Week 6 Morning Session Schedule

- Emergence of Cognitive Neuroscience Completed
- Break
- Workshop: Tying work from the first half of the quarter together by exploring the concept of reduction

More Clinical

More "Scientific"

Sacks: *The Man who….*

Ramachandran: *Brief Tour...*

Cognitive Neuroscience

Kandel *In Search of Memory*

Neuroscience side

This Lecture

Cognitive side

Seminar books in relation to Cognitive Neuroscience

Structuralism: Studied Mental Structure

- Wilhelm Wundt (1832 - 1920)
  - Separated psychology from philosophy and from physiology
  - Wundt's lab was established in 1879
  - Studied conscious mental events
    - feelings, perceptions, and recollections
    - Sought the building blocks (structural elements) of consciousness

Functionalism: William James "Stream of Consciousness

The order of our study must be analytic. We are now prepared to begin the introspective study of the adult consciousness itself. Most books adopt the so-called synthetic method. Starting with 'simple ideas of sensation,' and regarding these as so many atoms, they proceed to build up the higher states of mind out of their 'association,' 'integration,' or 'fusion,' as houses are built by the agglutination of bricks. This has the didactic advantages which the synthetic method usually has. But it commits one beforehand to the very questionable theory that our higher states of consciousness are compounds of units; and instead of starting with what the reader directly knows, namely his total concrete states of mind, it starts with a set of supposed 'simple ideas' with which he has no immediate acquaintance at all, and concerning whose alleged interactions he is much at the mercy of any plausible phrase

The Fundamental Fact. -- The first and foremost concrete fact which every one will affirm to belong to his inner experience is the fact that *consciousness of some sort goes on. 'States of mind' succeed each other in him.* If we could say in English 'it thinks,' as we say 'it rains' or 'it blows,' we should be stating the fact most simply and with the minimum of assumption. As we cannot, we must simply say that *thought goes on.*

Wundt's "Successors" Oswald Kulpe -- Edward Tichener

- Promoted introspection in a much stronger way than Wundt himself.
- The controversy that resulted dethroned the study of mind and set the stage for behaviorism to dominate.

Watson's arguments against a 'science of mind' were:

- There were no answers in sight as to the building blocks of consciousness. Psychologist were strongly divided on a variety of theoretical questions, with no signs of resolution.
- Results were not reproducible and therefore not scientific.
- Introspection was irrelevant to animal work.
- This work had no practical applications.

Classical Conditioning (Pavlov)

Unconditioned Stimulus (food) —> Unconditioned Response (salivation)

Unconditioned Stimulus (food) —> Unconditioned Response (salivation)
Conditioned Stimulus (bell)

Conditioned Stimulus (bell) —> Conditioned Response (salivation)

In classical conditioning, a neutral stimulus becomes associated with a reflex. The bell, a neutral stimulus, becomes associated with the reflex of salivation.

Operant (Instrumental) Conditioning (Skinner)

Response (press lever) —> Stimulus (reward) (food)

TIME

Conditioned Response (press lever) —> ConditionedStimulus (Reward)(food)

In operant conditioning, the learner "operates" on the environment and receives a reward for certain behavior (operations). Eventually the bond between the operation (pressing the lever) and the reward stimulus (food) is established.

“Skinner” box

Behavioral versus Cognitive Psychology:

- Behavioral approach: is restricted to only observable external behavior. The mind was considered to be a 'black box'. There was no theory about what might go on inside.
- Cognitive approach: develops theories about internal **mental representations** of an external (and internal) world from experimental observations. This method of 'inference to the best explanation' is sometimes called **transcendental inference** or Kant's **transcendental method**.

The Birth of Cognitive Psychology (as a paradigm)

- George Miller (Author of “The Magic Number Seven,1956”)
- Noam Chomsky (language)

Chomsky and the "old Guard"

Chomsky—Syntactic Structures (1957)

Obscure press, version of his dissertation

Linguistic splash: 1958 Third Texas Conference on Problems of Linguistics in English

Chomsky against Behaviorism: Review of Skinner's Verbal Behavior (1959) in *Language* (central journal)

Texas Conference

The traditional approaches to understanding language were doomed to fail. A complete inventory of elements in language [structuralism] could never give rise to a characterization of a possible sentences. Inductive procedures could never work.

He argued "I think that the failure to offer a precise account the notion 'grammar' is not just a superficial defect in linguist theory that can be remedied by adding one more definition. I seems to me that until this notion is clarified, no part of linguistic theory can achieve anything like a satisfactory development...

I have been discussing a grammar of a particular language here as analogous to a particular scientific theory, dealing with its subject matter (the set of sentences of this language) much as embryology or physics deals with its subject matter."

Following his presentation Chomsky engaged in debate from the floor with leading structuralists of the past generation, whose views he was opposing. While some them had hoped to defeat the young upstart once and for all, there was a very different outcome...[In the transcripts] we can see linguistic history documented as nowhere else—Chomsky, the *enfant terrible*, taking on some of the giants of the field and making them look rather like confused students in a beginning linguistics course.
Howard Gardner *The Mind's New Science*

Criticism of Skinner

Chomsky's review of Skinner's *Verbal Behavior* *Language 35,1959*

Negative Comments about Skinner's approach

Central concepts are not adequately defined

terms such as stimulus, response, reinforcement
and especially stimulus generalization

Notion of language itself is much too broad

verbal behavior is a behavior reinforced through the mediation of other persons (rat pressing bar? mechanic repairing a car?)

Specific analysis of language is inadequate

Suggestion of an alternative--Chomsky's own generative grammar approach

Cognitive Psychology: as a pure ‘Science of Mind’

- Can mind be defined in a way that allows empirical investigarion?
- If so, then ‘What is mind’?

Definitions

- Cognitive psychology involves the acquisition, storage, transformation and retrieval or use of knowledge.
- Central to the approach are mental structures and mental processes.
- Early on this approach was linked to an information processing model of mind

Basic Processes Are Studied

- pattern recognition
- attention
- Memory (is fundamental to the other processes)
- language
- problem solving
- reasoning
- decision making

Why Study Such Basic Processes?

