

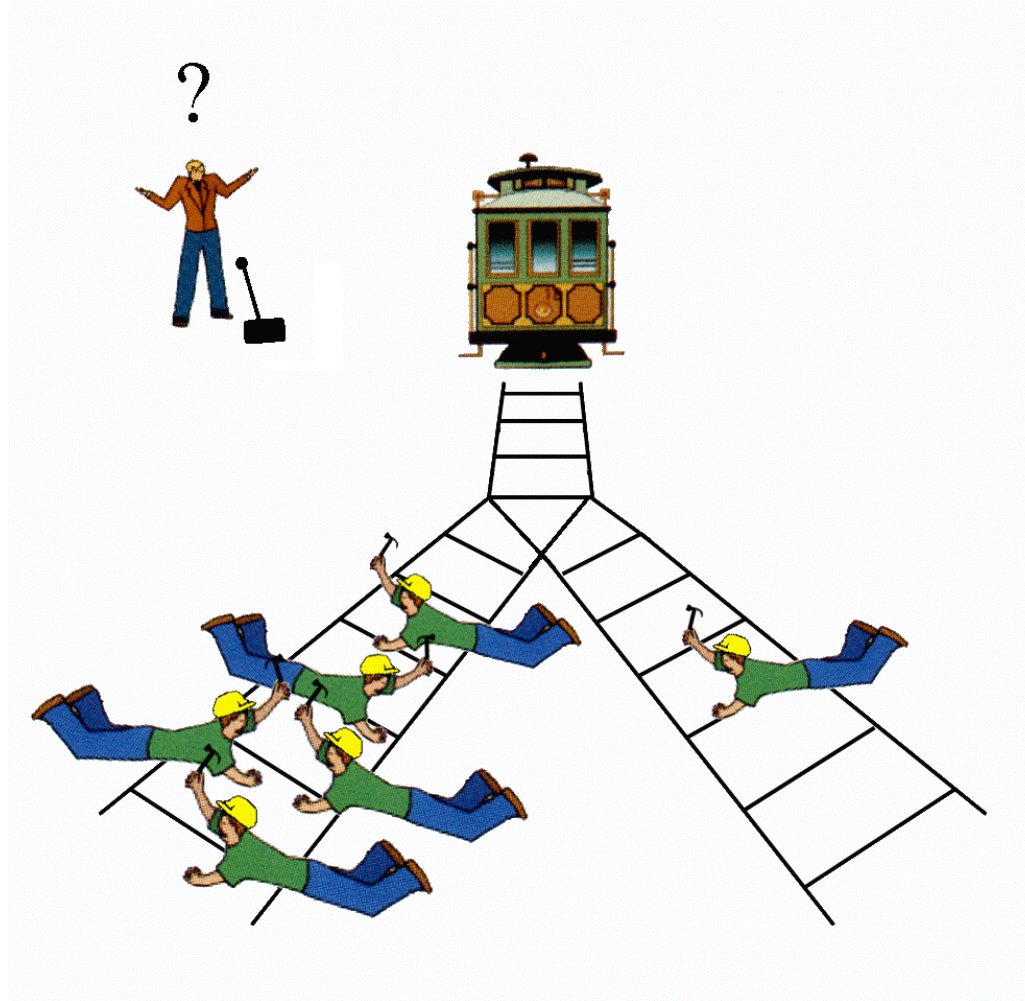
Neuroscience of Decision Making

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15 May 2008

The Ultimatum Game

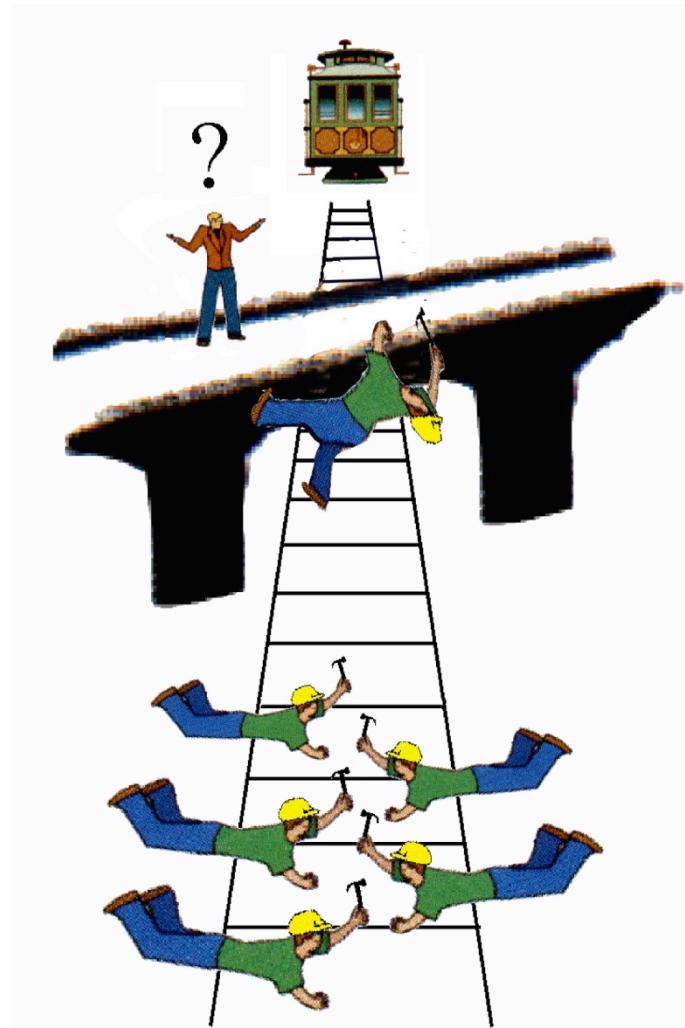
- \$10 to divide between two players
- “Proposer” chooses a division
- “Receiver” can either
 - Accept: both receive proposed amounts
 - Reject: both receive nothing
- How much should the Proposer offer?

The Trolley Problem



85%

The Footbridge Problem



12%

Intertemporal choice

- Choice involving rewards available at different time delays



Example

Would you rather have \$10 today or \$11 tomorrow?

Would you rather have \$10 in a year or \$11 in a year and a day?

Can behavior be captured by
formal models?

