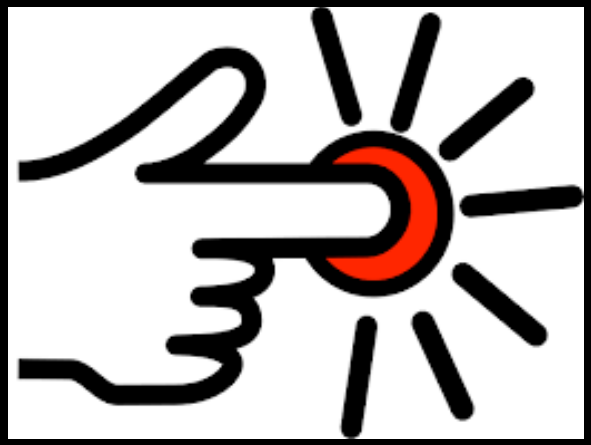
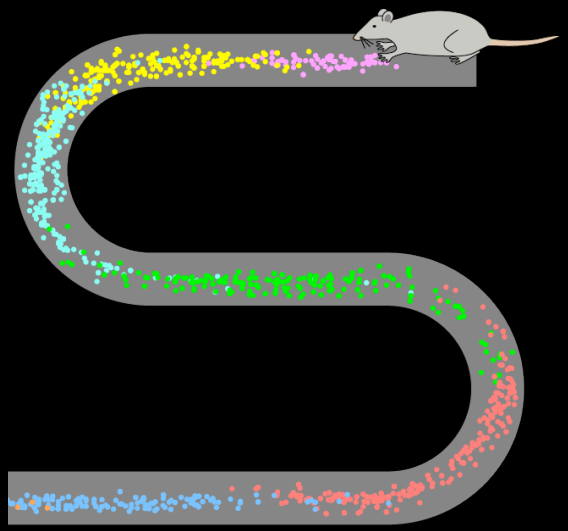
Experimental Methods:
From Behavior to Brain Imaging





Announcements

- Recently enrolled students:
  - Email the TAs to obtain access to Piazza
- Athletes and students with exam accommodations through OAE:
  - Email the Ellie Chestnut sooner rather than later to arrange alternate testing situations

Outline

- Tips for getting the most out of the class
- How do we study Learning and Memory?
  - Historical perspective
  - Types of experimental evidence

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- Tips for getting the most out of the class
- How do we study Learning and Memory?
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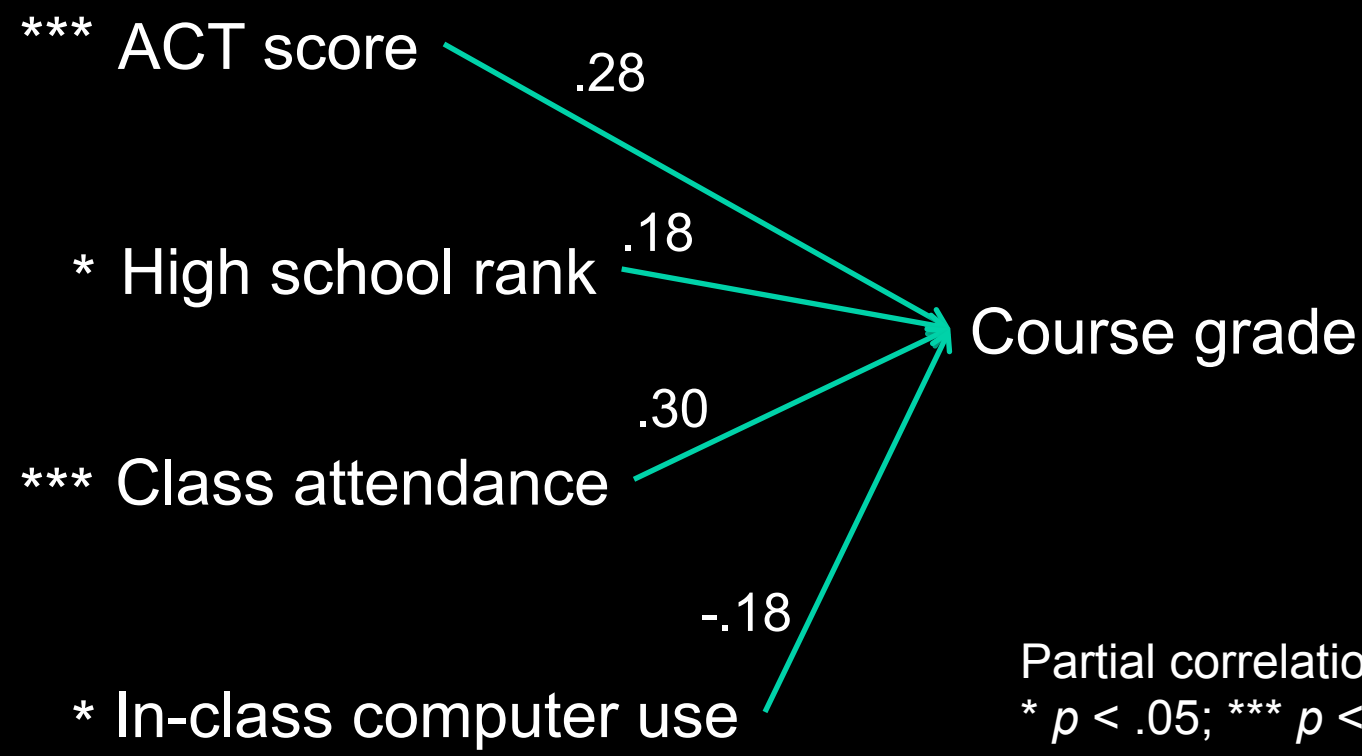
Multi-tasking during Class

137 college students in General Psychology course

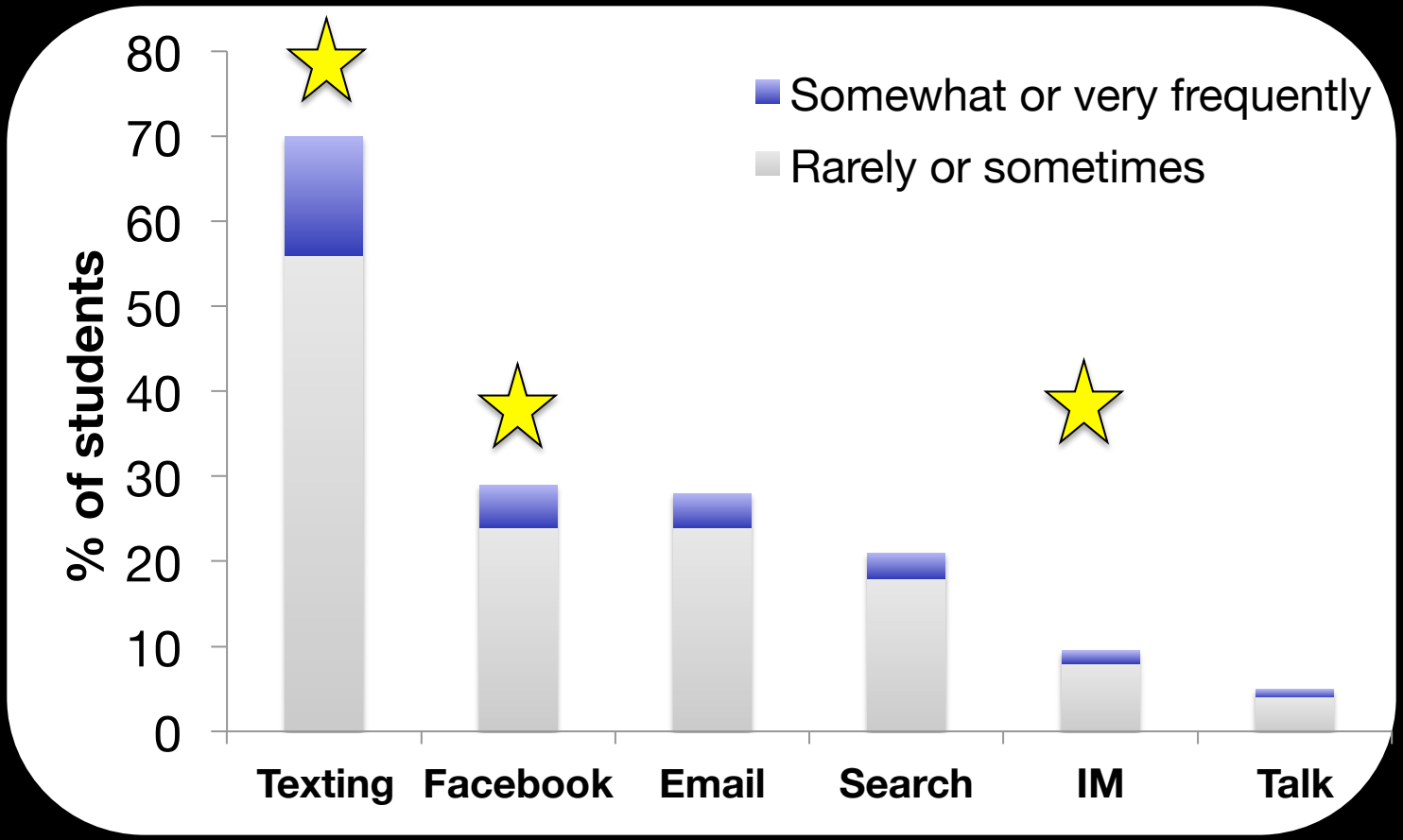


Partial correlations
* $p < .05$; *** $p < .001$

Fried, *Computers & Education*, 2008

Self-Reported Multi-tasking during Class

> 1800 college students at public universities in the northeast



★ Negatively correlated with GPA, controlling for other factors

Junco, *Computers in Human Behavior,* 2012

Immediate Recall after Note Taking

- College students assigned to classrooms equipped with either laptops or notebooks
- Listened to the same lectures (TED Talks), instructed to use their usual note-taking strategy
- 30 min later, tested on factual recall and conceptual learning

Guess which students took more notes, and wrote down more of the lecture verbatim?

