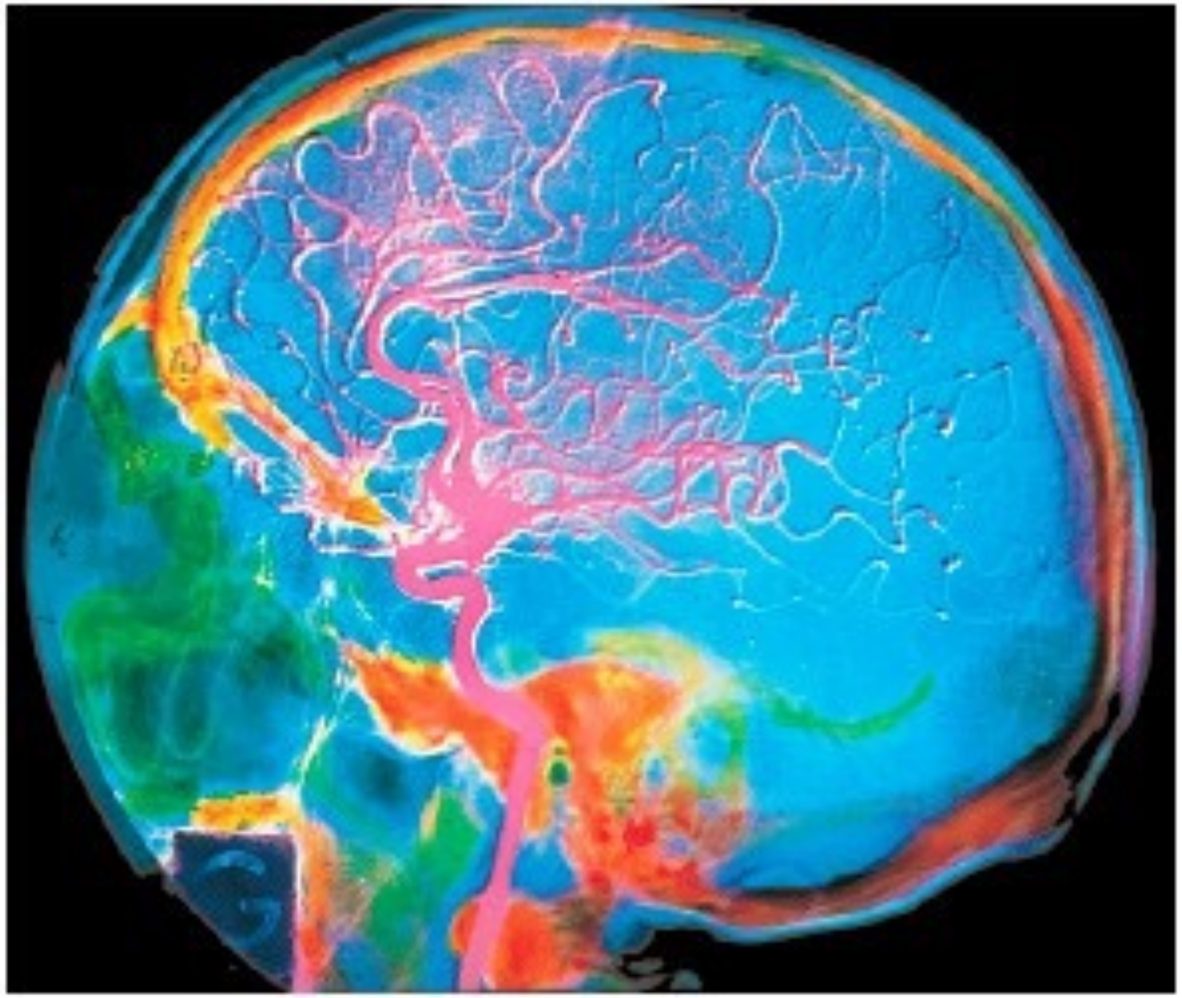
X-ray tube, X-ray beam, film (or detectors)

But what can be seen?

Structural imaging

Cerebral Angiography

Medical Body Scans/Science Source.



i.e. an *angiogram*

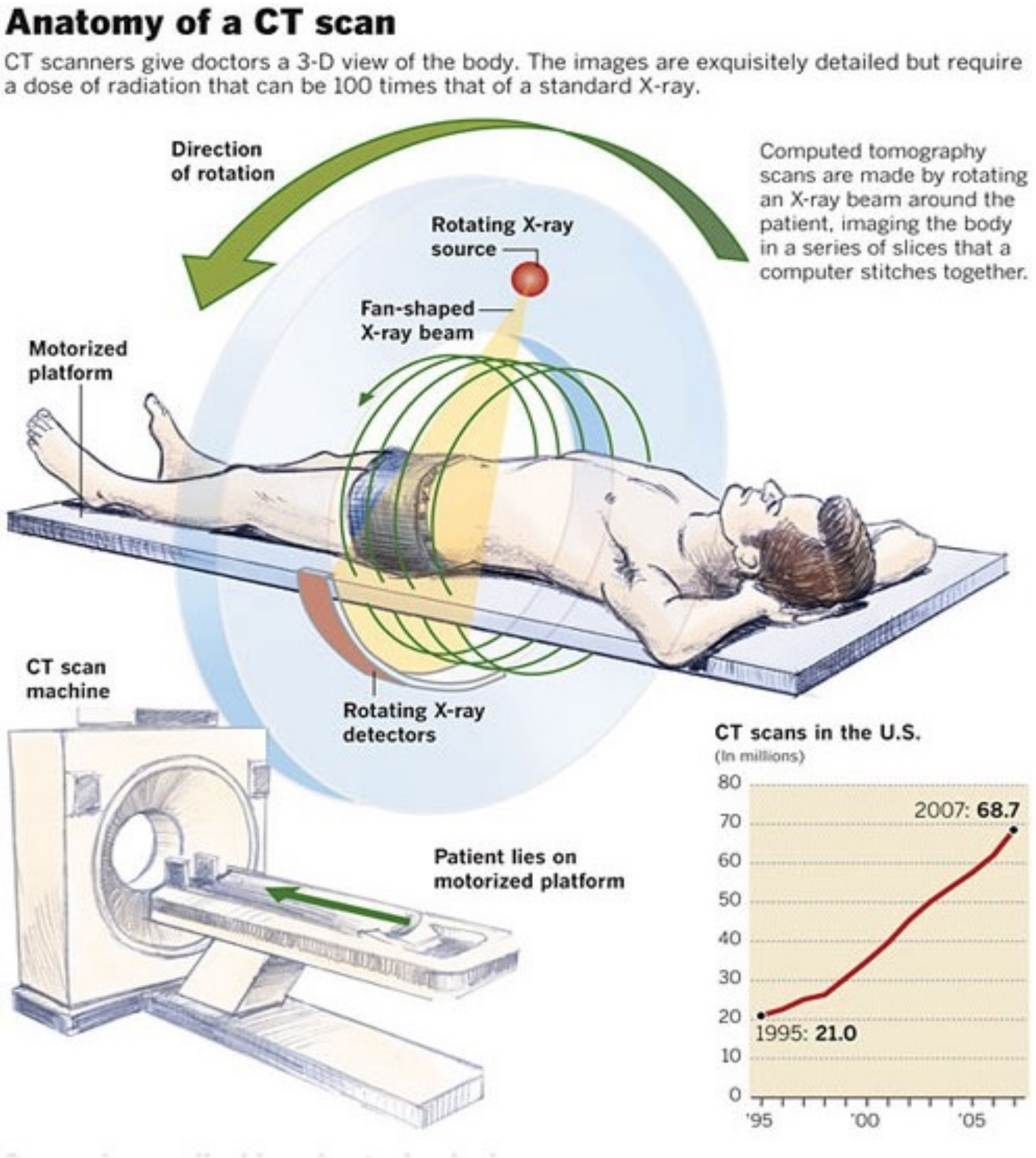
This is a *contrast X-ray technique*

Useful for?

Computed tomography (CT)

The tube and detector

Computed tomography (CT)

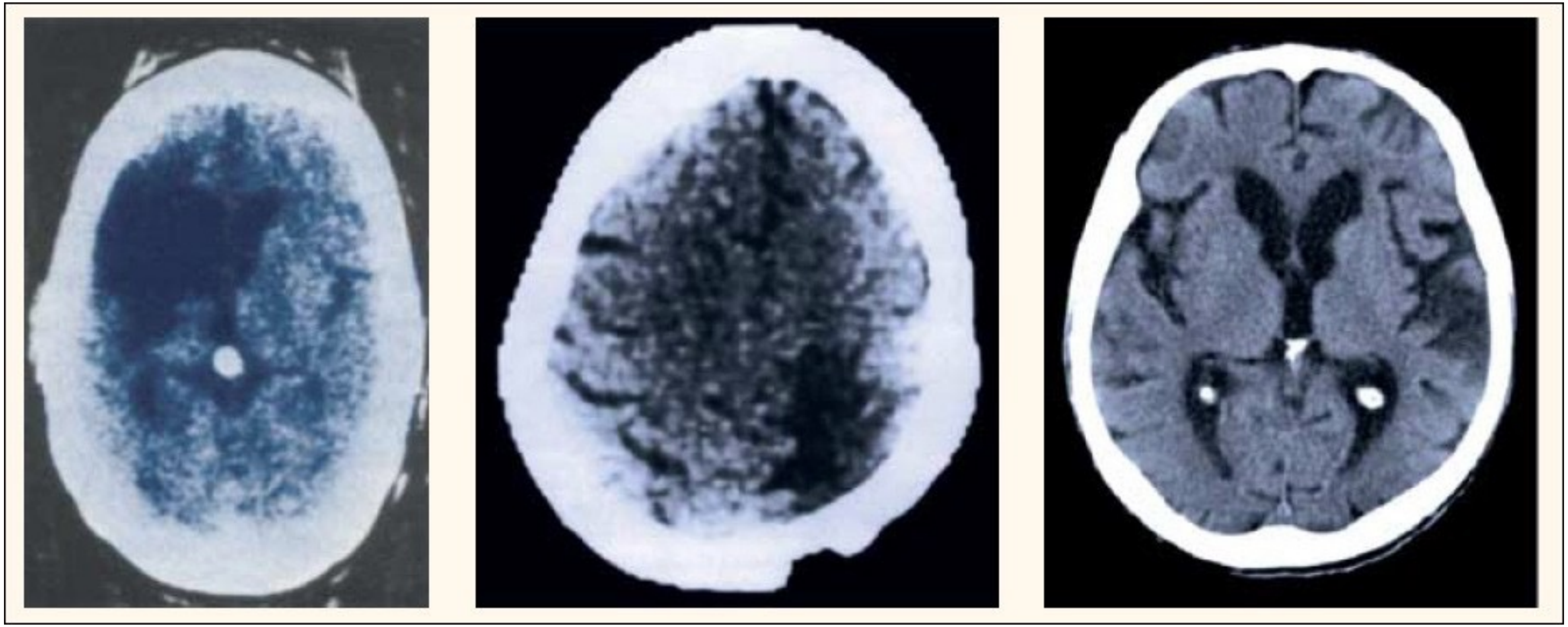


Overcoming limitations of traditional X-ray

"Reconstruction"

Computed tomography (CT)

Rorden & Karnath, 2004



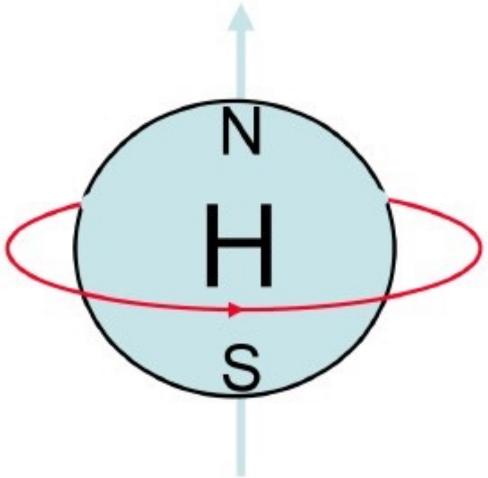
1977 1983 2004

Only as good as its algorithms

Useful for?