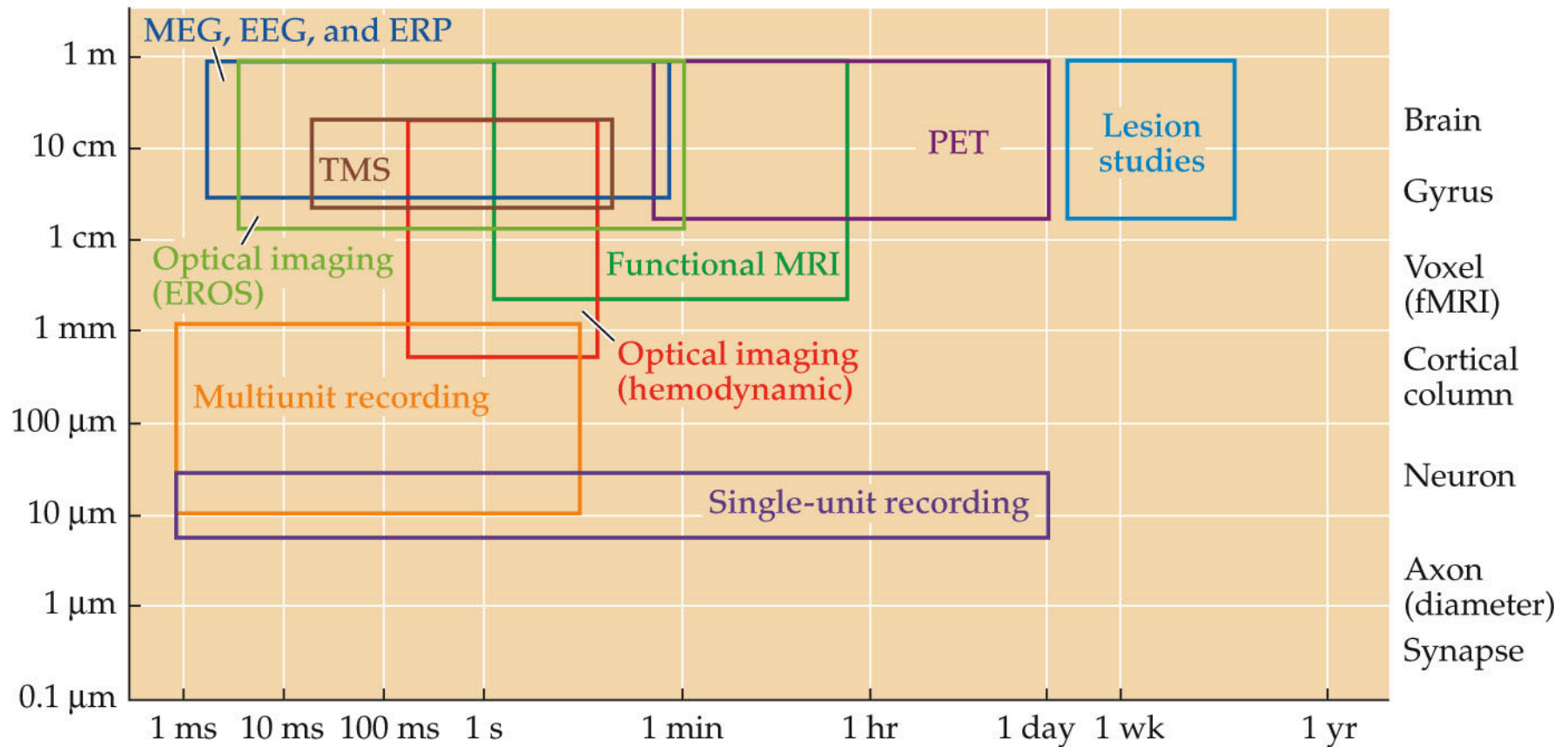
The astonishing hypothesis

- “You, your joys and your sorrows, your memories and your ambitions, your sense of personal identity and free will, are in fact no more than the behavior of a vast assembly of nerve cells and their associated molecules” (Crick)
- With mechanistic / computational models of the brain we may be able to derive laws of behavior

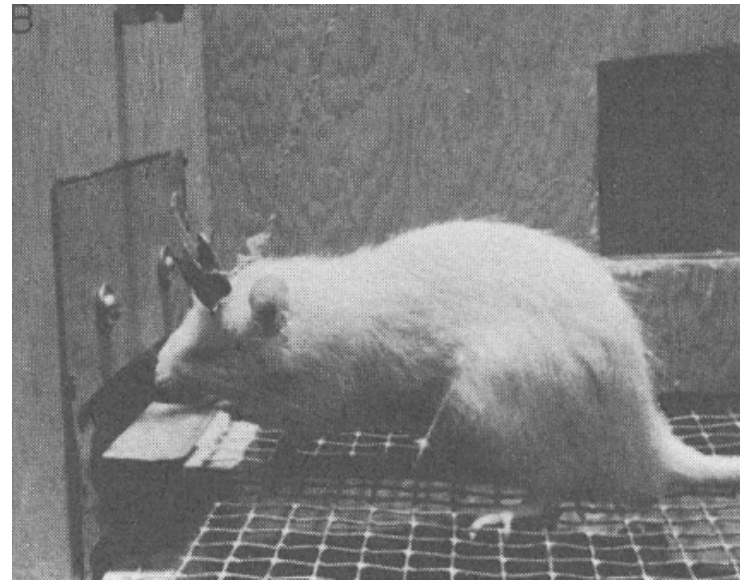
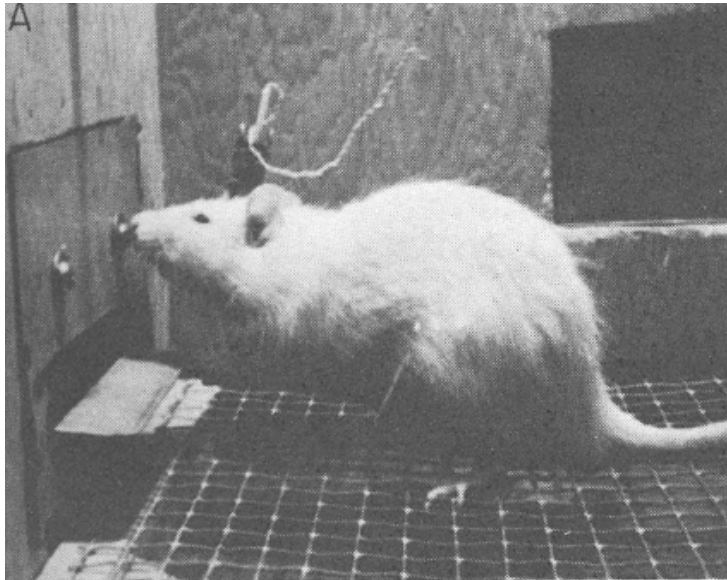
Introduction to the brain

- Approximately 100 billion neurons
- Each with up to 10,000 connections with other neurons
- Most complicated computation device known in the universe
- Communication via electrical impulses and propagated by chemical synapses

