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National Program on Technology Enhanced Learning (NPTEL)

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Course Title:

Basic Cognitive Processes

By: Dr. Ark Verma,
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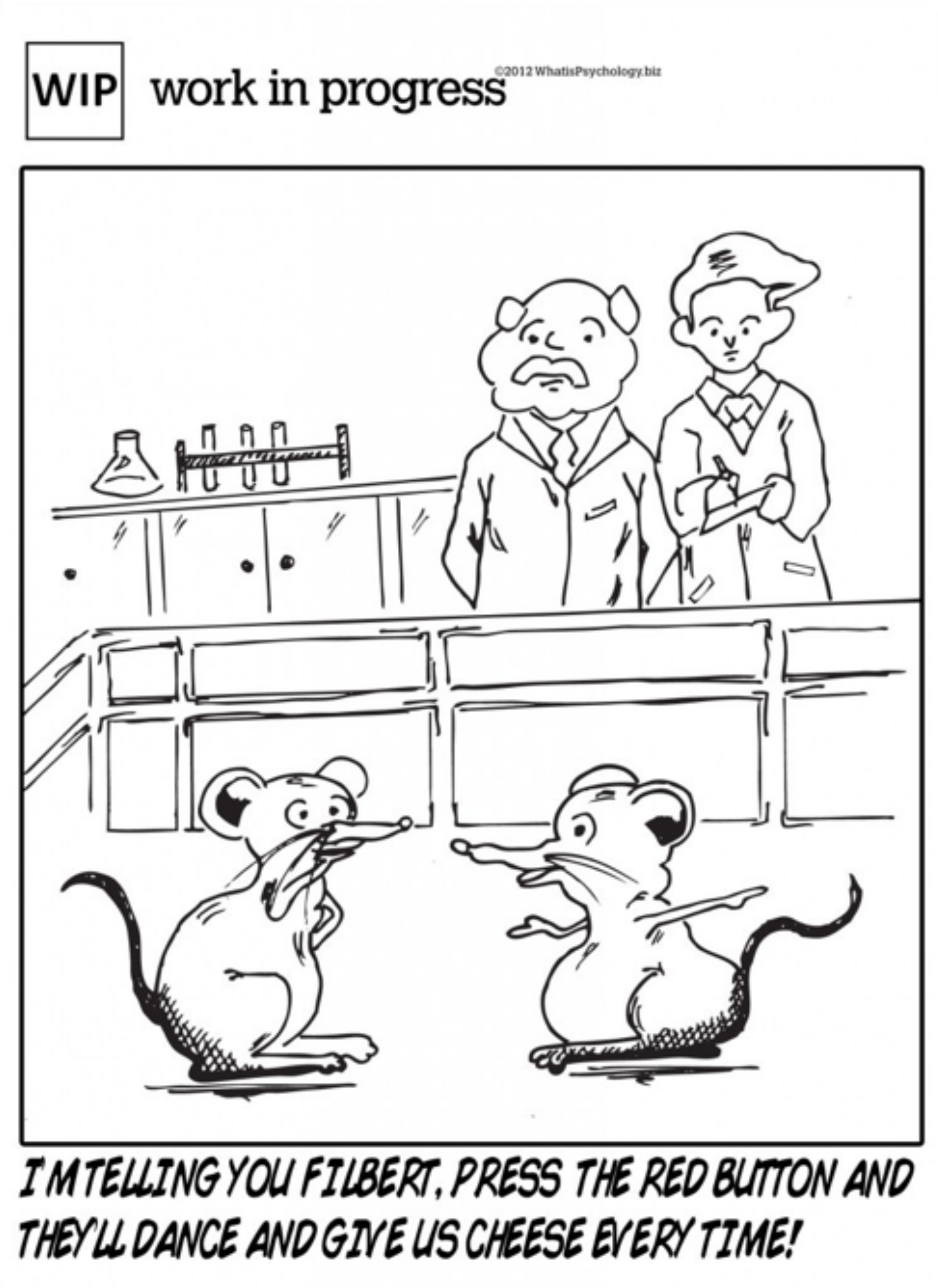
Lecture 01 – Introduction to Cognitive Psychology

A Preface…

- Before we get deeply involved with the topics in Cognitive Psychology, let us do a bit of background!!!

- What is Psychology?



yes, I am studying psychology.

no, that doesn't mean i can read your mind.

So, is Psychology just about Behaviour Modification?

- No, It's not!!!

What is the subject matter of Psychology?

- A science which studies **mental processes**, **experiences** & **behaviour** in different contexts.

  - ***mental processes*: **What goes on in the mind?
  - brain activity? or mental activity?
  - such as learning, remembering, perceiving, feeling, understanding.

- **Experiences**: *subjective feelings*
    - *What is your reality/awareness/soul?*
    - *What are you feeling at this point of time?*
    - *Normal/altered/active or passive?*

- **Behaviours:** responses or reactions to the events & actions in the world. Also spontaneous activity in order to achieve various goals or motives.

    - **Simple or complex.**

        - **Most simple instance could just be a Stimulus (S) & a Response (R).**

    - **Overt or Covert**

Is Psychology a Science or just Common Sense?

- Common sense has problems!!!
  - E.g. Confirmation biases, stereotypes, availability heuristics etc.
- So, probably not common sense!

Image reference: slideplayer.com/slide/3588230

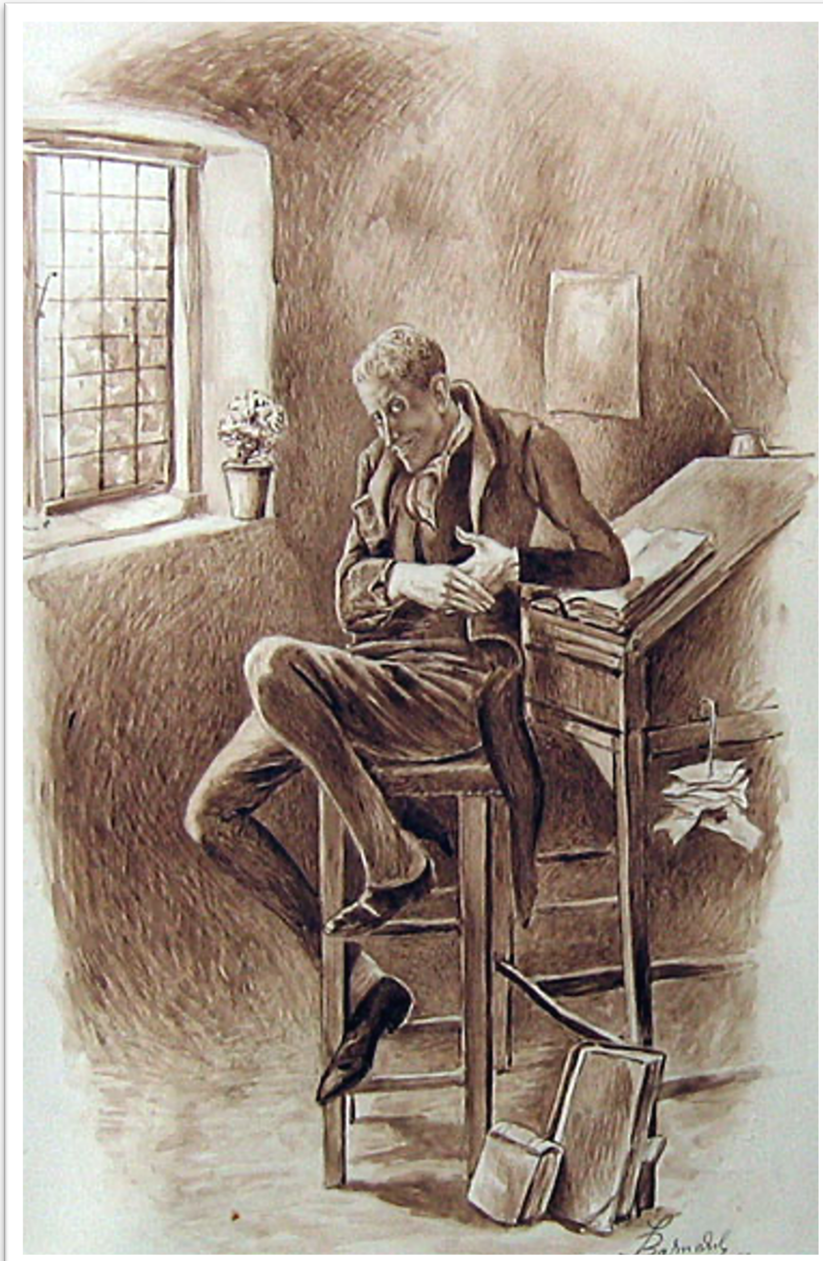


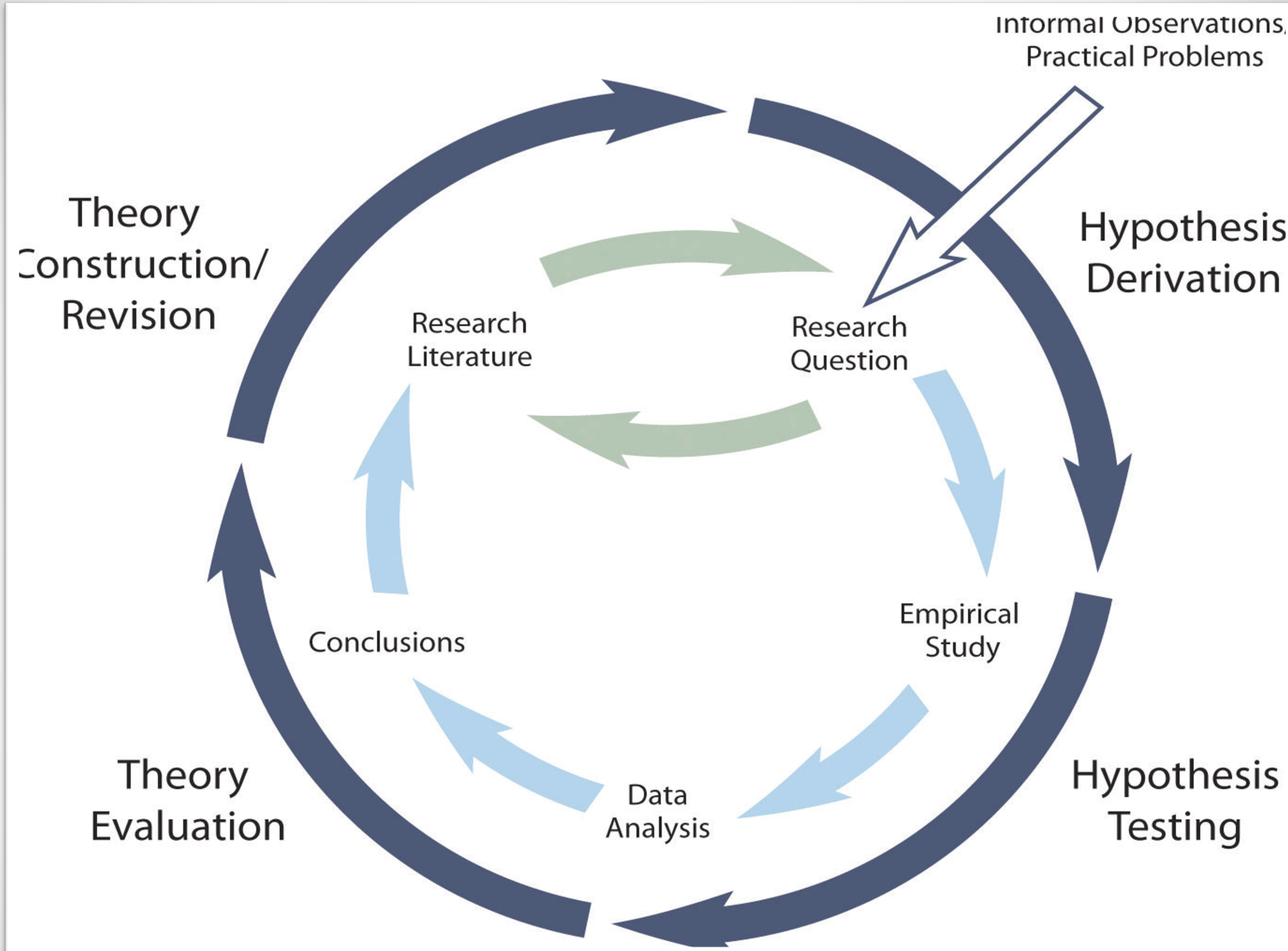
Image reference: Uriah Heep by Fred Barnard. Source: bookdrum.com

How is Psychology structured as a discipline?

- As a discipline, psychology:
  - Seeks to understand and explain how the mind works & how the different mental processes lead to different behaviours.
  - Tries to minimise biases in explanations of behaviour and experience in various ways.
  - However, it also recognises the importance of subjectivity in some cases; though trying to develop a scientific understanding.

- Most notably, psychology draws from two streams of knowledge:
  - one, which makes use of the methods in physical & biological sciences and the other which uses the methods in social & cultural sciences in studying a variety of psychosocial phenomena.
  - in the first case, psychology focuses largely on biological principles to explain human behaviour.
  - in the other case, psychology focuses on how behavioural phenomena can be explained in terms of the interaction that takes place between the person & the social context.

- as a science:
    - psychology applies the *"**scientific method**"*.
    - emphasises ***objectivity*.**
    - uses what is called a *"**hypothetico – deductive model**"***.**



- Image reference: catalog.flatworldknowledge.com

- finally, psychology attempts to understand ***mind & behaviour!!!***
  - ***What is Mind?***
  - ***What are the functions of the Mind?***
  - ***How does one study this concept called Mind?***

What is Cognitive Psychology?

- Is the branch of psychology devoted to scientific study of the ‘mind’.

What is ‘mind’?

- Let’s try to construct a simple definition.

- Please note in the following instances, the use of the term:

  - **“He was able to call to mind what he was doing on the day of the accident.” (The mind as involved in memory)**

  - **“If you put your mind to it, I’m sure you can solve that math problem.” (The mind as problem-solver)**

- **“I haven’t made up my mind yet” or “I’m of two minds about this.” (The mind as used to make decisions or consider possibilities)**

- **“He is of sound mind and body” or “When he talks about his encounter with aliens, it sounds like he is out of his mind.” (A healthy mind being associated with normal functioning, a nonfunctioning mind with abnormal functioning)**

- So, what exactly we know about the mind?
  - *The **mind** creates and controls mental functions such as perception, attention, memory, emotions, language, deciding, thinking, and reasoning*.
- Also,
  - *The mind is a system that creates representations of the world so that we can act within it to achieve our goals*.

What are mental functions?

- To understand what these ‘mental functions’ refer to, let us take a practical example:

As Raphael is walking across campus, talking to Susan on his cell phone about meeting at the student union later this afternoon, he remembers that he left the book she had lent him at home (● Figure 1.1). "I can't believe it," he thinks, "I can see it sitting there on my desk, where I left it. I should have put it in my backpack last night when I was thinking about it."

As he finishes his call with Susan and makes a mental note to be on time for their appointment, his thoughts shift to how he is going to survive after Wednesday when his car is scheduled to go into the shop. Renting a car offers the most mobility, but is expensive. Bumming rides from his roommate is cheap, but limiting. "Perhaps I'll pick up a bus schedule at the student union," he thinks, as he puts his cell phone in his pocket.

Entering his anthropology class, he remembers that an exam is coming up soon. Unfortunately, he still has a lot of reading to do, so he decides that he won't be able to take Susan to the movies tonight, as they had planned, because he needs time to study. As the lecture begins, Raphael is anticipating, with some anxiety, his meeting with Susan.

- Text reference: Goldstein (2011) Cogntive Psychology, page: 4

FIGURE 1.1 What's happening in Raphael's mind as he walks across campus? Each of the "thought bubbles" corresponds to something in the story in the text.

- Image reference: Goldstein (2011) Cogntive Psychology, page: 4

- So, what all is Raphael doing?

- ***Perceives*** his environment - seeing people on campus walking around, hearing Susan talking on phone.

- ***Pays attention*** - to one thing after another - the person approaching his left, what Susan is saying, how much time is left for class.

- ***Remembers*** - something from the past - that he had told Susan, he was going to return her book today.

- ***Distinguishes items in a category*** - when he thinks about different possible forms of transportation - rental car, roommate's car, bus.

- ***Visualises*** the book on his desk the night before.

- ***Understands & Produces language*** as he talks to Susan.

- ***Works to solve a problem*** - as he thinks about how to get to places while his car is in the shop.

- ***Makes a decision*** - when he decides to postpone going to the movies with Susan so he can study.

- So, taking into account the earlier definition of Cognitive Psychology, of mind, & of mental functions; we can say that:

    - ***Cognitive psychology*** is the study of mental functions such as attention, learning, memory, mental imagery, language, problem solving & decision making.

References:

- Goldstein, E. B. (2011) Cognitive Psychology: Connecting Mind, Research and Everyday Experience *Cengage Learning* 3rd Edition.

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Lecture 02: A Brief History of Cognitive Psychology

The word *Psychology*…

- *Psychology* the word basically derives from a combination of two Latin words:

    - *Psyche*: soul

    - *Logia*: the study of

- So, psychology began as the study of the soul!!!

The Origins…

- the origin of psychology can be traced back to two basic disciplines:

  - ***Philosophy***: a discipline that seeks to explore & explain human nature through introspection. & also uses tools of thought like epistemology, logic etc.

  - ***Physiology***: a discipline dedicated to understanding the functioning of the human body.

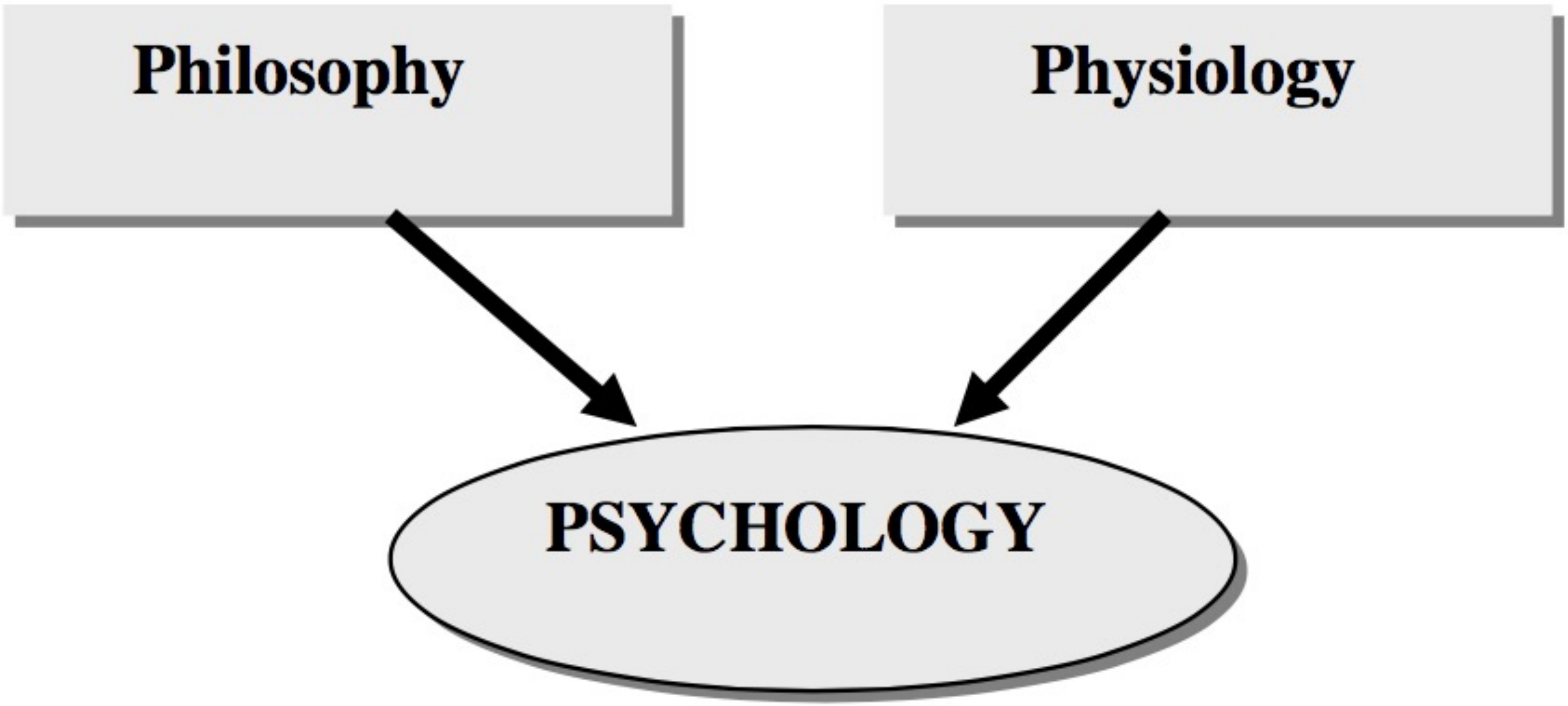

Figure 1.2 Roots of Psychology

Image reference: Stangor (2011) Introduction to Psychology.

- Surprisingly, one of the first reported experiments in psychology can be traced back to the Egyptian times, though there is no reason to believe that there were no similar investigations going on in other civilisations…(from Charles Stangor, "Introduction to Psychology").

The First 'Psychological Experiment"

An ancient King of Egypt, as far back as the seventh century B.C., can be considered the first psychology experiment. The king wanted to test whether or not Egyptian was t he oldest civilization on earth. His idea was that, if children were raised in isolation from infancy and were given no instruction in language of any kind, then the language they spontaneously spoke would be of the original civilization of man – hopefully, Egyptian.

The experiment, itself, was flawed, but the king deserves credit for his idea that thoughts and language come from the mind and his ambition to test such an idea. While the experiment failed to support the king's hypothesis, Morton Hunt (1993) suggests that it does illustrate perhaps the first evidence in written history that as long as 2700 years ago there was at least one individual who had the "highly original notion" that mental processes could be systematically investigated and studied.

[*source*: Morton Hunt, The Story of Psychology, 1993, p.1]

Image reference: Stangor (2011) Introduction to Psychology.

Philosophical Antecedent of Psychology

The Early Thinkers…

- Hippocrates (460 – 377 B.C.) proposed that mental illness was not caused by demons but physical malfunctions.
  - he dissected human cadavers & living organisms to conclude that *mind* controlled the body.
  - further, that *mind* resides in the brain.

Hippocrates
460-377 B.C

Image source: emaze.com

The Early Thinkers…

- Plato (427 – 347 B.C.)
  - Suggested that reality exists in our minds & the head is the seat of the mind.
  - Knowledge is gained through thinking & analysing as an effort to understand the world.
  - *mind* and body are different, but they interact.
  - A rationalist.

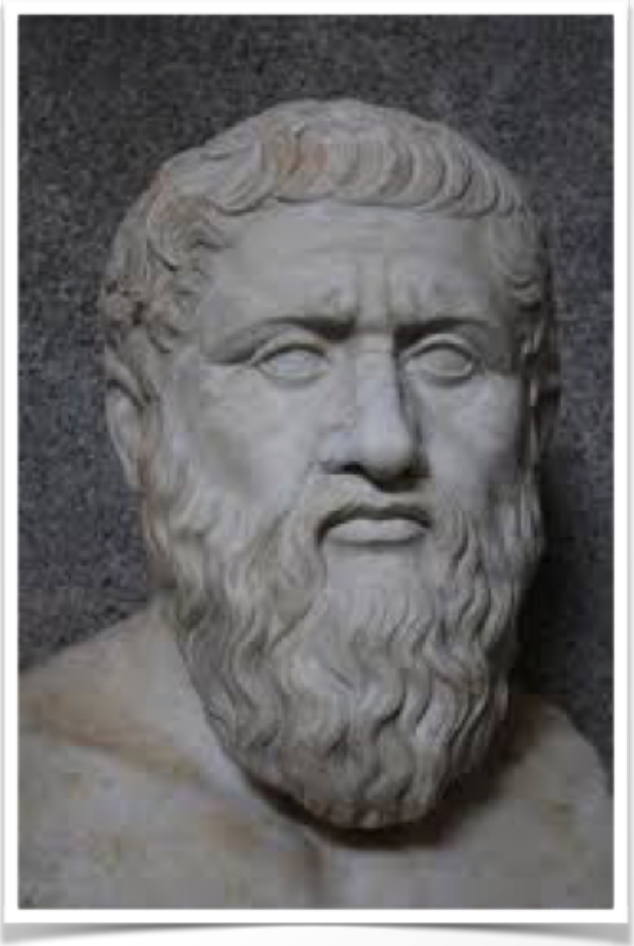

Image source: ancient.eu/plato/

The Early Thinkers…

- Aristotle (384 – 222 B.C.)
    - felt that *mind* & body were the same thing.
    - we can understand the mind by studying the body.
    - rely on concrete objects & actions rather than thoughts.
    - reality lies in the concrete world.
    - an empiricist.

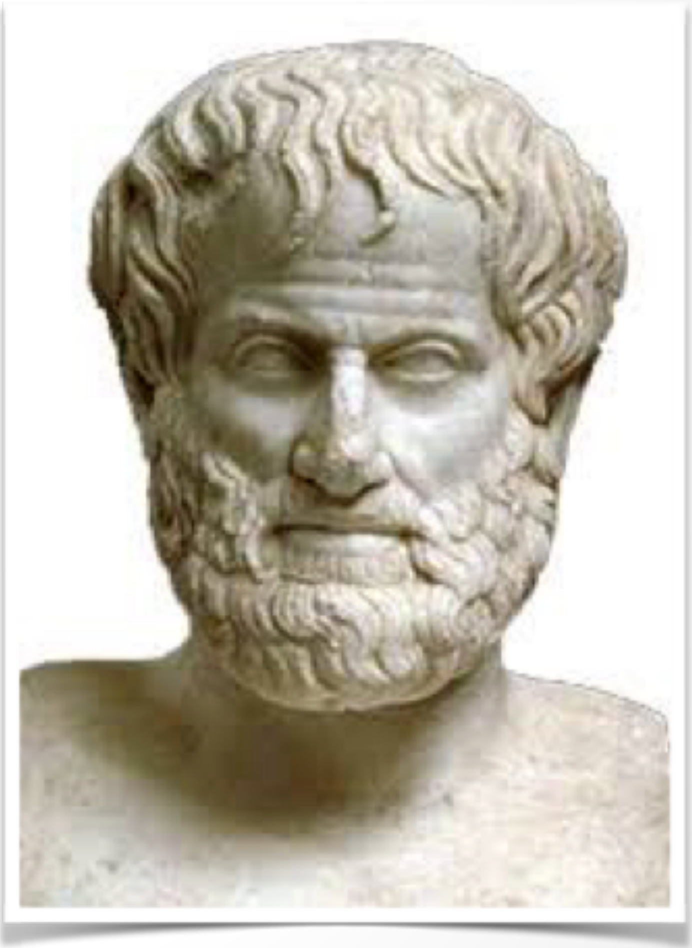

Image source: www.iggy.net

Moving to more Modern Thinkers…

The Modern Thinkers…

- Rene Descartes (1596-1650)
    - a French mathematician & philosopher.
    - introspection & reflection are better methods than observation.
    - mind & body are two separate things. spiritual & material.
    - *Cogito ergo sum.*

Image source: www.biography.com/people/rem-descartes

The Modern Thinkers…

- John Locke (1632-1704)
  - relationship between mind & body is an equal relationship of the two aspects of the same phenomenon.
  - mind depends upon the body through the senses for its informations, while the body depends on the mind to process & store sensory experiences.
  - empiricist & believed in *tabula rasa*.

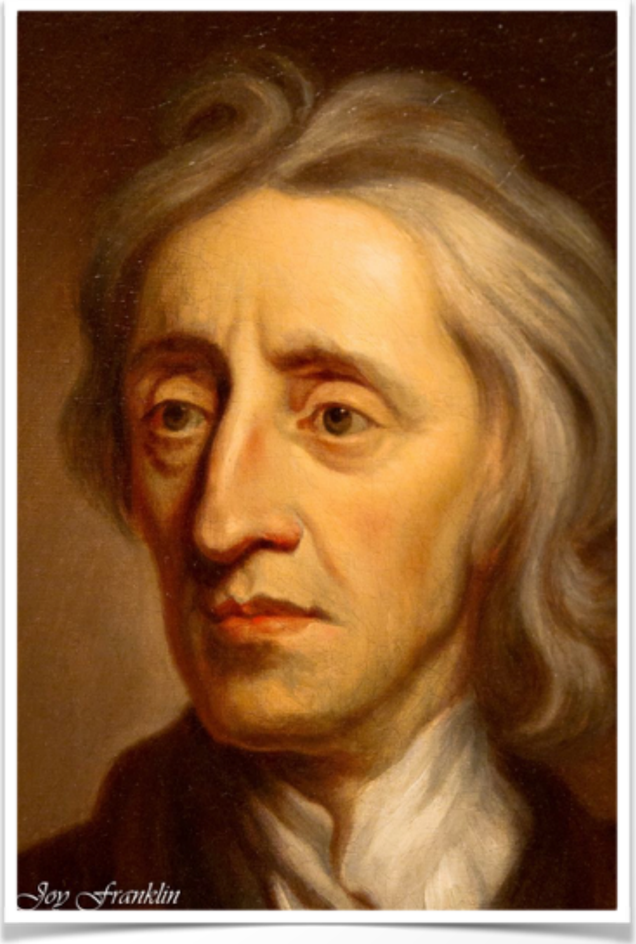

Image: leonardooh.wordpress.com

The Modern Thinkers…

- Immanuel Kant (1724-1804)
    - proposed that humans have a set of faculties - senses, understanding & reasoning, which work together to control the link between mind & body.

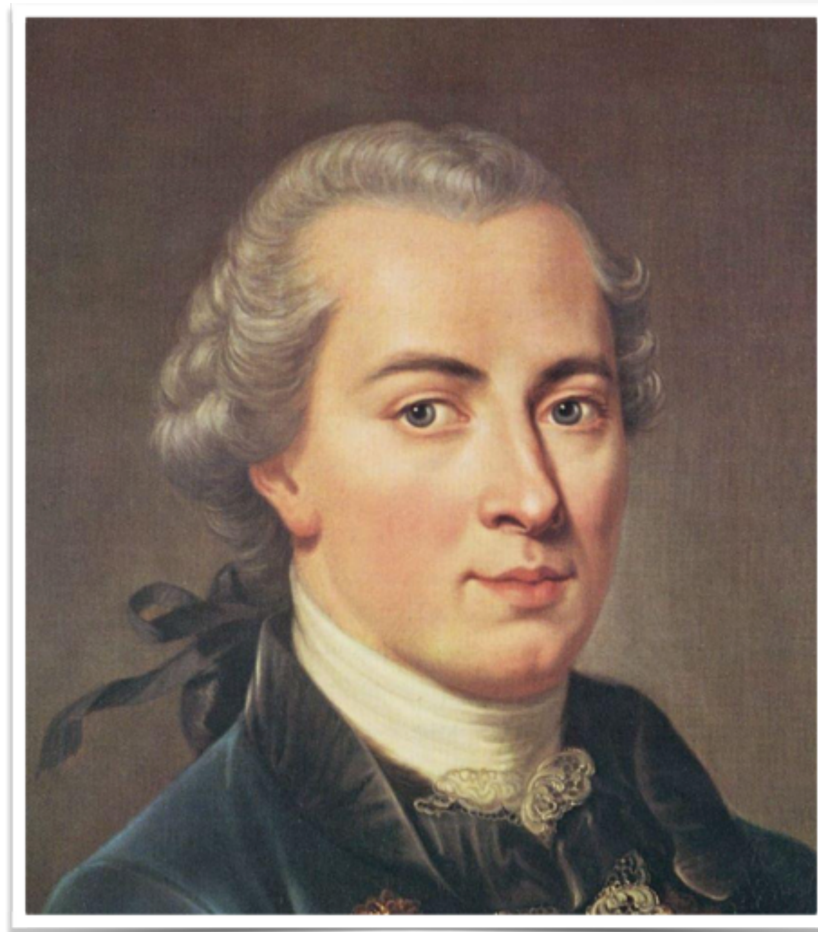

Image: en.wikipedia.org/wiki/immanuel_Kant

Taking a pause…

- So, the early thinkers basically laid out the broad subject matter of psychology.
- it had to be the elusive relationship between *mind* & *body*.
- *mind* could be studied through various ways, *observable behavior* was an important element.
- *body* on the other hand could be studied via the biological/neural substrates.

Various Schools of Psychology…

Structuralism

- Wilhelm Wundt (1832-1920) developed the first *psychology laboratory* in Leipzig, Germany.
- focussed on the nature of consciousness itself.
- believed that it was possible to analyse the basic elements of the mind & conscious experience.
- founded *structuralism*.

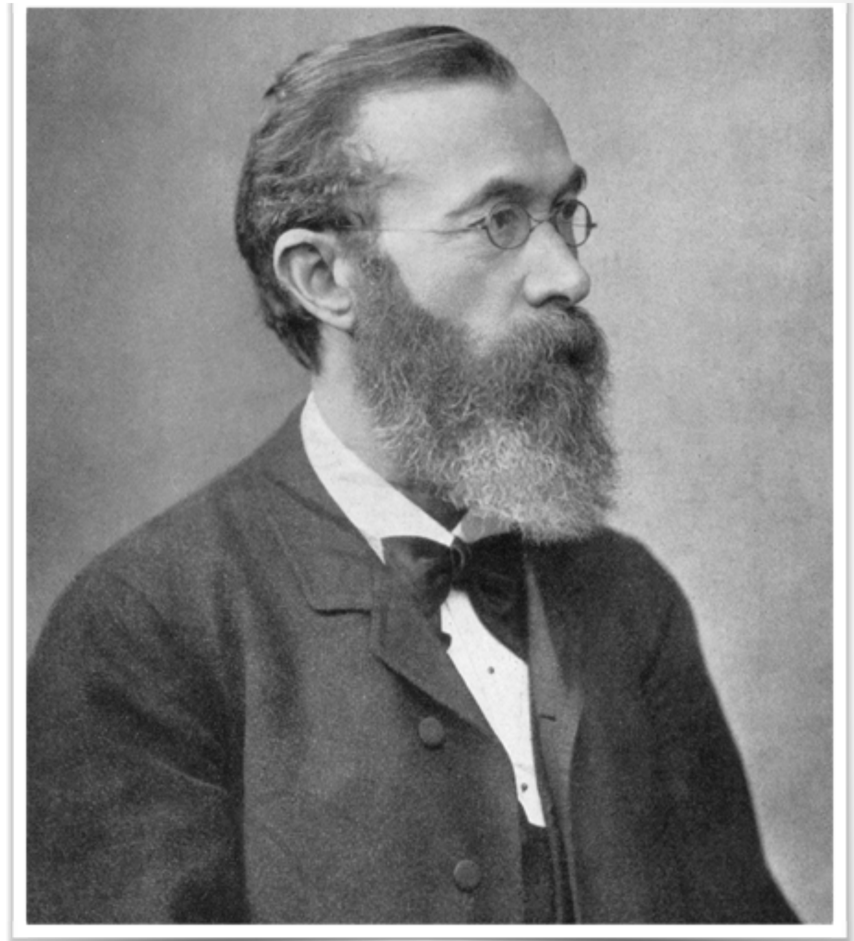

Image: en.wikipedia.org/wiki/Wilhelm_Wundt

- ***Structuralism***

  - aimed to identify the basic elements or structures of the psychological experience.