- The more basic the process the deeper is our understanding
- Used in every moment of real life
- Higher processes are uniquely human
- Forms much of the basis of social and educational psychology
- Relevant to all other branches of psychology
- Explains how our own minds work

Theory – Research - Data

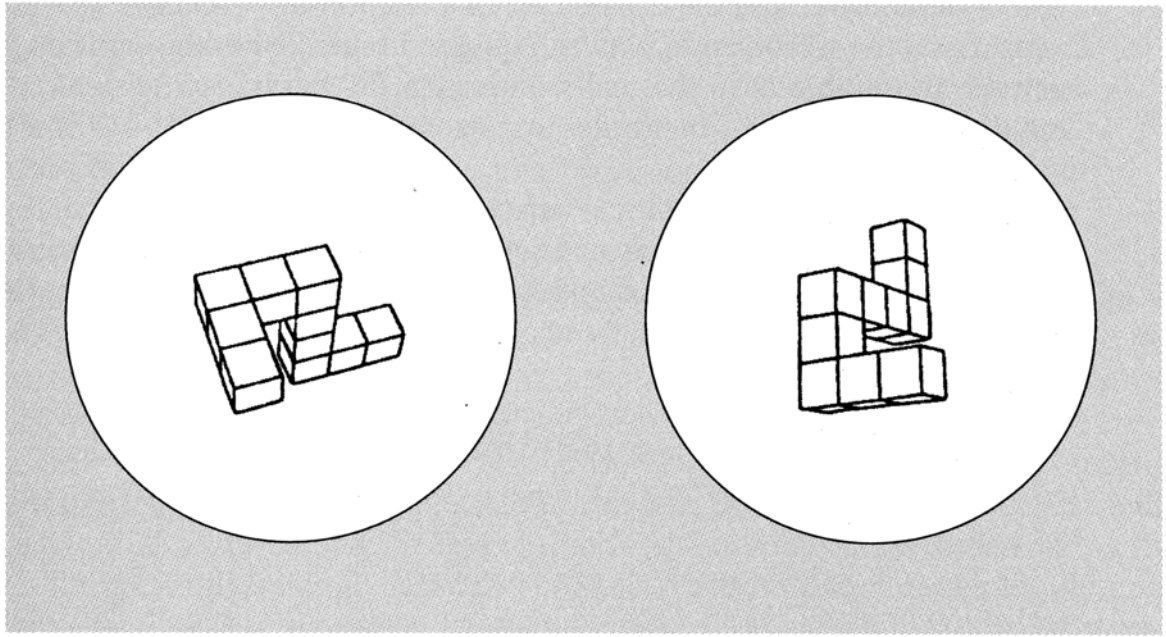
Theory is INFERRED by observing Cognitive PERFORMANCE (speed, accuracy or pattern of responses)

Specific hypotheses are tested (i.e., subjected to the possibility of falsification). Performance data are collected and interpreted to modify theory.

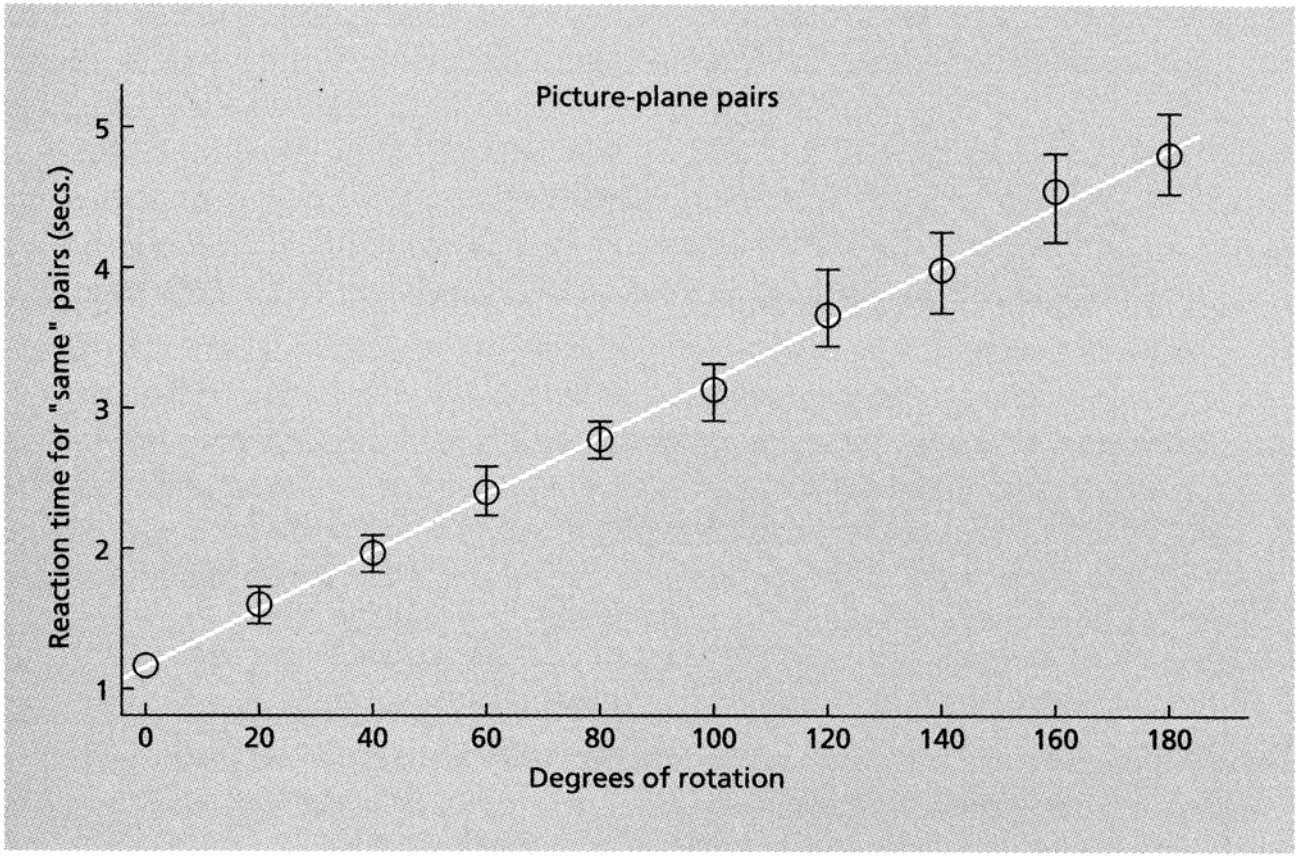
Mental Image Rotation

FIGURE 10.1

Typical visual forms used by Shepard and Metzler. Form at right is left-hand form rotated 90° counterclockwise. Adapted from Shepard and Metzler (1971).



