

# Neurophysiological Approaches to Understanding Behavior

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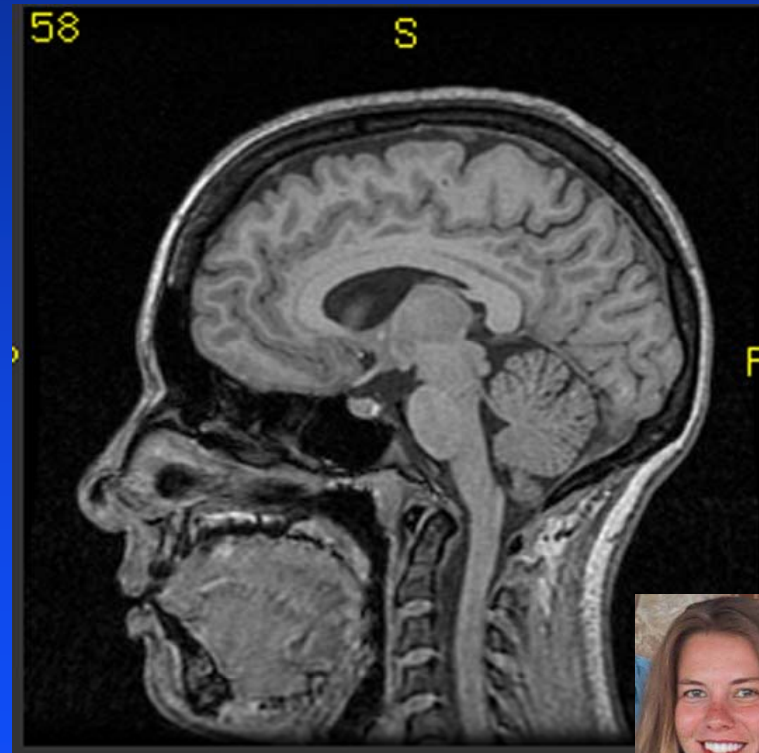
Psychological and Brain Sciences

Dartmouth College



# Overview

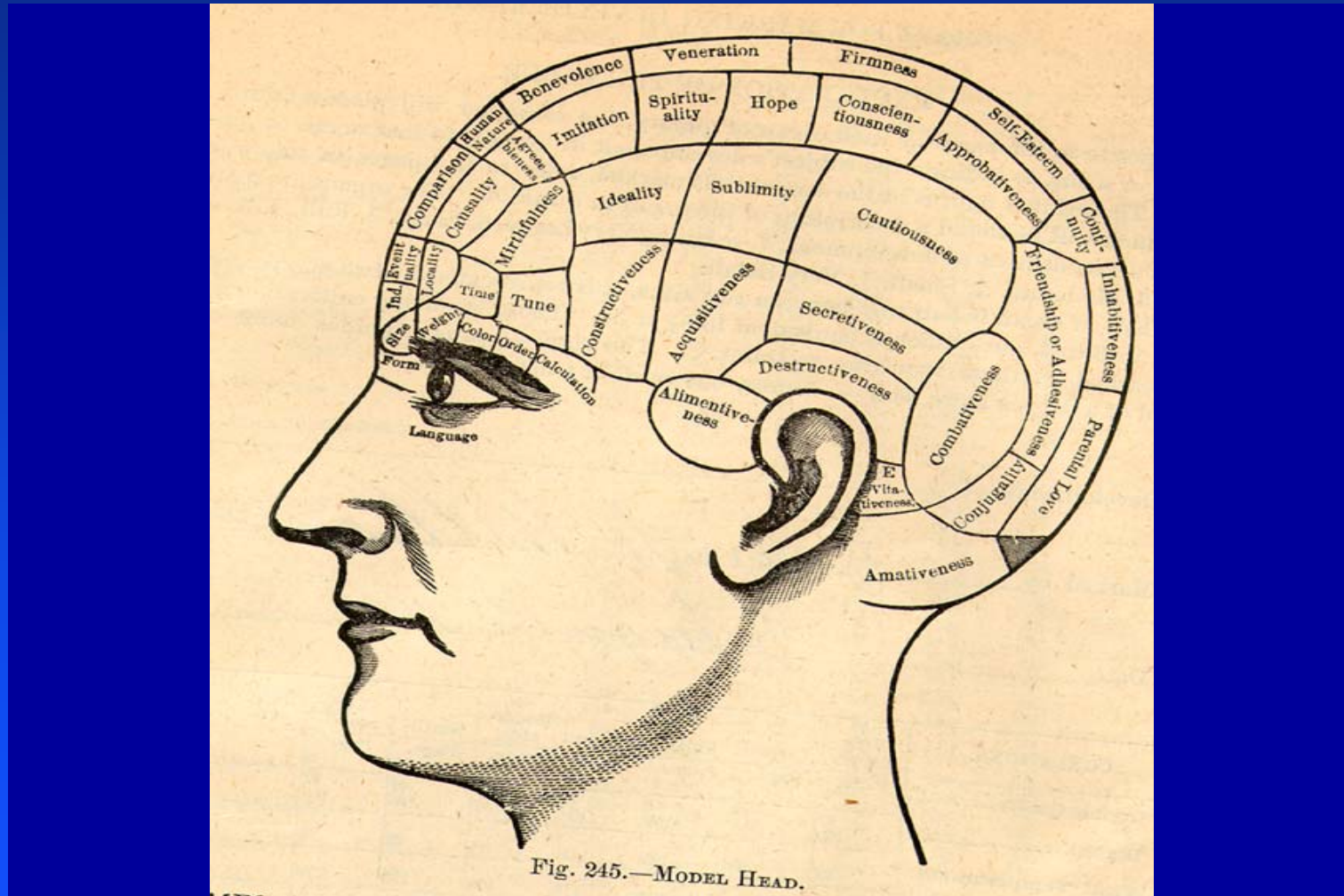
- Historical Context
- Methods
  - EEG, ERP, MEG
  - PET, fMRI
  - TMS
  - DTI
  - Morphometry
- Research Examples
- Conceptual Issues



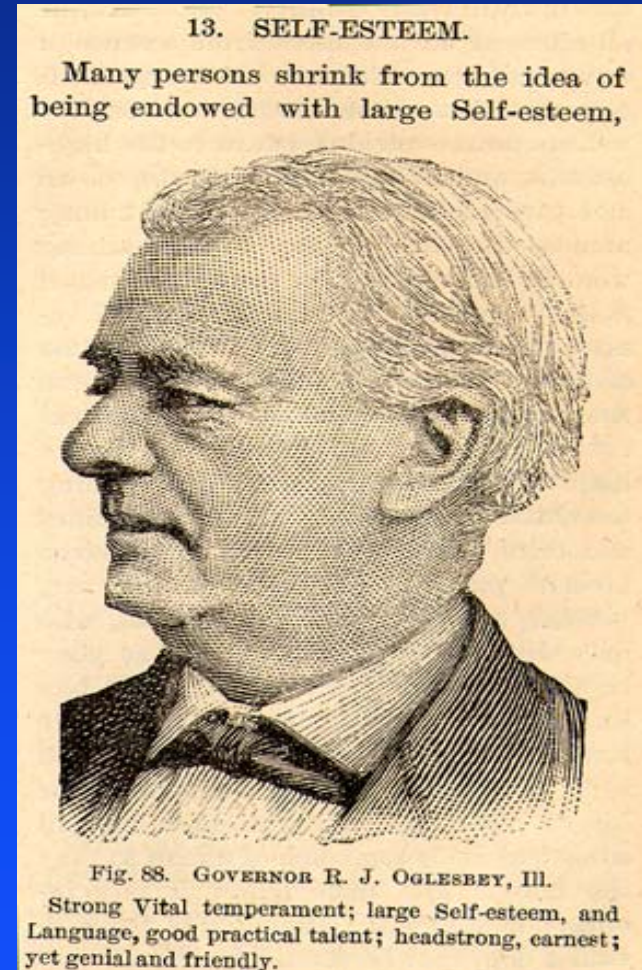
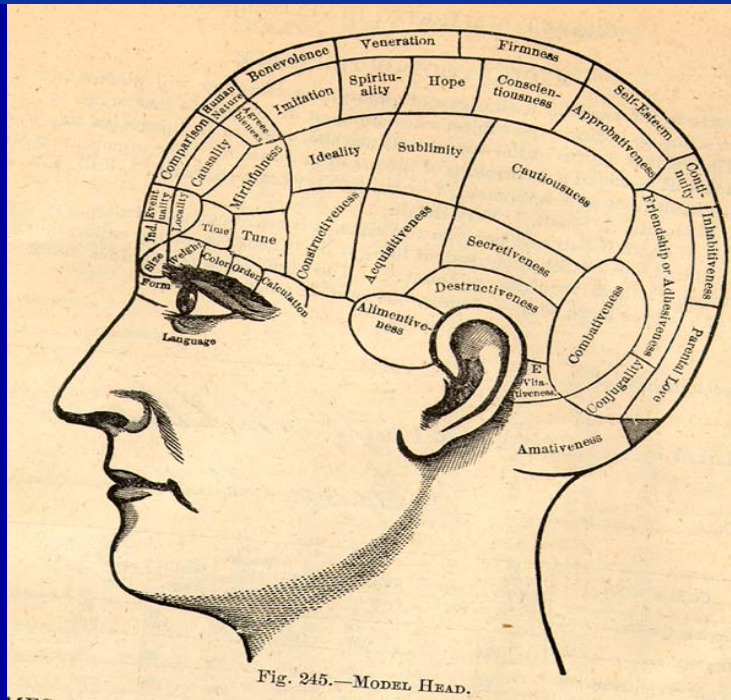
# Brief Neuroscience History

- Localization
  - Phrenology
  - Case studies of brain injury
  - Experimental studies
- Understanding Neurochemistry
  - Neuron Doctrine
  - Neurotransmission
- Brain Imaging

# Phrenology made an important point



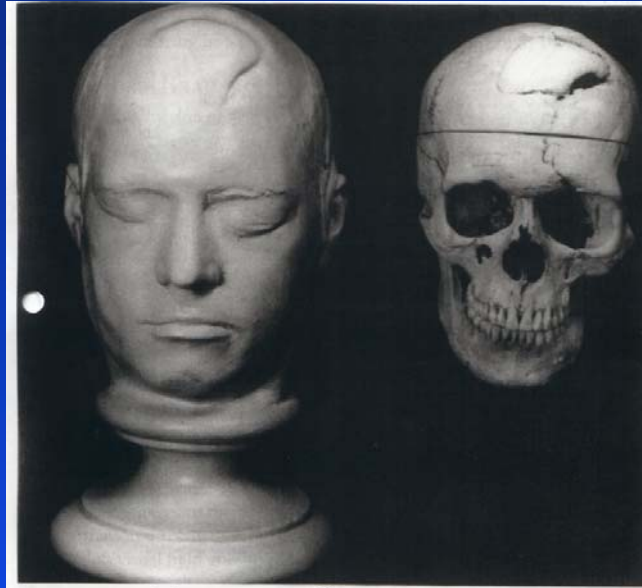
# But, Phrenology got a lot wrong!



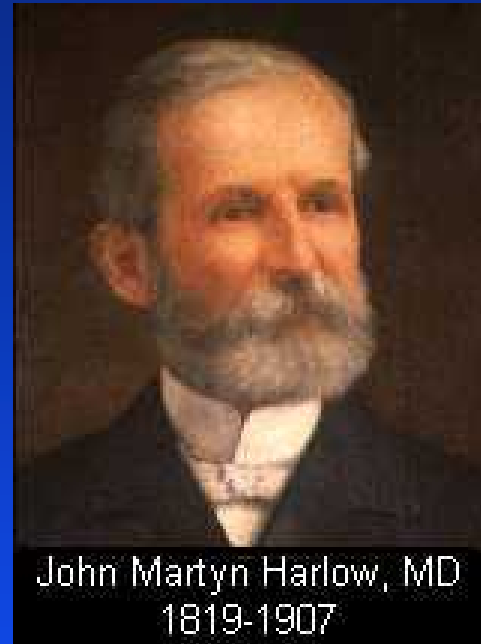
# Case Studies Support Localization

- Broca's study of patient Tan
- Phineas Gage

# A New England Celebrity

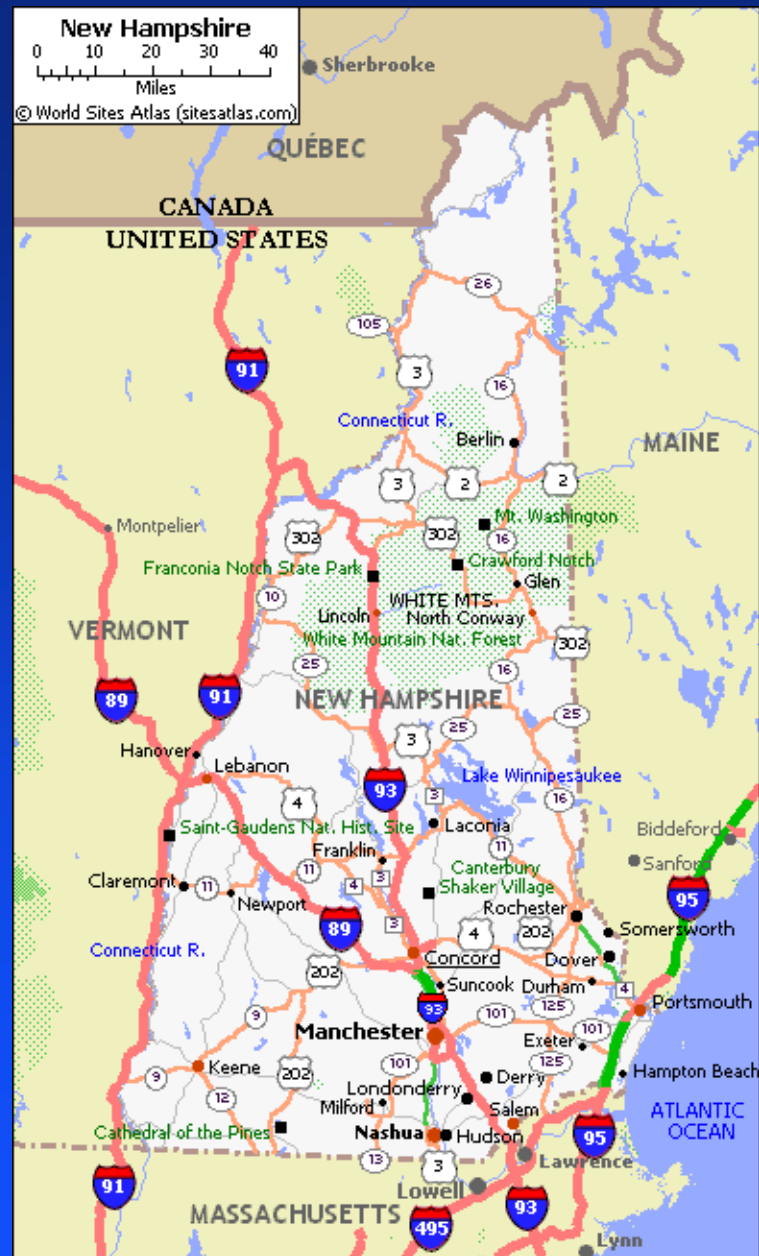
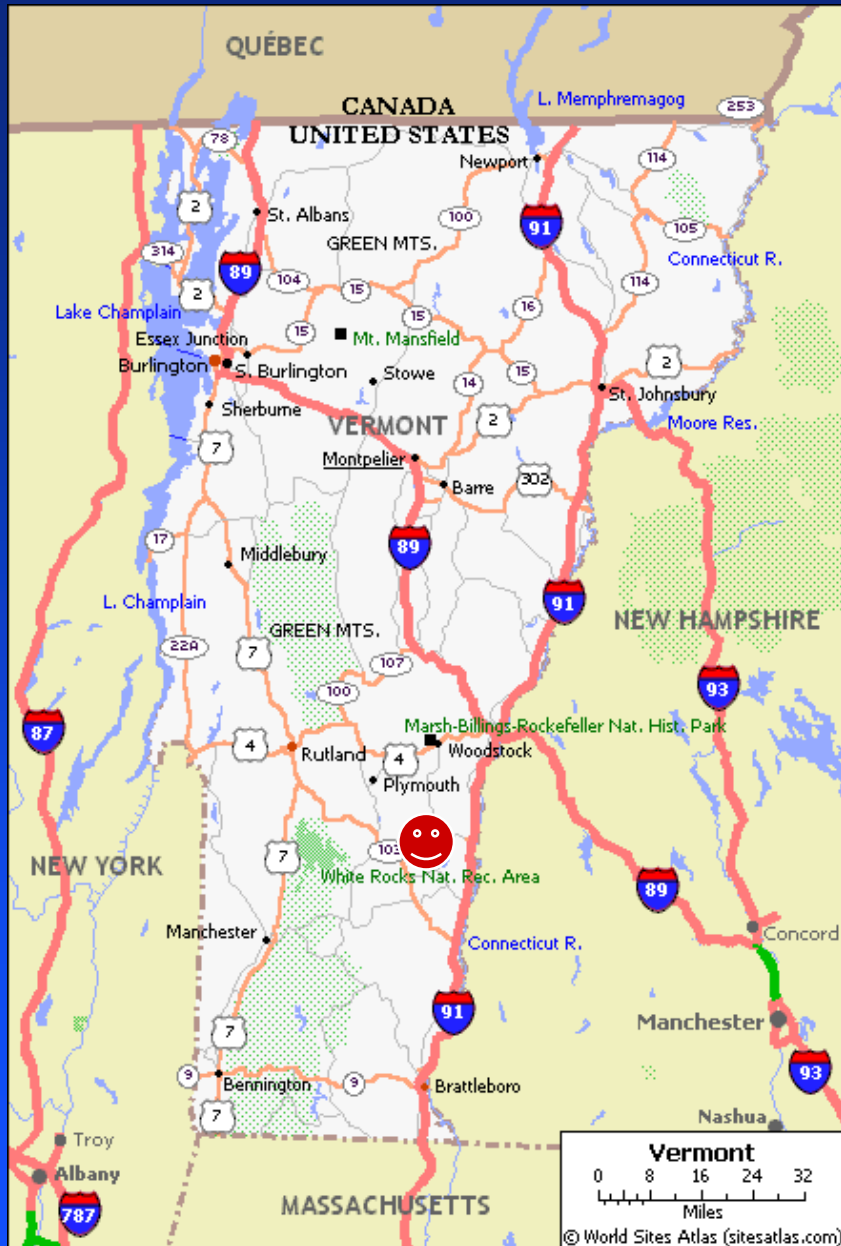