  - to create something like a *periodic table* of elements of sensations.

  - used the method of ***introspection*** to attempt a map of human consciousness.

  - asked participants to describe exactly what they experience as they work on mental tasks, such as viewing colours, reading etc.

- also used *reaction times* as a measure to systematically assess the workings of the mind.
    - identification of sound took longer than detection (Wundt)
- distinguished between *sensation* & *perception*.
- **Edward Titchener** (1867-1927) claimed to identify more than 40,000 sensations, as vision, hearing & taste.

- the approach was rigorous & scientific.
- quantifying mental events.
- had limits: *introspection*.

Functionalism

- William James (1842 – 1910)
  - founded ***functionalism.***
- seeks to understand what people do & why they do it.
- Interested in studying how the mind works & why the mind works as it does.

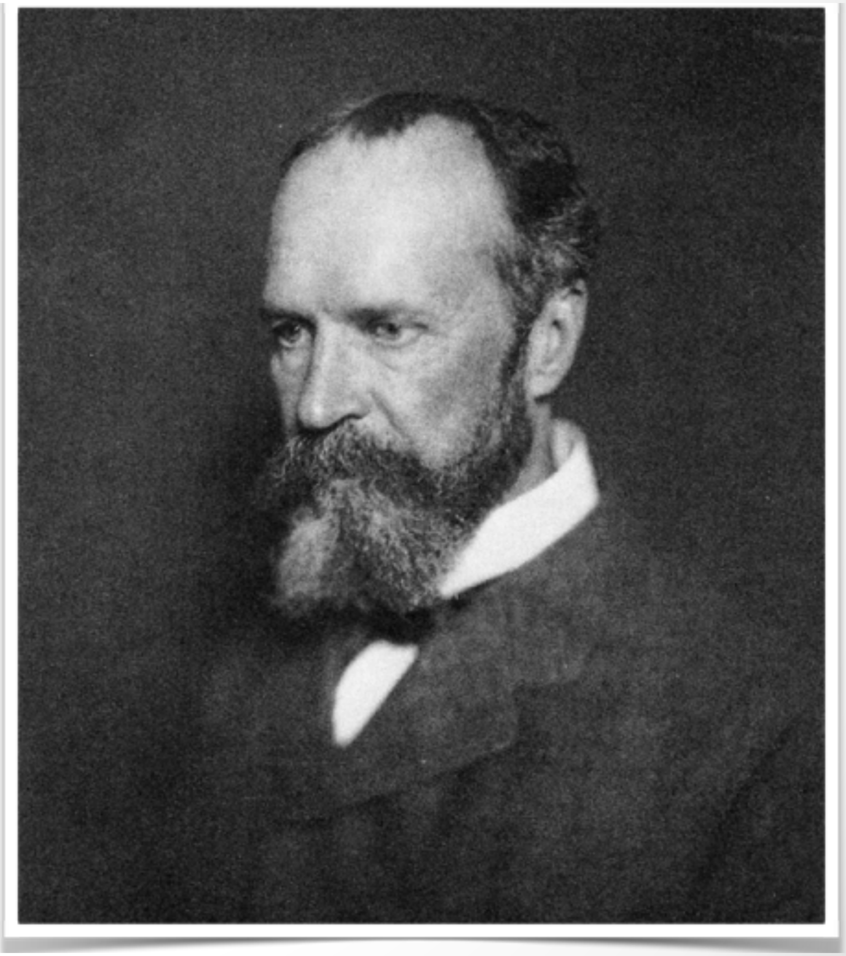

Image: en.wikiquote.org/wiki/William_James

- the functionalists believed in using whatever methods best answered a given researcher’s questions.

- the movement of *functionalism* gradually led to what is known as ***pragmatism*** in psychology, wherein the main assertion was that knowledge is valuable for it’s usefulness.

    - So, Pragmatists would be interested in studying something to learn what it helps one do. For e.g. how language helps you communicate your thoughts.

Associationism

- Another influential way of thinking in psychology was ***associationism*.**

  - Examines how the elements of the mind like ideas, feelings etc., can become associated with each other in the mind to result in a form of learning.

  - For e.g. ***contiguity*:** things that tend to occur together at about the same time.

    - ***contrast*:** we also tend to associate things together which represent two extremes like hot/cold; happy/sad etc.

- Hermann Ebbinghaus (1850 – 1909) applied the associationist principles systematically.
- He studied his own mental processes & made up a list of nonsense syllables that consisted of a consonant followed by a vowel and then a consonant. E.g. zat, cax, nad etc.
- Took careful note of how long it took him to memorize those lists, counted errors & recorded response times.

Image: Encycopaedia Britannica

- Through these self – observations, Ebbinghaus studied how people learn & remember material through *rehearsal* i.e. the conscious repetition of material to be learned.

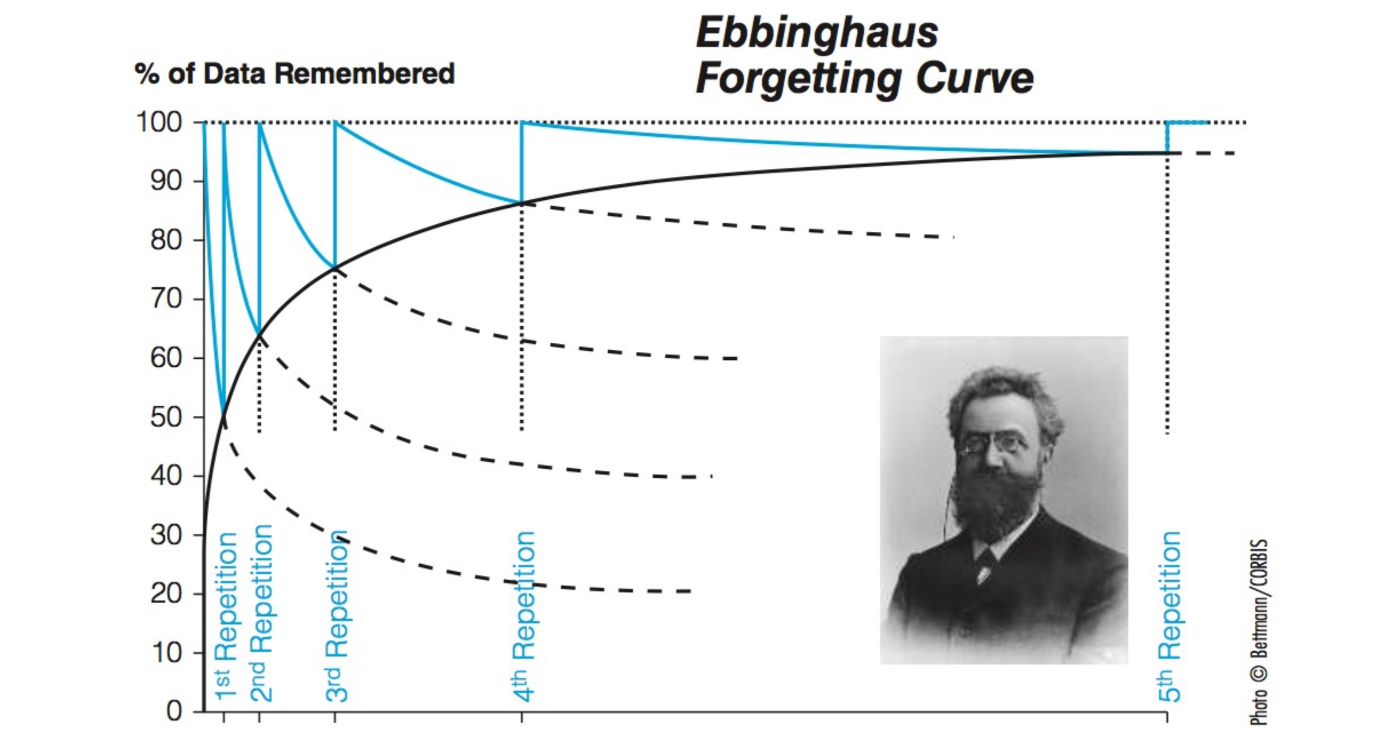

Figure 1.2 The Ebbinghaus Forgetting Curve shows that the first few repetitions result in a steep learning curve. Later repetitions result in a slower increase of remembered words.

Image: Sternberg, & Sternberg (2012) Cognitive Psychology

- Edward L. Thorndike (1874 – 1949) proposed that the role of "satisfaction" is the key to forming associations.

- termed his principle as *the* ***law of effect*** (1905): *"a stimulus will tend to produce a certain response over time if an organism is rewarded for that response"*.

- an organism learns to respond in a given way in a given situation if it is rewarded repeatedly for doing so.

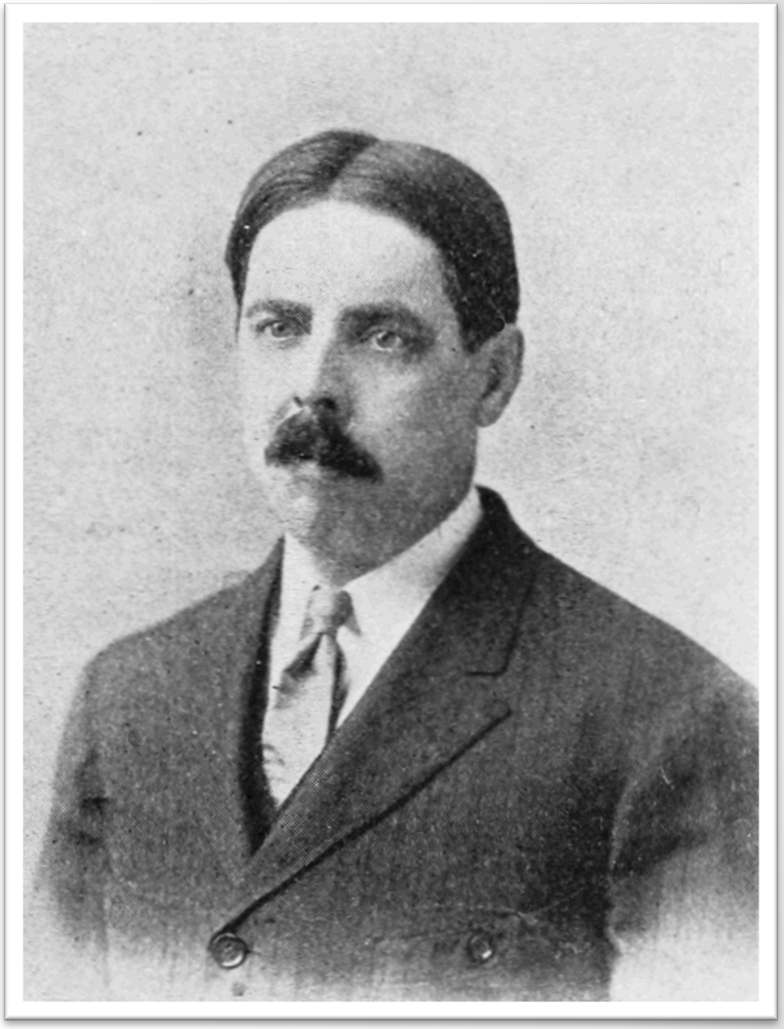

Image: https://en.wikipedia.org/wiki/Edward_Thorndike

To summarize…

- So, in today's lecture I took you on a ride through the origins of the main ideas & approaches that lead to the development of ***Cognitive Psychology***

- It might be an interesting to slowly go over & make a connection from:
  - The ideas of rationalism vs. empiricism.
  - The early philosophical thought about mind & body.
  - The early schools of psychology.
  - The cognitive revolution.

References

- Sternberg, R.J. & Sternberg K. (2012). Cognitive Psychology. 6th Ed. *Cengage Learning*.

- Braisby, N. & Gellaty, A. (2005) Cognitive Psychology. 1st Ed. *Oxford University Press.*

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Lecture 03: A Brief History of Cognitive Psychology contd...

Behaviorism

- Other psychologists operating at the same time as Thorndike began using animal experiments to probe *stimulus – response* relationships in slightly diferent ways.

- Those experiments led to the emergence of a field called ***behaviorism.***

- Behaviorism focused primarily on the relation between observable behavior and environmental stimuli.

- The idea was to move towards the *physical* from the *mental*.

- Russian physiologist, Ivan Pavlov (1849 – 1936) studied the effects of pairing two comlpetely unrelated stimuli on learning.
- He found out that when paired:
  - food > salivating response.
  - food + bell > salivating response.
  - bell > salivating response.
- ***Classical conditioning.***

Image: http://sciencepenguin.com/wp-content/uploads/2013/08/kapak2.jpg

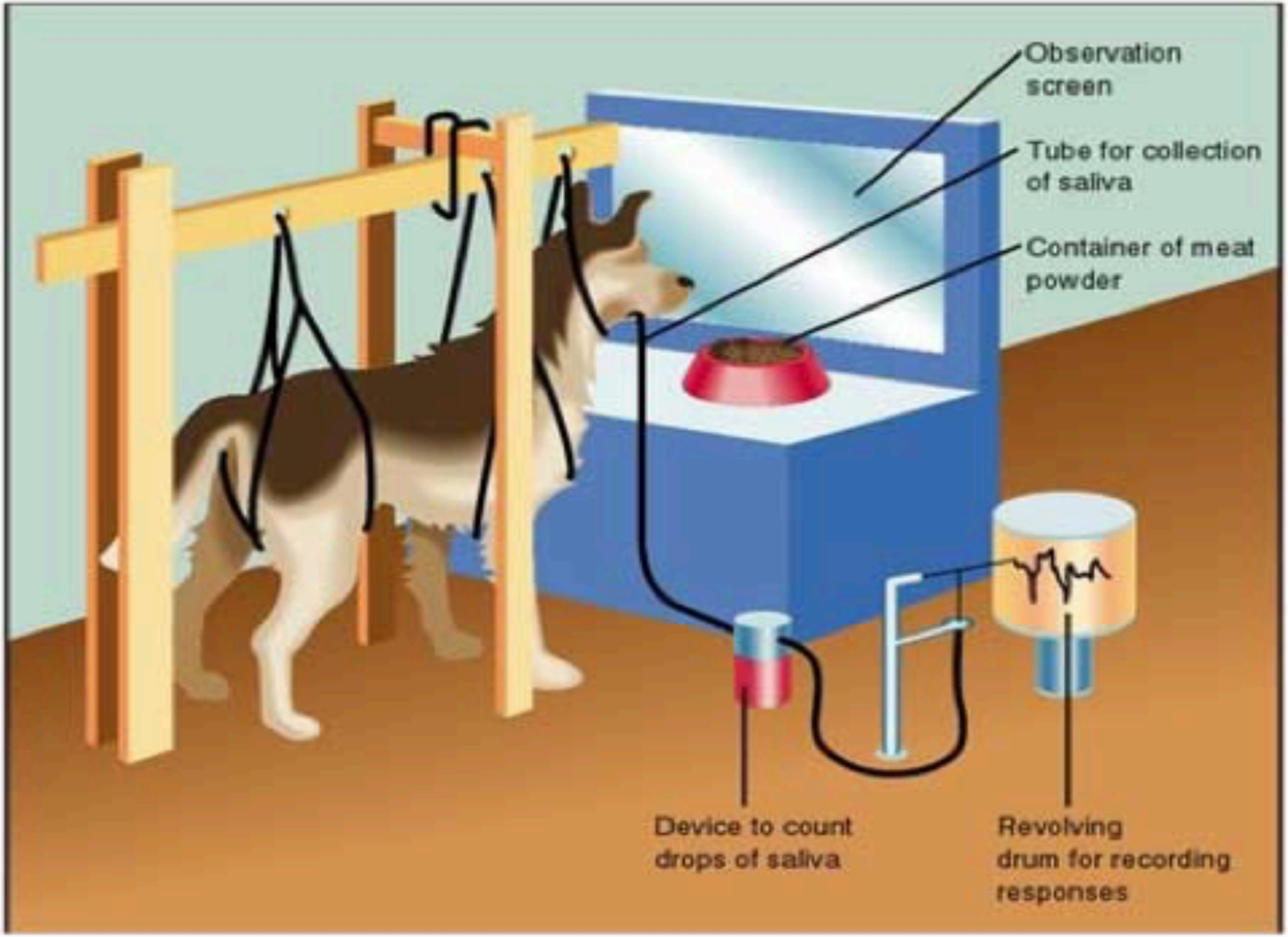

Image: https://www.simplypsychology.org/Pavlov.jpg

- John B. Watson (1878 - 1958)
  - founded *behaviorism*
  - based on the premise that it is not possible to objectively study the mind.
  - psychologists should limit their attention to the study of behaviour (overt) itself.
  - mind is a "black box".
  - no point in trying to determine, when we can predict behaviour.

Image: http://humanbehaviorexpert.com/wp-content/uploads/2014/10/john-watson-6.jpg

- B .F. Skinner (1904-1990)
    - used *reinforcements & punishments* to modify behavior.
    - used theses principles to develop theories about how to teach children & create peaceful societies.
    - influenced a lot of marketing strategies.
    - ***Operant conditioning***

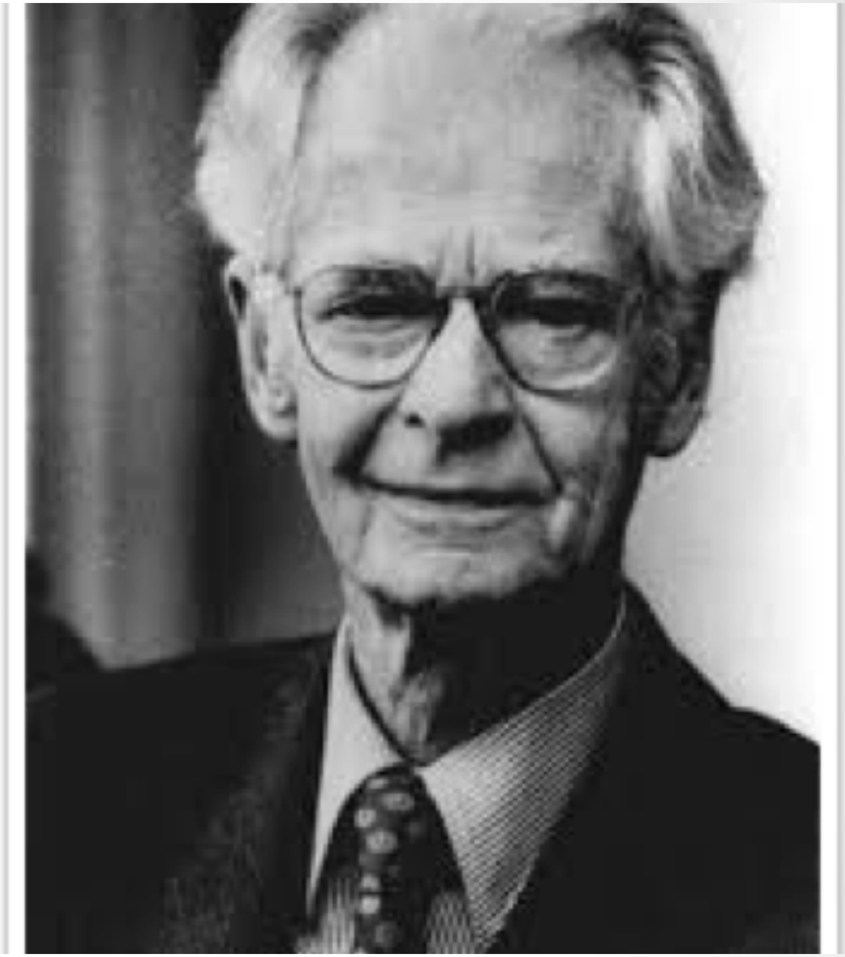

Image: http://www.childdevelopmentmedia.com/psychology/giants-of-psychology-b-f-skinner-a-fresh-appraisal/

Gestalt Psychology

- States that we best understand psychological phenomena when we view them as organised, structured wholes.
- Acc. to this view, we cannot fully understand behavior when we only break phenomena down into smaller parts.
  - For examples: while behaviorists chose to study problem solving by looking for observable behavioral correlates gestaltists would look to study the same through *insight*, i.e. the unobservable mental event by which someone goes from having no idea about how to solve a problem to understanding it fully in a mere moment of time.

- They believed in the maxim, “the whole is more than the sum of its parts”.

- To understand the perception of a flower, for example, we would have to take into account the whole of experience.

- We cannot simply understand the perception of a flower merely in terms of a description of its form, colour, size, smell or so on.

Emergence of Cognitive Psychology

The beginning…

- In the early 1950s, a movement called the *cognitive revolution* took place in response to behaviorism.

- *Cognitivism* rejects the notion that psychologists should not study the mental processes because they are unobservable; instead it looks to develop menthods & ways to study the internal workings of the mind.

- the field focuses on studying mental processes like perception, thinking, memory, language etc.

Preceding events...

- ***Influence of Psychobiology***
  - **Karl Lashley** (1890 – 1958) challenged the behaviorist view that human brain is a passive organ, merely responding o the environmental contingencies outside the individual (Gardner, 1985).
  - brain to be an active, dynamic organiser of behavior & sought to understand how the macro – organisation of the human brain made possible such complex ,planned activities as a sport activity, musical performance, language use etc.
  - Through his experiments with rats he concluded that memory is not localized rather distributed in the several regions of the brain.

Image: https://carnets2psycho.net/images/lashley.jpg

- Donald Hebb (1949) proposed the same concept of cell assemblies as the basis for learning in the brain.

- Cell assemblies are coordinated neural structures that develop through frequent stimulation.

- The develop over time as the ability of one neuron to stimulate firing in a connected neuron increases.

Image: http://www.spektrum.de/lexika/images/bio/f3f3731_w.jpg

- the attack on Skinner's ***Verbal Behaviour***
    - While a definite reaction against behaviorism was already brewing , Skinner wrote an entire book describing how language acquisition and usage could be explained purely in terms of environmental contingencies.
    - Linguist **Noam Chomsky (1959)** wrote a scathing review of Skinner's ideas.
    - Chomsky stressed both the biological & the creative basis of language.

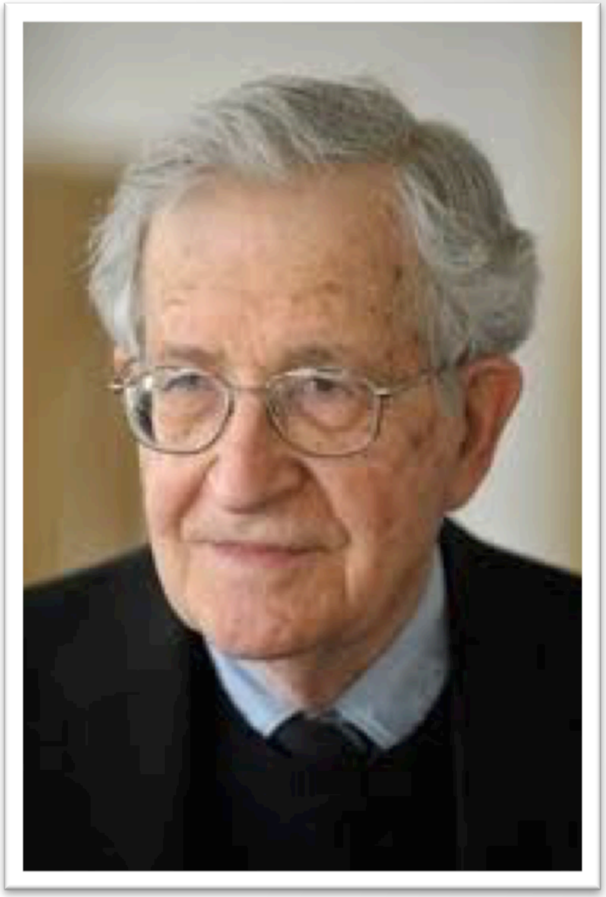

Image: http://www.thirdworldtraveler.com/PageMill_Images/noamchomsky.jpg

- He pointed out the infinite numbers of sentences that we can produce with ease without having learned them through either conditioning or instruction.

- He thereby defied the notion that we learn language through reinforcement.

- A similar idea, that what is leaned must often be more abstract than straightforward stimulus response associations, was also expressed by **Edward Tolman** (1932).

- Through his experiments with rats, he proposed that rats do not learn to navigate a maze through merely a system of rewards/ punishments , rather by actively processing information.

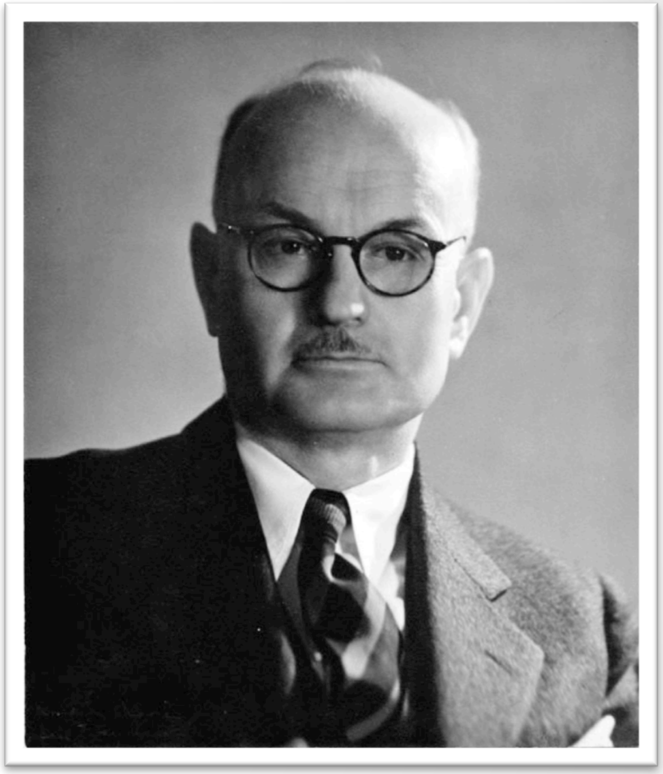

Image: https://alchetron.com/ Edward-C-Tolman-1271730-W

- ***Influence of technology***
  - by the end of te 1950s, psychologists were intrigued by the notion of whether machines could be programmed to demonstrate intelligent behavior.
  - Turing (1950) suggested that soon it would be hard to distinguish the communication of machines from that of humans.
  - He suggested a test, now called the ***Turing Test*** , by which a computer program would be judged successful to the extent that its output was indistinguishable, by humans.
  - The computers of the time passed the Turing Test (Schonbein & Behctel, 2003).

- By 1956, a new phrase erupted on the scene, called ***Artificial Intelligence***, i.e. an attempt by humans to construct systems that show intelligence or more precisely, intelligent processing of information.

- By the early 1960s, there were other developments in the fields of psychobiology, linguistics, anthropology & artificial intelligence which were now converging to create an entirely new era & approached towards studying the human mind.

- Early cognitive psychologists like George Miller, Alan Newell, Shaw & Herbert Simon argued that the traditional behaviorist accounts of behaviour were inadequate because they said nothing about how people think.
- George Miller (1956) introduced the concept of ***channel capacity*** wherein he proposed that the upper limit with which an observer can match a response to information given to him or her is about 7.

  - If you can remember seven digits presented to you sequentially, your channel capacity for remembering digits is 7.

- Ulric Neisser's book ***Cogniitve Psychology*** (Neisser, 1967) was especially critical in bringing cognitivism to prominence by informing the undergarduates, graduate students & academics about the newly developing field.

- Neisser defined *cognitive psychology* as the study of how people learn, structure, store and use knowledge.

- Subsequently, Allen Newell & Herbert Simon (1972) proposed detailed models of human thinking and problem solving from the most basic levels to the most complex.

- By the 1970s, cognitive psychology was recognized as a major field of psychological study with a distinctive set of research methods.

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Lecture 04: Foundational Assumptions of Cognitive Psychology

The Preliminaries

- The first questions…
  - What is ‘*behaviour*’?
  - What ‘*causes*’ behaviour?

Remember the definition of ‘cognitive psychology’?

- In some sense, actually the whole notion of Cognitive Psychology seems counter - intuitive!

- the basic assumption in cognitive psychology concerns the existence of an inner world, the mind - space, where the mental processes take place.

- & where each element of the external ‘real’ world is somehow ‘represented’.

- Without some understanding of the basic philosophical premises, it will be difficult to understand the root assumptions in Cognitive Psychology.

The Problem

- the first concepts:
    - ‘abstract’ used to designate something that is defined without reference to the material (physical) world - that of objects!
    - thoughts, beliefs, emotions, etc. are all abstract because, while they may describe aspects of the physical world; they themselves are not physical entities.

- however, the fact that we can talk & theorize about these abstract entities, is slightly problematic.

- one of the reasons, is the distinction between the ‘physical’ & the ‘mental’!!!

- Consider this statement, e.g. “William ‘decided’ to ‘make’ a sandwich because he ‘felt’ hungry’.

- How is it that two mental events, “feeling” & “deciding” can cause a physical event of “making a sandwich”?.

- there is very little indication of the means by which the mental & physical are supposed to interact (Fodor, 1981).

- however, as you will see, it is quite possible to discuss mental states & processes in the absence of any discussion of physical states & processes.

- in other words, it should be possible to posit that the mind is an abstract entity, with the only implication being that it can be discussed & defined without reference to the physical states and processes.

- from this perspective, cognitive psychologists are not so concerned with the physical states & processes that take place between the ears; they are more concerned with what mental states and processes might be like in their own right.

An important question

- Can science, which is concerned with the physical nature of the world, help us understand the nature of the mind, which essentially is non - physical?
- What methods could be applied to study the mind?

- psychologists attempt to understand human behaviour & assume that a large component of this understanding requires the detailing of how the mind works (Read Steven Pinker's "*How the Mind Works*").

Behaviorism: An alternate account

- Behaviorism, is the view that a true science of psychology strives to achieve a description of human nature in terms of **laws of behavior**.

    - we must strive to generate laws of behaviour in terms of physical events & physical processes.

- the laws will contain statements only about observable things that can be measured. Like Newton's Laws of Motion!

- the eventual theory of human behaviour therefore, should contain universally established principles (laws); that should correctly predict behaviour.

- For instance, “any given human will seek out pleasurable things over unpleasant things” and “given two outcomes, the human will choose the pleasurable option over the unpleasant one.

- the above is actually referred to as the **law of effect** which was proposed by Edward L. Thorndike.

- Thorndike put forward the idea that animals learn responses that result in rewarding consequences & they learn to drop responses that result in punishing consequences.

- because, “the effect” of making a particular response was thought to govern learning.

- Moving further with this assumption, one could posit associations between *stimuli* & their contingent *responses*.

- & discuss whether these associations could be strengthened or weakened.

    - strengthening a S - R bond implies that the tendency to make a particular R increases for a particular S.

    - weakening a S - R bond implies that the tendency to make a particular R decreases for a particular S.

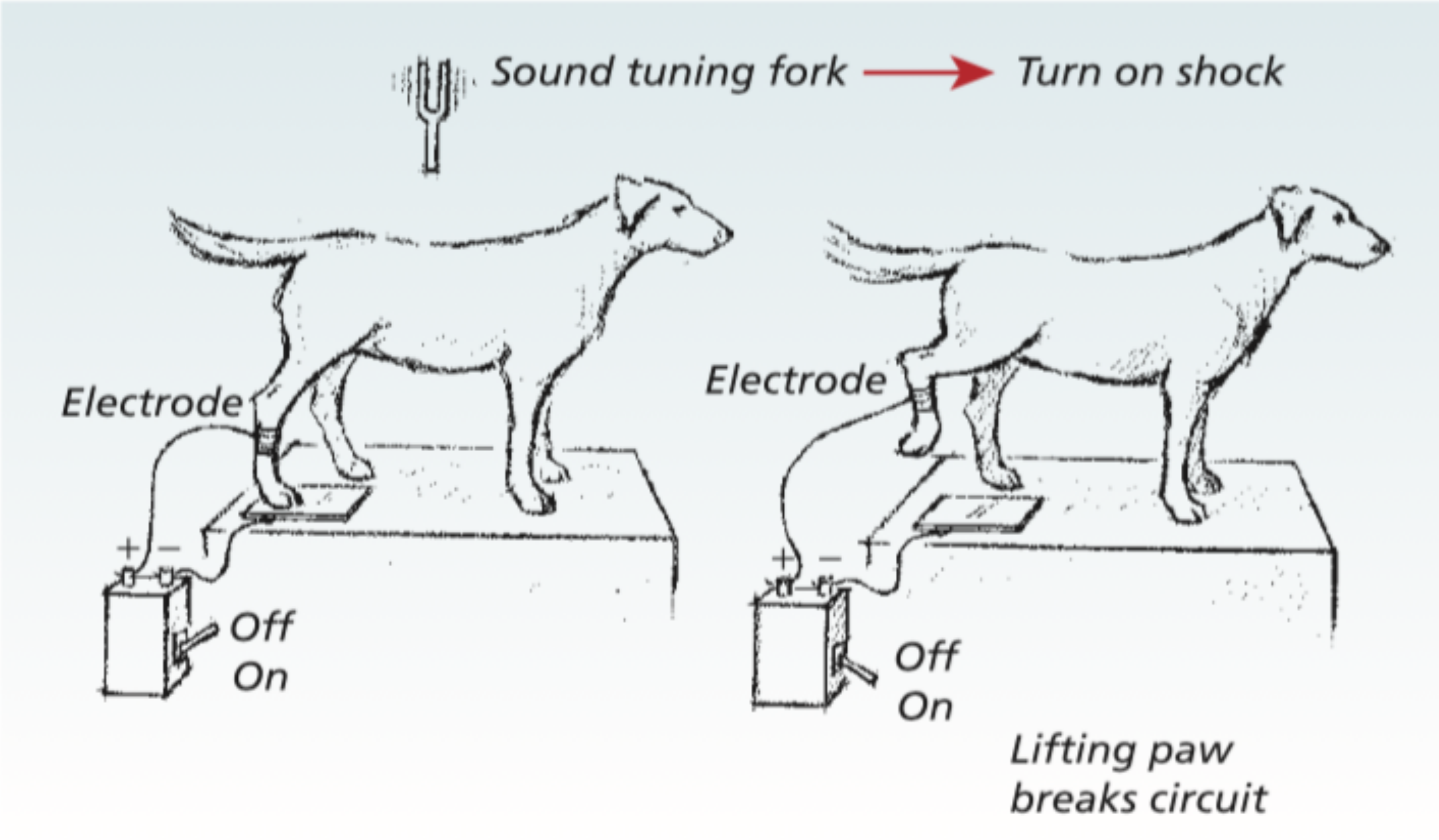

Figure 1.1 The law of effect in practice

Image: Quinlan, P. & Dyson B. (2008). Cognitive Psychology. *Prentice Hall*.