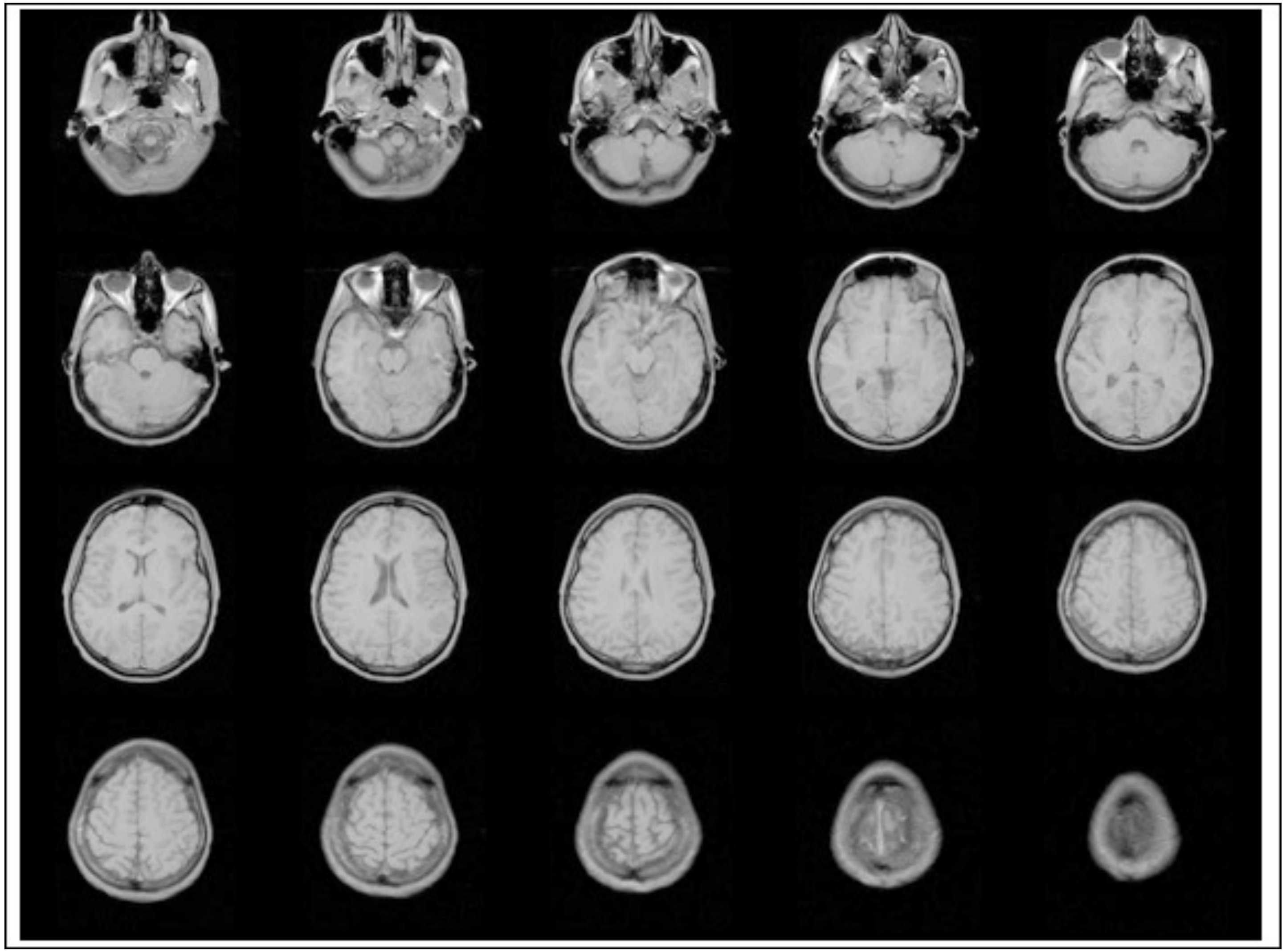
Drawbacks?

Magnetic Resonance Imaging (MRI)



https://www.youtube.com/watch?v=6BBx8BwLhqg

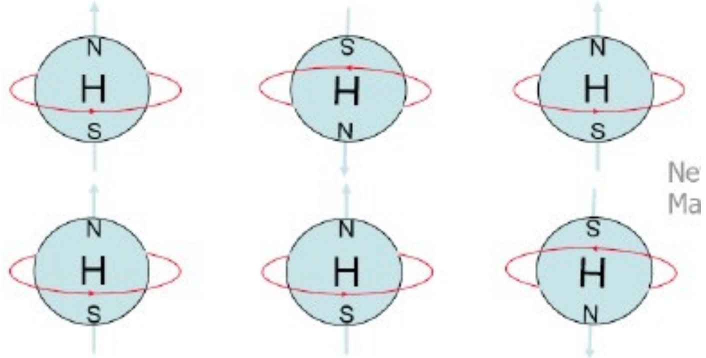
Magnetic Resonance Imaging (MRI)



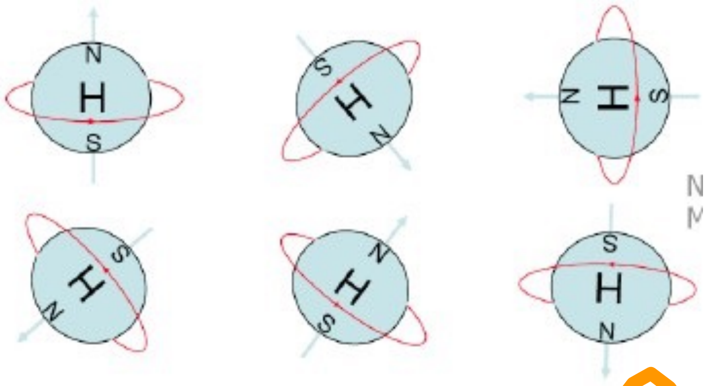
Structural imaging

MRI

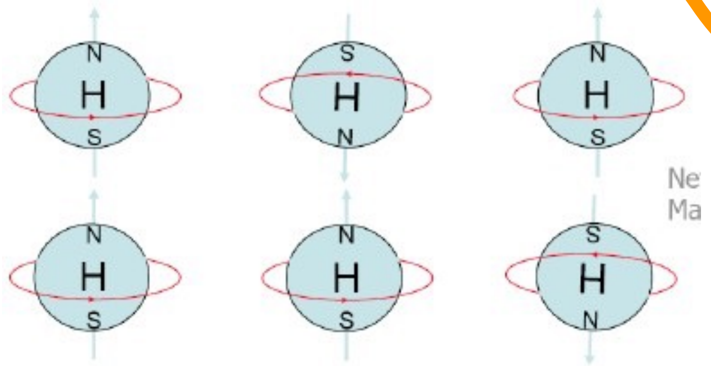
Step one:
Align all the protons with the large magnetic field.



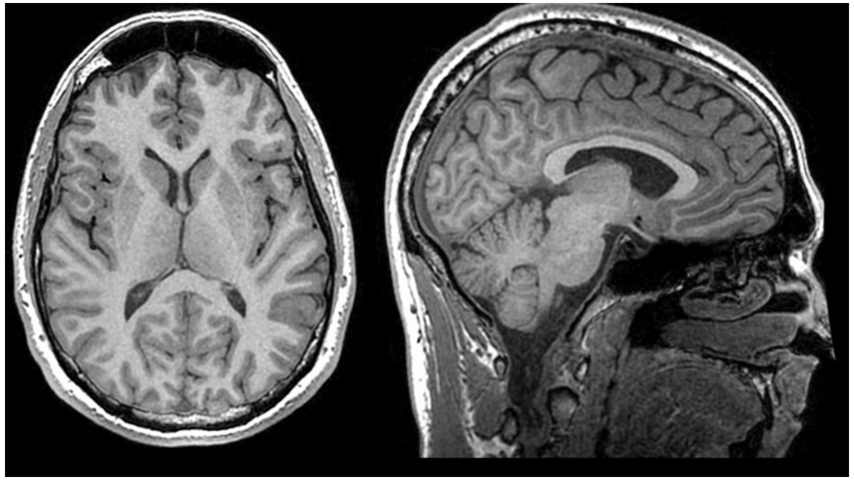
Step two:
Momentarily perturb that alignment with a second varying magnetic field.



Step three:
Measure radiofrequency (RF) signal produced during realignment with the large magnetic field ('relaxation').



RF signal

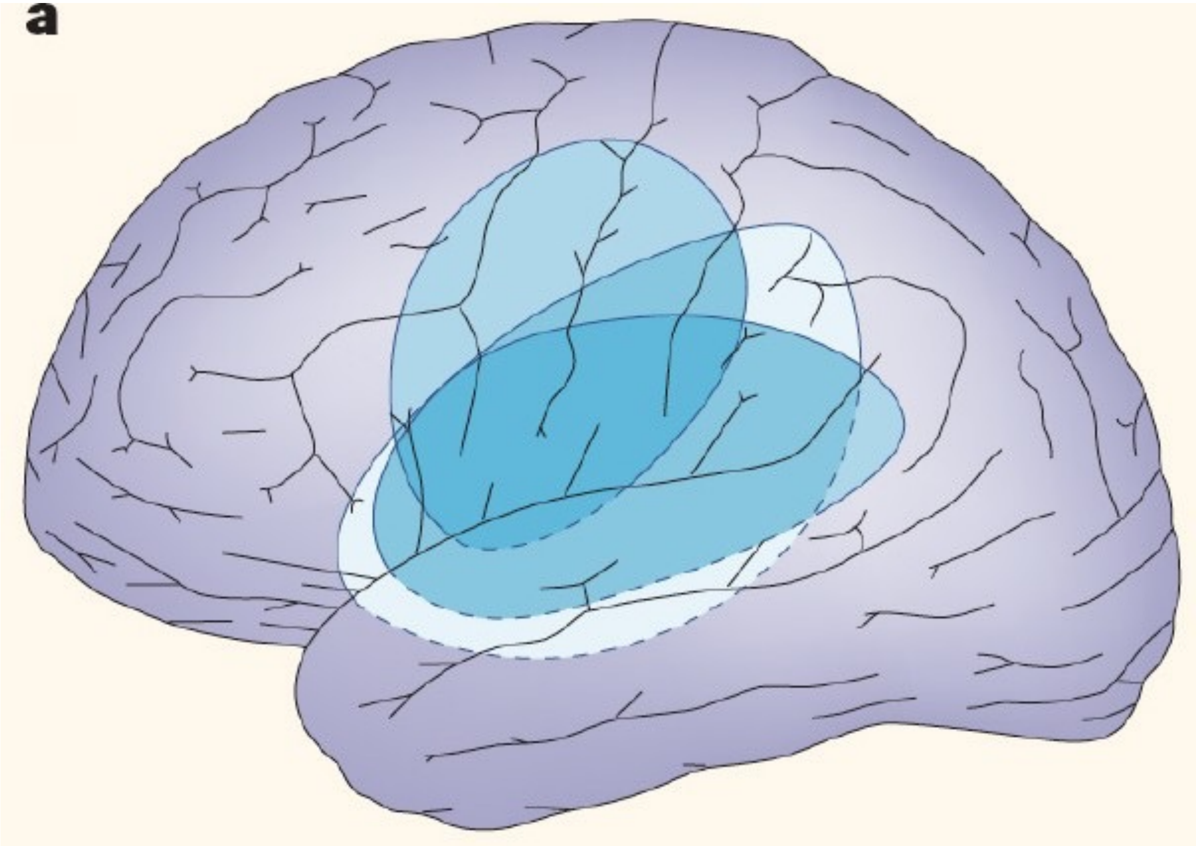


Structural imaging

Magnetic Resonance Imaging (MRI)