Reaction time as a function of degree of rotation of a form. Adapted from Shepard and Metzler (1971).



What is a mental image

- According to Kosslyn and Thompson (2003, p. 723), visual imagery occurs when a visual short term memory representation is present but the stimulus is not actually being viewed; visual imagery is accompanied by the experience of “seeing with the mind eye”.

- Aristotle (*De Anima*).
  "The soul never thinks without a mental image"

Cognitive psychology is part of the larger field of cognitive science.

- Cognitive psychology
- philosophy
- neuroscience
- artificial intelligence (computer science)
- linguistics
- Anthropology

Note: 100 years after Wundt establishes psychology as a separate science it is ‘reunited’ with physiology and philosophy.

Kosslyn /Pylyshyn Debate over Imagry

Zenon Pylyshyn—Descriptive Theory

Cognitively penetrable

Stephen Kosslyn–Quasi-Pictorial Theory

Cognitive Neuroscience:

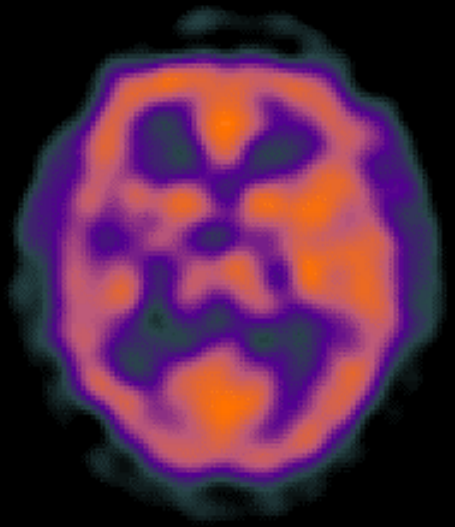
- Builds theories of mind that go from the **neurons** in our brains to the **mental models** of ourselves, each other and the world.
- It seeks to answer the question of how the mind works in terms of mental (e.g., information flow) and physical mechanics (neuro-activation).
- It uses experimental techniques of both cognitive science and neuroscience
- Has the time of a ‘pure science of mind’ come to an end?

Cognitive neuroscience depends on data from:

- Brain Lesions
- Positron Emission Tomography (PET)
- Functional Magnetic Resonance Imaging (fMRI)
- Electroencephalogram (EEG) – frequency, amplitude.
- Magnetoencephalogram (MEG)
- Event-Related Potentials (ERP) -<u>latency</u>, amplitude, polarity (excellent time resolution)
- Single Cell Recording Techniques

PET measures emissions from radioactively labeled chemicals that have been injected into the bloodstream and uses the data to produce two- or three-dimensional images of the distribution of the chemicals throughout the brain and body. Uses very short-lived radioisotopes—needs to be near a cyclotron.

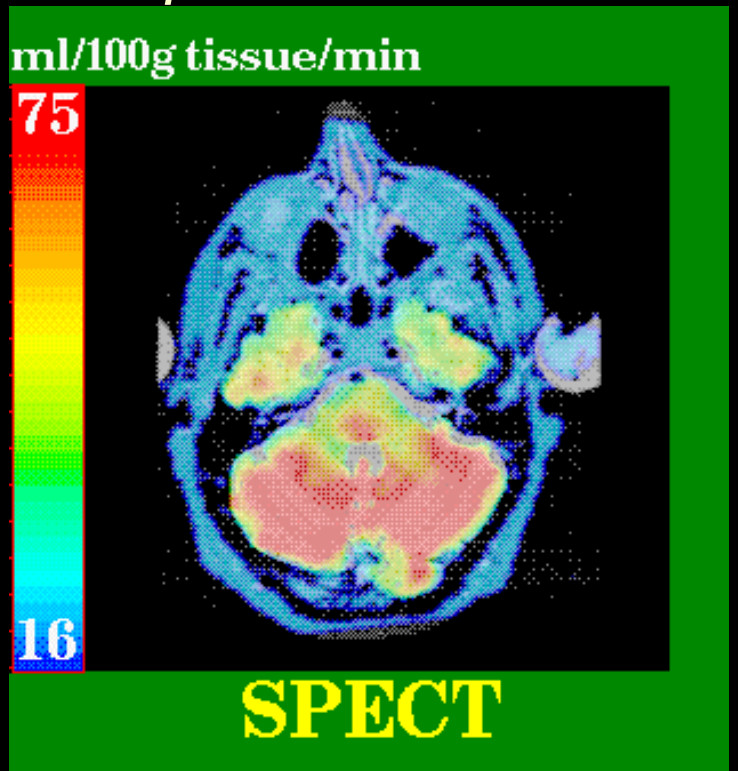
Resolution:	*temporal*	*40 sec*
	spatial	*4 mm*



SPECT-Single Photon Emission Computed Tomography

Similar to PET, this imaging procedure also uses radioactive tracers and a scanner to record data that a computer uses to construct two- or three-dimensional images of active brain regions.