Other Laws

- under **principles of associationism** contingent reward or punishment does not play a necessary role.

  - for e.g. the strength of a particular S - R bond is found to be directly related to the **frequency** with which S & R co - occur.

  - further, the association between S and R will also reflect how closely S & R have co - occurred in the past, i.e **recency.**

- For examplae: how frequently a criminal is punished for a crime & also how quickly.

- So, useful learning can take place from being able to register the contiguity (i.e. closeness in time & space) and the frequency of co - occurrence of stimuli and responses.
- Learning depends on the ability to register the covariation of stimuli & their corresponding responses.

- in other words, **association formation** provides an apparently straightforward account of learning about causation.

    - for e.g. given that event B always follows event A, in close temporal proximity, it is reasonable to predict that the next time A occurs, B will follow closely.

    - one could be led to conclude that A **causes** B.

Some reflections…

- applying the principles of associationism, the behaviourists had hoped to show that behaviour could be predicted & controlled.

- animal experiments were conducted in large numbers in controlled environments & their behaviours were predicted on knowing the previous history of reinforcement & by applying the laws of behaviour.

- the ultimate goal was to extrapolate the results of these experiments to the whole of human society and hence provide a theoretical framework for explaining & understanding human behaviour (Skinner, 1985).

- Note that, mind as an explanatory concept for behaviour was deliberately avoided.

- an implication (an unpleasant one!!!) of the behaviourist research programme was that animals & even humans are considered nothing more than machines!

- the point being conveyed is that, according to behaviourism, human behaviour is seen to be described in terms of a **deterministic system** whereby certain stimuli cause certain responses.

- So, as with any other machine, as long as we can identify the physical antecedents to some form of behaviour, we can then claim to understand the causes of that behaviour.

- In other words, behaviour, is fully determined by physical antecedents.

- Such an account is in line with all other scientific theories of the world; i.e. objects & events are linked by certain causal relations, & future actions can be predicted perfectly by the occurrence of their causal antecedents.

- much like a wall clock!!!
  - in winding up a wall clock, the rotational energy applied to the key is stored in the internal spring and the release of this energy results in the hands of the clock rotating.
  - this was referred to as an approach called **methodological behaviourism** by Searle (Searle, 1994, p. 33).

- in behaviourism, there is no room of FREE WILL as their aim is to provide an account of human behaviour that avoids any mention of decision making or choice.

- behaviourists limit themselves to describing behaviour solely in terms of deterministic principles.

The Behaviorist Stance…

- the theory of behaviour is defined with respect to a set of laws of behaviour and the aim of behaviourism is to uncover these laws in order to predict & control behaviour.

- any theory that attempt to explain human behaviour should only contain statements about observable objects & events.

Logical behaviourism

- **logical behaviourism is an extreme position that rules out discussion of anything but observable events and entities in our accounts of behaviour.**

- **it aims to rid our explanations of any mention of mental states or processes in a bid to focus only on observable entities.**

- Consider this statement:

    1. William is thirsty

    2. If there were water available then William would drink

- According to logical behaviourism, everything that you wish to predict from stating that “William is thirsty” can be accounted for by stating (2), these statements being referred to as **behavioural dispositions.**

- Logical behaviourists prefer statements like (2) because these make no mention of anything unobservable.

- Another example,

  1. Harry believes it will rain.

  2. Harry will be disposed to wear a raincoat and take an umbrella when he goes out.

- As Churchland (1984) notes, by such a behavioural perspective, mentioning mental entities is nothing more than a “shorthand way of talking about actual and potential patterns of behaviour”.

- Think!!! as this has been considered by many as a challenge to the cognitivist position.

Criticisms to Logical behaviourism

- there are very good reasons to resist this line of argument.
  - for e.g. when one begins to analyse any particular behavioural disposition. Consider what "disposition" amounts to.

- Harman (1989) noted, “Whether you are disposed to take an umbrella with you depends on not just your belief that it will rain but also your desire not to get drenched, your perception of the umbrella in the corner, your further belief that umbrellas are good for keeping rain off, & so on (p. 833)”

- attempting to analyse any behavioural disposition inevitably leads to some form of reference to mental states, and/or processes such as beliefs, emotions, thoughts etc.

- Another objection was raised by Searle (1994, p. 35).
  - he reflected about what it means to be human & asks whether you can honestly say that logical behaviourist view corresponds with the 'ordinary experiences of what it is like to be a human being'.
  - for instance, can we really explain our behaviour without mentioning our thoughts & feelings?
  - is 'to be religious' really only a collection of dispositions such as attending a place of worship on holy days?

- Consider this example:
    - Logical behaviourists would have us believe that to have a pain is nothing more than to ‘be inclined to wince, to take an aspirin etc. (Churchland, 1984, p. 24).

To sum up…

- In summary, logical behaviourists substitute statements about mental states & processes with statements about dispositions to behave in certain ways.

- yet, in attempting to explain all of human behaviour in terms of behavioural dispositions, the approach fails to acknowledge that we as humans are sentient beings and that we typically act in ways that are determined by our thoughts and feelings and beliefs.

References

- Quinlan, P. & Dyson B. (2008). Cognitive Psychology. *Prentice Hall*.

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Course Title:

Basic Cognitive Processes

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Lecture 05: Foundations of Cognitive Psychology

A brief recap…

- In the last lecture we were talking about:
  - Scientific method to approach the mind & explain behavior.
  - We talked about the Behaviorist approach, its implications & limitations.

The Cognitivist View

- the **Cognitivist View**:
  - assumes that there is an abstract entity called the mind & that is composed of mental states and mental processes; &
  - is concerned with exploring the nature of these mental states & processes.
- Cognitive Psychology may be defined as the study of mind, to the extent that we can generate testable statements about these abstract entities.

- How?
    - o we operate within a framework where we make certain assumptions about the subject of enquiry, & on the basis of these assumptions we generate certain hypotheses that result in testable predictions.
    - o importantly though, for our science to work properly we must attempt to generate falsifiable theories.

- e.g. in designing a new aircraft, one needs to test the safety of the aircraft in order to evaluate performance & safety standards.

- it would be foolish to only test the aircraft on a clear, sunny day; when the chances of failure are anyways minimal.

- we would like to test the aircraft in the hardest of flying conditions, in order to be sure about the safety standards of the design.

- Similarly, theories of human cognition will be useful only if they are falsifiable.

- Karl Popper (1963, 2000)concluded the following in order to evaluate the theory of anything:

    - it is easy to verify.

    - it is refutable, else unscientific.

    - every genuine test of the theory is any attempt to falsify it.

    - confirming evidence does not count unless it is a result of a genuine test of the theory.

- in line with the above, Cognitive Psychologists are allowed to posit abstract entities on the assumption that they can be tested in a scientific way.

- theories in cognitive psychology, must be testable, refutable, & falsifiable.

- Further, theories in cognitive psychology also should be extremely simple i.e. parsimonious.

- Let us try an example:

  - Mental Arithmetic, i.e. a set of numerical operations that are carried out in the mind. e.g. compare (14 x 5) with (17 x 3)

    - although we differ in our abilities to carry out mental arithmetic, from a cognitive perspective it seems fairly reasonable to assume that this ability depends upon mental representations (of numbers) & mental processes (for calculations).

- Whether the cognitive explanation is necessary to postulate mental operations?
    - It could be possible that there exists a rather simple device that can ‘solve’ these kinds of problems.
    - But we are reluctant to accept a cognitive operations theory.
    - So, maybe a physical device.

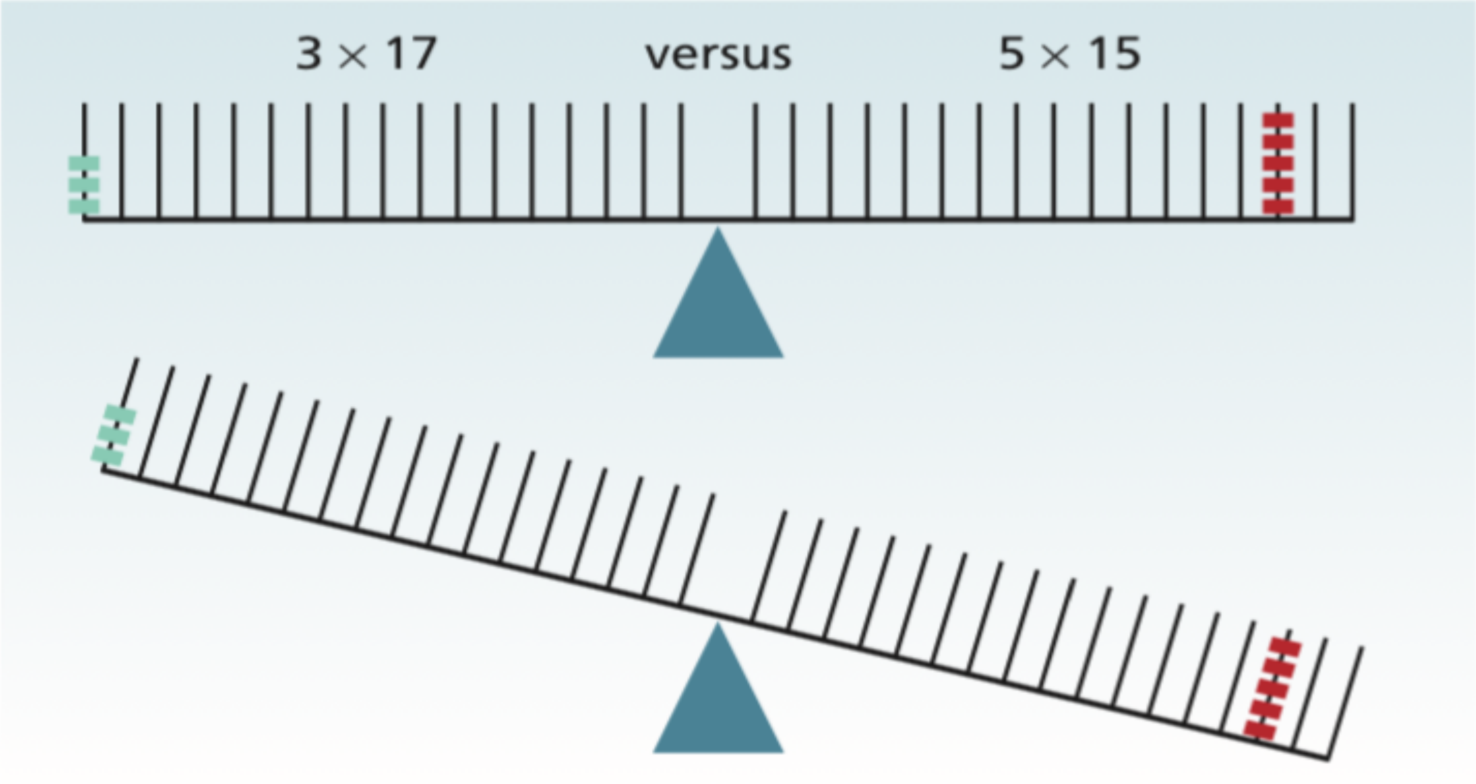

Figure 1.3 Balance beams 'do' mental arithmetic? Schematic representations of a balance beam and its ability to 'figure out' which of two products (i.e., weights × distance on the left vs. weights × distance on the right) is the greater.

Image: Quinlan, P. & Dyson B. (2008). Cognitive Psychology. *Prentice Hall*.

- the dilemma is that, while cognitive psychologists would wish to offer a cognitive account of the behaviour of the human in solving the problem, they would not wish to provide such an account for the balance beam.

- Solution = Considering the differences:
  - While the balance beam is stuck at the level of simple multiplication, and consequently, the special purpose mechanistic approach to mental multiplication offered by the balance beam fails to provide a more comprehensive explanation of how mental arithmetic is carried out in general.
  - Humans on the other hand can handle a versatile range of mental calculations that cannot best be handled by such a physical device.

Let us see why?

- in order to answer this question well, we have to look at the fundamental question we raised earlier: How are the mind (abstract) & the brain (Physical) related?
- Let us now explore various possibilities that have been proposed…

- **Central State Identity Theory**:
  - our mental lives are intimately connected with the things that go on in our brains. e.g. brain damage results in deleterious effects on aspects of cognition & behaviour.
  - Various attempts have been made to explore the mapping between mental events (e.g. thinking of a Burger) and neurological events (such as neuron assemblies firing).
  - The assumption is that the two are related, its the mechanisms & processes that are still under investigation.

- The **central identity theory** therefore forms the foundation of all current work in human neurosicence/ cognitive neuroscience.

- There are two versions of this theory:

- **Type Identity Theory:** each type of mental event maps onto a different type of neurological event; e.g. remembering to perform task X maps onto a pattern of nerve cells firing & choosing not to perform the task X maps onto a pattern of B nerve cells firing.

- one has to be careful with the words like “maps onto” or “corresponds to”; saying these terms we might be adopting the materialist view, which assumes only physical states & hence it is easier to say that mental states = brain states & processes.

- take an example: if you hurt yourself (say hitting the door with one of your toes!!!)

- the defining element of pain will be the sensation of hurting.

- something peculiar with pain is that is not merely a sensation but also a matter of perception/subjective experience.

- so, the problem with identity theory is that it seems to force different things to be the same, so there is the feeling of pain (a mental event) and there is this pattern of nerve cell firing (which is a physical event).

- if one follows the materialist perspective,we assume that everyone's experience will be perfectly predicted by the neural activity.

- Searle (1994) raise the **different brains problem.**

- Consider the following example:

    - Jones thinks it might rain, nerve cells A,B,C, & D fire.

    - Smith's brain is different from Jone's brain & hence when Smith thinks it might rain, nerve cells E, F, G, & H fire.

- Both men are entertaining the same thought, but different cells are firing in the different brains.

- this is the basic problem: different types of neural events might be underlying the same thoughts in the two different brains.

- **Token Identity Theory** asserts that mental events correspond with neurological event, but there is an acceptance that there may well be a variety of neurological events that may underlie each mental event.

- Hence, it is quite acceptable that the firings of nerve cells A,B,C, D and also E, F, G, H may separately correspond to the same thought in different brains.

- As it stands, it is token identity theory’s brand of materialism that provides the foundations for all kinds of work in cognitive neuroscience.

- Even, this version may run into difficulties concerning understanding of subjective experience. But, we need to assume that it's ok & move on!

- On a different note: if we accept that different patterns of nerve cells firing may give rise to the same thought, we need to be clear about what it is about these patterns of firing that gives rise to the particular thought.

Functions & functional Roles…

- function, could be the purpose of anything.
    - as the function of the umbrella or the chalk or the board etc.
- so, the structure of something could be different from its function: i.e. what is the physical make - up & what it does!

- Take an example of a car engine.
  - o we could offer a **functional description** of the engine by specifying what the purpose of each component is.
  - o the assumption is that to attain a full understanding of the workings of a car's engine we need to have:
    - a description of the structure of its components
    - a specification of how these are interconnected
    - a complete description of the functional role of each component.

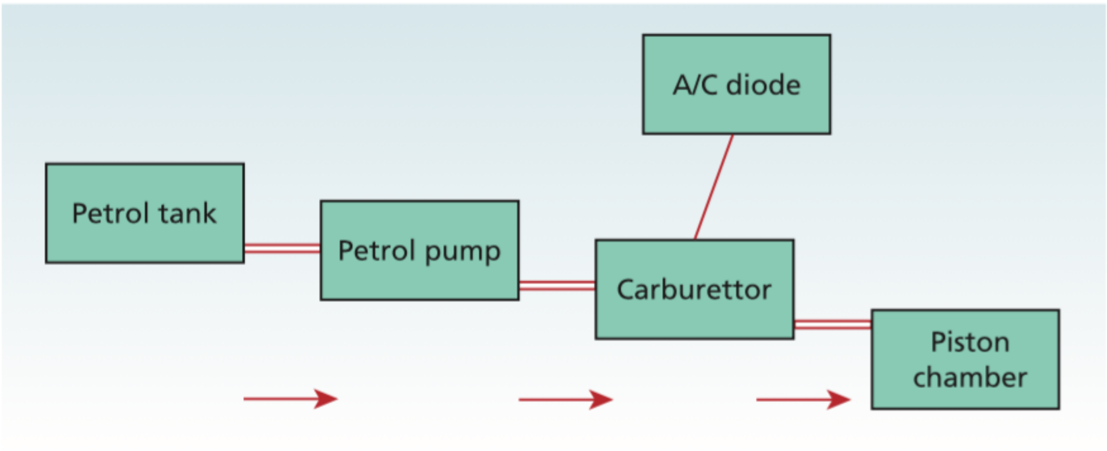

Figure 1.5 The usefulness of a blueprint
A schematic representation of some of the components of a car's engine.

Image: Quinlan, P. & Dyson B. (2008). Cognitive Psychology. *Prentice Hall*.

- now, while the earlier diagram is useful because it gives an idea of what the structural components are & how they are connected; it does not help us by telling how each of these function.

- We would be better served if we have a functional description of the components…

- traditionally, such a design eventuates in a **schematic diagram** that specifies each component and shows how each component is connected with other components.

- such a diagram may also reveal the flow of control between various components. e.g. the direction of flow petrol from the tank via the pump to the carburettor.

- Another interesting aspect of this is - that at the level of the diagram we are not so bothered about how close the different components are to one another - whether the pump is next to the tank or the carburettor - we are primarily concerned with how the components are interconnected with one another.

- however, if we embellish the structural information with a description of the functions of the individual components , it would be very useful.

- In our case, such a description allows us to discuss each of the individual components in the abstract, i.e. without commitment to any particular physical entity.

- the focus shifts to the function & not so much to the structure.

- **Functionalism**:
  - it is now possible to see how two different brain states may underlie the same mental state - as long as the two neurophysiological states serve the same functional role, then they capture the same mental state.
  - mental state **x** is defined purely in terms of its function.
  - this is called **functionalism.**

- **Function** is now defined in terms of causation – the mental state **x** has a particular function insofar as it leads to the same consequences, be the new mental states or some form of behavior.

- **E.g.** Anne thought it was going to rain & remembered that she had left her kitchen window open. She would go to close it.

- **Here,** mental state **x** caused mental state **y** and results in action/behavior **z**.

- So, as long as the functional description of the mental states and processes is the same for different individuals then our understanding the particularities of the underlying neural apparatus are generalizable.

To sum up..

- The cognitivist view of mind & behavior allows the assumption of abstract mental events as theoretical basis of human behavior.

- Further, it stresses on generation of scientifically testable assumptions which can form explain human behavior in a scientific, though simple manner.

- Further, it takes the functional description of mental states

References

- Quinlan, P. & Dyson B. (2008). Cognitive Psychology. *Prentice Hall*.

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Course Title:

Basic Cognitive Processes

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Lecture 06: Foundations of Cognitive Psychology

A brief recap...

- In the last lecture, we talked about the Cognitive Perspective on human behavior.
- We also talked about the issues of functional description of the mind's architecture.

Flow charts: the mind, the brain…

- the hardware/software distinction!
  - hardware refers to any physical device that is either a computer itself or a peripheral that may be linked up to a computer (e.g. printer).
  - software refers to the programs that run on the computer.

- We know that, the computer us a physical device but its programs are abstract (remember ‘abstract’).

- so we talk about the software without reference to the physical hardware involved in the computer.

- by adopting such a functional approach, we can argue that, by analogy, '**The mind is to the brain as the program is to the hardware**' (Searle, 1994; p.20).

- So, cognitive psychologists endeavor to understand the programs that collectively make up the mental activity: they essentially deal with **flowcharts of the mind.**

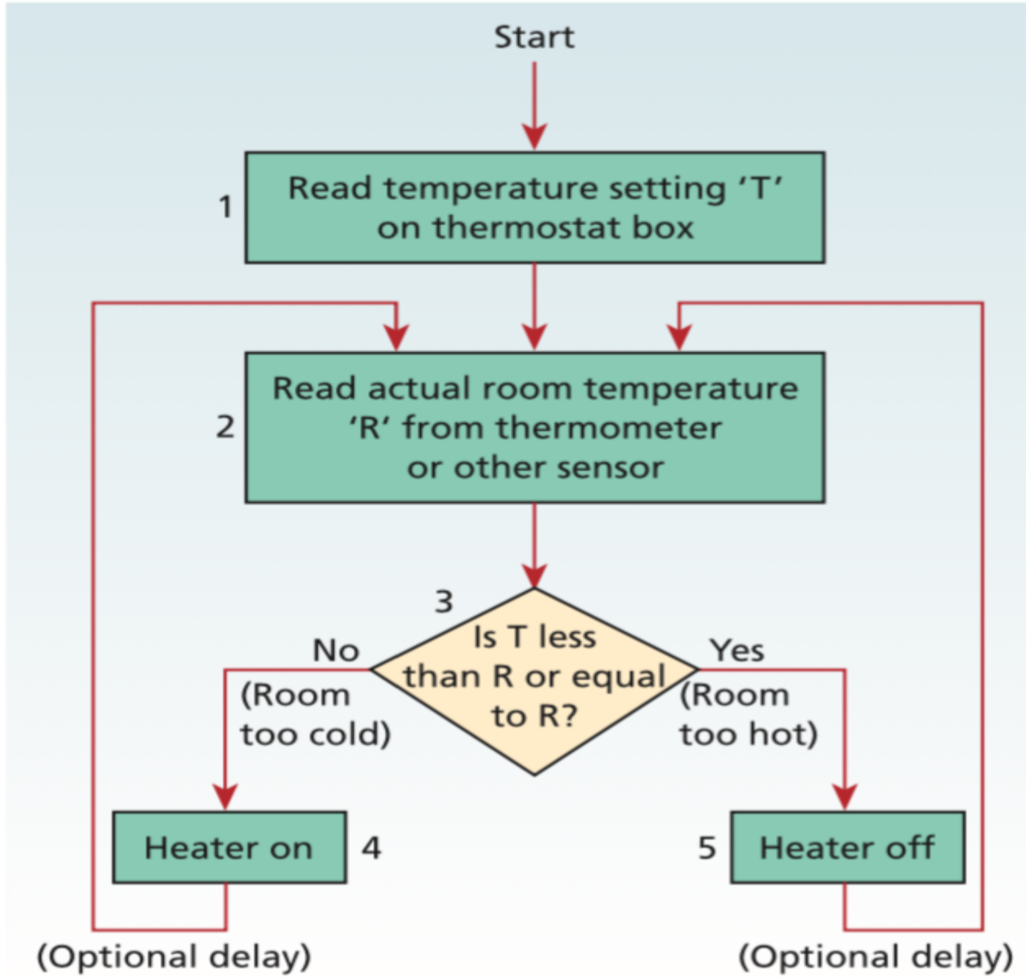

Figure 1.6 A flow chart of the operation of a thermostat

Source: Zaks, R. (1980). *Programming the 6502* (fig. 1.1, p. 9). Berkeley, California: Sybex.

Image: Quinlan, P. & Dyson B. (2008). Cognitive Psychology. *Prentice Hall*.

- while the last diagram gives us an idea of functional parameters of a thermostats; it needs to be supplemented with the knowledge of actual physical components to actually be able to build a thermostat.

- The problem is more complex when you consider human cognition: we already have our device ready (the brain) & we are trying to figure out just what is going on.
- So, we do **reverse engineering**, i.e. we are trying to understand how the workings of the brain underpin the mind.
- Big Jigsaw Solving Enterprise = Cognitive Psychology!

- we have to begin by accepting in the first place, that the brain is more complicated than thermostats & beam balances!

- then we need to talk about concerns relating to mental states, representations & processes (i.e. mental entities).

- by analogy they seem akin to computer states, representations & processes. hence, metal software analogy! or the idea that the brain be characterised as a **information processing system.**

- then we need to talk about the information from the world (input), the codes that represent the input and the responses (output).

Marr's Levels of Explanation...

- Acc. to Marr (1982) there can be 3 possible levels of explanation:

  1. The level of computational theory
  2. The level of the representation & the algorithm
  3. The level of the hardware implementation

- at the level of **computational theory**, the concern is with what the device does & why it does it.

- here is where Marr spells out the 'logic of strategy' (Marr, 1982, p.28).

- e.g. how does a calculator carry out arithmetic operations.
    - analysis at this level will address the fact that the calculator carries out various arithmetic calculations (what) & the fact that it uses a particular method to carry these operations out (why).

- for instance, an early HP calculator (the HP35) used a method known as Reverse Polish.

- So expressions such as (1+ 2) X 3

- were entered as 123 X +; known as the postfix notation.

- The computational theory would here be concerned with issues like why Reverse Polish was used & what the underlying principles are.

- **at the representation & algorithm level** detailed questions are asked about the nature of the calculator's operating system & the manner in which numbers & arithmetic processes are embodied in the device.

- so, how information is stored (i.e. represented)& also how arithmetic operations are instantiated.

- more simply put, how in any information processing device, information from the outside world is represented internally within the device.

- So for example when number 2 is entered into the calculator it is represented via some form of electronic code. This form of **internal representation** stand for number 2.

- By analogy where the mind is concerned such internal (mental states) stand for (i.e. represent) actual states in the world.

- what happens to such information is a matter for the **algorithm**, or the set of operations that are carried out on these representations.

- in computer science the word ‘algorithm’ is mainly used interchangeably with the phrase ‘computer program’.

- So, if you entered a + sign into the calculator & it is working properly then it should invoke it's addition algorithm.
- the addition algorithm comprises of the sequence of operations that determine that how two numbers are added together.
- So understanding the calculator depends on trying to specify the nature of internal representations & associated processes

- in terms of understanding of human cognition, then, we need to consider both mental representations & mental processes.

- in this respect the functional account should not only provide a flow chart that maps out the relations between component processes, but also some description of the sorts of internal representations that are implicated.

- at the **hardware implementation level,** concerns are about how the designated representations & processes are implemented physically.

- what physical components are needed to build up the device?

- this is strictly speaking outside the scope of our commitment but some explanation towards the same is warranted.

- at the **hardware implementation level,** concerns are about how the designated representations & processes are implemented physically.

- what physical components are needed to build up the device?

- this is strictly speaking outside the scope of our commitment but some explanation towards the same is warranted.

- If we accept some version of the central state identity theory; then we are accepting that mental states & processes are nothing other than neural states & processes.

- According to reductionists, understanding the human mind can be reduced to understanding the basic electrochemical states and processes that characterises the behaviour of neurons.

- So, if we understand these physical states and processes, we understand the mind.

- Another version of reductionism is known as **eliminative materialism**.
  - Churchland (1984) states, that once we have a full understanding of the behaviour of neurons in terms of basic electrochemical principles, we can then eliminate any mention of any other level of description from our science.
  - Maybe we can get rid of the mind after all?

- So, what would cognitive psychologists do?

- Even if one has a complete account of the nature & operation of neurons; this is a completely different level of explanation that what cognitive psychologists are actually concerned with.

- As cognitive psychologists, we are interested in uncovering the functional architecture of the mental components that constitute the mind - the flowcharts - & in this regard the properties of neurons are of little help.

To sum up...

- We talked about how the mental functions can be represented in a framework as hardware/software.

- We talked about the levels of description proposed by Marr (1982) to explain the nature of the human mind.

References

- Quinlan, P. & Dyson B. (2008). Cognitive Psychology. *Prentice Hall*.

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Course Title:

Basic Cognitive Processes

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Lecture 07: Approaches towards Cognitive Psychology

What do we know so far?

- Cognitive Psychology is the study of the human ‘mind’ & mental processes.

- Cognitive Psychology seeks to understand & explore the functional architecture of the human mind.

- Cognitive Psychology follows closely the human as a information processing system view or that , “*the mind is to brain what the software is to the computer*” analogy!

- In the current lecture we will try & look at this approach in more detail & often try to compare it with some other possible approaches!

- We will try to see possible architectures of the human mind.

The Problem at Hand...

- We are faced with a black box.

- The rules of engagement are quite clear: we cannot physically attempt to open the black box &

- So, in order to make some headway, we simply accept the foundational assumption that the black box contains an information processing system & set ourselves the goal of trying to understand the nature of its putative internal states & processes.

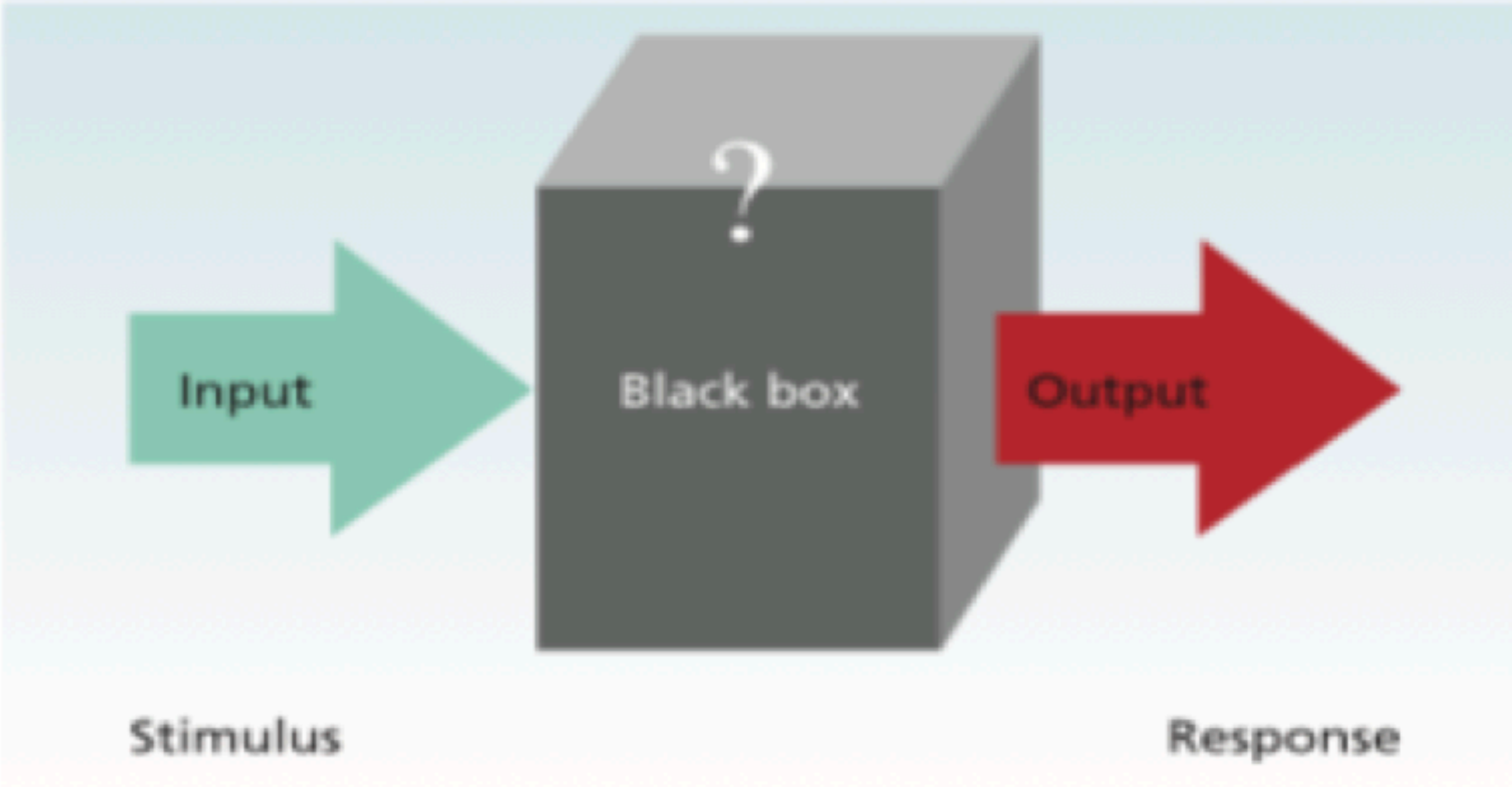

Figure 2.1 The black box that is the human mind
As cognitive psychologists, we are trying to figure out the internal workings of this black box merely from observing its behaviour.

Image: Quinlan, P. & Dyson B. (2008). Cognitive Psychology. *Prentice Hall*.

Where do we begin?

- "How do we understand what a computer is doing when it is running a particular program?'
  - the aim is to try to get someone else (a naive observer) to uncover what is going on when the computer runs the program.
- this is an example of the program:

- Line 1: **Program** Fun Yet
- Line 2: **Begin**
- Line 3: **Print** “Are we having fun yet?”
- Line 4 **Get** (response)
- Line 5: **If** response = “Yes” **GOTO** Line 6 **OTHERWISE GOTO** Line 3
- Line 6: **End.**

Various Approaches…

The Cognitive Approach

- the observer adopts a non - invasive method of studying the device.
- the observer attempts to vary the input to the program (i.e. types in different responses) and notes down any systematic changes tat relate to this variation.
- by noting any such systematic variation in what is typed in and what occurs as a consequence, the observer expects to generate a flow diagram of hypothesized component processes.
  - for instance:
    - certain input processes will be proposed, certain decision processes will be proposed & finally, certain output processes will be proposed.

The AI approach

- the aim is to try & generate a new computer program that mimics the behavior of the observed program.
- Success would be gauged if the new program mimics the behavior of our observed program in all critical aspects.
- Not only we have thought of a flowchart description, we have operationalized our ideas in the new computer program.
- we have provided a **demonstration proof** that the particular representations and processes embodied in the new program are sufficient to solve the task.

- a claimed benefit of this approach is that it forces the theorist to formulate, very precisely the assumptions that underlie theory.

