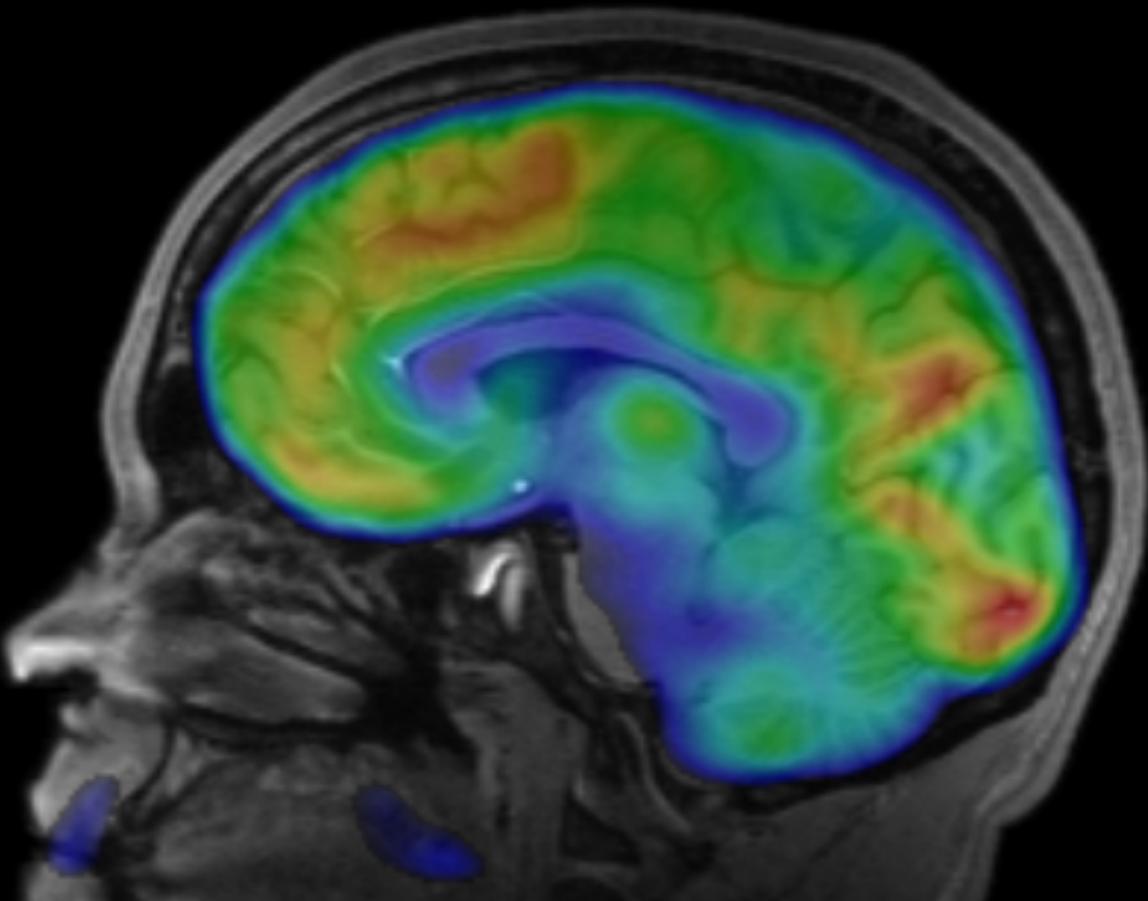


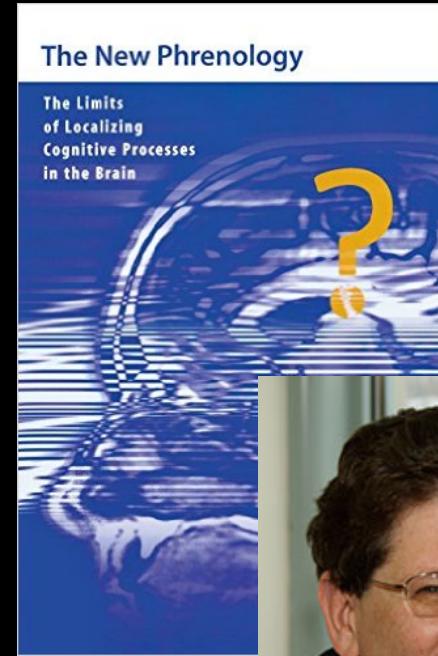
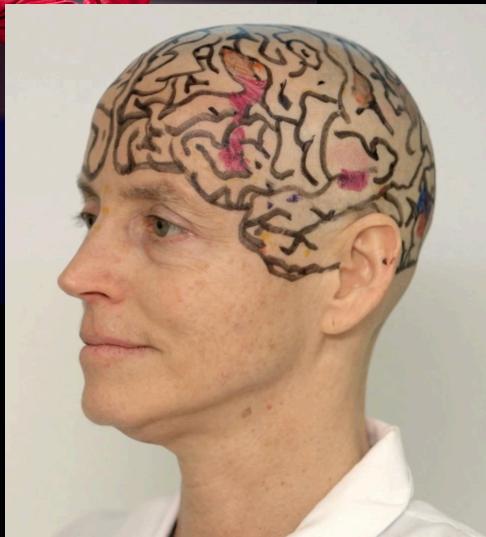
INTRO TO BRAIN IMAGING



Tom Morin

From the Homework:

- Can we localize brain function?



Kanwisher's TED Talk

- Specific brain regions are responsible for specific cognitive functions
- Clearly evident with the Fusiform Gyrus
 - Or is it? (*We'll get to this later...*)
- **INSERT STUDENT RESPONSE HERE?**

