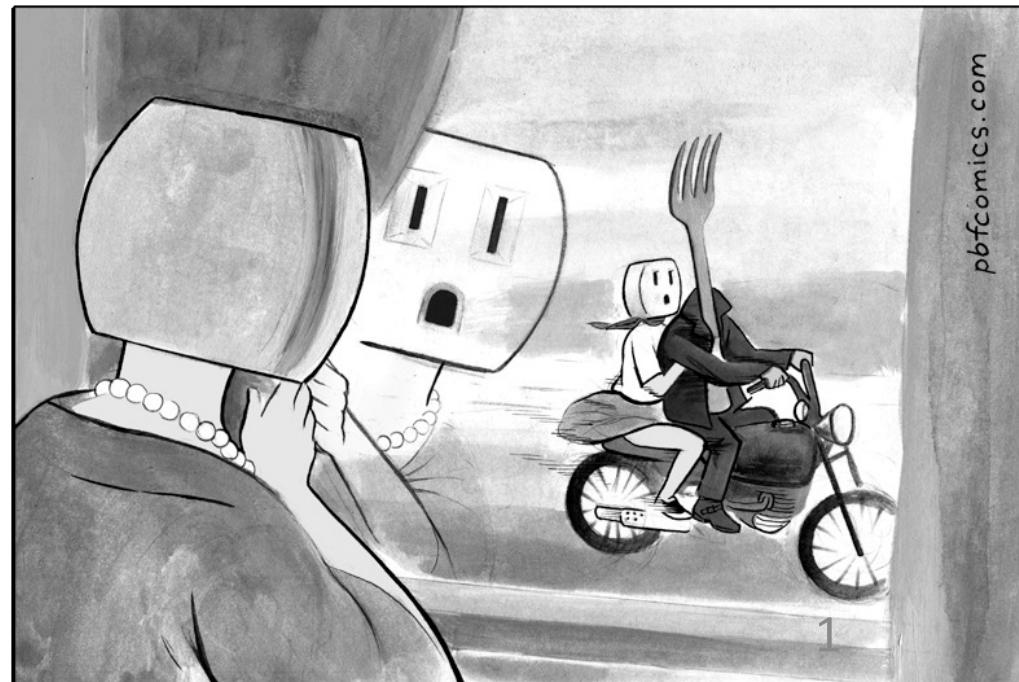


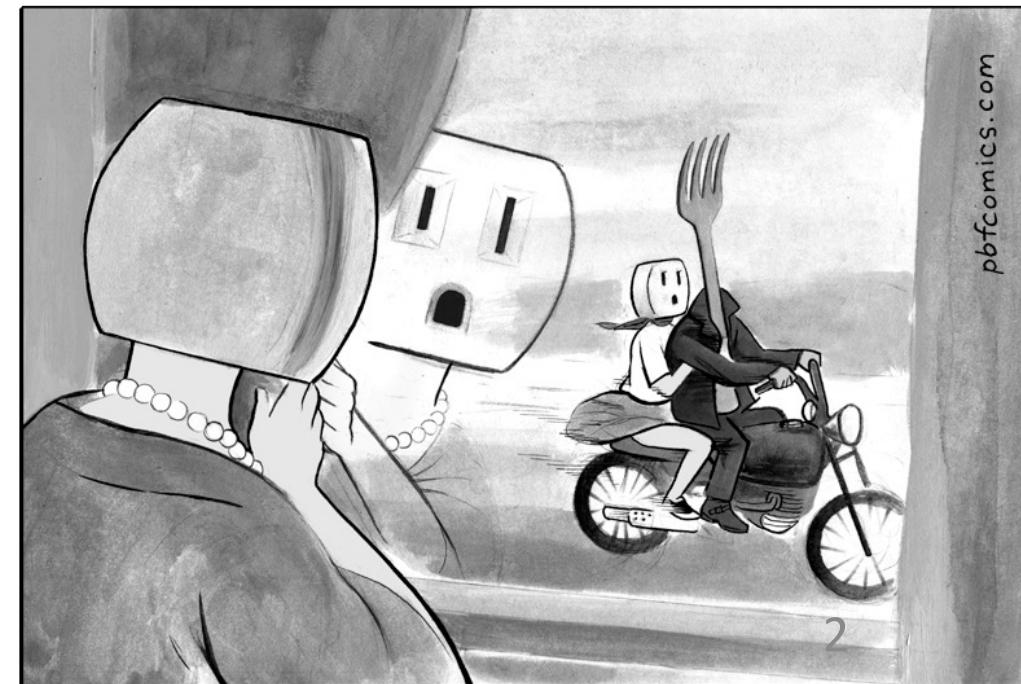
# PSYC301: Neuroimaging (structural and functional)

Jay Hosking, PhD

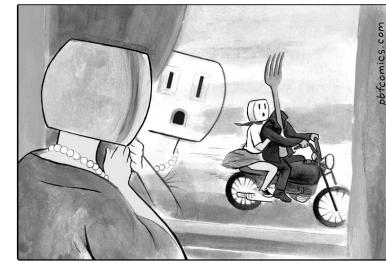


# Overview

- 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

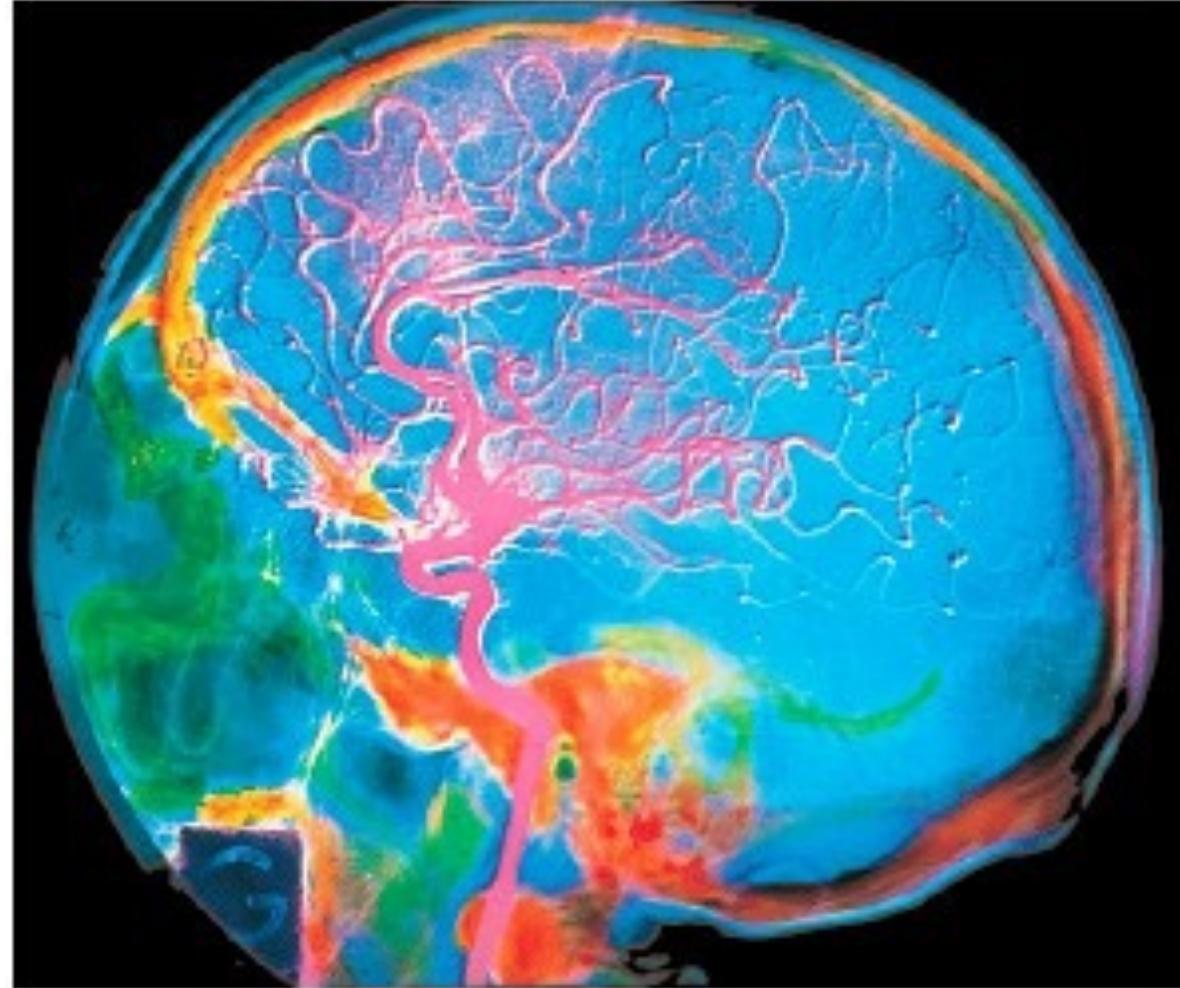


Medical Body Scans/Science Source.

i.e. an *angiogram*

This is a *contrast X-ray technique*

Useful for?



Structural imaging

# Computed tomography (CT)



The tube and detector

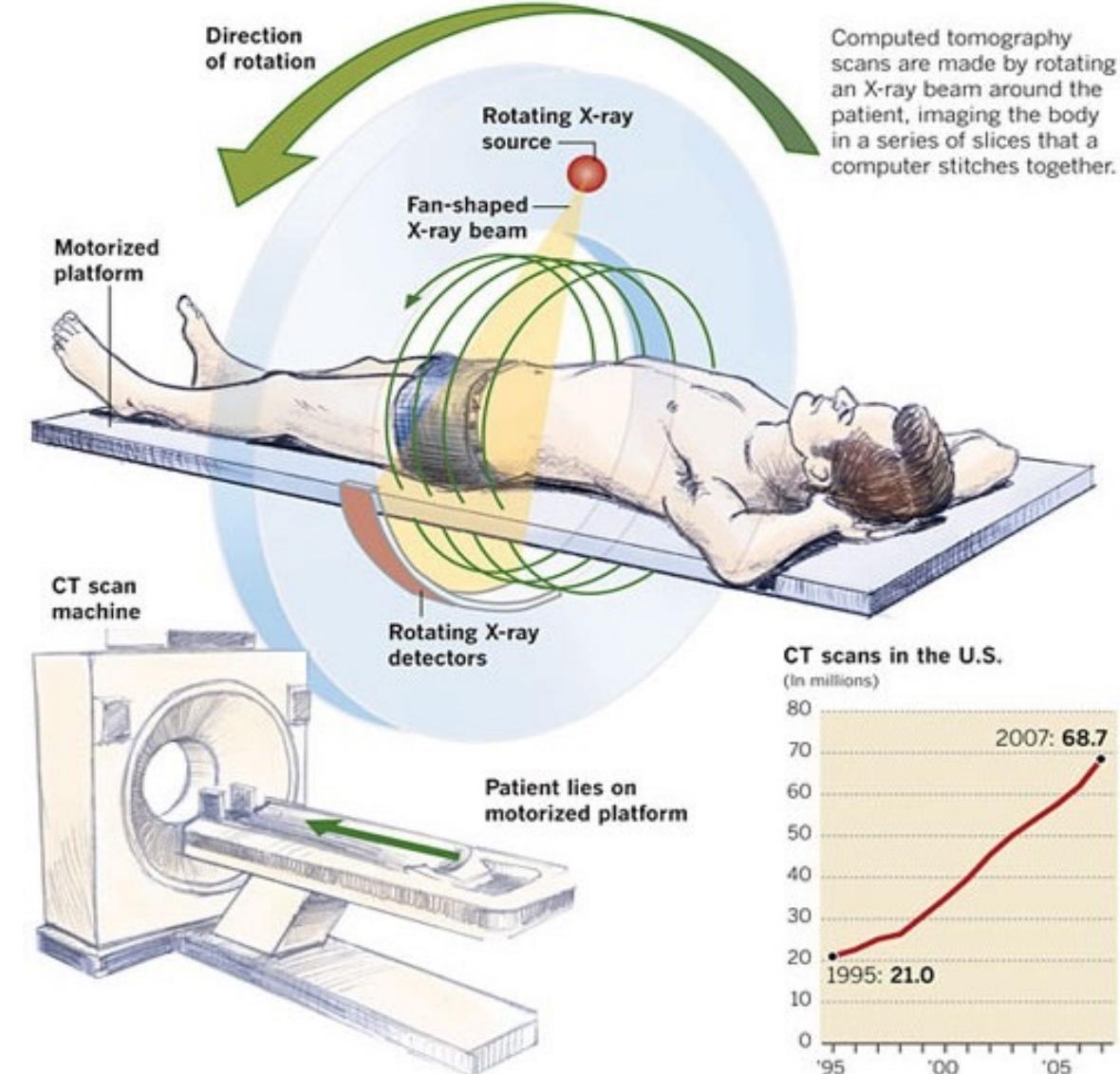
Structural imaging

# Computed tomography (CT)

Overcoming limitations of traditional X-ray  
“Reconstruction”