*Phineas Gage.*

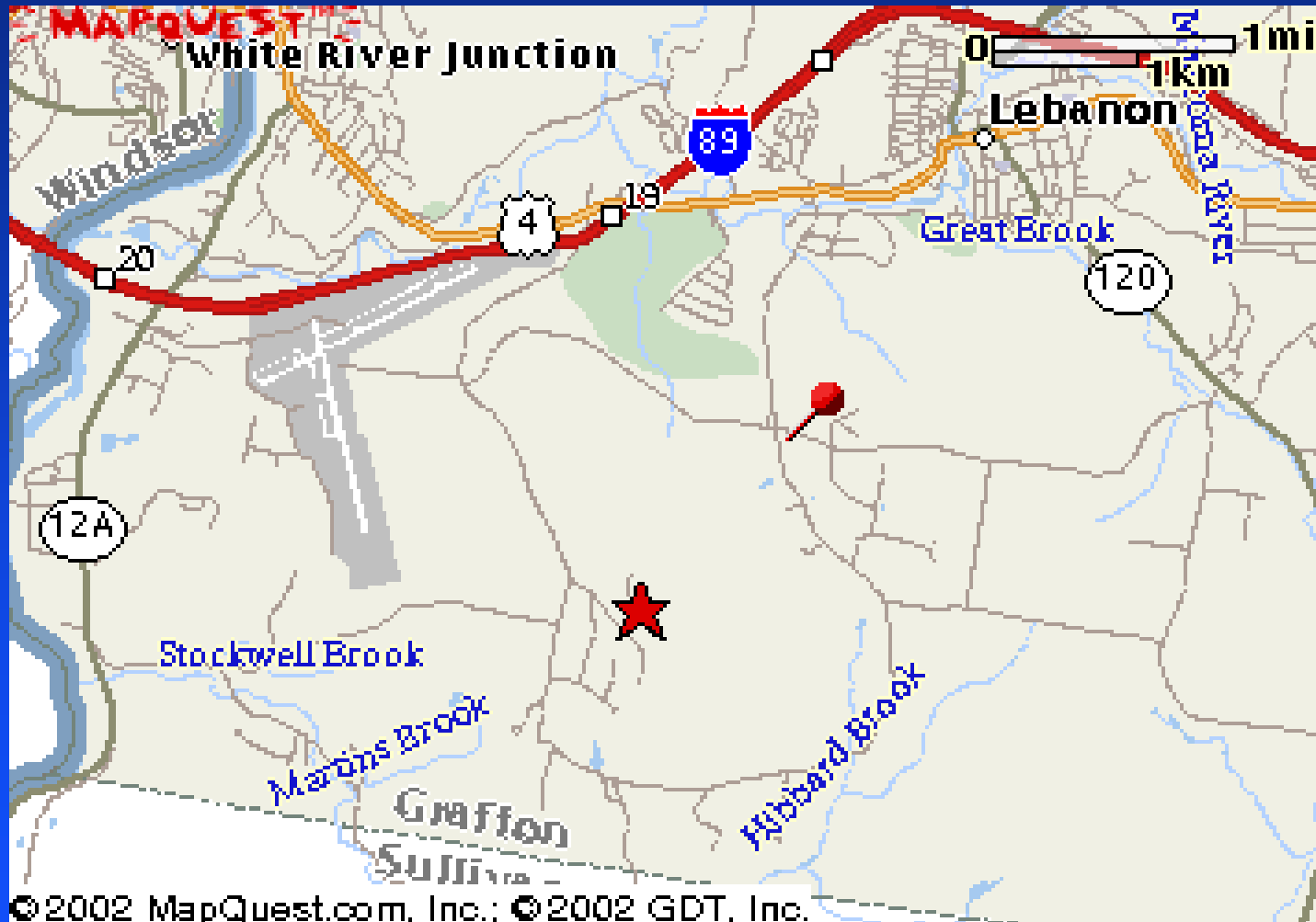


John Martyn Harlow, MD  
1819-1907





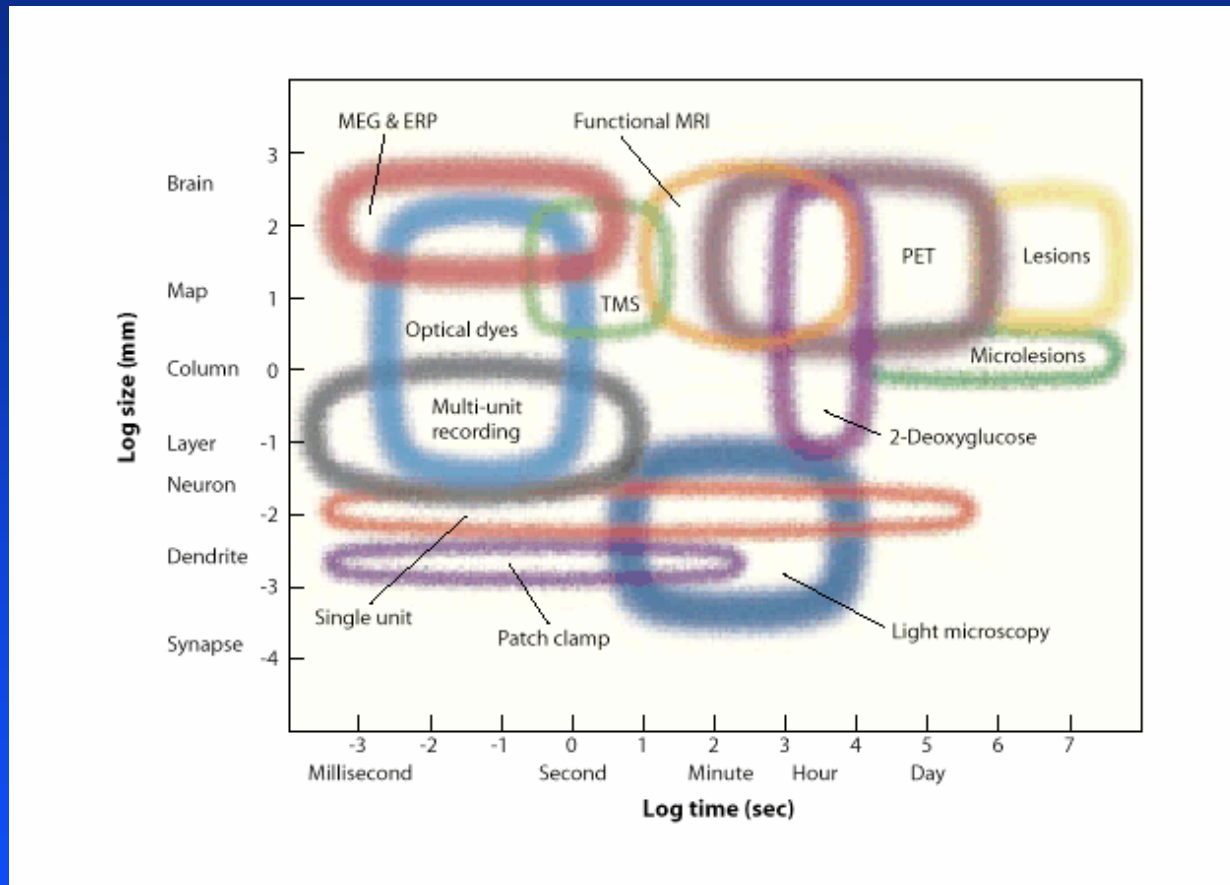
# Talk about self-relevance!



# Neuronal Functioning

- Neuron Doctrine
  - Neurons are distinct units
- Neurotransmitters
  - Rapid rise in identification of substances that act as neurotransmitters
  - Experimental manipulation of neurotransmitters to observe effects on behavior
- Brain imaging methods
  - PET at Washington University (Michael Ter-Pogossian)
  - MRI at SUNY - Stony Brook (Paul Lauterbur)

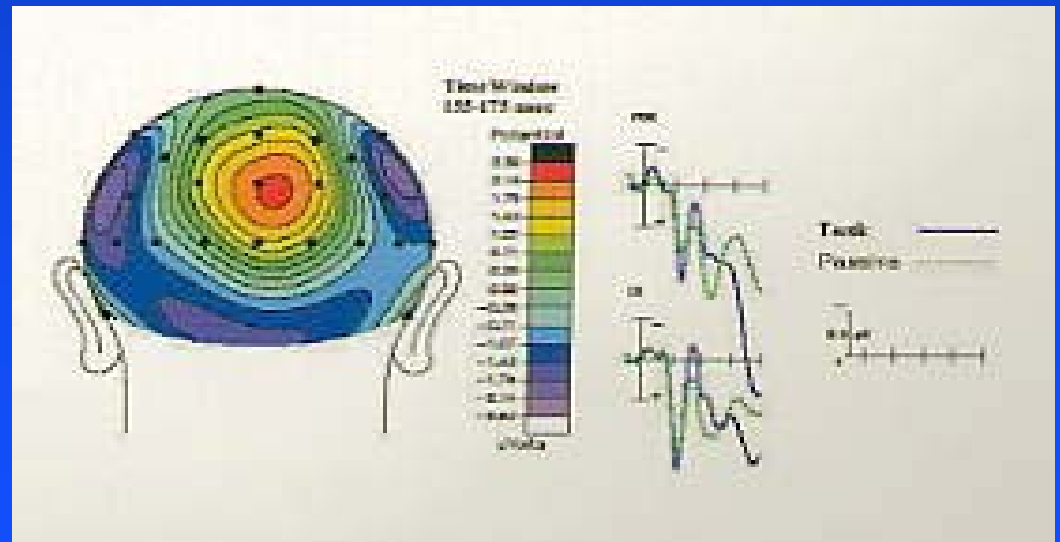
# Comparison of Methods

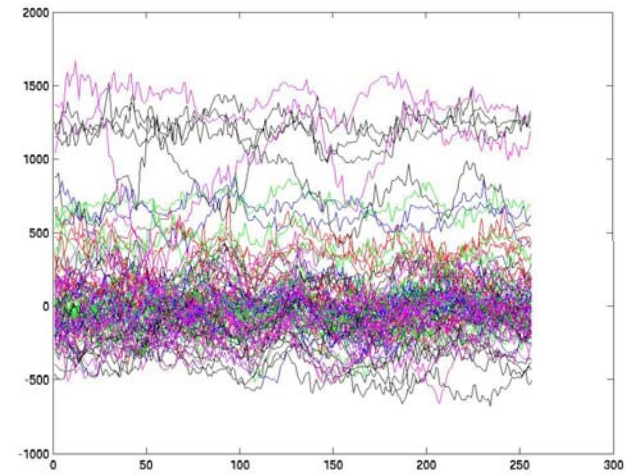
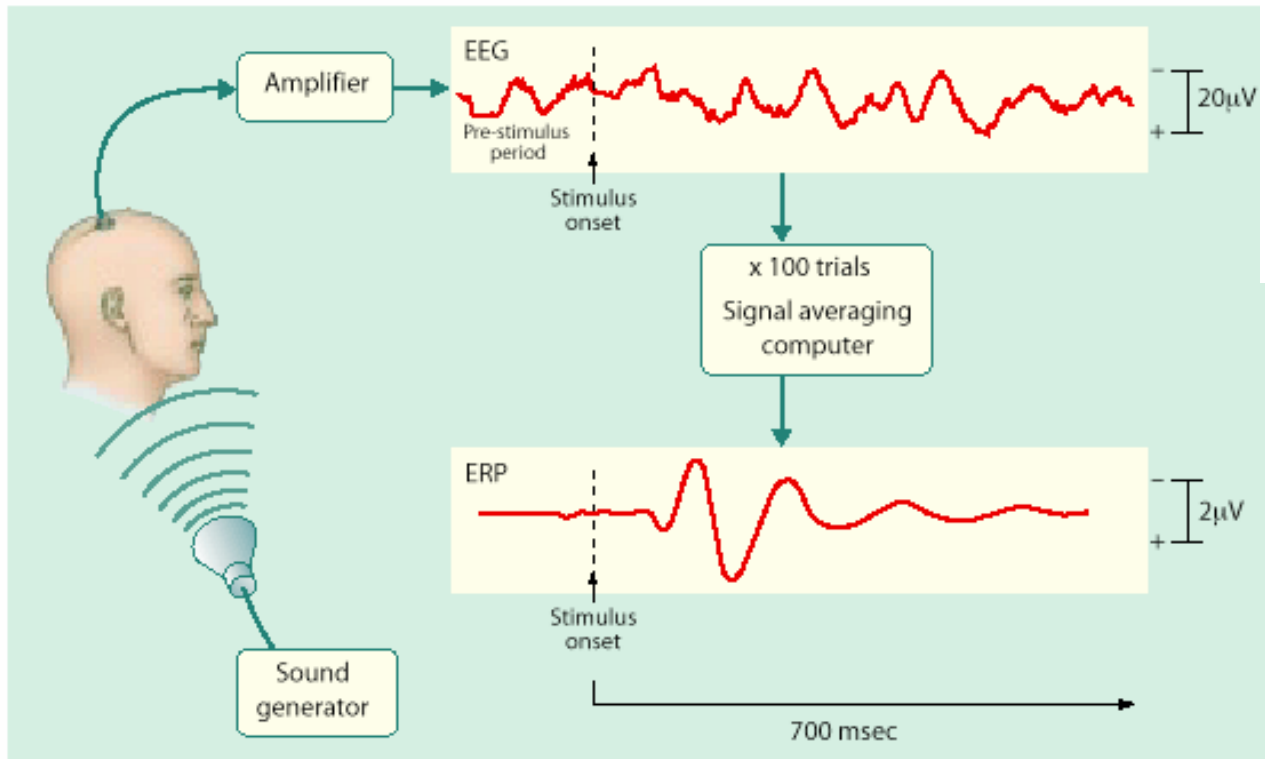


Temporal vs. Spatial Resolution

# Neurophysiology for Temporal Resolution

- Electroencephalography (EEG)
- Event-Related Potentials (ERP)
  - Evoked Responses
- Magnetoencephalography (MEG)





QuickTime™ and a  
TIFF (LZW) decompressor  
are needed to see this picture.

# Magnetoencephalography (MEG)

QuickTime™ and a  
TIFF (Uncompressed) decompressor  
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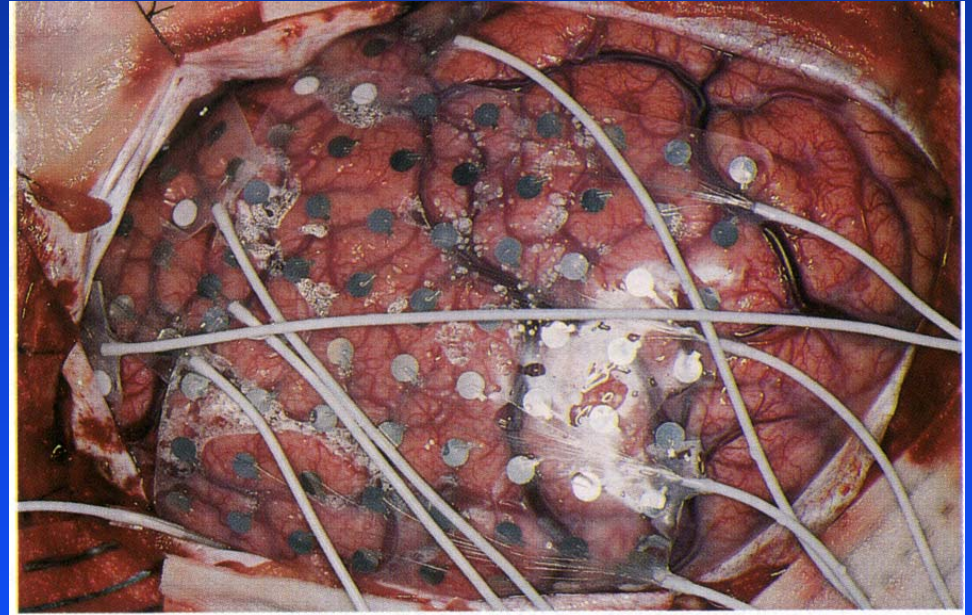
# Intracranial ERPs

## Advantages

- Much higher signal-to-noise ratio (need fewer trials)
- Better spatial resolution
- Subcortical implants possible

## Disadvantages

- Obviously, an invasive procedure
- Clinical patients



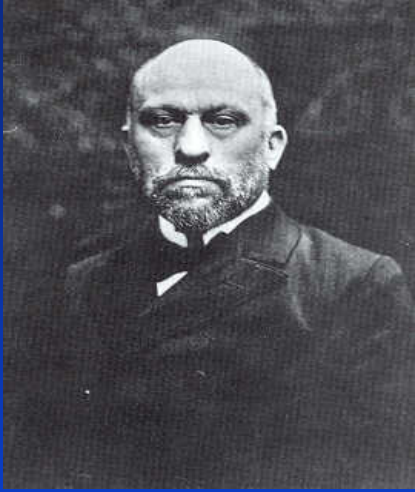
# The Value of Brain Imaging

“We must suppose a very delicate adjustment whereby the circulation follows the needs of cerebral activity. Blood very likely may rush to each region of the cortex according as it is most active, but of this we know nothing.”

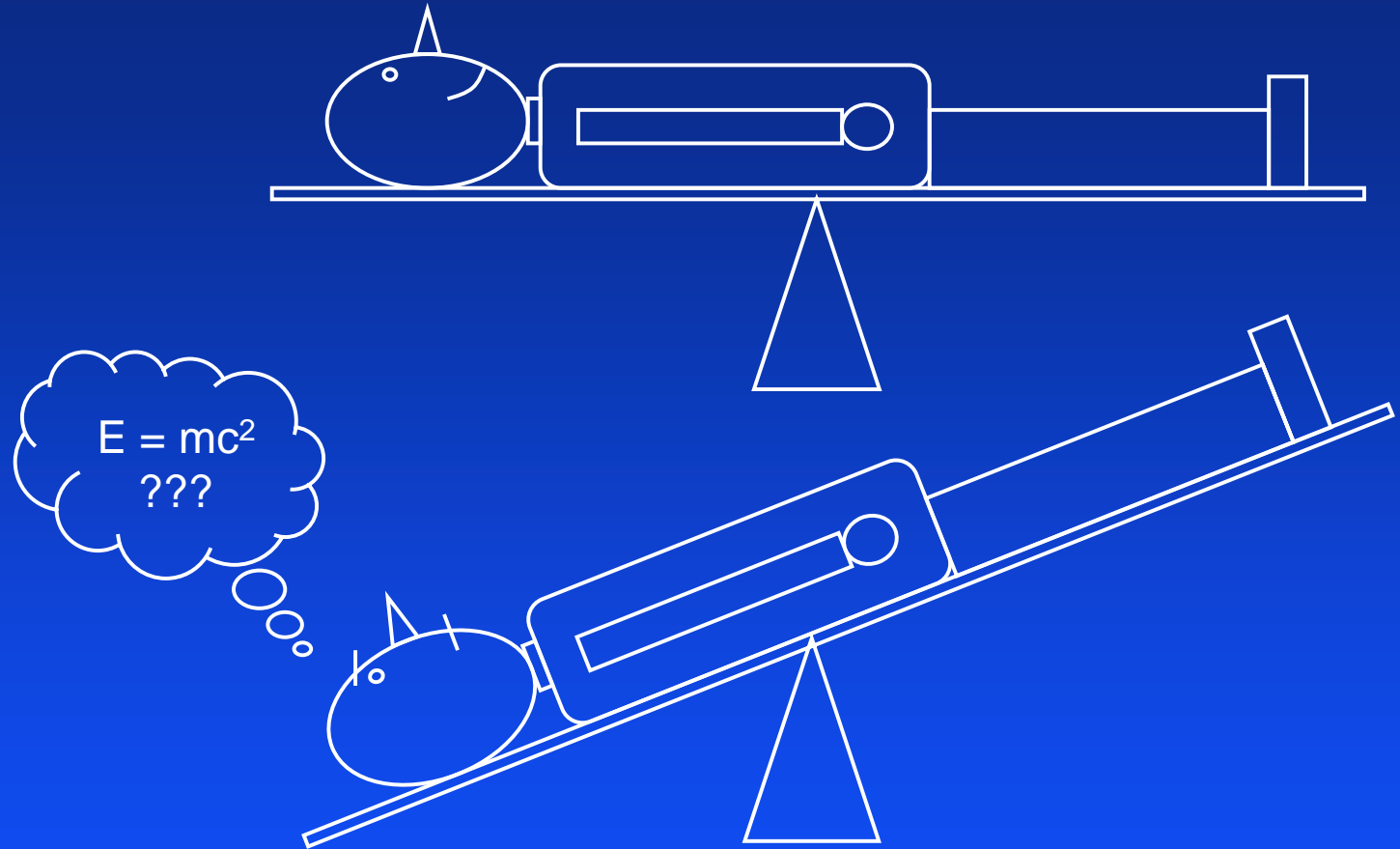
William James, 1890

# The First “Brain Imaging Experiment”

... and probably the cheapest one too!