When tested on facts, whom do you think did better?

Tied

When tested on concepts, whom do you think did better?

Mueller and Oppenheimer, *Psychological Science*, 2014

Long-term Recall after Note Taking

- Different students, same idea: College students assigned to classrooms equipped with either laptops or notebooks. Listened to the same lectures, instructed to use their usual note-taking strategy

- **When given the opportunity to use their notes to study for the exam a week later,** who benefited more: students with the more detailed typewritten notes or those with the handwritten ones…

when tested on facts?

when tested on concepts?

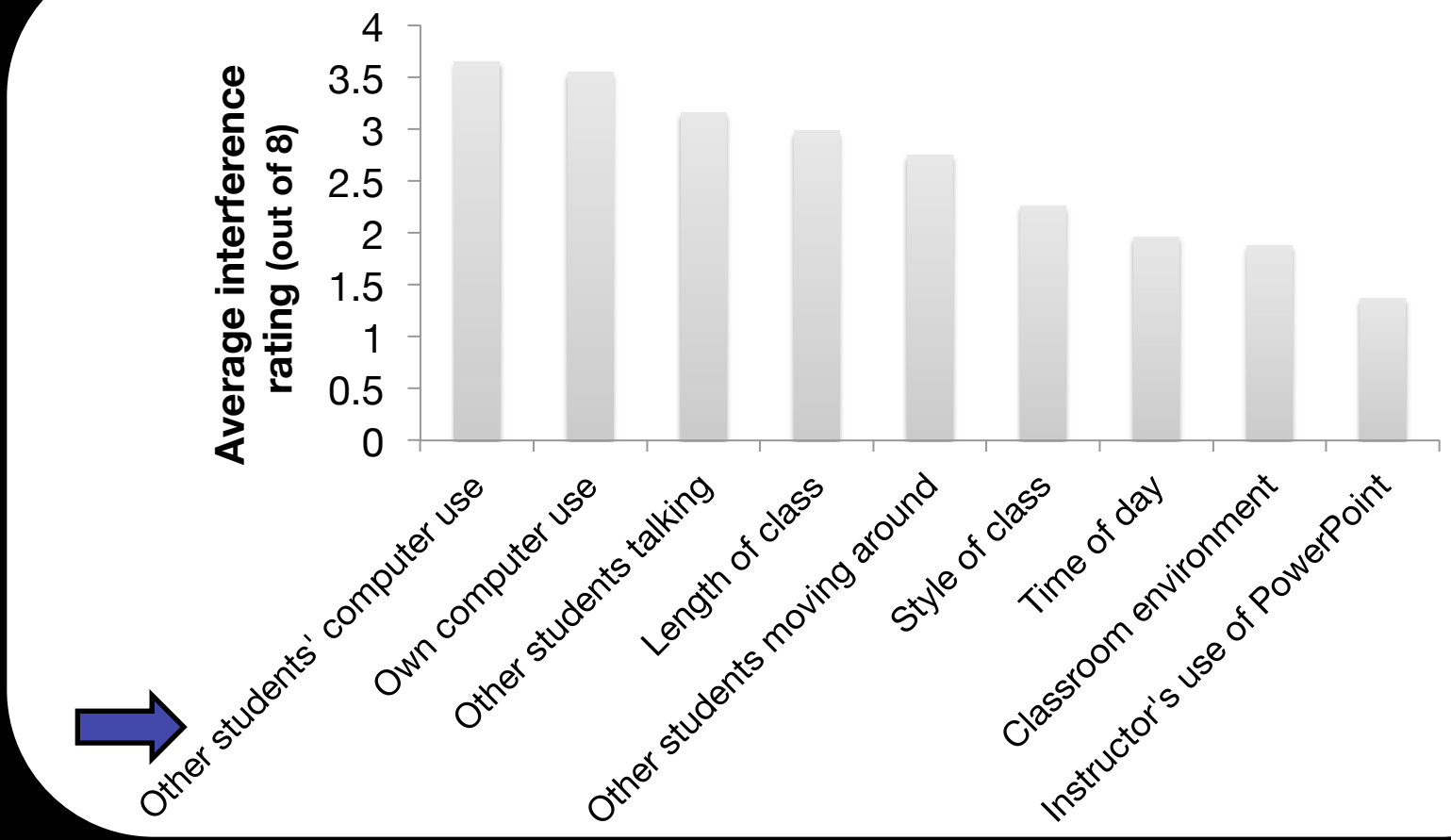
Even when laptop users were instructed not to transcribe lectures word for word, they kept doing it & their performance suffered. Pen & paper lends itself to deeper encoding.

Mueller and Oppenheimer, *Psychological Science*, 2014

Multi-tasking during Class

(137 college students in General Psychology lecture course)

Student ratings re: factors that interfered with ability to learn in class



Fried, *Computers & Education*, 2008

Tips to Get the Most Out of the Class

- Listen actively, ask questions, & take notes by hand.
- PDFs of slides will be posted on CourseWork before class.
  - But, I predict that you will encode the material more deeply if you come to class and take notes based on the lecture.
- IF you bring a laptop or other compute devise to class, please use it ONLY to view the slides.

Outline

How do we study Learning and Memory?

- Historical traditions
  - Birth of experimental psychology
  - Behaviorism
  - Cognitive revolution
- Types of experimental evidence
  - Behavior
  - Neuropsychology
  - Neurophysiology
- Neuroanatomy primer

“If any one faculty of our nature may be called more wonderful than the rest, I do think it is memory. There seems something more speakingly incomprehensible in the powers, the failures, the inequalities of memory, than in any other of our intelligences. The memory is sometimes so retentive, so serviceable, so obedient; at others, so bewildered and so weak; and at others again, so tyrannic, so beyond control! We are, to be sure, a miracle every way; but our powers of recollecting and of forgetting do seem peculiarly past finding out.”

– Jane Austin, *Mansfield Park* (1814)

Hermann Ebbinghaus

1850 – 1909

- First to study memory in a distinctly scientific way
- His approach was:
  - Experimental
    - Manipulated an independent variable (IV) and observed the effect on a dependent variable (DV)
  - Quantitative
    - Expressed observations numerically

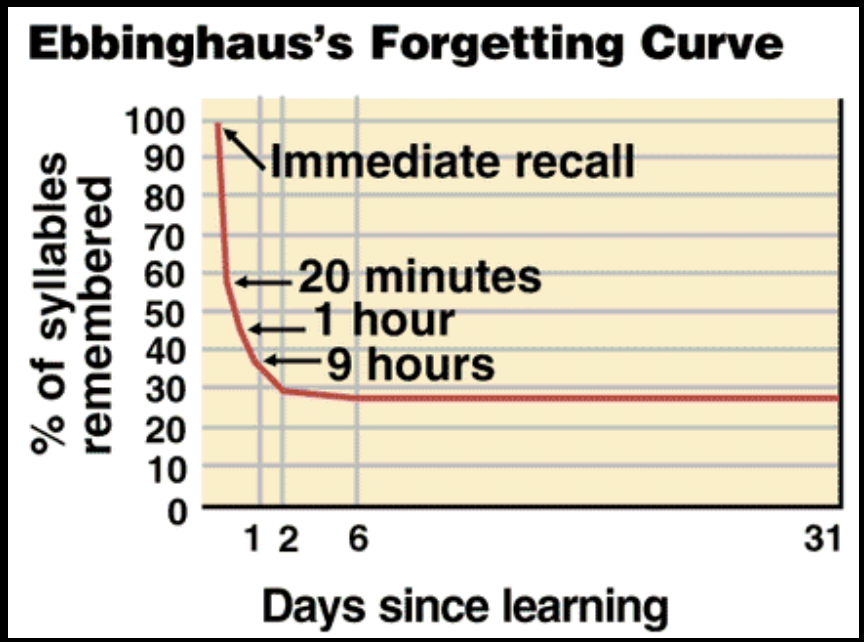
Hermann Ebbinghaus

- Subject = himself
- Stimuli = nonsense syllables
  - WUX, CAZ, BIJ, ZOL, BAP, KEP, DAK…
- Manipulated learning and retrieval variables, and observed the effects on memory performance
  - # of study trials, retention interval (length of delay from study to test)