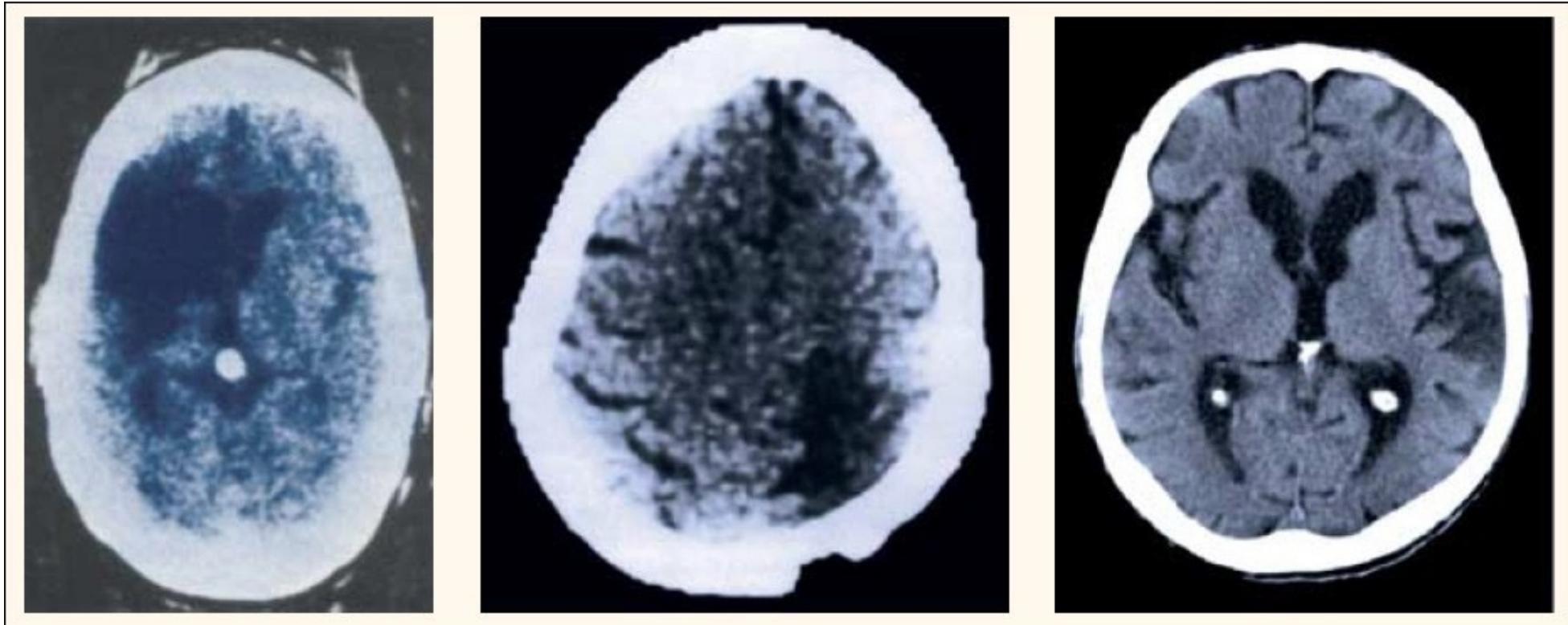
## Anatomy of a CT scan

CT scanners give doctors a 3-D view of the body. The images are exquisitely detailed but require a dose of radiation that can be 100 times that of a standard X-ray.



# Computed tomography (CT)

Rorden & Karnath, 2004



1977

1983

2004

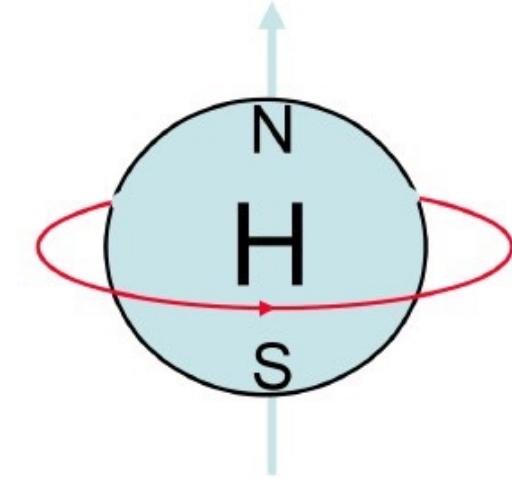
Only as good as its algorithms

Useful for?

Drawbacks?

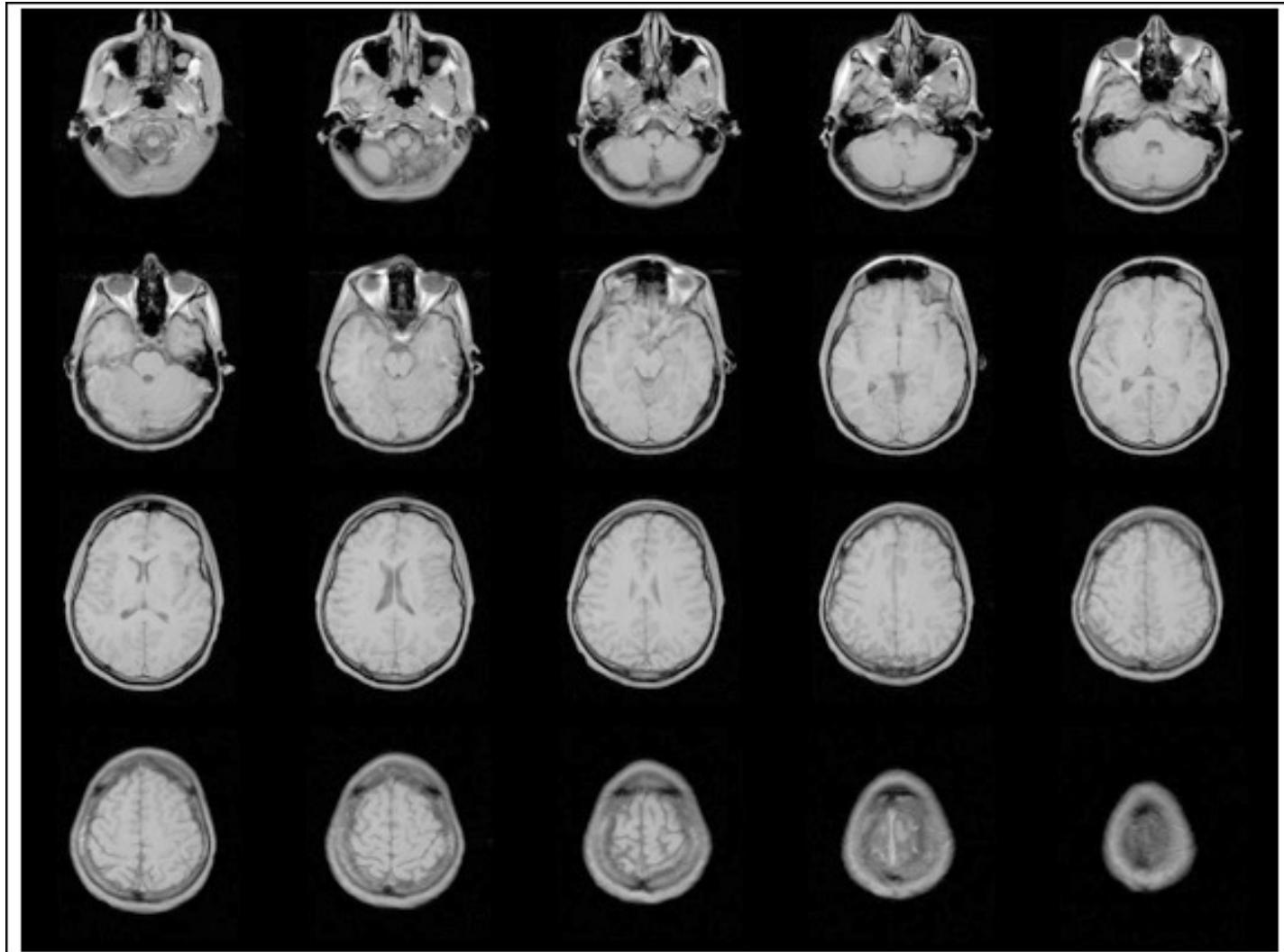
Structural imaging

# Magnetic Resonance Imaging (MRI)



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

# Magnetic Resonance Imaging (MRI)

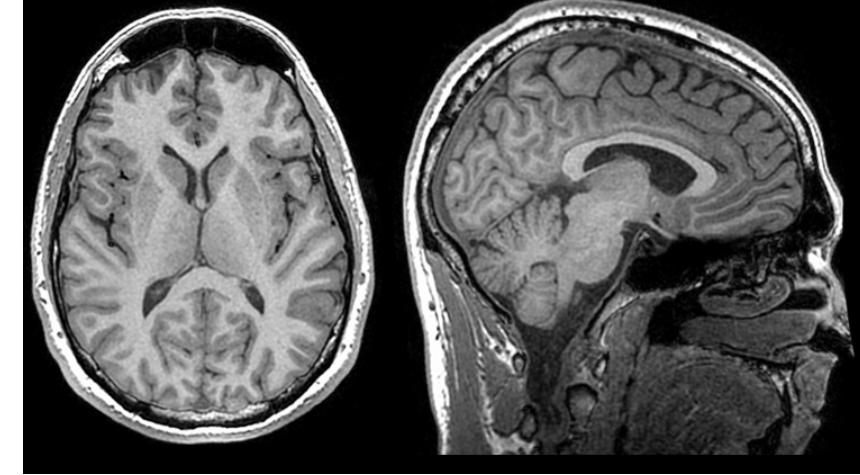
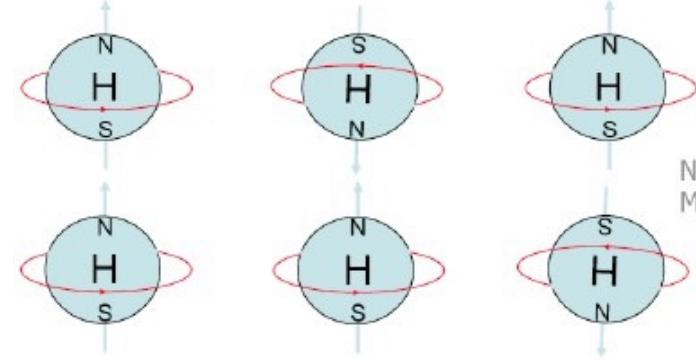


Structural imaging

# MRI

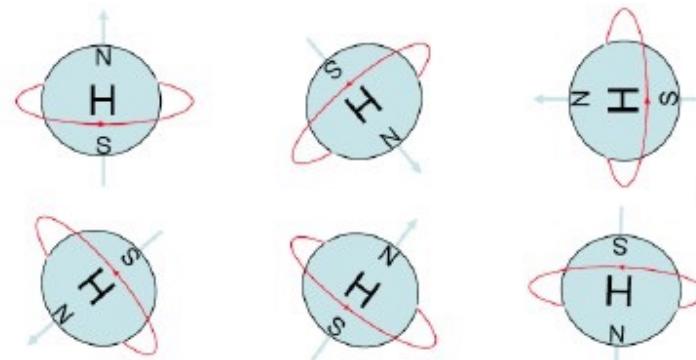
## Step one:

Align all the protons with the large magnetic field.