Brain Recording Methods

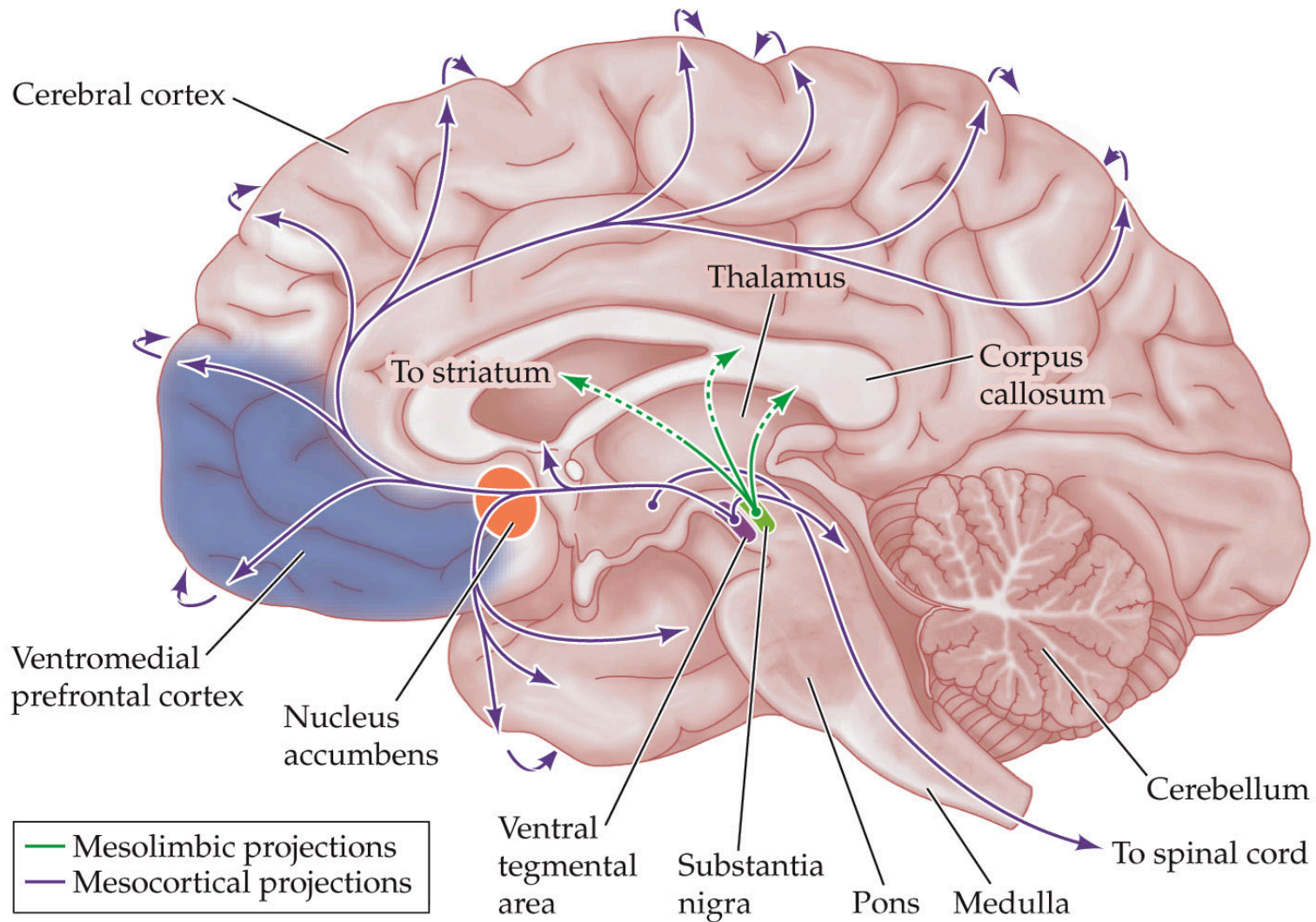


Brain Stimulation Reward



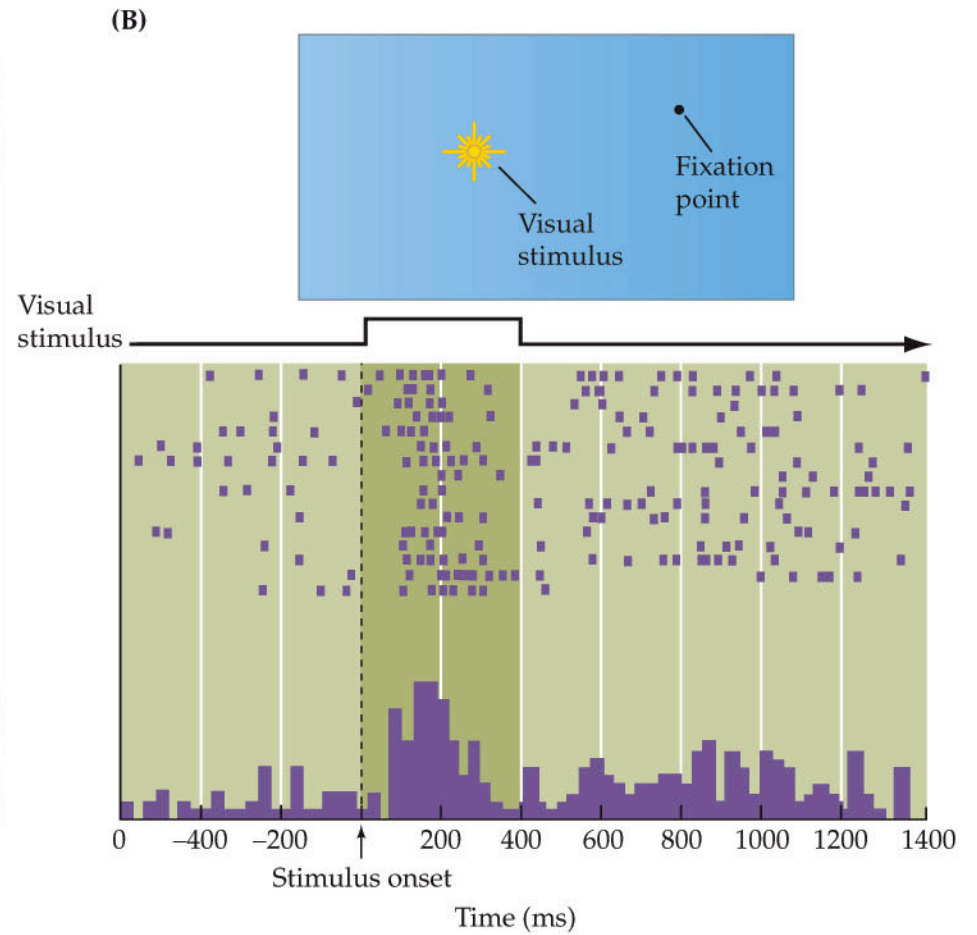
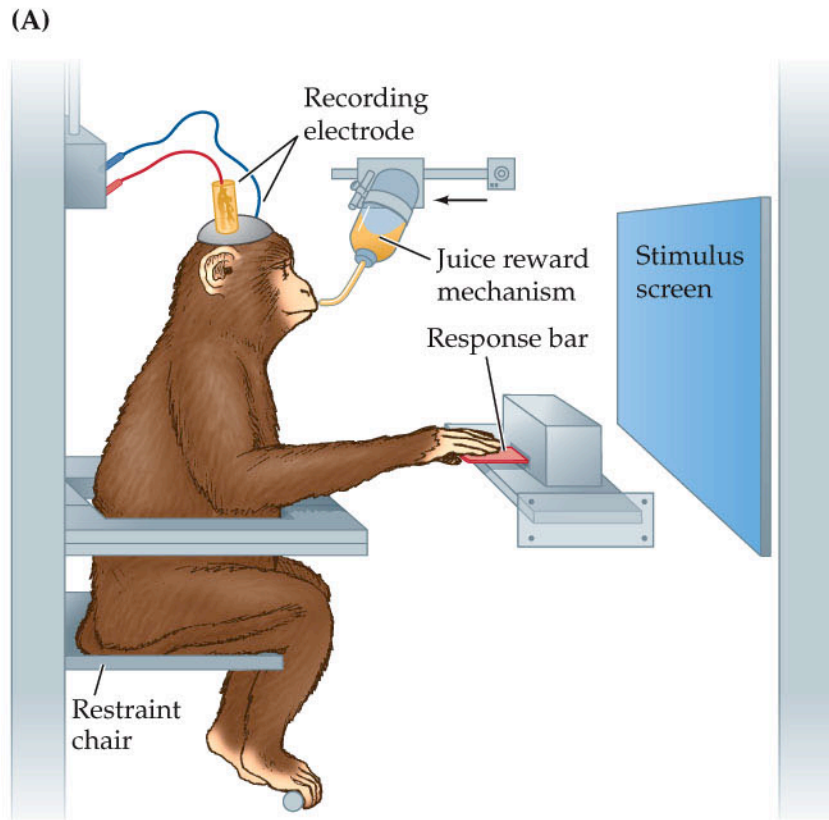
A neural substrate that replaces external reward