Angelo Mosso  
Italian physiologist  
(1846-1910)



“[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)

# Brain Imaging for Spatial Resolution

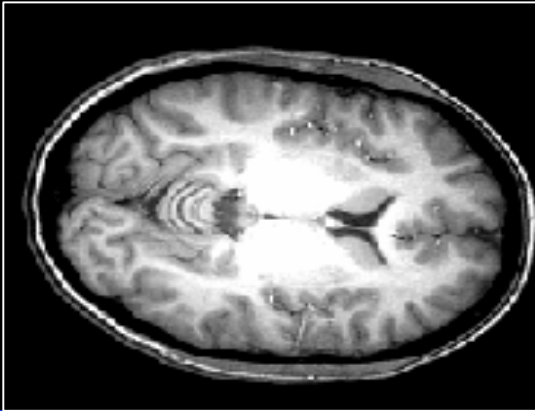
- PET and MRI



# MRI vs. fMRI

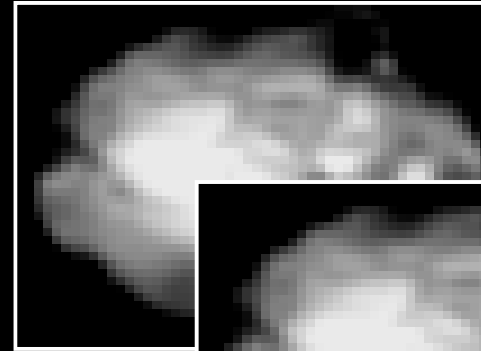
high resolution  
(1 mm)

MRI

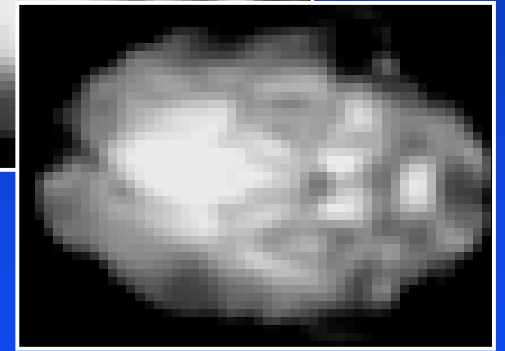
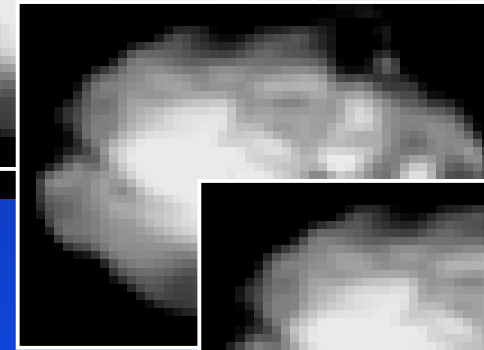


one image

fMRI



low resolution  
(~3 mm but can be better)



many images  
(e.g., every 2 sec)

...

Changes in information processing



Changes in neuronal activity



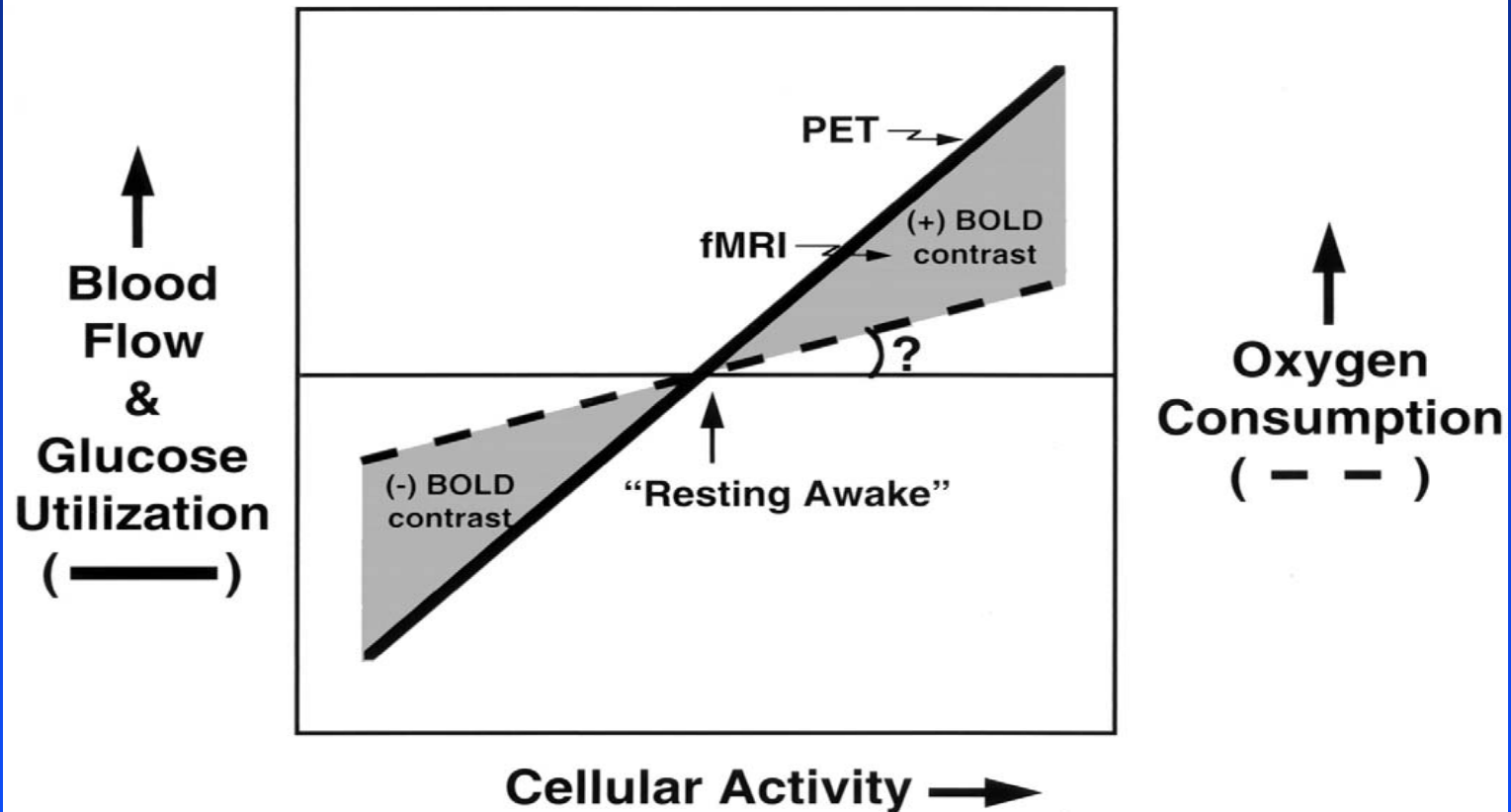
Changes in bloodflow (PET)  
and bloodflow metabolism (fMRI)

(fMRI = Blood Oxygen Level Dependent **BOLD** signal)



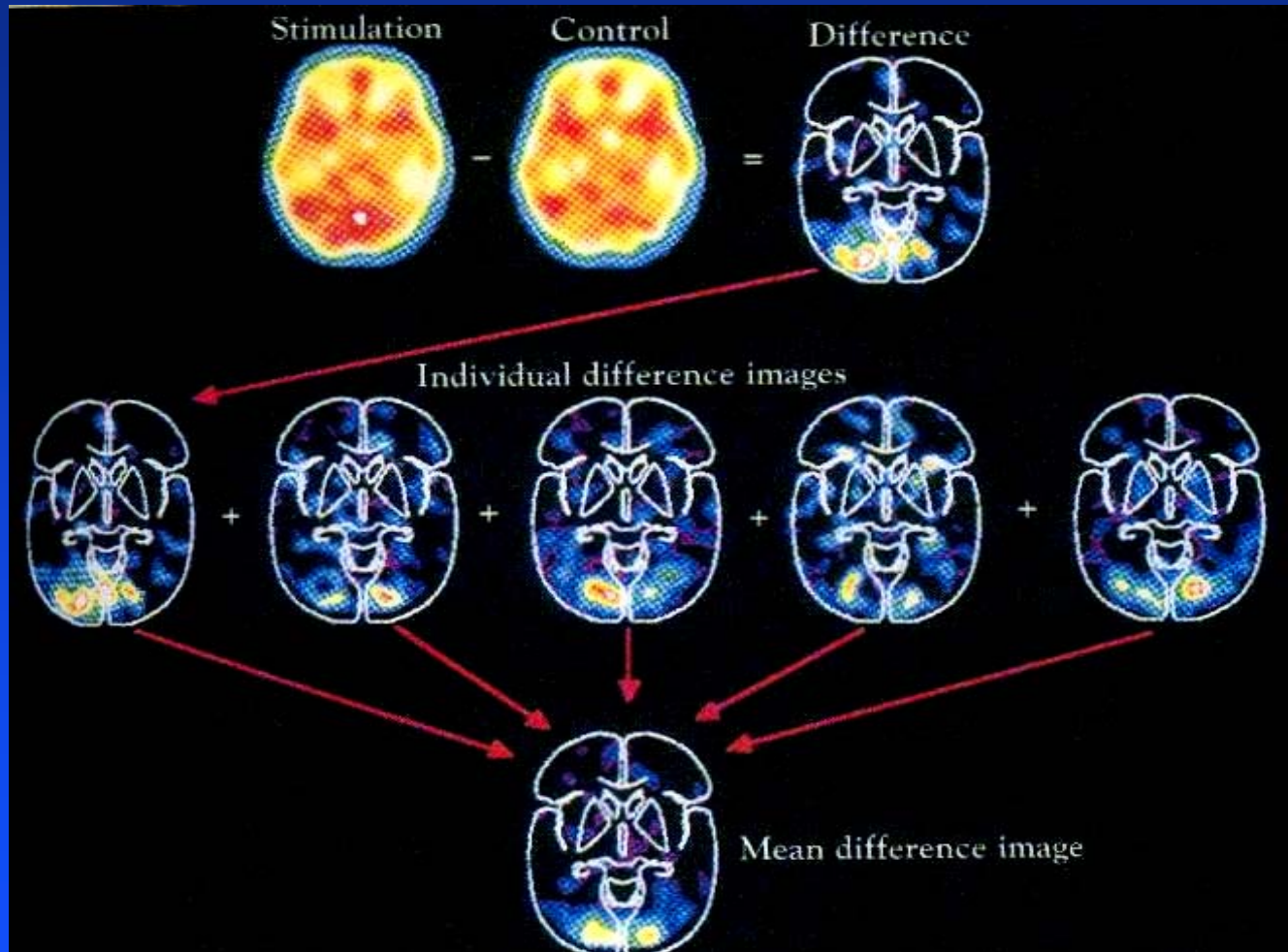
# Anaerobic metabolism

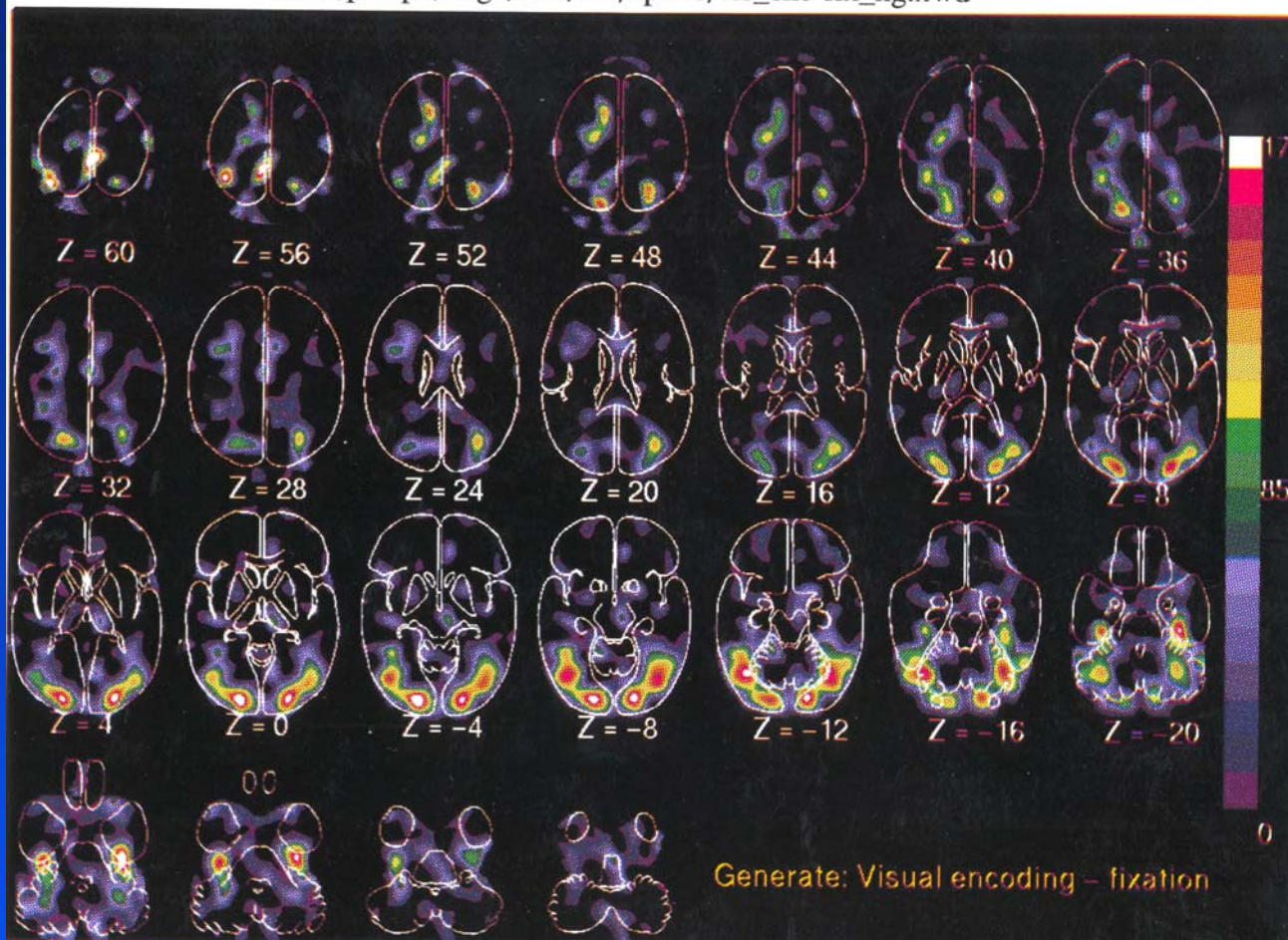
Relationship of Blood Flow & Metabolism to Cellular Activity in Human Brain



Raichle, Marcus E. (1998) Proc. Natl. Acad. Sci. USA 95, 765-772

# PET Activation





Difference Image across the whole brain

# Research Example: Know Thyself

- Self-referential effect in memory  
Are you happy?

# Knowing Your Self

- Self-referential effect in memory  
Are you happy?  
Is X (Jim Blascovich) happy?

QuickTime™ and a  
TIFF (Uncompressed) decompressor  
are needed to see this picture.

# Knowing Your Self

- Self-referential effect in memory

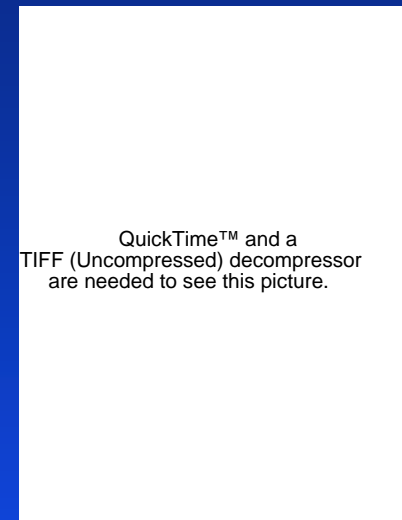
Are you happy?

Is X (Jim Blascovich) happy?

Memory advantage for self items

- Why does it happen?

Is there anything special about the self?



QuickTime™ and a  
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are needed to see this picture.