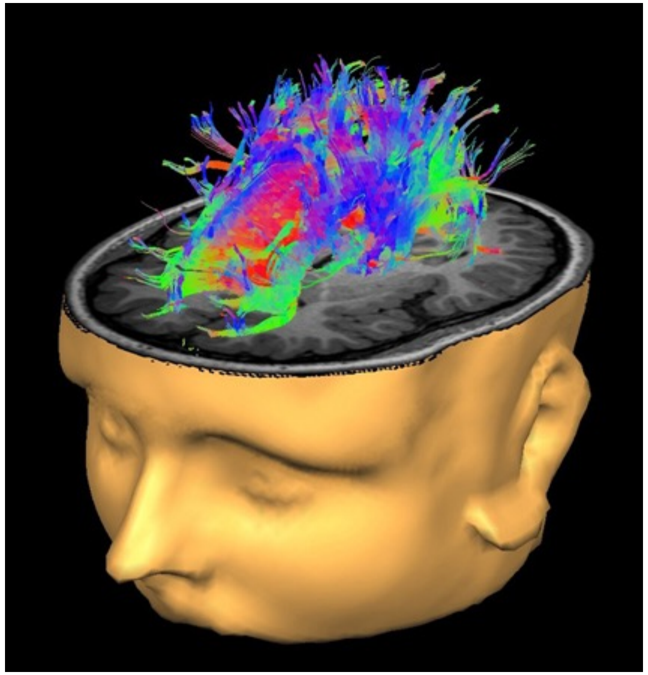
Structural imaging

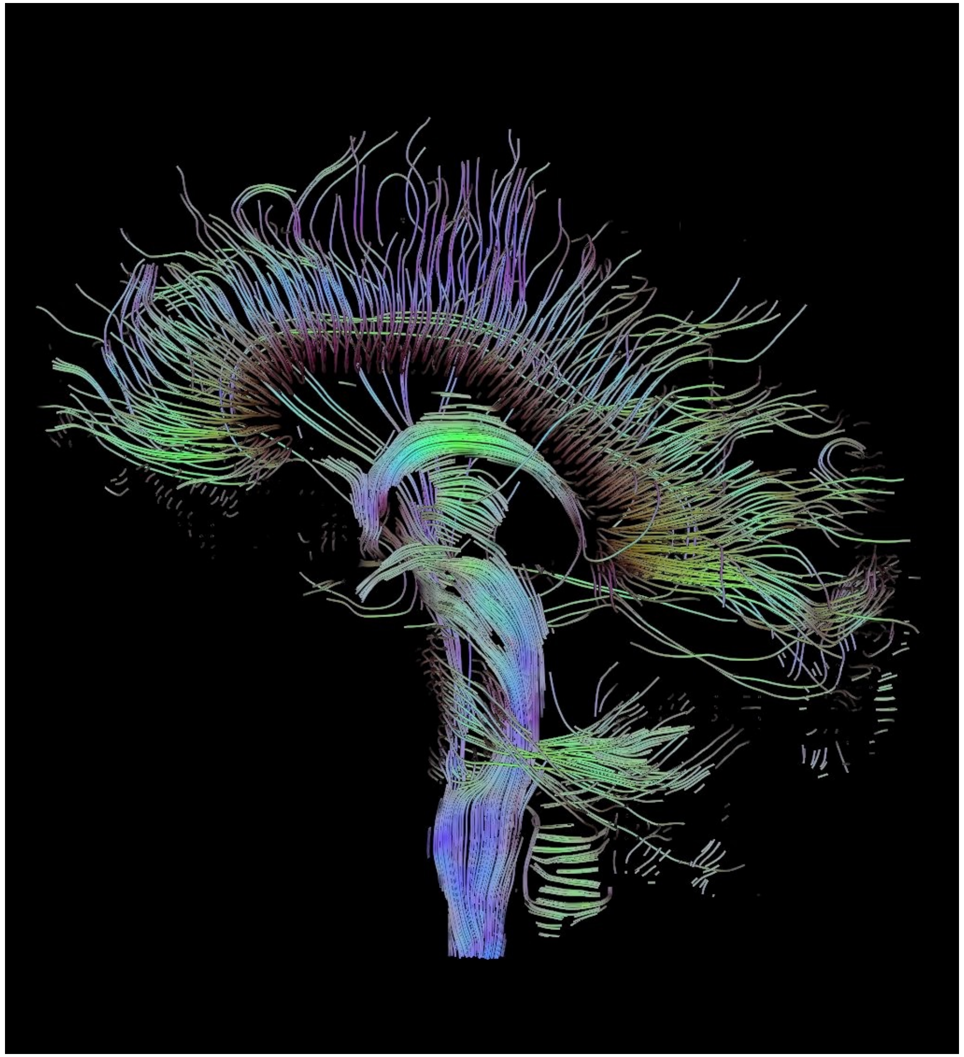
MRI

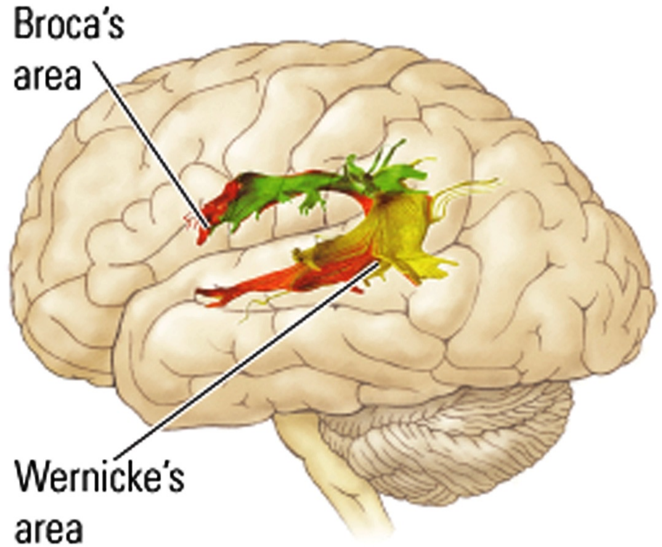


Example of an **overlay plot** (from Rorden & Karnath, 2004)
Advantage over traditional lesion studies?
https://www.ncbi.nlm.nih.gov/pubmed/15378041

Diffusion Tensor Imaging (DTI)



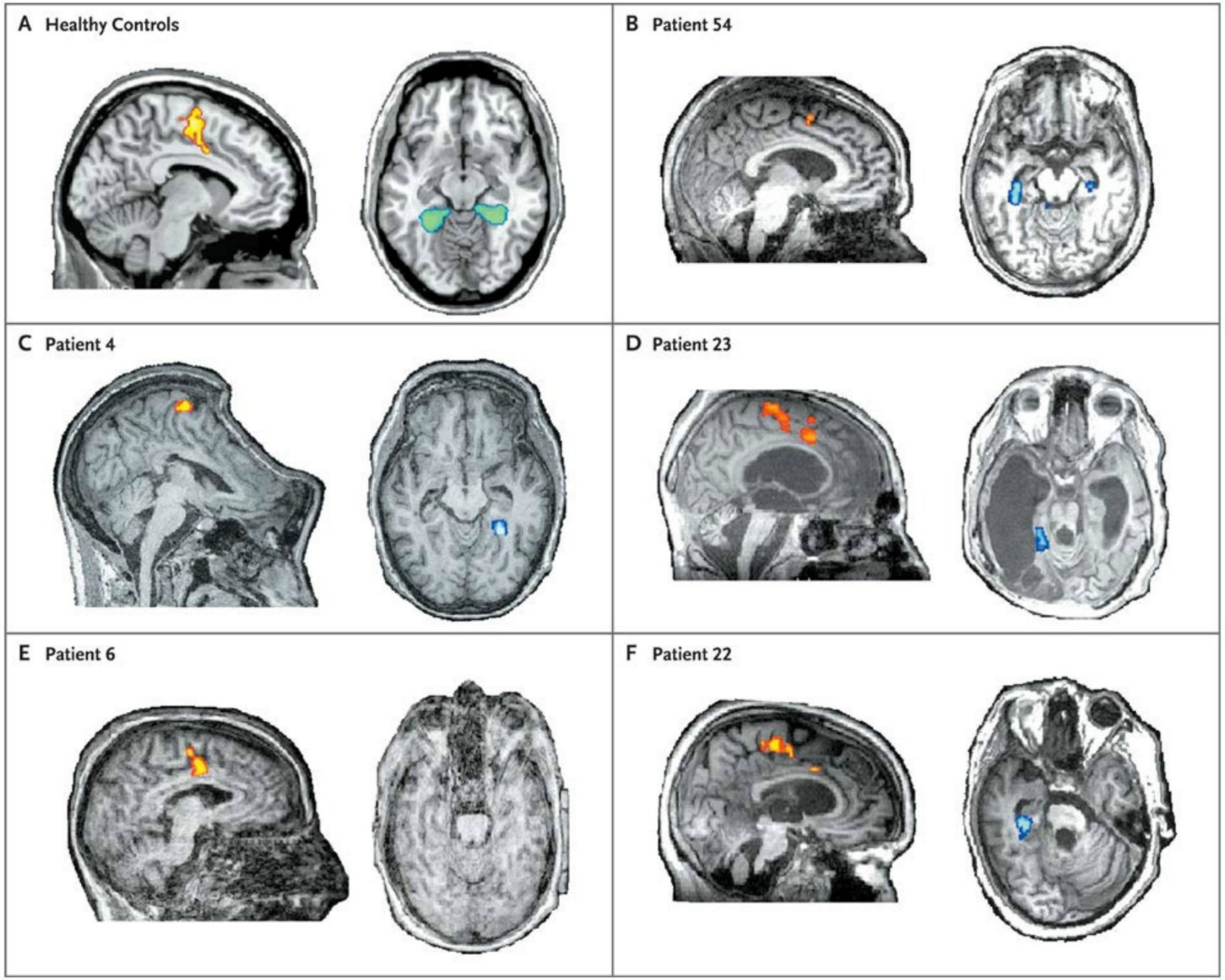




- Variant of MRI
- Relies on how water molecules move in brain
- Useful for?