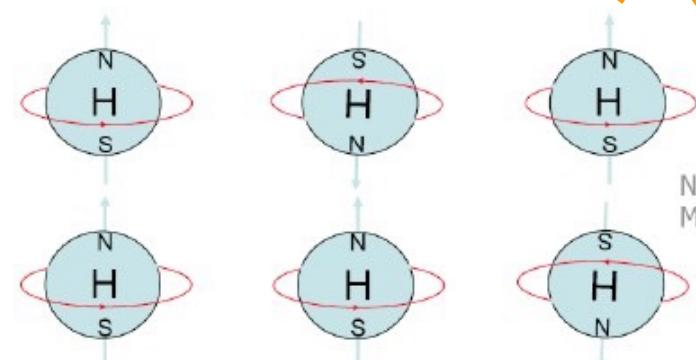
## Step two:

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').



# Magnetic Resonance Imaging (MRI)



The screenshot shows the homepage of the UBC MRI Research Centre. At the top, the UBC logo and "THE UNIVERSITY OF BRITISH COLUMBIA" are on the left, and "Contact us at 604-822-7352 or mriresearch@physics.ubc.ca" is on the right. Below this is a banner featuring a stylized green and blue graphic of a mountain and water, with a red and black salmon jumping. To the right is a photograph of three men standing around a white MRI scanner. A navigation bar below the banner includes links for Home, About Us, Facilities, News & Events, Image Gallery, Resources, and Contact Us.

**Welcome to the UBC MRI Research Centre**

**3T** [Enter 3T Website Here](#)

Our facility houses a 3.0 Tesla Philips Achieva whole body MRI scanner, which we use to make state of the art in vivo MR imaging and spectroscopy available to researchers like you.

We welcome your enquiries regarding the use of this first-class research centre; our staff are happy to provide assistance in planning your scan protocol. [Visit the 3T Website](#) 

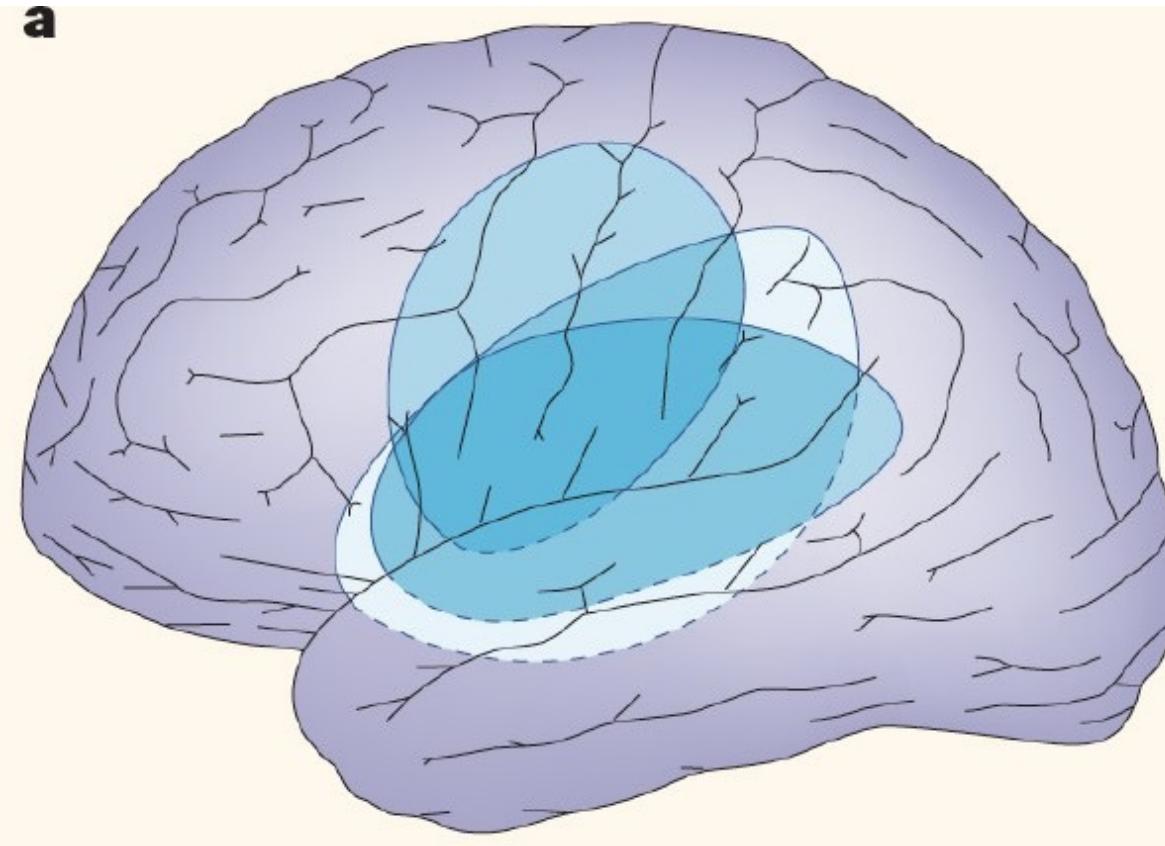
**7T** [Enter 7T Website Here](#)

We operate a state-of-the-art Bruker Biospec 70/30 7.0 Tesla MRI scanner for MR and spectroscopy applications. The scanner is capable of supporting all potential users of the MR Imaging Centre, and is an excellent platform for research studies.

We welcome your enquiries regarding the use of this first-class research centre. [Visit the 7T Website](#) 

Structural imaging

MRI

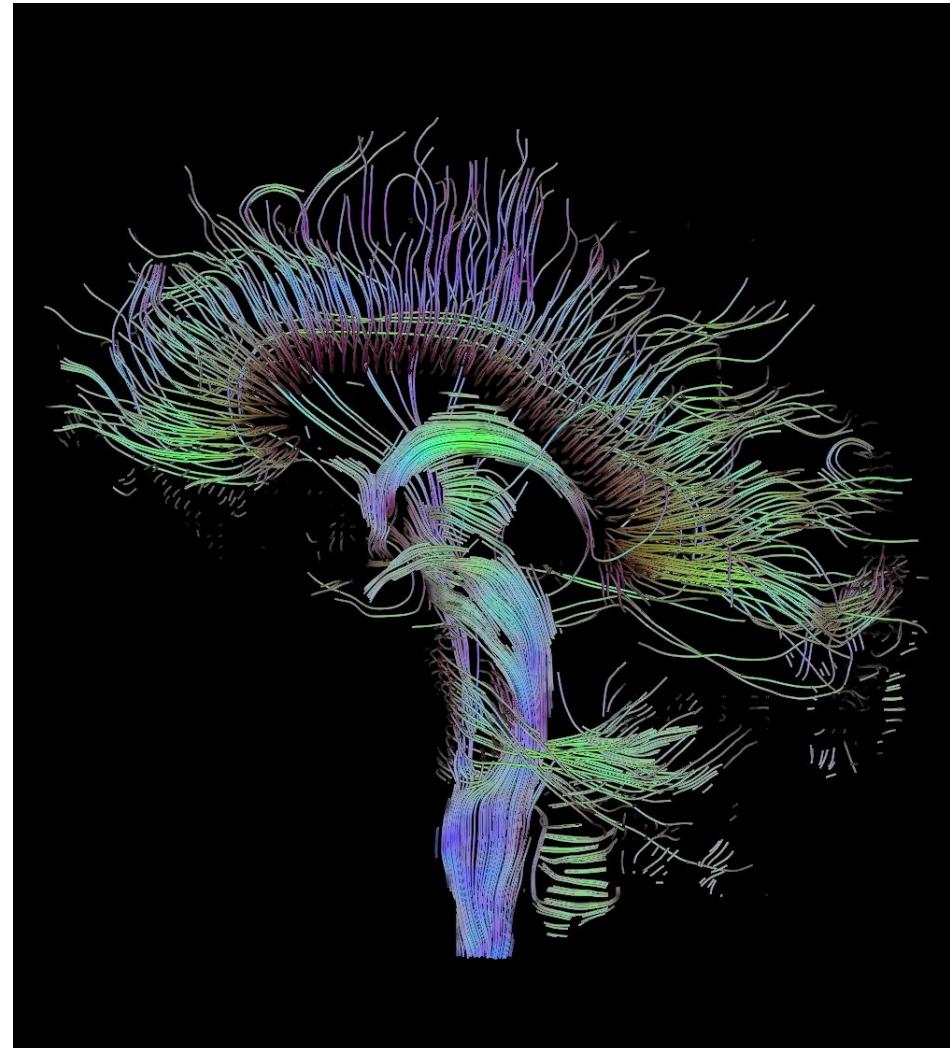
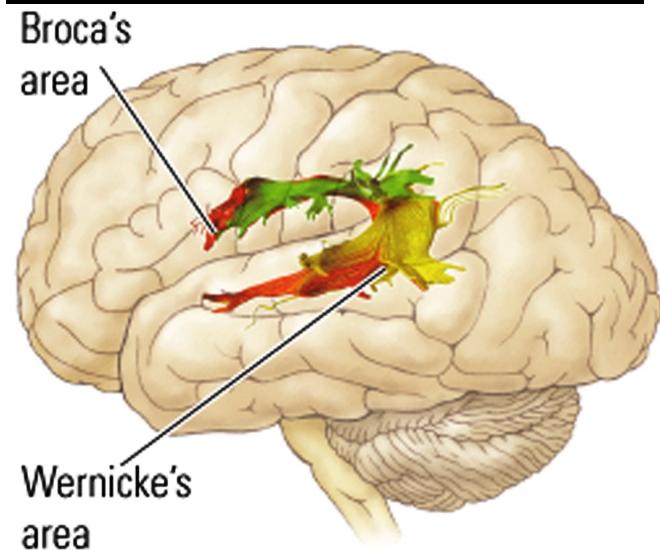
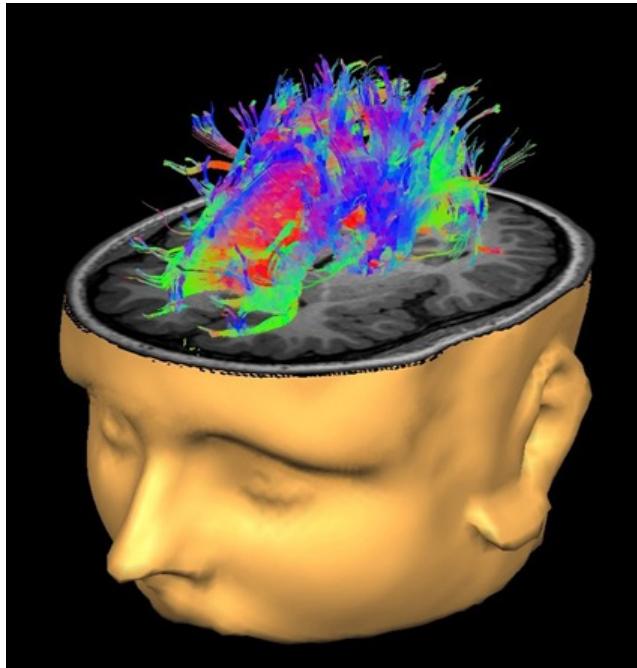


Example of an **overlay plot** (from Rorden & Karnath, 2004)

Advantage over traditional lesion studies?

