Cognitive Neuroscience

PSYC 313 - Lecture 2
Dr. J. Nicol

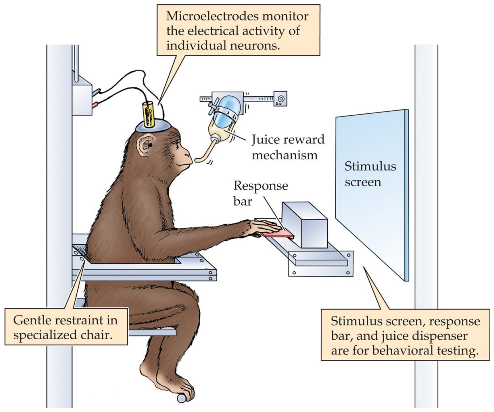
Cognitive Neuroscience

- Cognitive neuroscience is the interdisciplinary study of the neural mechanisms of cognition and behaviour (Eagleman & Downar, 2015)
- The goal of the field is to better understand how we perceive, think, learn, communicate, and control action — but with a focus on the role of brain mechanisms
- Cognitive neuroscience employs a variety of research tools for investigating the relationship between the brain and mental processes, each with its own strengths and weaknesses

Single Cell Recordings

- The goal of electrophysiology research is to find experimental manipulations that change the firing rate of a neuron, thereby demonstrating that neuron's function
- Electronic amplifiers are used that are powerful enough to make the extremely small electrical signals generated by a single neuron recordable

Single-cell recording

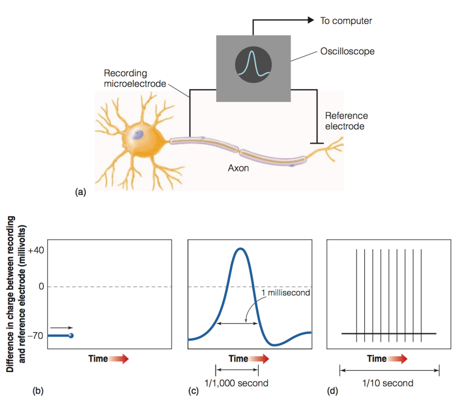


PSYCHOPHARMACOLOGY 2e, Figure 4.15

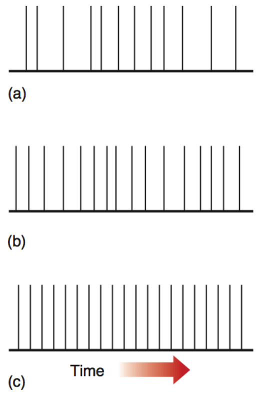
Single Cell Recordings

- The key principle for understanding how electrical signals are recorded from neurons is that the ***difference in charge*** between the recording electrode and the reference electrode is measured
- The difference in charge between them is displayed on an oscilloscope, which indicates the difference by the vertical position of a small dot that creates a line as it moves across the screen

A microelectrode is inserted into the brain to record the activity of a single cell and the firing rate of the cell is recorded as different stimuli are presented



Action potentials recorded from a single neuron in response to three levels of pressure stimulation on the skin



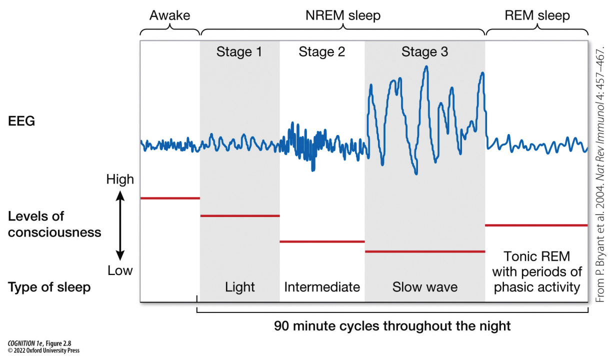
Adrian (1928)

Electroencephalography (EEG) *recordings measure neural activity directly by measuring the electrical signals that are produced when large clusters of neurons fire synchronously*

Electroencephalography (EEG)

- Electroencephalography (EEG) uses electrodes on the scalp to detect and amplify global electrical activity
- Each electrode picks up signals from groups of neurons that fire together
- The signals are very rapid, occurring on a time scale of fractions of a second