- the ideas must be precise as they are to be operationalized in a computer program.

- we have a demonstration proof that the operations specified in the program are sufficient to explain the behaviour. & the theory has been shown to work.

- Such an AI approach provides the means to address detailed issues at the level of representation and the algorithm (Marr, 1982).

The neuroscience approach

- Or, we might just decide to try to observe & measure the inner workings of the particular computer that the program is supposed to run on.

- Now because we are following a non - invasive approach & are not allowed to break open the the computer's casing, nor tamper with any of the internal components in any way - maybe we should measure changes in the magnetic fields that are generated by the computer's components as the program runs?

- the ultimate hope, is that if we observe the changes in the states of its physical components (i.e. of the transistors) as we run the program, then this will tell us something fundamental about the nature of the program itself.

- The idea is very similar to the neuroscience approach that is being adopted.

- We are beginning to map out which areas of he brain become particularly exercised when a person is engaged in certain cognitive tasks.

- However, so far, little has been learnt about cognitive processes that are assumed to be associated with such changes in brain activation.

- Much is being learnt about the structural organisation of the brain (where stuff happens) but, little has been learnt about cognitive functioning (what is happening & how).

Information Processing Approach

- Information theory was introduced by Shannon and Weaver (1949) as a mathematical account of the operation of any type of communication system.
- It provides basic assumptions that underpin our ideas about information processing systems.
- Consider the example of two (Speaker Andy & Listener Lou), conversing over the telephone where both participants are talking via a landline phone.

- An information source (i.e. Speaker Andy)
- A transmitter (i.e. Speaker Andy's telephone).
- A channel (i.e. the cable interconnecting the two handsets)
- A receiver (i.e. Listener Lou's telephone)
- The destination (Listener Lou)

Figure 2.2 The basics of a communication system
A schematic representation of a communication system as described by Shannon and Weaver (1949) in their discussion of information theory.

Source: Haber, R. N. (1974). Information processing. In E. C. Carterette, & M. P. Friedman (Eds.), *Handbook of perception* (Vol. 1, fig. 1, p. 315). London: Academic. Reproduced with permission from Elsevier.

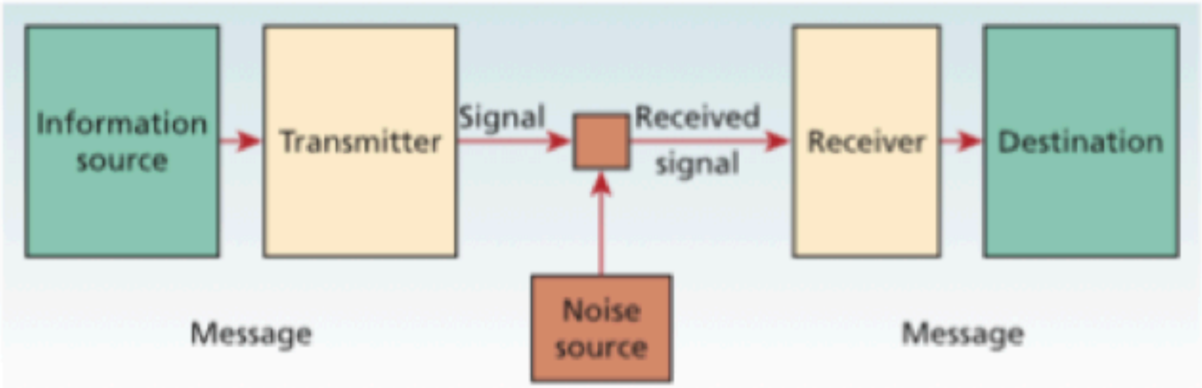

Image: Quinlan, P. & Dyson B. (2008). Cognitive Psychology. *Prentice Hall*.

- In this communication system, the auditory input is converted by the transmitter into an electrical signal which then travels downtime line.

- This signal is then re-converted into an auditory output at the receiver.

- For Shannon & Weaver (1949), the important issues concerned how efficiently such a system might operate. In this regard, they attempted to quantify a number variables, namely:
    - the channel capacity
    - the rate of transmission
    - redundancy of encoding
    - noise

- Shannon & Weaver (1949) developed a general statistical formulation for describing the inter - relationships between the variables.

- importantly, their account was couched at an abstract level because their ideas were developed independently of how the communication system might actually be physically instantiated.

- Haber (1974) wrote that their objective was to develop a communication system with general statistical concepts ‘independent of the specific types of channels; the types of senders & receivers and most critically, the nature or the content of the information flowing through the channels’.

- **Information Theory & Redundancy**

    - the notion of redundancy can be used to refer to the amount of information present in a given signal (here the signal refers to a given stimulus).

    - the important point is that in being able to define and quantify information, it s also possible to measure it.

    - this was a vital addition as now psychologists could conceive of ways measuring something couched at the psychological level; that is independently of stimulus & responses.

- another way of thinking about redundancy is in terms of how much of the signal can be correctly predicted from the other parts of the signal.

  - a highly redundant signal is highly predictive. But how is this to be measured?

  - in addressing this, the aim was now to try & quantify how predictive signals are. for e.g. if a message is highly predictive, we could get away with deleting the irrelevant bits and just leaving the relevant.

- Shannon & Weaver took it upon themselves to try to quantify information purely in terms of statistical means by using things like the frequency of co-occurrence of parts of the message. for instance, they realized that the amount of information increases with the number of things that might have occurred at a given point in the signal.

- e.g. in the message, “We should meet tonight because that’s a good time to elope’. it has very low redundancy as Lou would be unable to reconstruct the intended meaning if all that he heard was “We should meet ****** because that’s a good ***** to ****.”

- here Andy could have asked Lou to meet “at the corner” or “at 9 pm” etc.

- In contrast if you take another example: if y invariably follows x and hearing x implies hearing y, then y is fully redundant with respect to x.

- **Information Theory & human information processing**

    - We now know that the modern world depends upon the telecommunication systems that are fundamentally based on the properties & principles identified by Shannon & Weaver (1949).

    - these early ideas also influenced cognitive psychologists; for example by providing them a framework for thinking about how the human mind might operate in the abstract.

    - it also provided the foundations for the assumption that the mind may be characterized as an information processing system whereby stimulation at the senses enters into a complex communication system.

- Models of cognitive processing based on the central tenets of this information processing framework soon began to appear.

- Psychologists were quick to realize that for humans, the notion for information was more difficult to define than by the simple sorts of statistical measures used in the information processing theory.

- It is not so much about the words which are spoken but the what meanings are trying to conveyed (Mac Kay, 1961): ‘dog bites man’ is much less informative than ‘man bites dog’.

- But the approach forced psychologists to consider a whole new way of thinking about human cognition.

- The classical information processing view is that the human organism consists of certain sensory systems (eyes, ears etc.) which operates as receivers of external inputs; these receivers operate to encode these inputs via sensory transduction.

- the encoded information is then passed on, via abstract information processing channels, to more central systems.

- the central system operate on the information in such a way that an appropriate response can be made.

- While it might resemble the behavioral stance, cognitive psychologists are more concerned with the internal (abstract) events that intervene between the stimuli & responses.

To sum up...

- In this lecture we talked about a variety of possible approaches that can be taken towards understanding the architecture of the human mind.

- Also, we looked at the information processing approach to the human mind & possible consequences that had for cognitive psychology.

References

- Quinlan, P. & Dyson B. (2008). Cognitive Psychology. *Prentice Hall*.

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Course Title:

Basic Cognitive Processes

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Lecture 08: Modularity and Cognitive Neuropsychology

What do we know so far?

- The definition of Cognitive Psychology.
- Various Possible approaches towards understanding the architecture of the mind.
- In this lecture we will see how the concept of modularity forwarded by Jerry Fodor helps us in understanding the architecture of the human mind.
- How can the field of Cognitive Neuropsychology help us understand the human mind/brain relationship?

So, What is the Mind really like?

- Let us turn to the architectural considerations of the mind.
    - Fodor (1983) would like us to discuss the functional architecture of the mind!
    - he puts forward something called the **modularity hypothesis**, i.e. the idea that the mind may be composed into smaller & discrete sub processes & modules (Fodor, 1983).

- **Marr's Modular Design**
  - Marr (1982) was particularly interested in something he termed as **the principle of modular design** & he advanced the argument in terms of the example of a computer programmer who is designing a large & complex computer program.
  - One approach to this problem has already ben discussed in the car - engine example.
  - The central idea is to break down the overall endeavor into manageable sub - projects where each sub - project maps onto a particular component (or module).

- the program may be divided into separate modules or sub - routines that can be developed independently of the program.
- Indeed, with very large software packages, each sub - routine will have its own dedicated set of programmers who collectively work to develop it.
- Although Marr (1982) wrote with respect to implementing large & complex computer programs, his points should be taken as applying, by analogy to the evolution of intellectual capabilities.
- Acc. to him, there are clear advantages in having a complex system evolve along the lines of independent specialized sub - processes.

- One particular advantage of having a system evolve like this is that it becomes resistant to damage - it exhibits **resistant to damage**.
  - if the system is composed of the independent interconnected components; then damage to one component may not have catastrophic consequences for the operations of other components.
  - Consider, if a program comprises of just one monolithic set of instructions then a change in any one instruction would have consequences for all ensuing instructions.
  - On the contrary, if the program is composed of independent routines, then it is possible to see that damage to only one componential not lead to problems with other components.

- Finally, Marr (1982) was also particularly taken with this principle of modular design because it allowed for a degree of operational independence across the different core components.

- The idea is that within a complex information processing system , the different modules can be getting on with their own tasks quite independently of what is going on in the other parts of the system.

- **Other conceptions of Modularity**

  - **Fodor's (1983) modularity hypothesis**.

  - Fodor (1983) began by discussing what he called Faculty Psychology - a loosely held set of beliefs that maintains that the mind is composed of very many different sort of special - purpose components.

  - Acc. to Marshall (1984), the bases of these ideas may be traced back to the ancient Greek philosopher Aristotle.

  - Aristotle's framework for thinking starts with the considerations of the five senses (sight, sound, touch, smell & taste) which map onto the respective sense organs.; which eventually do the sensory encoding or sensory transduction.

- Acc. to this view, sensory transduction associated with each sense organ eventuates in information being transformed into a common perceptual code - information presented in any modality is rendered into the same code.

- This code is then operated on 'in sequence, by the faculties of perception, imagination, reason & memory' and each of these faculties effected its own intrinsic operations upon input representations irrespective of the nature or type of those representations (Marshall, 1984).

- **Horizontal Faculties:** Fodor (1983) labeled the faculties of perception, imagination, reason & memory as horizontal faculties.

- these reflect general competencies that cut across different domains. For instance, cognitive abilities may be conceived as containing a memory component and, therefore, memory can be construed a a horizontal faculty.

- Remember the mental arithmetic examples (compare 17 x 3 vs. 14 x 5). the assumption is that performance in this task depends to some extent also on memory.

- Memory can therefore be construed as a horizontal faculty insofar as similar memory constraints apply to other quite unrelated competencies, such as ting to learn a poem off by heart.

- Acc. to Fodor (1983), horizontal faculties are defined with respect to what they do & are not defined in terms of what they operate on. e.g. same more constraints may apply to letters, number, pictures etc.

- **Vertical Faculties:** Another alternative is to carve up the mind into vertical strips or that of **vertical faculties.**

- Fodor cited the work of **Francis Joseph Gall (1758 - 1828)**. Gall's idea was that the mind is composed of distinct mental organ, with each mental organ defined with respect to a specific content domain.
    - For instance, there is a mental organ that underlies musical ability and a different mental organ that underlies mathematical ability and so on & so forth.

- So, vertical faculties are defined in terms of what they operate on.

- Gall took the argument further & proposed that each of these different mental faculties or organs could be identified with the unique region of the brain. i.e. He firmly believed that individual intellectual abilities, such as being musically adept; were directly linked with particular brain regions - that there are really distinct areas of the brain that embody a special purpose mechanism for music or math.

- This view formed the basis of Gall's phrenology, where particular bumps on the head could be interpreted as being associated with particular regions of the brain.

- Each of these regions embodied a particular intellectual capability & the prominence of the bump was indicative to the size of the underlying brain region. i.e. the size corresponded to how well developed the corresponding cognitive function was.

Image: http://throughablogdarkly.blogspot.in/2014/03/neo-phrenology.html

- In positing the vertical faculties, Gall provided a critique of the traditional view of horizontal faculties (Fodor, 1983).

- the notion of general faculties for memory, perception etc.was dismissed in favor of a framework for thinking in which a whole battery of distant mental organ are posited, each one of which has particular characteristics with respect to memory, perception etc.

- Gall's vertical faculties do not share - and hence do not compete for - such horizontal resources as memory, attention, intelligence, judgment, etc.

- So, the conflict between general purpose - vs specialised faculties.

- **Fodor's Modules**:
  - With the publication of Fodor's *The Modularity of Mind* **(1983)** a quite different meaning of modules was introduced.
  - Fodor (1983) distinguished between sensory transducers, input systems and central processors.
  - In order to understand these, let us also consider; **the proximal stimulus**: the stimulation of the sense organs and **the distal stimulus** the actual external object responsible for the sensory stimulation.
  - for example: the distal stimulus could be a stereo system & therefore the associated proximal stimulus would be sound vibrations one receives in the ear.

- the sensory transducers are the sense organs, & are responsible for taking the proximal stimulus and converting them into a basic sensory code.
- the code then acts as the input to the corresponding input system. For Fodor (1983), input systems are the modules referred to in the modularity hypothesis.
- Modules operate as the interface between the sensory transducers and the central processors. they deliver to the central processors; the best first guess of what the distal stimulus is, which gave rise to the stimulation.
- The final decision, about what the distal stimulus may actually be, is made by the central processors. Central Processors are concerned with the fixation of belief & planning of intelligent action.
- the fixation of perceptual belief is the act of making a final decision about the distal stimulus.

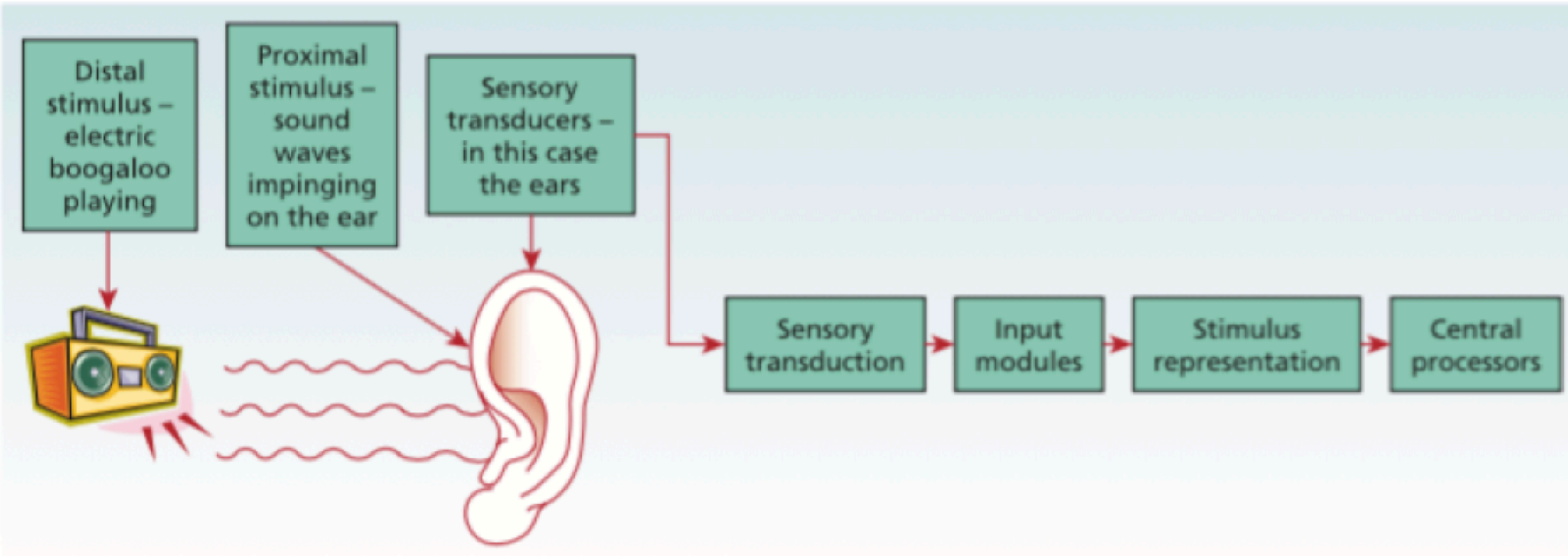

Figure 2.8 The modularity of mind thesis
A schematic representation of the core ideas behind the modularity of mind thesis.

Image: Quinlan, P. & Dyson B. (2008). Cognitive Psychology. *Prentice Hall*.

- All the really interesting things about thinking, believing & feeling are taken care of by the central processors.

- Fodor (2000) also claimed that the operation of central processors remains essentially unknown. The Black Box persists!

- **Making sense of modules!**

    - Fodor's modules are **domain specific**. there are many more modules than sense organs, so the visual system may contain more then one module; each of which takes on a different job: separate module exist for colour perception, for analysis of shape & the analysis of three dimensional spatial relations (Fodor, 1983).

    - Similarly, within the domain of language processing, Fodor, (1983) the possibility exists that different modules are used for encoding different sorts of linguistic input. Ex. separate modules for visual & spoken language.

- a recent take on the same has been ventured by Coltheart (1999) who stated that ' *a cognitive system is domain specific, if it only responds to stimuli of a particular class*'. & he speculates; there might exist a module responsible purely for face recognition & that comes into play only when confronted with faces & for no other visual objects.

Modularity & Cognitive Neuropsychology

- Fodor also proposed that:
    - Modules are associated with fixed neural architecture; of the adult human brain.
    - Modules exhibit characteristics and specific break down patterns.
- Now, if we accept the above two points we are conceding that a critical dependency relations holds between the mind & the brain.
    - if the brain is damaged, it is very likely that there will be negative consequences at the cognitive level.

- **Cognitive Neuropsychology:**
  - Cognitive Neuropsychologists are concerned with the operation of disordered brains. In that the assumption is, that much can be learned about the cognitive level when brains do not function normally.
  - Evidence from brain damaged individuals can provide converging evidence for particular functional accounts and may also provide critical constraints for such accounts.

- **Developmental Cognitive Neuropsychology** is the branch of the discipline concerned with brain disorders that develop as a person ages & that lead to some form of cognitive impairment, i.e. **developmental disorders.**
    - there are also **acquired disorders** that occur during the normal course of development, through injury or illness.
    - E.g. acquired aphasia due to stroke or other illnesses.

- In adopting the cognitive neuropsychological approach, the theorist attempts to understand the cognitive deficits following brain damage, by accepting certain key assumptions.
    - for instance, Coltheart (2001) discussed the foundational assumption that the same functional architecture is assumed to operate in all normal individuals.
    - Acc. to him, cognitive neuropsychology would simply fail if 'different individuals had different functional architectures for the same cognitive domain'.
    - Remember, that if we are trying to pursue cognitive psychology, then we are attempting to establish general principles that apply across individuals; i.e. if the functional architecture is same across people.

- the logic behind cognitive neuropsychology:
  - Cognitive neuropsychology is primarily concerned with the patterns of similarities and differences between normal cognitive abilities and the abilities of those who possess a disordered/damaged brain.
  - Typically, the interest is in the performance across a whole battery of tests; where each test is designed to examine a particular cognitive operation.

- Cognitive neuropsychology is distinctive in that it is the intensive study of single cases.

  - Performance of participants with brain damage is compared to that of normal individuals (control participants).

- **Association Deficits:** When a patient performs poorly on say, two different tests. for e.g. in understanding both written & spoken words.

    - this pair of impairments is said to be associated because they arise in the same person.

    - it might be tempting to conclude that performance in both tests depends upon the operation of a single underlying module.

- **Dissociation Deficits:** Funnel (1983) reported one patient who was able to read aloud more than 90% of the words but was unable to read even the simplest of non - words correctly ('dreed' was read as 'deared').
  - In such cases the abilities are said to be dissociated, because within the same person; one is impaired but the other is intact. The deficit on the two tasks in question could also be that of degree.

- However, if we look more closely:
    - in terms of our single dissociation, we have a case of two tasks that may either arise because of the operation of two different modules each of which operates on its own pool of resources (modular) or we can think of a non -modular system that contains a single resource.
    - In explaining the single dissociation; it is easy to accept the modular explanation; but it can also be explained through a non - modular system.
        - it maybe that the two tasks are not equated in their inherent difficulty so that the single dissociation may merely reflect the different demands that the two tasks place on a single resource.

- we can assume that the dissociation shows that task A performance is unimpaired or relatively unimpaired whereas task B performance shows a substantial deficit.

- By the resource arguments this can happen if task A is an easier task than task B.

- Task A makes fewer demands on resources than does task B; so any damage that results in depletion of mental resources will have a more catastrophic consequences for task B than task A.

- **double dissociation deficits:** Firmer evidence for mental modules arises when we consider the notion of double dissociation.
  - o the critical conditions for demonstrating double dissociations are two tasks A & B and two different patients I & II
    - A double dissociation arises, when patient I performs well on A & worse on B &patients II performs worse on A & well on B.

- Coltheart (2001) provided the following example: patient A is impaired in comprehending printed words but normal at comprehending spoken words; patient B is normal at comprehending printed words but impaired at comprehending spoken words.

- From this example there are seemingly good grounds for concluding that different modules underpin text & speech comprehension, respectively/

- More specifically, the double dissociation is most consistent with the idea that there is at least one module that is unique to comprehending printed words (damaged in patient A) and there is a unique module dedicated to comprehending spoken words (damaged in patient B).

- Moreover, such a double dissociation cannot be explained away in terms of resource allocation within a single non -modular system.
    - in simple terms, if task A demands fewer resources than B then; as we saw task A performance can remain intact even if task B performance is impaired.

- the reverse pattern cannot occur if the problem is assumed to lie in the allocation of resources in single non -modular system.

- Any problems in resource allocation will hurt the difficult tasks first & then the easy task; decrement on which will come out only after decrement in the difficult task.

- Colt heart (2001) however, also pointed out that this by no means definitive proof of modular architecture. for examples; double dissociations can arise in cases where different impairments to the same unified information processing system arise.

To sum up…

- In this lecture we talked about various possible architectures of the human mind.

- We talked about two conceptions of modularity (Marr & Fodor) and how they influence the approach to understanding the mind – brain relationship.

- We also talked about how the field of Cognitive Neuropsychology may help us understand the nature of interaction between the mind & the brain.

References

- Quinlan, P. & Dyson B. (2008). Cognitive Psychology. *Prentice Hall*.

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Course Title:

Basic Cognitive Processes

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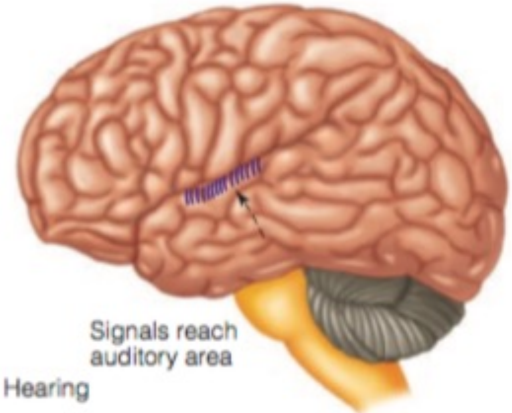
Lecture 09: Basic Concepts in Cognitive Neuroscience

What is Cognitive Neuroscience?

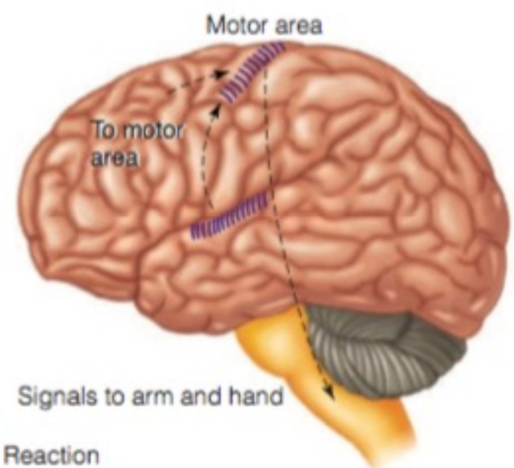
- Cognitive Neuroscience is the study of the physiological basis of cognition.

● **FIGURE 2.1** Some of the physiological processes that occur as Juan turns off his alarm. (a) Sound waves are changed to electrical signals in the ear and are sent to the brain. (b) Signals reaching the auditory areas of the brain—which are located inside the brain, under the hatched area—cause Juan to hear the alarm. (c) After Juan hears the alarm, signals are sent to the motor area. The two arrows pointing up symbolize the fact that these signals reach the motor area along a number of different pathways. Signals are then sent from the motor area to muscles in Juan's arm and hand so he can turn off the alarm.

(a) Sound to electricity



(b) Hearing



(c) Reaction

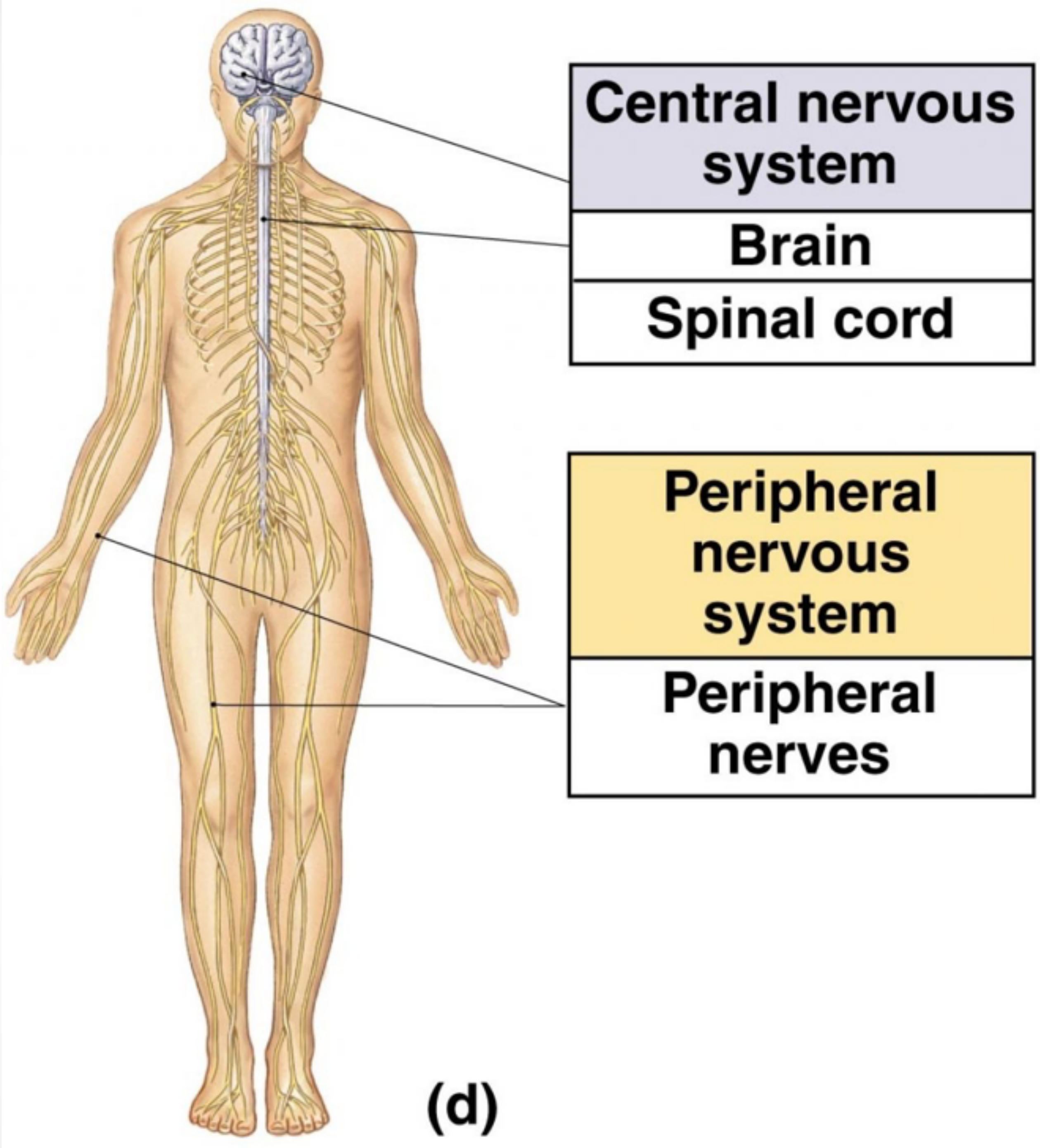
What do we do?

- We will study the brain's various structures & their relationship with human cognitive processes.

- We will try & figure out how such an investigation can contribute towards developing a theory of human cognition.

Organisation of the Nervous System

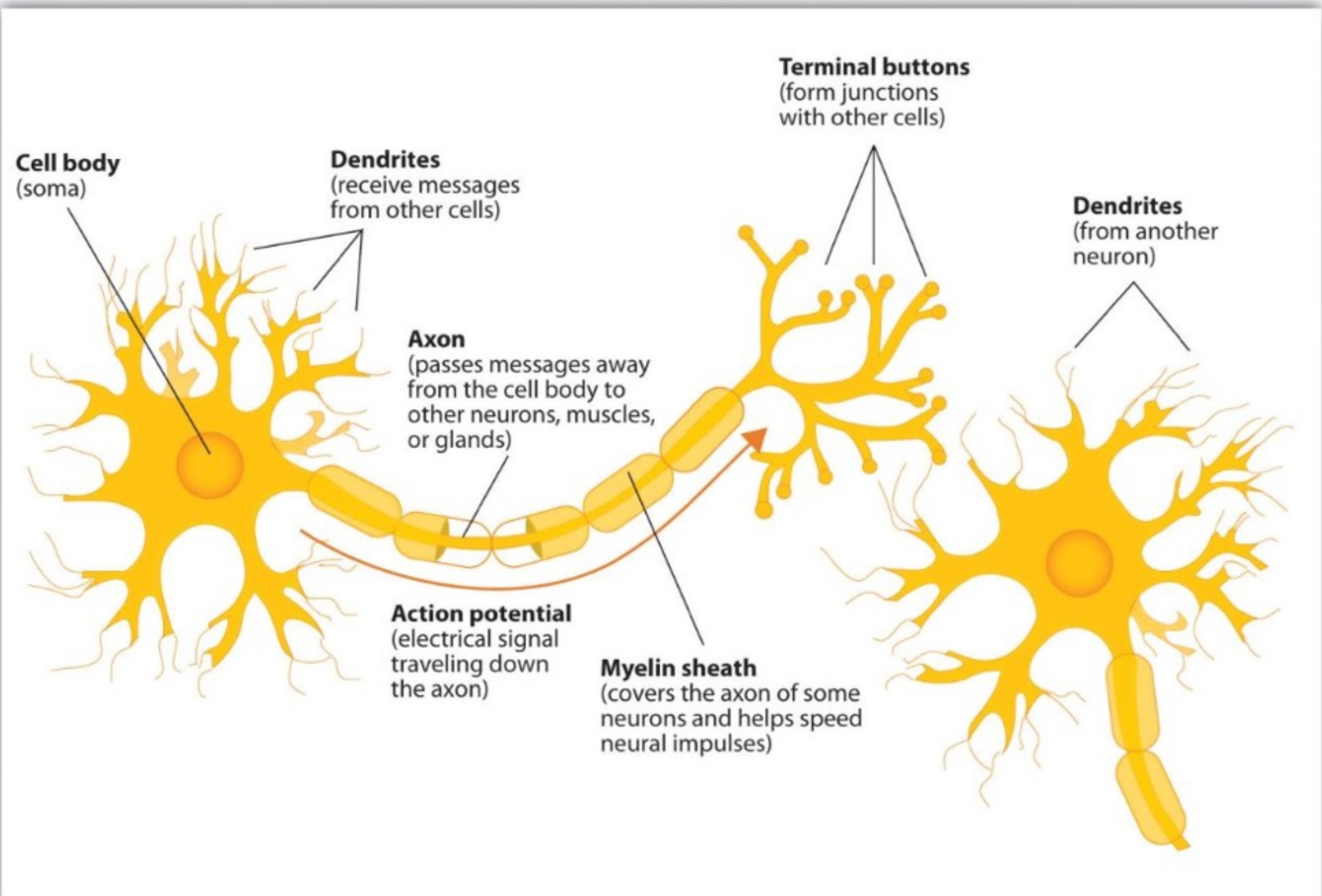
- The ***nervous system***, i.e. a collection of hundreds of billions of specialised and interconnected cells through which messages are sent between the brain and the rest of the body.
  - the ***central nervous system*** (*CNS*), made up of the brain and the spinal cord, and
  - the ***peripheral nervous system*** (*PNS*), the neurons that link the CNS to our skin, muscles and the glands.
  - a large part of our behaviour is also controlled by the ***endocrine system***, the chemical regulator of the body that consists of the glands that secrete hormones, influencing behaviour.


Central nervous system
Brain
Spinal cord
Peripheral nervous system
Peripheral nerves
(d)

Neurons: The Building Blocks of the Brain

- Cajal's discovery that individual units called neurons were the basic building blocks of the brain was the centrepiece of **neuron doctrine** - the idea that individual cells transmit signals in the nervous system, and these cells are not continuous with other cells as proposed by the nerve net theory.

Figure 3.2 Components of the Neuron



- ***cell body*** - contains mechanisms to keep the cell alive.
- ***dendrites*** - branches which emerge out of the cell body to receive signals from other neurons,
- ***axon*** - transmits signals to other neurons.
- for all neurons, there is a small gap between the end of the neuron's axon and the dendrites or cell body of another neuron. this gap is called a **synapse**.
- neurons are not connected indiscriminately to other neurons, but form connections only to specific neurons; to form **neural circuits.**

Communication of Neurons

- the nervous system operates using an *electrochemical process*.

- The neurons exist in an electrically charged environment, both inside & outside of the neurons exist electrically charged particles, called *ions*. Some of these are *positively charged* while others are *negatively charged*.

- When a neuron is inactive or resting, more of the "plus" charges exist outside the neutron and more "minus" charged charges exist inside; as a result the inside of each resting neuron in the brain has an electrical charge of about -70 mV.

- the electrical charge of an inactive neuron is called its ***resting potential.***

- however, the neurons are mostly busy:

  - messages arriving from other neurons raise & lower the resting potential.