# Is There Anything Special About the 'Self'?

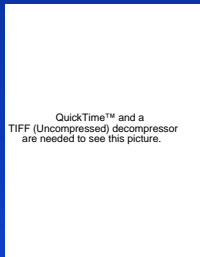
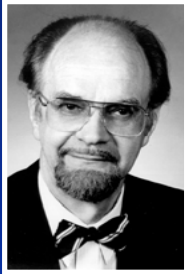


The self is special: the self is a unique cognitive structure that possesses extraordinary or additional mnemonic abilities (Rogers et al., 1977)

Extension of levels of processing: the wealth of knowledge we have about ourselves in memory simply encourages more elaborative encoding (e.g., Klein & Kihlstrom, 1986; Greenwald & Banaji, 1989)

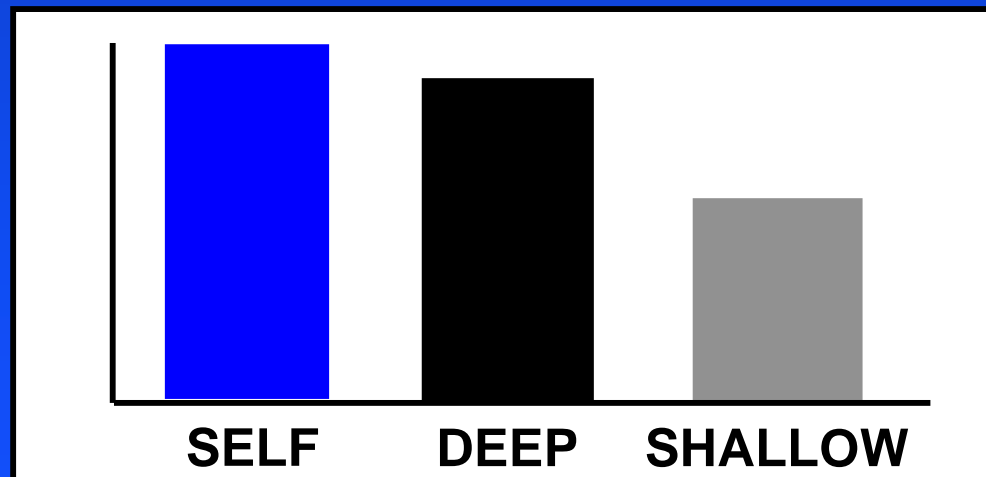


# The Ordinary Self: Levels of Processing in Memory

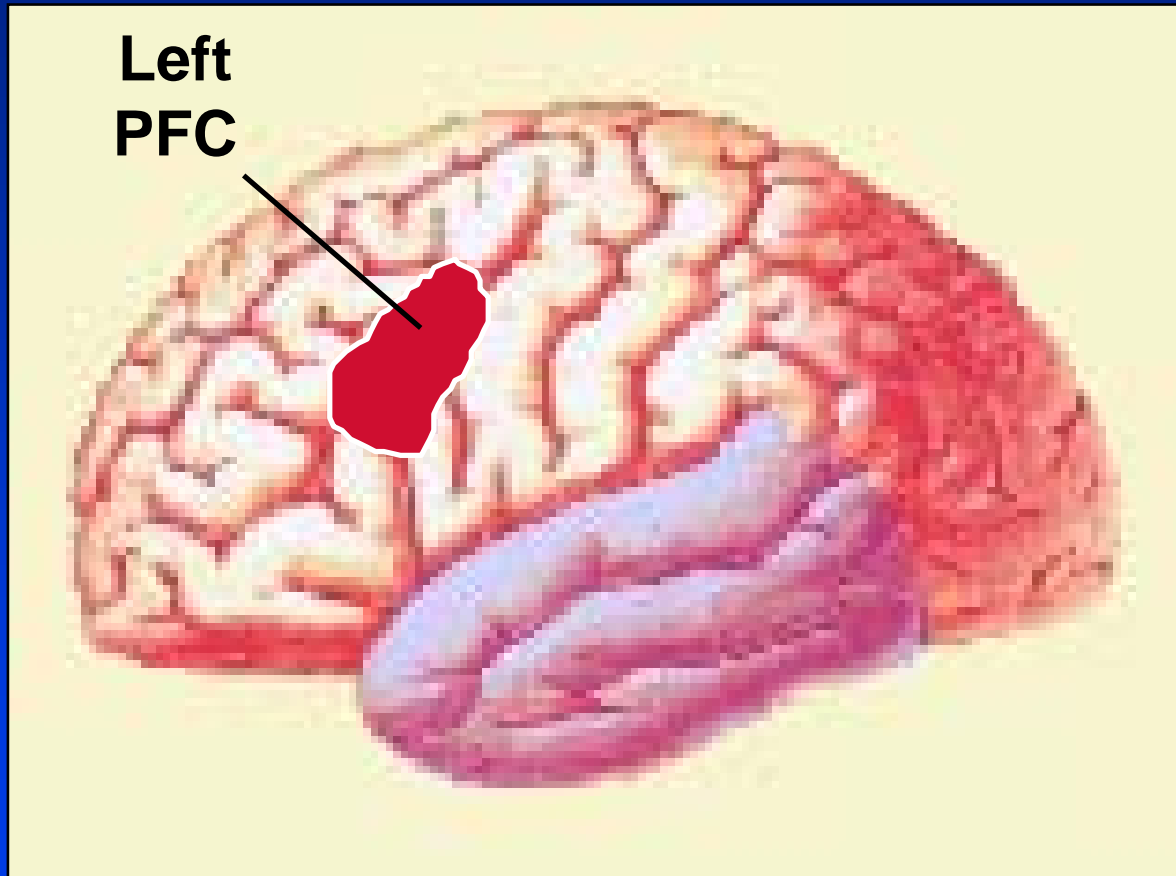


Deep (or meaning-based) processing produces better subsequent memory than shallow (or surface-based) processing

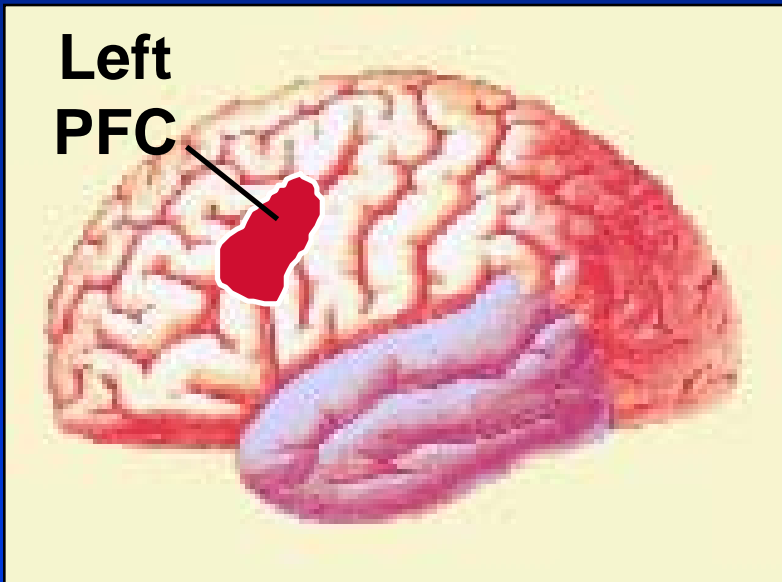
Self-referential encoding = deep processing



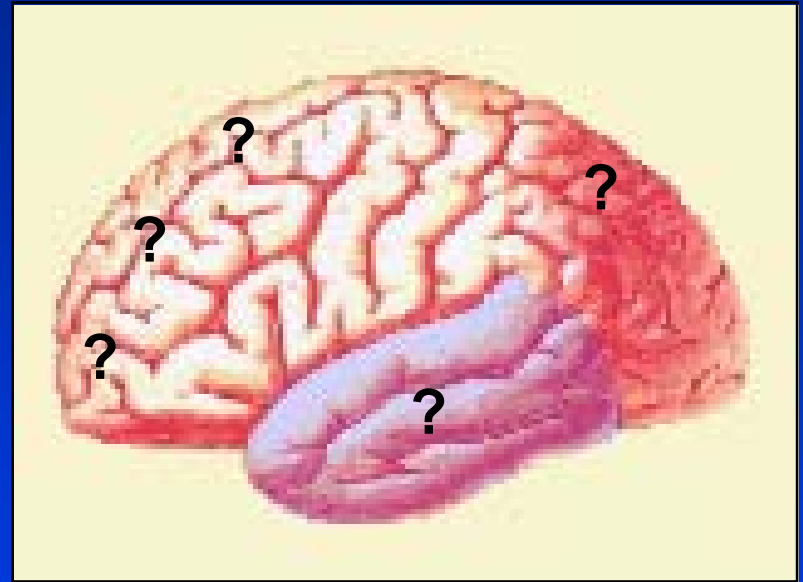
# Imaging Studies of Semantic Processing



# Self-Referential Processing: Special or Ordinary?



'Ordinary'



'Special' or 'Different'

# Craik et al. 1998, *Psychological Science*

QuickTime™ and a  
TIFF (LZW) decompressor  
are needed to see this picture.

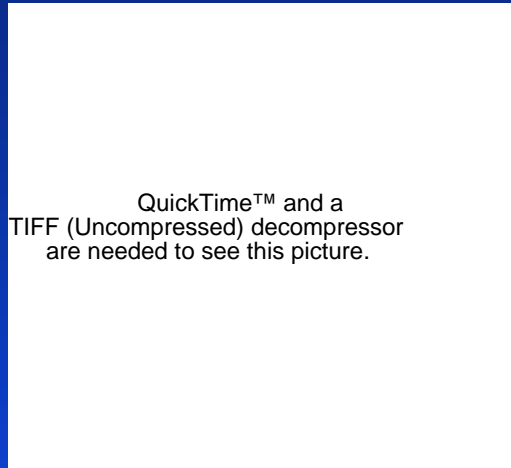
## Craik et al. 1999, *Psychological Science*

QuickTime™ and a  
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Problem: No self-reference effect

PET does not allow enough trials

# PET



Shutter speed = 40 secs

Half-life = 120 seconds

Wash-out 10 minutes

Trials few

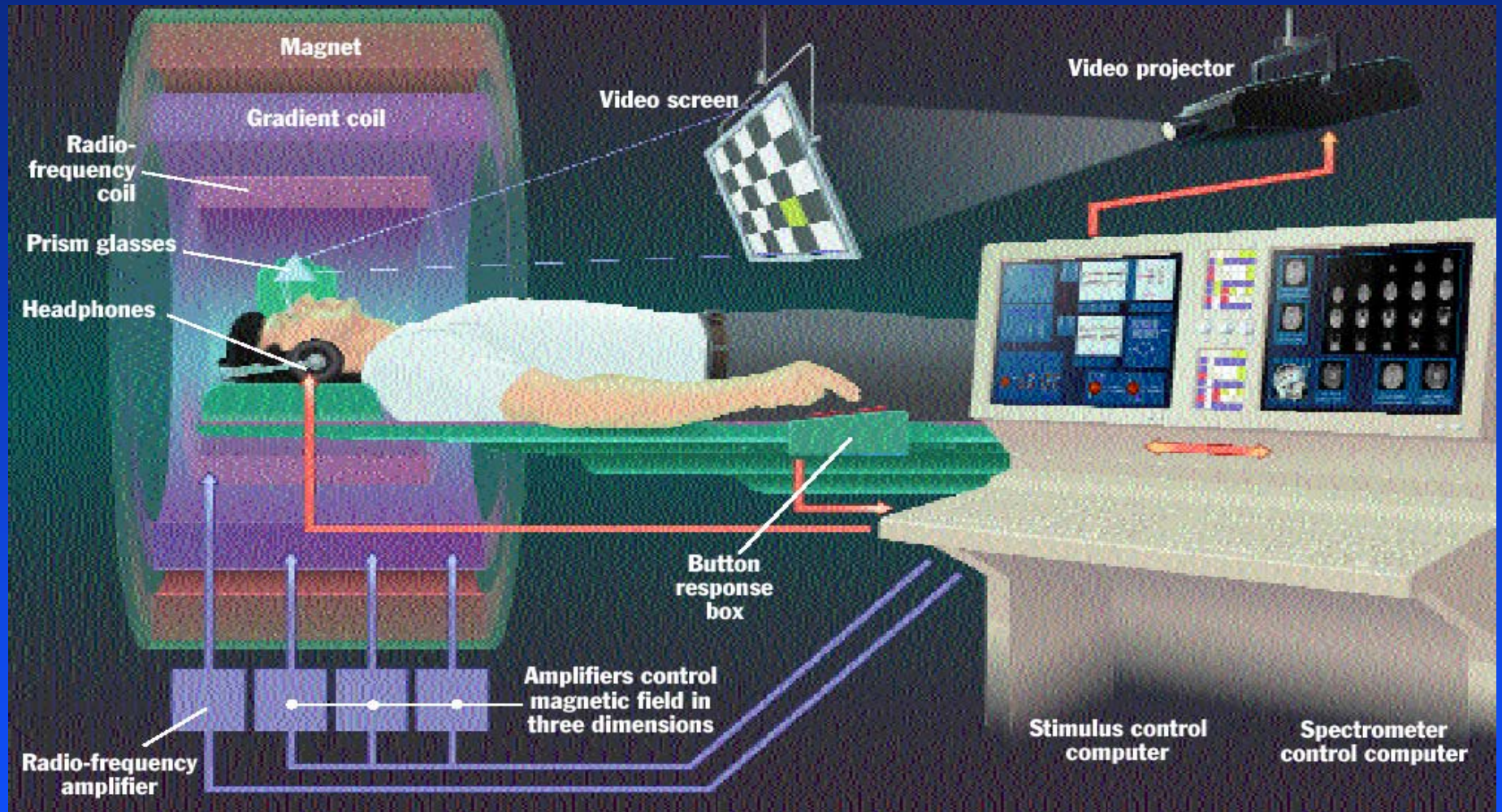
# fMRI



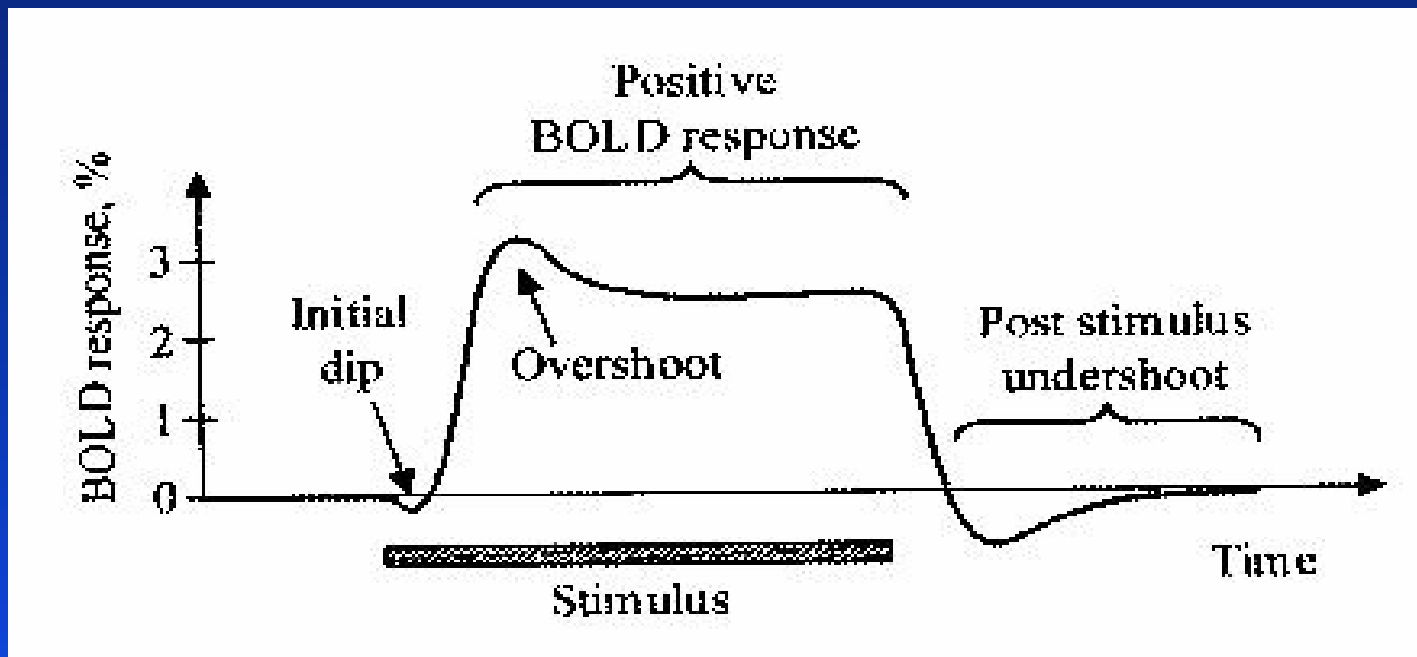
Shutter speed = 2 secs

Trials - unlimited

# fMRI Setup



# Hemodynamic Response Function



## % signal change

=  $(\text{point} - \text{baseline}) / \text{baseline}$   
usually 0.5-3%

## time to rise

signal begins to rise soon after stimulus begins

## initial dip

-more focal and potentially a better measure  
-somewhat elusive so far, not everyone can find it