Midbrain dopamine system

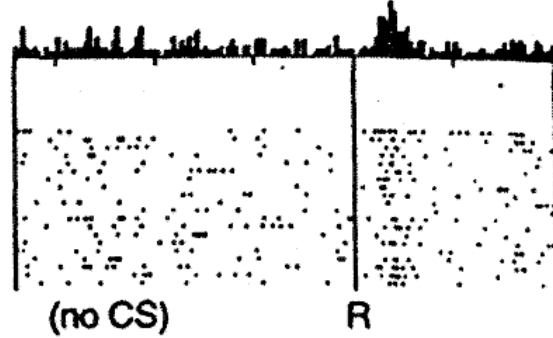


Principles of Cognitive Neuroscience, Figure 24.5

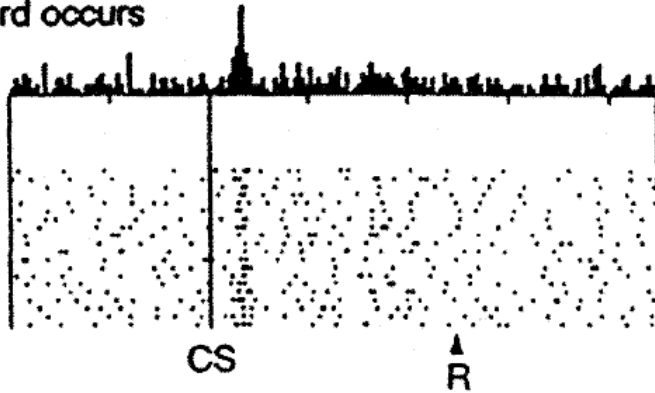
Single-unit Recording



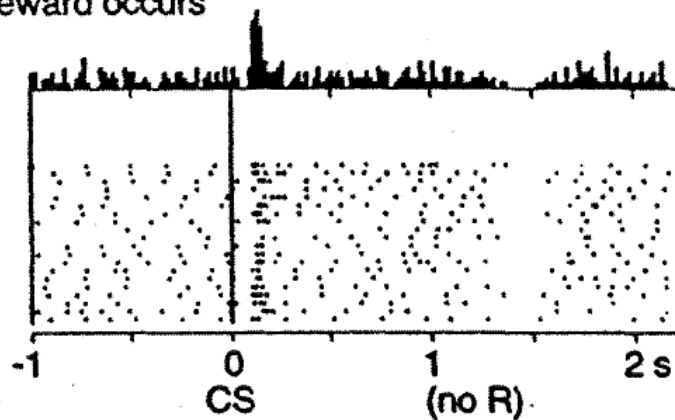
No prediction
Reward occurs



Reward predicted
Reward occurs



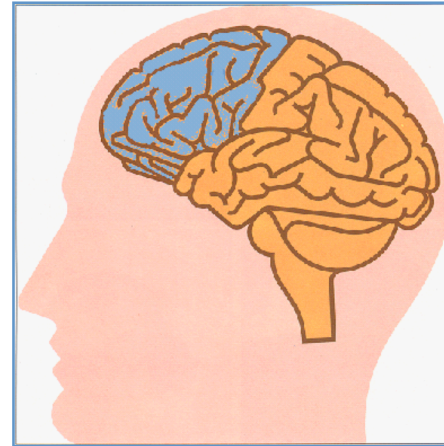
Reward predicted
No reward occurs



- Encode a reward prediction error
- For a stimulus that predicts reward, dopamine firing indicates value of reward

(Schultz et al., 199

Role for the prefrontal cortex



- Greatly expanded in people compared to other animals
- Supports higher cognitive processes (working memory)
- Critical for decision-making (e.g. shopping experiment)

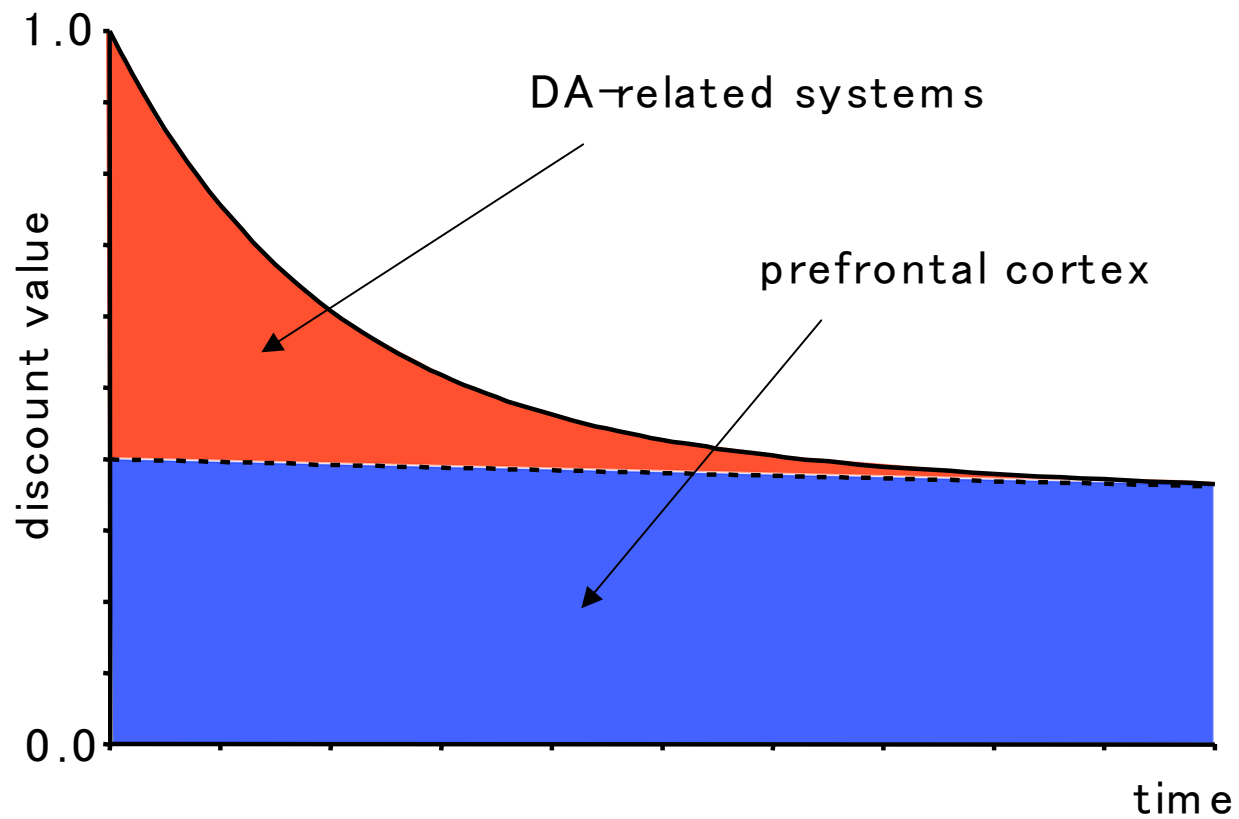
Recording human brain activity: Functional Magnetic Resonance Imaging



- Allows measurement of brain activity at the scale of individual brain structures (mm)
 - Temporal resolution is on the order of many cognitive processes (sec)
 - Non-invasive
- For the first time we can measure close to the root cause of decision making