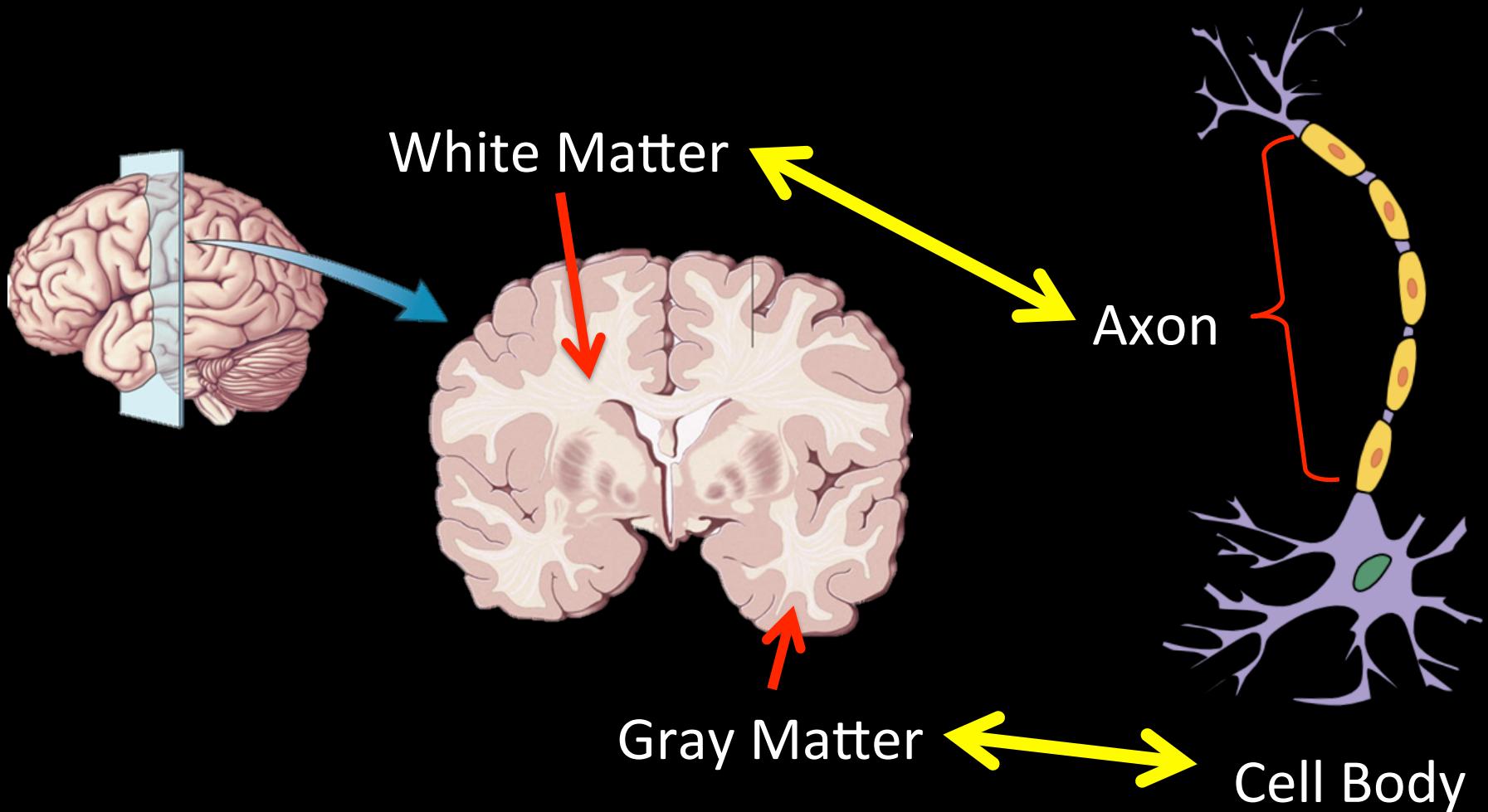
Uttal's: The New Phrenology

- How exactly do we define a cognitive function?
- Believes we are making an inappropriate assumption that behavior manifests itself in biology
- **INSERT STUDENT RESPONSE HERE?**

AGENDA

- Quick Brain Anatomy Review
- How Does MRI Work?
 - Structural MRI
 - Functional MRI
- How Does PET Work?
- Looking to the Future

Quick Brain Anatomy Review

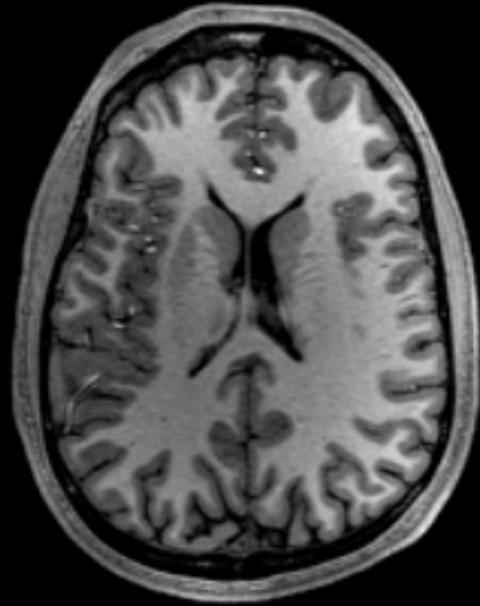
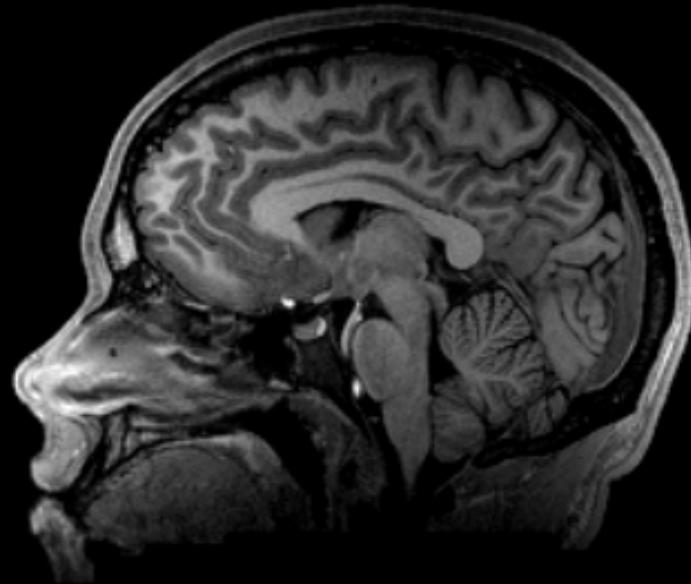
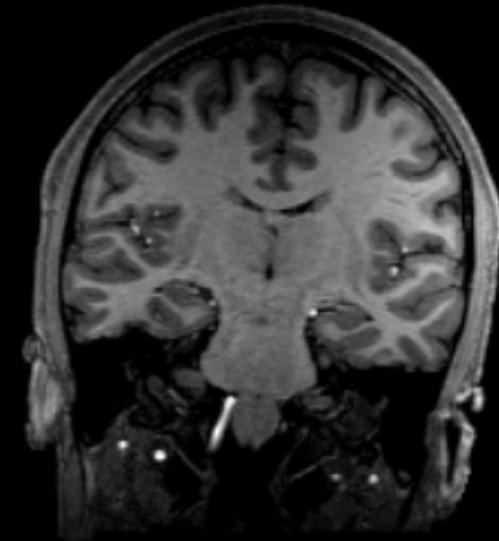


What am I Looking at?

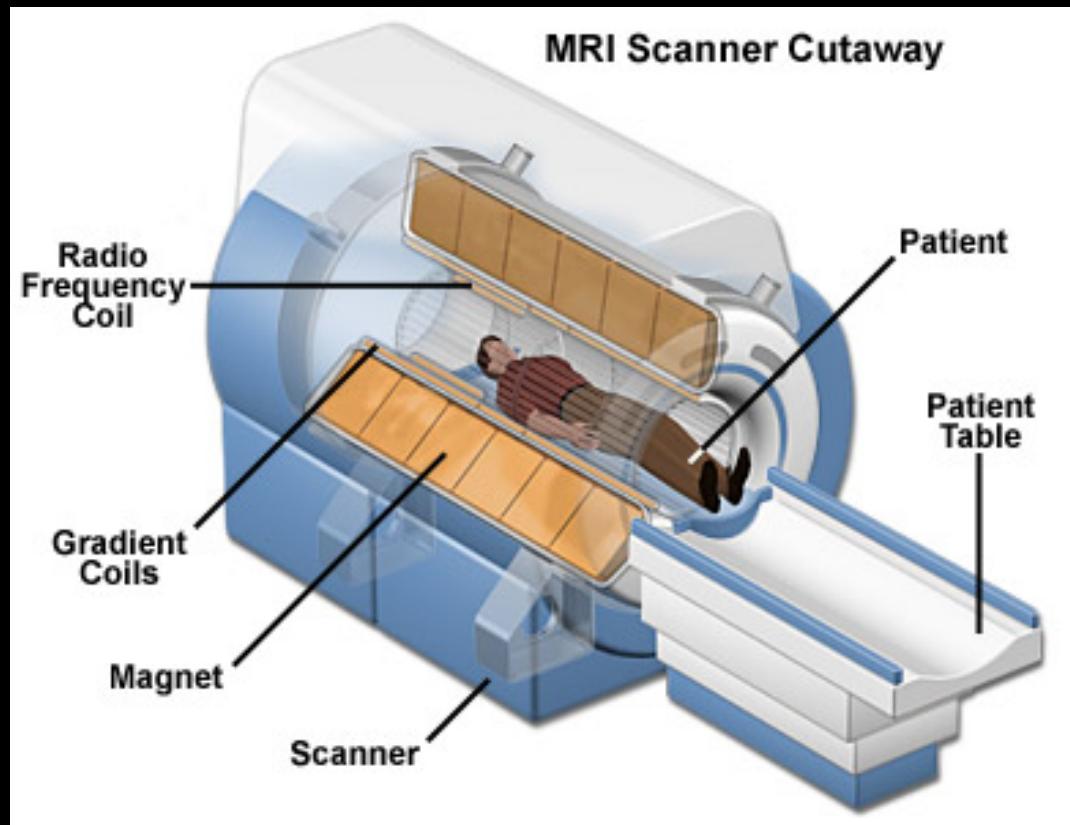
Coronal

Sagittal

Axial



How Does MRI Work?



How Does MRI Work?

1. Place subject in a strong magnetic field
 - Protons align to the direction of the field

ILLUSTRATION OF PROTONS ALIGNED

How Does MRI Work?