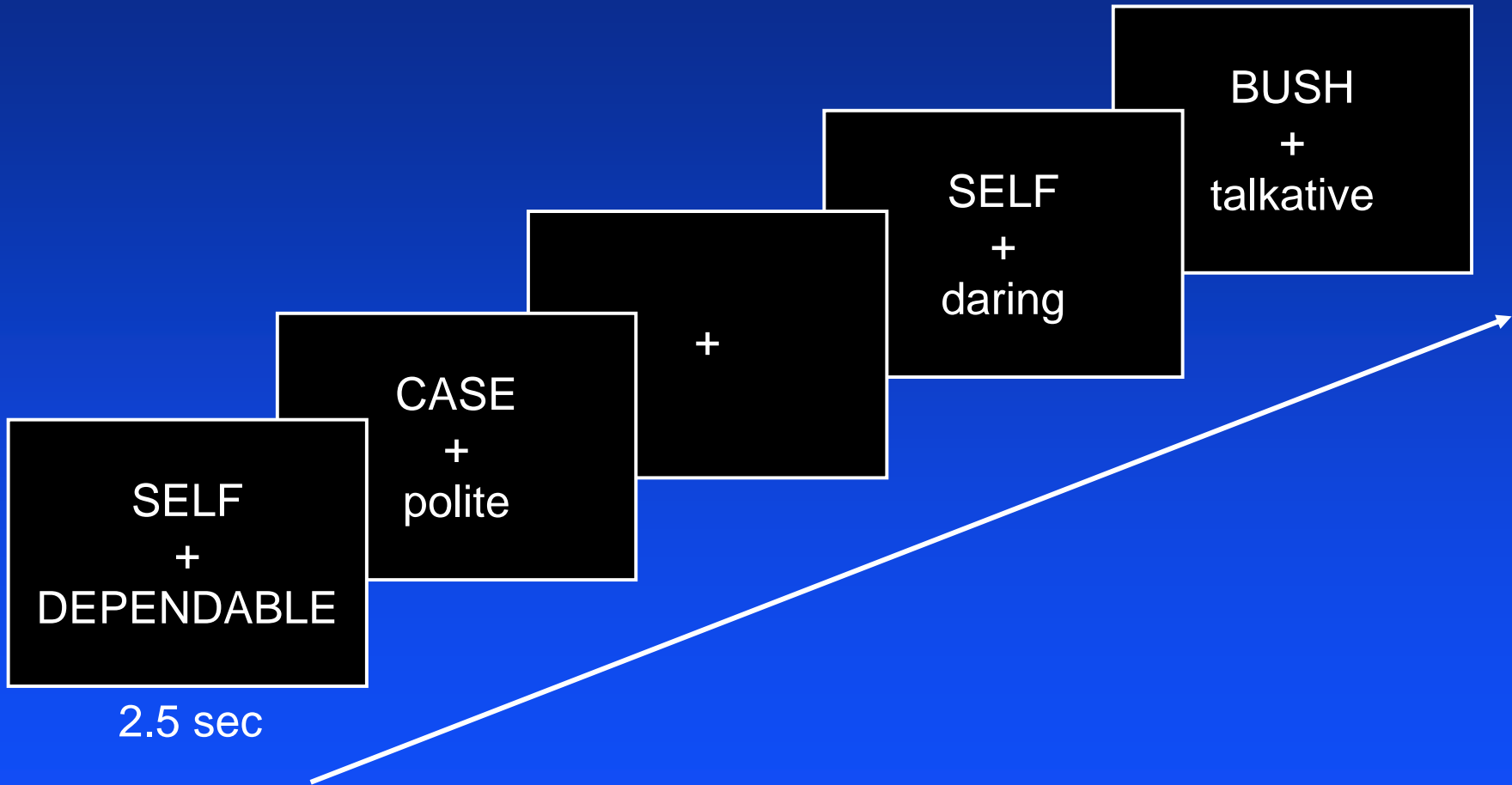
## time to peak

signal peaks 4-6 sec after stimulus begins

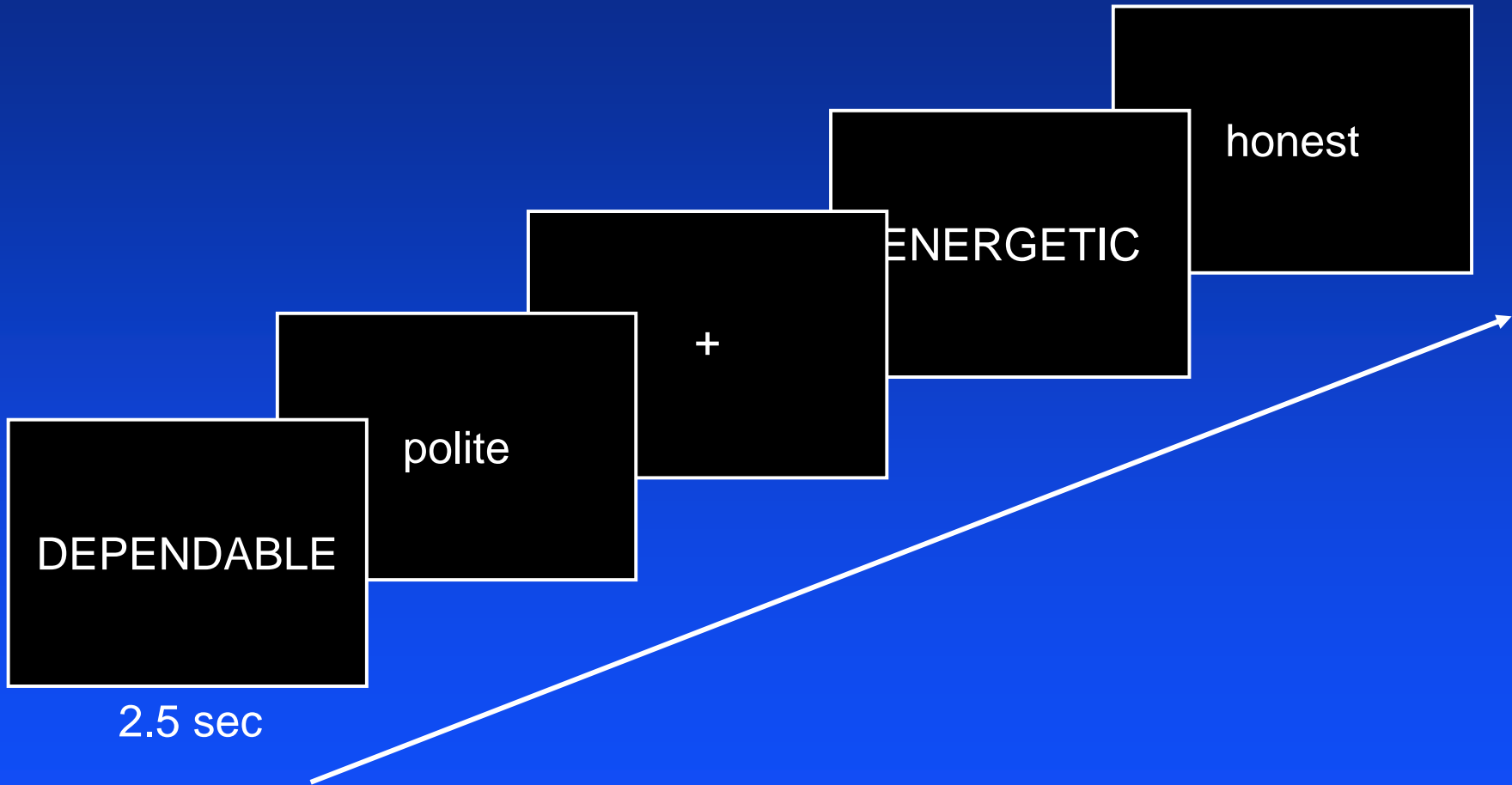
## post stimulus undershoot

signal suppressed after stimulation ends

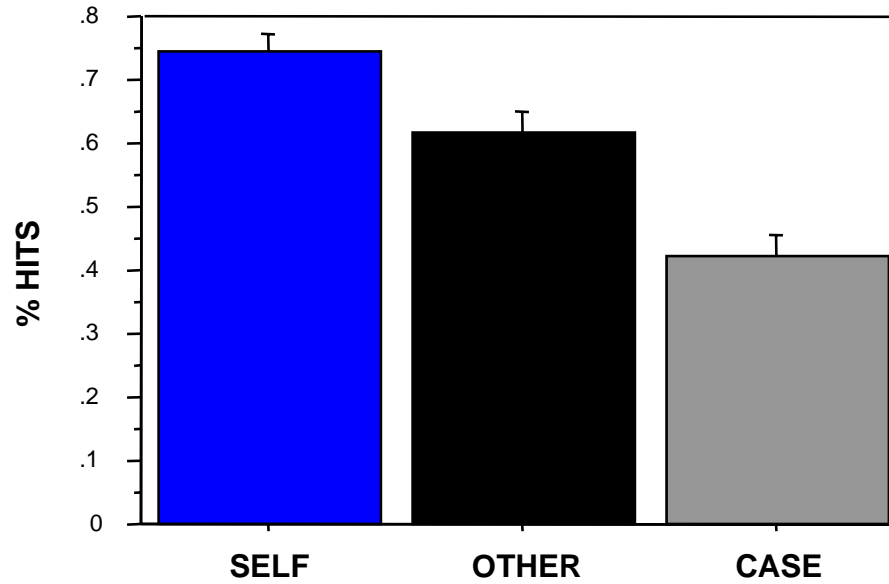
# Rapid Event-Related Design



# Subsequent Memory Test

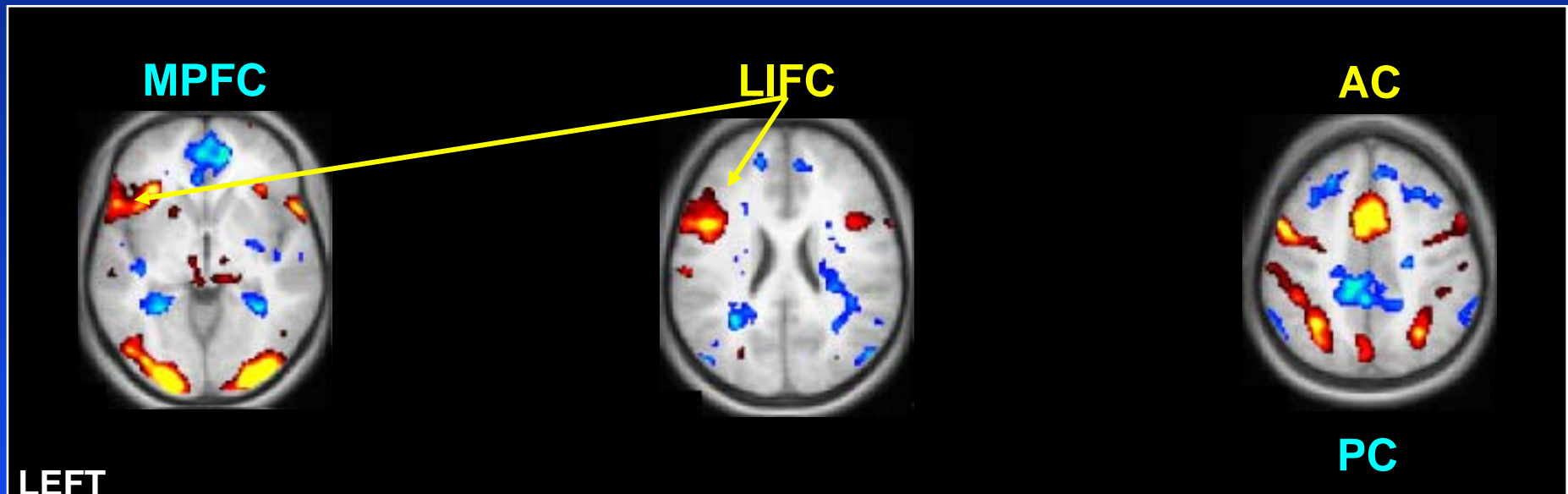


# 'Self' Words Remembered Best



# General Task-Related Increases and Decreases

SELF + OTHER + CASE



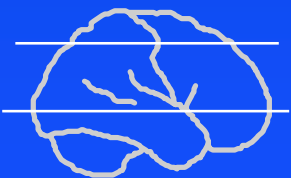
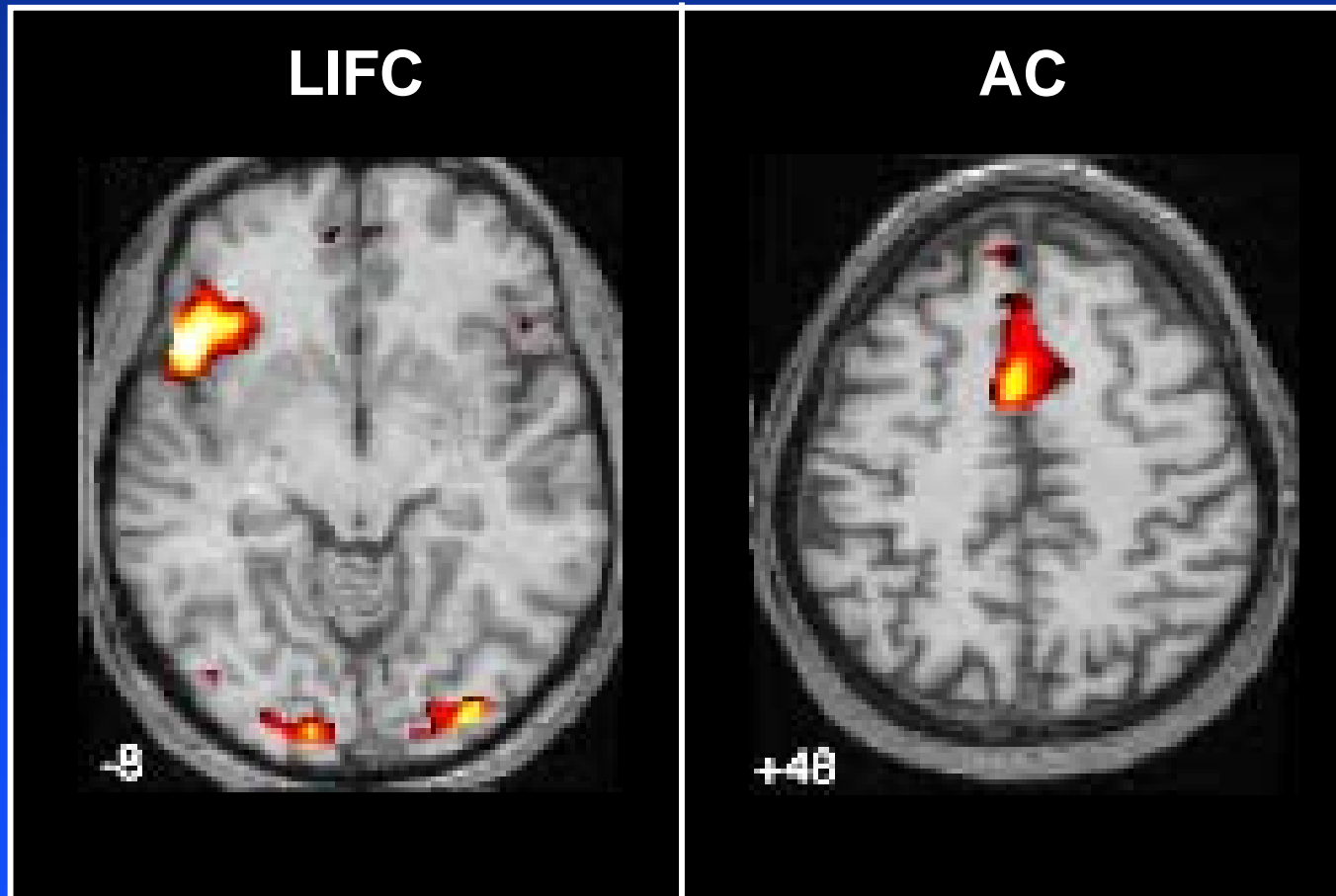
Increases



Decreases

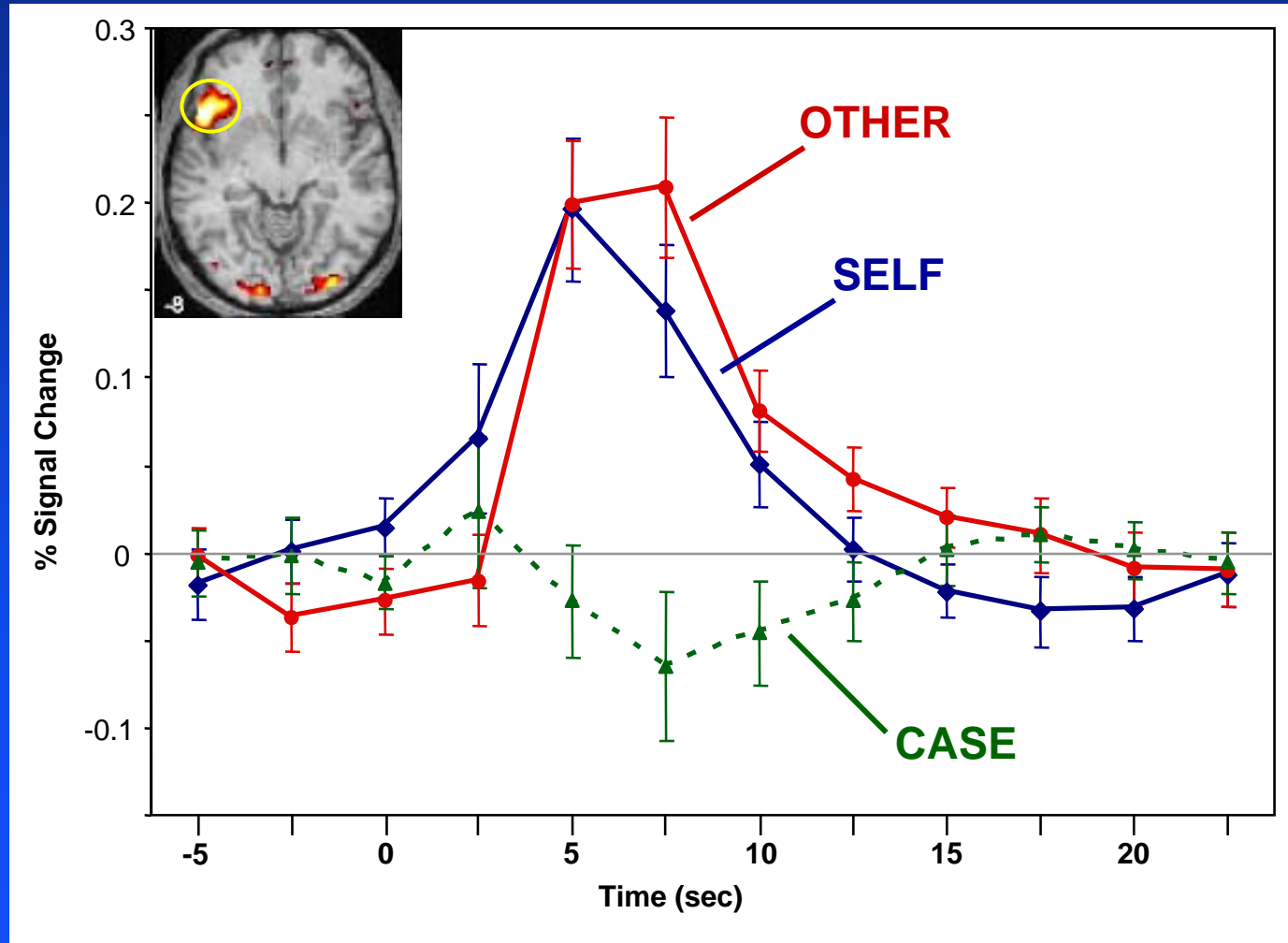
# Levels of Processing Effect

SELF + OTHER > CASE



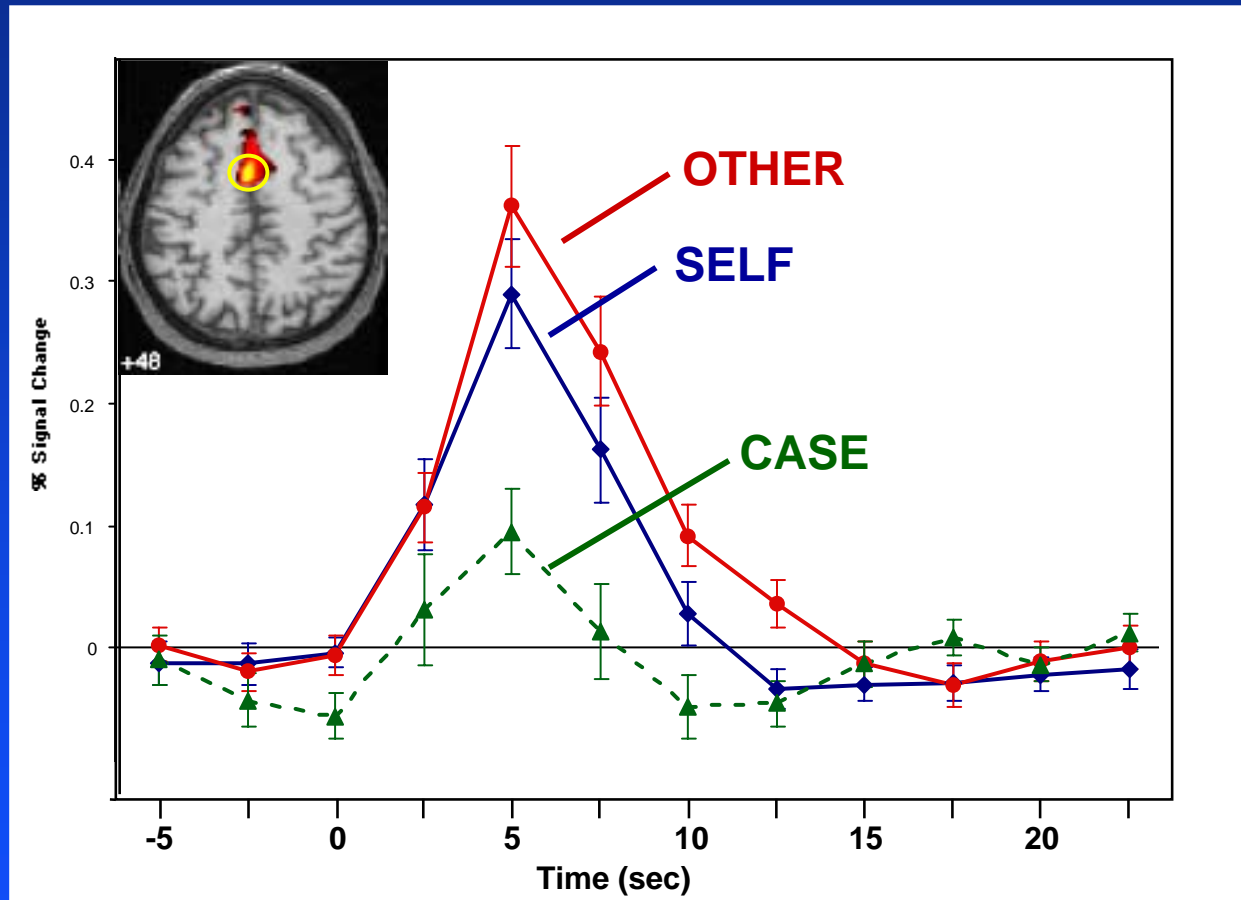
# Levels of Processing Effect

## Left Inferior Frontal Cortex



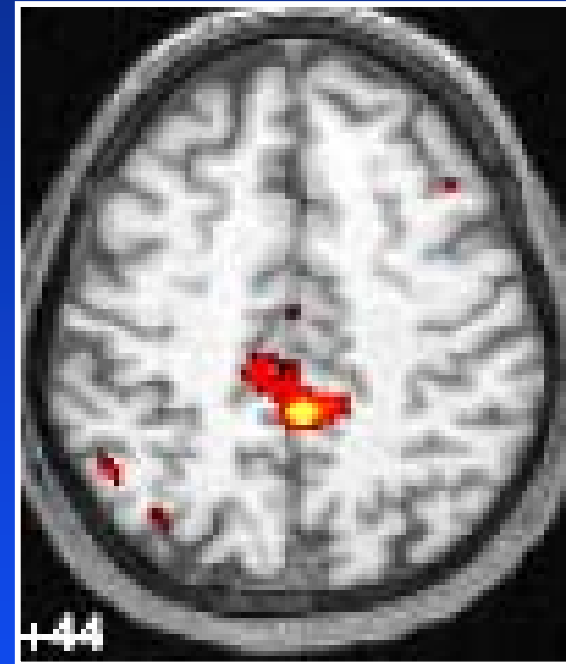
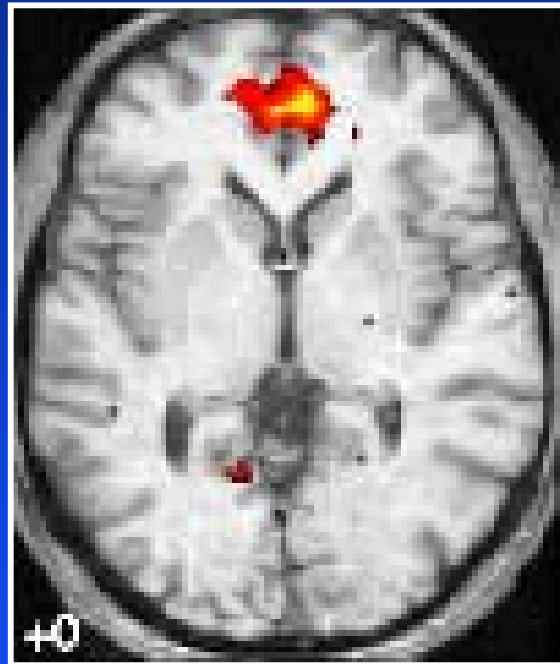
# Levels of Processing Effect

## Anterior Cingulate



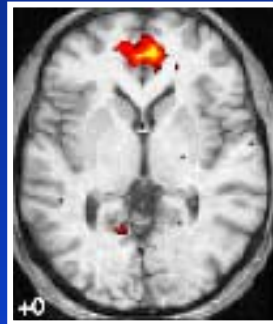
# Is there anything special about the 'self'?