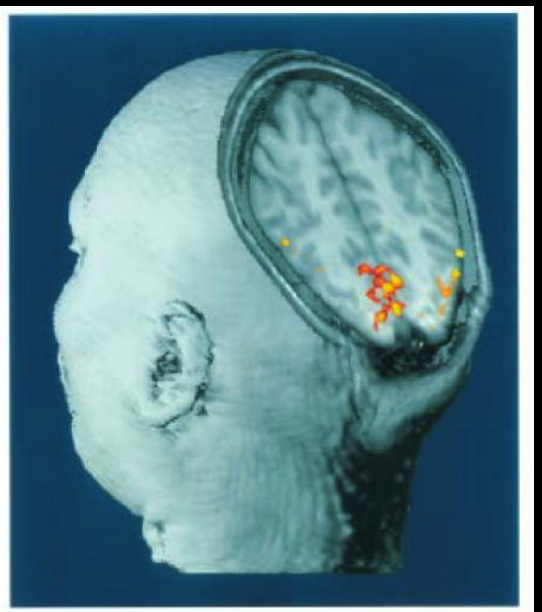
Better resolution than a pet scan

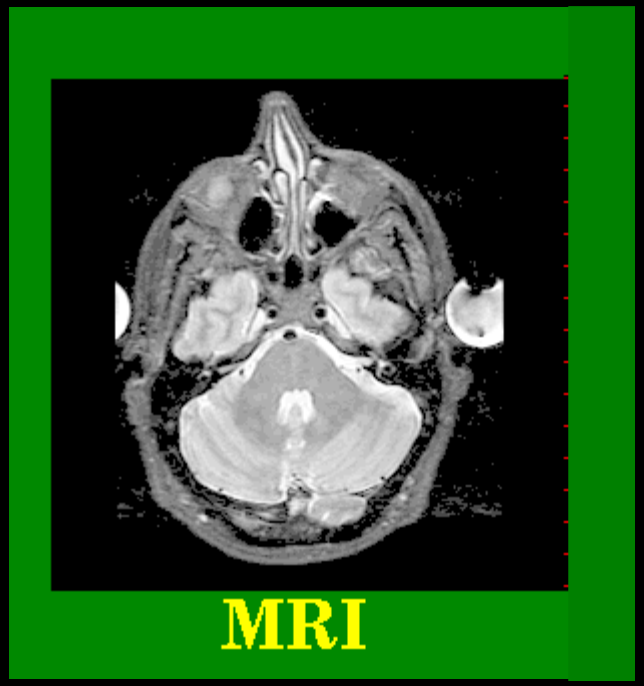


MRI-Magnetic Resonance Imaging

MRI uses magnetic fields and radio waves to produce high-quality two- or three dimensional images of brain structures without injecting radioactive tracers. Functional MRI (fMRI) relies on the magnetic properties of blood to enable scientists to see images of blood flow in the brain as it is occurring

Resolution	*Temporal*	*1 sec*
	Spatial	*1 mm*





EEG-Electroencephalography

Electroencephalography uses electrodes placed on the scalp to detect and measure patterns of electrical activity emanating from the brain.

Resolution	*Temporal*	*better than PET or fMRI*
	Spatial	*worse*

MEG

The magnetoencephalogram (MEG) is caused by the minute magnetic fields produced when ionic currents flow inside the brain as the result of neural activity. Magnetic sensors that are placed around the head pick up these fields. The … resolution of MEG array systems is a few mm on a side at the cortex, but decreases to the order of cm in deep brain structures such as the thalamus. It is also quite expensive,

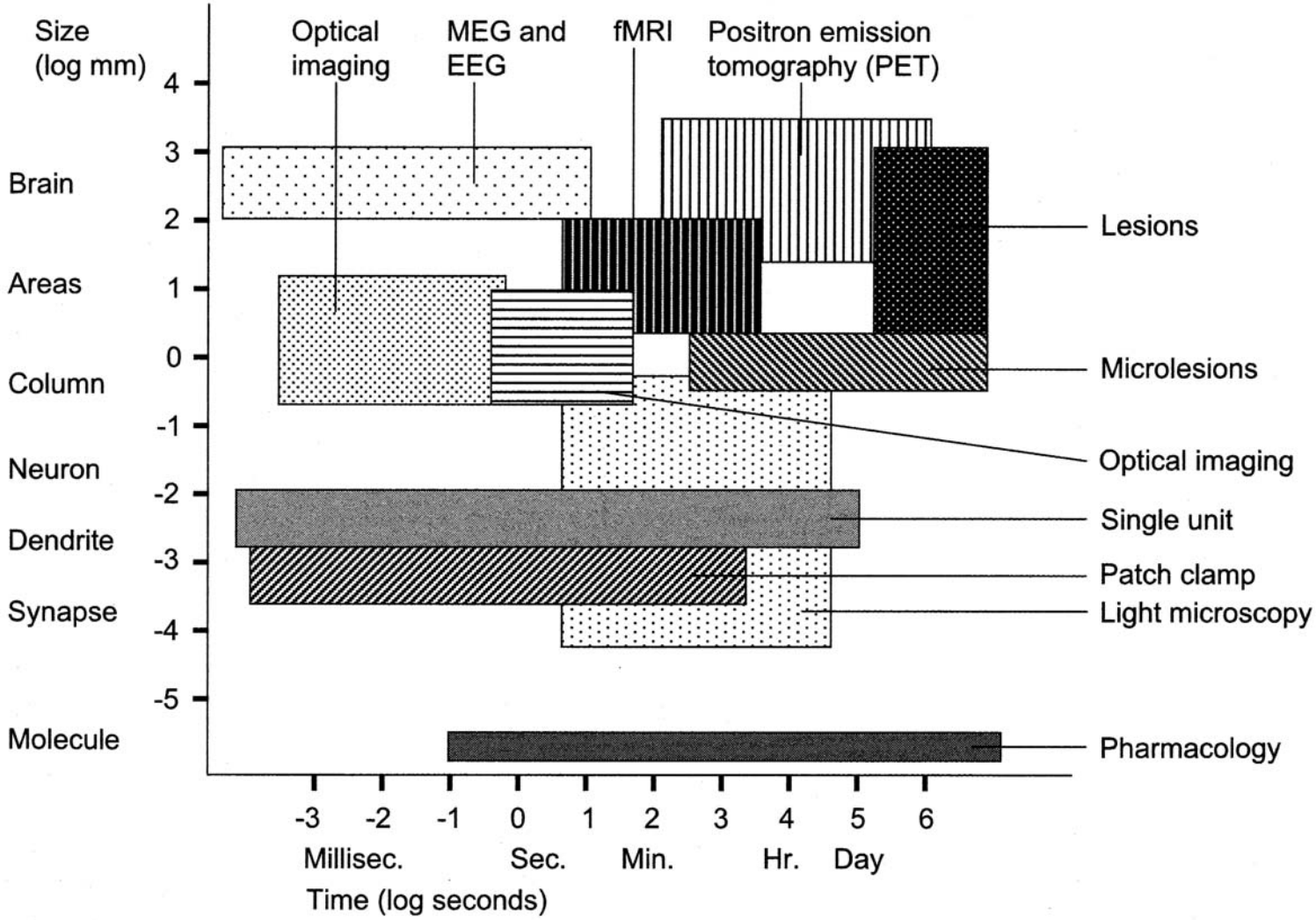


Figure 1.9 Comparison of the temporal and spatial resolutions of various brain-mapping techniques. MEG indicates magnetoencephalography; ERP, evoked response potential; EROS, event-related optical signal; MRI, magnetic resonance imaging; fMRI, functional MRI; PET, positron emission tomography; and 2-DG, 2-deoxyglucose. (Adapted from Churchland and Sejnowski 1988.)