2. Apply a radiofrequency pulse, temporarily misaligning protons

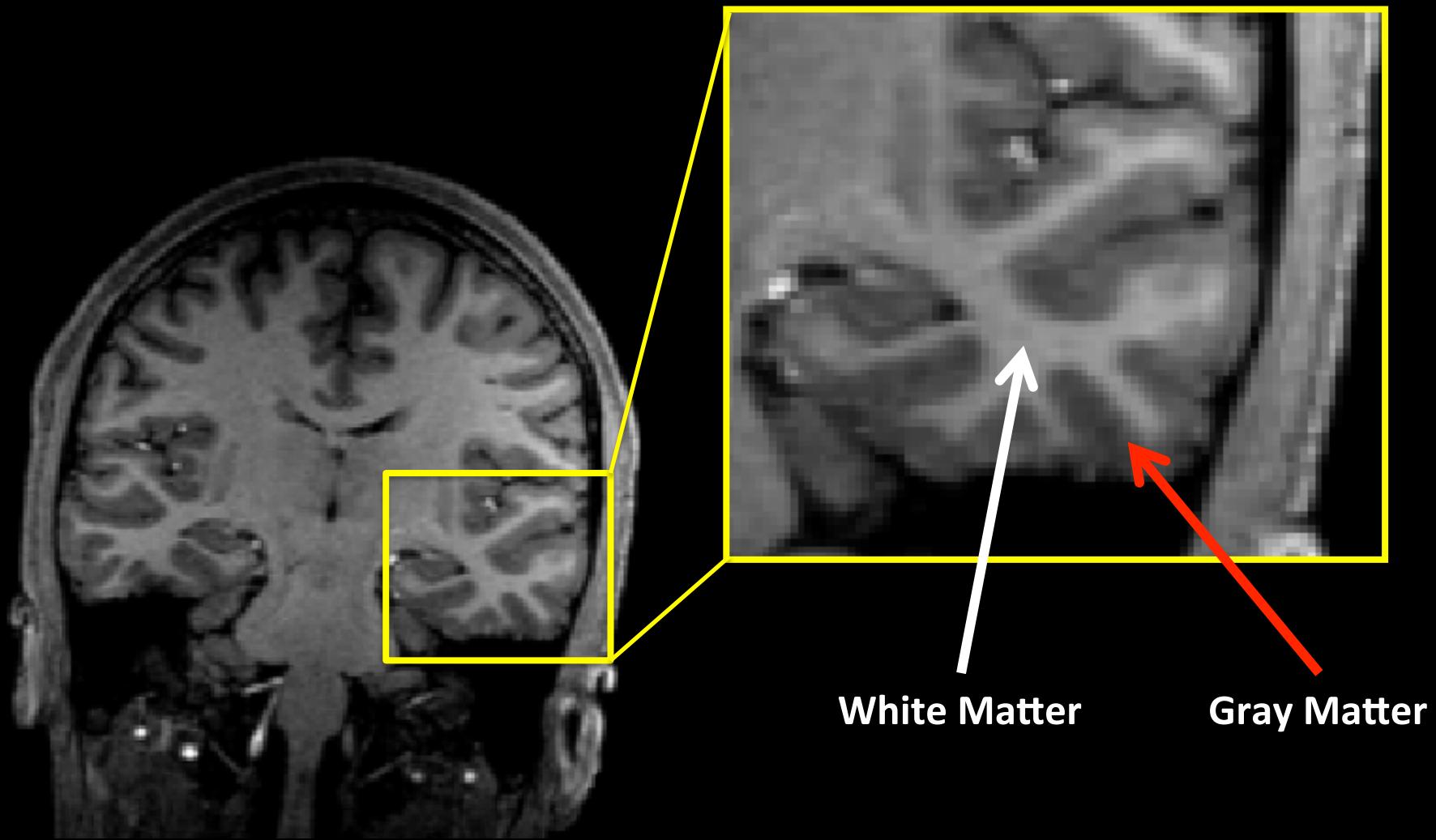
ILLUSTRATION OF PROTONS MISALIGNED

How Does MRI Work?

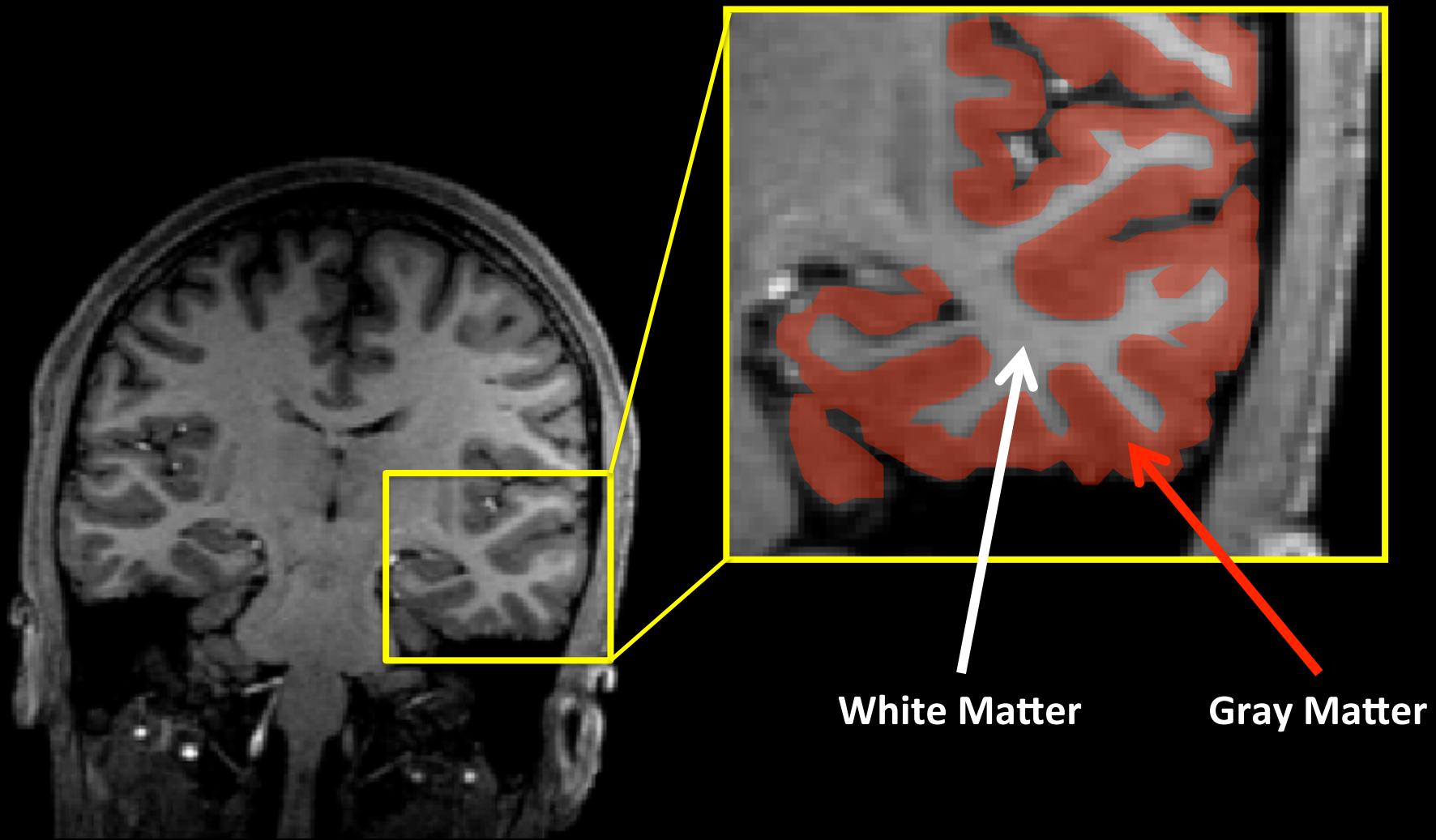
3. End the pulse, allowing protons to relax back
 - As they re-align with the strong magnetic field, they emit radiowaves which are detected by RF coils (different tissues emit different radiowave patterns (e.g. Gray Matter vs. White Matter))