Some History in Learning & Memory

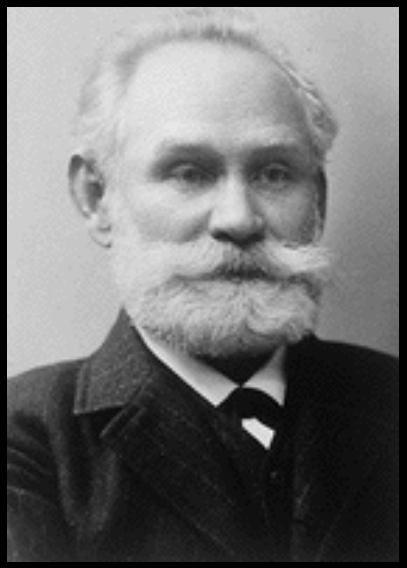
Ebbinghaus's Key Principles:

- Forgetting function is non-linear
- Repetition improves memory
- Distributed practice is better than massed practice



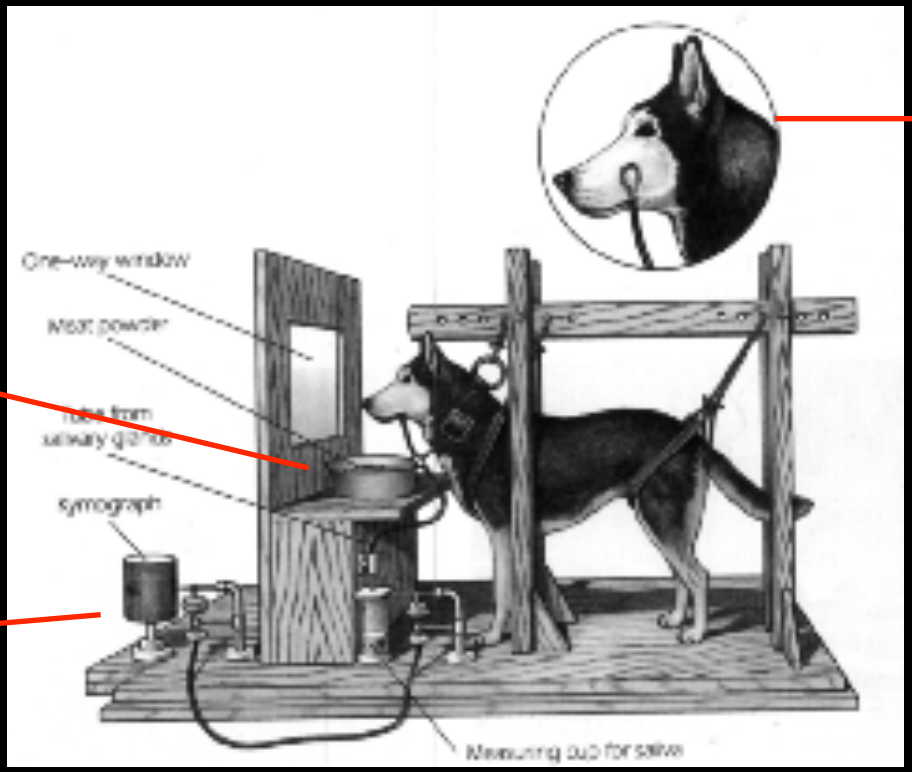
Application of the scientific method and careful measurement of behavior can reveal the workings of memory

Pavlovian / Classical Conditioning

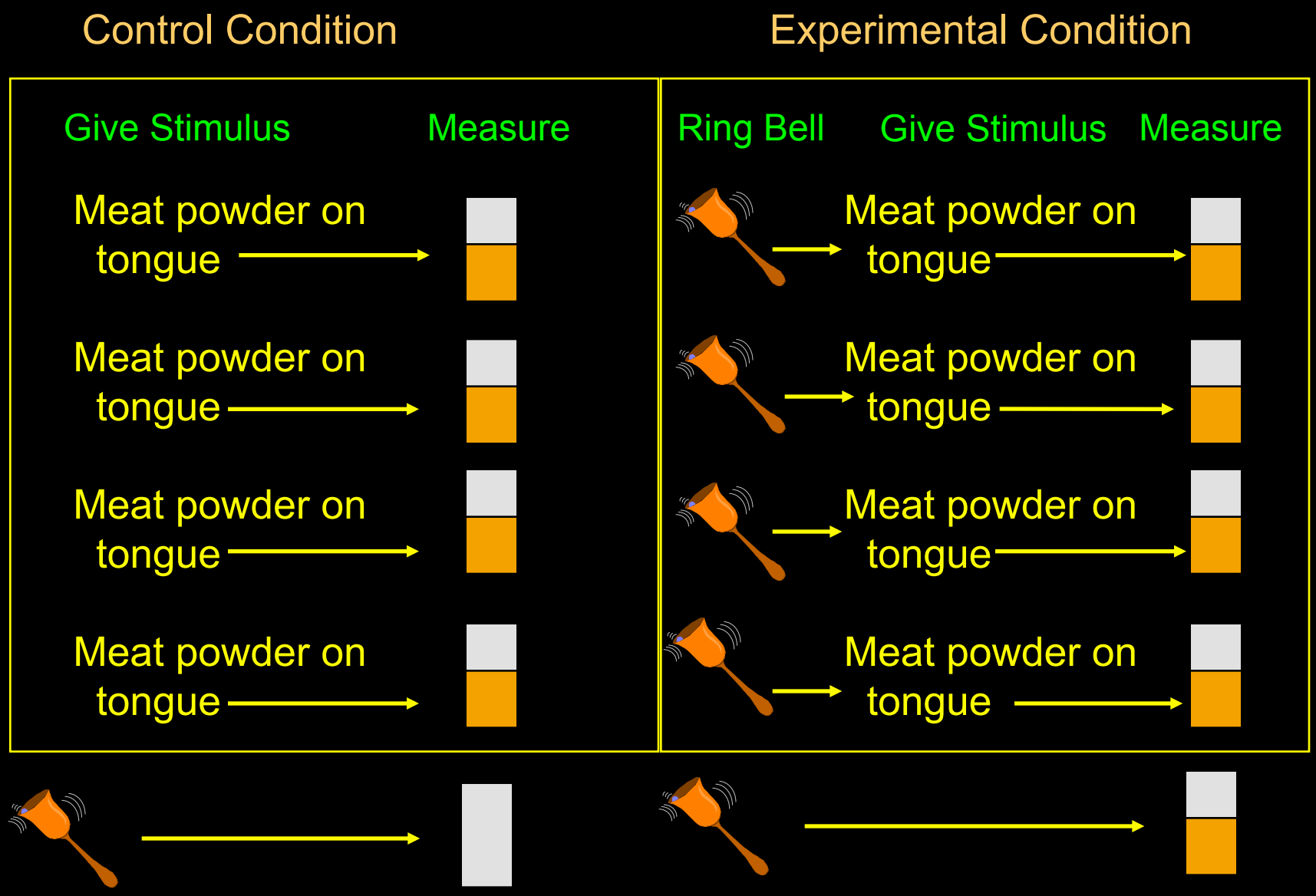


Military Medical Academy
St. Petersburg, Russia

1849 – 1936



Classical Conditioning: The Experiment



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Emergence of Behaviorism

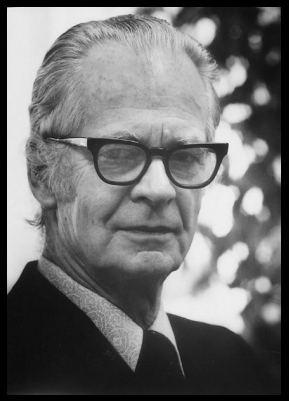
- Prior to the birth of experimental psychology, the field relied on debate, introspection, anecdotes, dream analysis
- Behaviorists thought psychology was too subjective
  - Were inspired by new experimental studies (e.g., Pavlov)
  - Wanted to move away from internal mental processes and focus on **observable behaviors**

John Watson
(1878 – 1958)