  - if the electrical charge rises to about -50 mV, the neuron will reach its ***threshold*** or trigger point for firing.

  - when a neuron reaches its threshold, an ***action potential*** or ***nerve impulse*** sweeps down the axon at up to 200 miles per hour.

- ***What happens during an action potential***:

    - the axon membrane is pierced by tiny tunnels or holes called *ion channels*.

    - these tiny channels act like gates, which opens to allow the sodium ions to rush into the axon.

    - the channels open first near the soma, & then throughout the length of the axon as the action potential zips along.

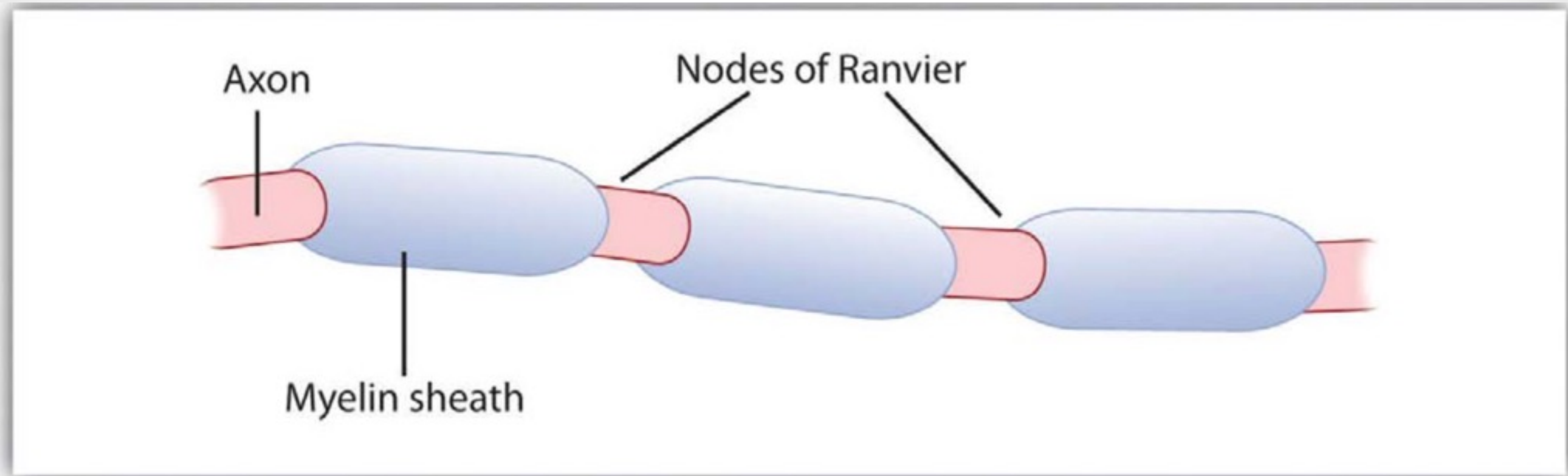
    - each action potential is an *all - or - nothing* event. So, a nerve impulse is first triggered near the soma, & then a wave of activity travels down the length of the axon.

- after each nerve impulse, the cell briefly dips below its resting level and becomes less willing or ready to fire. This negative after-potential occurs because potassium (K+) ions flow out of the neuron while the membrane gates are open.

- ***Saltatory Conduction***: the axons of some neurons are coated with a fatty layer called *myelin*, small gaps in the myelin help nerve impulses move faster.

- instead of passing down the entire length of the axon, the action potential jumps from gap to gap, a process called *saltatory conduction*.

- when the myelin layer is damaged, a person may suffer from numbness, weakness or paralysis. in fact, that is what happens in **multiple sclerosis**, a disease that occurs when the immune system attacks & destroys the myelin in a person's brain (Khan et al., 2010).


Axon
Nodes of Ranvier
Myelin sheath

- ***Synapses and Neurotransmitters*:**

  - in contrast to nerve impulses, communicated between neurons is chemical in nature.

  - the microscopic space between two neutrons, over which the messages pass is called a ***synapse*.**

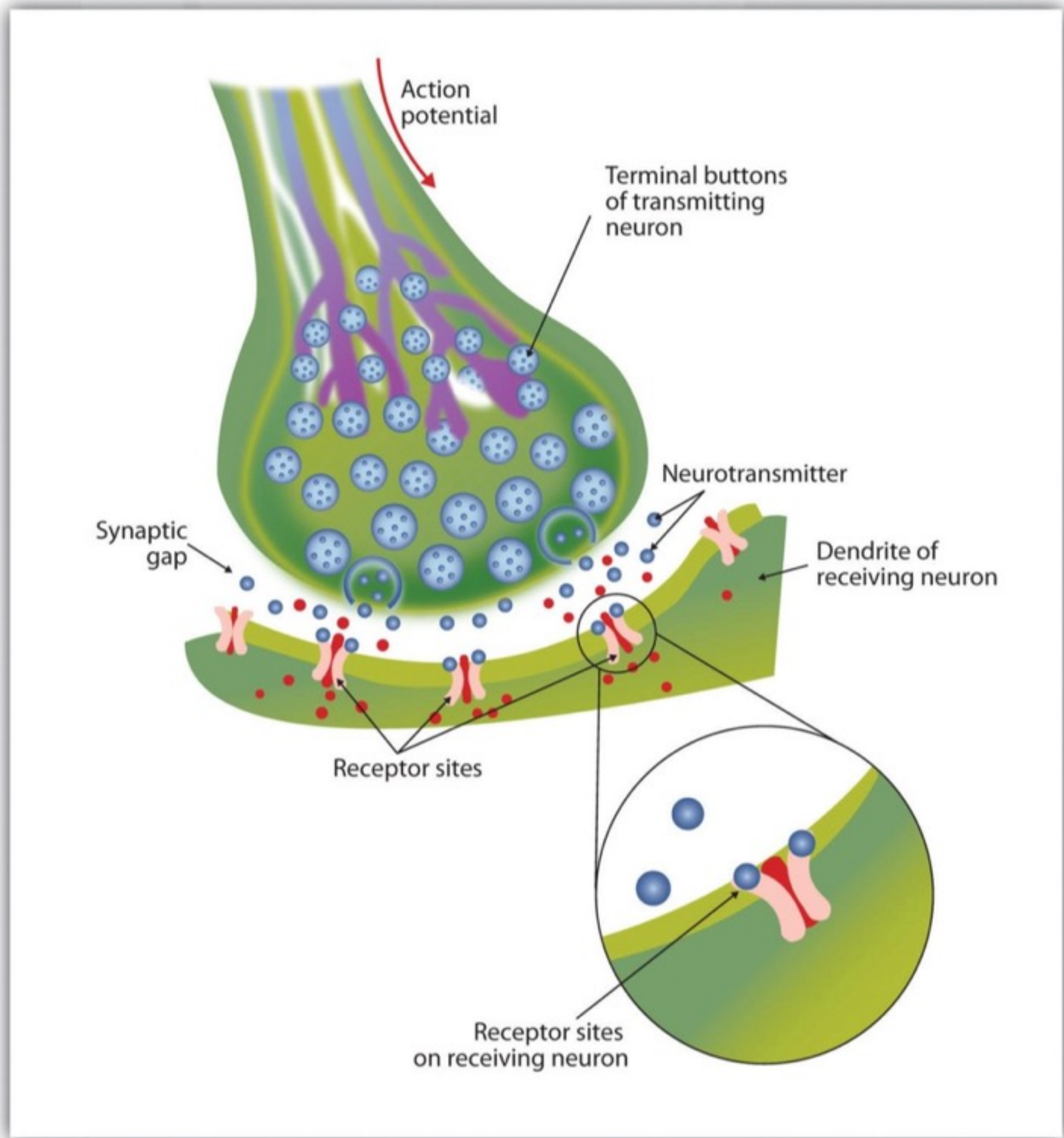
  - when an action potential reached the tips of the axon terminals, ***neurotransmitters*,** are released into the synaptic gap.

  - these are chemicals that alter activity in neurons.

- neurotransmitters travel across the synaptic space between the terminal button of one neutron and the dendrites of another neuron where they bind to the dendrites in the neighbouring neurons.

- different terminals release different neurotransmitters and different dendrites are particularly sensitive to different neurotransmitters.

- the dendrites will admit the neurotransmitters only if they are the right shape to fit in the receptor sites on the receiving neuron, the mechanism resembling that of a lock & key.


Action
potential
Terminal buttons
of transmitting
neuron
Neurotransmitter
Synaptic
gap
Dendrite of
receiving neuron
Receptor sites
Receptor sites
on receiving neuron

- When neurotransmitters are accepted by the receptors on the receiving neurons, their effects may be either *excitatory* or *inhibitory.*
- if the receiving neuron is able to accept more than one neurotransmitter, then it will be influenced by the excitatory or inhibitory processes of each.
- the summation of the two influences, governs the behaviour of the particular neuron.

Table 3.1 The Major Neurotransmitters and Their Functions

Neurotransmitter	Description and function	Notes
Acetylcholine (ACh)	A common neurotransmitter used in the spinal cord and motor neurons to stimulate muscle contractions. It's also used in the brain to regulate memory, sleeping, and dreaming.	Alzheimer's disease is associated with an undersupply of acetylcholine. Nicotine is an agonist that acts like acetylcholine.
Dopamine	Involved in movement, motivation, and emotion, Dopamine produces feelings of pleasure when released by the brain's reward system, and it's also involved in learning.	Schizophrenia is linked to increases in dopamine, whereas Parkinson's disease is linked to reductions in dopamine (and dopamine agonists may be used to treat it).
Endorphins	Released in response to behaviors such as vigorous exercise, orgasm, and eating spicy foods.	Endorphins are natural pain relievers. They are related to the compounds found in drugs such as opium, morphine, and heroin. The release of endorphins creates the runner's high that is experienced after intense physical exertion.
GABA (gamma-aminobutyric acid)	The major inhibitory neurotransmitter in the brain.	A lack of GABA can lead to involuntary motor actions, including tremors and seizures. Alcohol stimulates the release of GABA, which inhibits the nervous system and makes us feel drunk. Low levels of GABA can produce anxiety, and GABA agonists (tranquilizers) are used to reduce anxiety.

The Organisation of the Brain

- There a number of ways to conceptualise the structure of the brain.

    - based on location:

        - the ***hindbrain,*** which includes all the structures located in the posterior part.

        - the ***midbrain,*** located in the middle of the brain &

        - the ***forebrain,*** which includes the structures located in the front part of the brain.

- based on function:

  - o ***the central core*** or ***brainstem***, which regulates our most primitive behaviours, such as coughing, sneezing etc. & primitive behaviours which are under voluntary control as vomiting, sleeping, eating, drinking, temperature regulation & sexual behaviour.

    - It includes all the structures in the hindbrain & midbrain & two structures in the forebrain viz. the hypothalamus & thalamus.

  - o ***the limbic system***, which controls our emotions

  - o ***the cerebellum***, which regulates our higher intellectual processes.

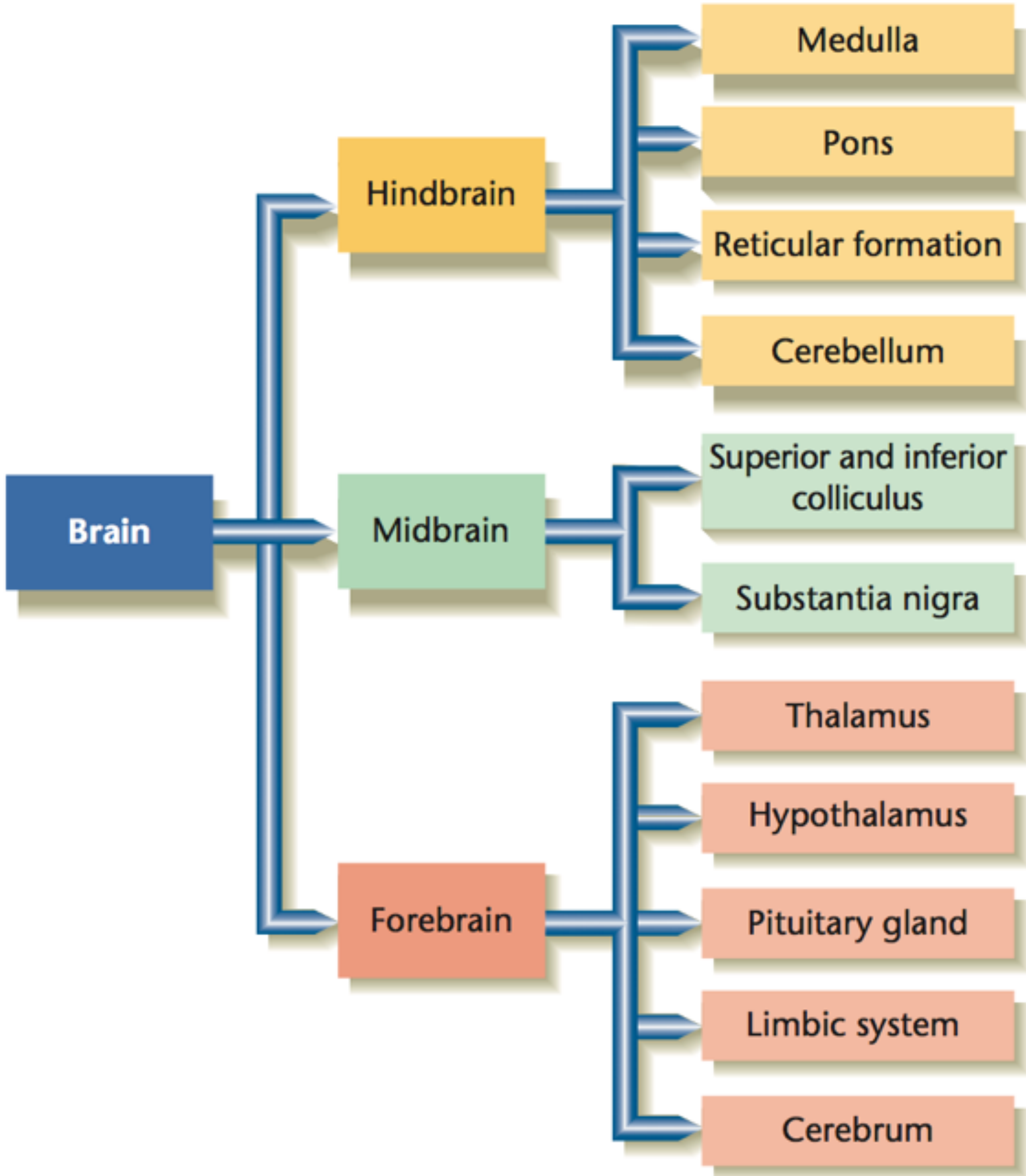
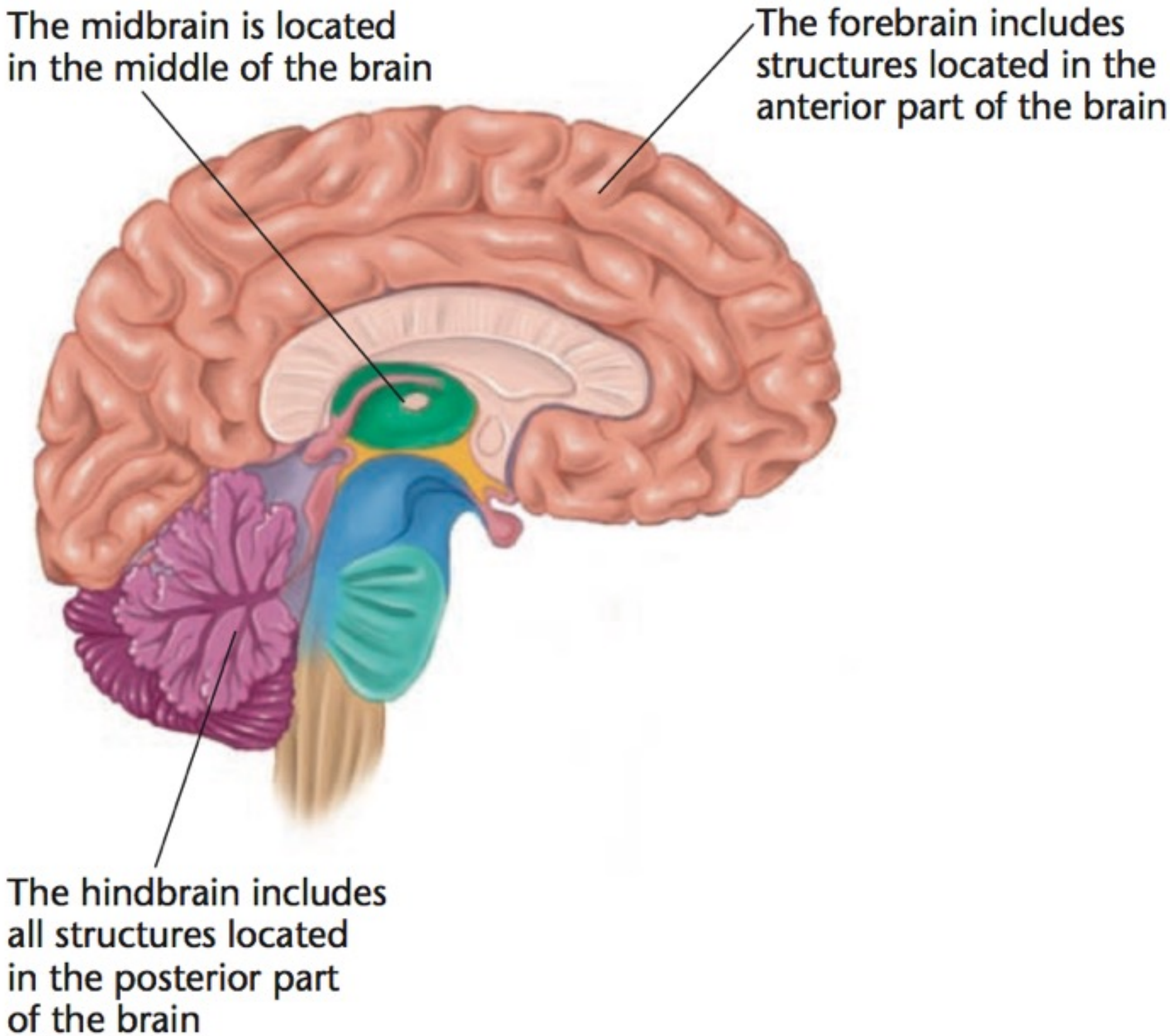


Figure 2.10 Organization of the Brain.



The midbrain is located in the middle of the brain
The forebrain includes structures located in the anterior part of the brain
The hindbrain includes all structures located in the posterior part of the brain

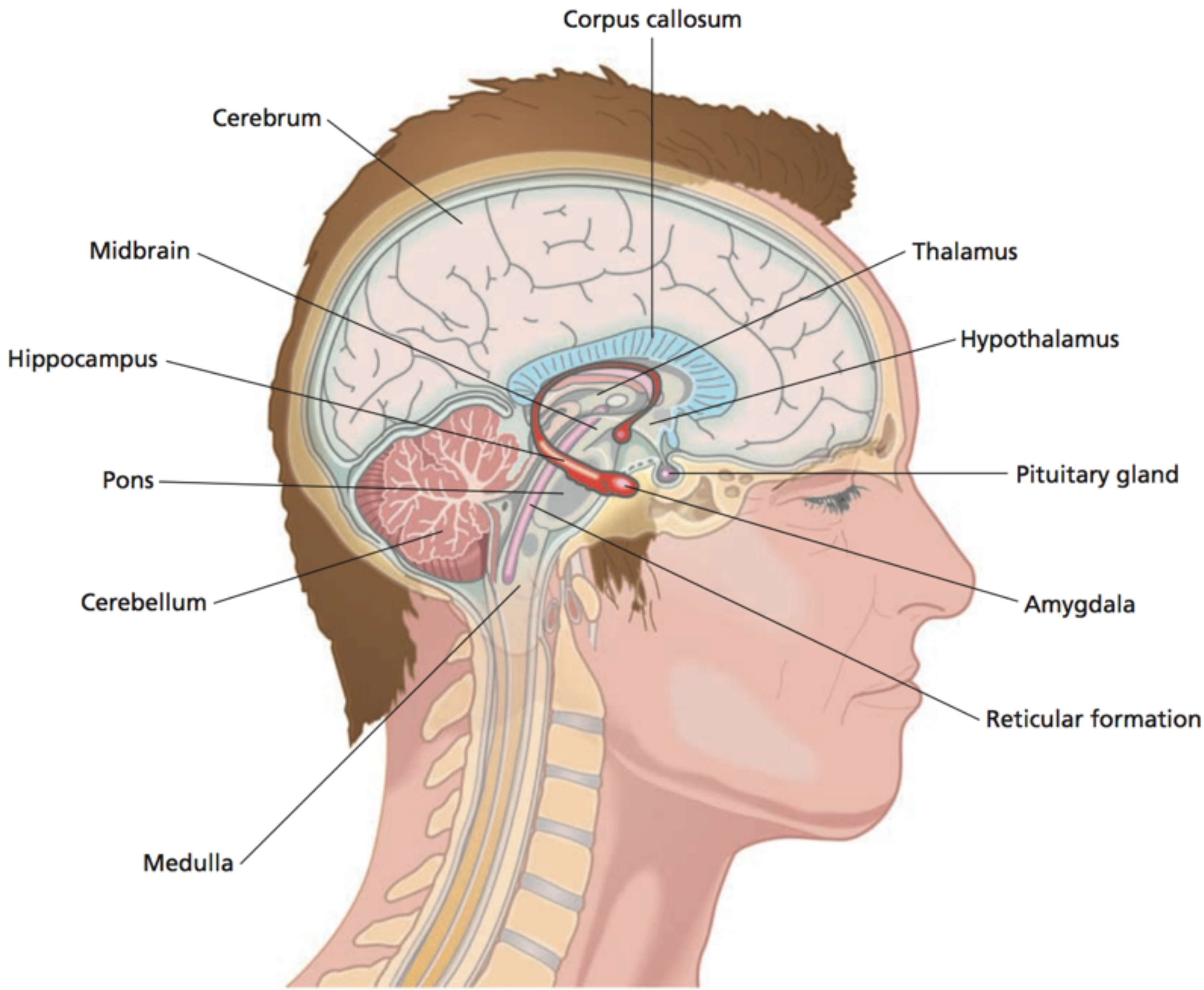


Figure 2.11 The main structures of the human brain.

Parts of the brain

- ***The Hindbrain*** sits on the top of the spinal cord, & it is crucial for basic life functions.

  - Medulla: the first slight enlargement of the spinal cord as it enters the skull is the medulla, a narrow structure that controls breathing and some reflexes that help maintain upright posture.

  - Pons: above the medulla is the pons, important for the control of attentiveness, as well as the timing of sleep. At this point, the major nerve tracts coming up from the spinal cord cross over so that the right side of the brain is connected to the left side of the body and the left side of the brain is connected to the left side of the body.

- ***Reticular formation***: a network of neural circuits that extends from the lower brainstem up to the thalamus in the forebrain, & the transversing some of the other central core structures is called reticular formation.

    - this network of neurons acts to control arousal.

    - the reticular formation also plays a role in our ability to focus attention on particular stimuli.

    - all of the sense receptors have nerve fibres that feed into the reticular system, which appears to act as a filter. it allows some sensory messages to pass to the cerebral cortex while blocking others.

- ***Cerebellum***: attached to the rear of the brain stem slightly above the medulla is a convoluted structure called the cerebellum.

  - it is primarily concerned with the coordination of movement.

  - specific movements may be initiated at higher levels, but the coordination of those movements depends on the cerebellum.

  - damage to the cerebellum results in jerky, uncoordinated movements.

- it is also important for learning new motor responses.

- direct neural connections between the cerebellum and frontal parts of the brain are involved in languages, planning, & reasoning.

- cerebellum may also play a role in the control & coordination of higher mental processes also.

- ***The Midbrain***: the midbrain is relatively small in humans & found just above the pons & surrounded by the forebrain.

    - Superior & inferior colliculus: the midbrain consists of two small structures, which are important for relaying sensory information to the brain & for movement control.

    - Substantia nigra: located just above the midbrain is the substantia nigra, a crucial part of the dopamine-containing pathway (also known as the reward pathway). This structures deteriorates in Parkinson’s disease.

- *The Forebrain*:

  - In humans the forebrain is relatively large, and covers the midbrain & parts of the hindbrain.

  - a large part of it, the cerebrum is especially more developed in humans than in any other organism.

  - the outer layer of the cerebrum is called the cerebral cortex (or simply cortex), from the Latin word for ‘bark’.

  - the other structures of the forebrain (the thalamus, the hypothalamus & the areas comprising the limbic system) are found just beneath the cerebrum & are referred to as subcortical structures.

- Thalamus: located just above the midbrain inside the cerebral hemispheres are two egg shaped groups of nerve cell nuclei, the thalamus.

- it acts as a sensory relay station, directing incoming information from the sense receptor (such as vision & hearing) to the cerebrum.

- ***Hypothalamus***: the hypothalamus is a much smaller structure, located just below the thalamus.
  - centers in the hypothalamus regulate eating, drinking & sexual behaviour.
  - the hypothalamus is involved maintaining homeostasis by exerting control over the autonomic nervous system.
  - *homeostasis* is a term that refers to the level of functioning that is characteristic of a healthy organism, such as normal body temperature, herat rate, & blood pressure.

- When an organism is under stress, homeostasis is disturbed, & processes are set in motion to correct this lack of equilibrium. e.g. if we are too warm, we perspire and if we are too cool, we shiver.

  - both these processes tend to restore normal temperature and are controlled by the hypothalamus.

- the hypothalamus also plays an important role in the sensation of emotions and in our response to stress producing situations.

- mild electrical stimulation of certain areas in the hypothalamus produces feelings of pleasure; stimulation of adjacent regions produces unpleasant sensations.

- Pituitary Gland: the pituitary glans is the most important part of a system of glands called the endocrine system; the hypothalamus controls the endocrine system and thus the production of hormones.

- Limbic System: around the central core of the brain and closely interconnected with the hypothalamus is the limbic system, a set of structures that impose additional control over some of the instinctive behaviours regulated by the central core.

  - the hippocampus: a part of the limbic system, the hippocampus plays a special role in memory.

  - the amygdala, an almond shaped structure deep within the brain, is critical in emotions such as fear. e.g. monkeys with damage to the amygdala exhibit marked reduction in fear.

  - humans with such damage are unable to recognise facial expressions of fear of learn new fear responses.

To Sum Up…

- In this lecture we talked about the basic neural organisation that governs human behaviour.

- More specifically, we talked about the structure & function of neurons.

- Also, we talked about the basic organisation principles of the brain.

Indian Institute of Technology
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In Collaboration with

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National Program on Technology Enhanced Learning (NPTEL)

Presents

Course Title:

Basic Cognitive Processes

By: Dr. Ark Verma,
Assistant Professor of Psychology,
Department of Humanities & Social Sciences,
IIT Kanpur

Lecture 10: The Cerebral Cortex

What do we know so far?

- Neurons as building blocks of the brain's communication network.
- The organisation of the brain & its critical components.
- In this lecture, we will focus in more detail about the structural and functional organisation of the Cerebral Cortex.

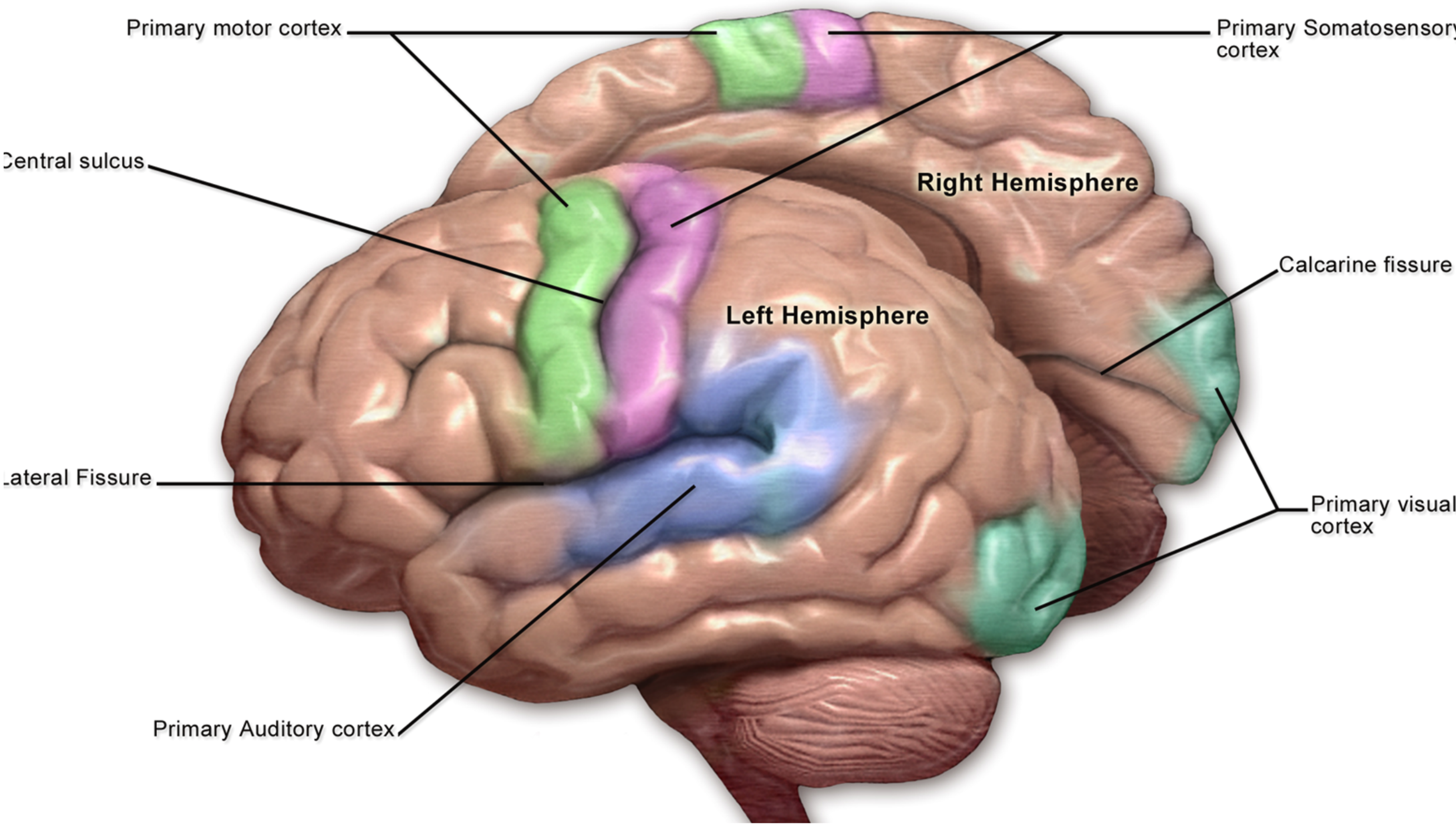
The Cerebral Cortex

- each of the sensory system send information to specific areas of the cerebral cortex.
- motor responses, or movements of body parts, are controlled by specific areas of the cortex.
- the rest of the cortex, which is neither sensory nor motor consists of ***association areas.***
- these areas occupy the largest portion of the human cortex and are concerned with memory, thought & language.

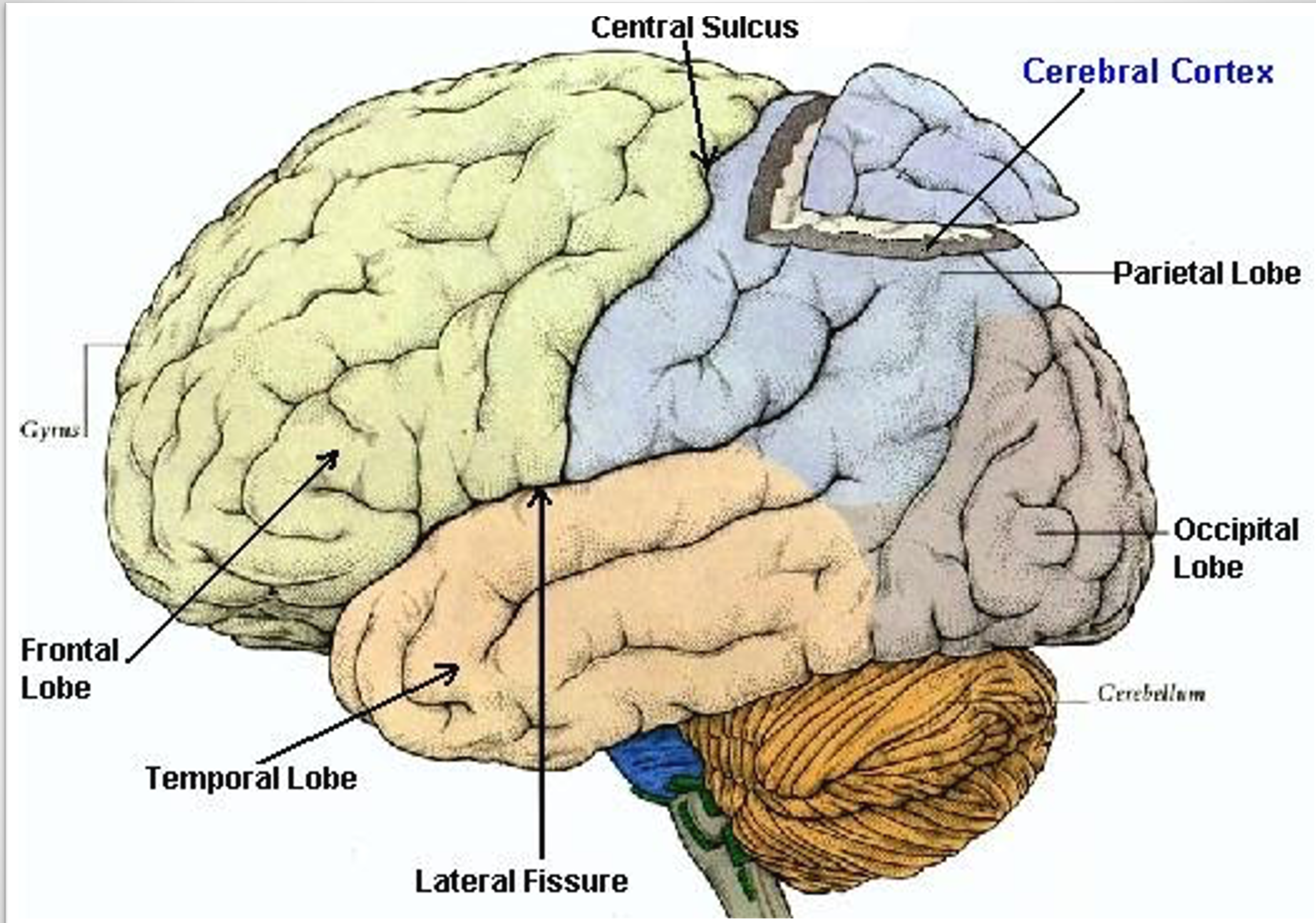
- the cortex is composed of two hemispheres on the left & the right sides of the brain that are connected by a the corpus callosum.