ILLUSTRATION OF PROTONS RELAXING & EMITTING RADIOWAVES

Signal Differs in WM/GM

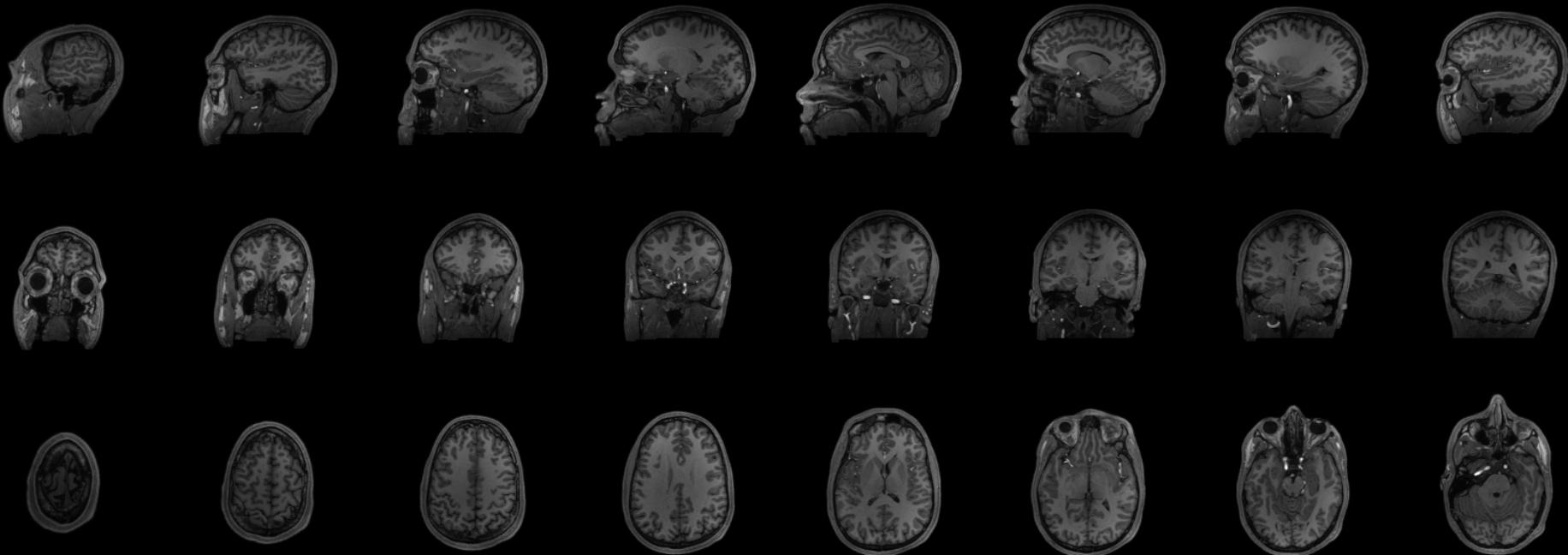


Signal Differs in WM/GM



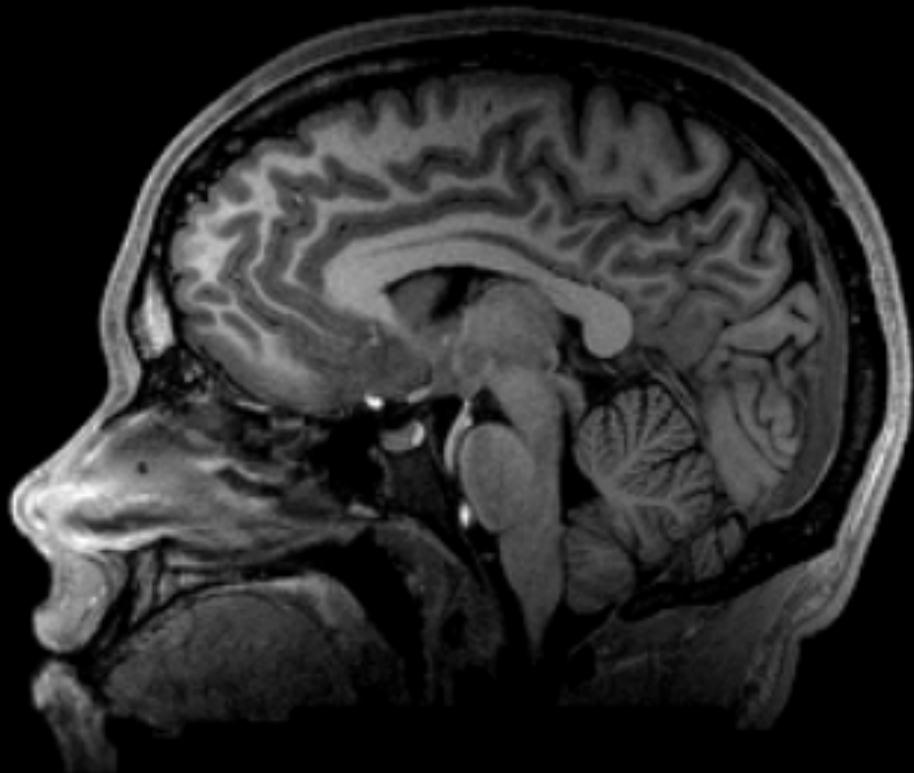
We Acquire One Slice at a Time

- Online Example of Brain Slices:
 - tmmorin.com/Tom.html

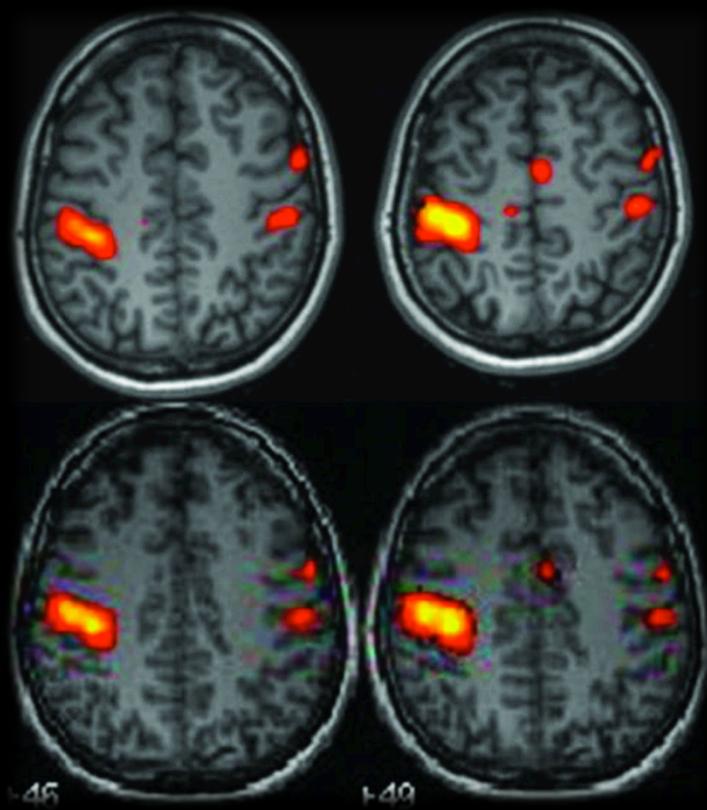


Structural MRI

- 5-10 minutes to acquire
- ~1mm resolution
- 3 Dimensional
- It's not just an image, it's DATA! ☺