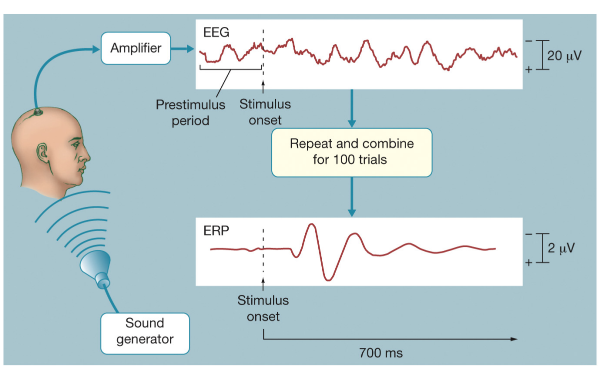
EEG reveals how levels of consciousness change across different sleep stages

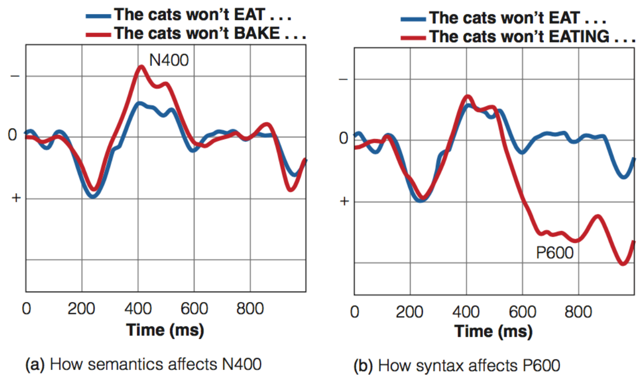


Event-Related Potentials (ERPs)

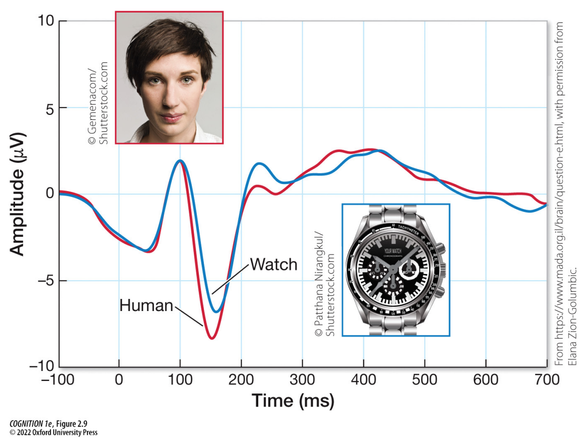
- Reflect the momentary changes in electrical activity of the brain when a particular stimulus is presented
- The ERP waveform consists of inflections in the EEG that occur at different delays after a stimulus is presented and that can be linked to different functions

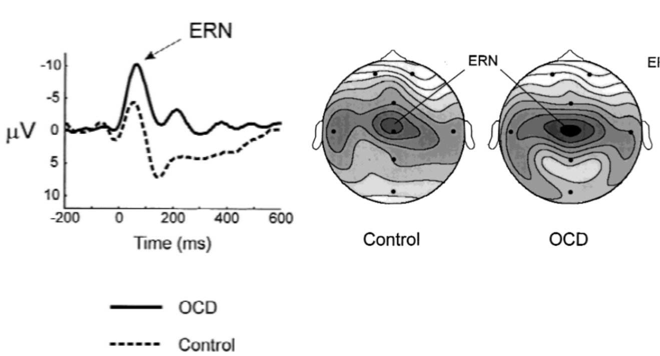
*An **event-related potential (ERP)** is a brief change in the electrical activity in the brain that occurs in response to presentation of a stimulus*





Osterhout et al. (1997)

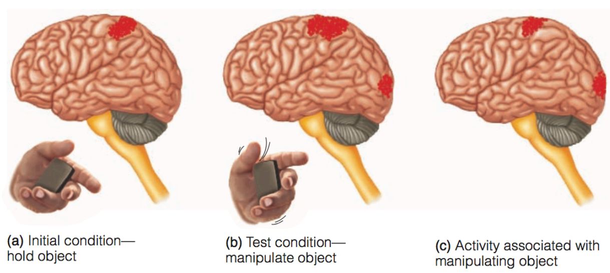




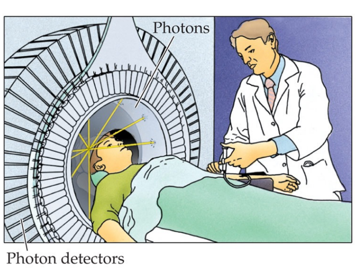
Gehring et al. (1999)

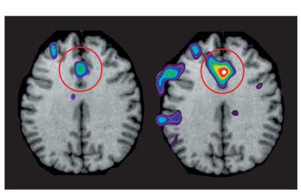
The Subtraction Technique

- PET and fMRI measure neural activity ***indirectly*** by measuring the changes in blood flow to different areas of the brain while a person performs a cognitive task
- Both of these brain imaging techniques employ a procedure called the subtraction technique
- Brain activity in the person is measured first in a "control state" before being exposed to the stimulus, and again while the stimulus is presented
- Subtracting the activation in the control state from activation during the task indicates the brain activity that is associated with performing the task