- they are basically symmetrical, with a deep division, i.e. the longitudinal fissure, between them. & are referred to as the left and right hemispheres.

- each hemisphere is divided into 4 lobes:
  - the frontal
  - the parietal
  - the occipital &
  - the temporal lobes.



Primary motor cortex
Primary Somatosensory cortex
Central sulcus
Right Hemisphere
Calcarine fissure
Left Hemisphere
Lateral Fissure
Primary visual cortex
Primary Auditory cortex


Central Sulcus
Cerebral Cortex
Parietal Lobe
Gyrus
Occipital
Lobe
Frontal
Lobe
Cerebellum
Temporal Lobe
Lateral Fissure

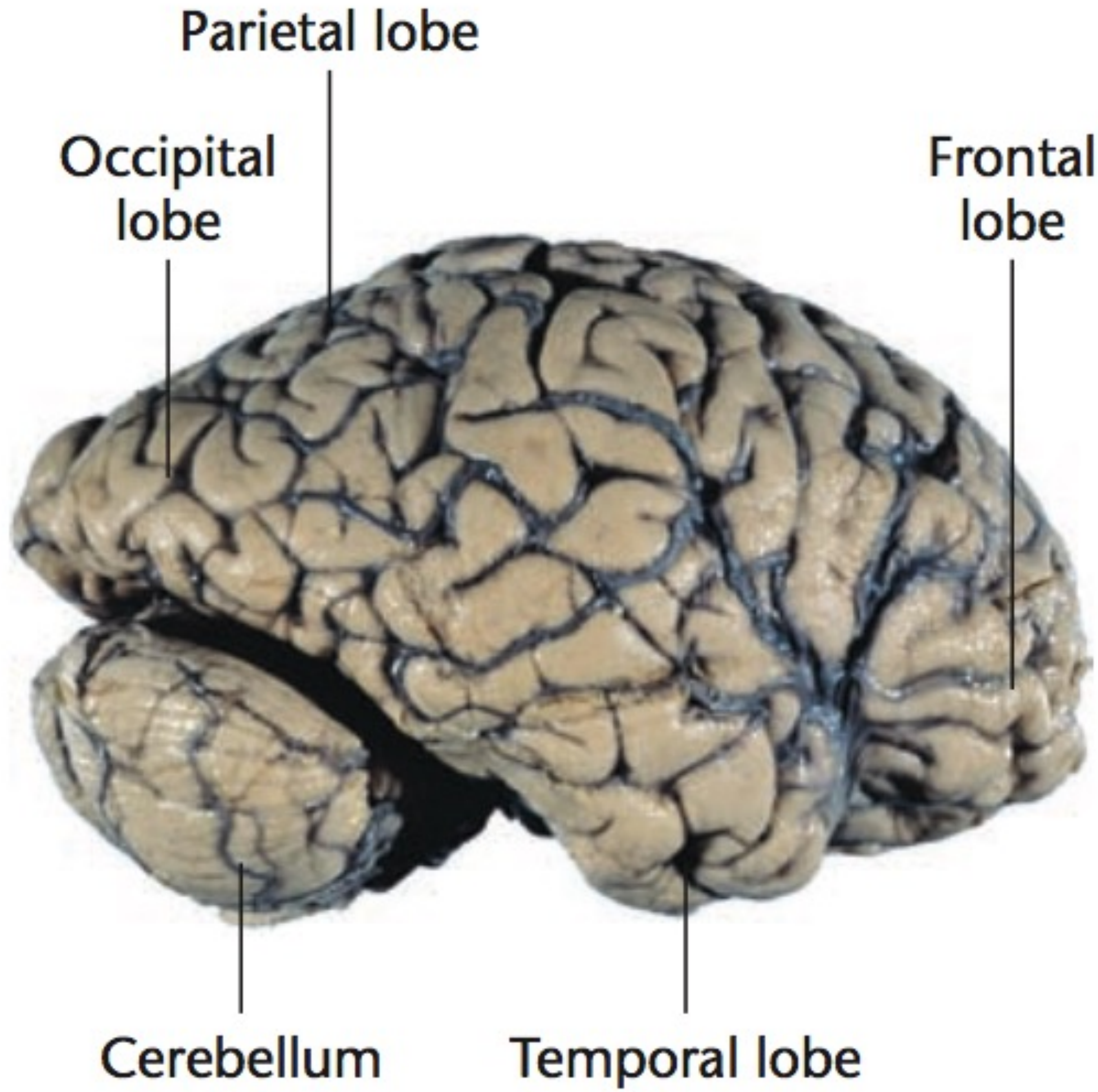


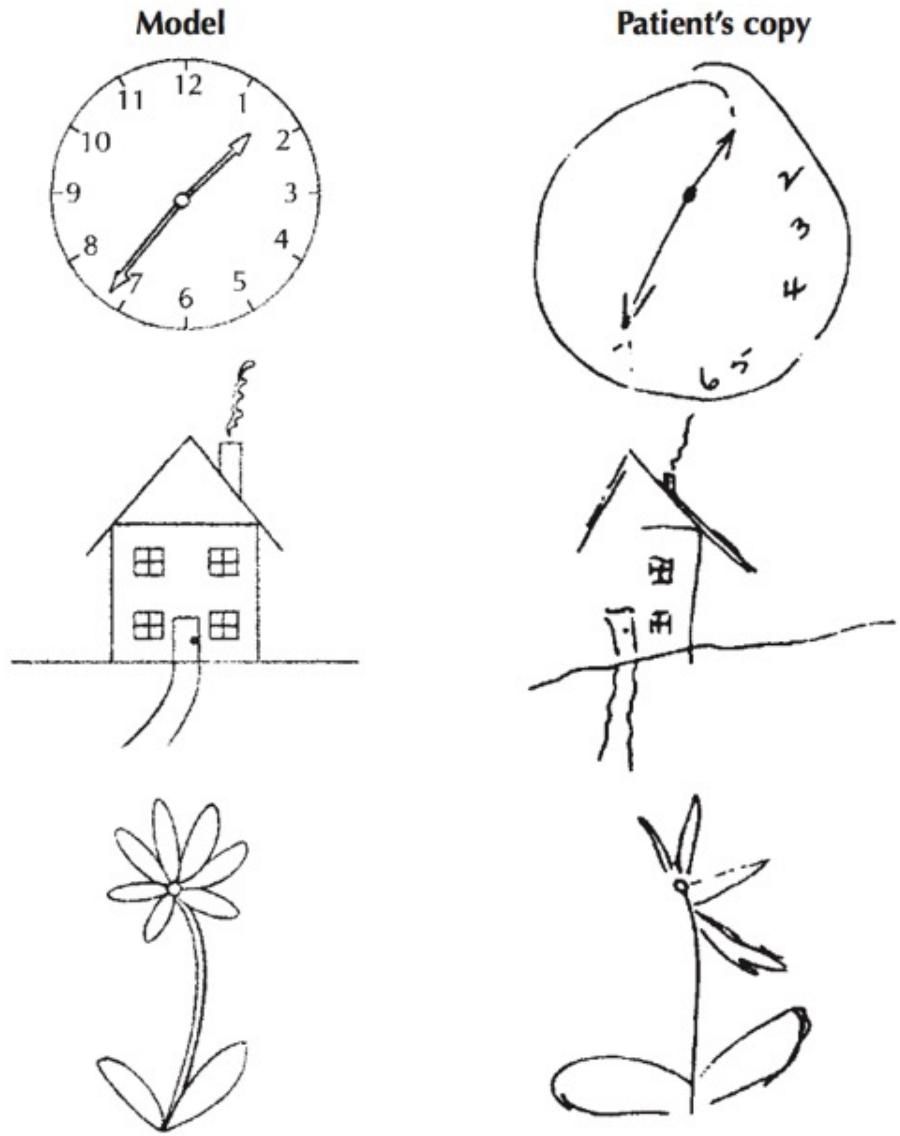
Figure 2.12 Photograph of human brain.

The Cerebral Hemispheres

- the cortex is composed of two sides or *cerebral hemispheres,* connected by a thick band of axon fibers called the *corpus callous*.

- the left side of the brain mainly controls the right side of the body, while the right side mainly controls the left side of the body.

- damage to a particular hemisphere ma also cause a curious problem called *spatial neglect*.
  - a patient with right hemisphere damage may pay no attention to the left side of the visual space. e.g. he/she may not eat food on the left side of the plate. etc.



● **Figure 2.18** Spatial neglect. A patient with right-hemisphere damage was asked to copy three model drawings. Notice the obvious neglect of the left side in his drawings. Similar instances of neglect occur in many patients with right-hemisphere damage. From *Left Brain, Right Brain* (5th ed.) by Sally P. Springer & Georg Deutsch. © 1981, 1985, 1989, 1993, 1998 by Sally P. Springer and Georg Deutsch. Used with permission of W. H. Freeman and Company.

- ***Hemispheric Specialization***: the concept that the two cerebral hemispheres may be differently adept in the capabilities & functions. e.g. language, perception, music etc.
    - "Split Brains": patients who have gone a particular kind of surgery, wherein the corpus callosum is severed, usually done to control epileptic seizures.
    - the result is essentially a person with two brains in one body (Gazzaniga, 2005).
    - after the right & left brain are separated, each hemisphere will have its own separate perceptions, concepts & impulses to act.

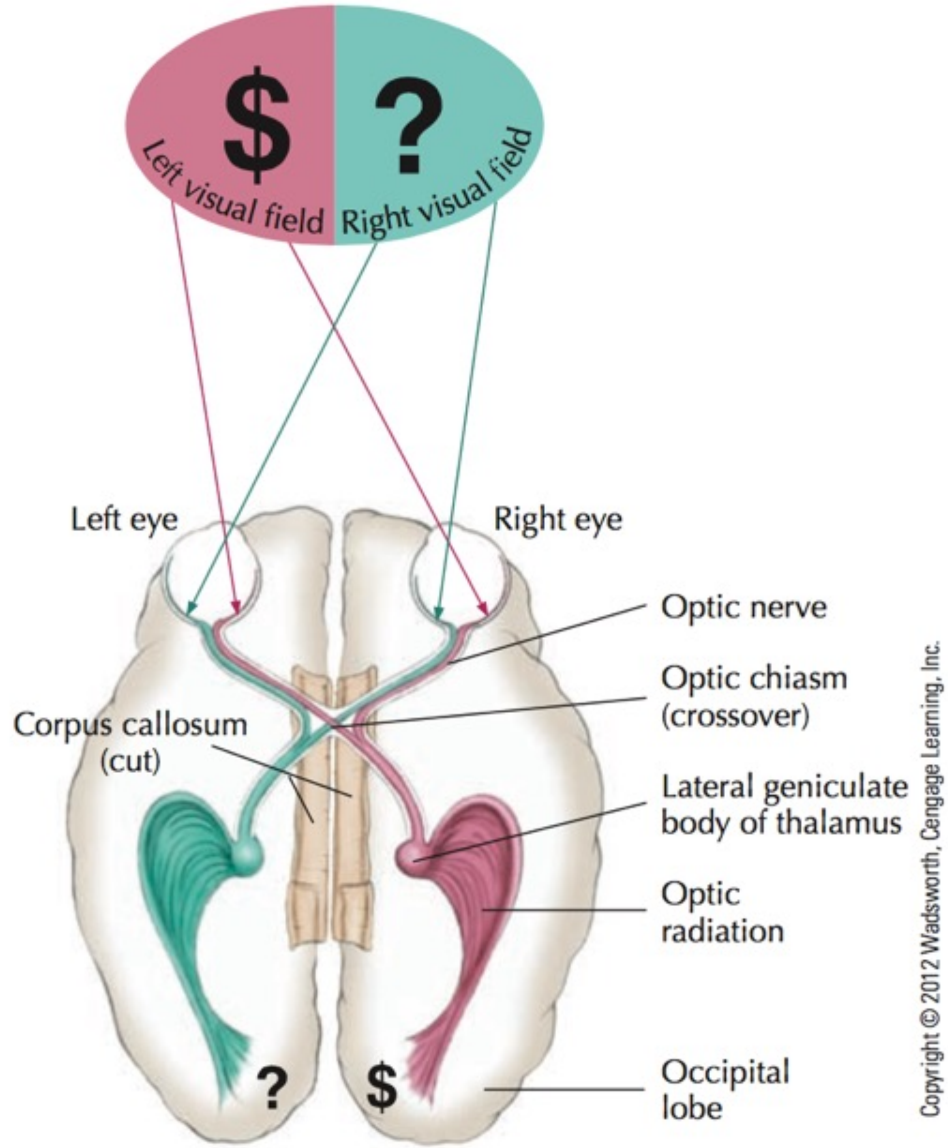
- Interesting scenarios get created with split brain patients: for e.g. when one split brain patient dressed himself, he sometimes pulled his pants up with one hand (that side of his brain wanted to get dressed) & pulled down with the other (while this side did not).

    - Split brain patients are easiest to see in specialised testing. e.g. we flash a $ sign to the right brain & a ? mark to the left brain of a patient name Tom.

    - Next, Tom is asked to draw what he saw, using his left hand, out of sight.

    - Tom's left hand draws a $ sign.

    - If Tom, is then asked to point with his right hand to a picture of what his hidden left hand drew, he will point to a question mark (Sperry, 1968).



• Figure 2.19 Basic nerve pathways of vision. Notice that the left portion of each eye connects only to the left half of the brain; likewise, the right portion of each eye connects to the right brain. When the corpus callosum is cut, a "split brain" results. Then visual information can be sent to just one hemisphere by flashing it in the right or left visual field as the person stares straight ahead.

Left Brain

- Language
- Speech
- Writing
- Calculation
- Time sense
- Rhythm
- Ordering of complex movements

Right Brain

- Nonverbal
- Perceptual skills
- Visualization
- Recognition of patterns, faces, melodies
- Recognition and expression of emotion
- Spatial skills
- Simple language comprehension

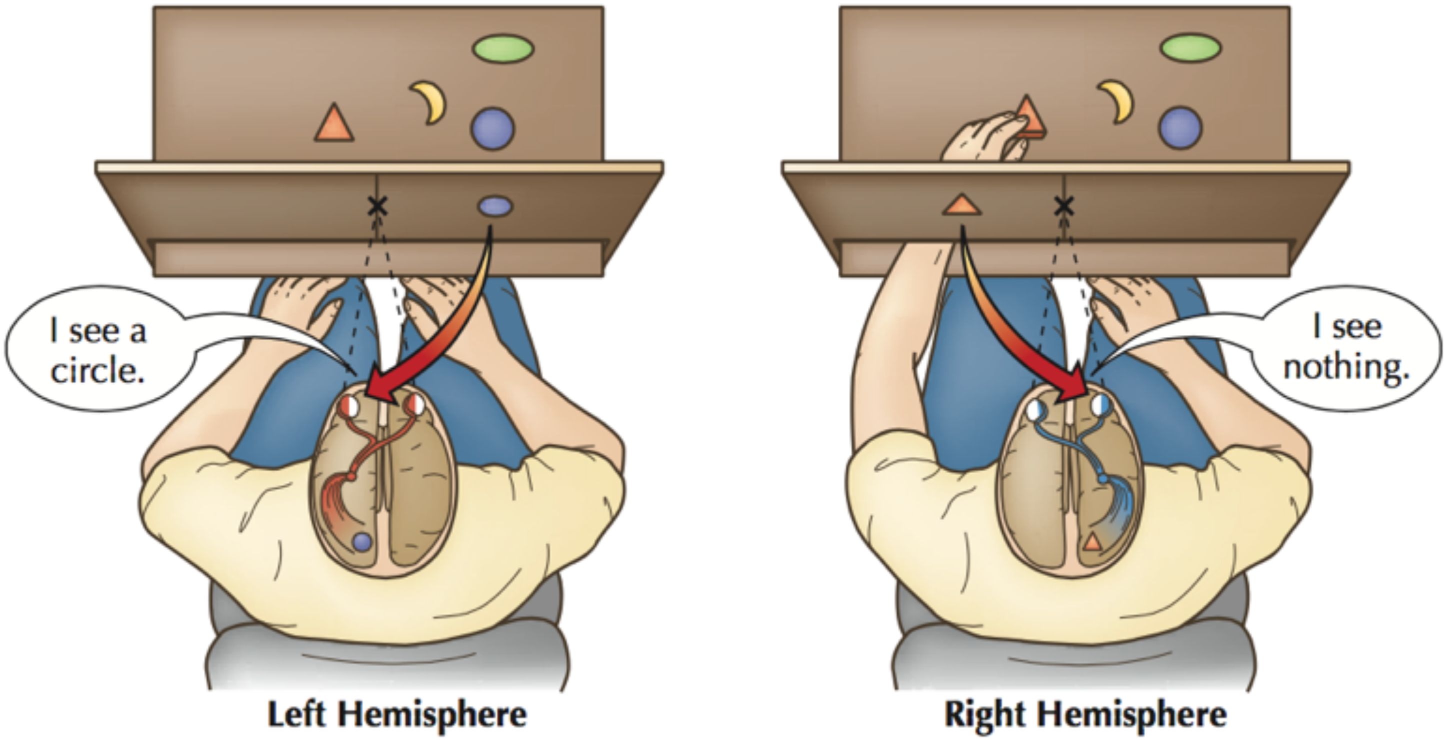


Figure 2.20 A circle is flashed to the left brain of a split-brain patient and he is asked what he saw. He easily replies, "A circle." He can also pick out the circle by merely touching shapes with his right hand, out of sight behind a screen. However, his left hand can't identify the circle. If a triangle is flashed to the patient's right brain, he can't say what he saw (speech is controlled by the left hemisphere). He also can't identify the triangle by touch with the right hand. Now, however, the left hand has no difficulty picking out the triangle. In other tests, the hemispheres reveal distinct skills, as listed above the drawing.

- ***The Right Brain or the Left***: both the hemispheres of the brain are capable of performing most cognitive functions, however, one might be more adept than the other at particular cognitive functions.
    - roughly 95 % of us use our left brain for language (speaking, writing, and understanding).
    - also, the left hemisphere is superior at math, judging time & rhythm, and coordinating the order of complex movements, such as those needed for speech (Pinel & Dehanenence, 2010)

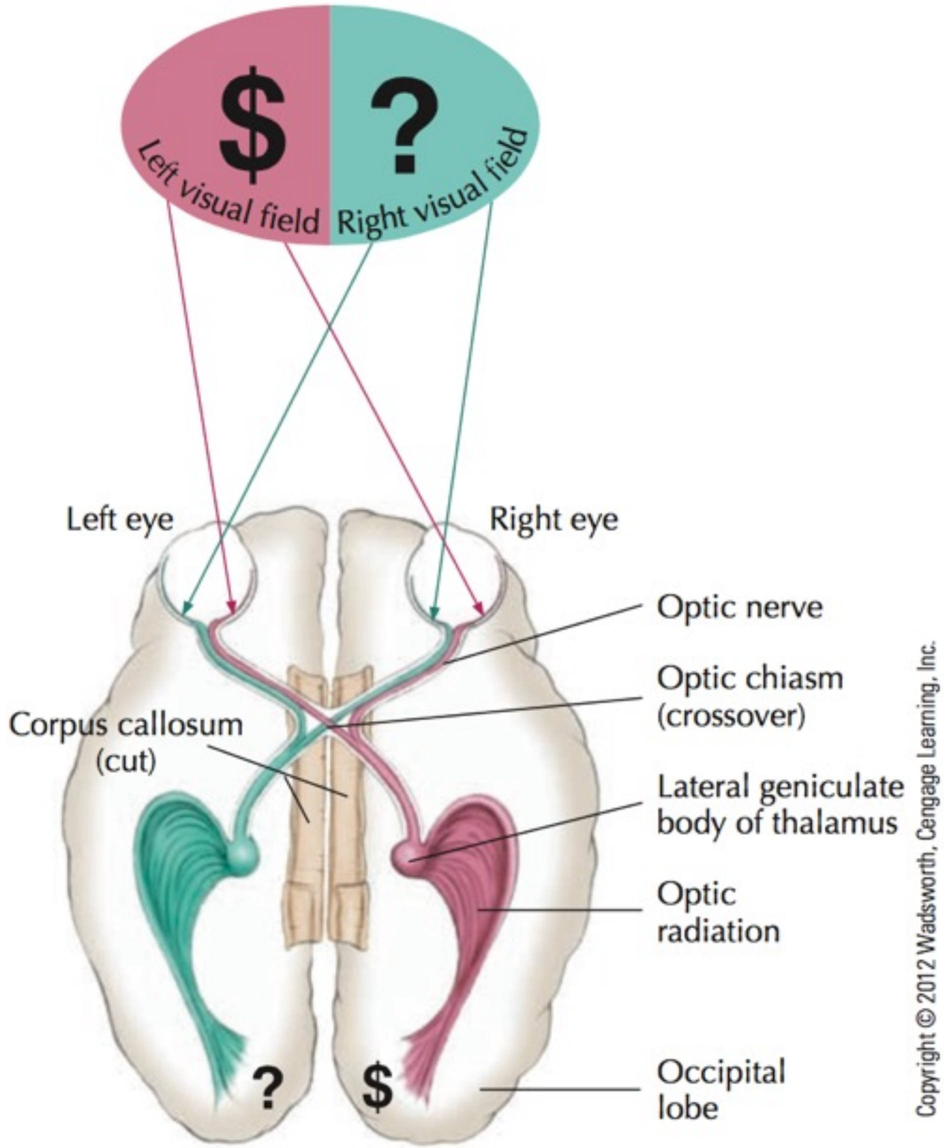
- in contrast, the right hemisphere can produce only the simplest language & numbers.
- however, the right brain is good at perceptual skills, such as recognising patterns, faces & melodies; putting together a puzzle, or drawing a picture.
- the right hemisphere also helps one express emotions & detect the emotions that the other people are feeling.
- also, the right hemisphere of the brain is superior at some aspects of understanding language for e.g. understanding jokes, irony, sarcasm, implications and other nuances of language.

- Let us take a real example: from a range of studies it had come to light that the left is hemisphere is responsible for detection & use of ‘tools’, but nothing was clear about ‘objects’.

- We decided to investigate whether ‘tool recognition’ as a cognitive function is lateralised to the left hemisphere.

Tool Recognition

- Tool use & recognition have been established as left hemisphere tasks (Osiurak et al., 2009; Randerath et al., 2010,Vingerhoets, 2008; Vingerhoets et al., 2012).
- Behavioral evidence for left lateralization of tool recognition, missing.
- Use the VHF task to investigate the lateralization of tool recognition, employing a control task (object recognition) and an experimental task (tool recognition).



• Figure 2.19 Basic nerve pathways of vision. Notice that the left portion of each eye connects only to the left half of the brain; likewise, the right portion of each eye connects to the right brain. When the corpus callosum is cut, a "split brain" results. Then visual information can be sent to just one hemisphere by flashing it in the right or left visual field as the person stares straight ahead.

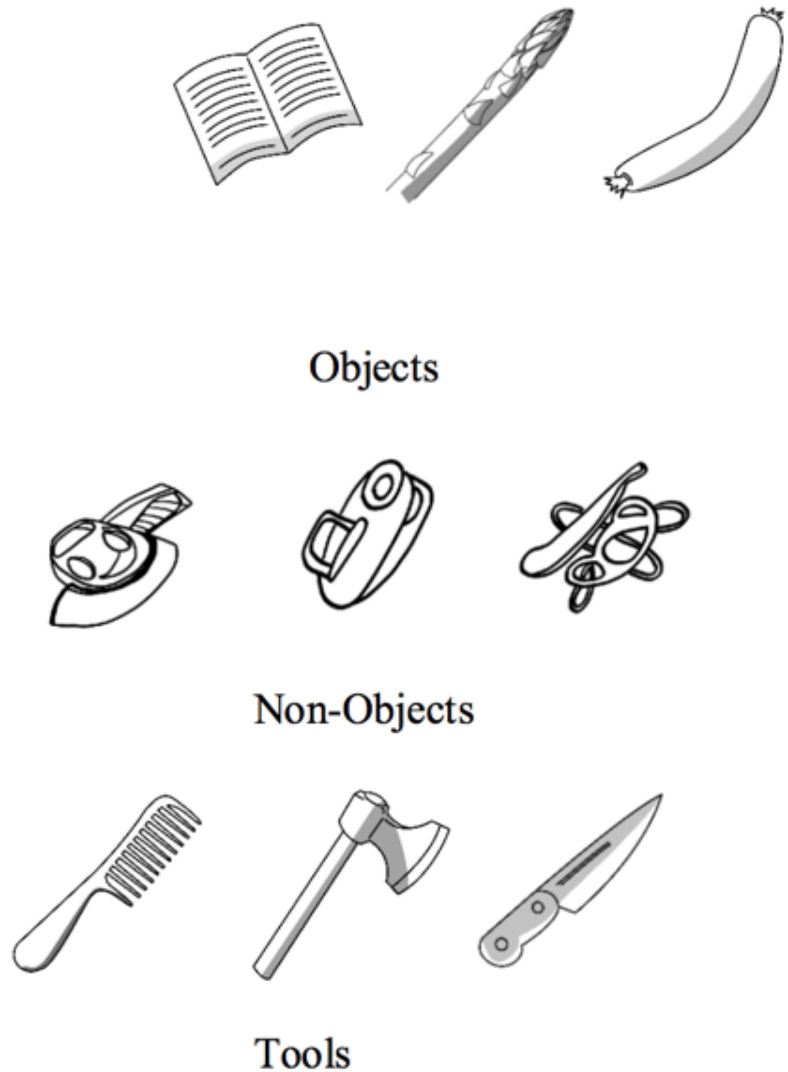
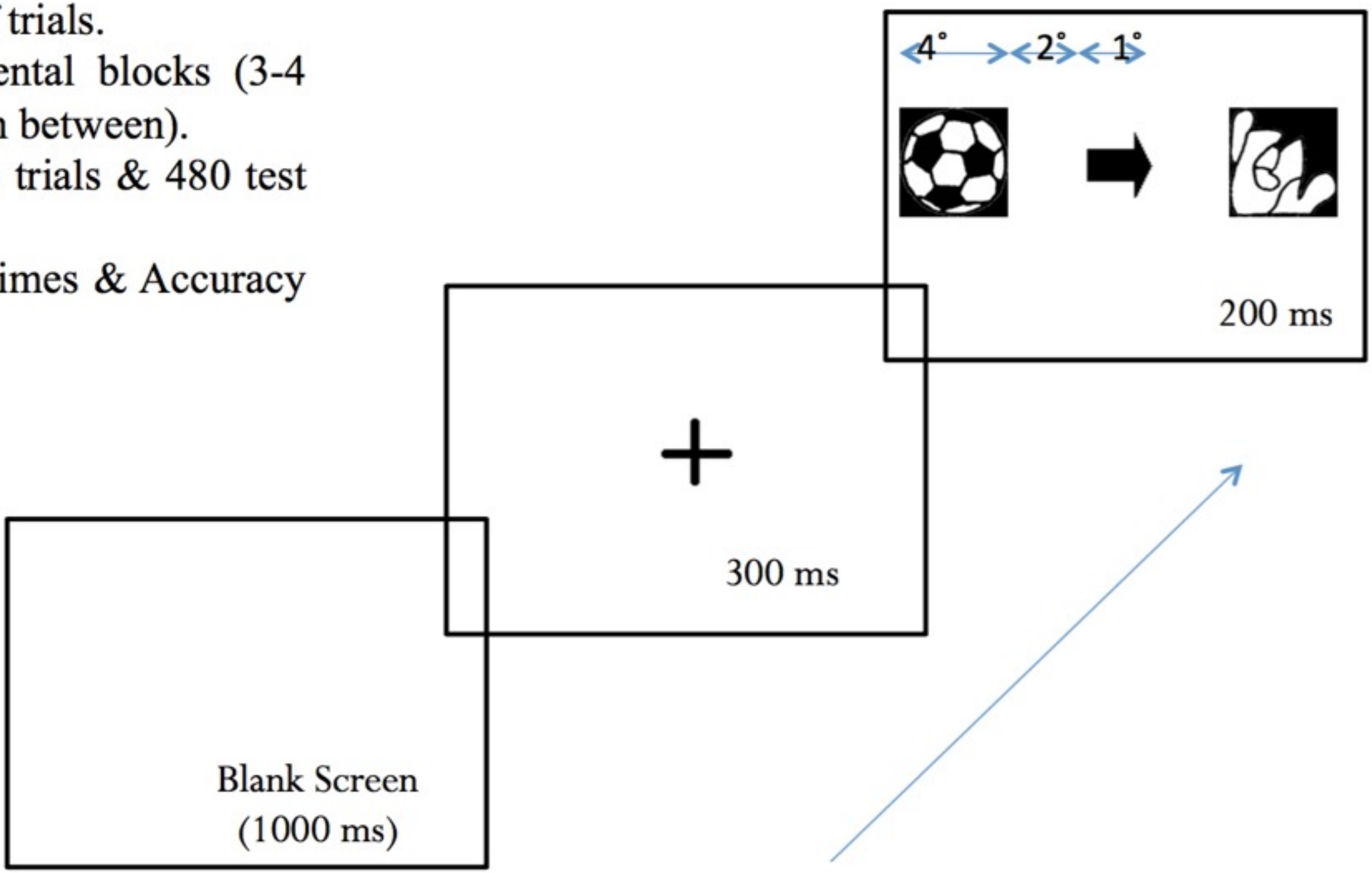


Figure 1: Showing examples of Objects (Non-tools), Non-Objects and Tools. While Objects and Non-Objects were used in Experiment 1, Objects and Tools were used in Experiment 2.

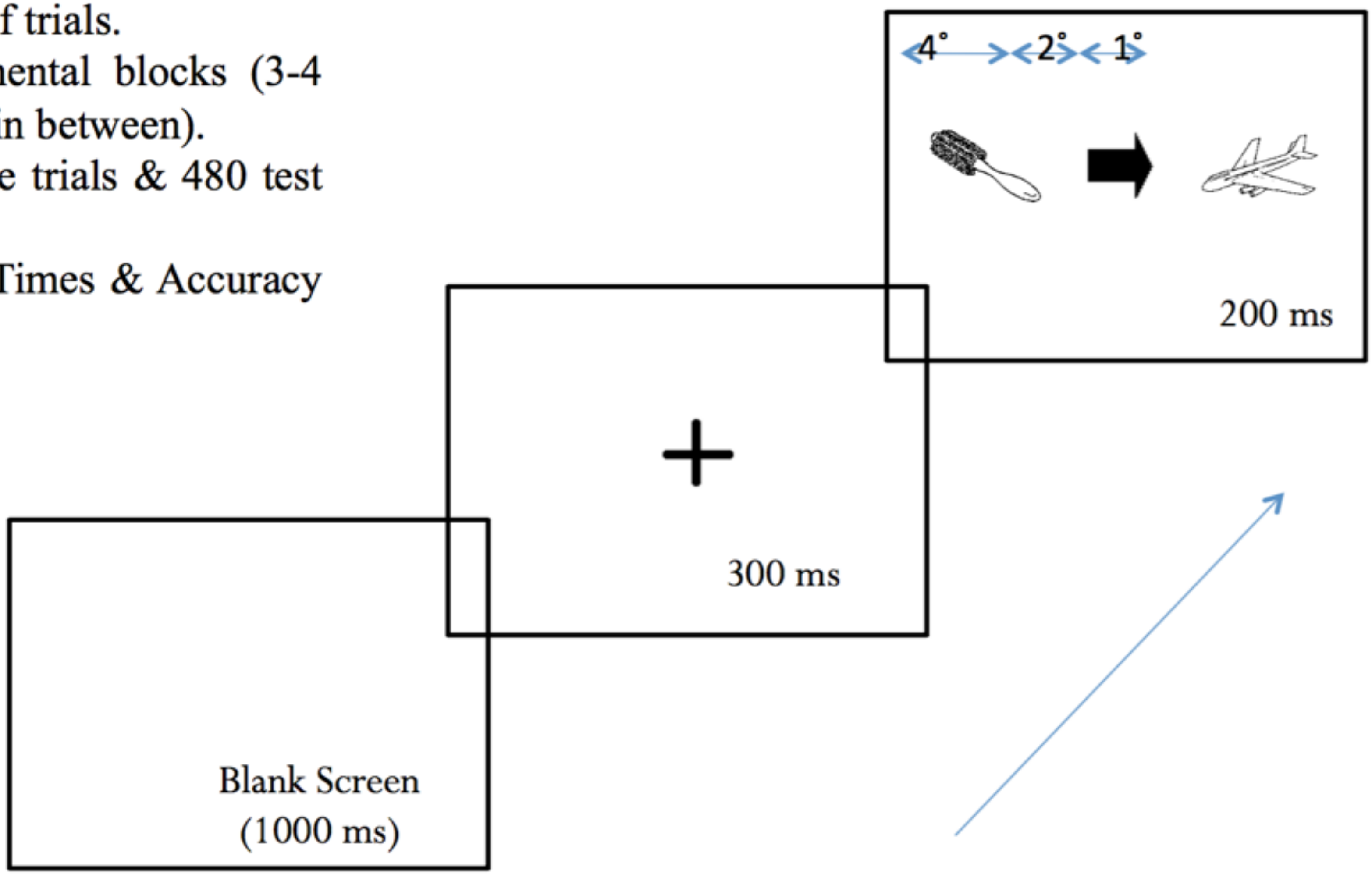
OBJECT RECOGNITION TASK

- 8 Types of trials.
- 2 experimental blocks (3-4 min break in between).
- 48 practice trials & 480 test trials.
- Reaction Times & Accuracy Measured.



TOOL RECOGNITION TASK

- 8 Types of trials.
- 2 experimental blocks (3-4 min break in between).
- 48 practice trials & 480 test trials.
- Reaction Times & Accuracy Measured.