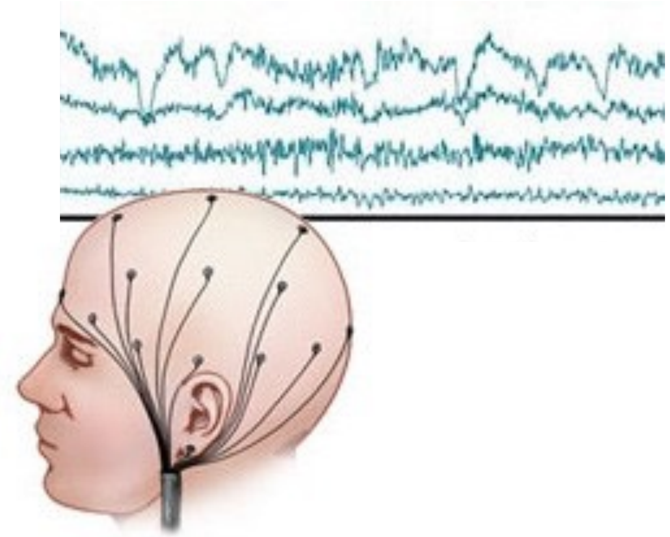
Image from: https://upload.wikimedia.org/wikipedia/com- mons/8/82/DTI-sagittal-fibers.jpg

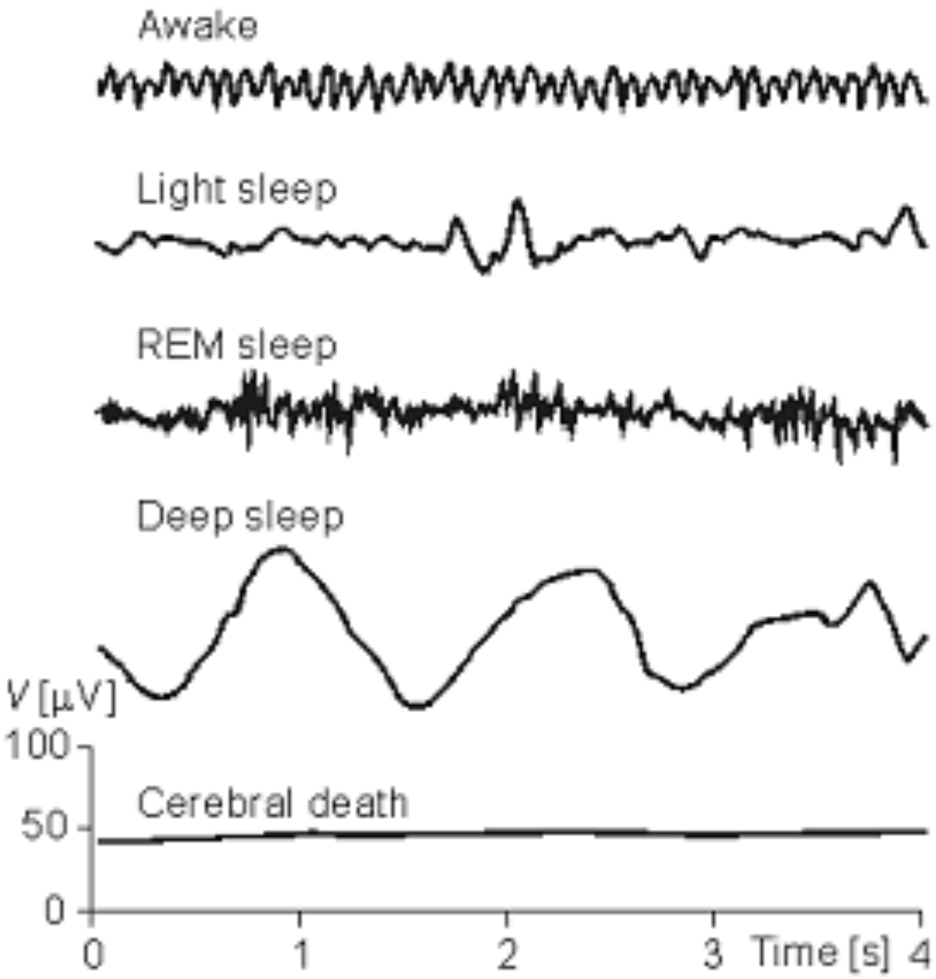
Adrian Owen’s research
(read the paper!)



Functional imaging

Electroencephalography (EEG)

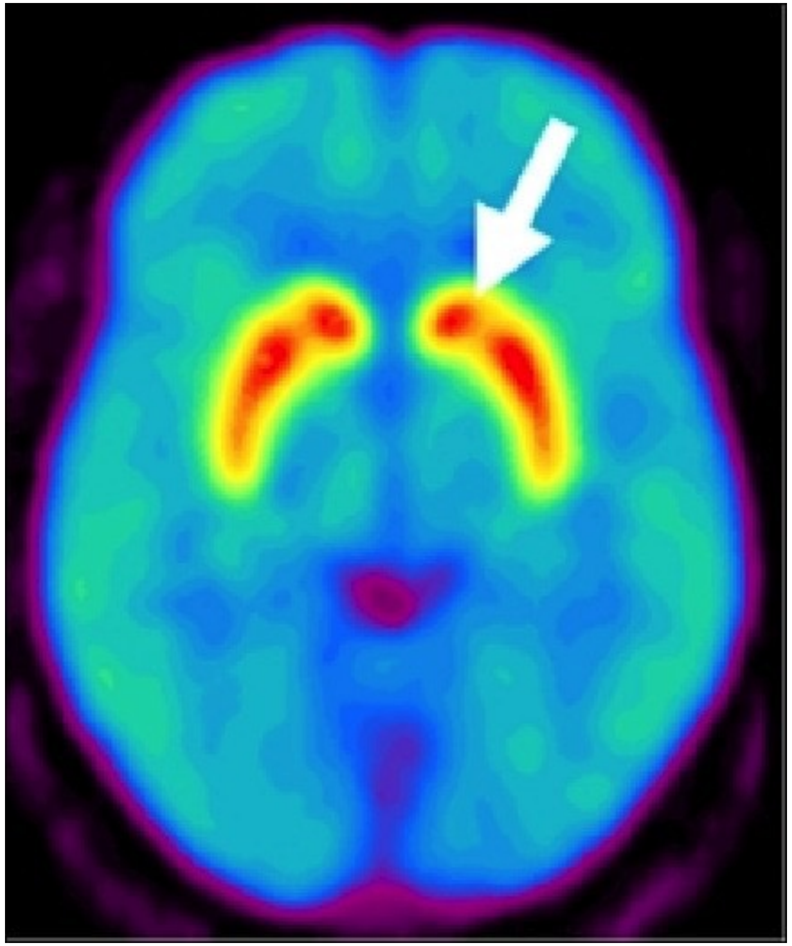




Alpha = 8-12 Hz
Beta = 12-30 Hz
Gamma = 26-100 Hz
Delta = 0-3 Hz
Theta = 4-7 Hz
Mu = 8-12 Hz (over motor areas)

*you aren't responsible for knowing these numbers

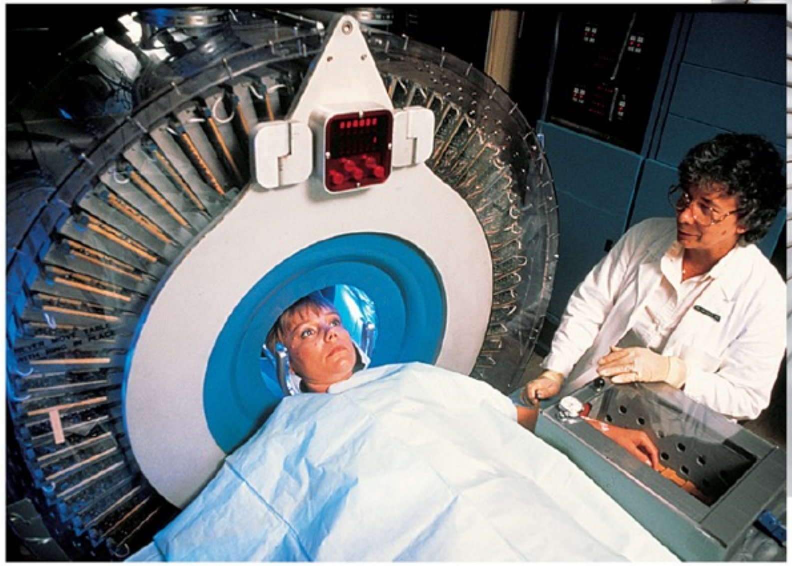
Positron Emission Tomography (PET)

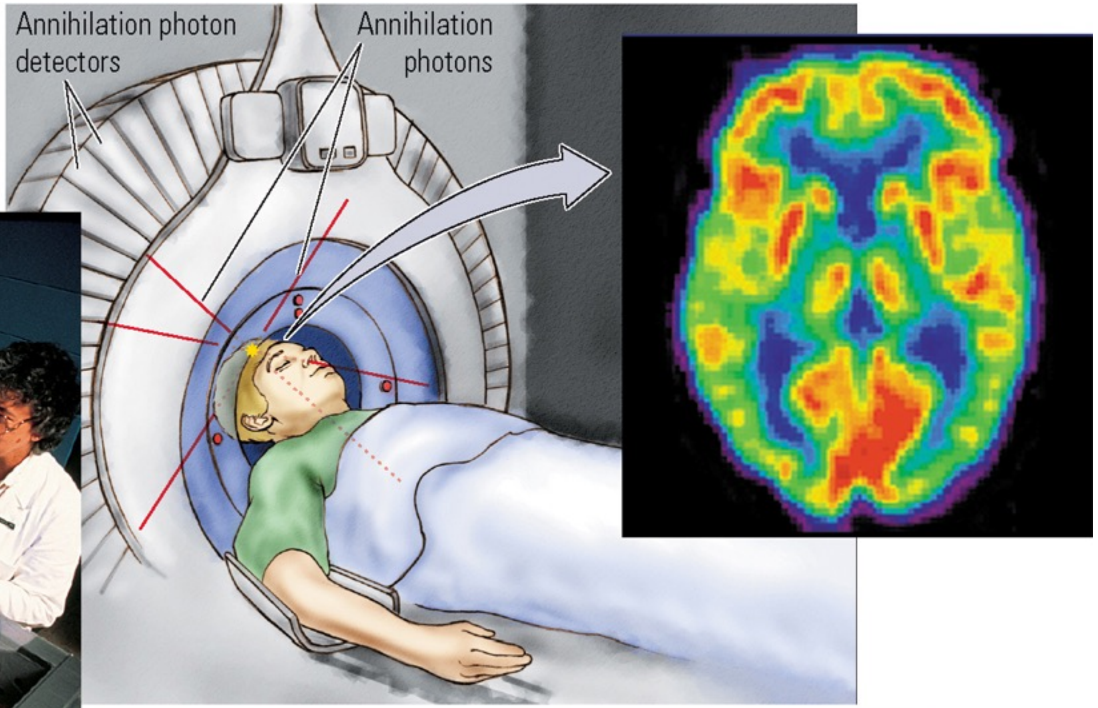


PET using radiolabelled cocaine (from Shumay et al., 2011)

PET

A small amount of radioactively labeled water is injected into a subject. Active areas of the brain use more blood and thus have more radioactive labels.