Positron Emission Tomography (PET)





Positron Emission Tomography (PET)

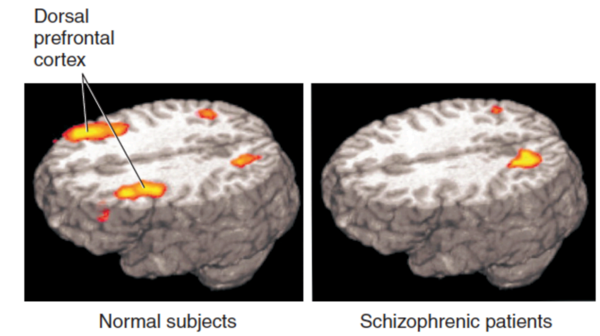
- Takes advantage of the fact that blood flow increases in brain areas that are activated by a cognitive task
- To measure blood low, a low dose of radioactive tracer (i.e., a glucose-like substance) is injected into the bloodstream of the person being scanned
- The person's brain is then scanned by the PET scanner while they perform a cognitive task, which measures the signal from the tracer at each location in the brain
- Since the brain's fuel is glucose, higher signals indicate higher levels of brain activity

functional Magnetic Resonance Imaging (fMRI)

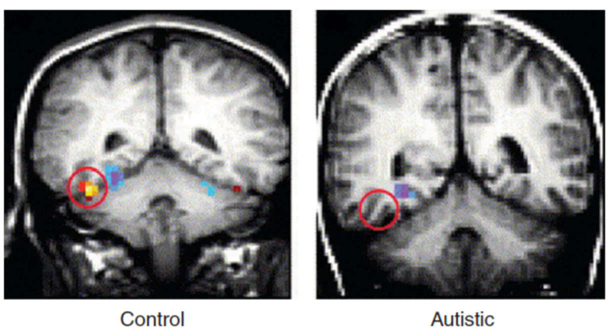
COGNITION 1e, In-Text Art, Ch. 2, p. 38

fMRI

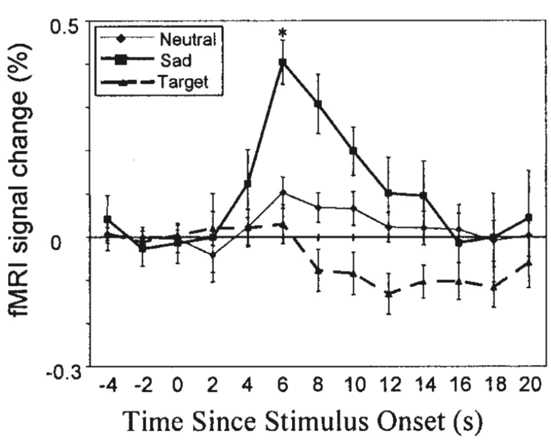
- Doesn't require radioactive tracers and is more spatially precise, so this technique is the main method for determining which areas of the brain are activated by different cognitive functions
- fMRI takes advantage of the fact that hemoglobin, which carries oxygen in the blood, contains a ferrous (iron) molecule and therefore has magnetic properties
- fMRI indicates the presence of brain activity because if a region becomes active because of mental processing, an increase in oxygenated hemoglobin is required in that region
- fMRI measures the blood oxygenation level-dependent response (***BOLD*** signal) to infer brain activity



MacDonald et al. (2005)

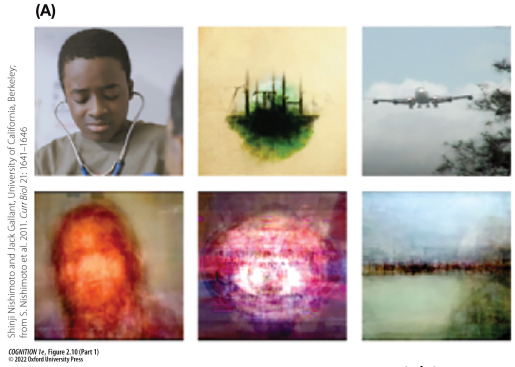


Schultz (2005)



Wang et al. (2005)

The top row shows clips from videos shown to observers in fMRI scanners. Based on decoding fMRI measurements collected with participants viewed these images, the bottom row shows what computer algorithms guessed the participants was viewing