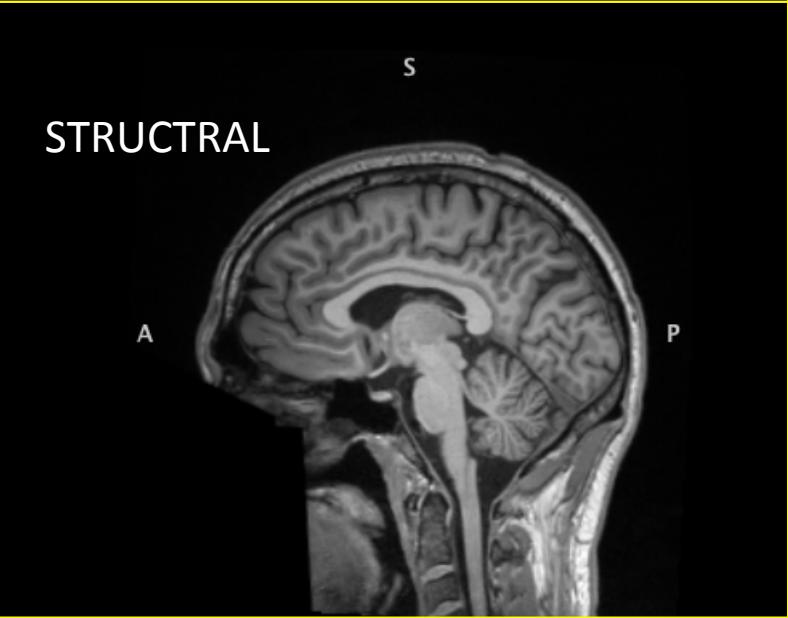
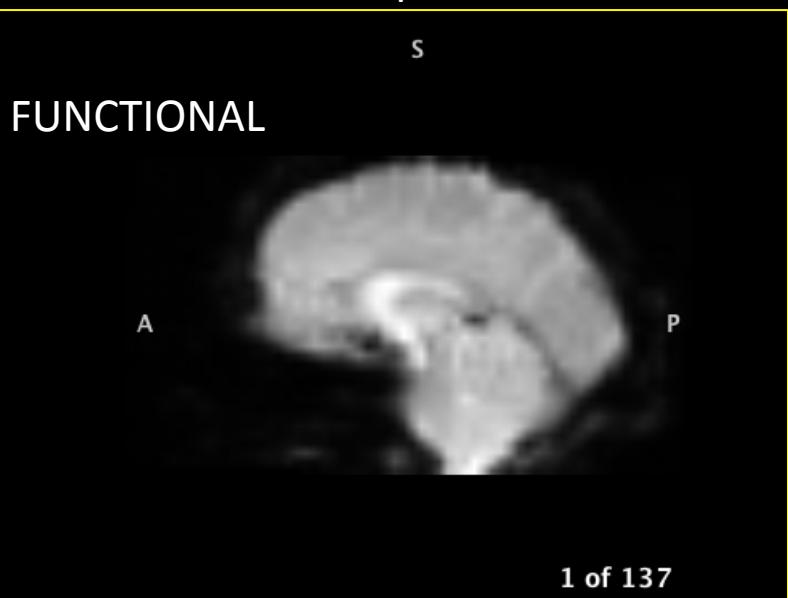
Functional MRI (fMRI)



fMRI

OpenfMRI ds000115

- 4D “Video” of brain activity
- One image every 3 seconds
- Poor spatial resolution, like a blurry photograph
- It’s not just a video, it’s DATA!



What Are We Measuring With fMRI?