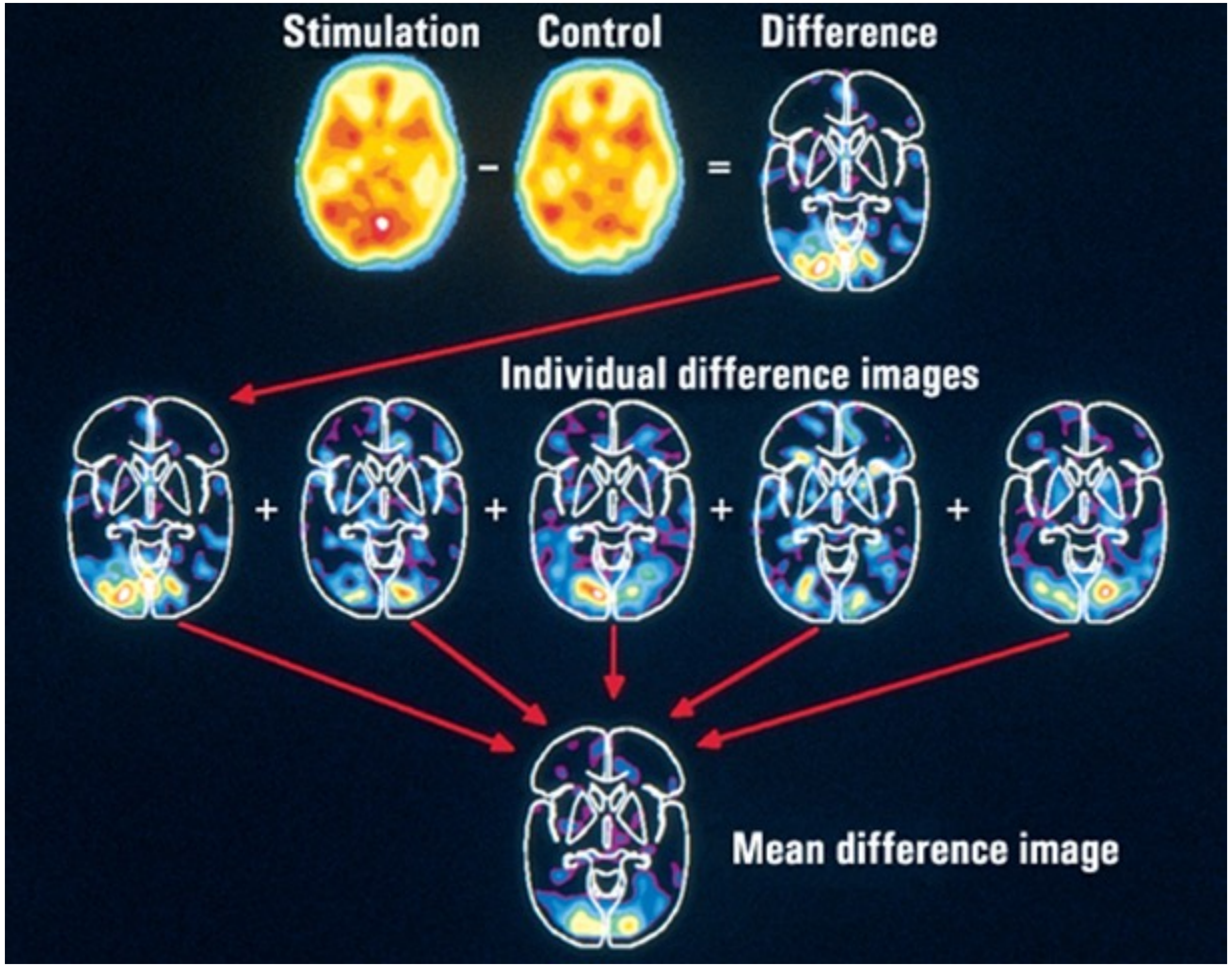


Positrons from the radioactivity are released; they collide with electrons in the brain, and photons (a form of energy) are produced, exit the head, and are detected.

PET scanner from Hank Morgan/Science Source; PET scan from Science Source.

- Indirect measure (as is fMRI)
  - Meaning? Potential issues?

Mean difference images



- Subtraction method / mean difference images (similar for some fMRI)
  - Potential issues?

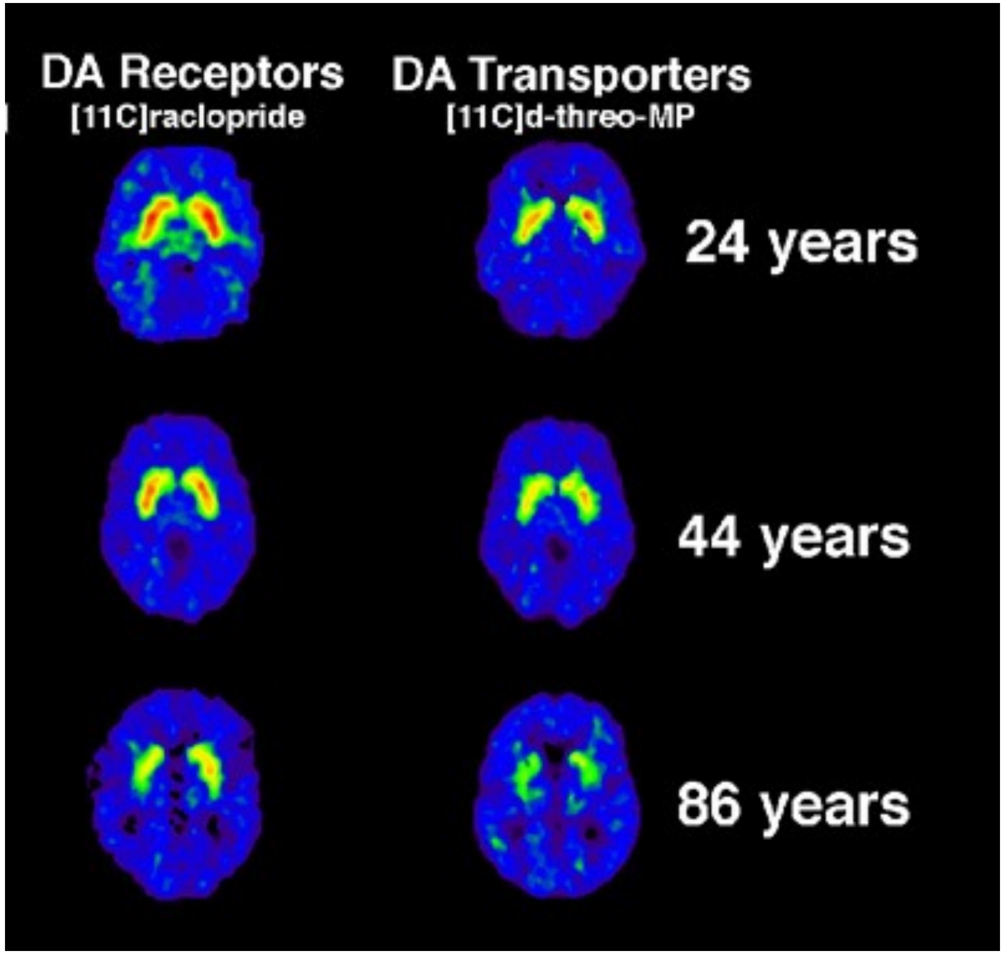
cyclotron

PET: less common now, but…

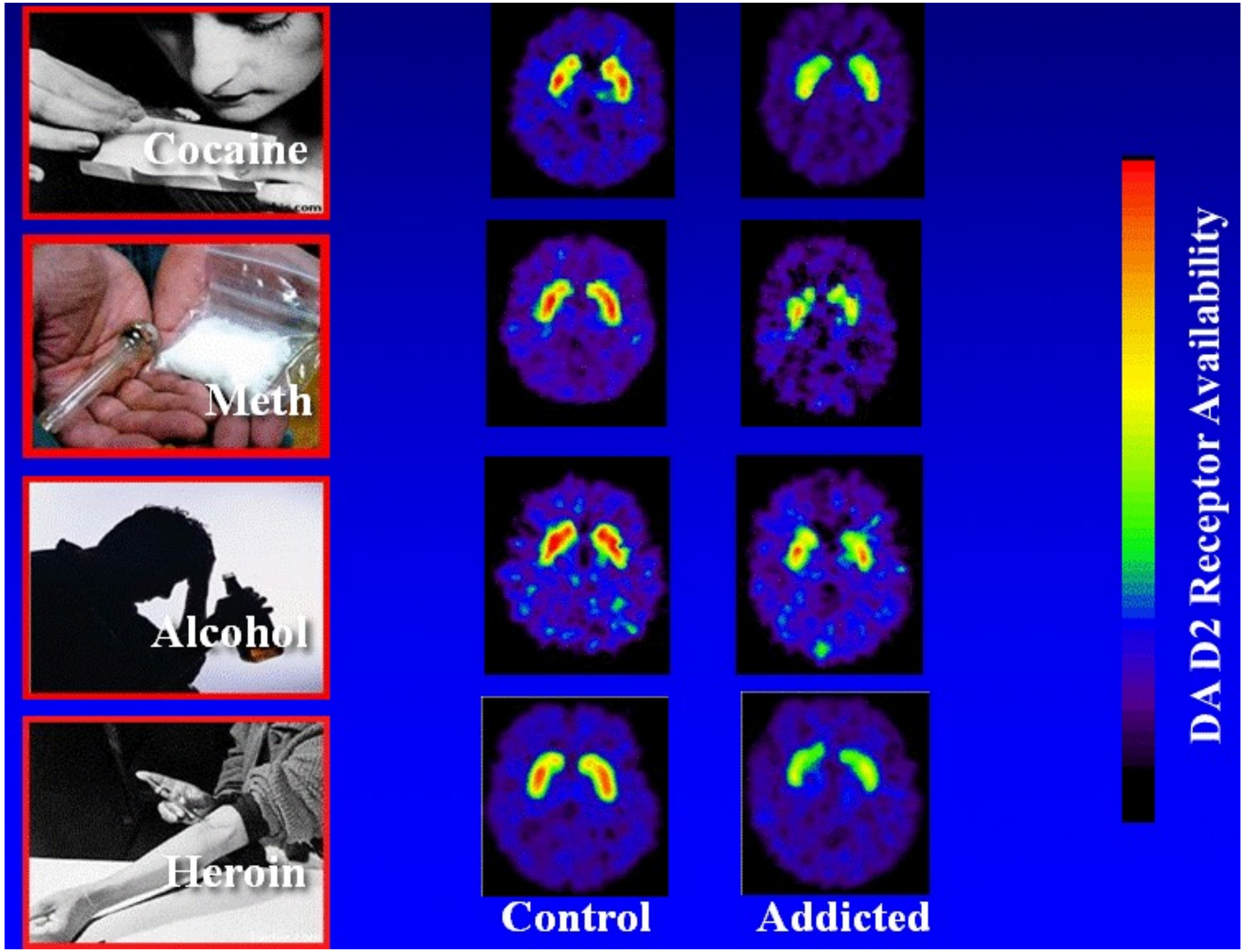
- Very expensive
- Temporally slow
- Poor spatial resolution

BUT

- Useful for looking at specific systems (e.g. DA) or proteins (tau)
- Useful for looking at lifespan/condition changes (e.g. stroke, maybe CTE?)