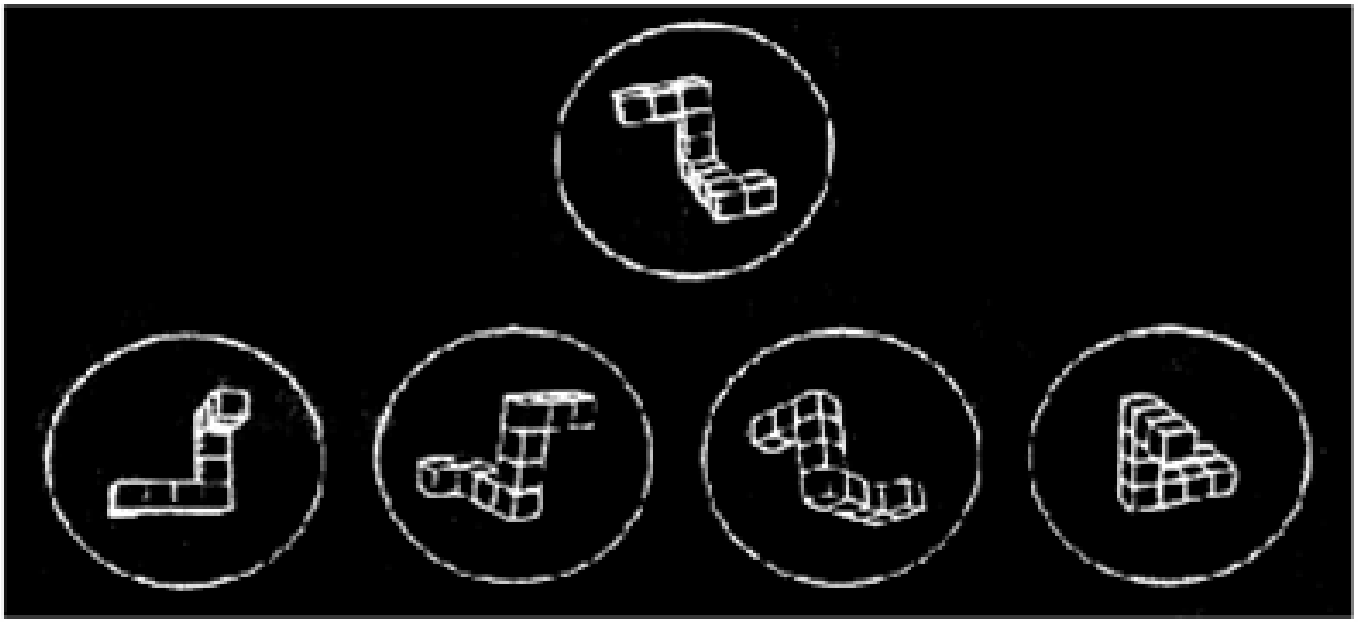


Figure 1: Rotation task stimulus image

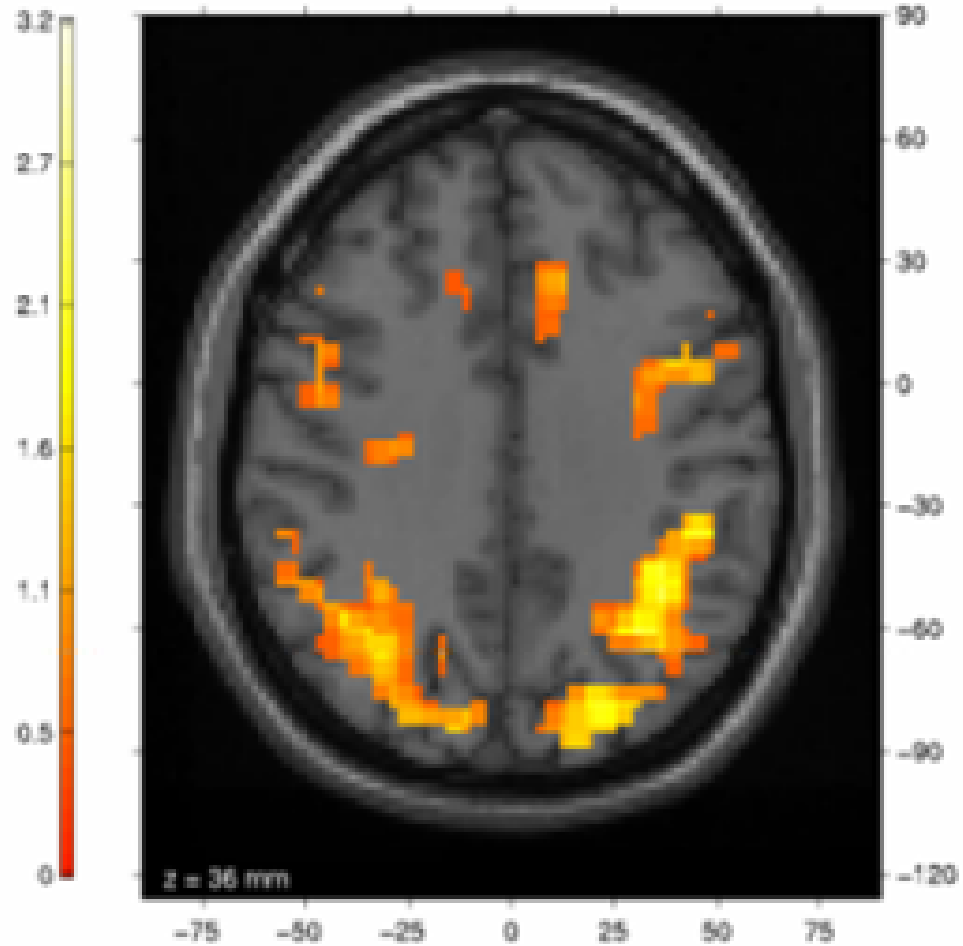
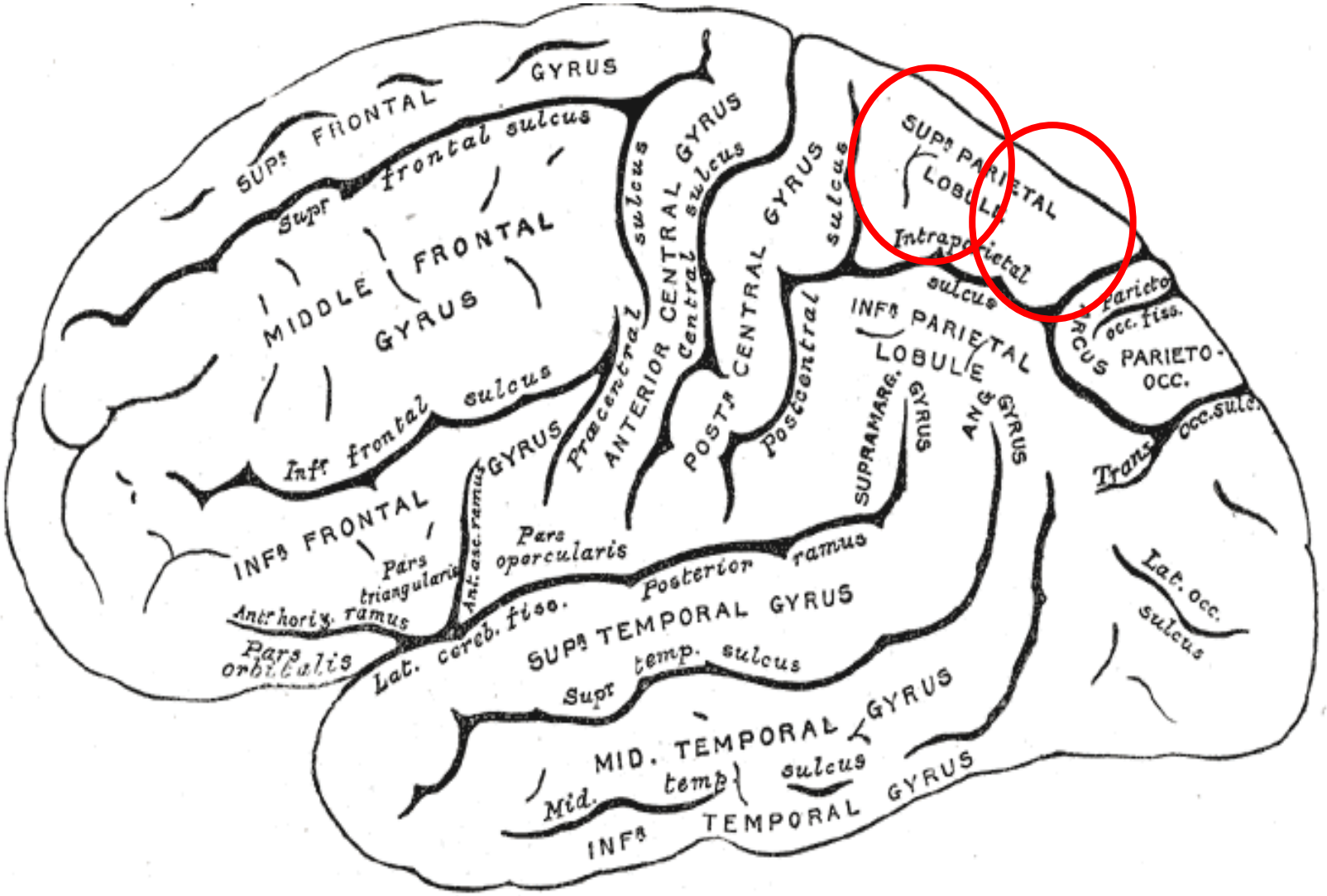


Figure 2: 3-D mental rotation activation regions displayed on SPM99 T1 template.

- Muthukumaraswamy, Johnson and Hamm (2003): participants were presented with random shapes (silhouettes) which they had to judge as congruent or incongruent to a test figure (i.e. a similar procedure to earlier mental rotation studies).
- Both behavioural data (reaction times) and Event-related Potential (ERP) data (EEGs) were collected in the experiment.
- The behavioural data was consistent with earlier studies, though there was evidence of individual differences in strategy (e.g. some participants only rotated the objects clockwise).
- The ERP data showed two stages of activation. Firstly, bilateral activation in the posterior parietal cortex at approximately 232–300 ms.
- Secondly activation was observed in the right anterior parietal region after approximately 424–492 ms.