- Blood oxygenation level dependency (BOLD) Signal

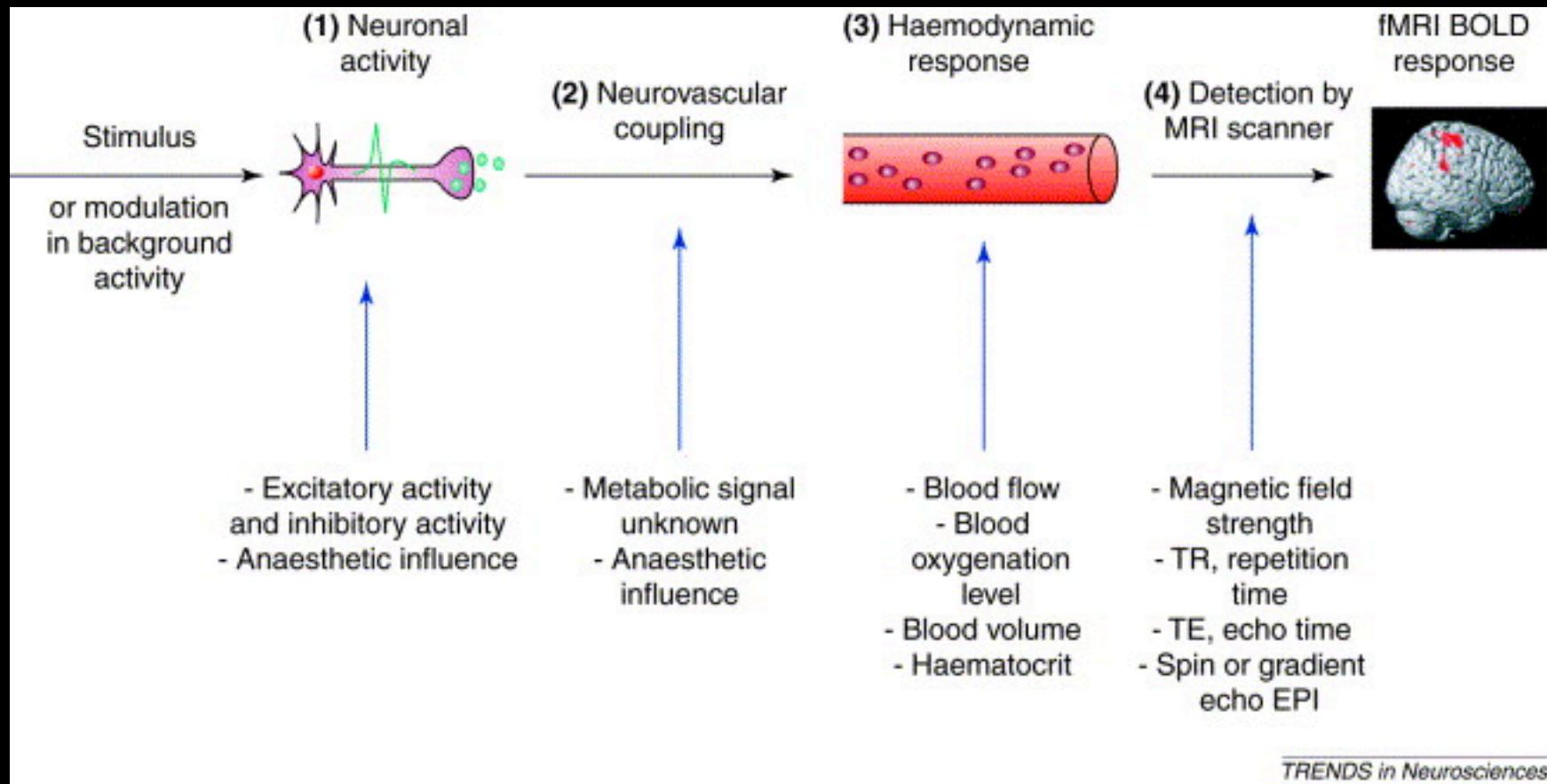


Image Subtraction

- To find areas of “activation,” subtract a control image from a task image

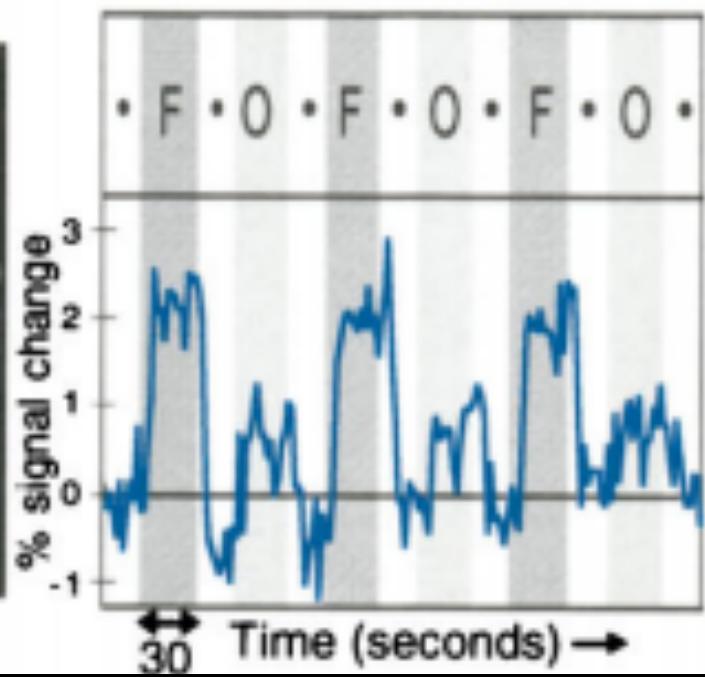
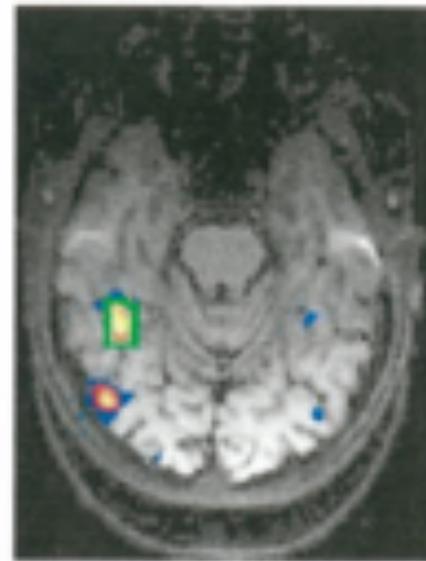
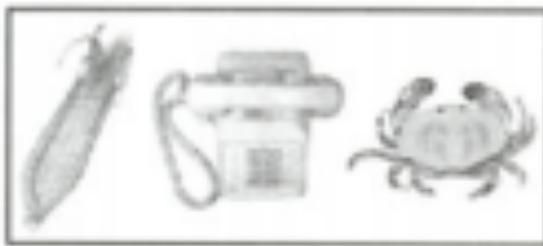
ILLUSTRATION HERE

$$\text{TASK} - \text{CONTROL} = \text{ACTIVATION MAP}$$

Finding Functional Brain Regions

- Design a Task/Control Paradigm

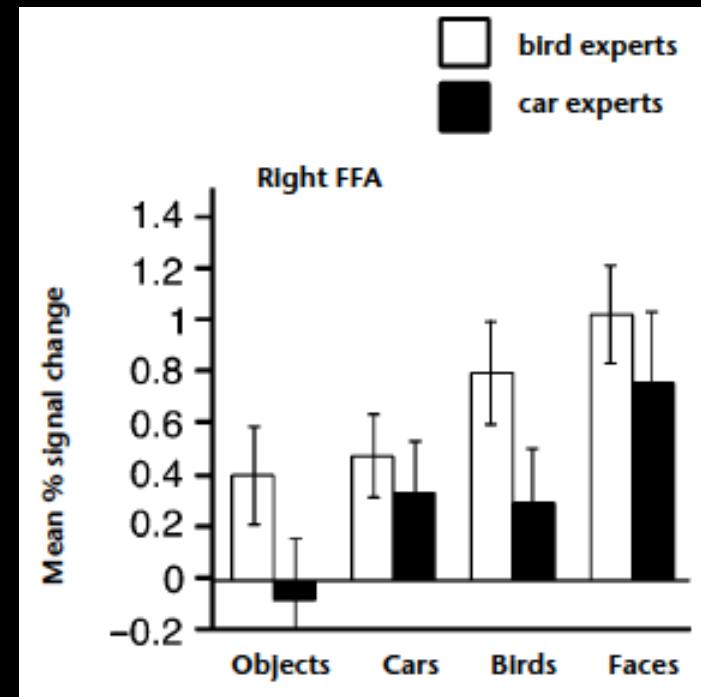
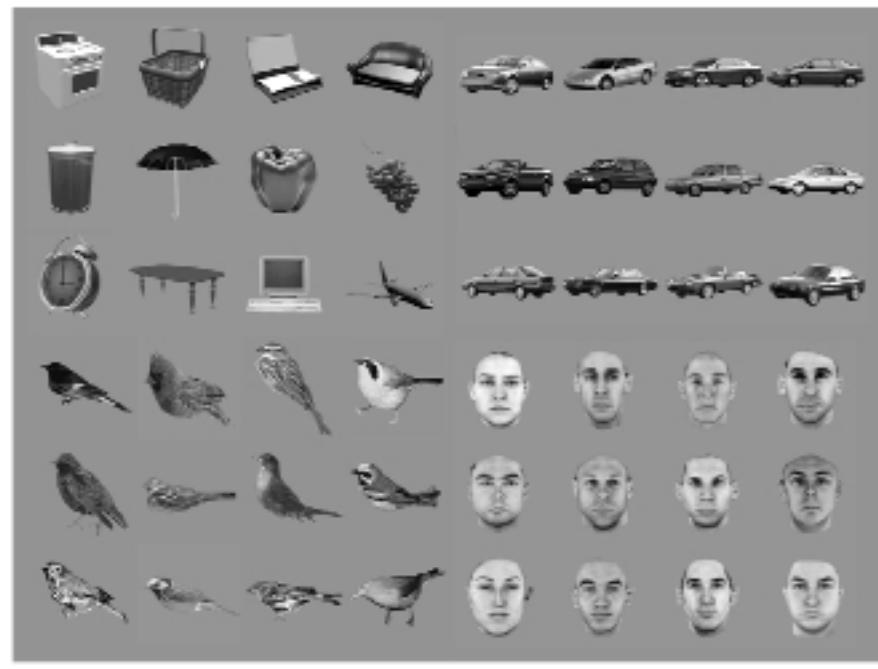
3a. Faces > Objects



Kanwisher, et al. (1997)

Is the FFA Face-Specific?

- Car Experts & Bird Experts show increased FFA activation when viewing cars/birds compared to viewing objects



Other fMRI Examples

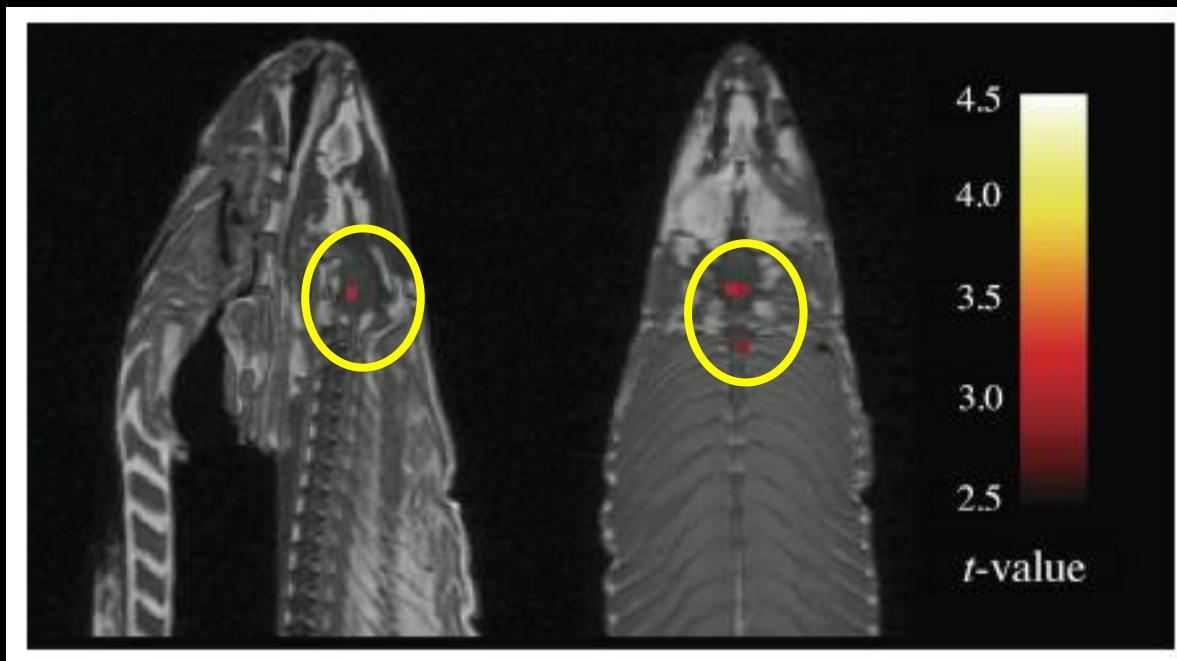
- Working Memory Tasks
- Attention Tasks
- Executive Function
- Decision Making & Reward
- Almost any cognitive function!