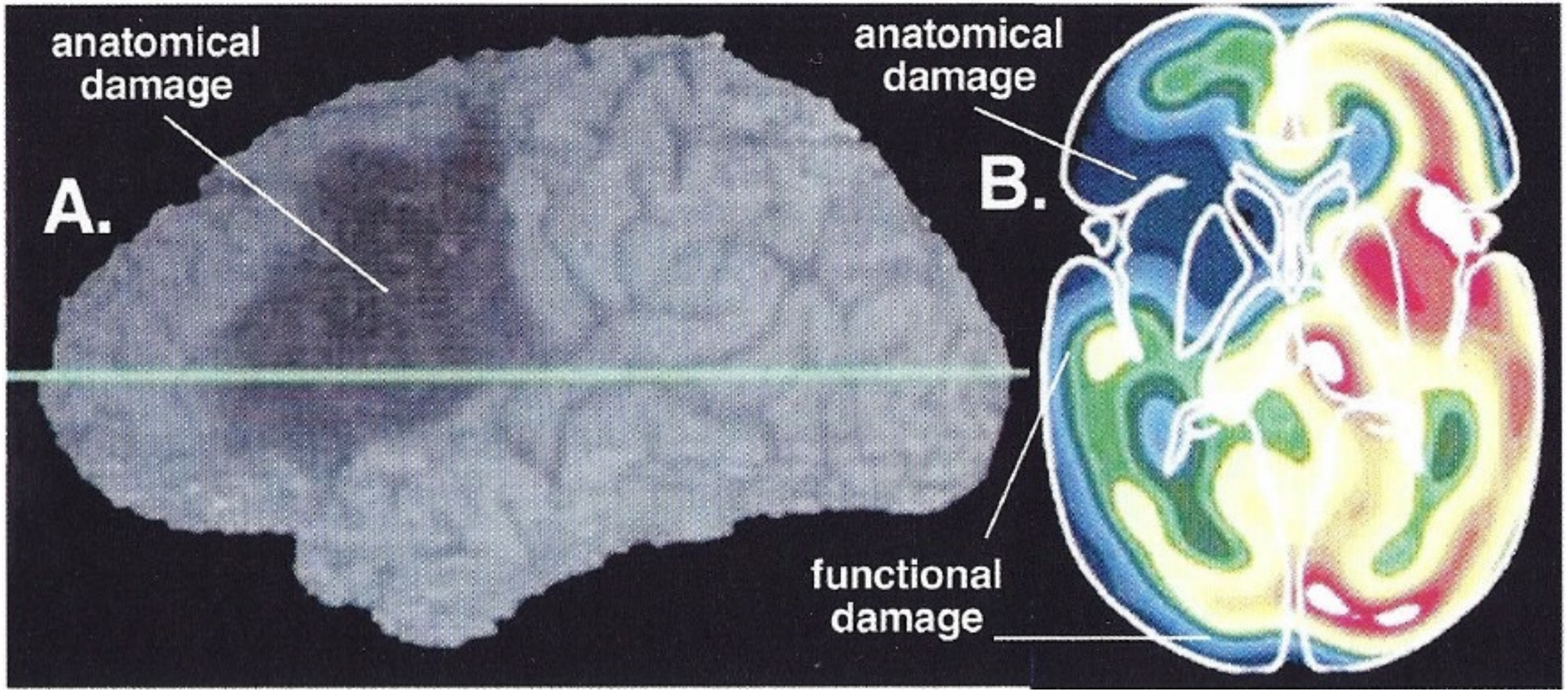


PET: dopamine D_2 receptors decreased by addiction

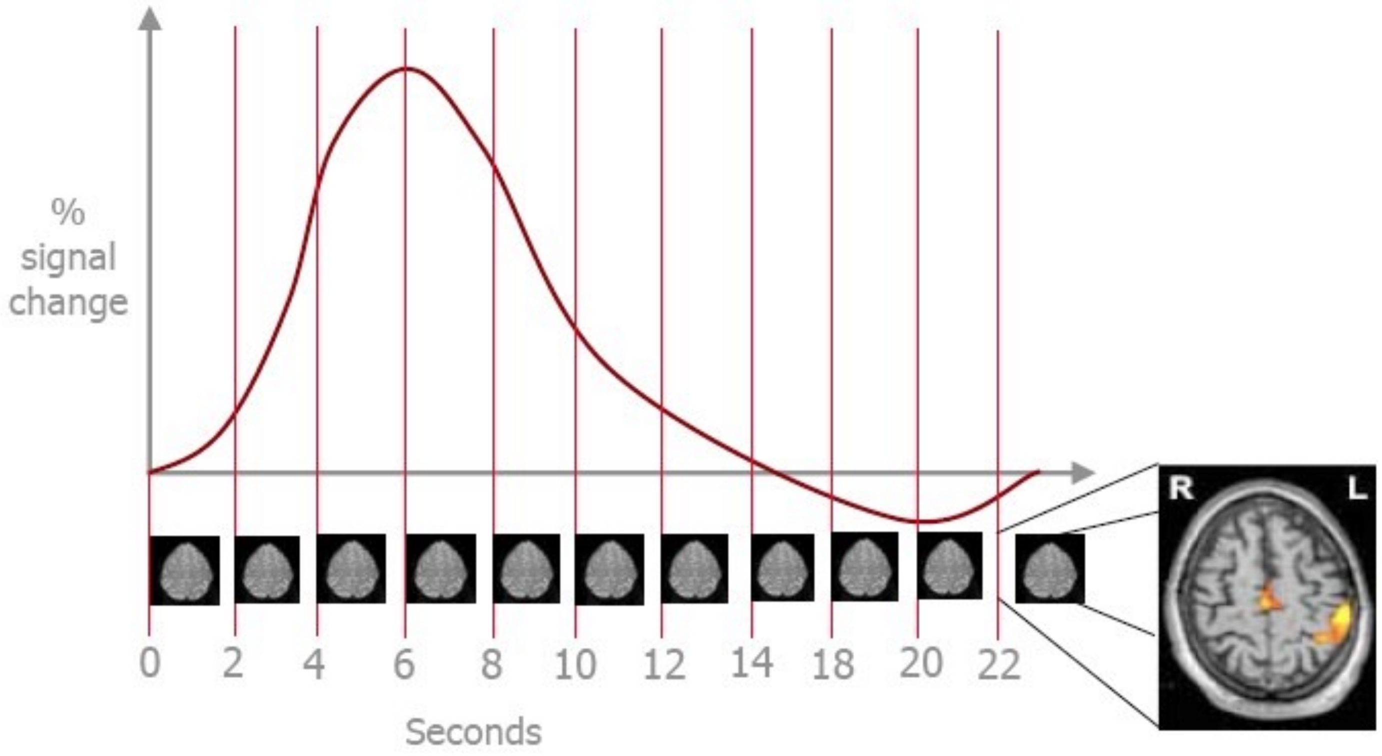


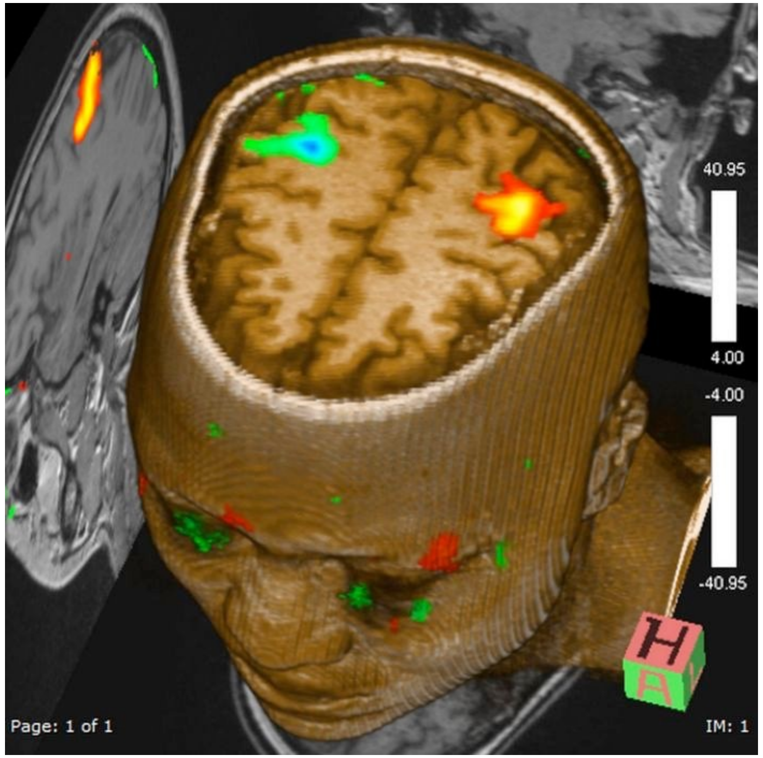
Functional imaging

Using PET to image diaschisis



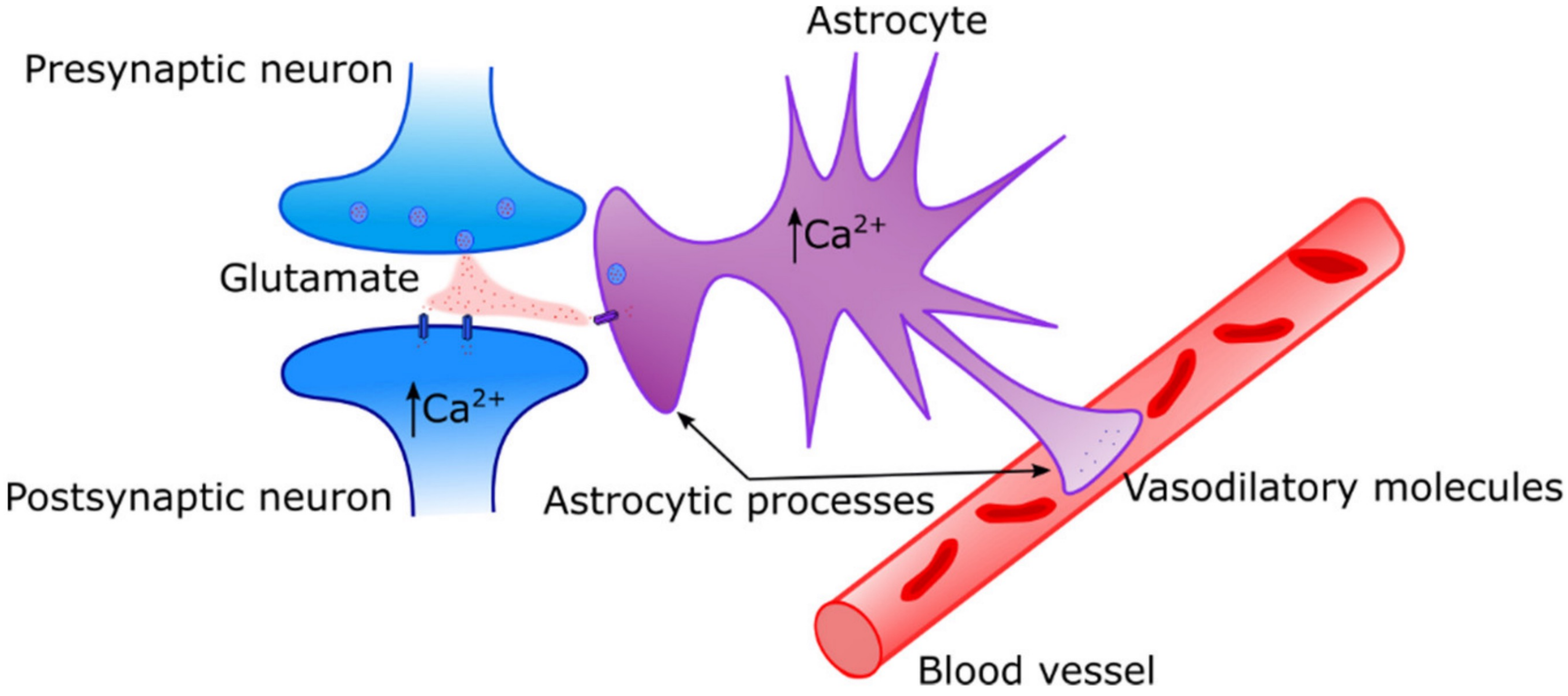
Functional MRI (fMRI): the BOLD response