Hypothesis

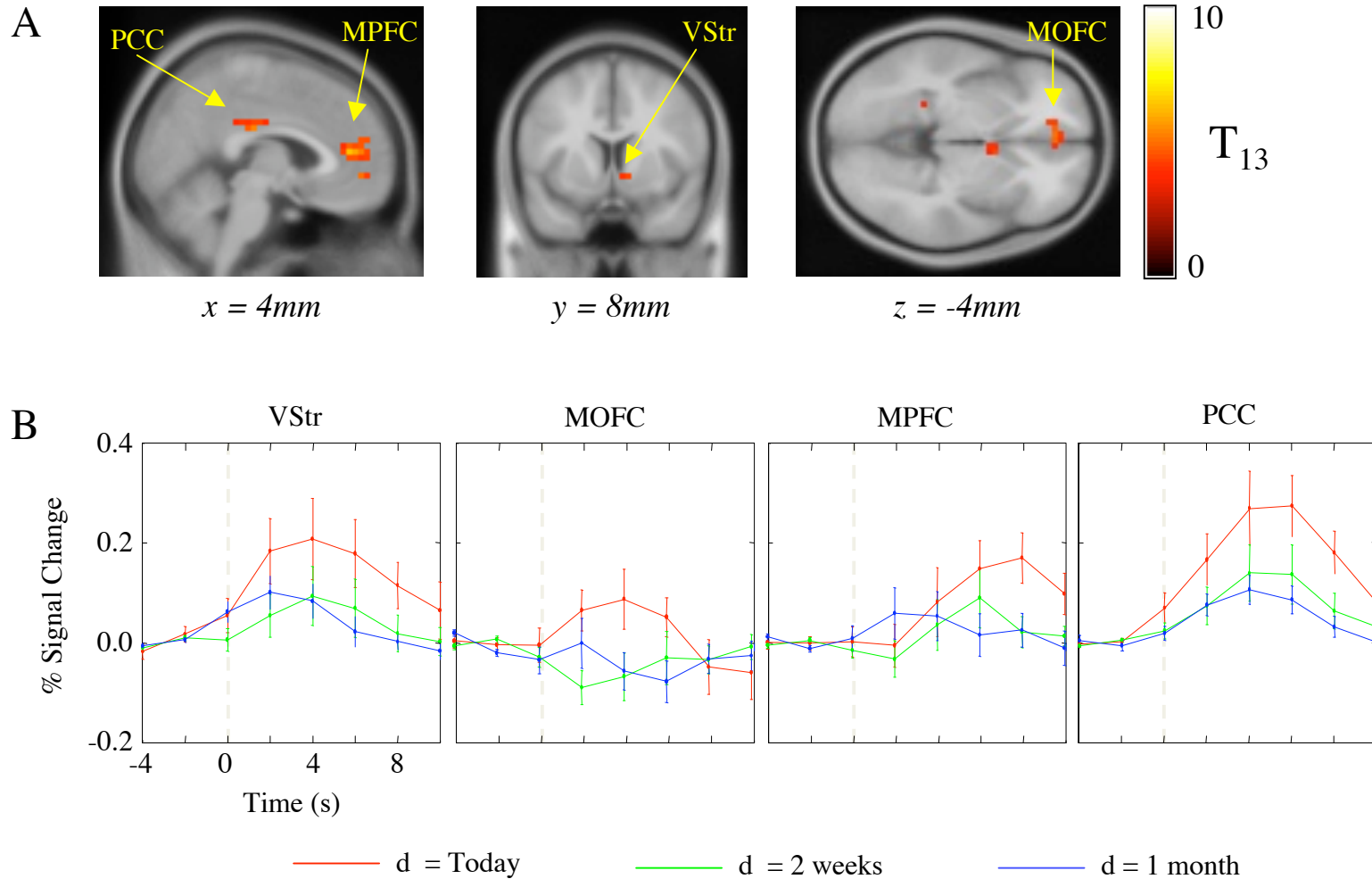
Dopamine-related reward systems discount reward at a higher rate than does the prefrontal cortex.





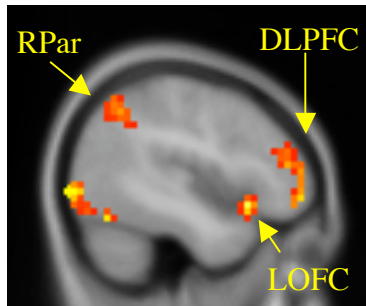
$d \in \{ \text{Today, 2 weeks, 1 month} \}$
 $d' - d \in \{ \text{2 weeks, 1 month} \}$
 $(R' - R) / R \in \{ 1\%, 3\%, 5\%, 10\%, 15\%, 25\%, 35\%, 50\% \}$