SELF > OTHER

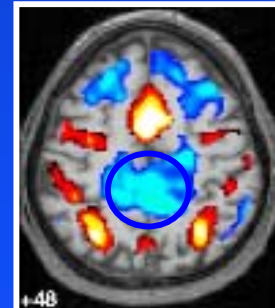
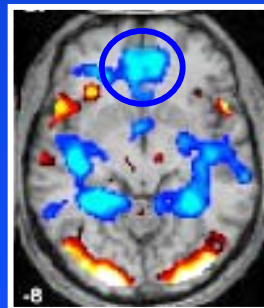


# Is There Anything Special About the 'Self'?

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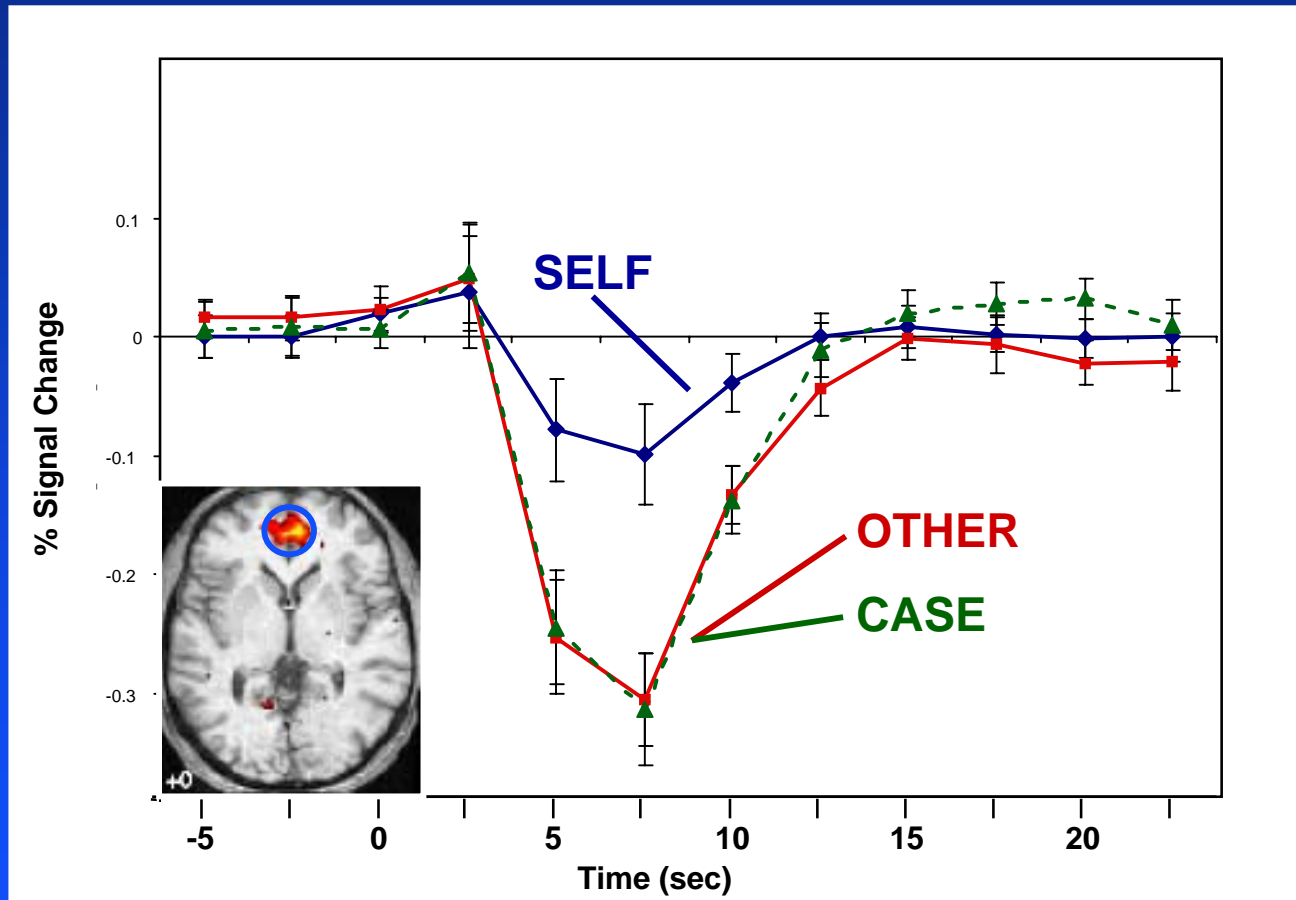


TASK-RELATED DECREASES



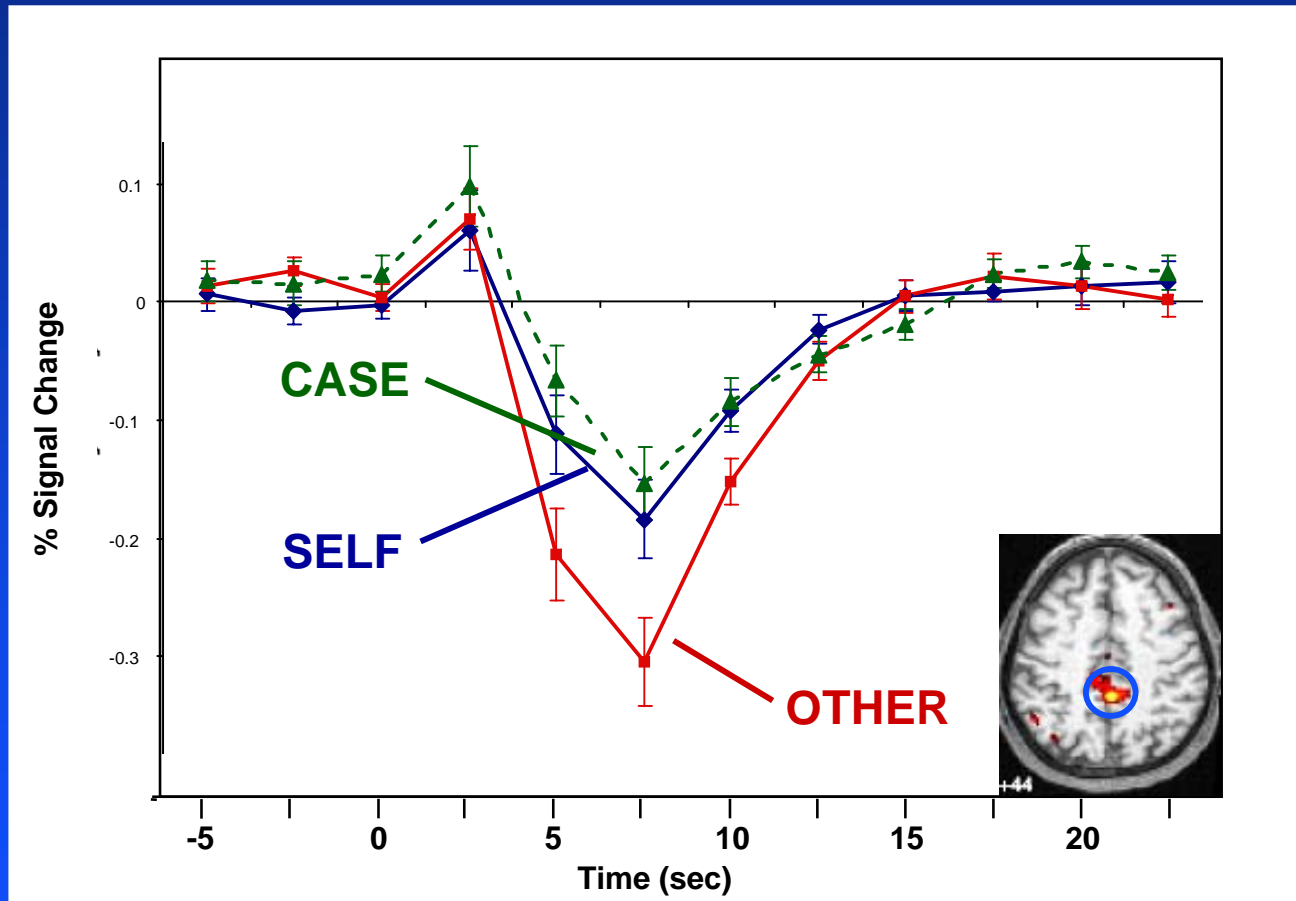
# Self-Referential Activity

## Medial Prefrontal Cortex



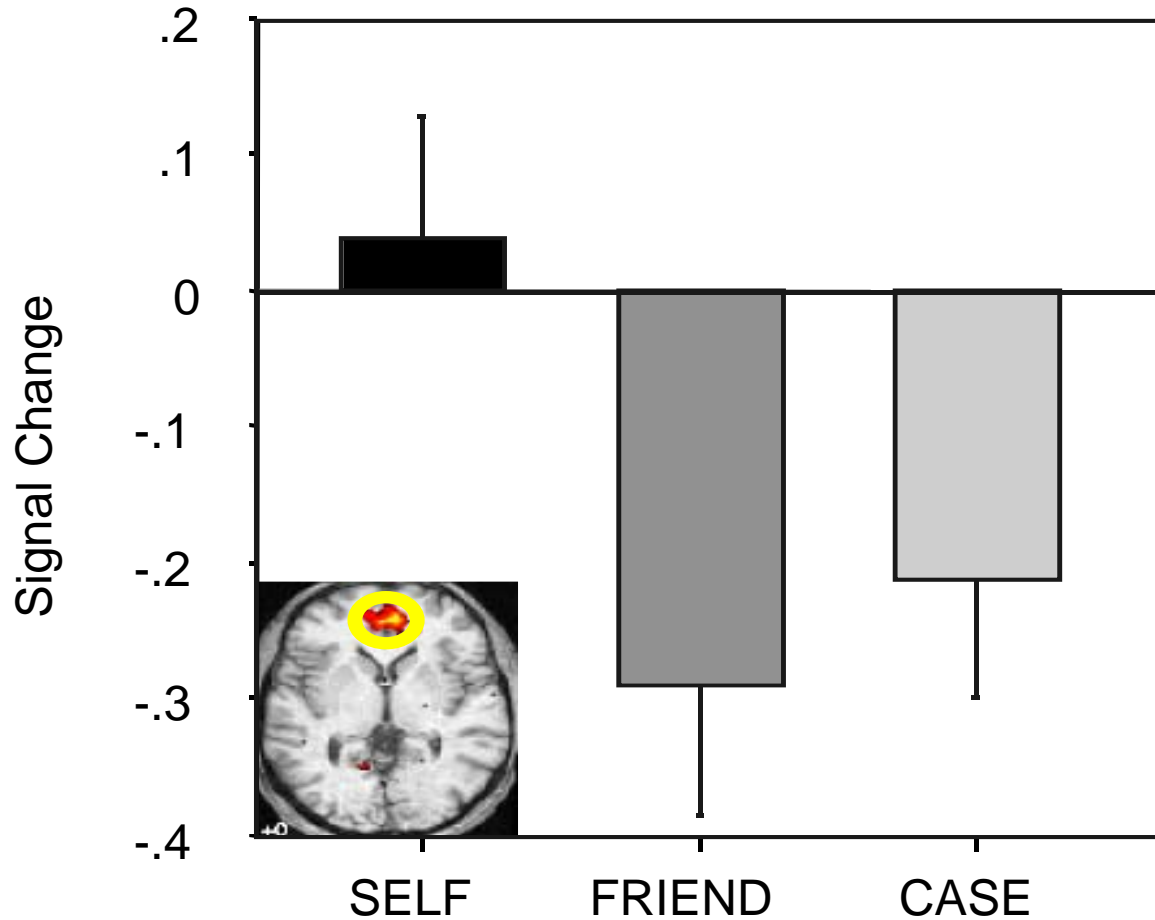
# Activity in Posterior Cingulate is Not Unique to 'Self'

## Posterior Cingulate



Is it Familiarity?

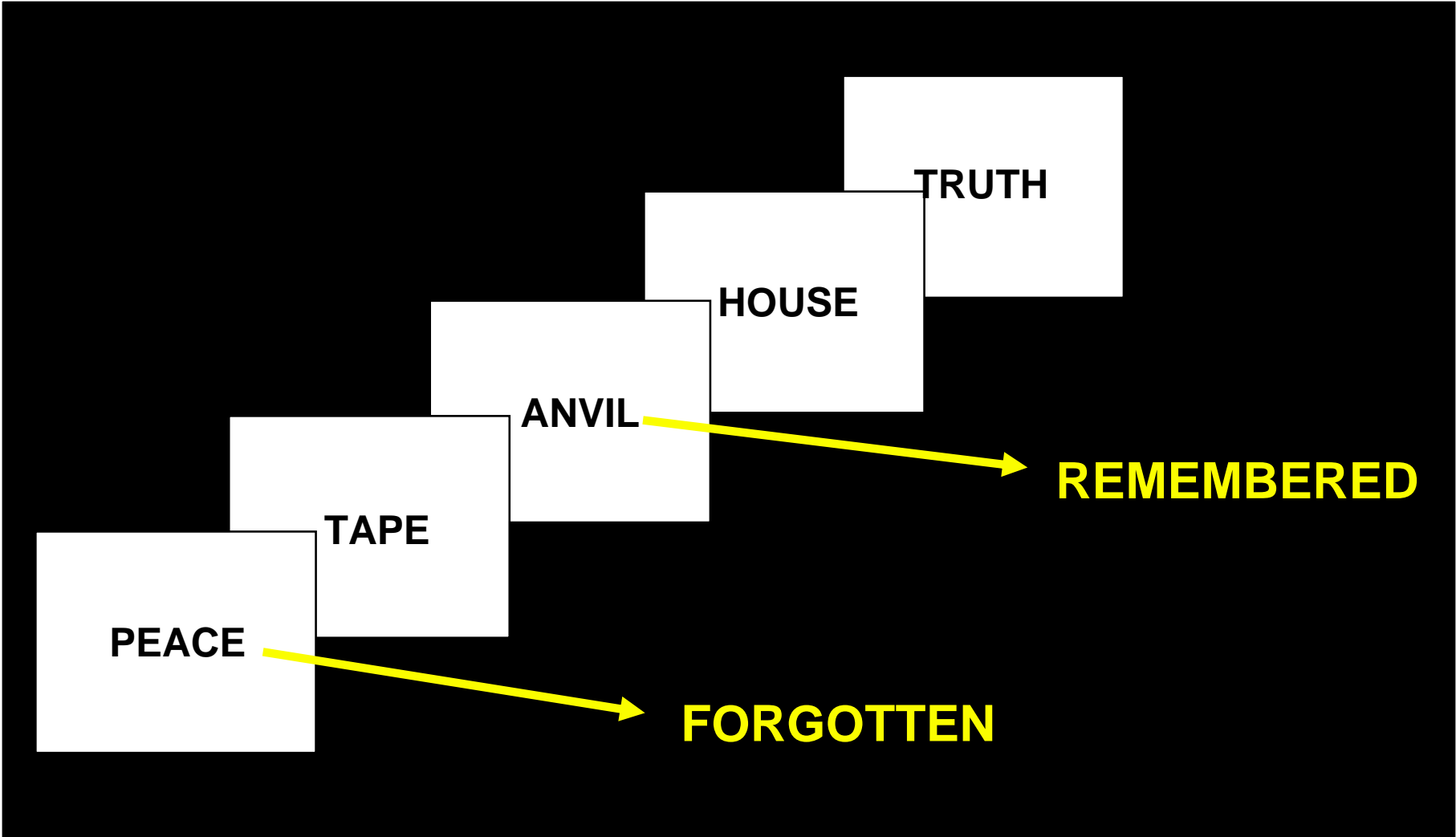
# Is it Familiarity?