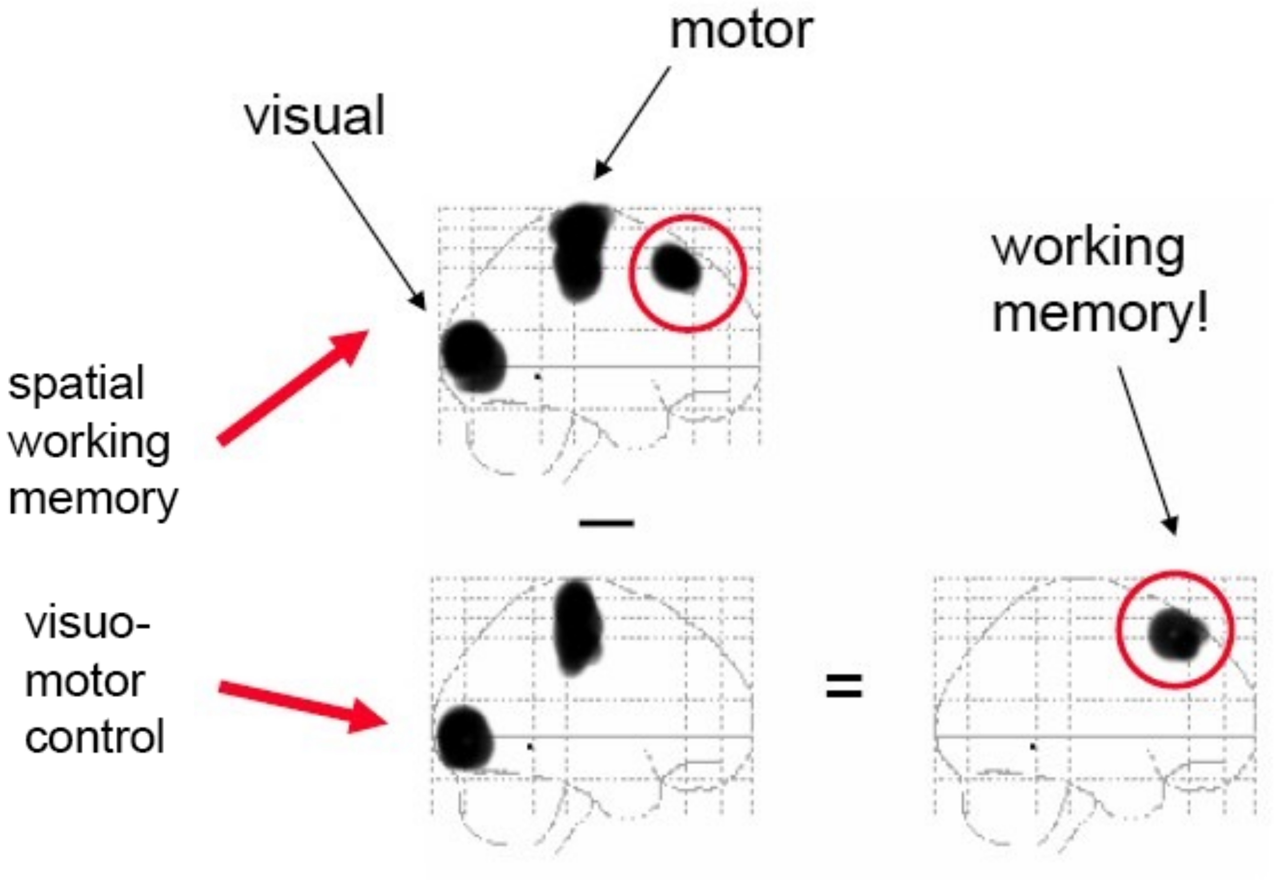


Hemodynamic response

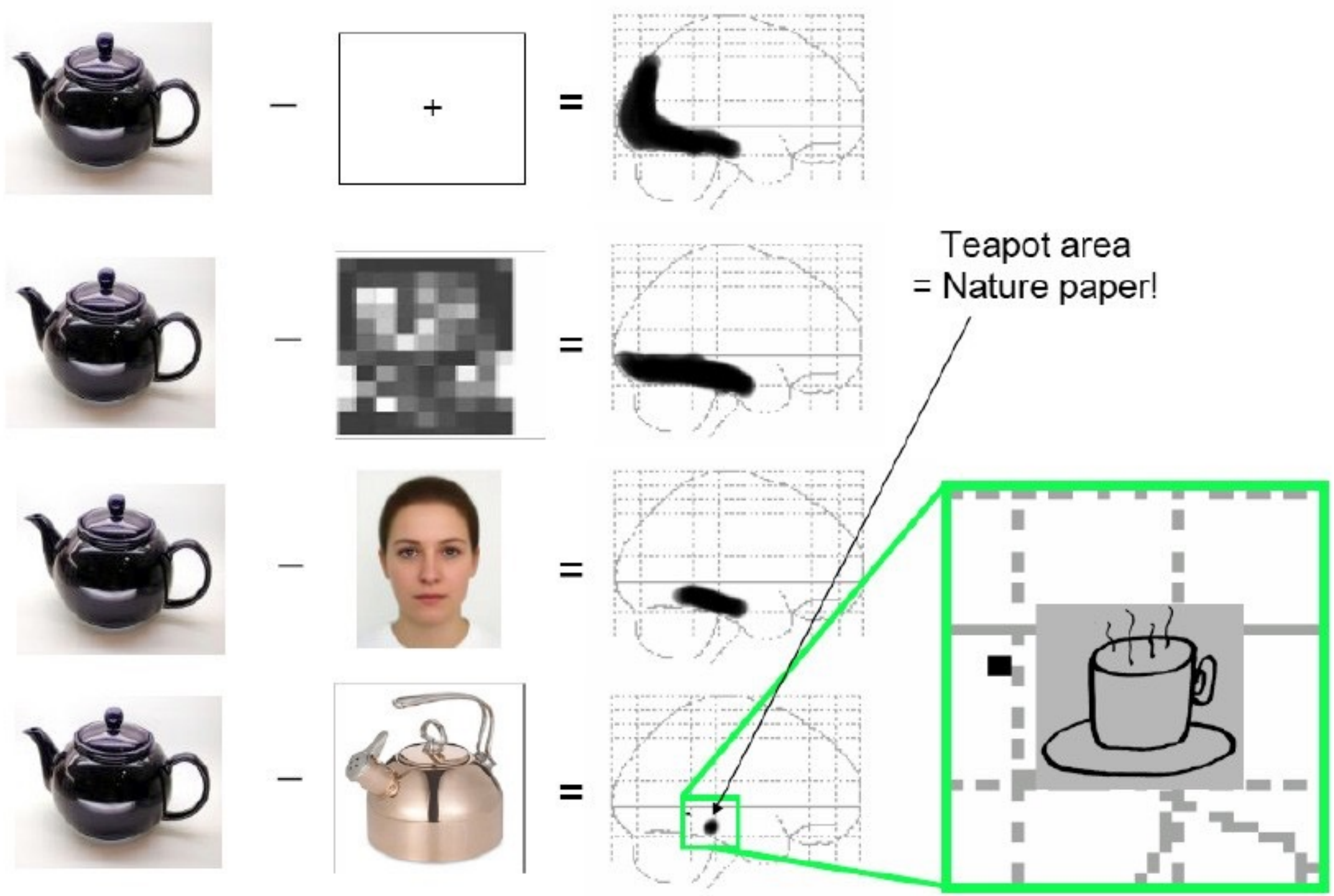
fMRI: BOLD response



Paired Image Subtraction



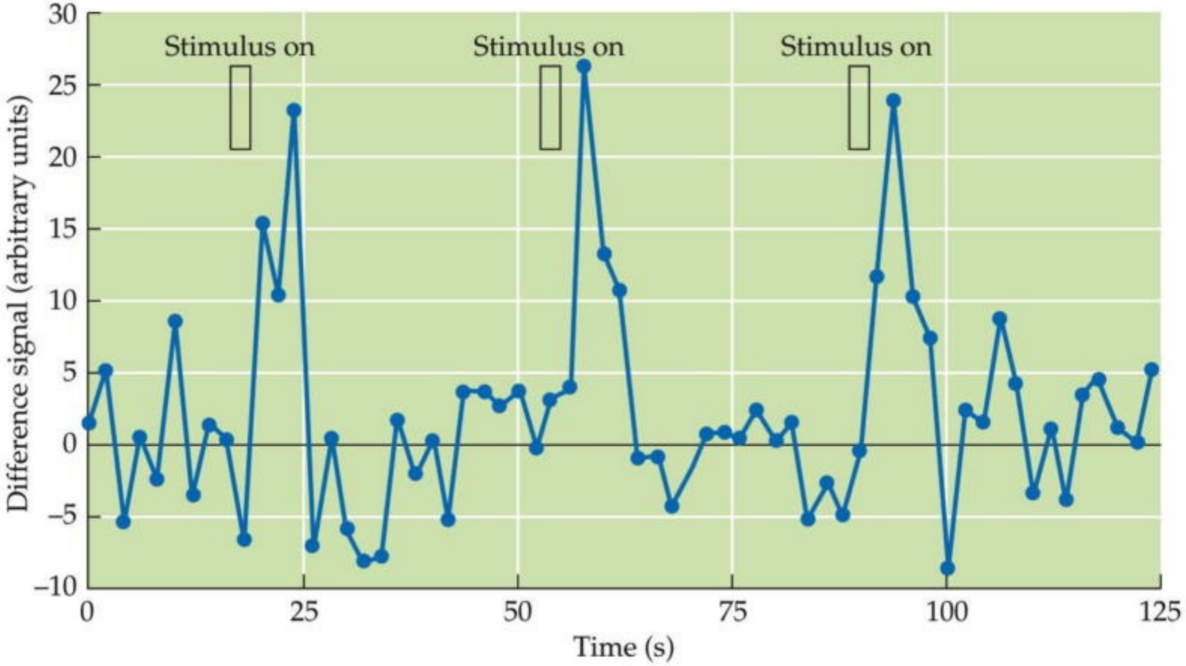
Paired Image Subtraction



The quality of your results depends on the quality of your controls!

Event-related fMRI

Hosking et al. 2017



Huettel 2012,
adapted from Blamire *et al.* 1992

Mostly the norm in fMRI these days
Allows you to avoid paired image subtraction
Has many of its own challenges (e.g. boredom!)

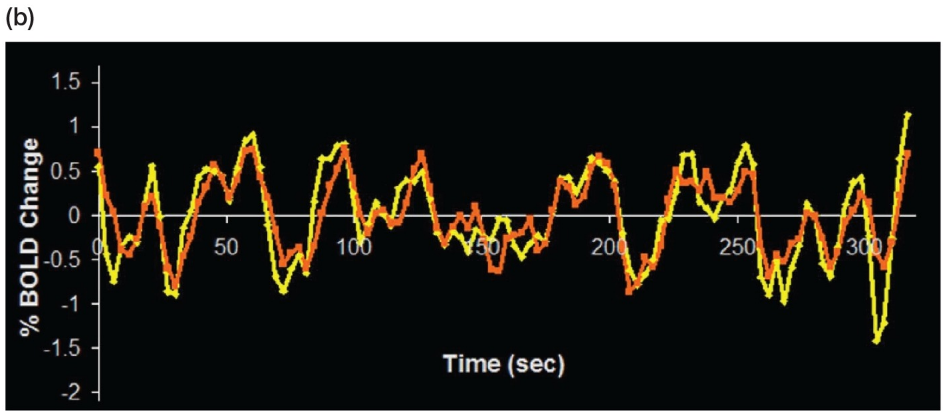
Problems with interpreting fMRI studies?