Regions that respond preferentially to immediately available rewards

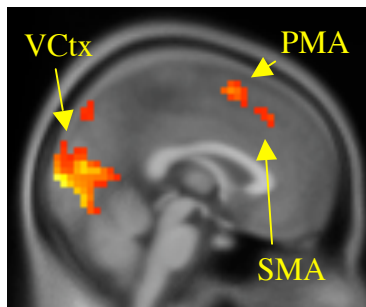


Regions that respond equally to rewards at all delays

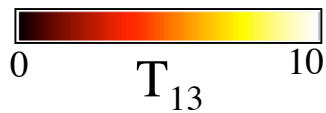
A



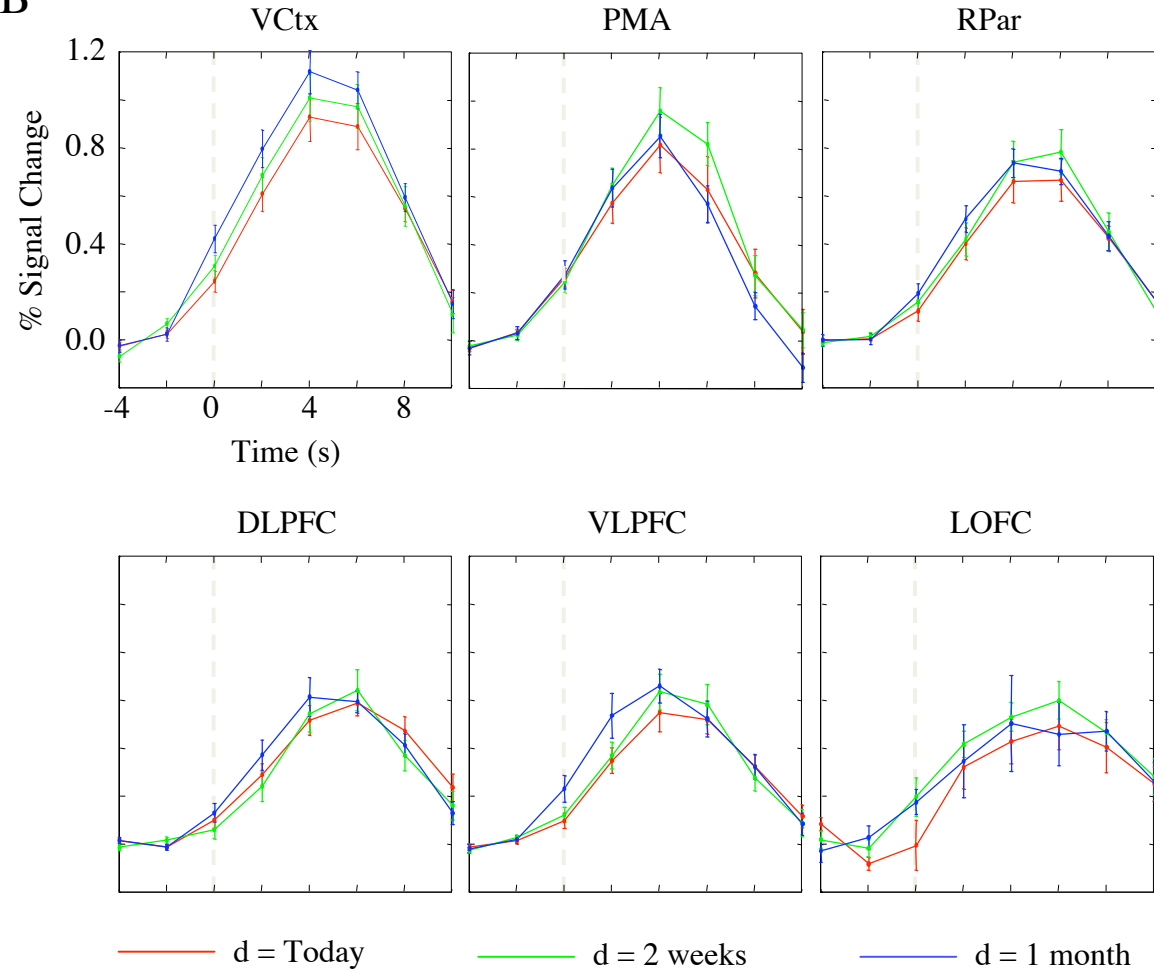
$x = 44\text{mm}$



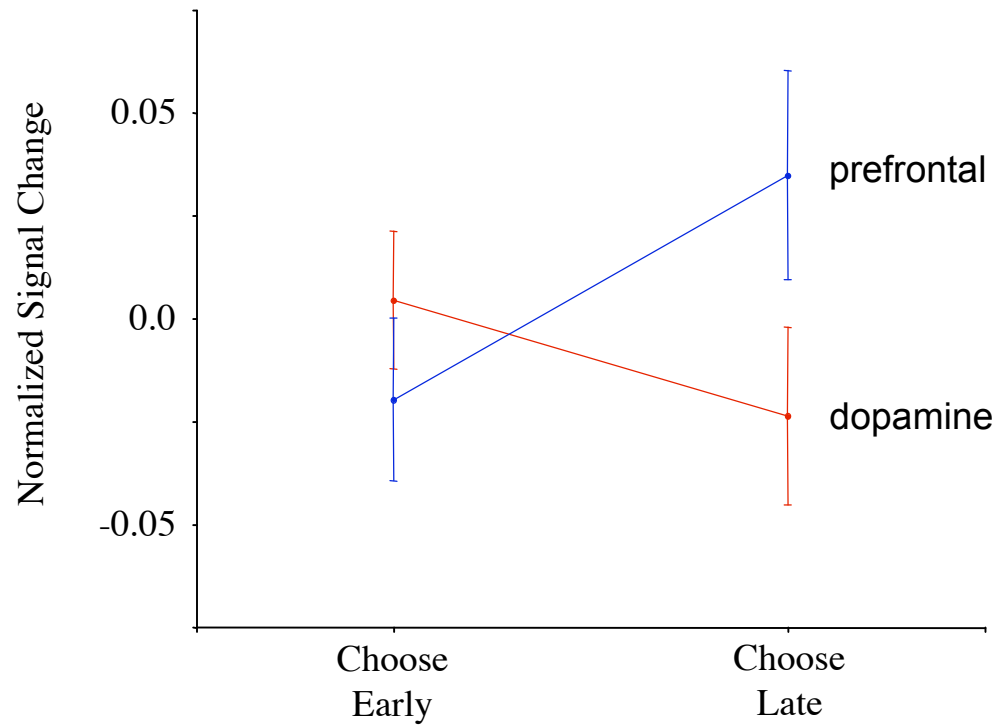
$x = 0\text{mm}$



B



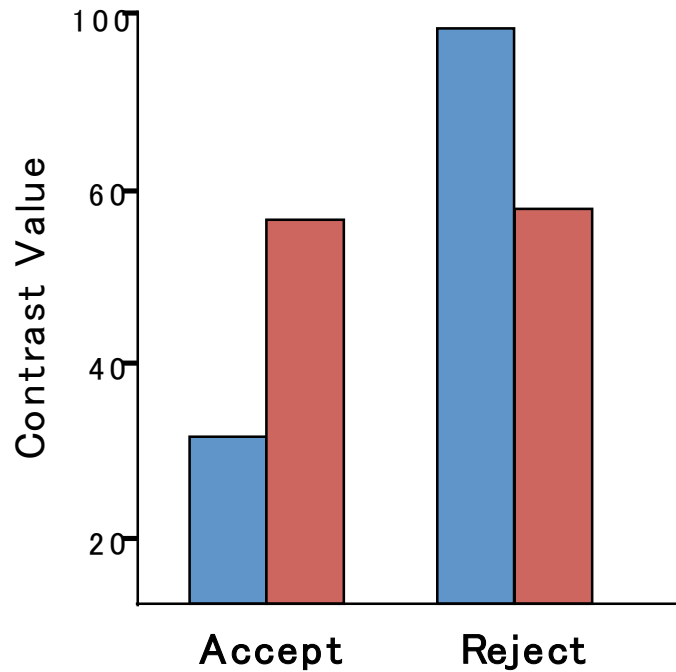
Relative activity by choice



Amygdala and the Ultimatum Game

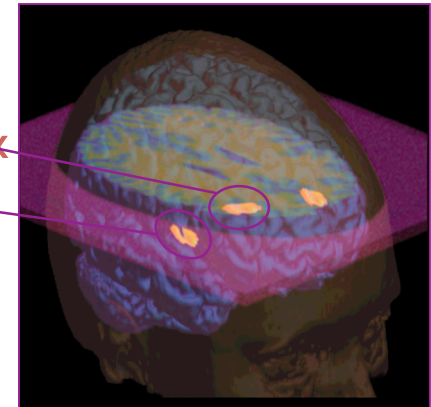
Sanfey et al. (2003)