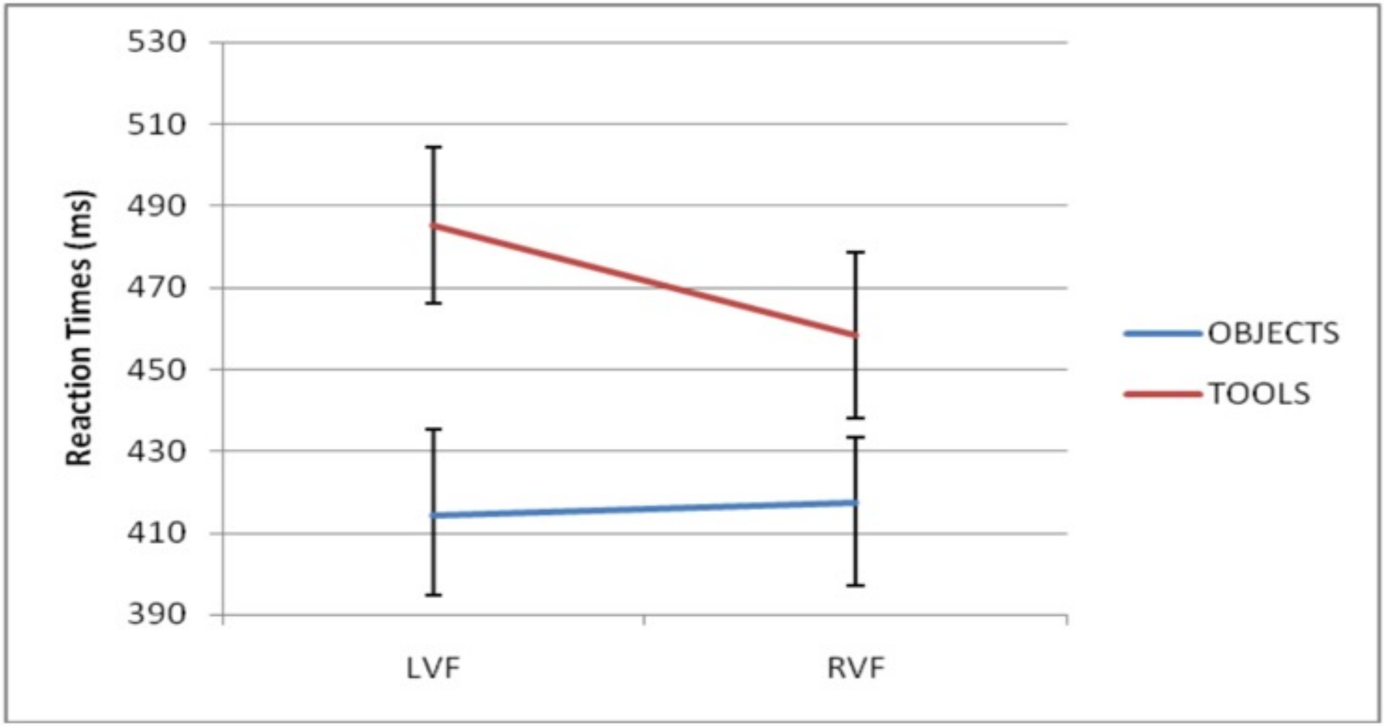
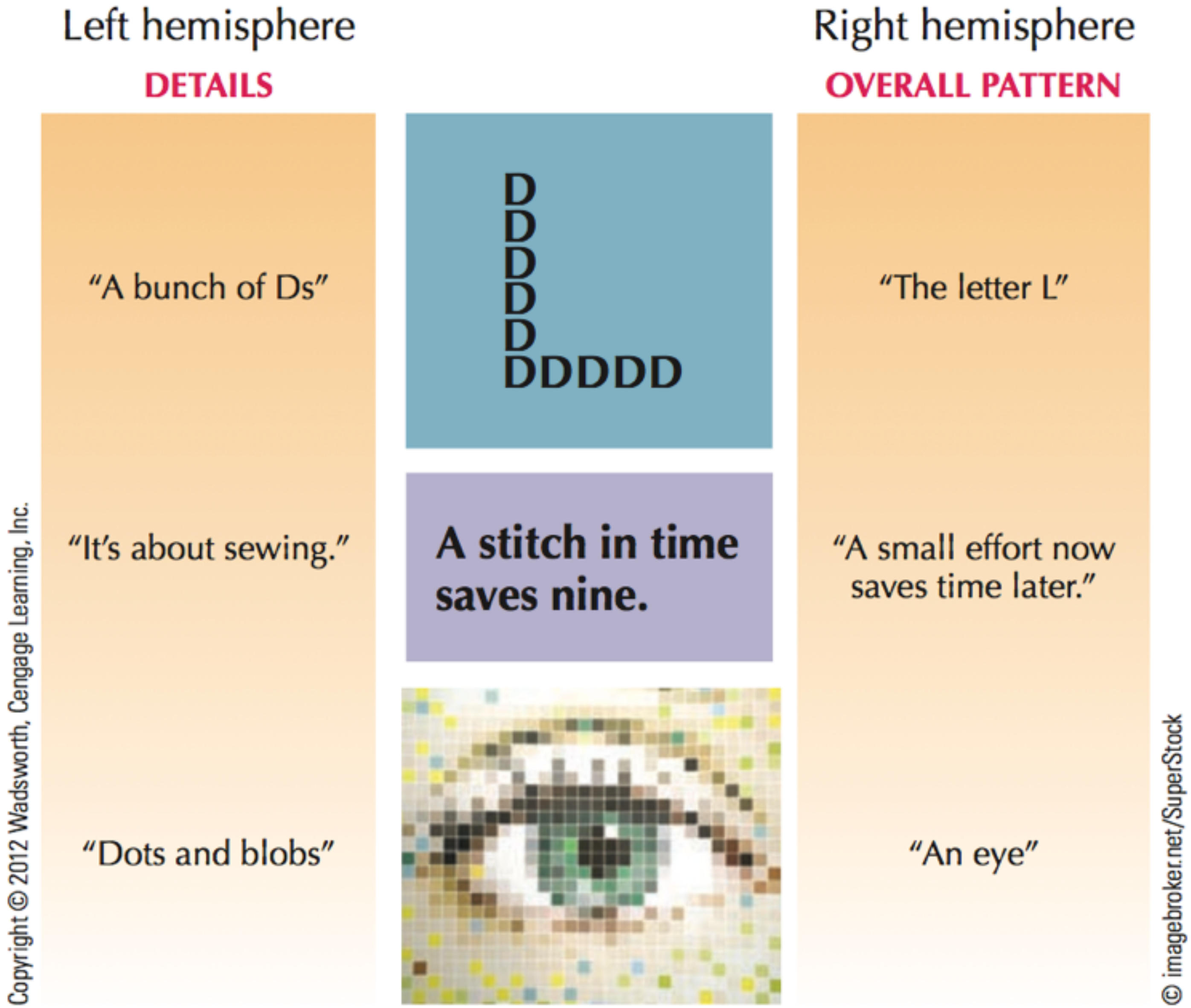


Figure: Showing significant RVF (17ms) facilitation for tools, while no such facilitation is seen for objects.

- Why do the two halves of the brain differ with respect to different cognitive functions?

- A possible answer is style of processing:
  - the left hemisphere is involves mainly with analysis (breaking information into parts). it also processes information sequentially (in order, one item after the next).
  - the right hemisphere appears to process information holistically (all at once) and simultaneously (Springer & Deutsch, 1998).



● **Figure 2.21** The left and right brain have different information processing styles. The right brain gets the big pattern; the left focuses on small details.

Lobes of the Cerebral Cortex

- Lobes of the cerebral cortex: each of the two cerebral hemispheres of the cerebral cortex can be divided into several smaller lobes, defined by the larger fissures on the surface of the cortex.

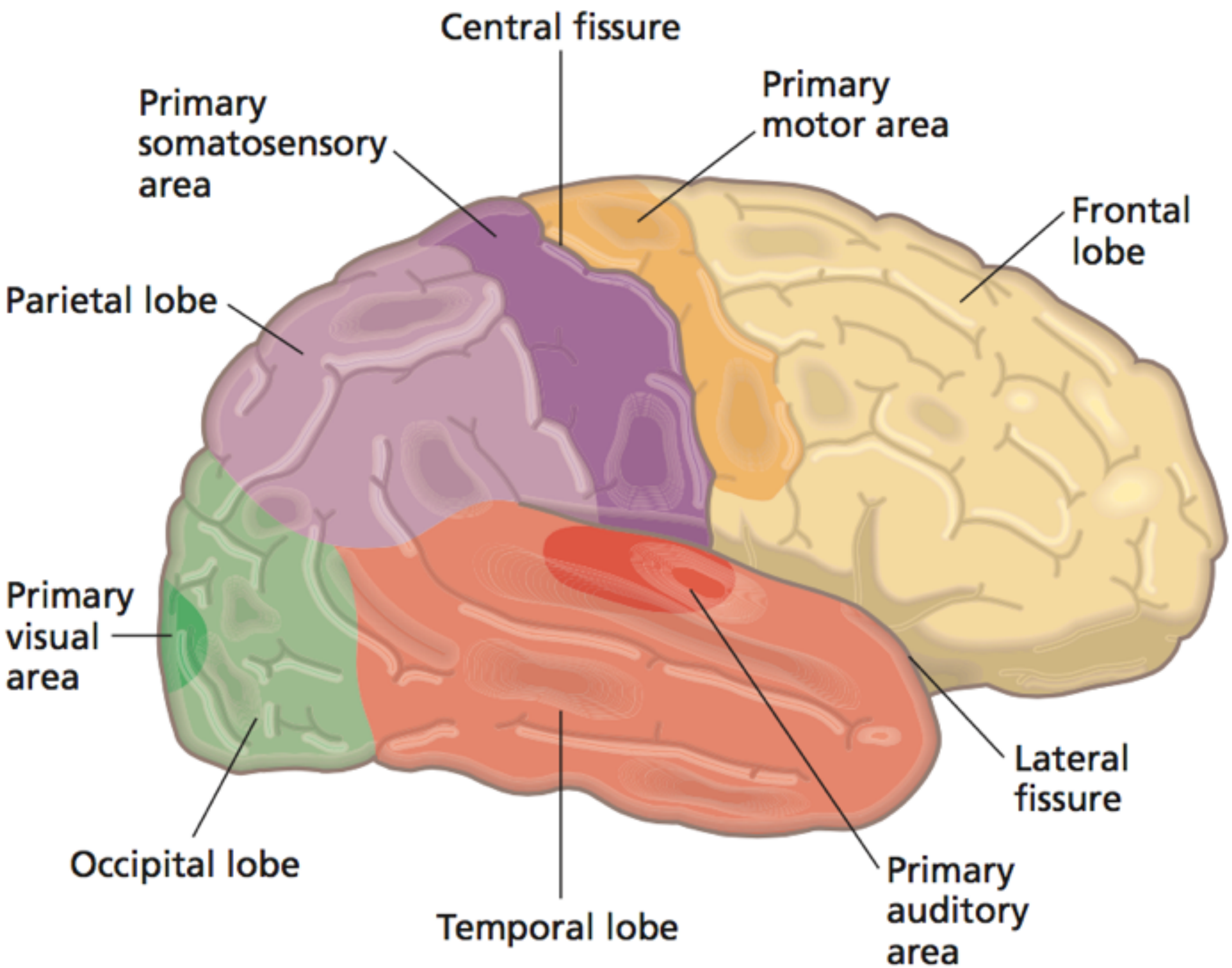


Figure 2.13a **Cerebral cortex.** *(a) Lateral view*

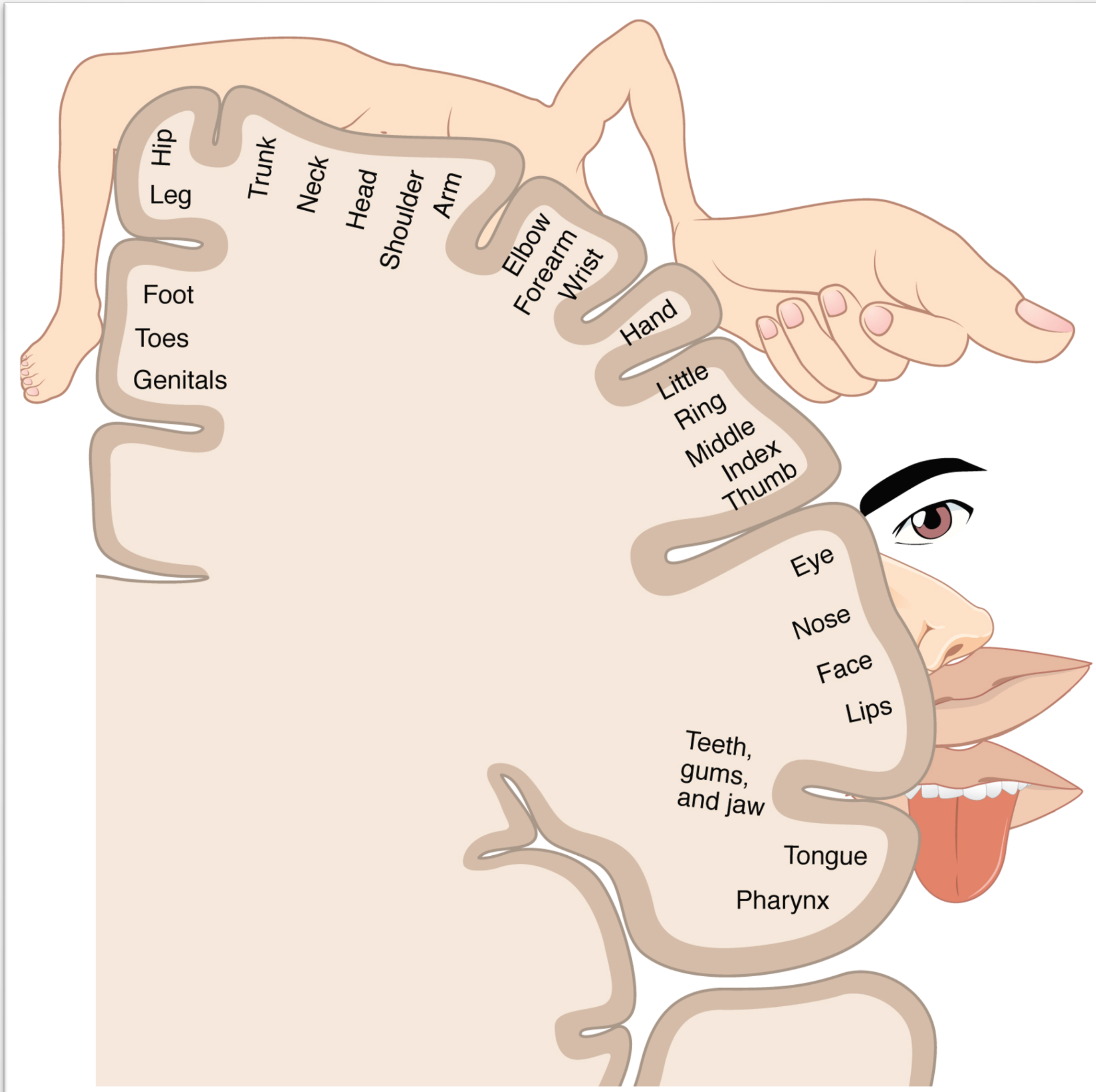
Figure

- ***The Frontal Lobes***: the frontal lobes are associated with higher mental abilities and play a role in your sense of self.

  - also responsible for the control of movements. an arch of tissue at the rear of the frontal lobes, called the *primary motor cortex,* directs the body's muscles.

  - the *homunculus map* represents the *dexterity* of the body areas, not their size.

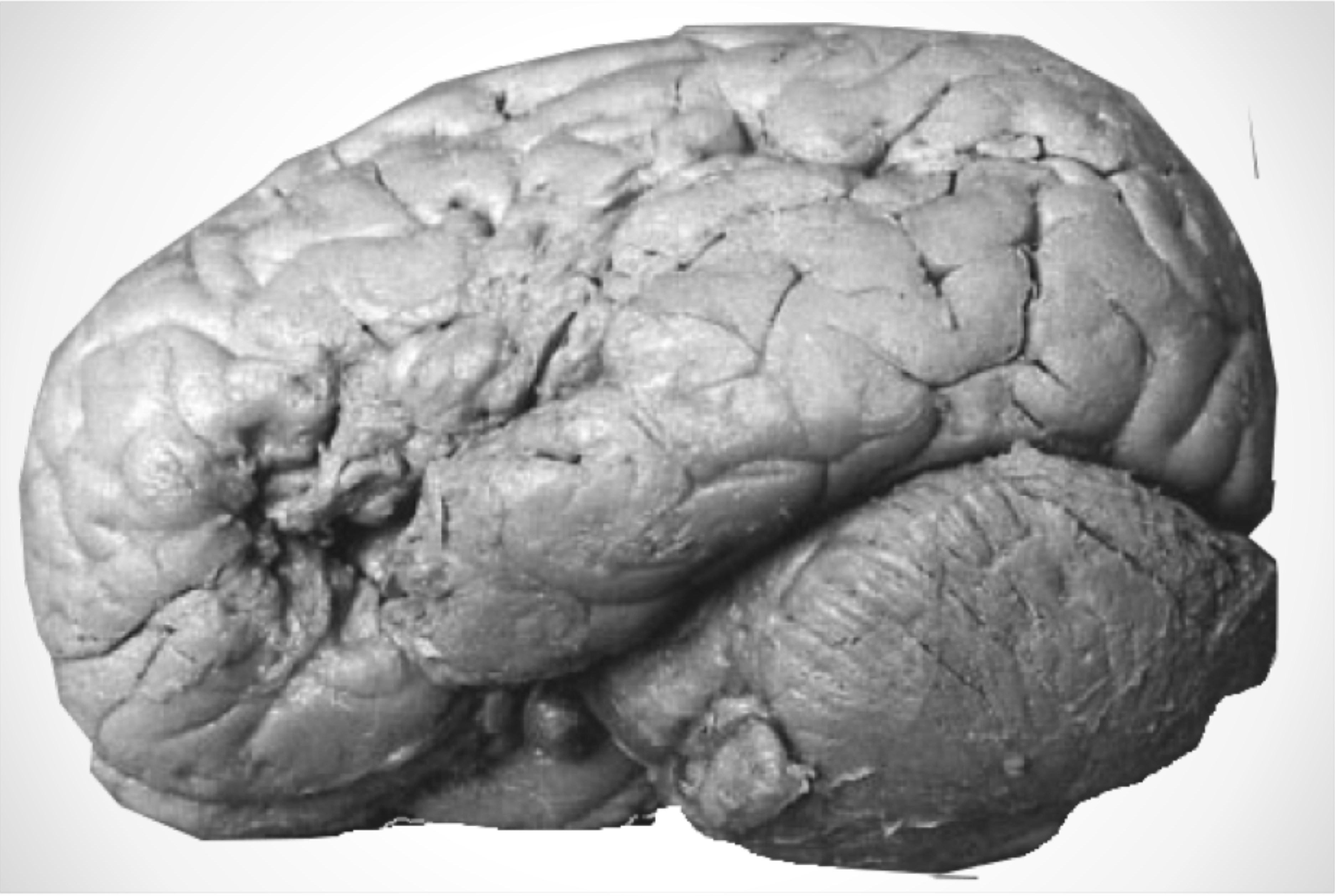
  - the motor cortex is one brain area that contains *mirror neurons,* those neurons which become active when we perform an action and when we merely observe someone else carrying out the same action.


Hip
Leg
Trunk
Neck
Head
Shoulder
Arm
Elbow
Forearm
Wrist
Hand
Little
Ring
Middle
Index
Thumb
Foot
Toes
Genitals
Eye
Nose
Face
Lips
Teeth,
gums,
and jaw
Tongue
Pharynx

- the rest of the frontal lobes are often referred to as *frontal association areas*. i.e. only a small portion of the cerebral cortex directly controls the body or receives information from the senses;

- the surrounding areas called the *association areas (association cortex)* combine & process information. e.g. if you see a rose, the association areas will help you connect your primary sensory impressions with memories, so that you can recognise & name it.

- some association areas also contribute to the higher mental abilities, such as language. e.g. a person with damage to association areas in the left hemisphere may suffer *aphasia,* i.e. an impaired ability to use language (speak). e.g. Broca's aphasia.



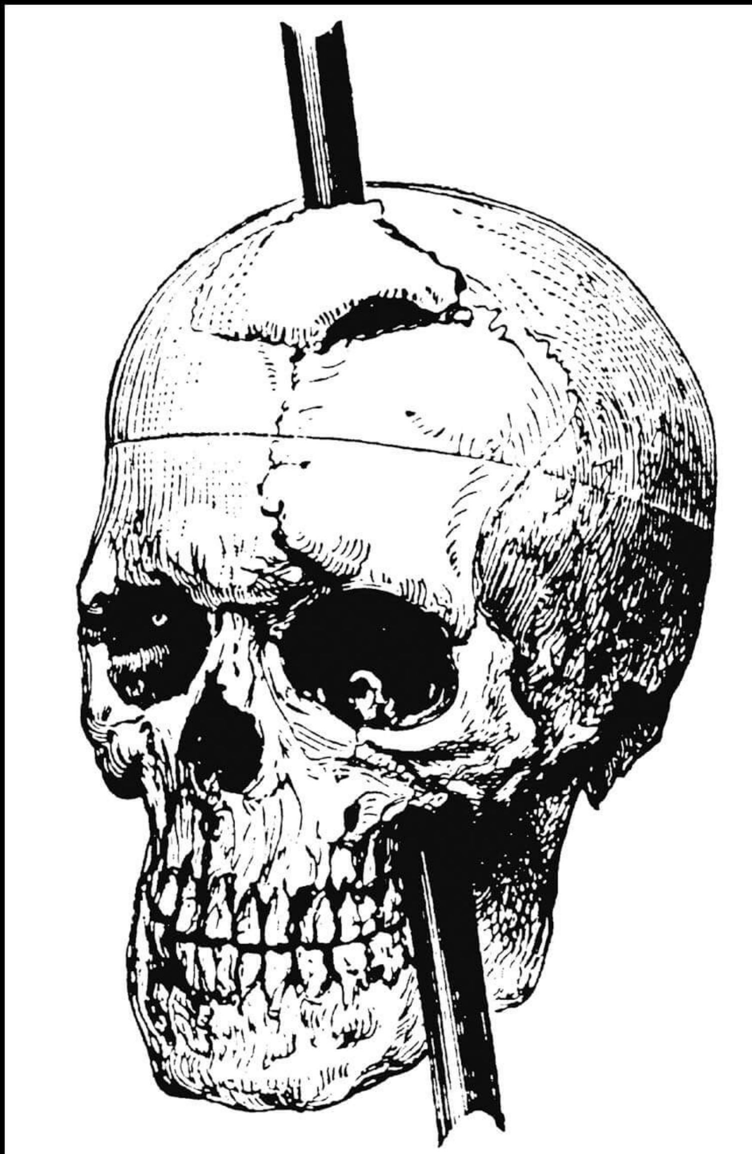
- the very front of the frontal association region is known as the *prefrontal area (prefrontal cortex)*.

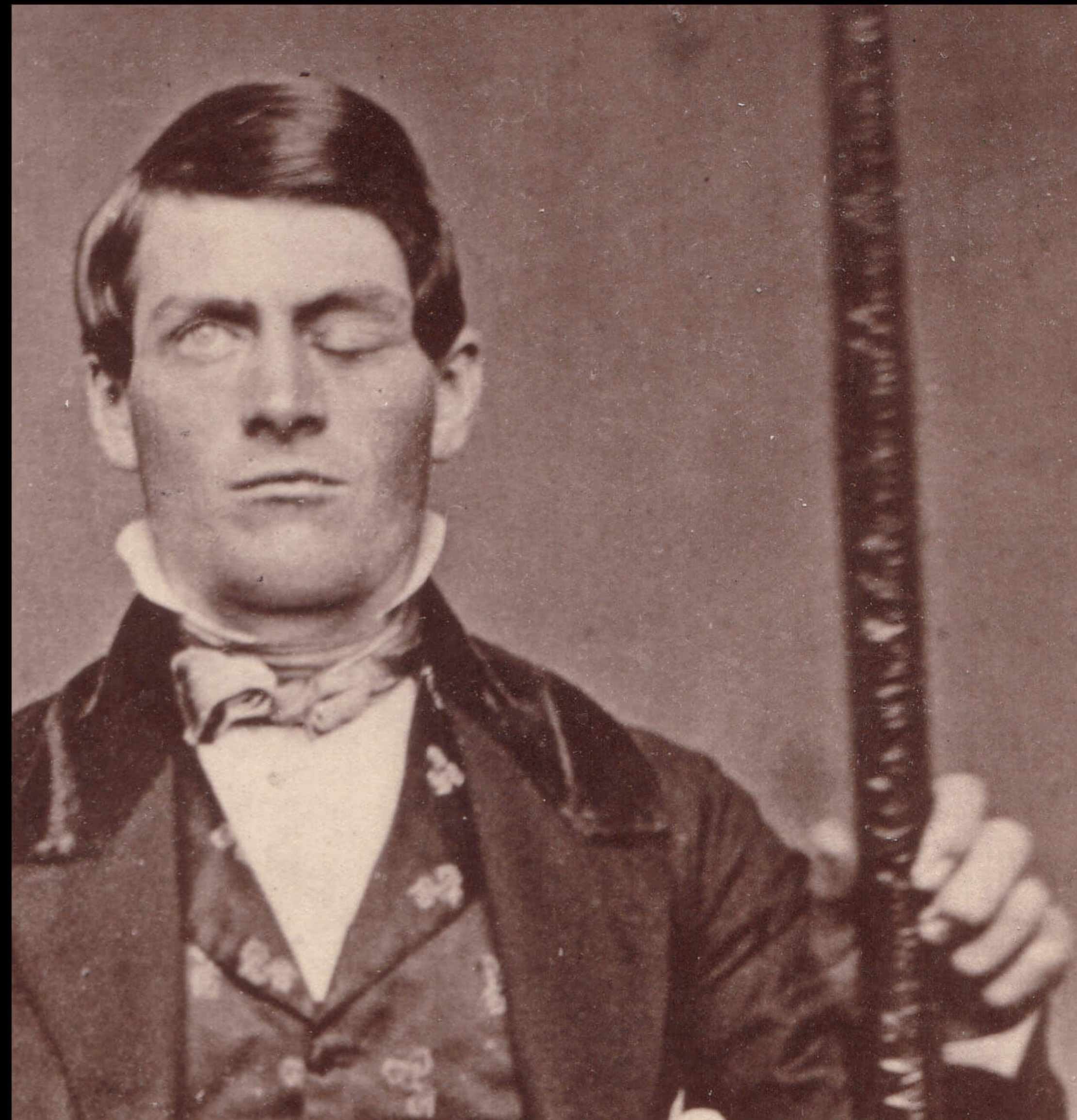
- this part of the brain is related to more complex behaviours (Banich & Compton, 2011).

- remember Phineas Gage?

    - if frontal lobes are damaged, a patients personality & emotional life may change dramatically. reasoning or planning may also be affected.

    - reduced frontal lobe function may also lead to greater implusivity, including risk for drug addiction etc.

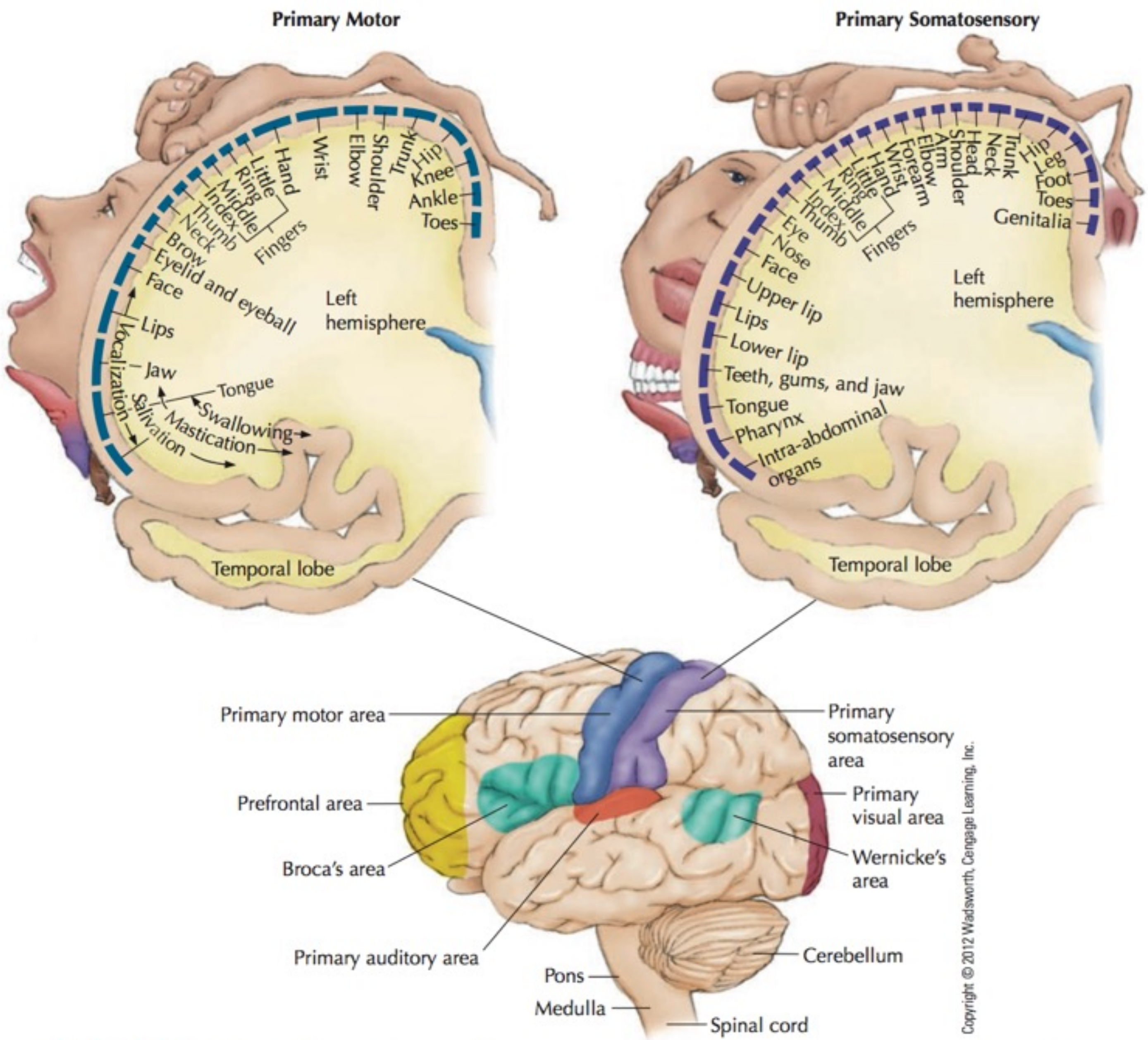




- ***The Parietal Lobes*:** bodily sensations get registered in the parietal lobes.

  - touch, temperature, pressure & other somatic sensations flow into the *primary somatosensory area* of the parietal lobes.

  - we can notice that the map of bodily sensations is distorted e.g. lips are larger in the drawing because of their sensitivity; hand& fingers also occupy a large space because of their various functions etc.



• **Figure 2.23** The lobes of the cerebral cortex and the primary sensory, motor, visual, and auditory areas on each. The top diagrams show (in cross section) the relative amounts of cortex "assigned" to the sensory and motor control of various parts of the body. (Each cross section, or "slice," of the cortex has been turned 90 degrees so that you see it as it would appear from the back of the brain.)

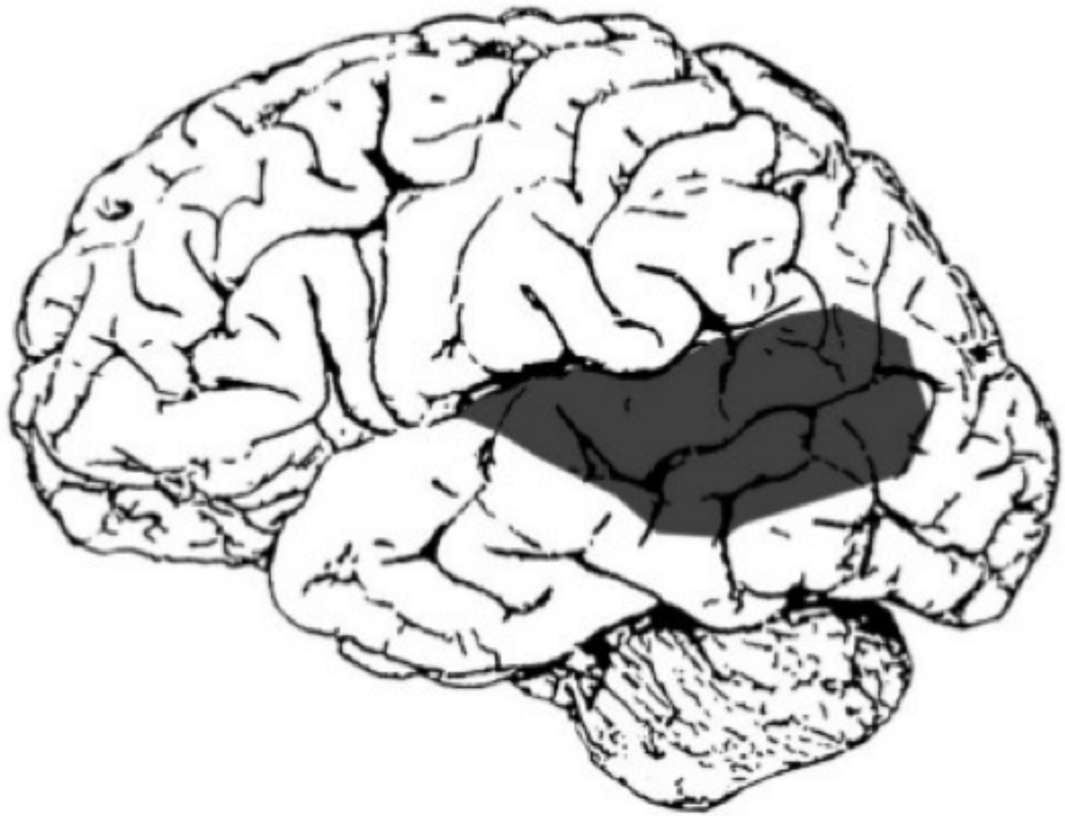
- ***The Temporal Lobes***: the temporal lobes are located on each side of the brain.

  - auditory information projects directly to the primary auditory area, making it the main site where hearing is first registered.