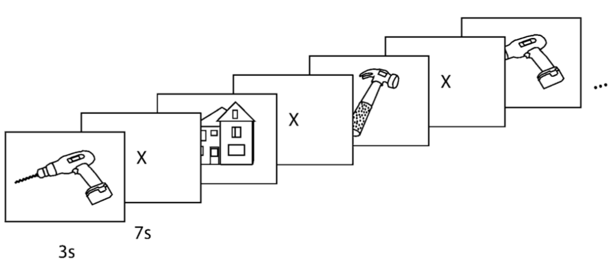


Nishimoto et al. (2011)

Original faces are what participants viewed in the scanner, while reconstructed faces were generated by computer algorithms that decoded brain responses to draw a best guess of which face the participant was viewing

Cowen et al. (2014)

Participants' saw pictures of five different tools and five different dwellings while in a brain scanner, which measured the fMRI response to each picture



They were asked to think of properties of the object as they looked at the picture

Shinkareva et al. (2008)

Measuring Brain Activity to Read the Mind

- By determining which voxels were activated by each picture and how strongly they were activated, the computer created a ***neural signature*** for each object
- After collecting patterns from the participants, the computer determined the pattern of neural activity associated with each class of object (tool vs. dwelling) and with each individual object (e.g., hammer, apartment, or screwdriver)

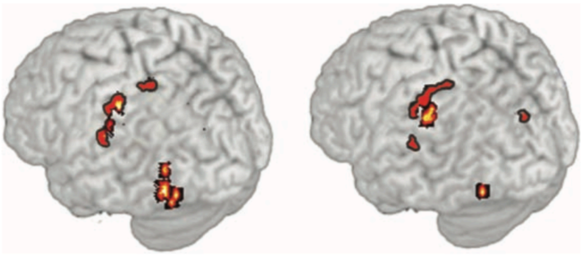
Measuring Brain Activity to Read the Mind

- When the computer's task was simply to indicate whether the person was looking at a tool or a dwelling, the accuracy was 87% (chance performance being 50% because there were only two possible answers)
- The average accuracy for identifying specific objects was 78% (chance being 10%, because there were 10 different objects)

Measuring Brain Activity to Read the Mind

- This ability to determine what a particular person is seeing based on the data from other people is possible because patterns of brain activation are similar for different people
- In other words, different people have similar neural signatures for specific types of objects

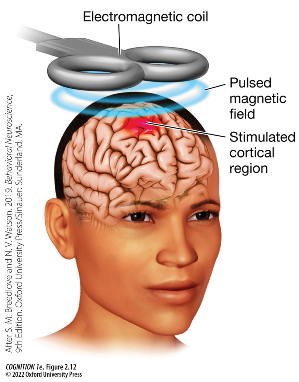
This commonality among people is illustrated in this figure, which shows the location of the voxels that provided information the computer used to determine that two different participants were both looking at "tools"



Participant A Participant B

Shinkavera et al. (2008)

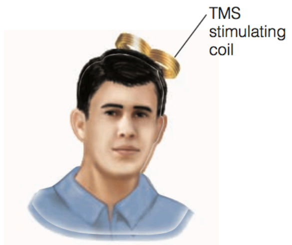
Transcranial Magnetic Stimulation (TMS)

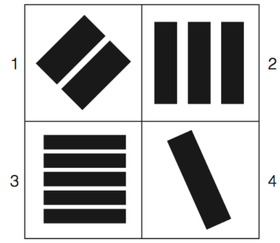


Transcranial Magnetic Stimulation

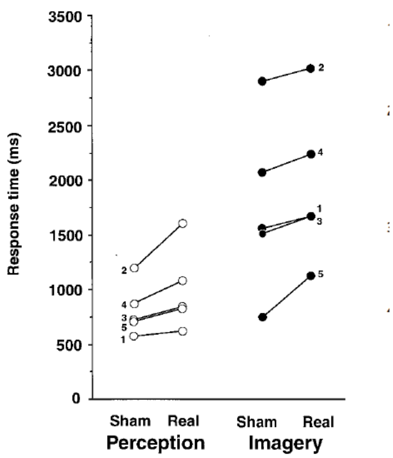
- A method to temporarily disrupt brain activity using focal magnetic pulses targeted over different areas of the scalp
- Temporarily and safely disrupts neural processing, helping to determine whether a brain region is important for a particular brain function
- So-called "virtual lesions" induced TMS can help establish whether a brain region play a causal role (Pascual-Leone, 1999)

Participants made discriminations about two quadrants in a perception condition or an imagery condition while TMS was applied to their visual cortex





Kosslyn et al. (1999)



Kosslyn et al. (1999)

Different methods for studying the brain