<https://www.ncbi.nlm.nih.gov/pubmed/15378041>

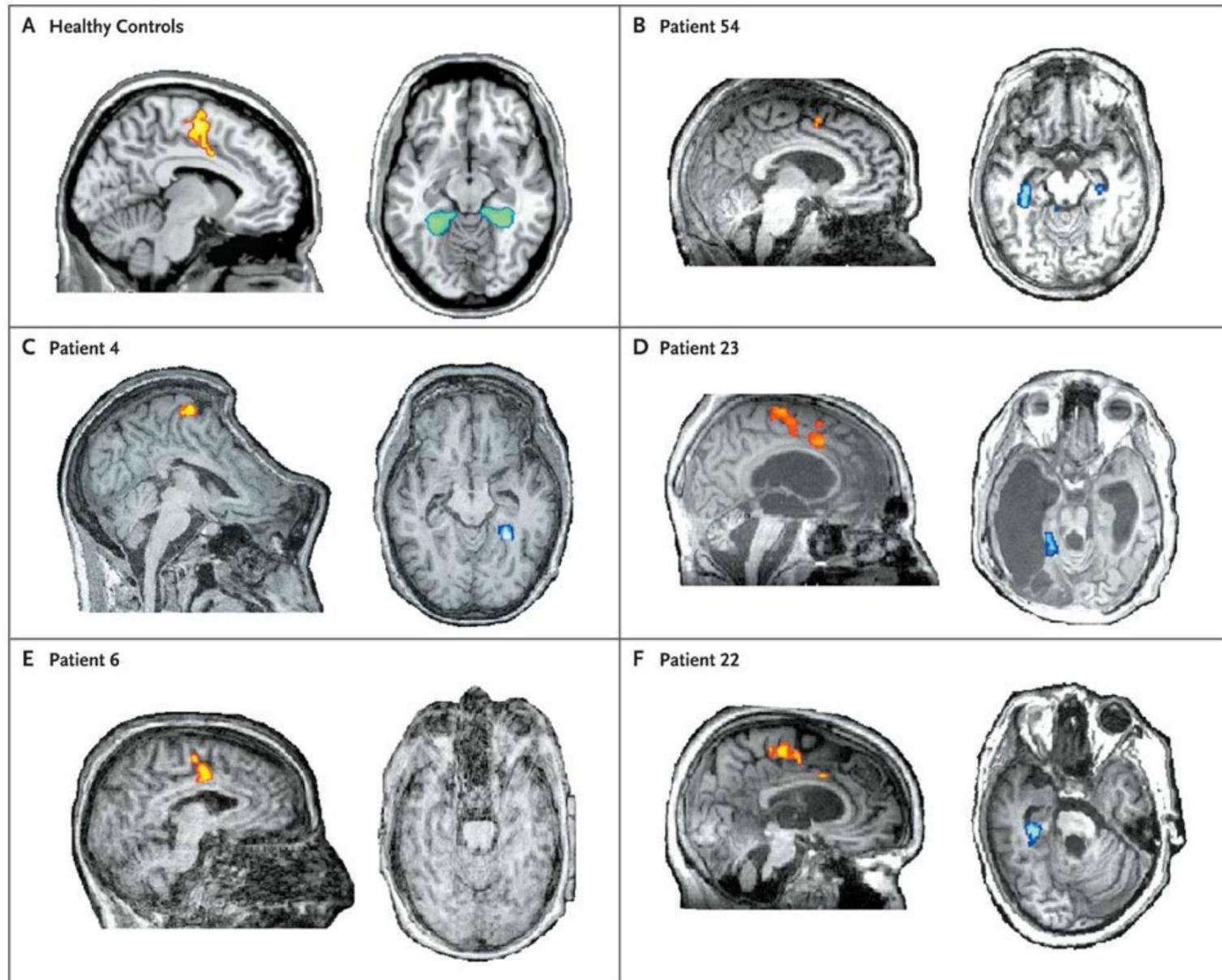
# Diffusion Tensor Imaging (DTI)



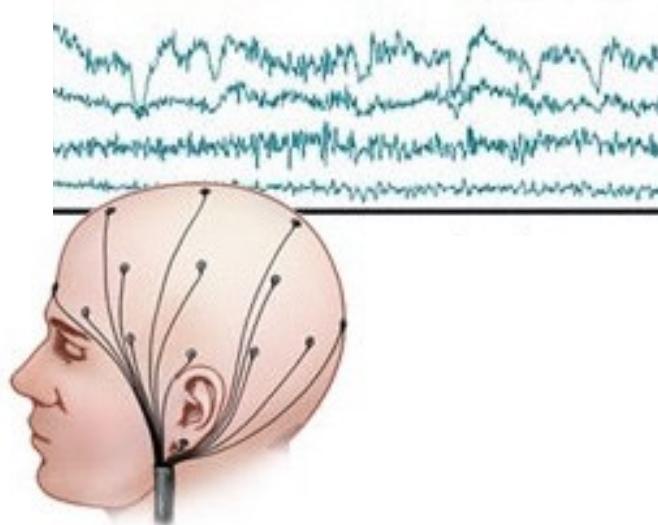
- Variant of MRI
- Relies on how water molecules move in brain
- Useful for?

Image from:  
<https://upload.wikimedia.org/wikipedia/commons/8/82/DTI-sagittal-fibers.jpg>

Adrian Owen's research  
(read the paper!)



# Electroencephalography (EEG)



Alpha = 8-12 Hz

Beta = 12-30 Hz

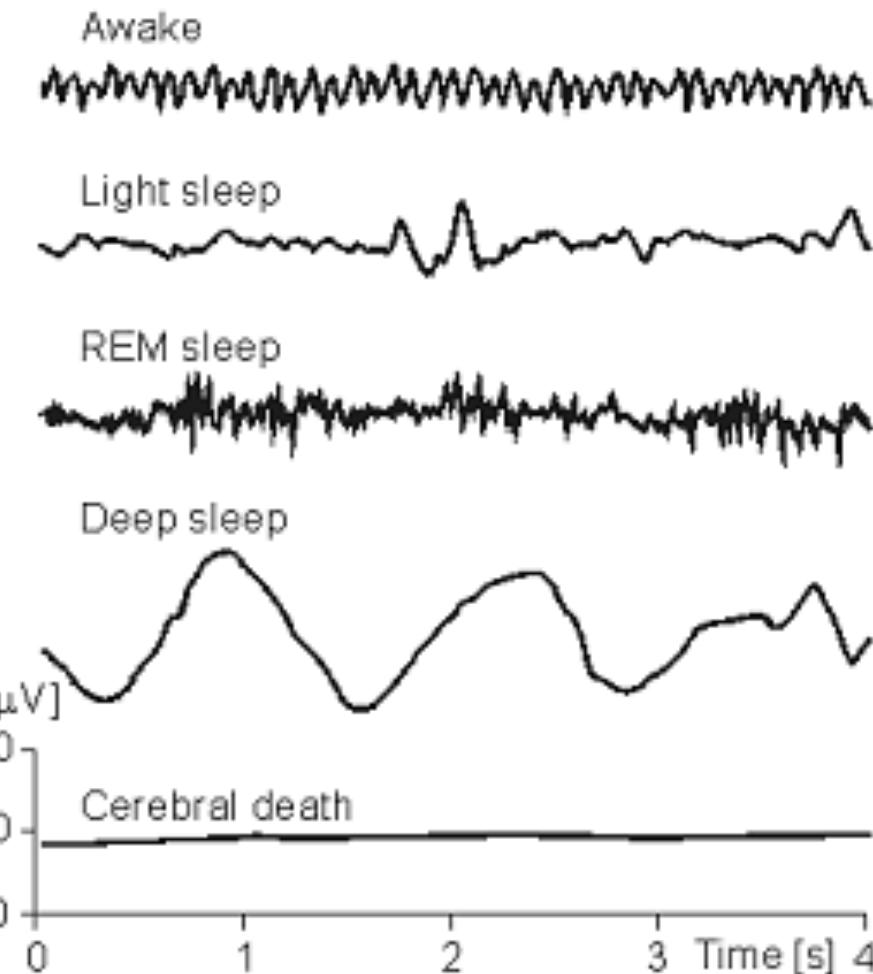
Gamma = 26-100 Hz

Delta = 0-3 Hz

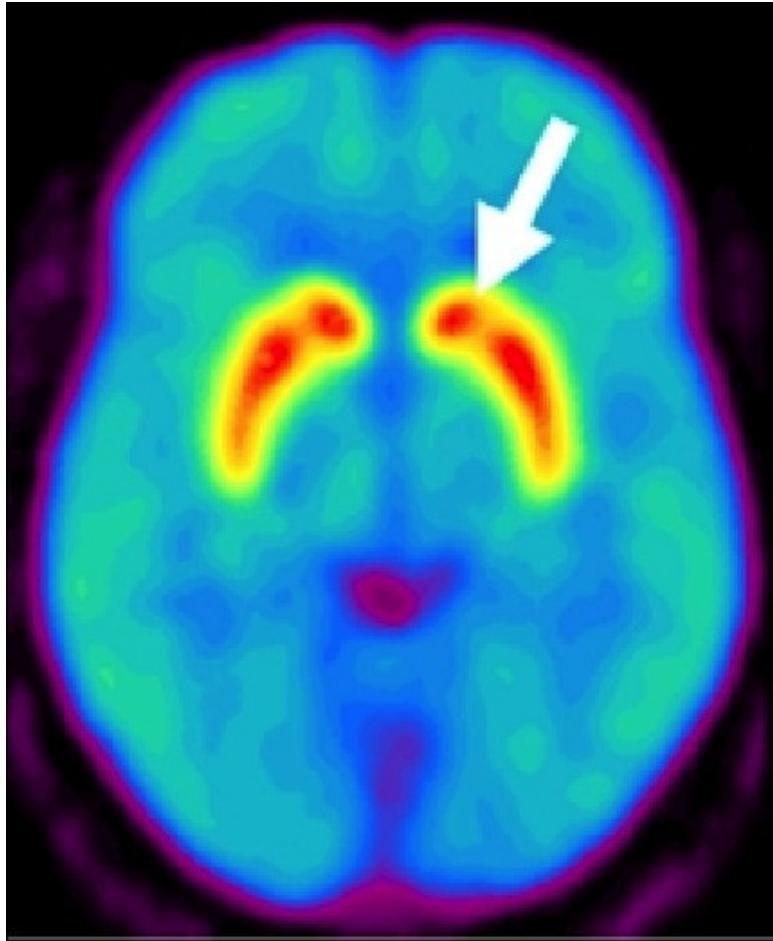
Theta = 4-7 Hz

Mu = 8-12 Hz (over motor areas)