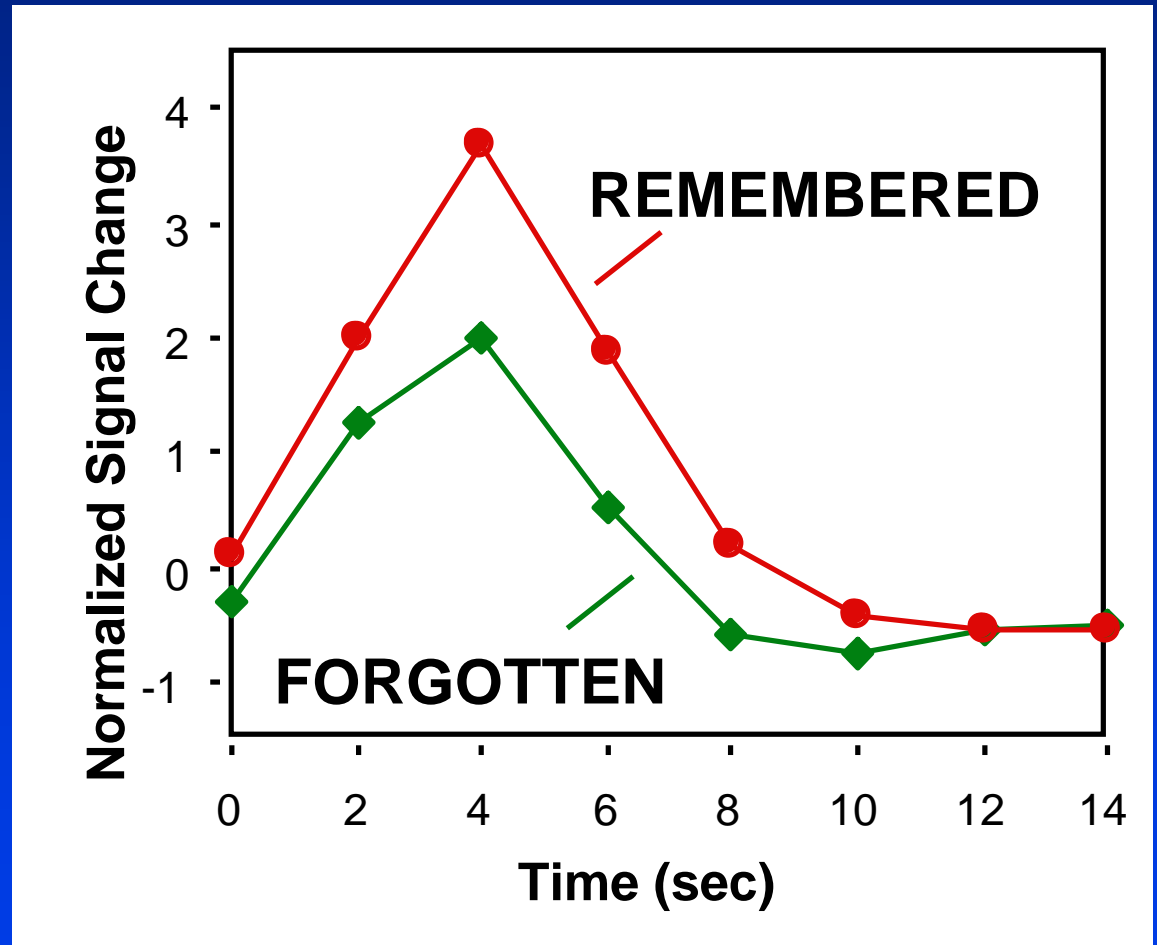
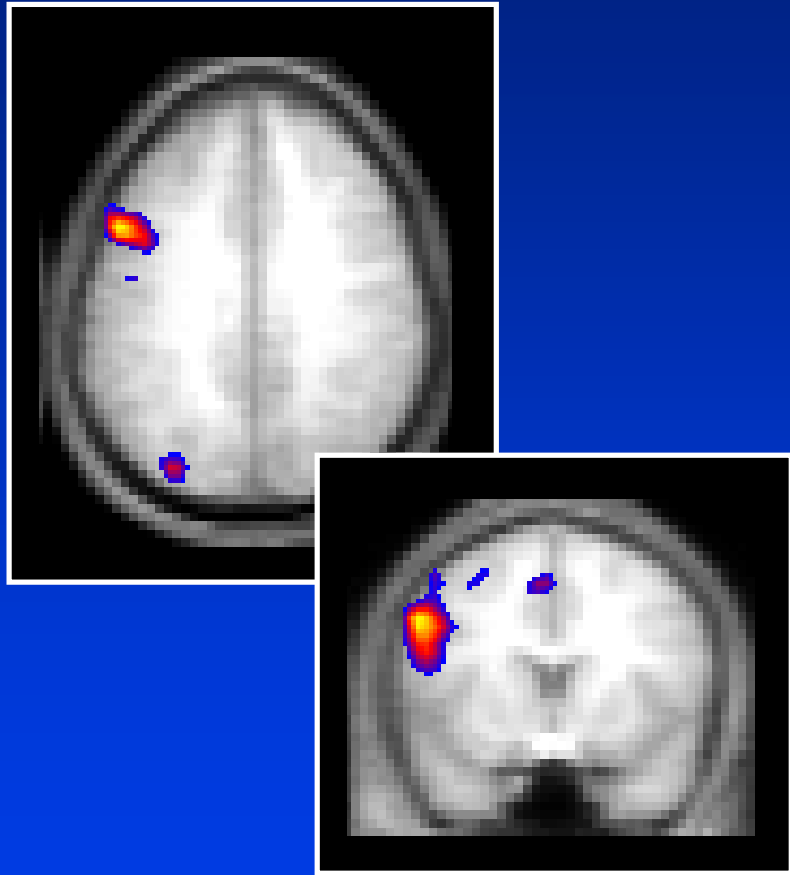
# Unresolved Issue

- **Is activity in MPFC responsible for the boost in memory performance observed for self-referenced items?**
- **Although the results the first experiment suggest that MPFC may mediate this memory enhancement, they do not directly tie activity in this region to subsequent memory performance.**

# Subsequent Memory Performance

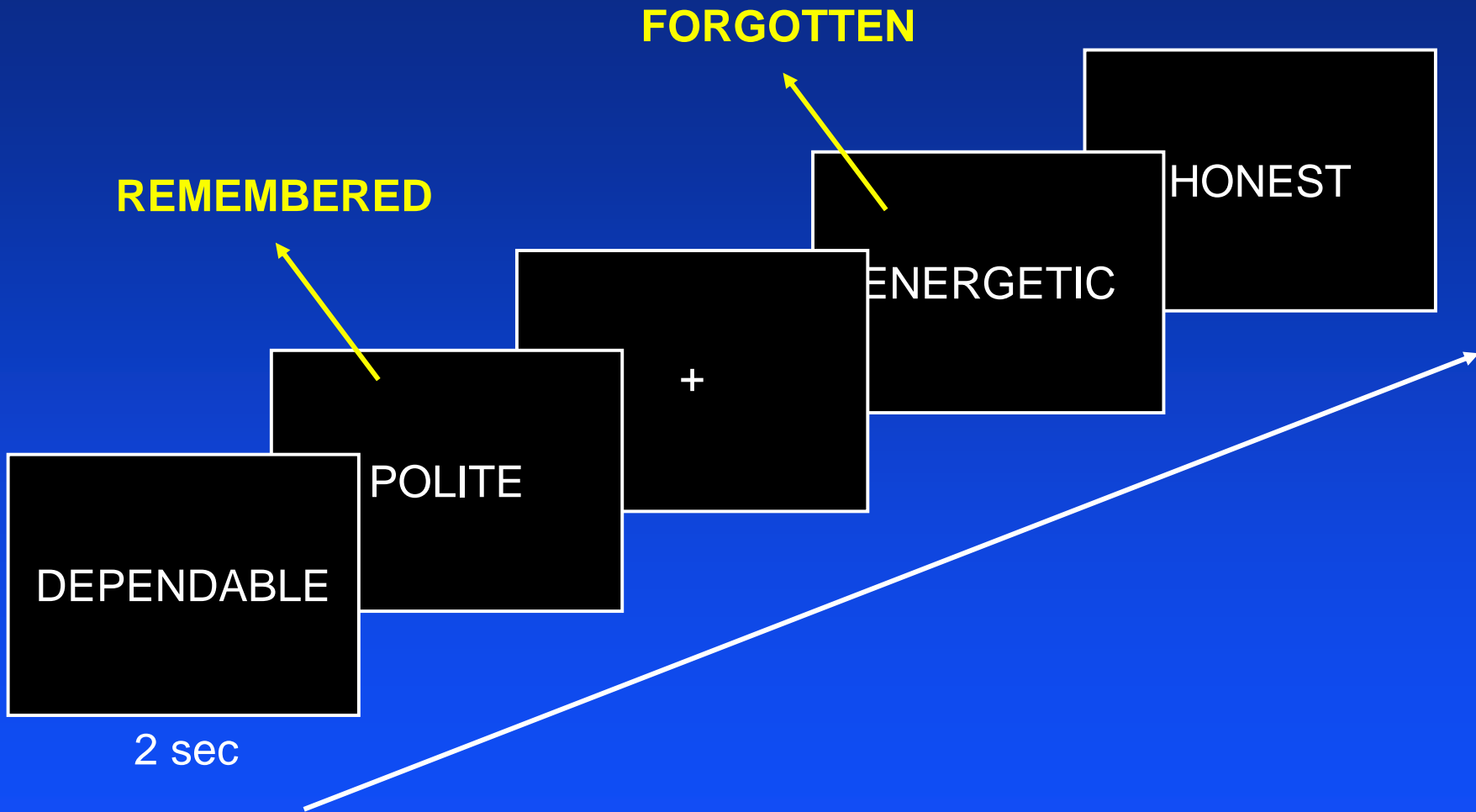


# Sorting Based on Subsequent Memory Performance



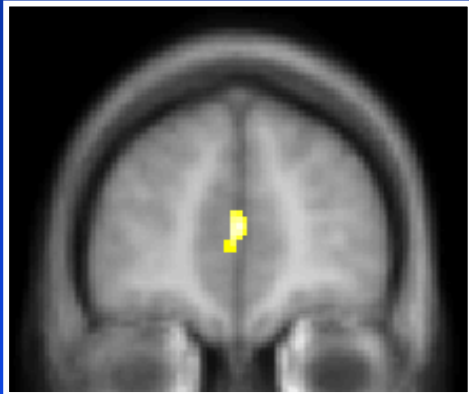
Wagner et al., 1998

# Self Reference and Subsequent Memory

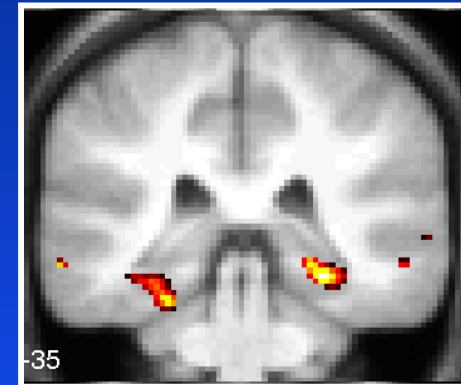


# Sorting Based on Subsequent Memory Performance

MPFC



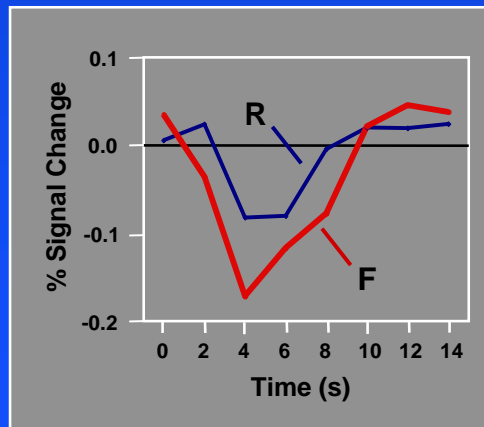
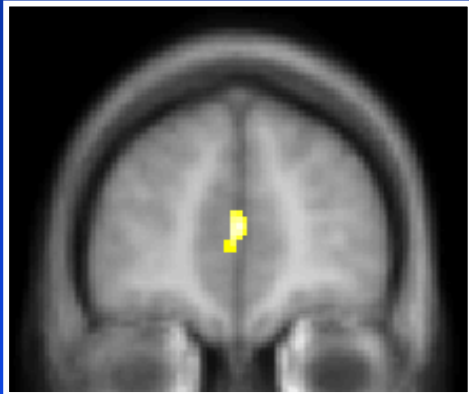
MTL



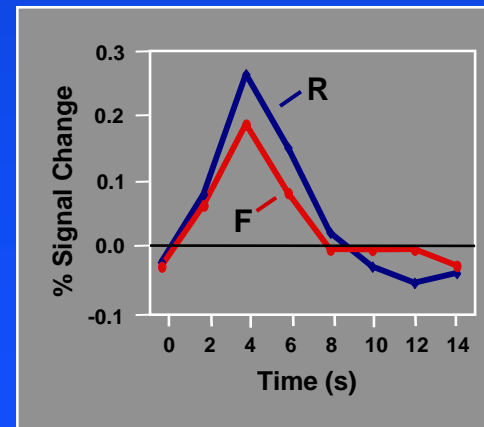
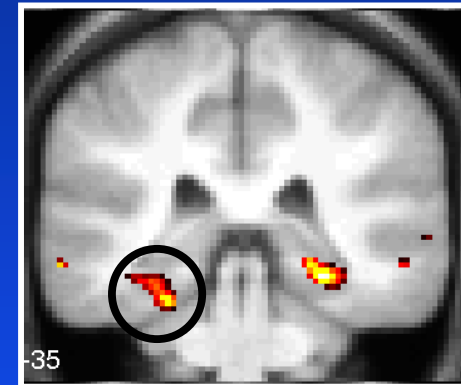
Remembered > Forgotten

# Sorting Based on Subsequent Memory Performance

## MPFC

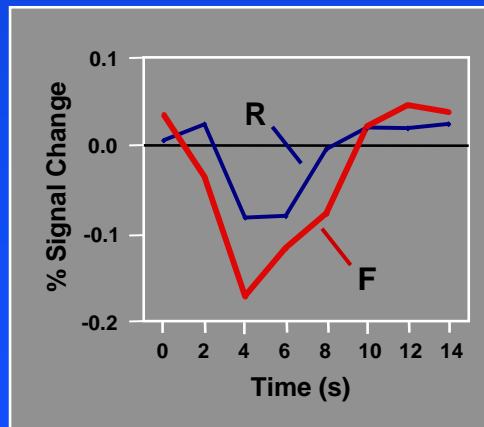
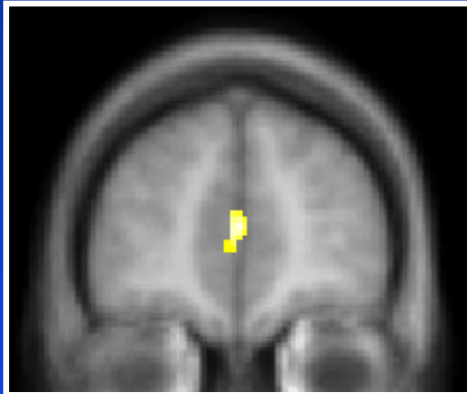


## MTL

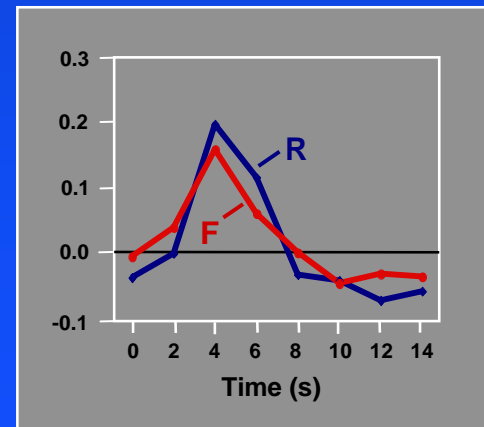
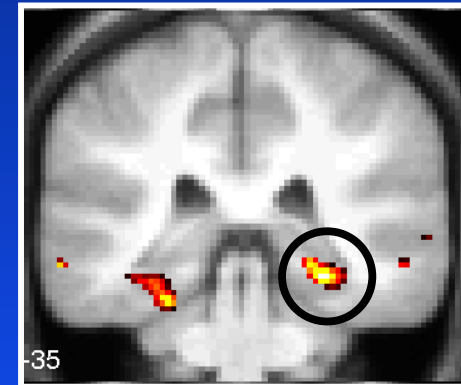


# Sorting Based on Subsequent Memory Performance

## MPFC



## MTL



# Transcranial Magnetic Stimulation

- All brain imaging methods are correlational
  - Hence, subject to all of the limits of correlational research
- How do you manipulate brain activity through experimentation?
  - Animal research
- TMS - experimentally disrupt a brain region
  - If it is critical for a task, disrupting that region will interfere with task performance

QuickTime™ and a  
TIFF (Uncompressed) decompressor  
are needed to see this picture.

During a TMS session a researcher holds an electromagnetic coil against the scalp of a patient. This coil emits magnetic pulses that easily pass through the skull. The pulses then form an electric current that alters the activity of the brain's nerve cell

QuickTime™ and a  
Cinepak decompressor  
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# Morphology

- Assess shape and size of various brain structures
- Voxel-Based Morphometry
  - Automated segmentation of white and grey matter
- Cortical Thickness
  - Expresses value for cortical thickness
- All methods allow for assessing relation between brain structures and aspects of personality or psychopathology
  - e.g. Wright et al. Correlates of Extraversion/Introversion

QuickTime™ and a  
TIFF (LZW) decompressor  
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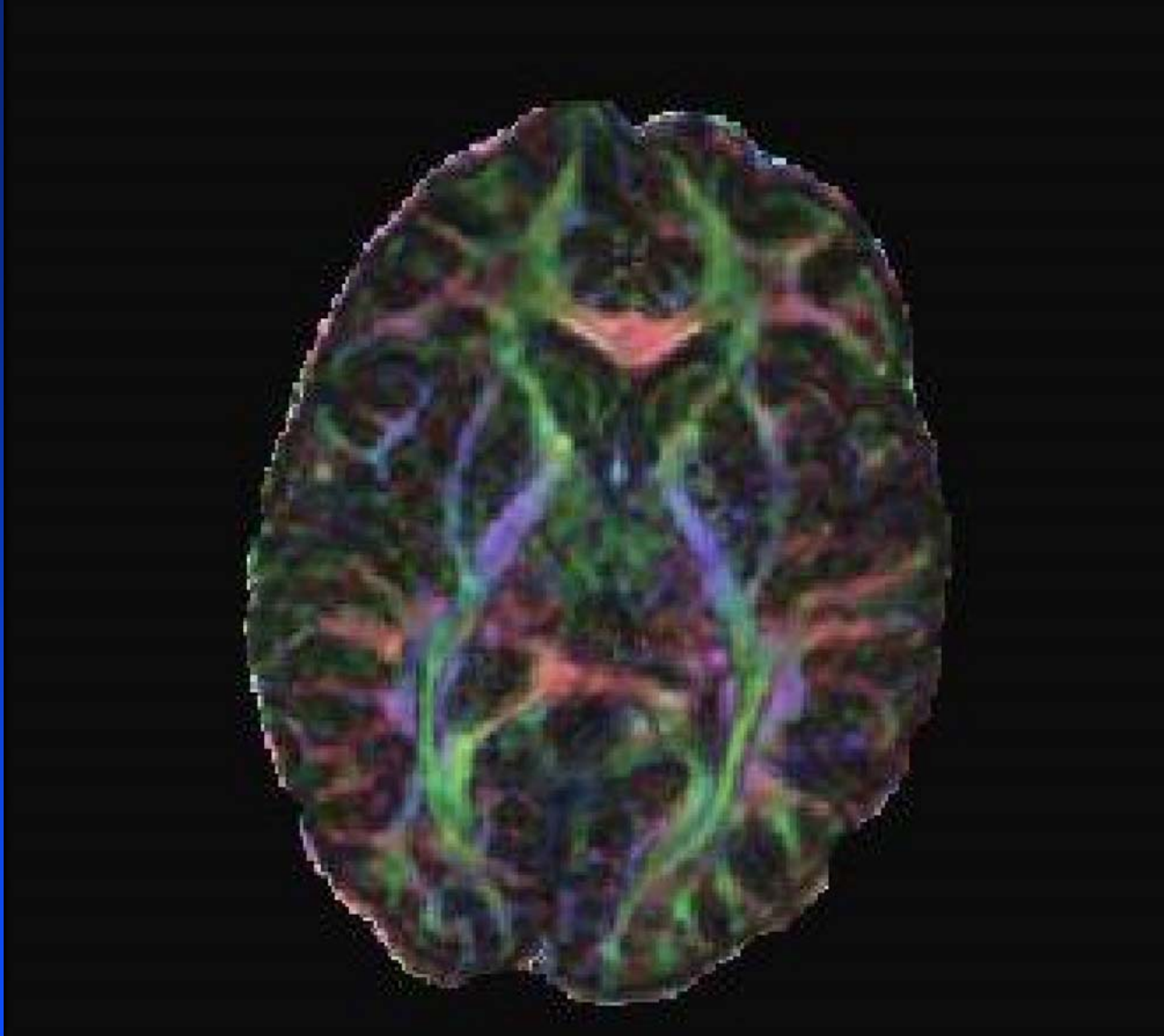
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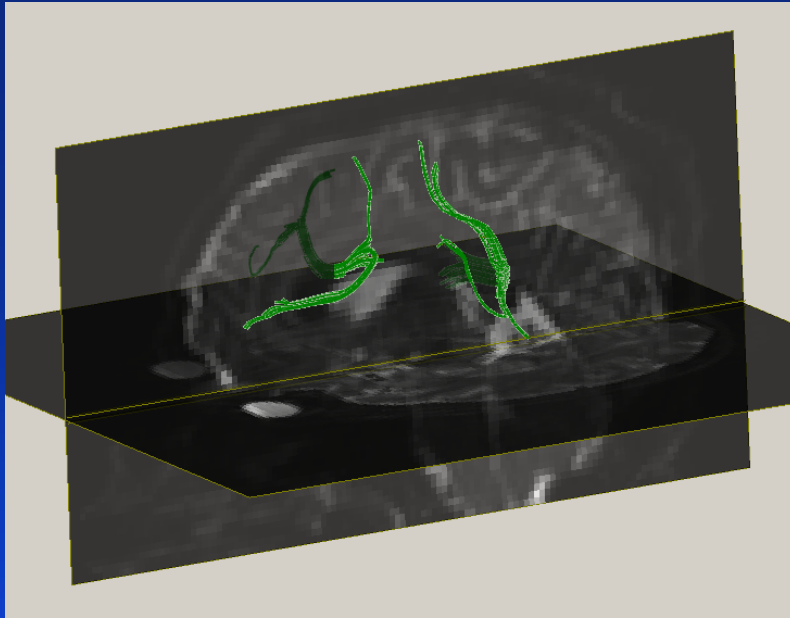
QuickTime™ and a  
TIFF (LZW) decompressor  
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# Diffusion Tensor Imaging