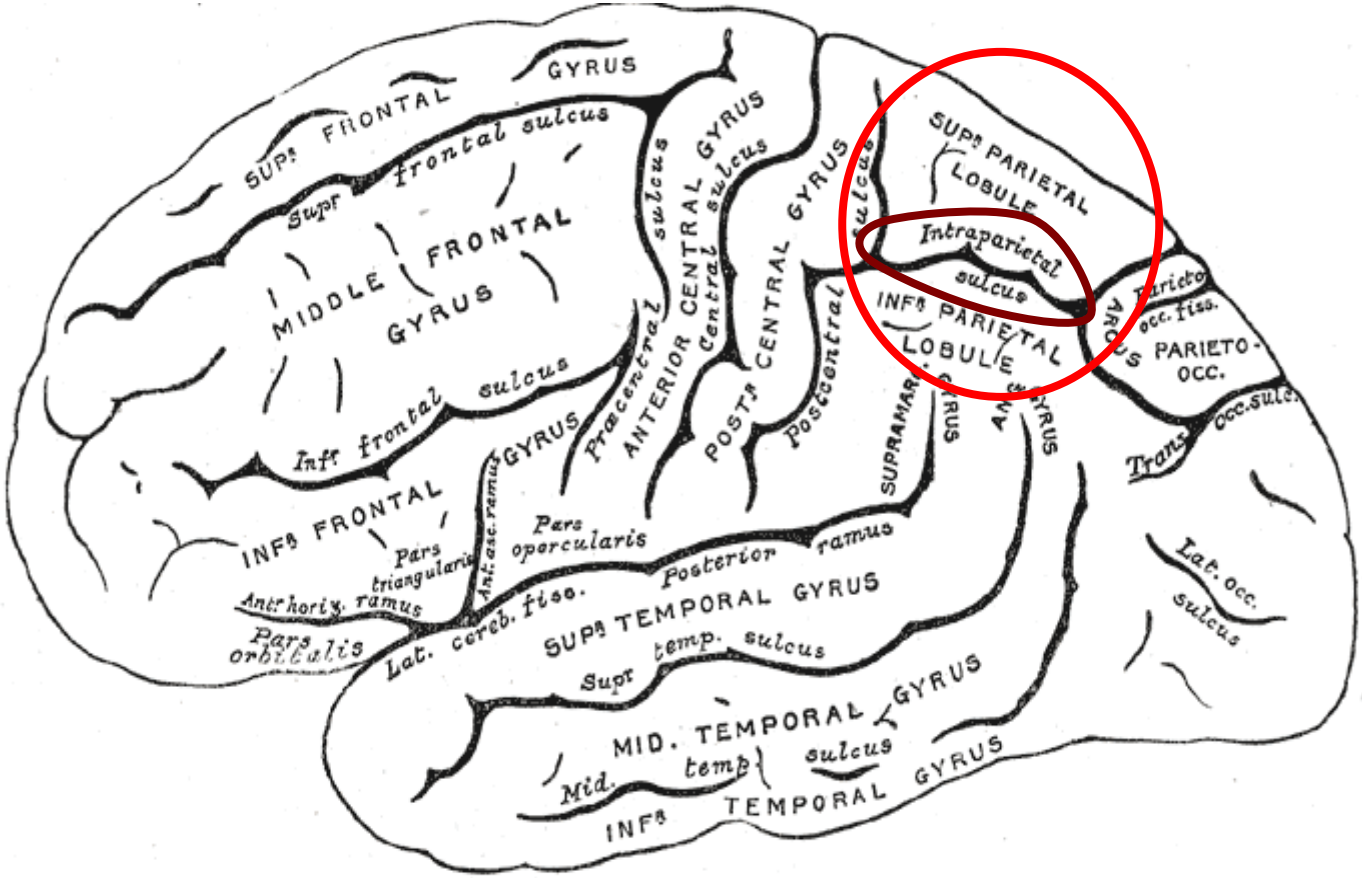
Adapted from Barry Devereux slide


SUPR FRONTAL GYRUS
Supr frontal sulcus
MIDDLE FRONTAL GYRUS
Inf frontal sulcus
INFR FRONTAL GYRUS
Pars orbitalis
Pars triangularis
Pars opercularis
Ant. asc. ramus
Ant. horiz. ramus
Lat. cereb. fiss.
Praecentral sulcus
ANTERIOR CENTRAL GYRUS
central sulcus
POSTR CENTRAL GYRUS
Postcentral sulcus
SUPR PARIETAL LOBULE
Intraparietal sulcus
INFR PARIETAL LOBULE
SUPRAMARG. GYRUS
ANG. GYRUS
Parieto occ. fiss.
PARIETO-OCC.
Trans occ. sulc.
Lat. occ. sulcus
Posterior ramus
SUPR TEMPORAL GYRUS
Supr temp. sulcus
MID. TEMPORAL GYRUS
Mid. temp. sulcus
INFR TEMPORAL GYRUS

- Harris and Miniussi (2003) demonstrated that the posterior parietal cortex is *necessary* for mental rotation. They used rTMS (repetitive transcranial magnetic stimulation) to temporarily disrupt the posterior parietal cortex.
- When rTMS was applied to the region between 400-600ms after presentation of the stimulus it disrupted mental rotation task performance.
- The results are important as they associate mental imagery with an area known to be important in visual perception (especially movement perception) namely the posterior parietal cortex.
- Similar findings were found by Jordan et al (2001), using fMRI. They presented their participants with pictures of 2D and 3D objects; some were random and some were familiar (e.g. letters).
- Their behavioural RT data again replicated earlier findings.
- They fMRI data gave no evidence of differential processing in the case of different types of stimuli.

Adapted from Barry Devereux slide

- They did not find any significant activation outside the parietal lobe.
- They found bilateral cortical activation in the superior and inferior parietal lobe. The activation was centred on the intraparietal sulcus.