\*you aren't responsible for knowing these numbers



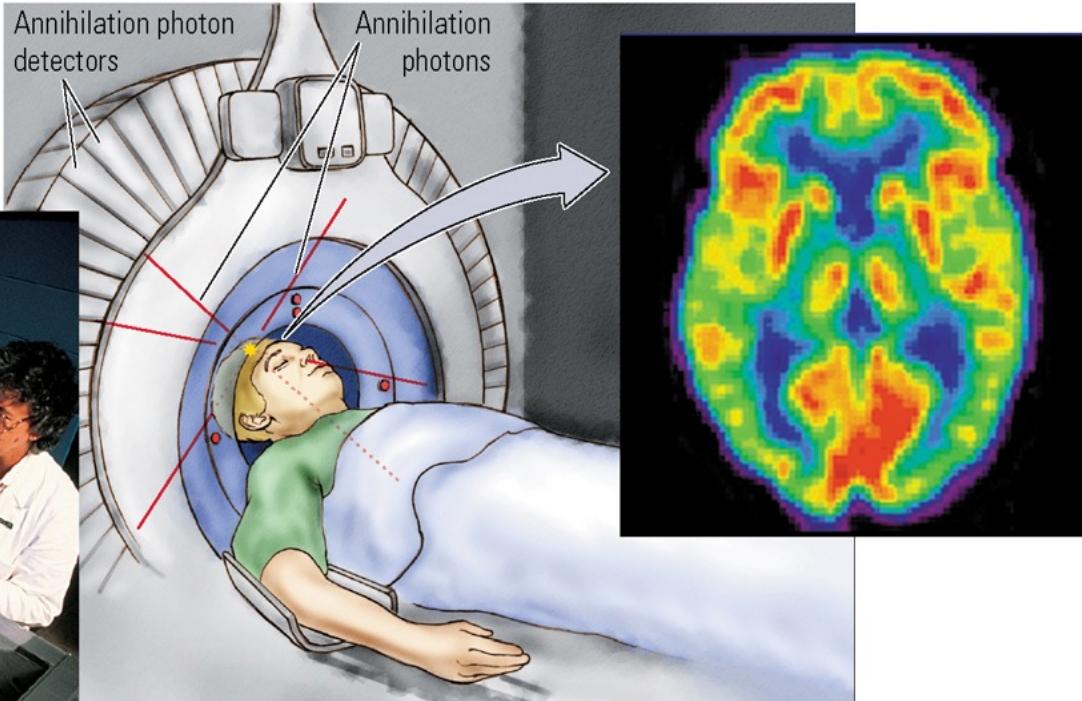
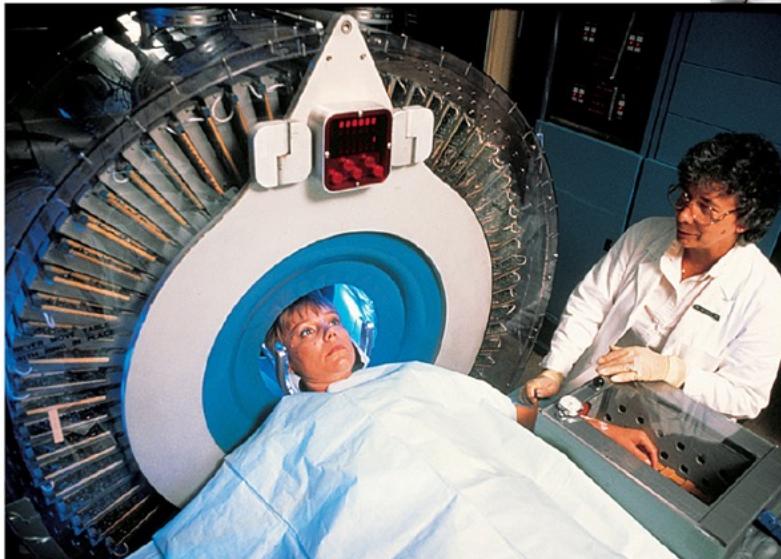
# Positron Emission Tomography (PET)



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.

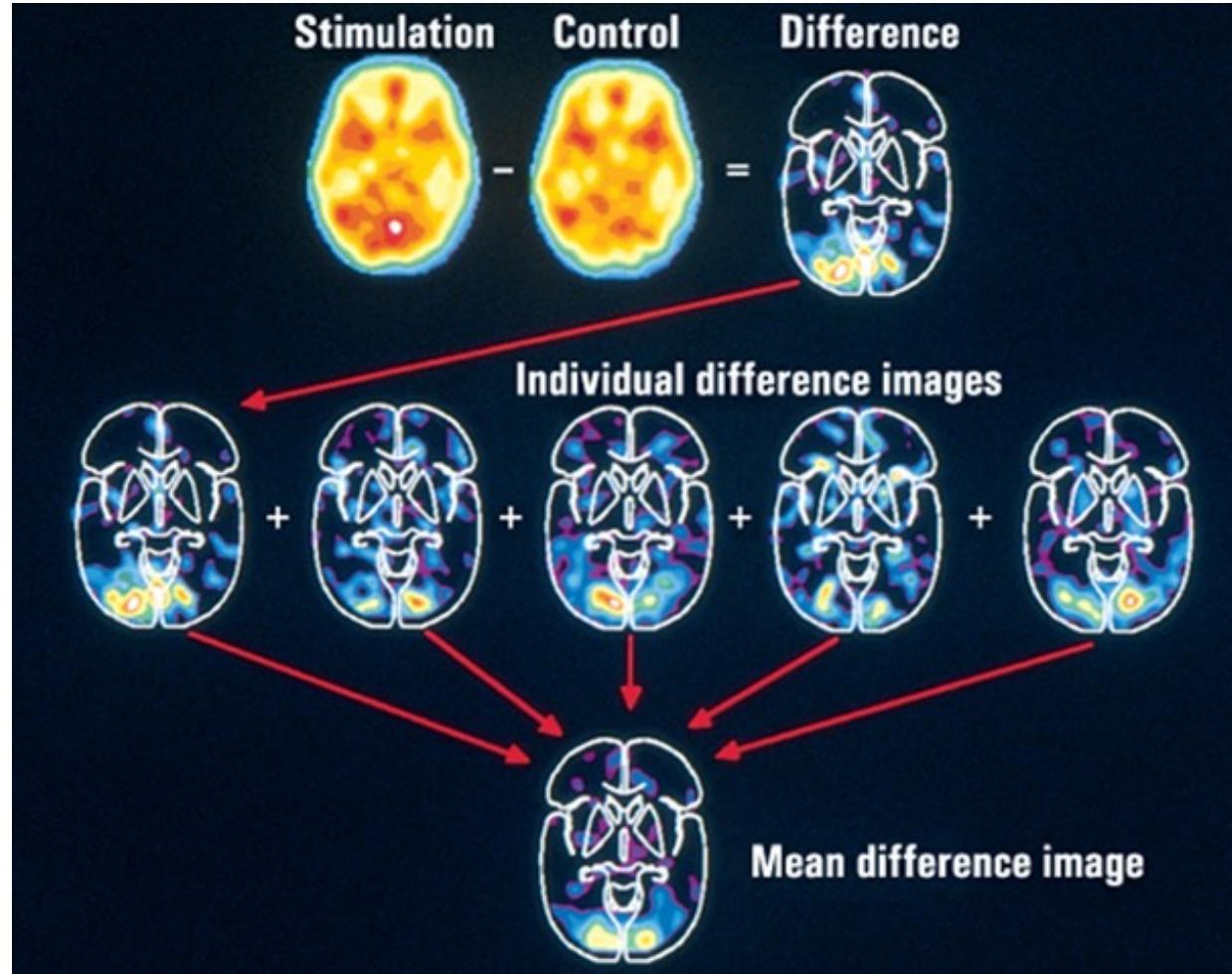


Positrons from the radioactivity are released; they collide with electrons in the brain, and photons (a form of energy) are produced, exit the head, and are detected.

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

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

# Mean difference images



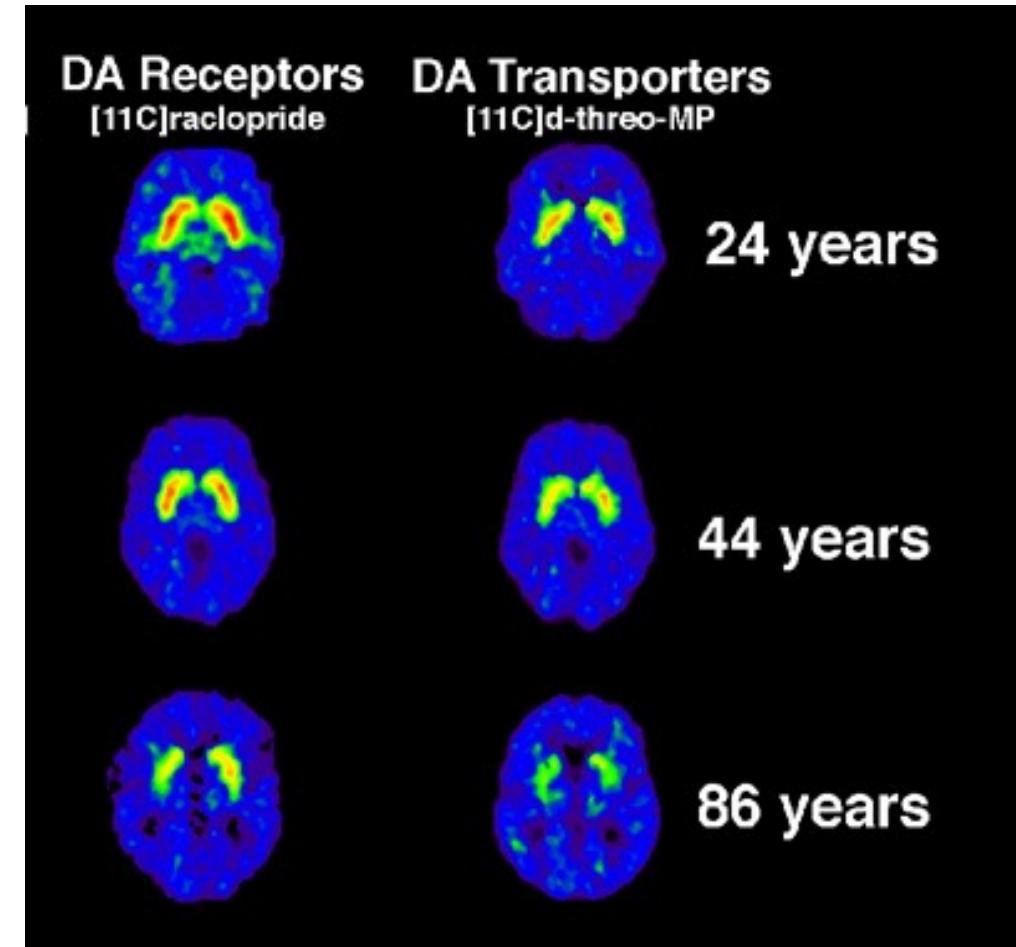
- Subtraction method / mean difference images  
(similar for some fMRI)
  - Potential issues?

# PET: less common now, but...

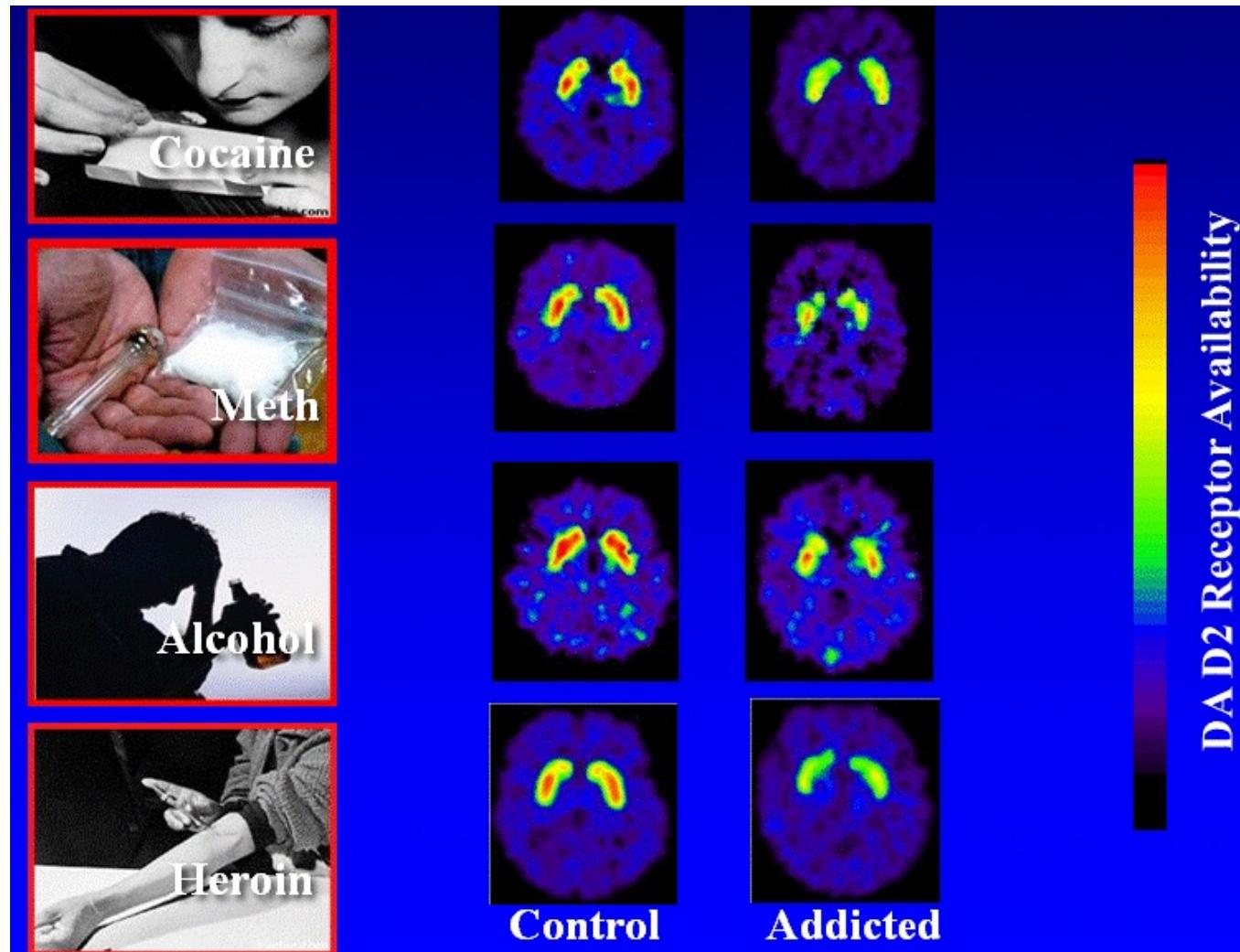
- Very expensive
- Temporally slow
- Poor spatial resolution

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?)