Unfair Offers



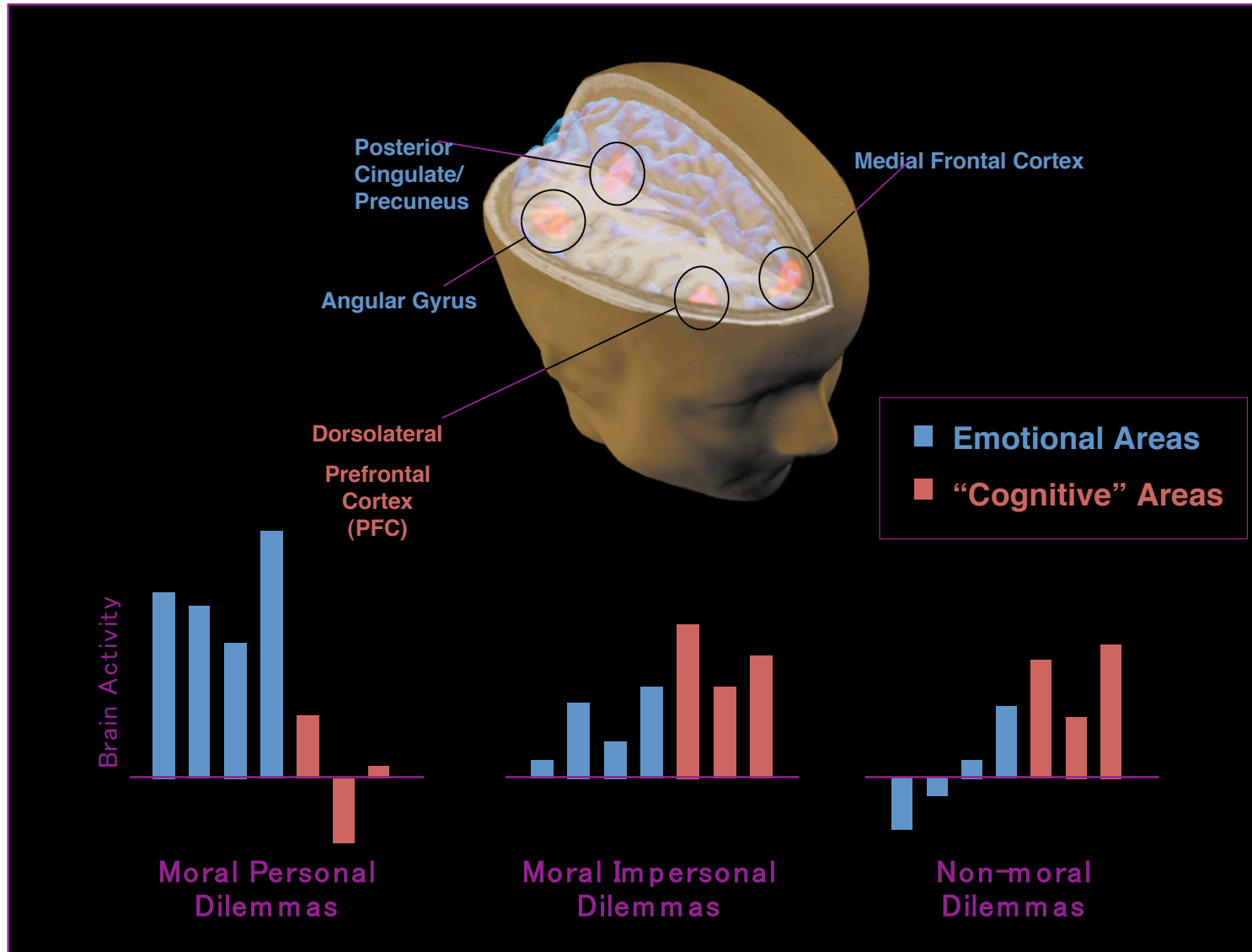
Prefrontal Cortex

Insular Cortex

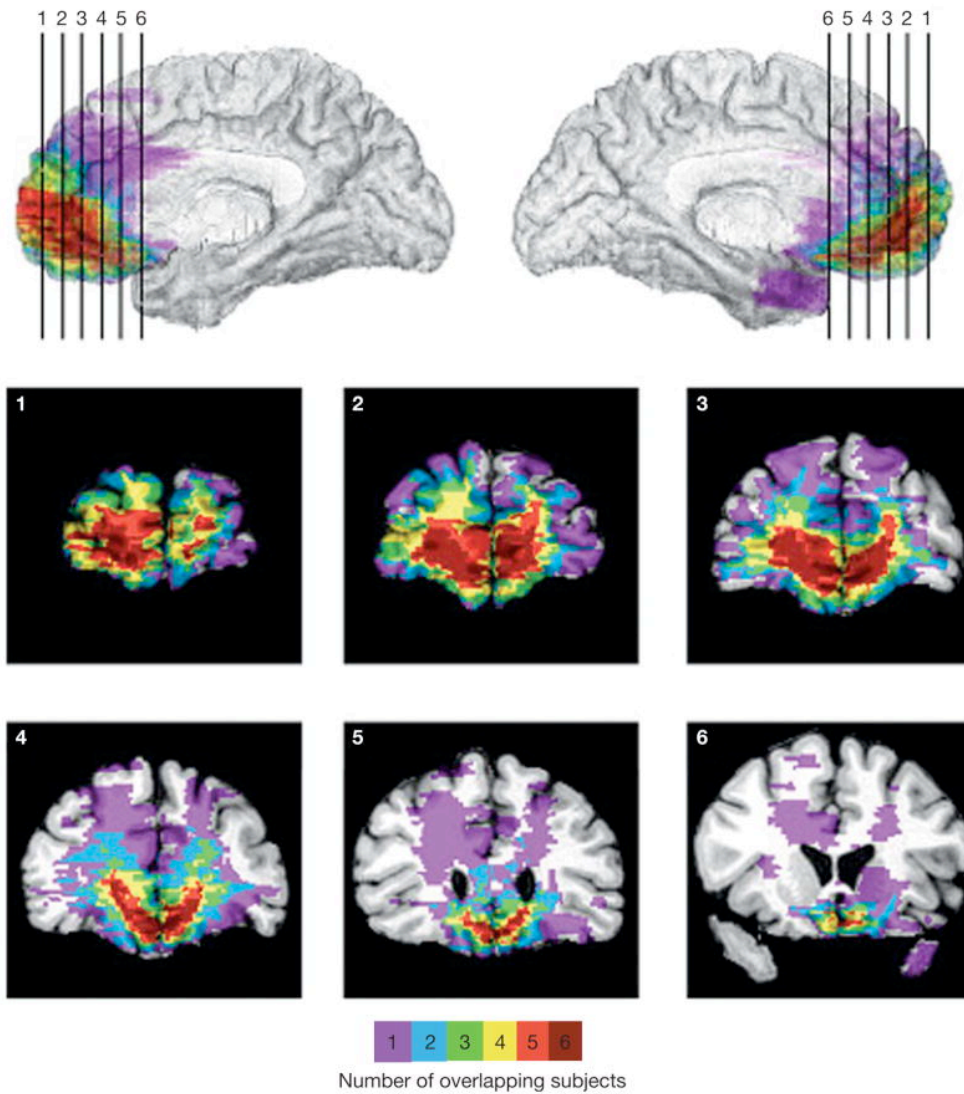


fMRI Results

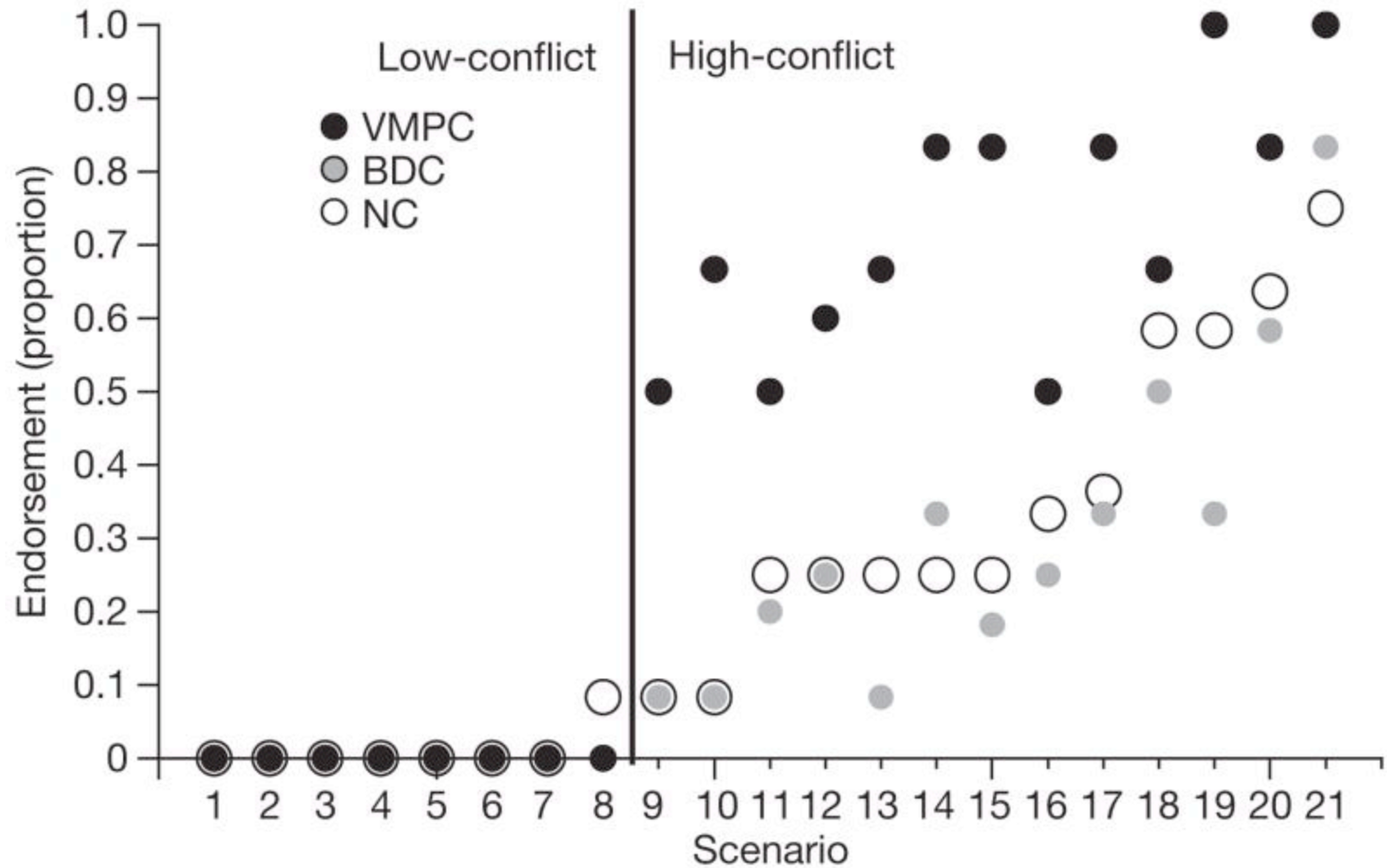
Greene et al. (2001)