Principles of Behaviorism

- Empiricism
  - Disputed whether the study of mental constructs is scientifically tractable
  - Behavior can be measured and explored by experimental manipulation
    - Why do particular behaviors become more prevalent, and others less prevalent?
  - Treated the organism as a "black box"
    - How can we predict the output (behavior) based on the input and history of the organism?
- Evolutionary perspective
  - Humans are similar to other animals; what can be learned from rodents, birds and other animals can be applied to humans
- Aimed to identify laws that could generalize to many behaviors

BF Skinner (1904 – 1990)



- Advocated for **radical behaviorism**
  - Free will is an illusion; our behaviors are simply learned responses to stimuli
- He developed the Skinner box
  - Automated learning apparatus in which animals received food upon action, e.g., pressing a lever
  - Over time, animals increased their lever-pressing behavior
  - General procedure now known as **operant conditioning**

Operant Conditioning (instrumental conditioning)

Associating a behavior and a consequence

Outcomes select and reinforce behaviors

http://www.youtube.com/watch?v=I_ctJqjlrHA

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The Cognitive Revolution (1950's-present)

- Adopted the empirical aspects of behaviorism, but expanded focus to study internal processes and mental constructs
  - internal processes
    - Episodic encoding – benefits from 'elaborating' on information / experience
  - mental representations
    - Working Memory = active memory
    - Cognitive Control depends on goal representations
- Tended to neglect neuroscience

The Cognitive Neuroscience Revolution (1990s to present)

Study of the mind and brain as a unified complex system

- Fundamentally interdisciplinary

Several avenues of research led to the development of cognitive neuroscience

- Lesion studies showing dissociations between cognitive tasks
- Neurophysiological studies of perception and action in animals
- Development of brain-like computational models
- Development of brain imaging technologies

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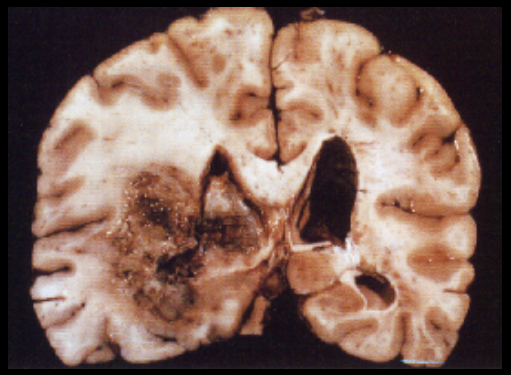
Neuropsychological Studies

How can we determine which parts of the brain are important for memory?

Evaluate structure – function relationship

- focal lesions
  - e.g., due to stroke, tumor, virus, surgical resection
- neurodegenerative disorders
  - e.g., Alzheimer's disease, Parkinson's disease
- disruption methods
  - e.g., TMS to create a "virtual" or "transient" lesion

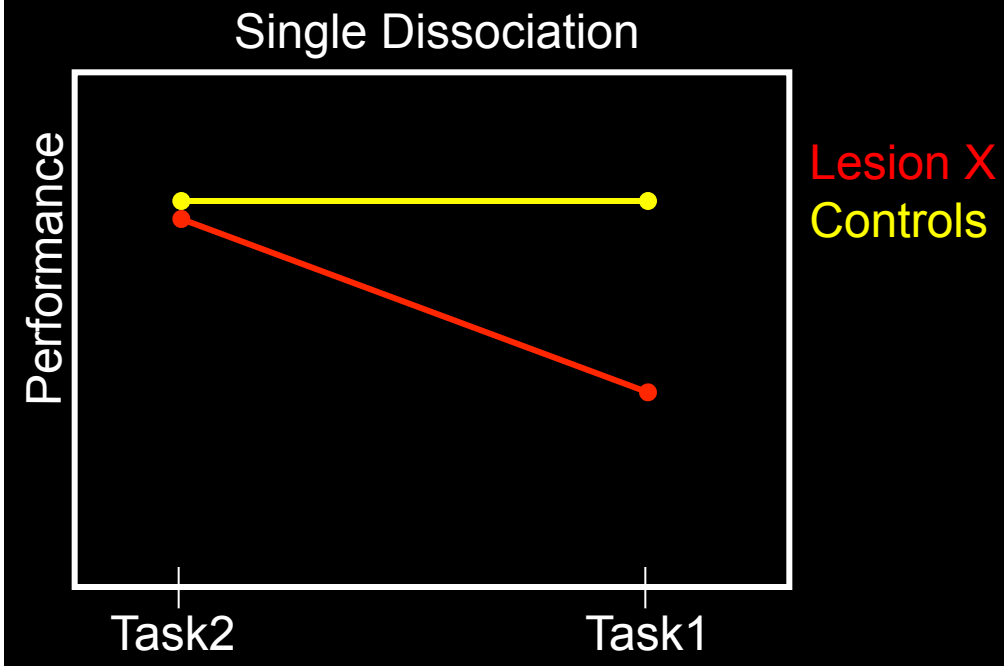
Tumor



Stroke

Dissociation Logic

- Lesion to brain region X affects performance on task 1 but not task 2



Dissociation Logic

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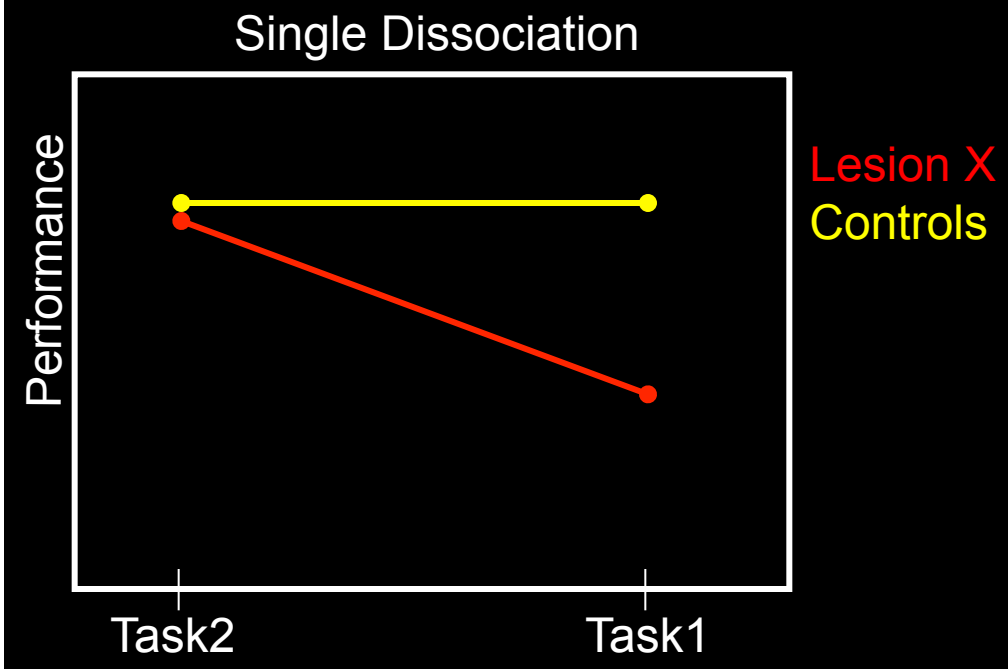
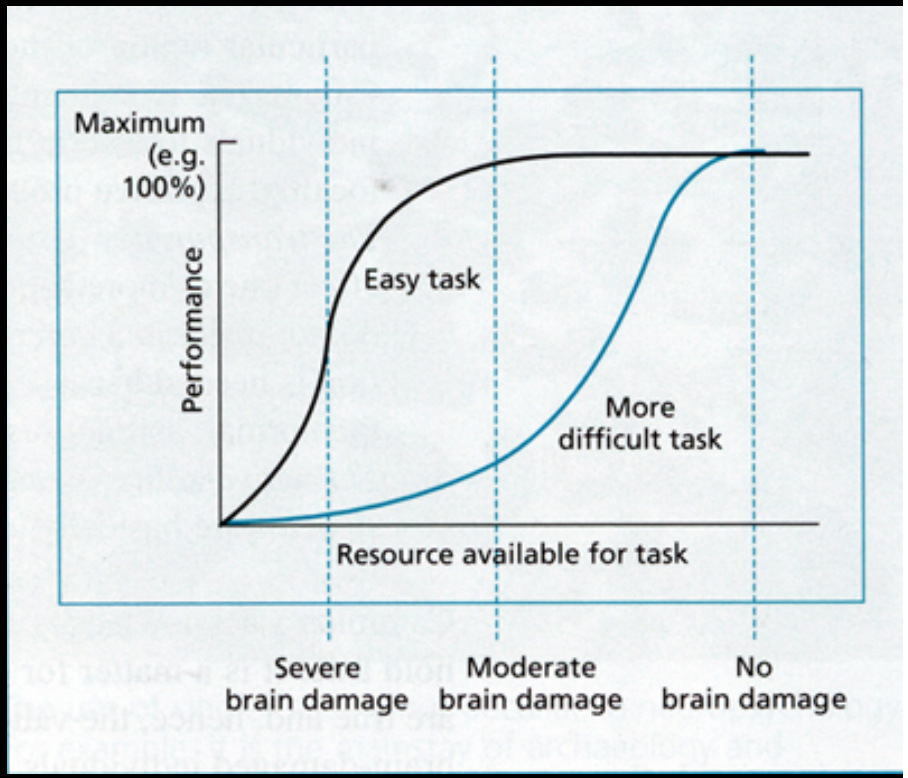
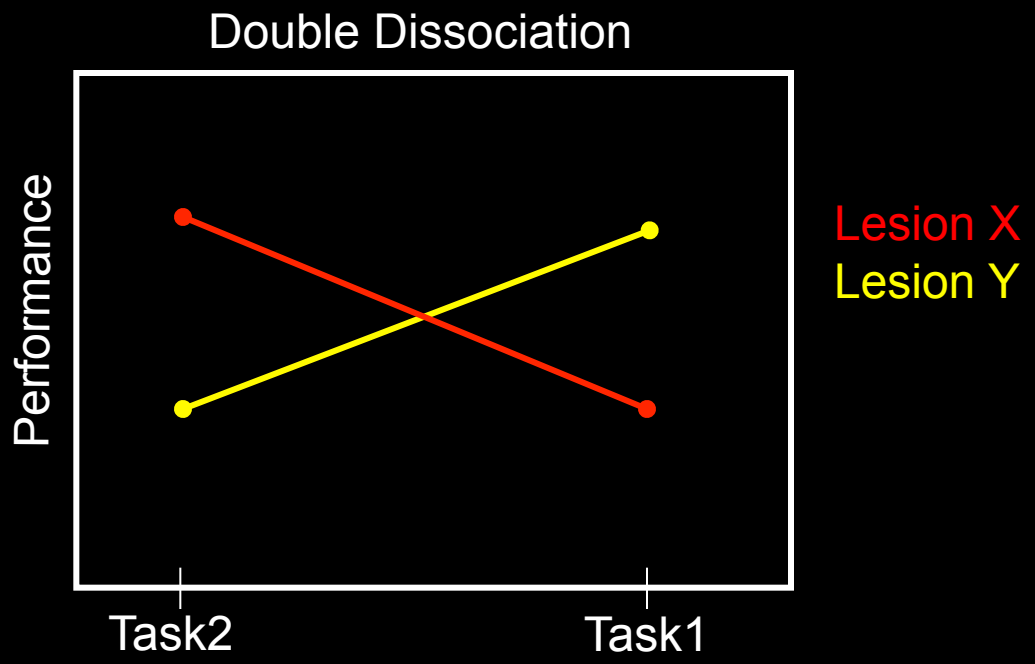