Limitations and Controversy

- This is “macro” imaging
 - Our best resolution is about 1mm³
 - About half a billion synapses per voxel
- The “frame-rate” with fMRI is in seconds
 - EEG can measure brain activity in milliseconds
 - Neurons can fire hundreds of times per second
- Participants are lying down in a dark, loud, crammed tunnel

Limitations and Controversy

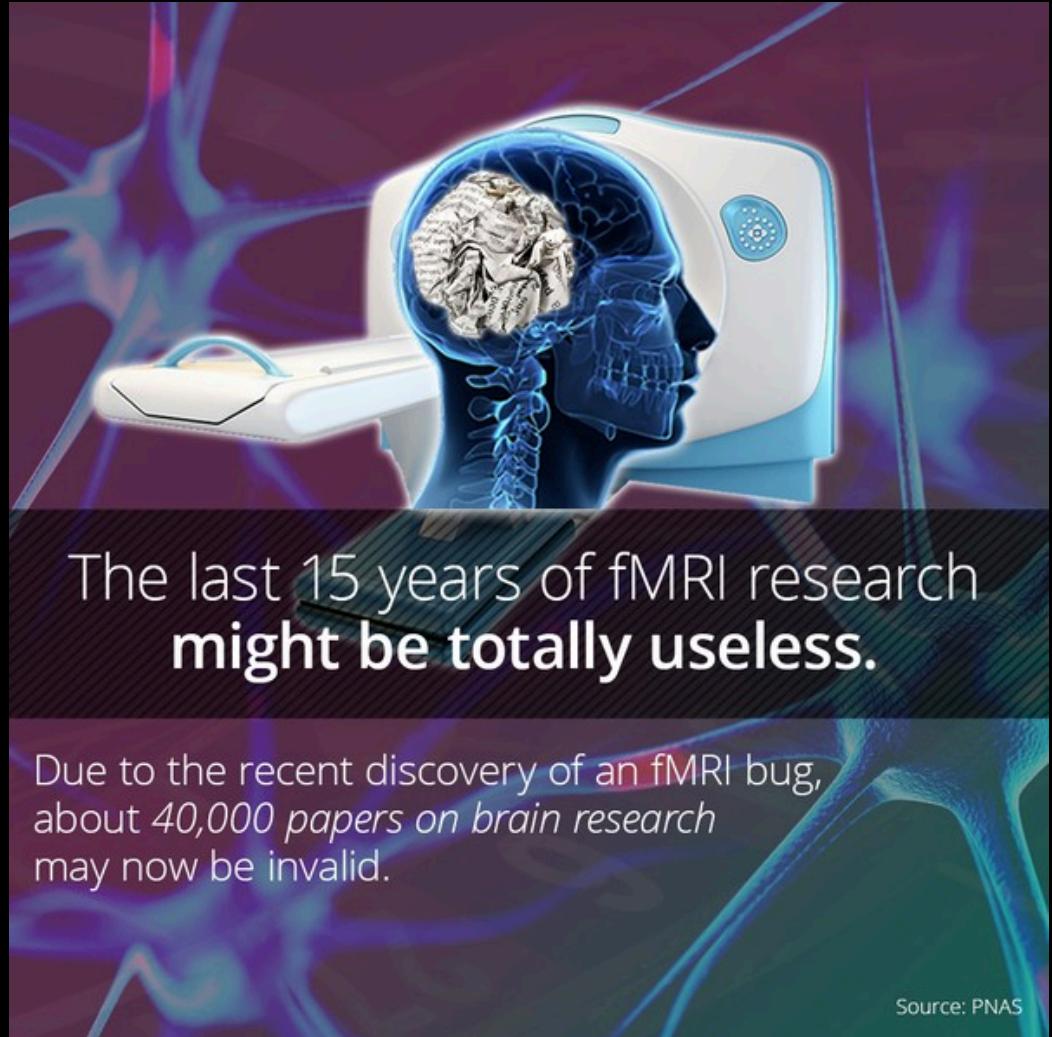
- fMRI is noisy!
- Dead salmon shows neural activity



Bennett, et al. (2009)

Limitations and Controversy

- Last summer a study was published claiming that as many as 40,000 fMRI studies may be invalid due to statistical errors found in fMRI analysis software
- “40,000” has been redacted, but many studies may still be effected
- Most studies are fine though

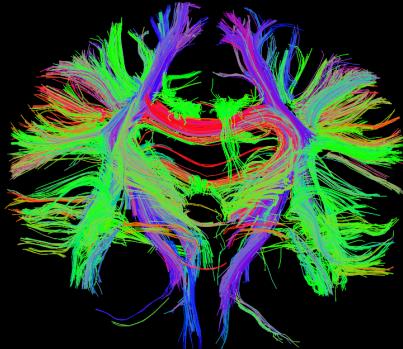


Other Kinds of MRI

- Radiologists and Physicists can tune the MRI machine to look at lots of different physiological features
- Quantitative MRI
 - Perfusion Imaging
 - pH Imaging
 - Sodium Imaging
 - And More!

Other Kinds of MRI

- Diffusion Tensor Imaging (DTI)



- Image white matter fiber tracts in the brain
- Look at the direction that water is travelling
- Map structural connections

- Resting State fMRI (rs-fMRI) (Coming Up Wednesday!)



- The brain is always “buzzing” with activity
- Measures the low-frequency signals associated with “background” (not task-related) activity
- Map functional connections

Positron Emission Tomography

- [https://www.youtube.com/watch?
v=oySvkmezdo0](https://www.youtube.com/watch?v=oySvkmezdo0) (1 min video – no sound)
- [https://www.youtube.com/watch?
v=yrTy03O0gWw](https://www.youtube.com/watch?v=yrTy03O0gWw) (4 min video - UCL)

How Does PET Work?

1. Label a chemical with a radioactive isotope
 - For example, flourodeoxyglucose or FDG is just sugar with an [^{18}F] tag

How Does PET Work?

2. Inject the radiotracer into the patient
 - [Optional] Wait for radiotracer to accumulate in the body

How Does PET Work?

3. As the radioactive tag decays, positrons are emitted. When a positron collides with a nearby electron, gamma rays are emitted

How Does PET Work?

4. Gamma rays are detected by the scanner and the data is recorded. An image is later reconstructed by the computer.

PET Examples

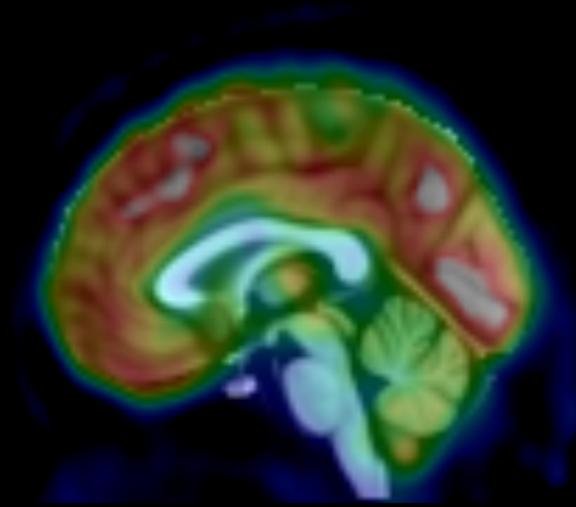
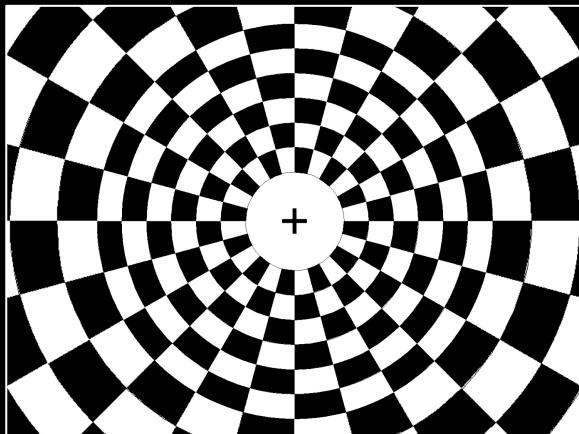
- Haxby (1991) used H_2^{15}O (radioactive water) to map blood flow in the brain
 - Looked at activity associated with face-matching or dot-location-matching (faces vs. places) in the visual cortex
 - Studies like this were the inspiration for fMRI

PET Examples

- FDG Imaging (Cancer & Neurology)
- Dopamine Imaging
- Opioid Imaging
- Amyloid Imaging (Alzheimer's)
- Imaging Neuroinflammation & Microglia
- HDAC (epigenetic) imaging
- And Many More!