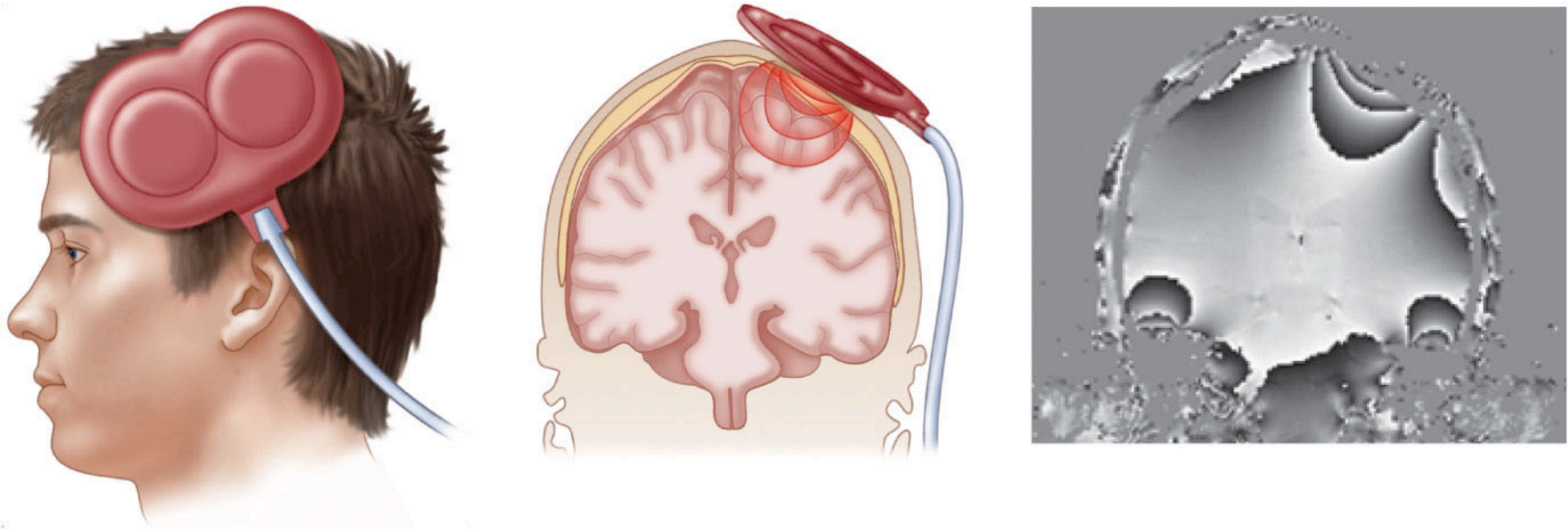
VMPFC and morality



People are utilitarian without VMPFC

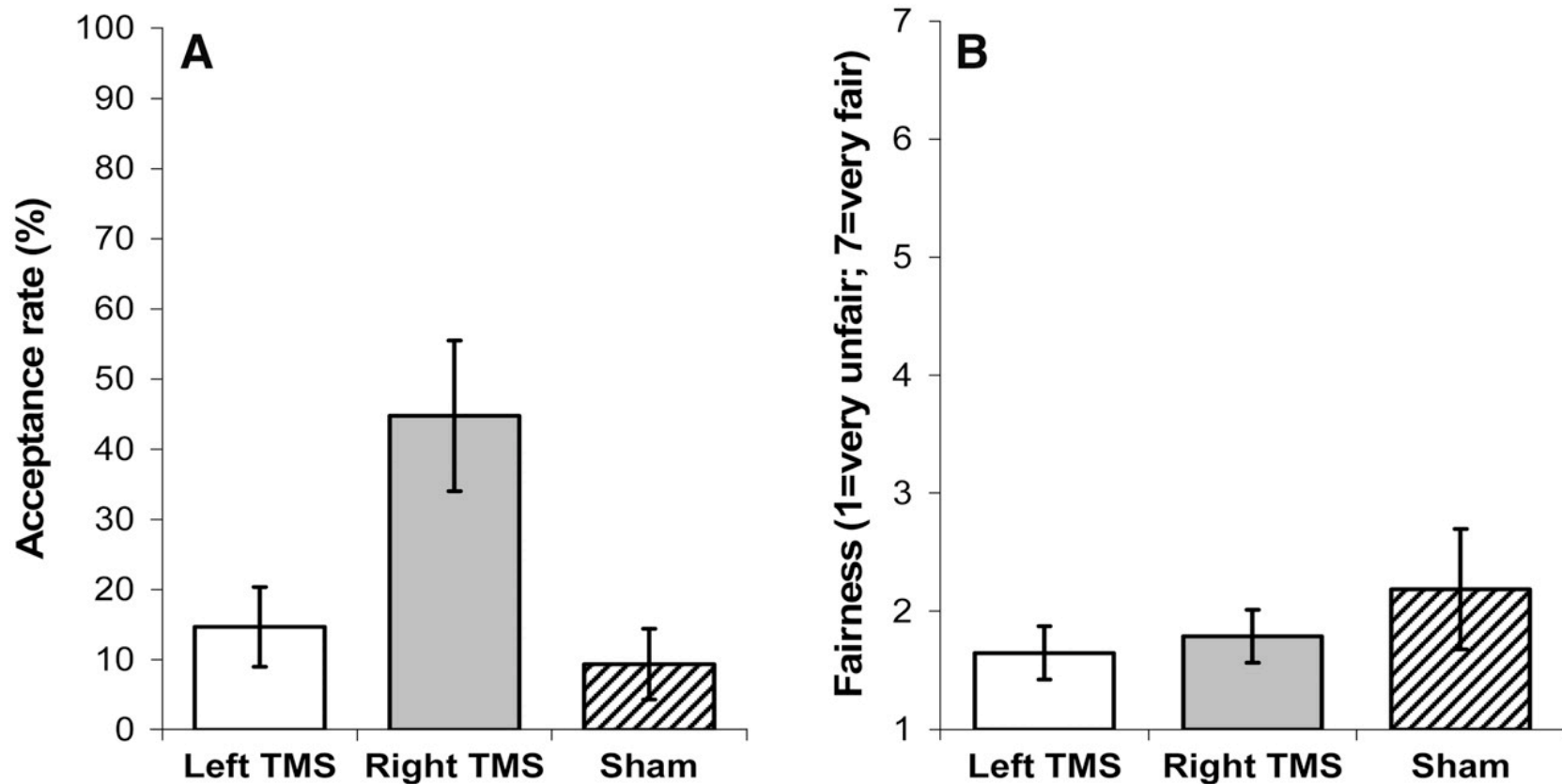


Transcranial Magnetic Stimulation (TMS)



Stimulating DLPFC increases acceptance of unfair offers in the Ultimatum Game

16/4 offers



Are people generally rational?

- “Automatic” brain responses create biases and heuristics that are probably generally correct
- We also have a prefrontal cortex to enable flexible behavior and correct decision errors (sometimes)