Double Dissociations

- Lesion to region X affects task 1, but not task 2
- Lesion to region Y affects task 2, but not task 1

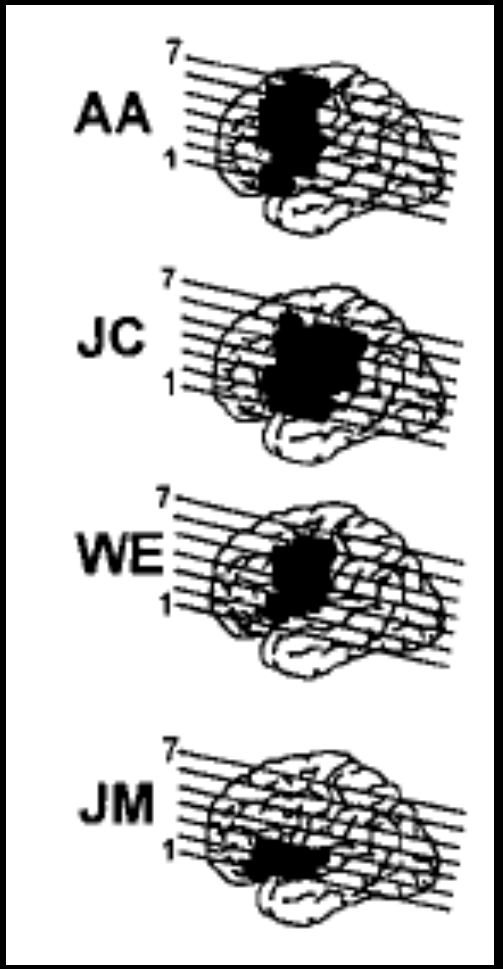


Neuropsychological Studies

Pros: Can establish **causation** – reveals the necessity of a brain region or neural circuit for a particular cognitive process

Cons:

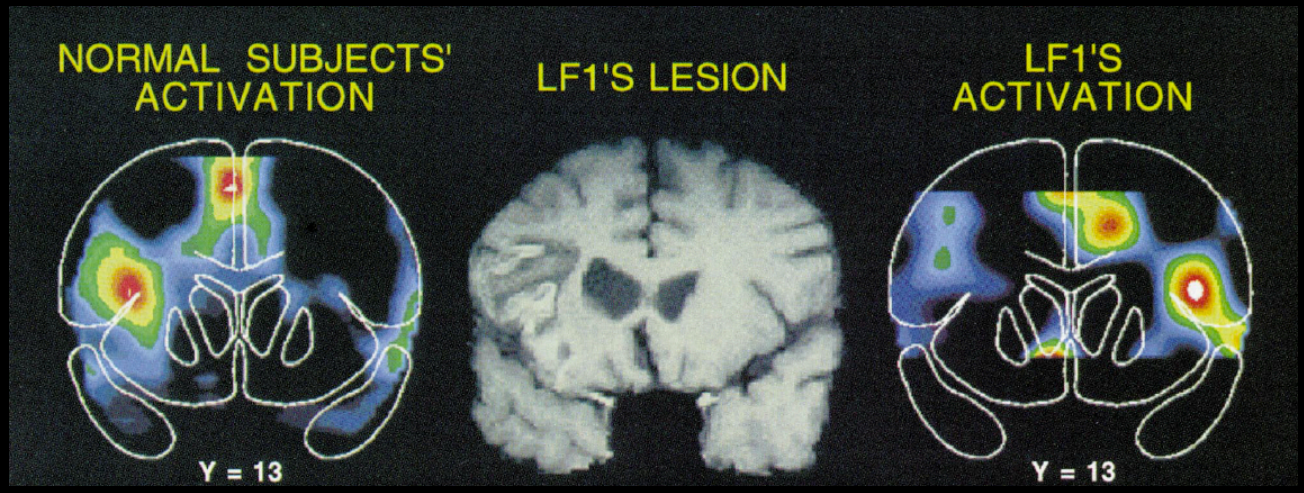
1) Damage often is not restricted to one area
   – poor spatial resolution / specificity



Neuropsychological Studies

Cons:

2) Cortical plasticity / functional reorganization
   - other regions can take over function



Buckner et al. (1996)

3) Unclear which stage of memory is affected
   - encoding, consolidation/retention, retrieval?

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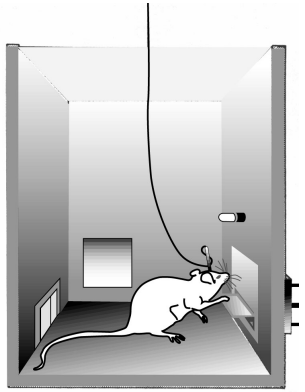
Neurophysiology

- Non-human animal studies
  - Direct recordings of neural activity
- Human studies
  - Neuroimaging
  - Direct recordings of neural activity

Direct Recordings using Implanted Electrodes

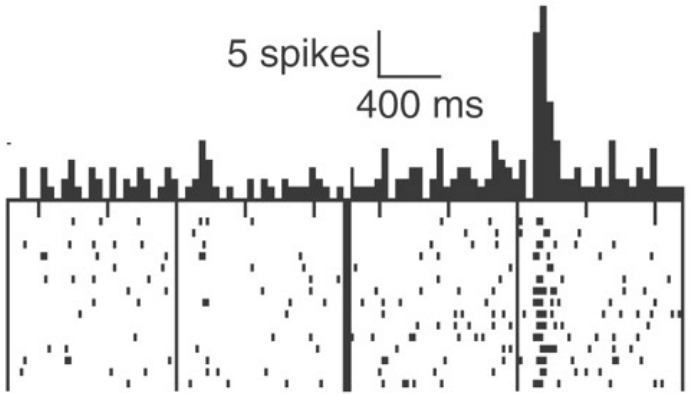
(Neurophysiological data / Unit recordings)