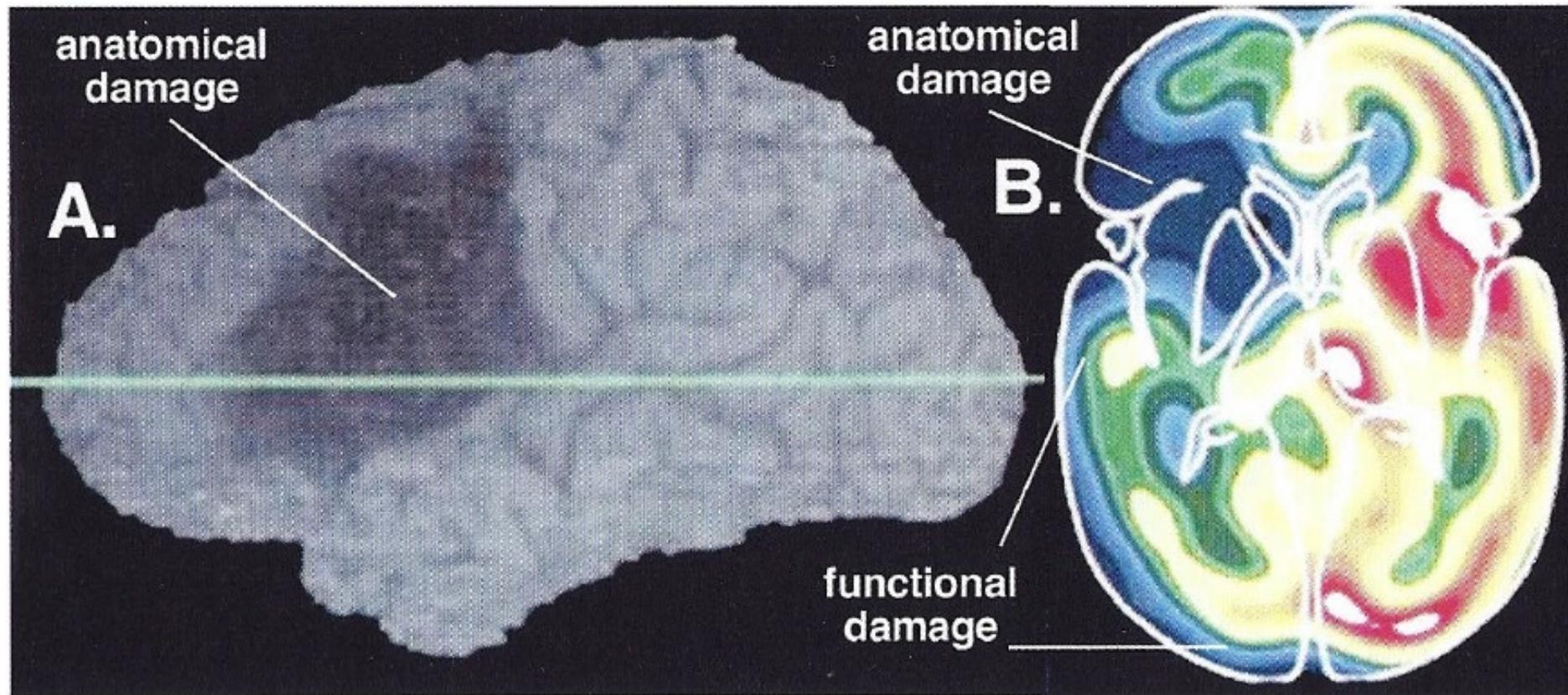


# PET: dopamine D<sub>2</sub> receptors decreased by addiction



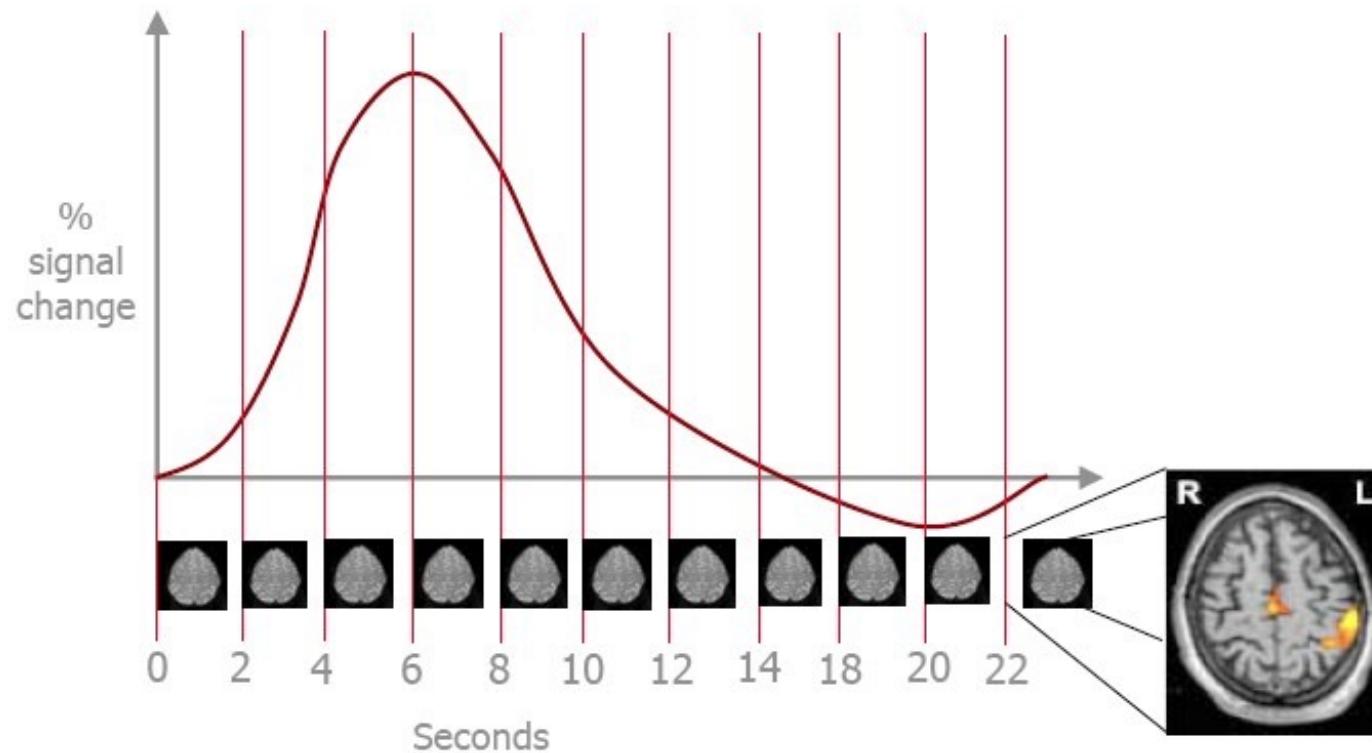
Functional imaging

# Using PET to image diaschisis

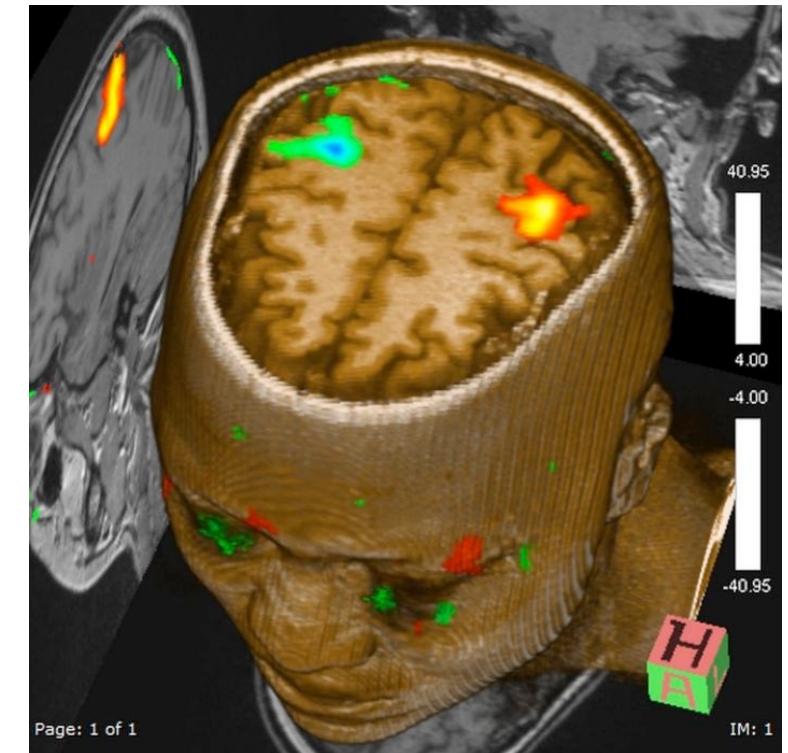


Functional imaging

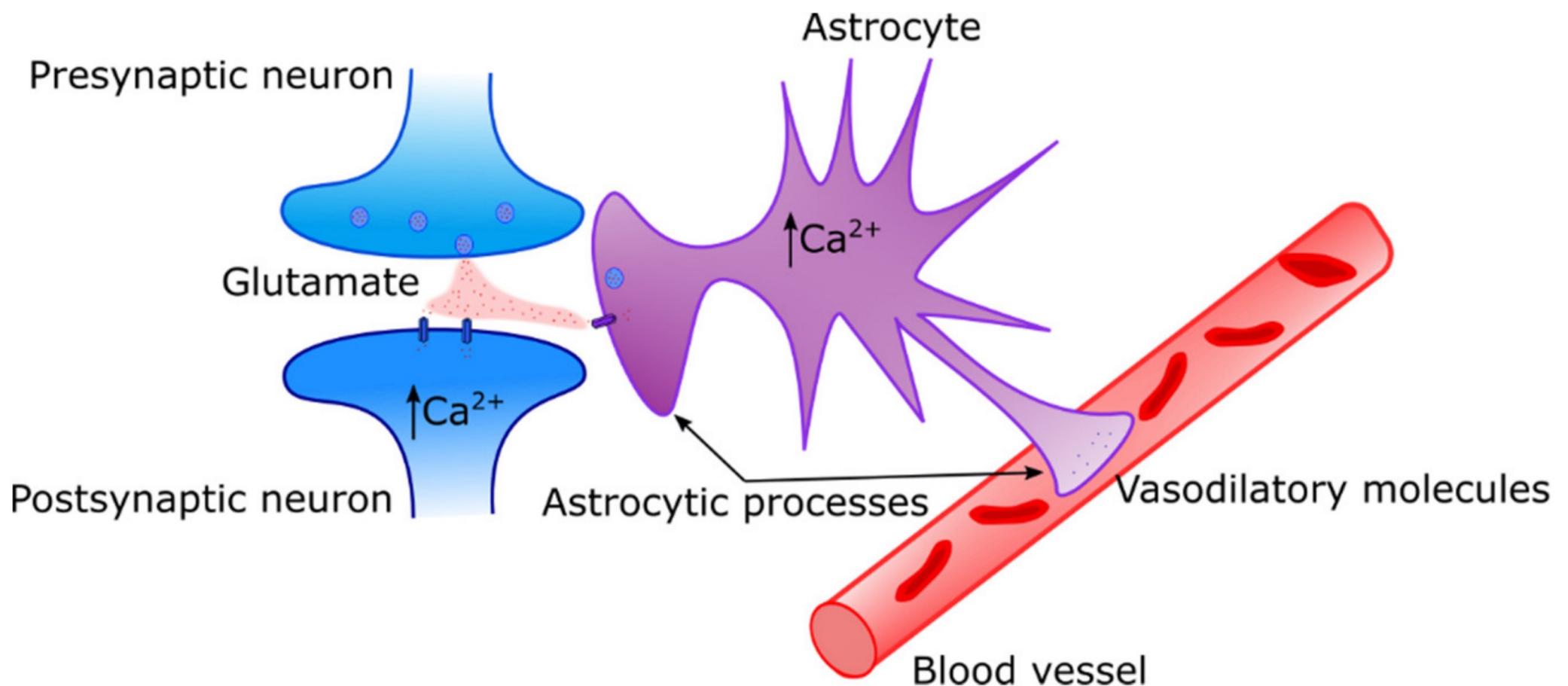
# Functional MRI (fMRI): the BOLD response