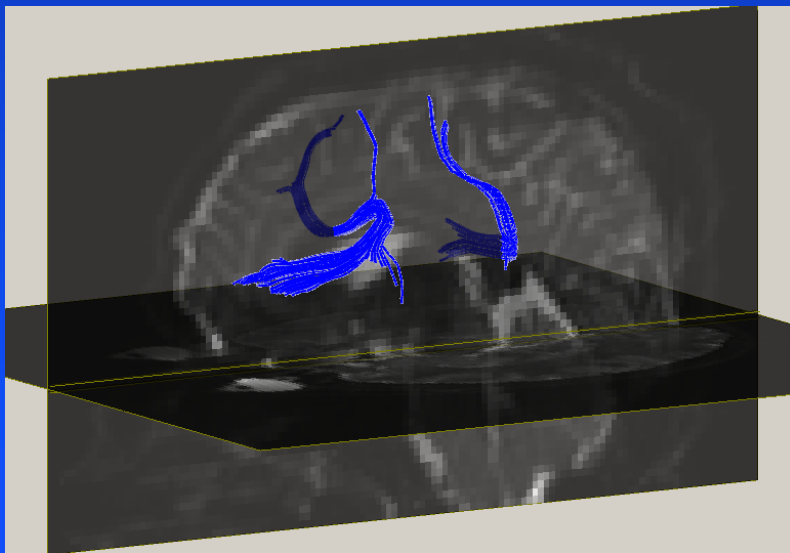
- Allows assessment of how various brain regions are connected
  - Directionality (anisotropy of white matter fiber tracts)
  - Assesses integrity of tracts



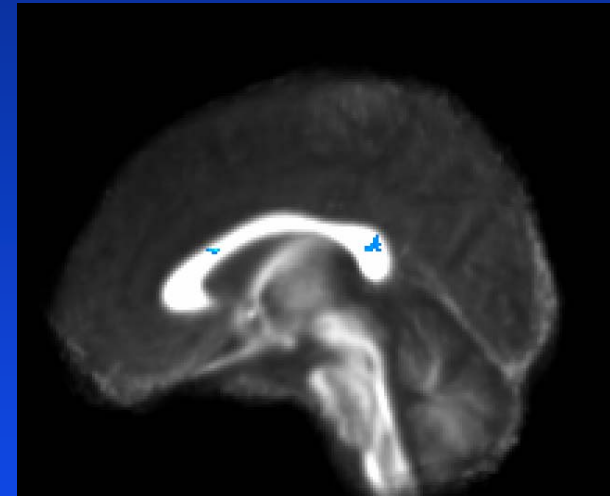
Red = horizontal Blue= front/back Green=up/down



Subject A



Subject B



# Tractography

# Conceptual Issues

- Imaging is correlational
  - TMS limited to cortical regions near skull
- Relation between blood flow and brain activity is underspecified
  - Nature of BOLD response unknown
- Correspondence between brain activity and psychological processes
  - Many brain regions involved in multiple tasks
- Importance of hypothesis testing
  - Rather than brain mapping

# Research Example: Social Rejection

Prior research has demonstrated that dorsal regions of anterior cingulate cortex (ACC; BA 32) exhibit increased activity during the experience of physical pain.



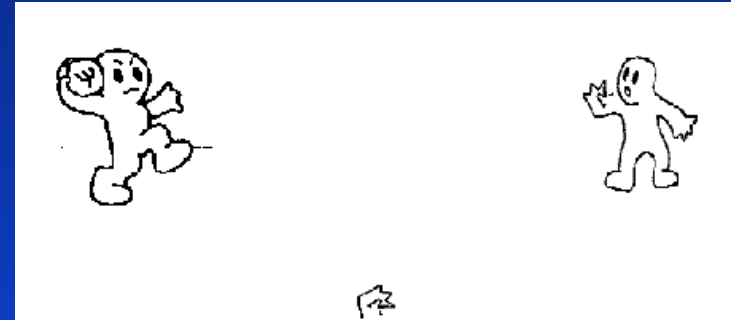
QuickTime™ and a  
TIFF (Uncompressed) decompressor  
are needed to see this picture.



More recent studies suggest that the dorsal ACC may be responsive during the pain associated with social rejection (Eisenberger et al, *Science*, 2003).

## Eisenberger et al. (2003)

- Cyberball Game
  - Scan 1 (ISE) watch others play
    - You can't play because of technical difficulties
  - Scan 2 (Inclusion)
    - Players throw ball to each other and you



# Eisenberger et al. (2003)

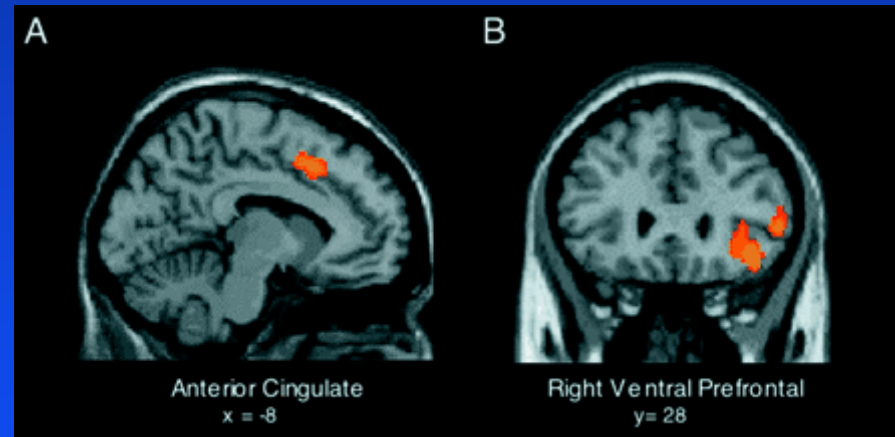
- Cyberball Game

- Scan 1 (ISE) watch others play
  - You can't play because of technical difficulties
- Scan 2 (Inclusion)
  - Players throw ball to each other and you
- Scan 3 (ESE)
  - After 7 throws they stop sending it to you
    - Self-reports indicate distress



# Eisenberger et al. Findings

- Dorsal ACC
  - Greater for exclusion than inclusion
  - But, also greater for ISE than for inclusion



**Does ACC activity index actual social and physical pain, or does ACC activity in these studies reflect expectancy violations at a more general level?**

# Anterior Cingulate

- **Dorsal ACC** cognitive
  - Error Detection
  - Expectancy violations
  - Conflict between brain regions
  - Response Selection
  - Working memory
- **Ventral ACC** affective
  - Assessing emotional salience
  - Motivational value
  - Regulation of emotion
  - Activated by induced sadness
  - Activated in depression

QuickTime™ and a  
TIFF (LZW) decompressor  
are needed to see this picture.

# Anterior Cingulate

## Bush, Luu & Posner, 2000

QuickTime™ and a  
TIFF (LZW) decompressor  
are needed to see this picture.

Meta-analysis of 64 studies

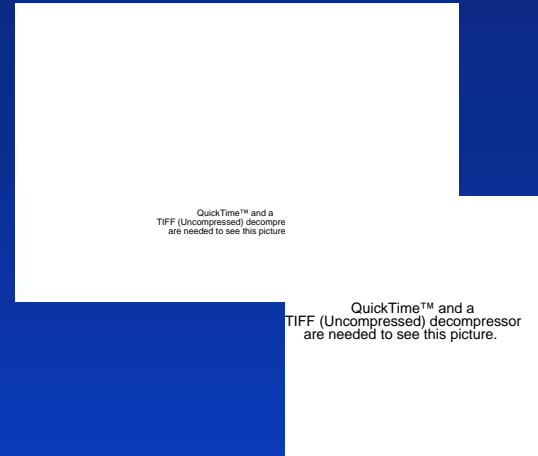
# Exp 5: Method

## Session 1: Cover Story

20 right-handed volunteers (10 female, mean age = 20)  
Subjects were told they were participating in a multi-university study on first impressions. Subjects believed they would be rating photos of subjects from other schools and believed these individuals would also be rating their face. Subjects were photographed as part of the ruse.

## Session 2: fMRI scanning

Subjects were scanned while performing a social judgment task on photos believed to be the participants from other schools.



**Do you think you would like this person?**



**Yes/No?**

For some trials, subjects received feedback indicating whether or not they were liked by the person in the picture.



Cue  
0-3000 ms

**Subject decides, “Would I like this person?”**



**Yes**

Delay  
0-4000 ms

**Subject response displayed on the left**



**Yes**

**No**

Feedback  
2000 ms

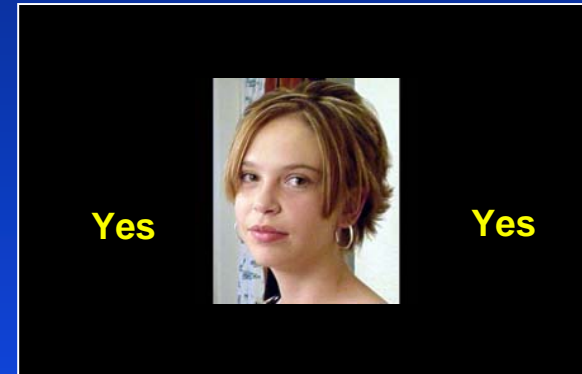
**Feedback indicating whether the individual in photo liked the subject displayed on right**

‘Catch’ trials (partial trials that do not run to completion) were included to permit unique response estimates for each subcomponent.

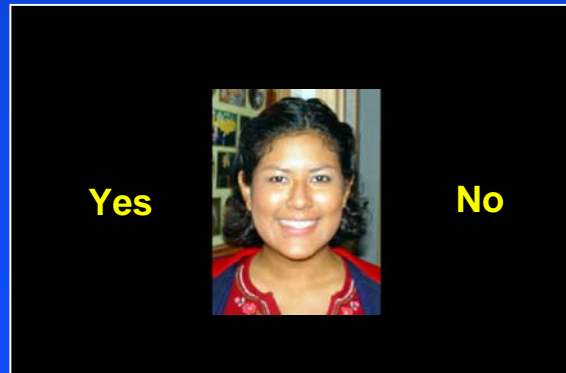
**Rejected**

**Accepted**

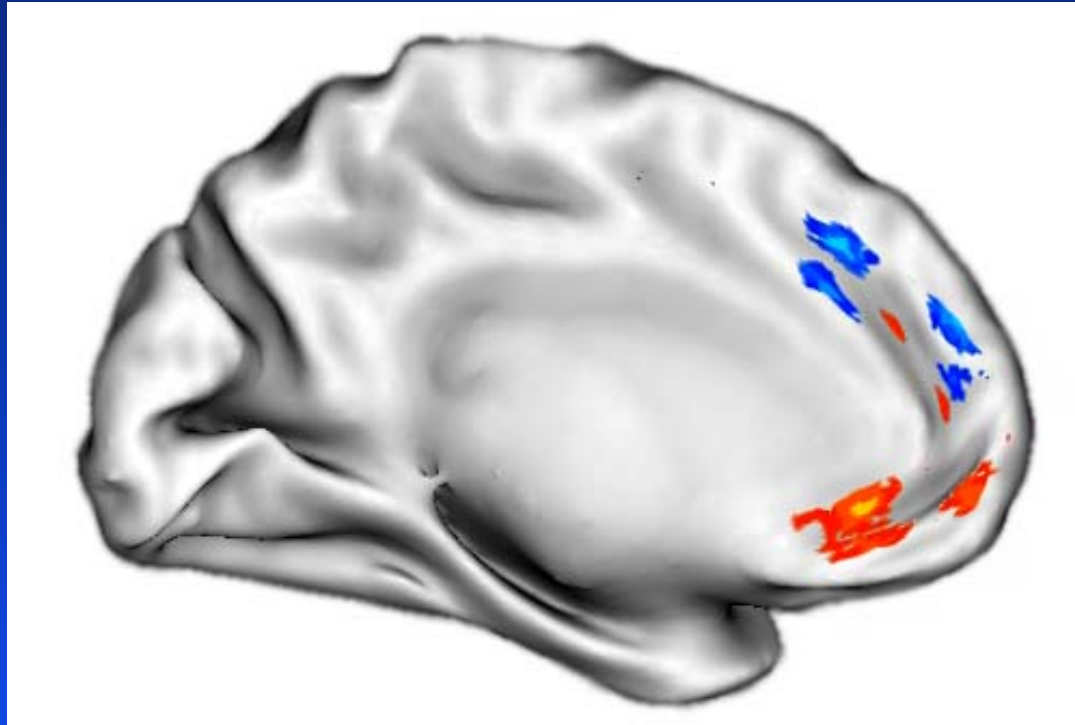
**Congruent**



**Incongruent**



A voxel-wise 2 x 2 ANOVA was conducted examining the effects of congruency (congruent vs. incongruent) and feedback (rejected vs. accepted)

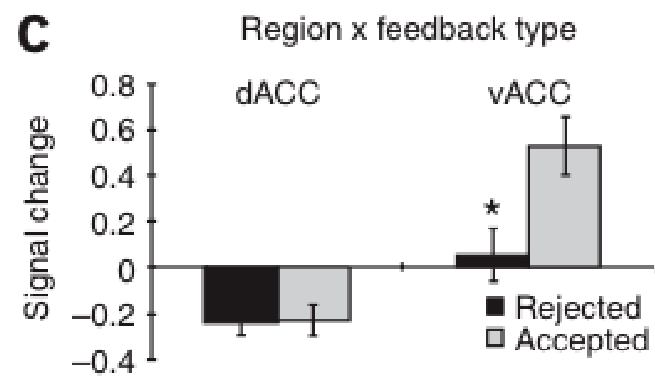
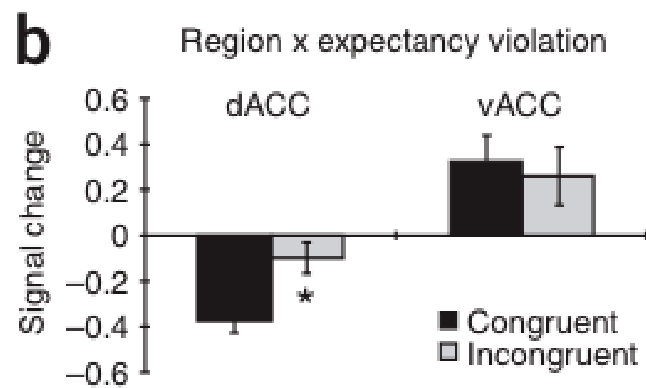
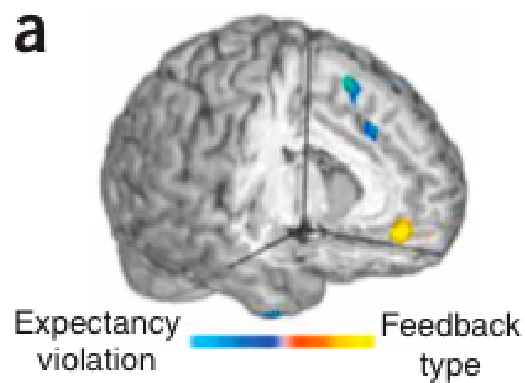


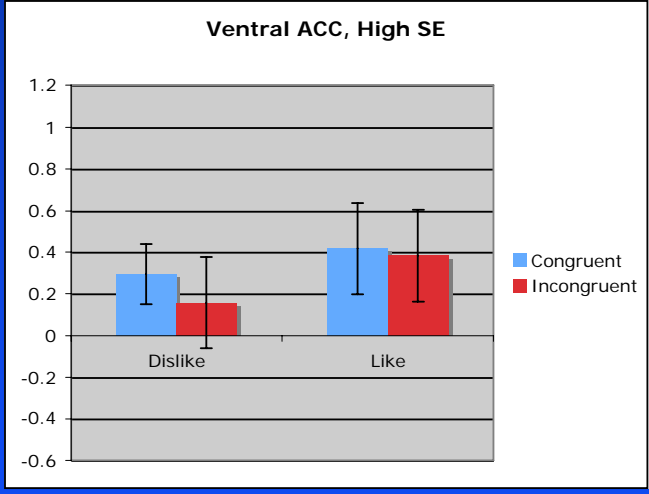
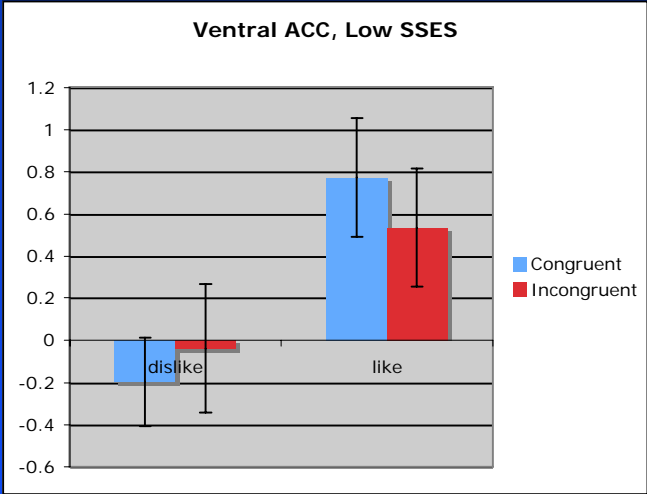
Congruency



Feedback

**A voxel-wise ANOVA revealed a functional dissociation between dorsal ACC and ventral ACC**





# General Summary

- Biological Revolution is underway
  - Watching the working brain in action
- Neurophysiology is best for temporal resolution
- Brain imaging methods are best for spatial resolution
- New techniques are providing novel ways to test longstanding scientific issues

What do we learn from observing activity?