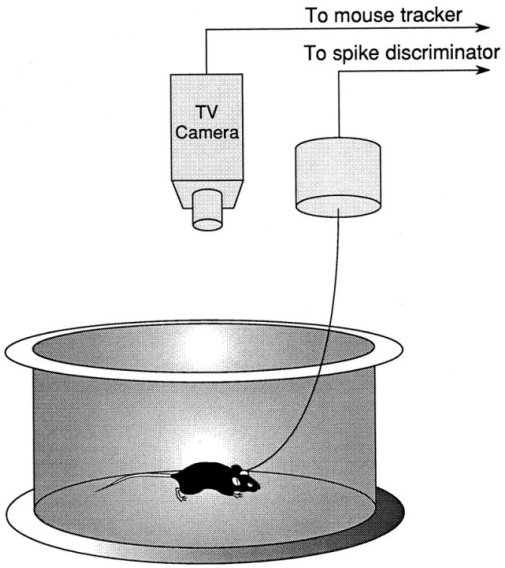
– "The workhorse of neuroscience"



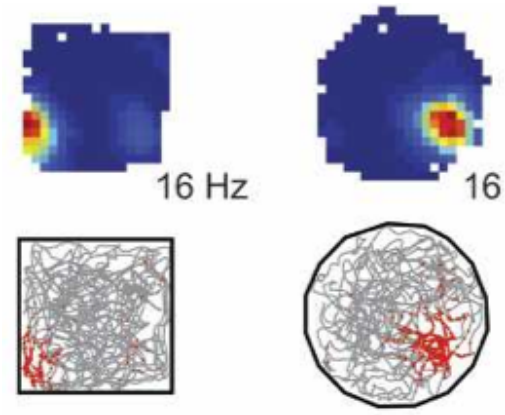
Spike frequency histogram

Raster plot





Place fields



Direct Recordings using Implanted Electrodes

(Neurophysiological data / Unit recordings)

- Pros
  - Direct recordings from neurons allow for excellent spatial and temporal resolution
- Cons
  - Can’t tell you about causation, only correlation
  - Limited coverage of the brain
  - Can be difficult to translate animal findings to humans

Neuroimaging in Humans

Two types of brain imaging:

1) Structural imaging
   - Images the structure/composition of tissue
   - e.g., MRI; diffusion tensor imaging (DTI)

2) Functional imaging
   - Images brain function
   - e.g., functional MRI

Functional Neuroimaging

Electrophysiological

- Measure electrical or magnetic signals related to neural activity
  - Electroencephalography (EEG)
  - Magnetoencephalography (MEG)
- Better temporal resolution; worse spatial resolution

Hemodynamic

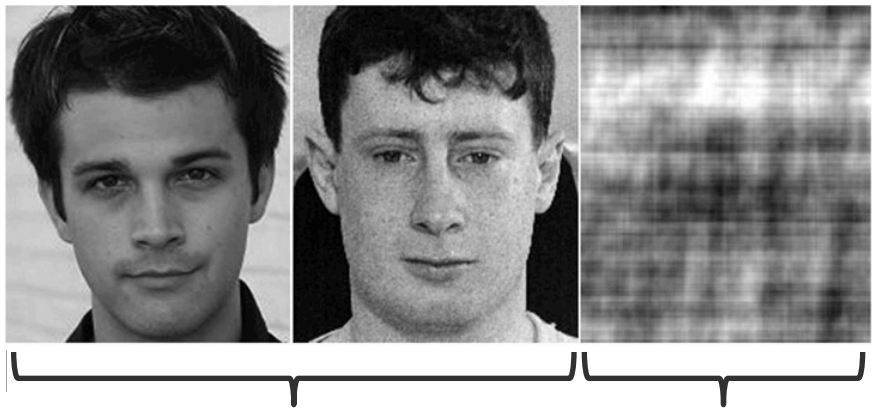
- Measure changes in blood flow, oxygenation, or metabolism correlated with neural activity
  - Positron emission tomography (PET)
  - fMRI
- Worse temporal resolution; better spatial resolution

Functional Neuroimaging

- Both electrophysiological and hemodynamic techniques are *relative*
  - Brain is always active
  - To measure the brain's response to stimuli, need to compare two conditions (subtraction technique)
    - Condition 2 – Condition 1 = difference image

Neuroimaging "Subtractive" Logic

What regions are used for perceive faces?

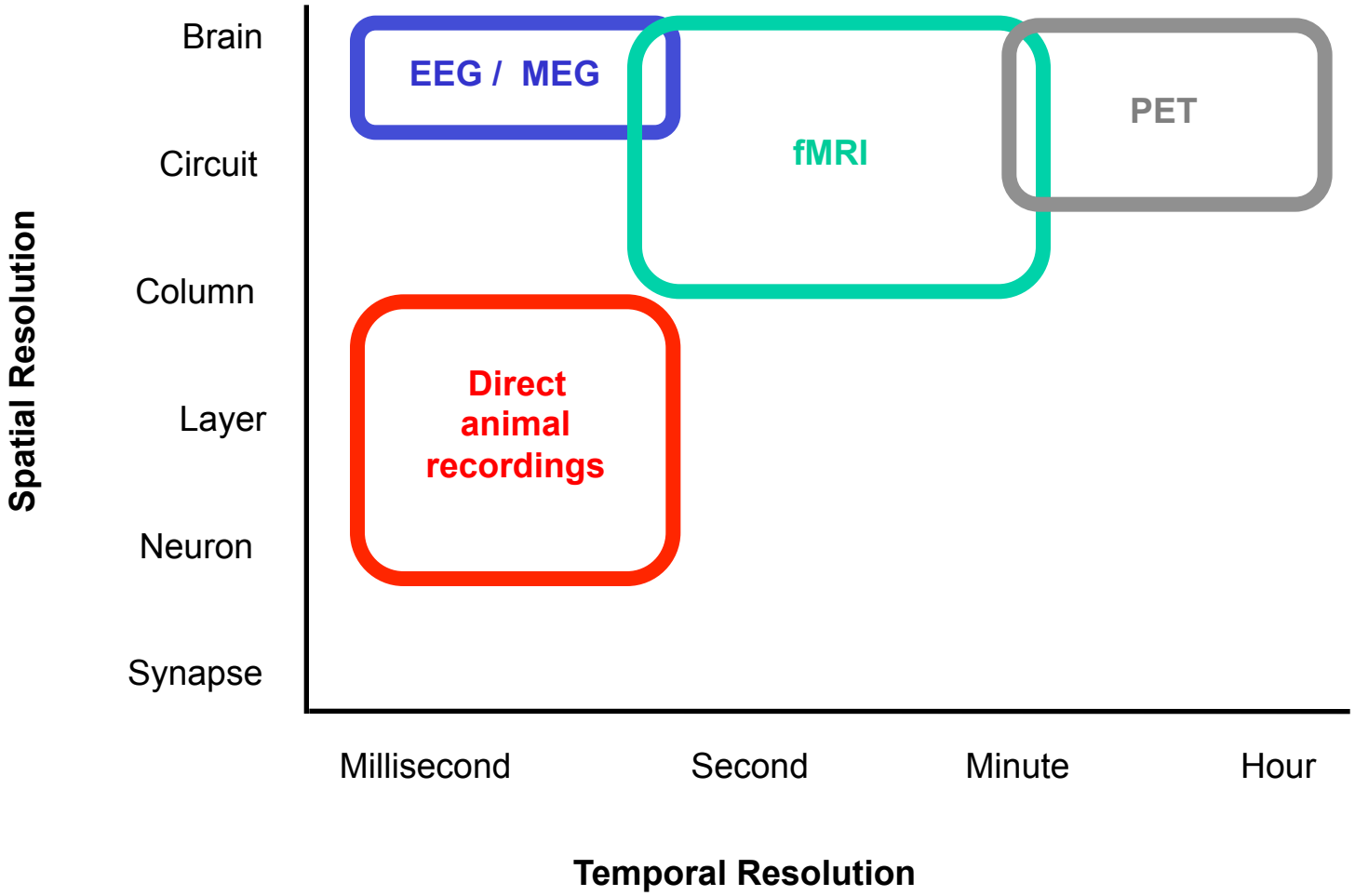


Difference image: experimental condition – baseline condition

Functional Neuroimaging

- Pros
  - Non-invasive technique for measuring brain function in humans
  - Can evaluate function across multiple regions simultaneously
- Cons
  - Can’t tell you about causation, only correlation
  - Relative to direct animal recordings, relatively poor spatial resolution

Neurophysiology Summary



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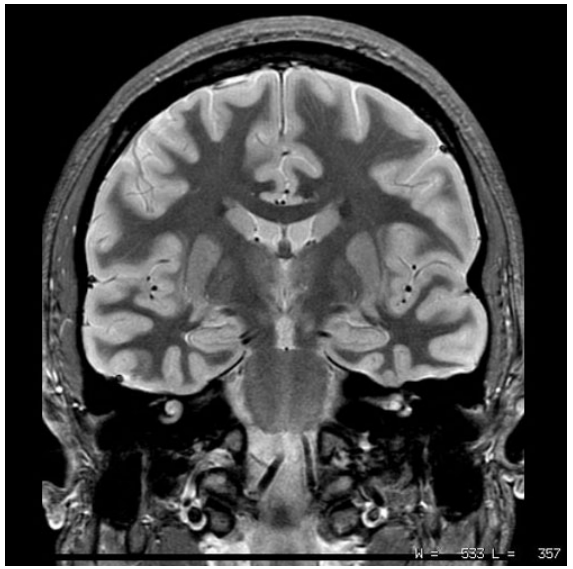
Brain Sections