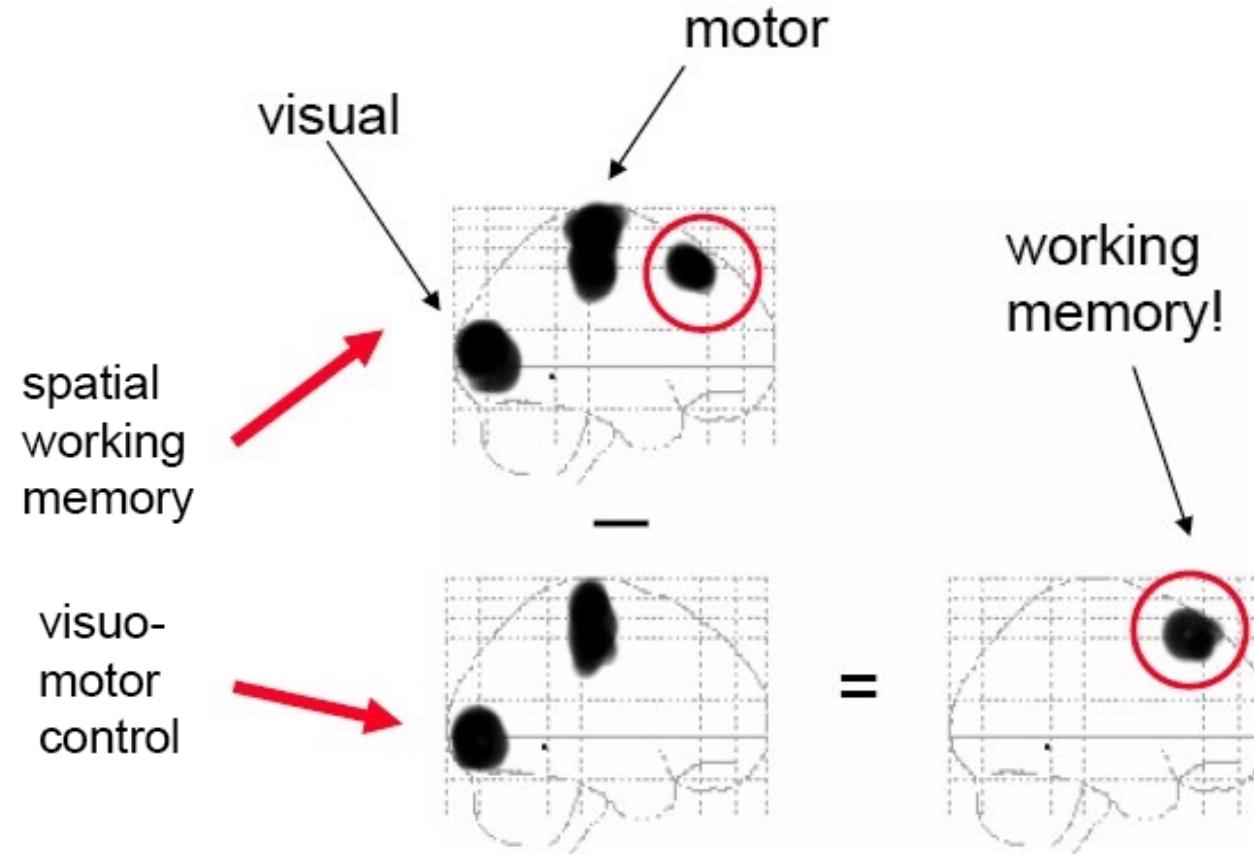
Hemodynamic response



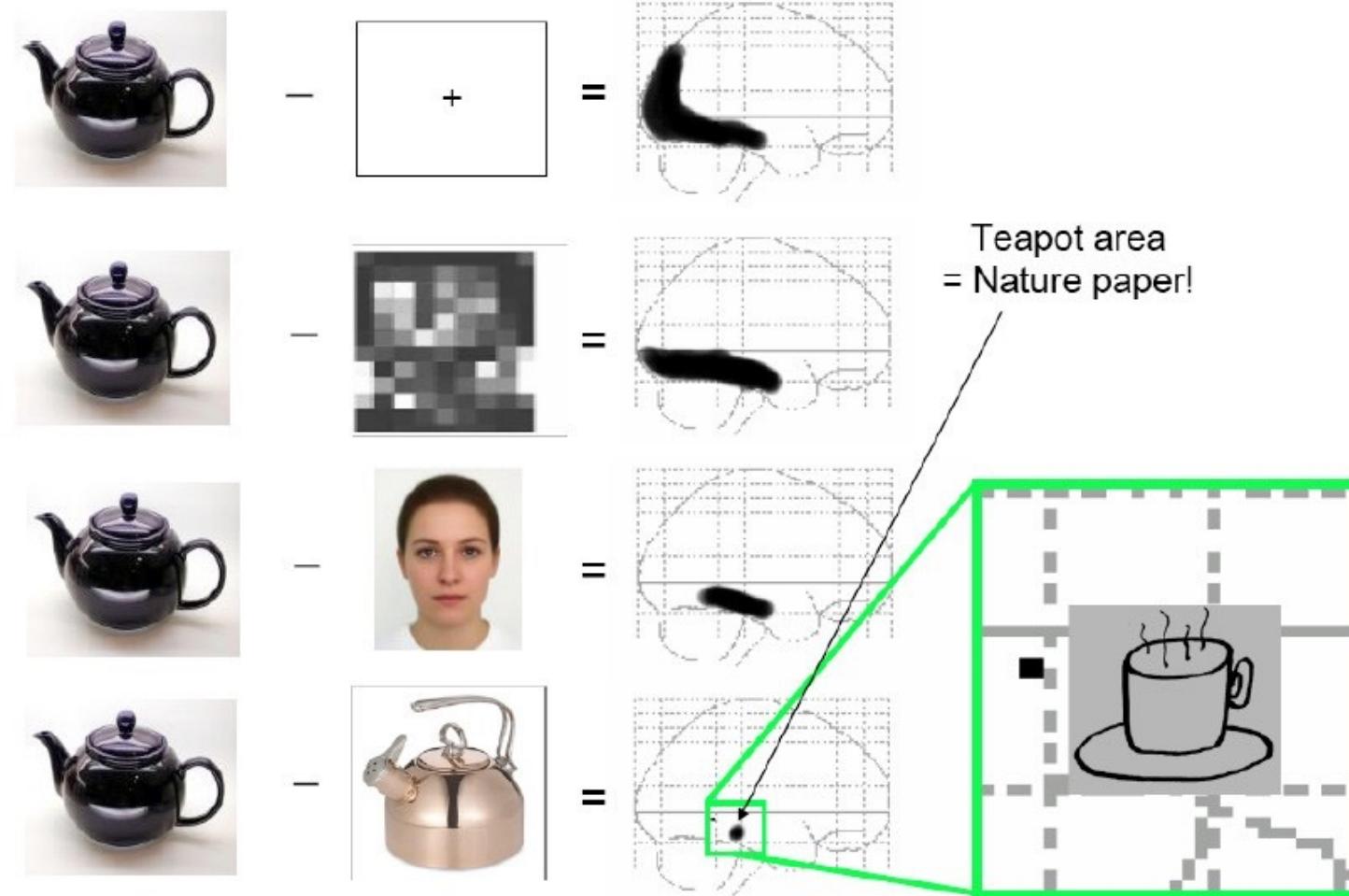
# fMRI: BOLD response



# Paired Image Subtraction



# Paired Image Subtraction

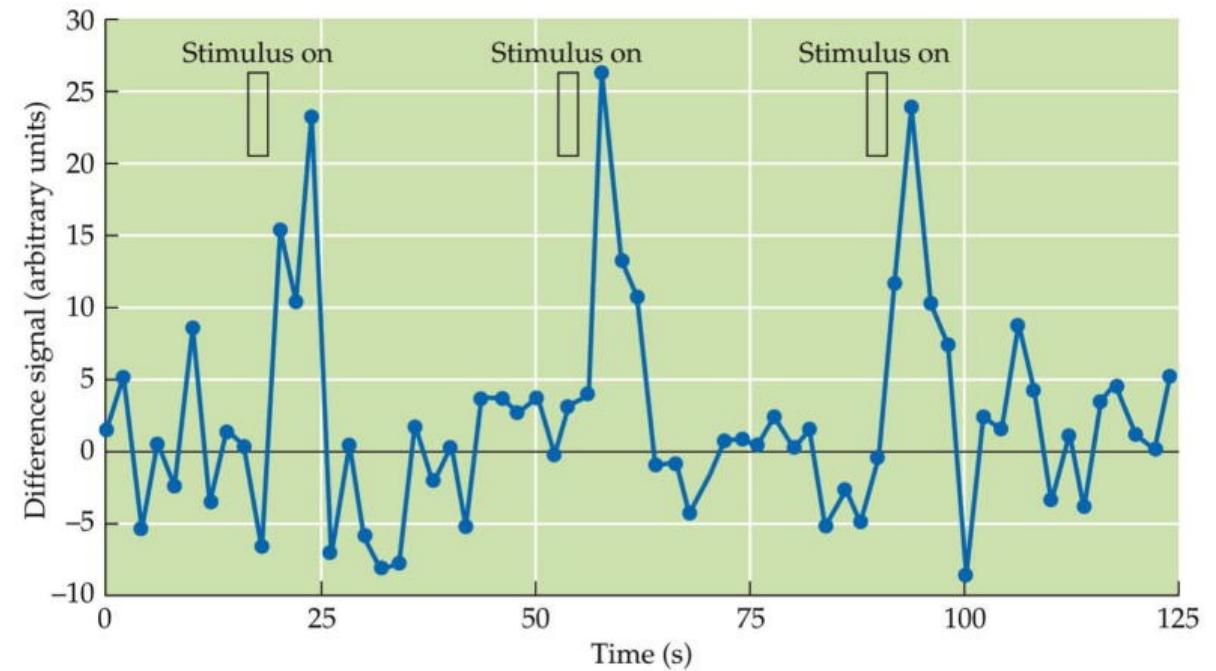


The quality of your results depends on the quality of your controls!