Functional PET (fPET)

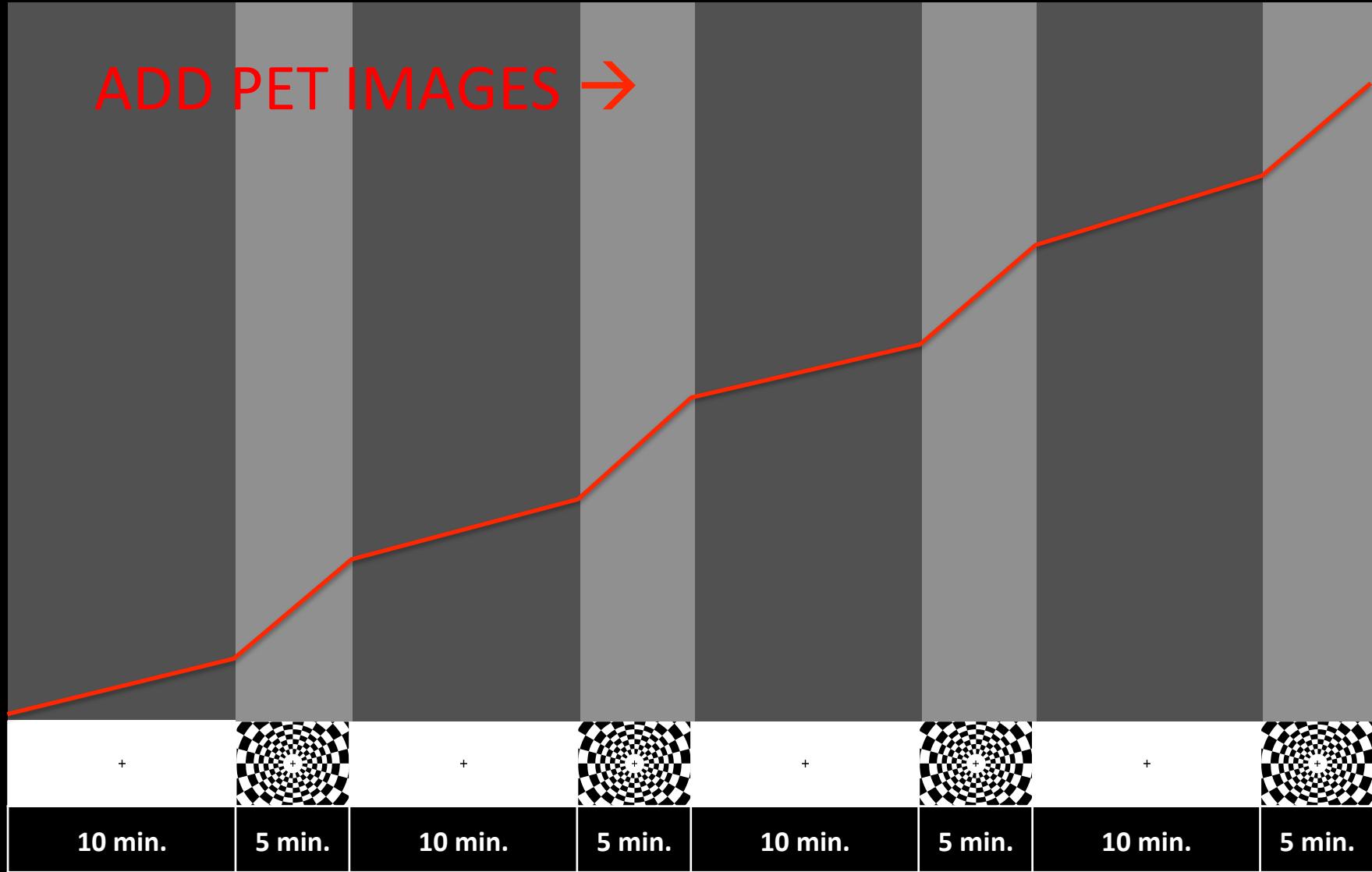
- Instead of injecting it all at once, we constantly infuse the radiotracer
- FDG radiotracer builds up in the brain
- Take a 1-hour PET “video” and pair it with a visual stimulus



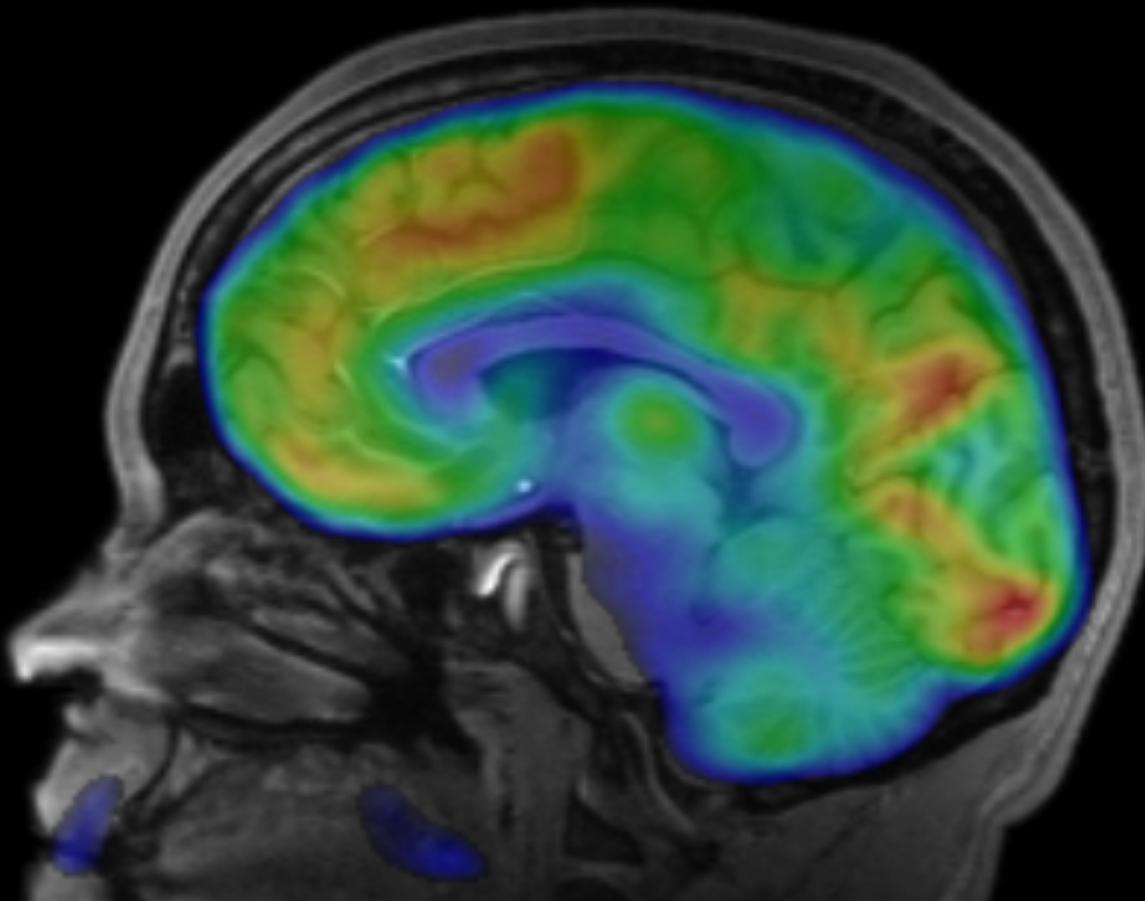
fPET

Glucose Metabolism in Visual Cortex

ADD PET IMAGES →



Simultaneous MR/PET



Questions?

Acknowledgements



Project Mentor:
Dr. Hsiao-Ying (Monica) Wey



Principle Investigator:
Dr. Jacob Hooker