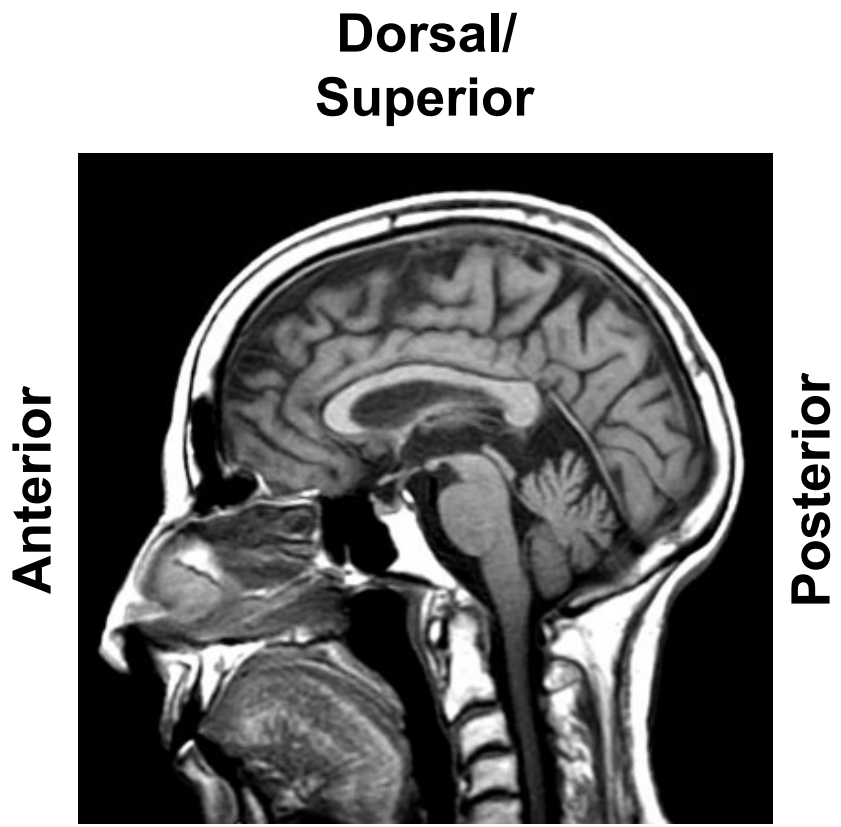


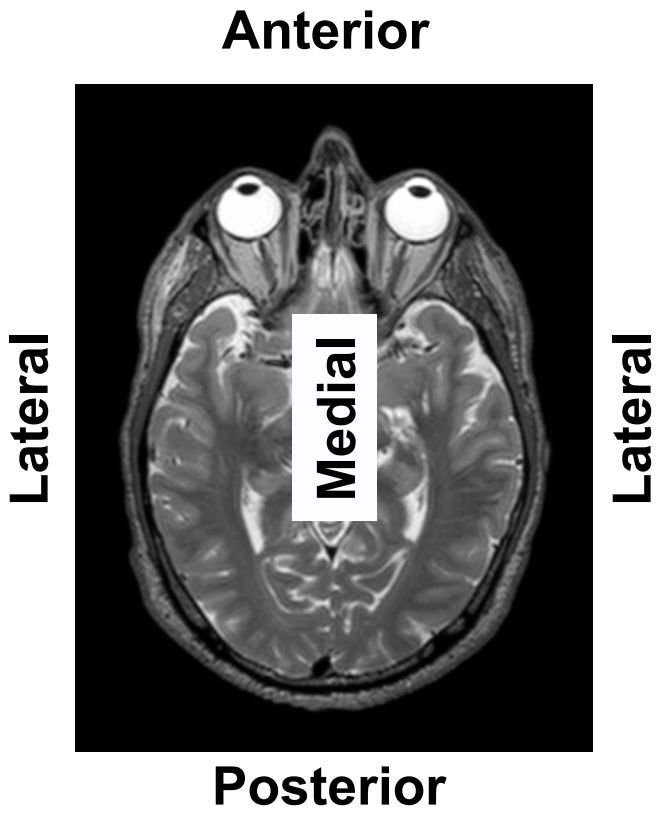
Sagittal
(Brain from the side)

Horizontal / Axial
(Brain from above)

Frontal / Coronal
(Brain from the front)