# Event-related fMRI



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



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

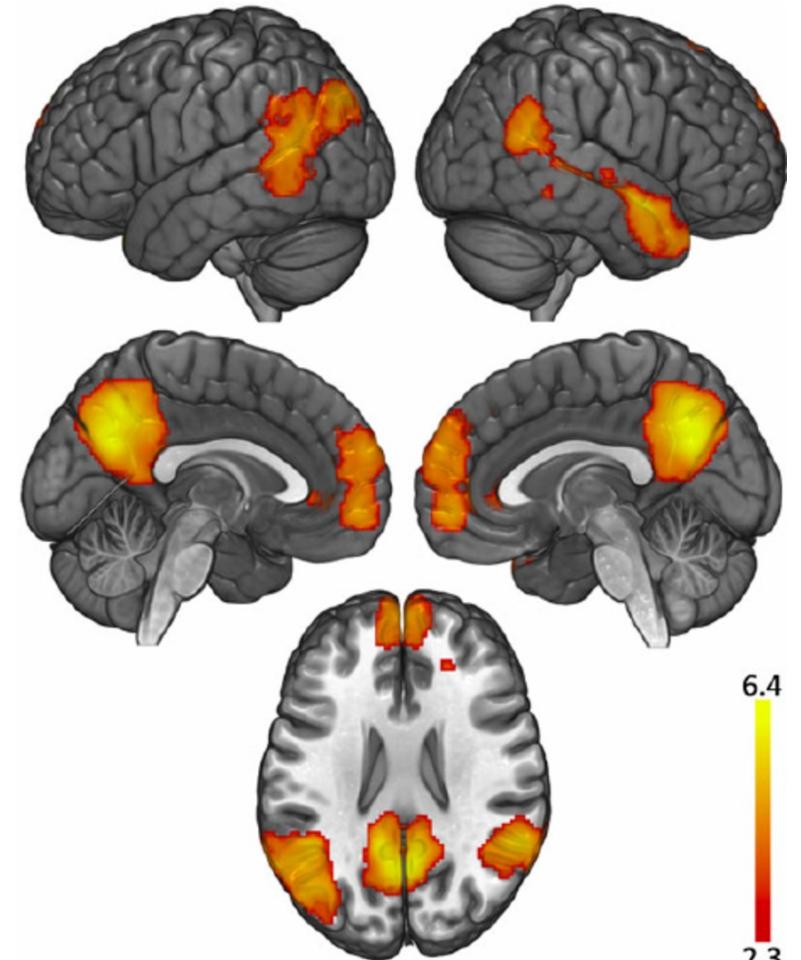
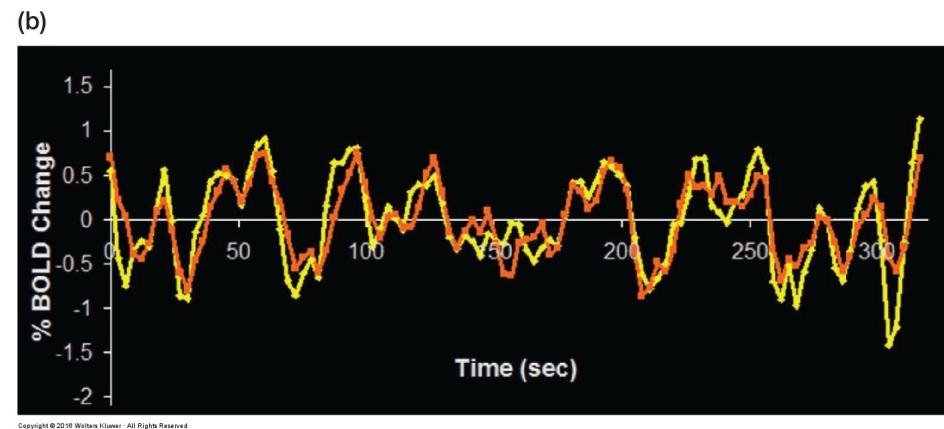
# Problems with interpreting fMRI studies?

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!

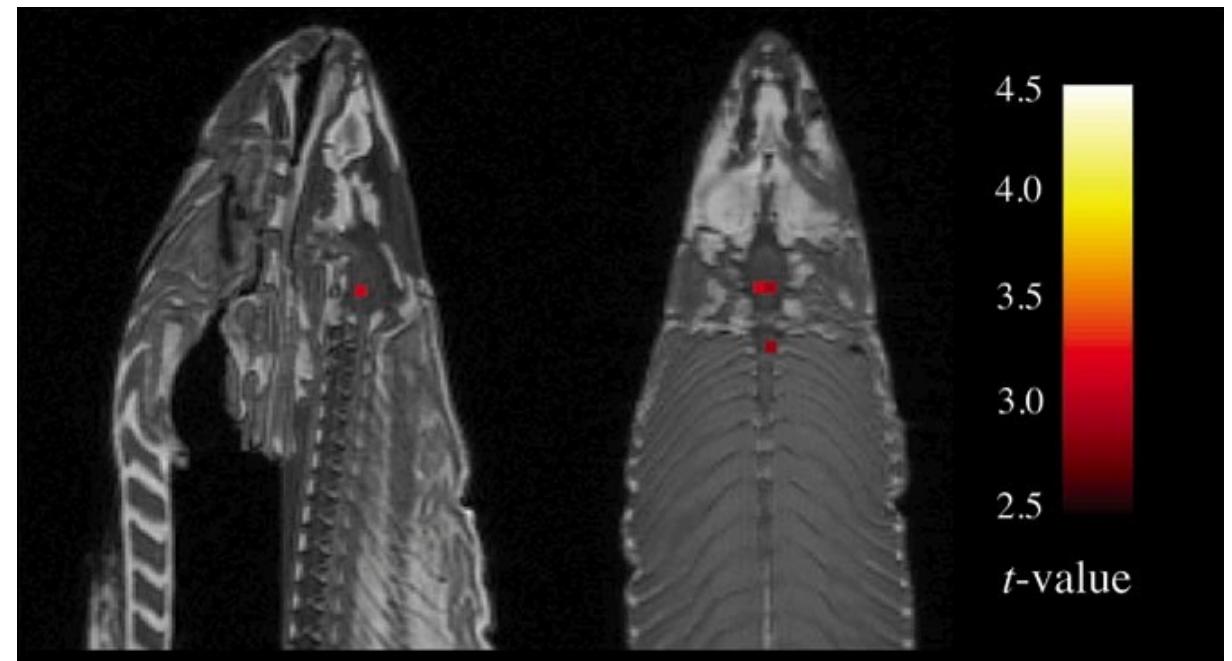
# The default mode network

Resting state functional connectivity MRI

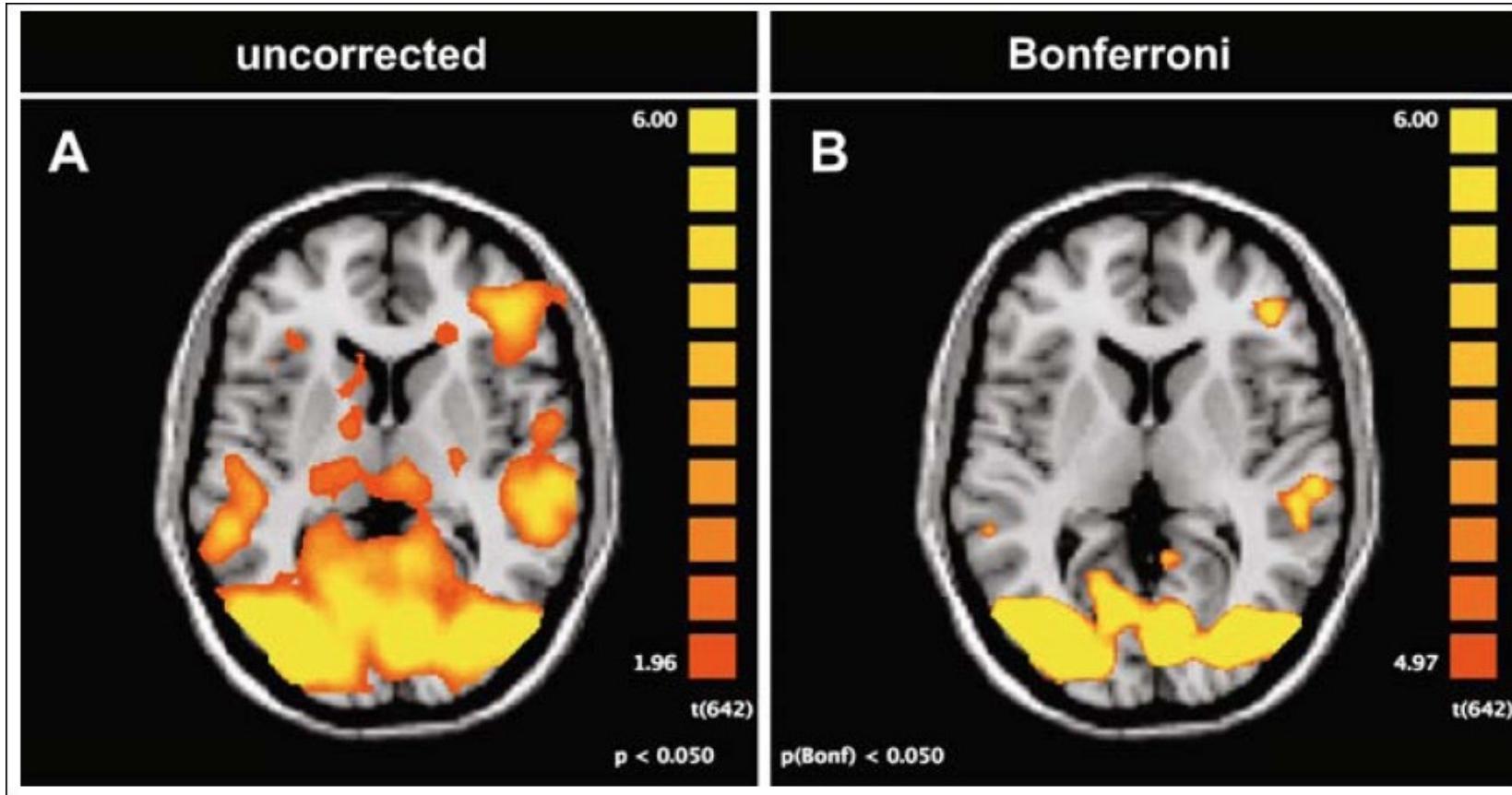


# Problems with interpreting fMRI studies?

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



# 11. Statistics



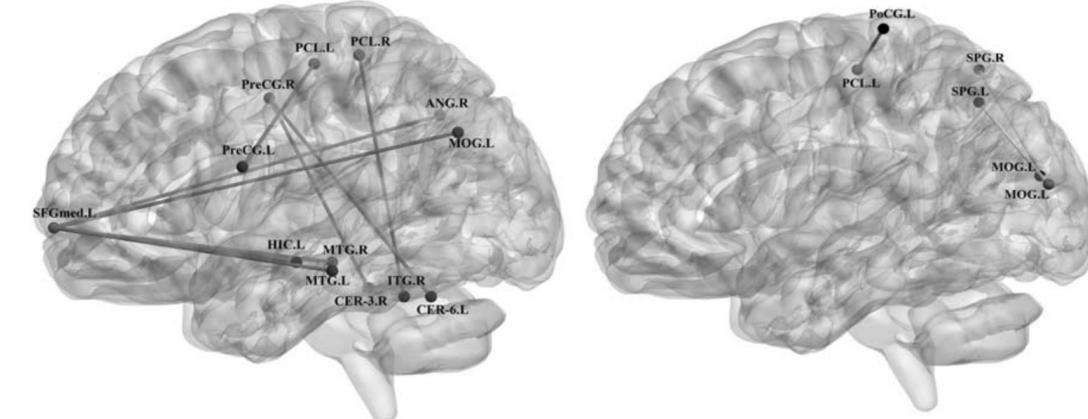
# The heavy metal brain?

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

Yan Sun<sup>a,b</sup>, Congcong Zhang<sup>a,b</sup>, Shuxia Duan<sup>a,b</sup>, Xiaoxia Du<sup>c</sup> and Vince D. Calhoun<sup>d,e,f</sup>

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 Copyright © 2017 Wolters Kluwer Health, Inc. All rights reserved.



- Demonstrates the need for more than just neuroimaging