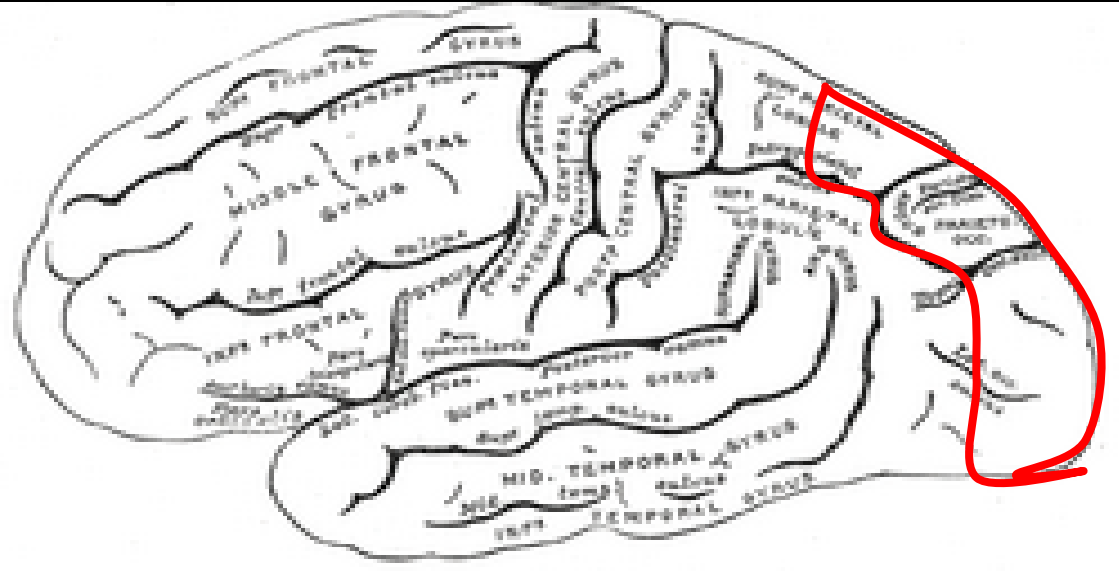


- This is important as it implicates an area of the brain associated with visual-spatial perception (especially motion perception) in mental imagery.
- There is therefore strong convergent evidence from EEG/ERP, fMRI and rTMS (and PET) that the bilateral parietal cortex is important for mental rotation.

Adapted from Barry Devereux slide

Kosslyn Revised

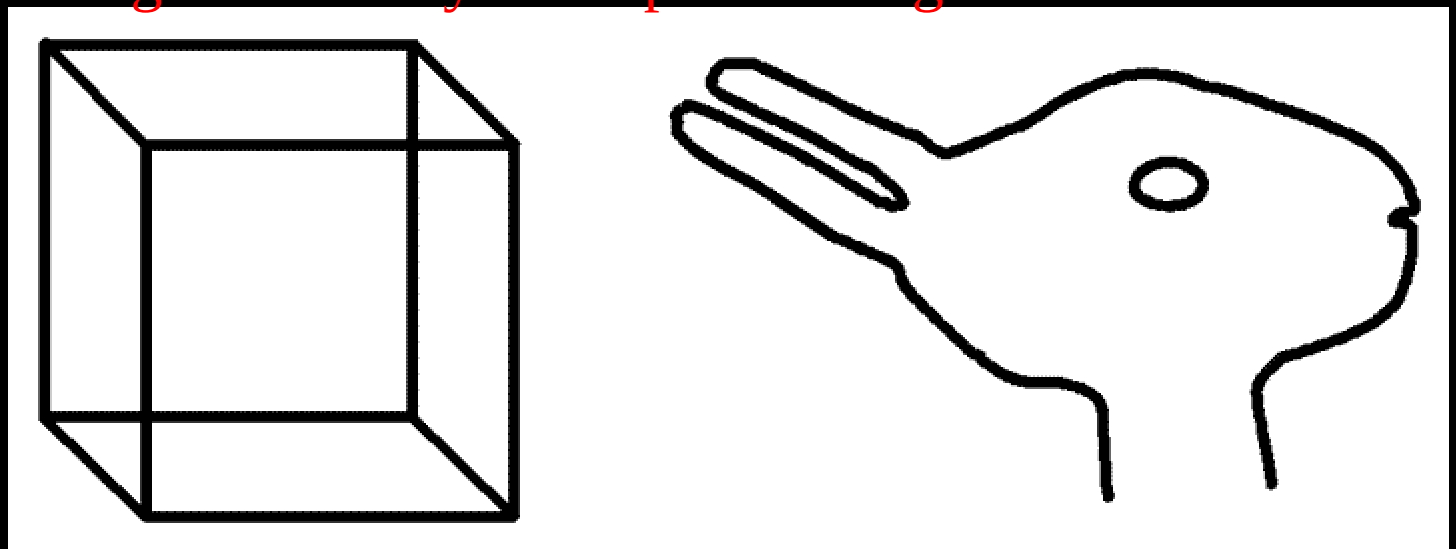
- Kosslyn and Thompson (2003) proposed that the visual buffer is associated with the primary and secondary visual cortex, as well as the posterior parietal cortex.
- Kosslyn also proposed that images are formed in a **visual buffer.** The visual buffer is used both during mental imagery and during visual perception, and therefore accounts for the close similarities between visual perception and imagery.



Problems with the quasi-pictorial (analogical) view of Imagery

The blind can do it. the major experimental effects that supposedly reveal the spatial and non-verbal properties of visual imagery (such as mental rotation, scanning, size/inspection time effects, and selective interference), have now been demonstrated in totally congenitally blind subjects using touch

The seeing can't always manipulate images



The concept of bistable ambiguous figures was introduced by showing subjects some examples, then showing them one of the figures that they had not previously seen, but only for 5 seconds, too short a time for them to see more than one of the possible interpretations. They were then asked to form a mental image of the figure they had just seen, and to try to find a second interpretation in their image. Despite having plenty of time, and being given hints and encouragement by the experimenters, in no trial (out of 55 in all) did any of the subjects manage to see or even guess the alternative interpretation. Even more strikingly, when the subjects were then asked to draw the figures they had seen, on the basis of the image they had formed, in the vast majority of cases they were soon able to see the alternative interpretation in their own drawing

Some Convergence

- Kosslyn proposed that mental images are generated in the visual buffer from propositional information stored in long term semantic memory.
- For visual perception, on the other hand, images are generated from the input from the senses.

Propositional theory

- Pylyshyn (2002, 2003) proposed that images are not depictions.
- For Pylyshyn, mental images are the result of unconscious, propositional knowledge about what something ***would*** look like, if one was looking at it, rather than something that has direct functional correspondence with the thing depicted.

Evidence for the analogical and propositional theories

- Most of the brain imaging and neuropsychological research supports Kosslyn's theory.
- In a meta-analysis of 58 brain-imaging studies, Kosslyn and Thompson (2003) identified that studies that required participants to inspect their mental images in great detail were associated with increased activation in the visual cortex.
- Many studies have shown that many brain-damaged patients with impaired visual perception also have impaired mental imagery (Bartolomeo, 2002).
- However, there are some patients who have normal visual perception and impaired mental imagery.
- This can be explained in the theory by the possibility that retrieval of semantic information from long term memory is hindered in such patients. This possibility is supported by the fact that such patients often have damage to the left temporal lobe (associated with semantic memory

Adapted from Barry Devereux slide

That's All Folks