1. Spatial averaging
2. Spatial resolution
3. Temporal resolution
4. Not necessarily necessity
5. Focus on increases in activity

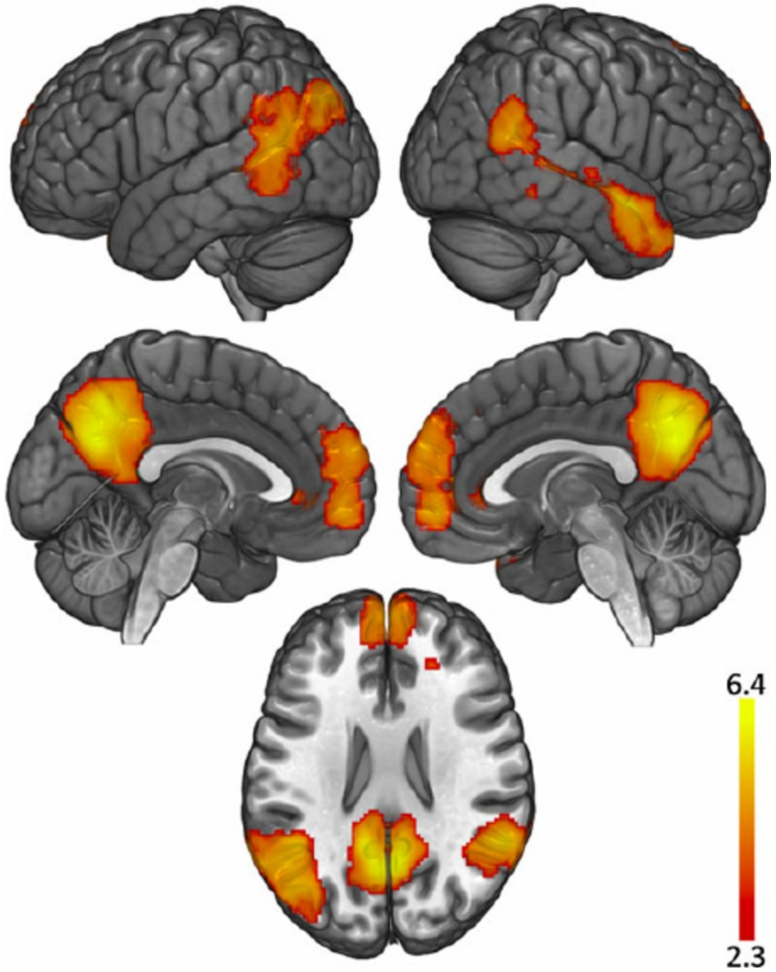
5. Focus on increases in activity: some regions are more active at rest than during task!

The default mode network

Resting state functional connectivity MRI

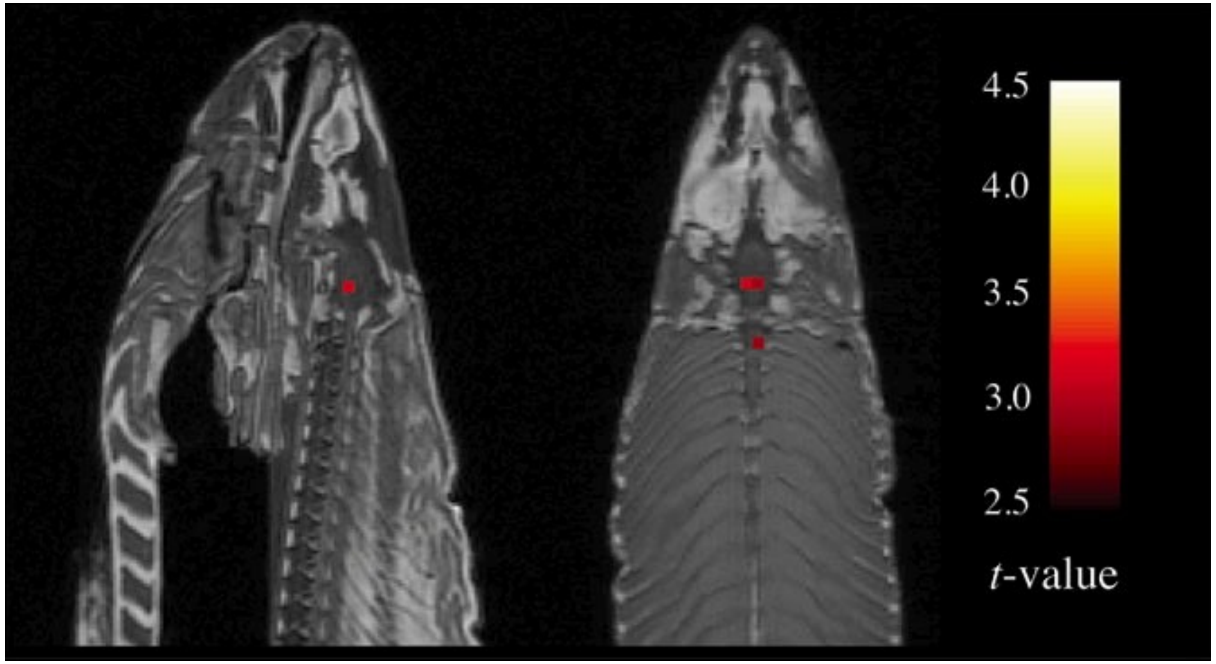


seed

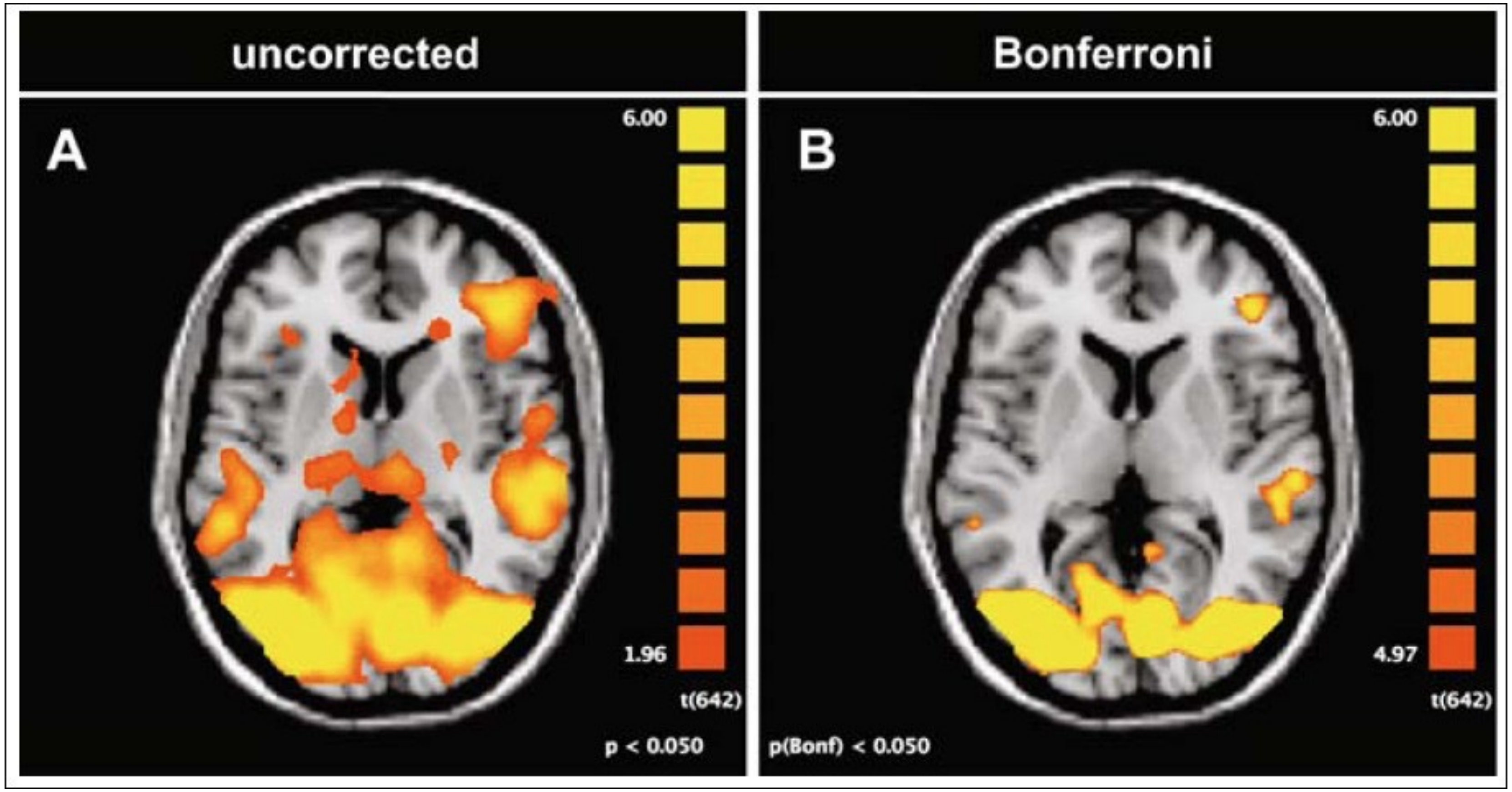


Problems with interpreting fMRI studies?

6. Regional hemodynamics
7. Confounds: anxiety, boredom
8. Confounds: drugs
9. Anticipatory hemodynamics
10. Reliability
11. Statistics



11. Statistics

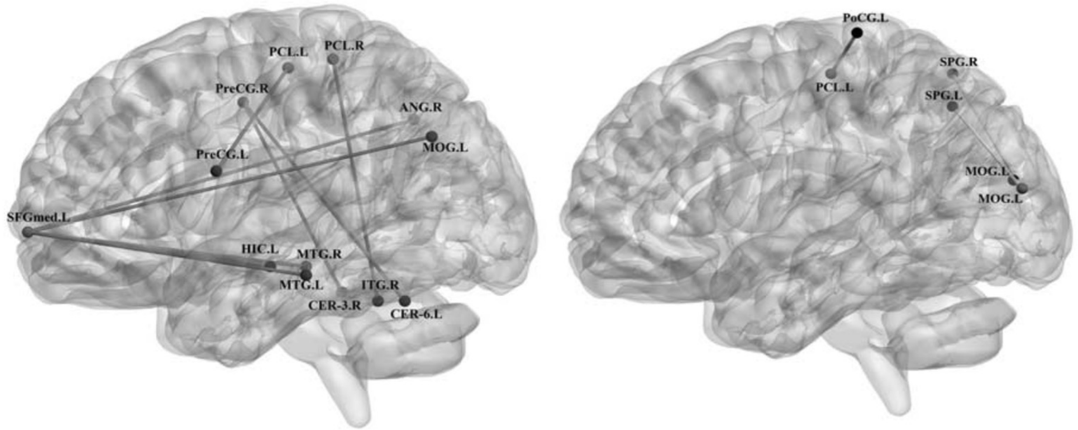


The heavy metal brain?

Altered resting-state functional connectivity of default-mode network and sensorimotor network in heavy metal music lovers

Yan Sun[a,b], Congcong Zhang[a,b], Shuxia Duan[a,b], Xiaoxia Du[c] and Vince D. Calhoun[d,e,f]

The aim of this study was to investigate the spontaneous neural activity and functional connectivity (FC) in heavy metal music lovers (HMML) compared with classical music lovers (CML) during resting state. Forty HMML and 31 CML underwent resting-state functional MRI scans. Fractional amplitude of low-frequency fluctuations (fALFF) and seed-based resting-state FC were computed to explore regional activity and functional integration. A voxel-based two-sample *t*-test was used to test the differences between the two groups. Compared with CML, HMML showed functional alterations: higher fALFF in the right precentral gyrus, the bilateral paracentral lobule, and the left middle occipital gyrus, lower fALFF in the left medial superior frontal gyrus, an altered FC in the default-mode network, lower connectivity between the right precentral gyrus and the left cerebellum-6 and the right cerebellum-3, and an altered FC between the left paracentral lobule and the sensorimotor network, lower in the right paracentral lobule and the right inferior temporal gyrus FC. The results may partly explain the disorders of behavioral and emotional cognition in HMML compared with CML and are consistent with our predictions. These findings may help provide a basic understanding of the potential neural mechanism of HMML. *NeuroReport* 00:000–000



- Demonstrates the need for more than just neuroimaging