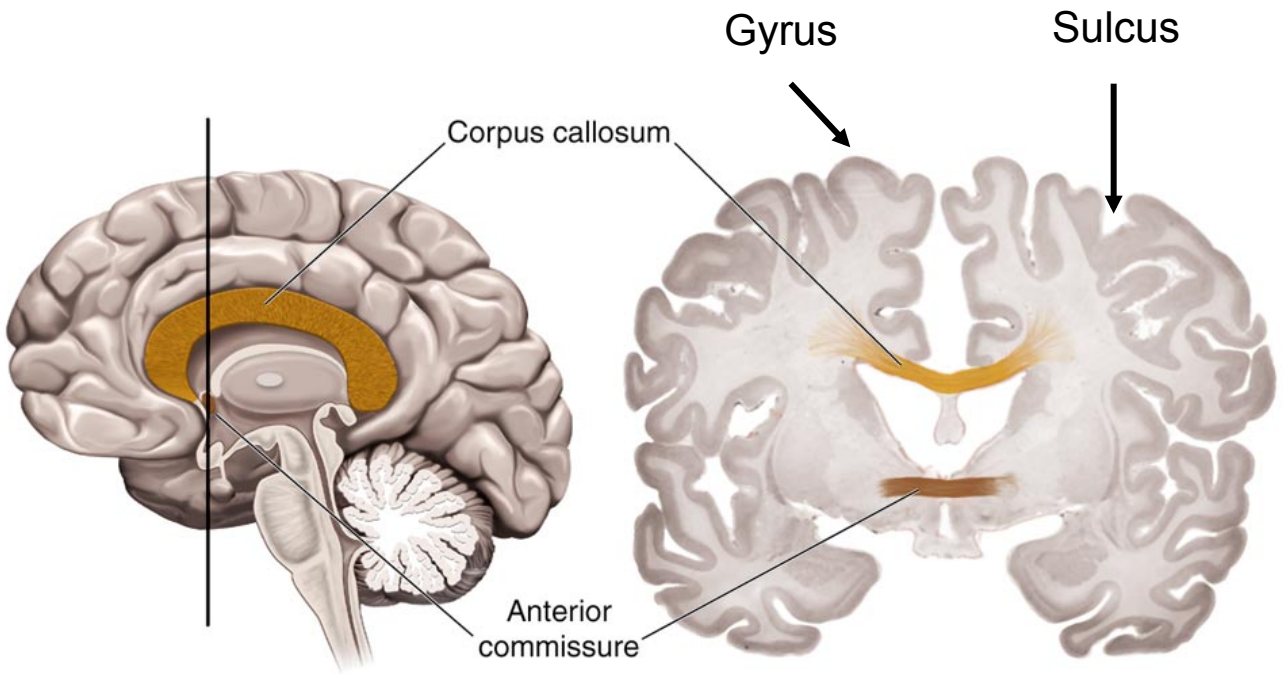
Directional Terminology





Cerebral Cortex

- Cortex (“bark”): outermost layer of the brain
- Deeply folded structure



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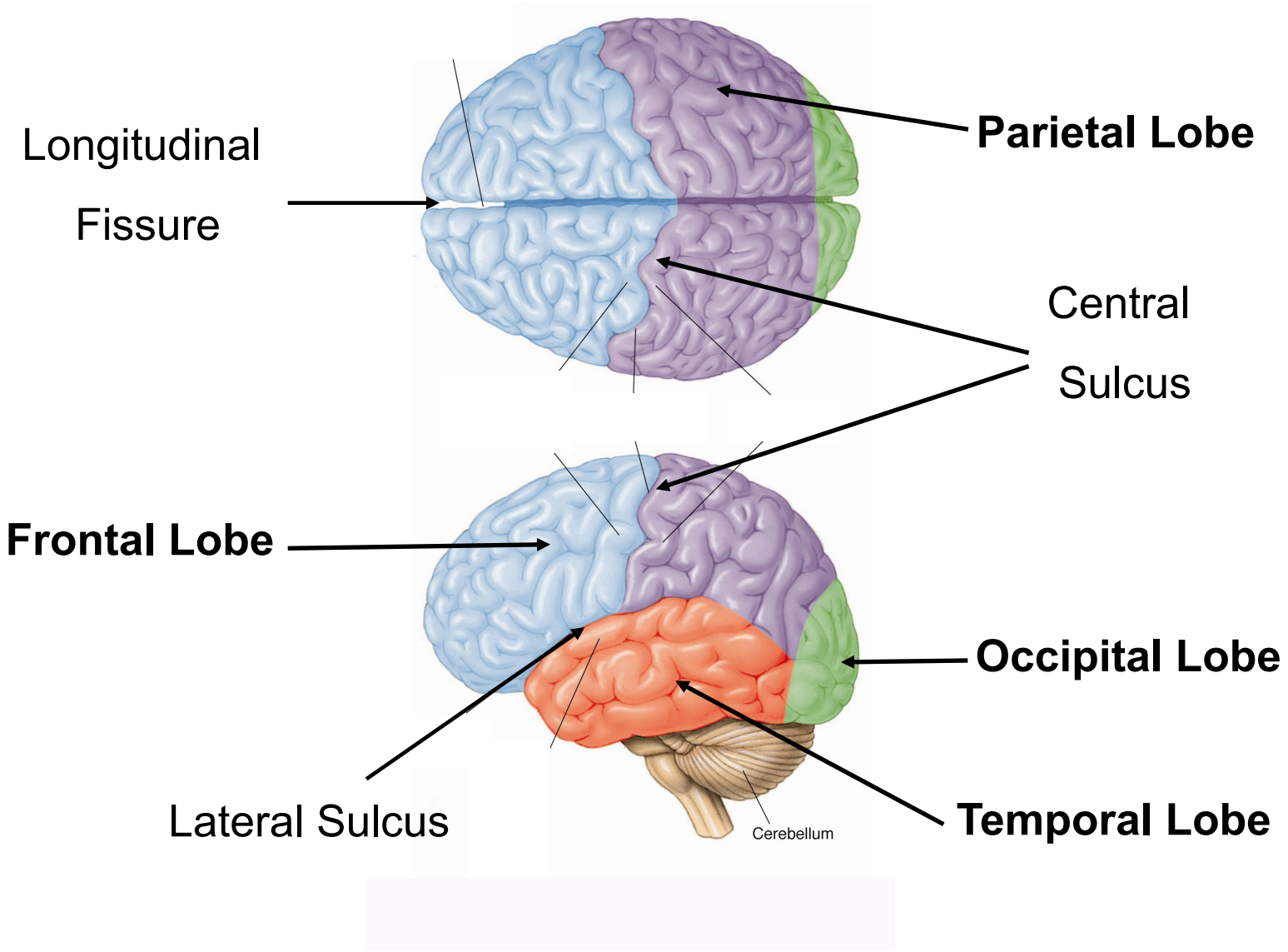
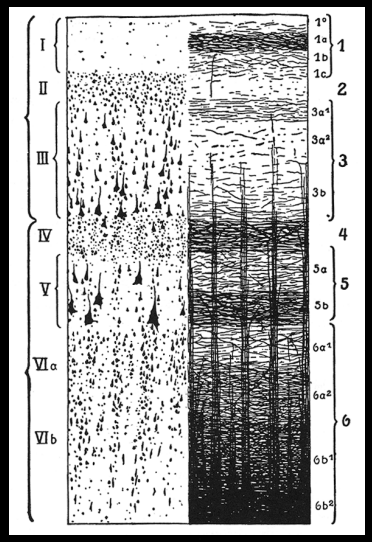
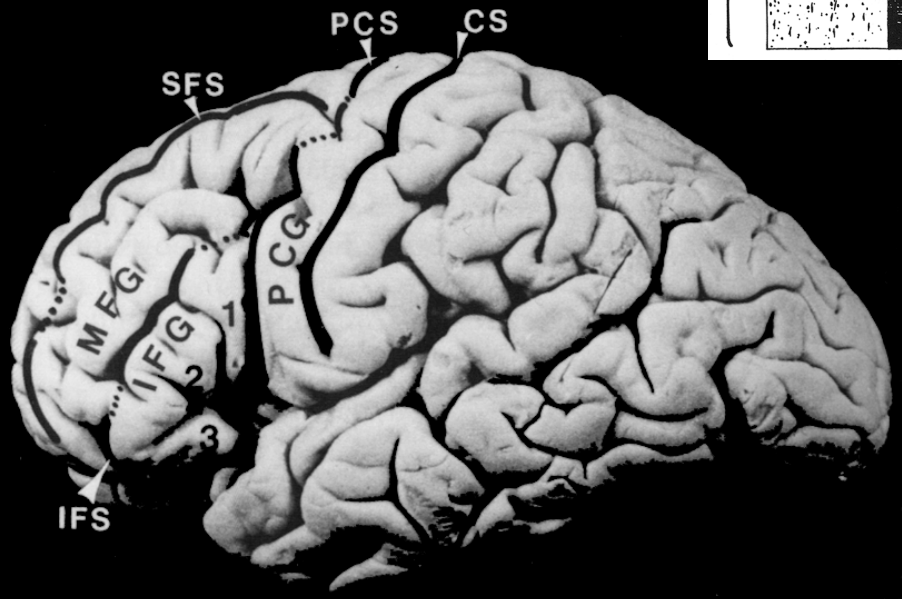


Anatomical Areas and Cytoarchitecture

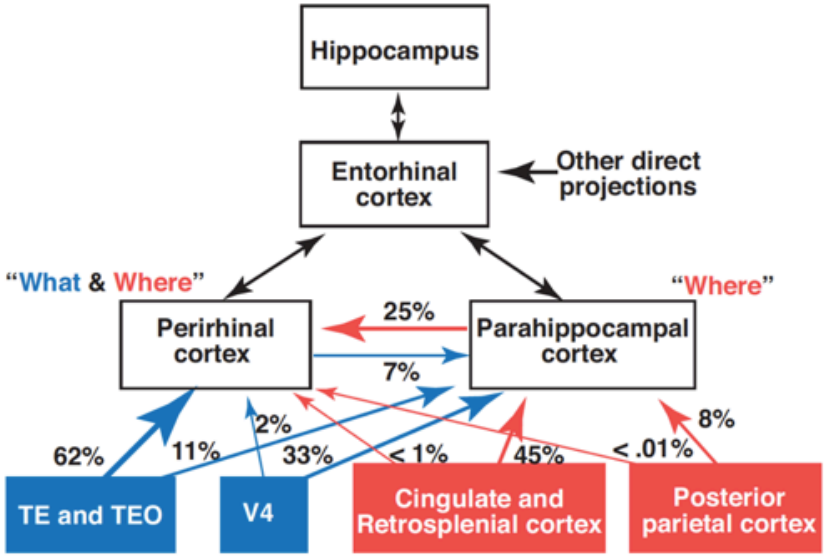




Brodmann Areas

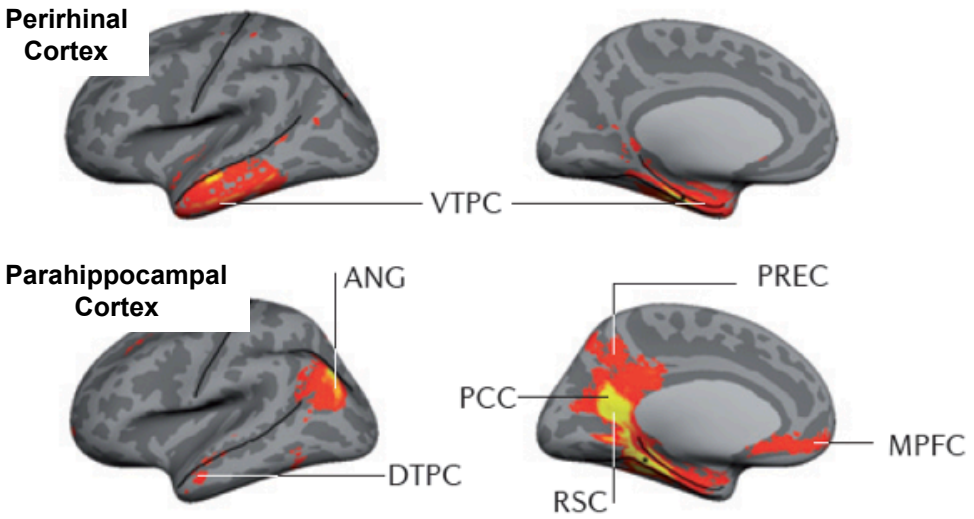
Anatomical Areas and Connectivity

Structural Connectivity



[Wixted & Squire, 2011; adapted from Buffalo et al., 2006]

Functional Connectivity



[Ranganath & Ritchey, 2012]

Next time…

- Types of Experimental Evidence
- Working memory