  - an association area, called ***Wernicke's area,*** lies on the left temporal lobe (for 5% of the people on the right). Wernicke's area also functions as a language site.

  - damage to the Wernicke's area leads to *receptive aphasia,* i.e. a person can hear speech but has difficulty understanding the meaning of words.

Wernicke's Aphasia



- Damage to Wernicke's area alone is not enough to produce Wernicke's aphasia
- Usually involves Wernicke's area + surrounding areas including MTG & angular gyrus.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- ***The Occipital Lobes***: the occipital lobes are situated at the back of the brain & are concerned with vision.

  - how do the visual areas represent vision?

  - images from the retina are mapped onto the cortex, but the map is greatly stretched & distorted (Carlson, 2010). visual information creates complex patterns of activity in neurons, & does not make a television like image.

- an interesting result of brain injury is **visual agnosia,** an inability to identify seen objects.

- visual agnosia is often cause by damage to the association areas on the occipital lobes (Farah, 2004). often called **mind blindness.**

  - for e.g. if we show Alice, an agnosia patient, a candle, she can see it & describe it as “a long narrow object, that tapers at the top.” Alice may also be able to draw the candle, but not name it.
  - however, if she is allowed to touch the candle, she will be able to name it.
  - In short, Alice can still see color, size, shape etc. but can’t form the associations necessary to perceive the meanings of objects.

- ***Are agnosia limited to objects?***
  - No. A fascinating form of agnosia is **facial agnosia,** an inability to perceive familiar faces.
  - a patient with facial agnosia could not recognise her husband or mother when they visited her in the hospital, & she was unable to identify pictures of her children. however, as soon as the visitors spoke she knew them by voices.
  - so, areas devoted to recognising faces lie in the association areas on the underside of the occipital lobe & the areas seem to have no other function.

To Sum Up…

- In this lecture we talked about the structural & functional organisation of the cerebral cortex.

- More specifically, we talked about:

  - Hemispheric Specialization.

  - & The Functions of the cortical lobes.

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Course Title:

Basic Cognitive Processes

By: Dr. Ark Verma,
Assistant Professor of Psychology,
Department of Humanities & Social Sciences,
IIT Kanpur

Lecture 12: Research Methods in Cognitive Psychology

What do we already know?

- The basics of research methods in psychology.
- Variety of research designs: descriptive, correlational & experimental.
- An emphasis of quantifying aspects of behaviour, so that they can be empirically measured.
- Aspects of reliability & validity of research findings.

Methods in Cognitive Psychology

- Methods used in cognitive psychology are mostly ***experimental in nature***, i.e. they follow experimental design.

- The idea is to quantify abstract mental variables like memory, attention, perception etc. & find a way to measure them.

- Measure could be in terms of two things:
    - Time taken
    - Accuracy

Mental Chronometry: Reaction Time Studies

- ***Mental Chronometry*** is the use of response time in pereceptual – motor tasks to infer the content, duration and temporal sequencing of mental/cognitive operations.

- Mental chronometry is one of the core paradigms of experimental & cognitive psychology & has also found application in other disciplines such as cognitive neuroscience.

- One of the ways of doing that is using ***Reaction Time (RT)***, which is elapsed time between the presentation of a sensory stimulus and a subsequent behavioral response

- RT is considered to be an index of processing speed, i.e. it indicates how fast an individual can execute the various stages of mental processing needed to complete a given task.

- Also, this processing speed is considered to be an index of the individual's processing efficiency. E.g. tasks in which an individual is highly proficient should take less time as compared to tasks that the individual is not very good at.

- The behavioural response could be amongst a variety of possible responses, e.g. keypress, voice onset, limb movement, eyemovement etc.

Types of Reaction Time (RT) Tasks

- One of the first persons to use a reaction time task was Fransiscus Donders, a Dutch Physiologist, who in 1868, did one of the first ever experiments in the field of ***Cognitive Psychology***.

- Donders, was interested in determining how long it takes for a person to make a decision.

- He determined this by measuring **reaction time**: i.e. how long it takes to respond to presentation of a stimulus.

- In the first part of his experiments, he asked his participants to press a button on the presentation of a light. This is called a ***simple – reaction time task*.**

- In the second part of the experiment, he made the task more difficult by presenting two lights, one on the left and one on the right. The participants' task in this part of the experiment was to push one button when the light on the left was illuminated and another button when the light on the right was illuminated. This is called a ***choice reaction time task***.

(a) Press J when light goes on.

(b) Press J for left light, K for right.

FIGURE 1.2 A modern version of Donders' (1868) reaction time experiment: (a) the simple reaction time task; and (b) the choice reaction time task. In the simple reaction time task, the participant pushes the J key when the light goes on. In the choice reaction time task, the participant pushes the J key if the left light goes on and the K key if the right light goes on. The purpose of Donders' experiment was to determine the time it took to decide which key to press for the choice reaction time task.

- Donders reasoned that choice reaction time would be longer than simple reaction time because of the additional time it takes to make the decision and the difference in the reaction time would indicate how long it took to make the decision.

    - Because the choice reaction time took one-tenth of a second longer than simple reaction time, Donders concluded that it took one-tenth of a second to decide which button to push.

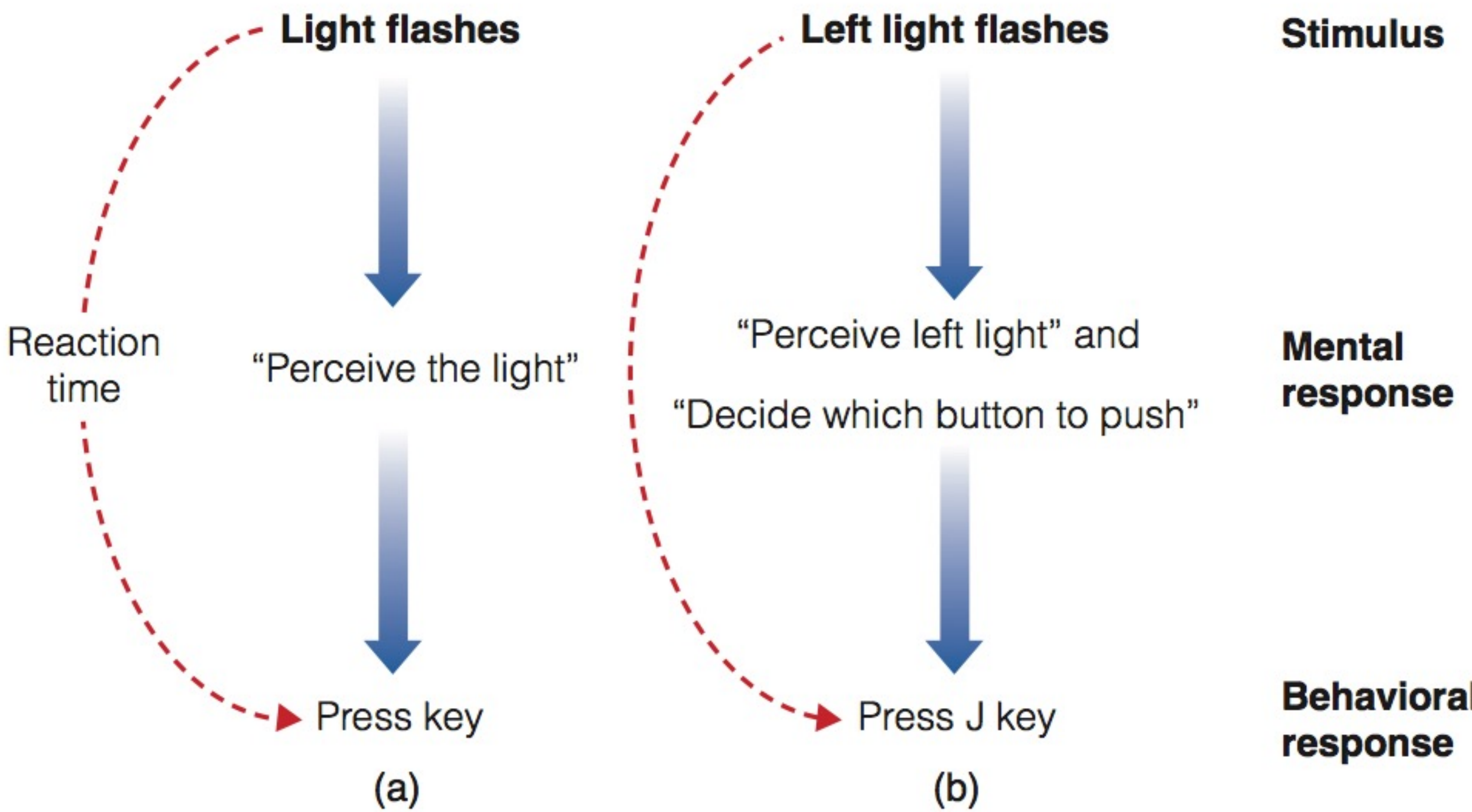


FIGURE 1.3 Sequence of events between presentation of the stimulus and the behavioral response in Donders' experiment. The dashed line indicates that Donders measured reaction time, the time between presentation of the light and the participant's response. (a) Simple reaction time task; (b) choice reaction time task.

- Another kind of reaction time task that Donders introduced was the ***recognition reaction time task.,*** wherein the participants were just asked to recognise the presented stimuli. The ‘Symbol Recognition Task’ or the ‘Tone Recognition Task’ could be examples of the same.

Other aspects of Reaction Time (RT) studies

- Mean RTs: 190 ms for light stimuli & 160 ms for sound stimuli (Galton, 1899; Fiendt et al., 1956; Brebner & Welford, 1980).

- Donders (1868) showed that SRT is shorter than the RRT & the RRT is shorter than the CRT.

- Laming (1968) concluded that SRTs averaged around 220 ms & RRTs averaged around 384 ms.
  - In line with studies suggesting that more complex stimuli (several letters in symbol recognition vs. one letter) elicits a slow reaction time.

- Miller & Low (2001) determined that the time for motor preparation (e.g. tensing muscles) and motor response (e.g. pressing the key) was the same in all three types of reaction time tasks, implying that the differences in reaction time are due to processing time.

- ***Hick's Law***: Hick (1952) found that in CRT experiments, the response time was proportional to log (N), where N is the number of different possible stimuli.

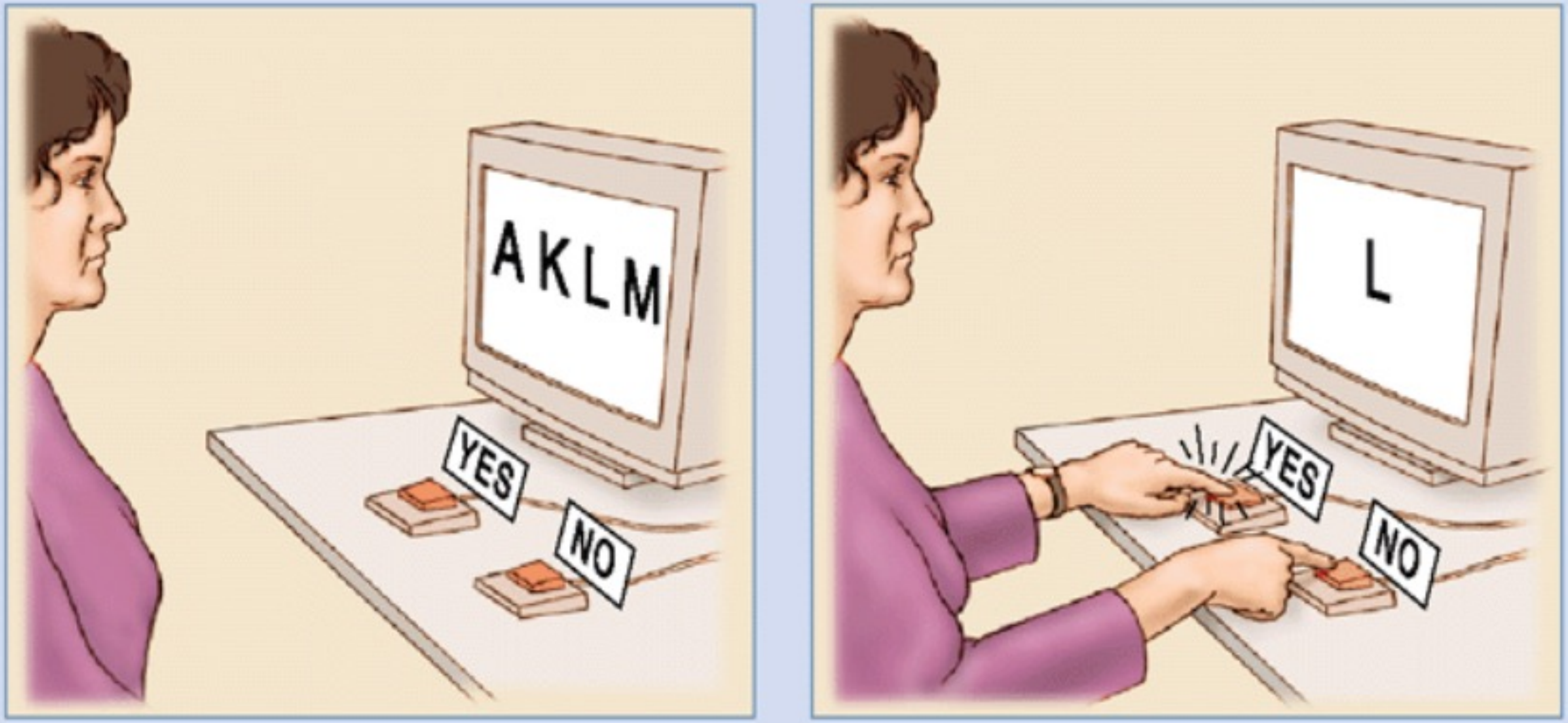
- More specifically, reaction times rise with N, but once N gets large, reaction time no longer increases so much as when N was small.

- This relationship is called Hick's Law.

- Sternberg (1969) maintained that in recognition experiments, as the number of items in the memory set increases, the reaction time rises proportionately (~N & not log (N)).

- Reaction times ranged from 420 ms for 1 valid stimulus (such as 1 letter in symbol recog) to 630 ms for 6 valid stimuli, increasing by about 40 ms every time another item was added to the memory set.

(a)



(b)

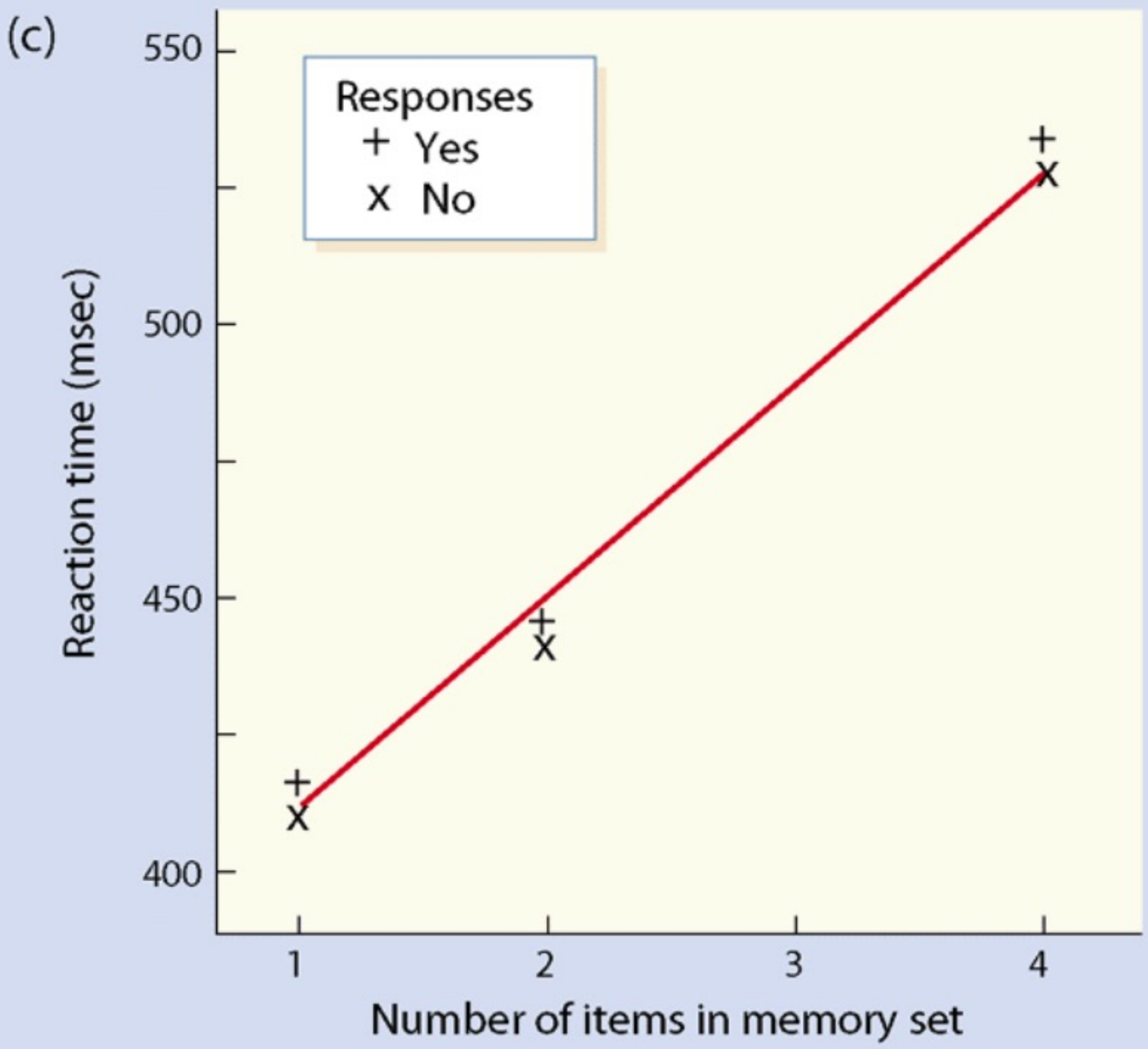
Hypothesized stages

Stage 1: Encode

Stage 2: Compare

Stage 3: Decide

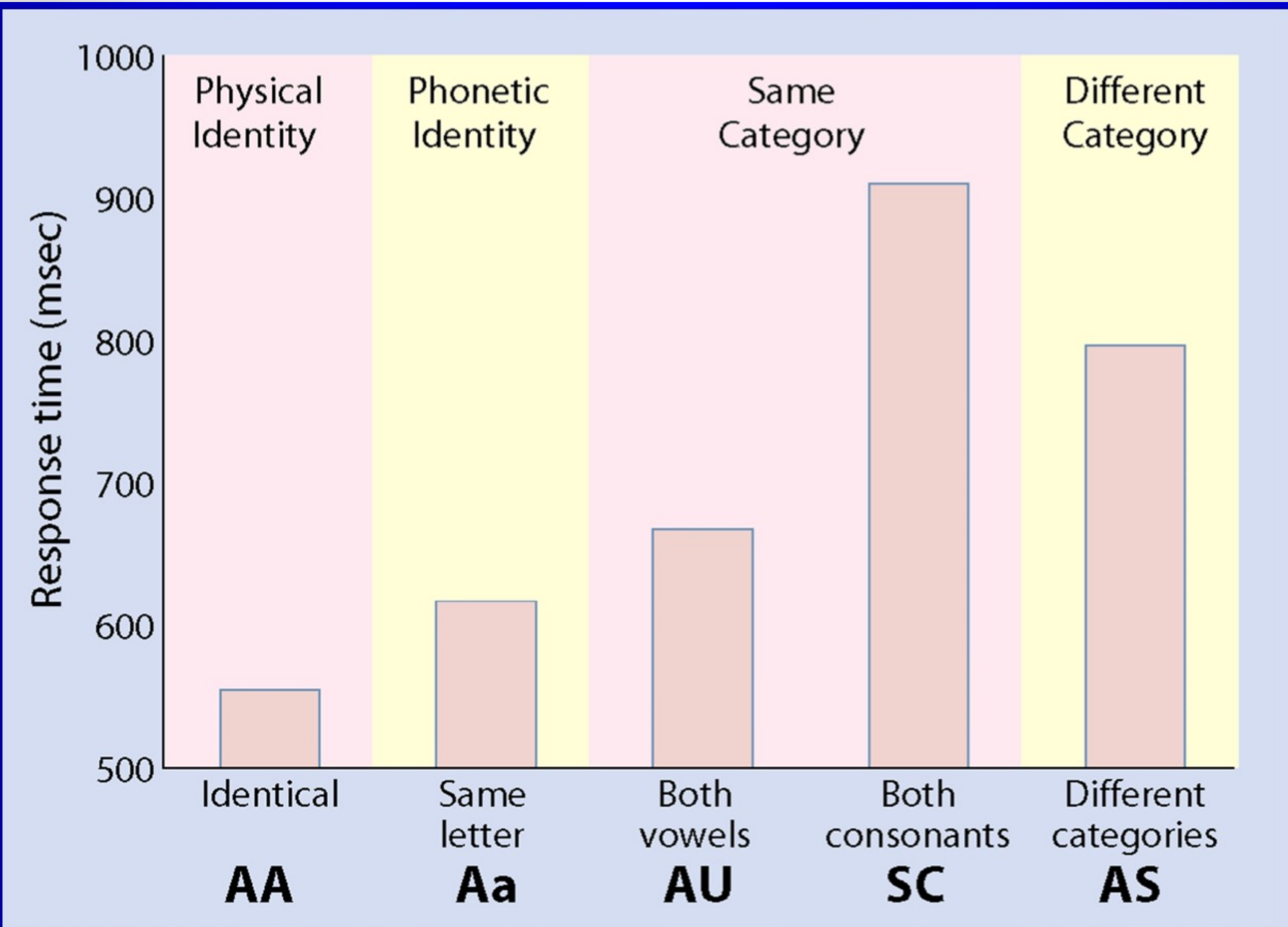
Stage 4: Respond


(c)
Responses
+ Yes
x No
Reaction time (msec)
550
500
450
400
1
2
3
4
Number of items in memory set

- ***Implications of Sternberg's Task***
  - Memory retrieval is a serial comparison process between items in memory & those in the world.
  - Each comparison takes a fixed amount of time.
  - Mental operations can be quantified in terms of the amount of time they take.

Other Important Tasks

- ***The Posner Task***: Posner (1978) used a series of letter – matching studies to measure the mental processing of several tasks associated with recognising a pair of letters.
    - In the physical match task, in which subjects were shown a pair of letters and had to identify whether the two letters were physically identical or not.
    - The next was name matching task, whether the two letters had the same name.
    - The most time consuming was rule matching task, whether both letters were vowels.

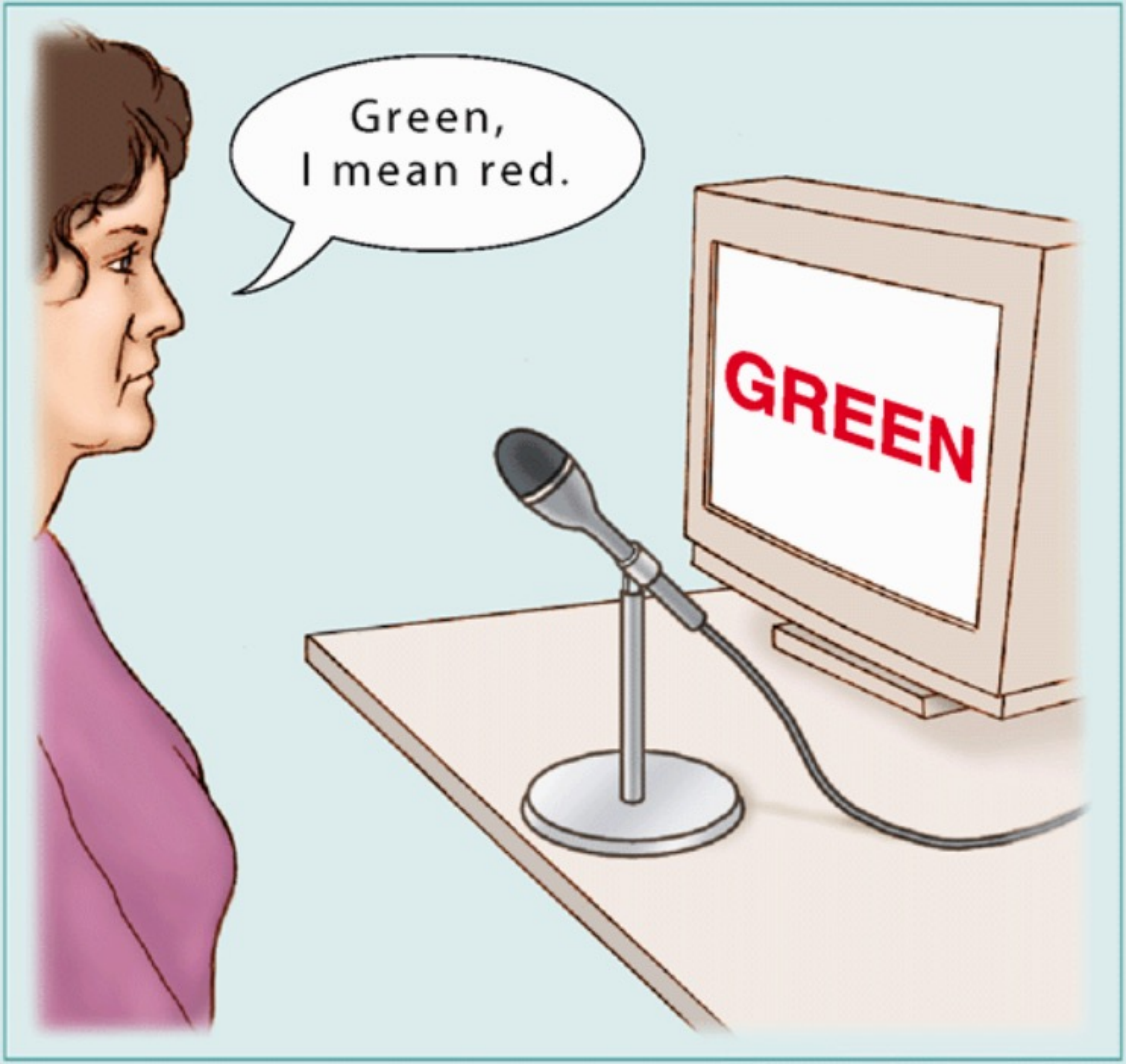

1000
900
800
700
600
500
Response time (msec)
Physical Identity
Phonetic Identity
Same Category
Different Category
Identical
AA
Same letter
Aa
Both vowels
AU
Both consonants
SC
Different categories
AS

- ***The Stroop Task:*** J. R. Stroop (1935) asked participants to read out names of colour words (e.g. red, blue, green etc.) when they were printed in an ink colour which could either match/not – match the colour word.

- Participants performed worse when there was no match between the colour word & colour ink.

- It showed that not only multiple representations do get activated on presentation of stimuli, some of them could have privilege over others.

Color matches word	Random colors	Color doesn't match word
RED	XXXXX	GREEN
GREEN	XXXXX	BLUE
RED	XXXXX	RED
BLUE	XXXXX	BLUE
BLUE	XXXXX	GREEN
GREEN	XXXXX	RED
BLUE	XXXXX	RED
RED	XXXXX	BLUE


Green,
I mean red.
GREEN

Factors Influencing RTs

- Reaction time to sound is faster than reaction to light, mean auditory reaction times are between 140 – 160 ms & mean visual reaction times being 180 – 200 ms (Galton, 1899; Brebner & Welford, 1980).

- Froeberg (1907) found that visual stimuli that are longer in duration elicit faster reaction times, Wells (1913) found the same for auditory stimuli.

- So, much about the reaction time studies.

- They have been used since a long time for investigating a huge variety of mental processes like:
  - Langauge (naming times, LDT times)
  - Attention (Visual search RTs)
  - Memory (Recognition RTs)

- Also, the RT studies form the base of variety of experiments using additional methodologies like those in Cognitive Neuroscience.

Methods in Cognitive Neuroscience

- One of the first demonstrations of localisation of function is the **primary receiving areas** for the senses. These are the first areas of the cerebral cortex to receive signals from each of the senses.

  - e.g. sound stimulates the receptors in the ear, the resulting electrical signals reach the auditory receiving area in the **temporal lobe.**

  - the primary receiving area for vision occupies the **occipital lobe**; the area for the skin senses (touch, temperature, & pain - is located in the **parietal lobe**; & the areas for taste & smell are located on the underside of the **temporal lobe**.

- the **frontal lobe** receives signals from all of the senses and plays an important role in perceptions that involve the coordination of information received through two or more senses.

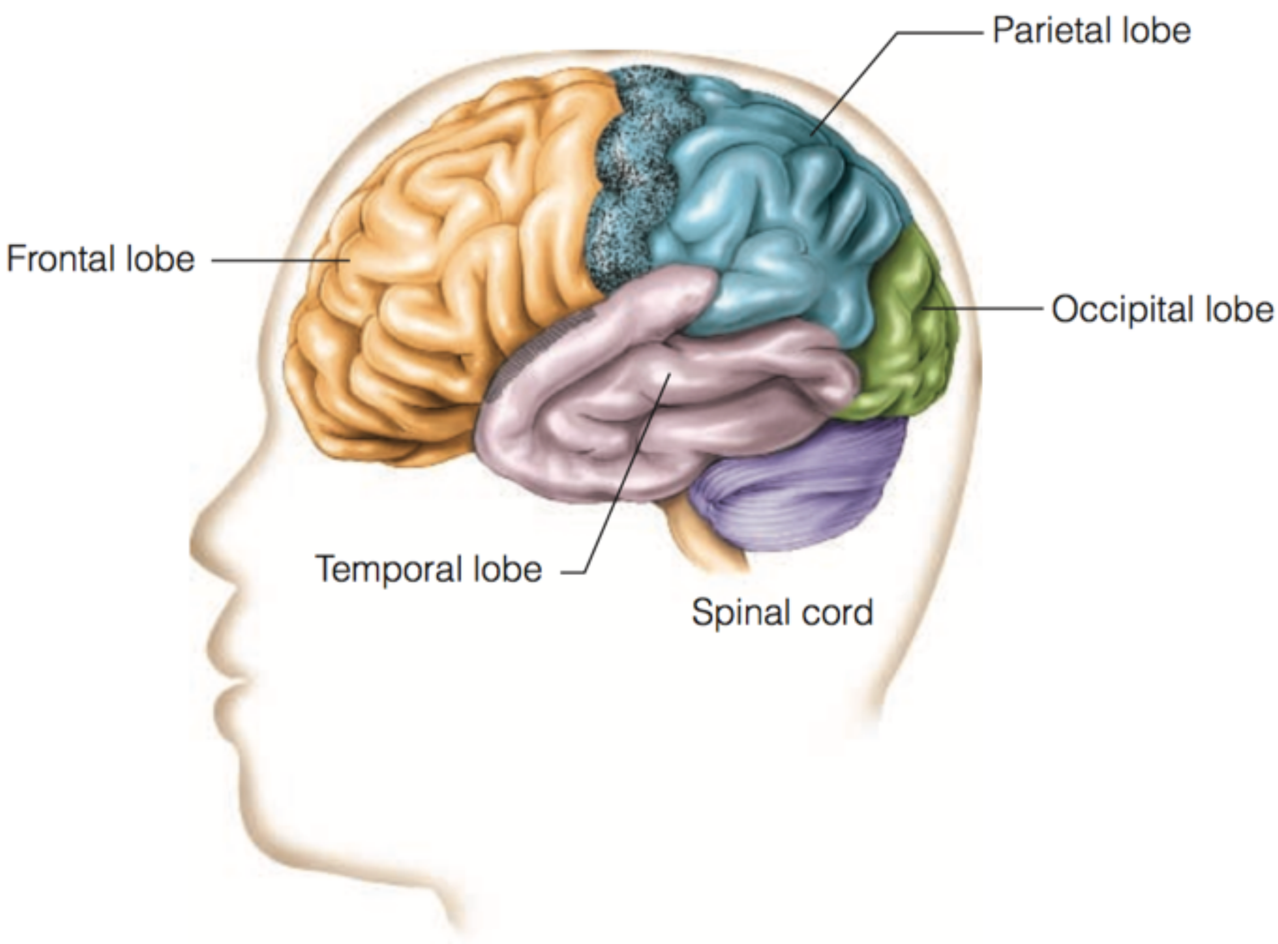


FIGURE 2.7 The human brain, showing the locations of the primary receiving areas for the senses: vision = occipital lobe; skin senses = parietal lobe (dotted area); hearing = temporal lobe (located within the temporal lobe, approximately under the hatched area). Areas for taste and smell are not visible. The frontal lobe responds to all of the senses and is involved in higher cognitive functioning.

- ***Methods for Localisation of Brain Function***

- A widely used technique for measuring brain activity in humans is **brain imaging**, which allows researchers to create images that show which areas of the brain are activated as awake humans carry out various cognitive tasks.
  - **Positron Emission Tomography (PET)** takes advantage of the fact that blood flow increases in areas of the brain that are activated by a cognitive task.
    - To measure blood flow, a low dose of a radioactive tracer is injected into a person's bloodstream. The person's brain is then scanned by the PET apparatus, which measured the signal from the tracer at each location in the brain. Higher the signal higher the brain activity.

- PET has enabled researchers to track changes in blood flow, & thus to determine which brain areas were being activated.

- To use this tool, researcher's developed the **subtraction technique**.

  - the brain activity is measured first in a "control state", before stimulation is presented; and again while the stimulus is presented.

    - for e.g. in a study designed to determine which areas of the brain are activated when a person manipulates an object; activity generated by simply putting an object in the hand is measured first; this being the **control state.**

- then the activity is measured as the person manipulates the object. this is called the **stimulation state.** Finally, the activity due to manipulation is determined by subtracting the control activity from the stimulation activity.

• **FIGURE 2.9** The subtraction technique used to interpret the results of brain imaging experiments. (a) Colored area indicates activation when a person is holding a small object. (b) Colored areas indicate activation when the person begins manipulating the object. (c) Subtracting the activation in (a) from the activation in (b) indicates the activation due to manipulation of the object. (Source: B. Goldstein, *Sensation and Perception*, 8th ed., Fig. 4.16, p. 83. Copyright © 2010, Wadsworth, a part of Cengage Learning. Reproduced with permission. www.cengage .com/permissions.)

- Another neuroimaging technique called **functional magnetic resonance imaging (fMRI)** was introduced to take advantage of that the fact that blood flow can be measured without radioactive tracers, as well.

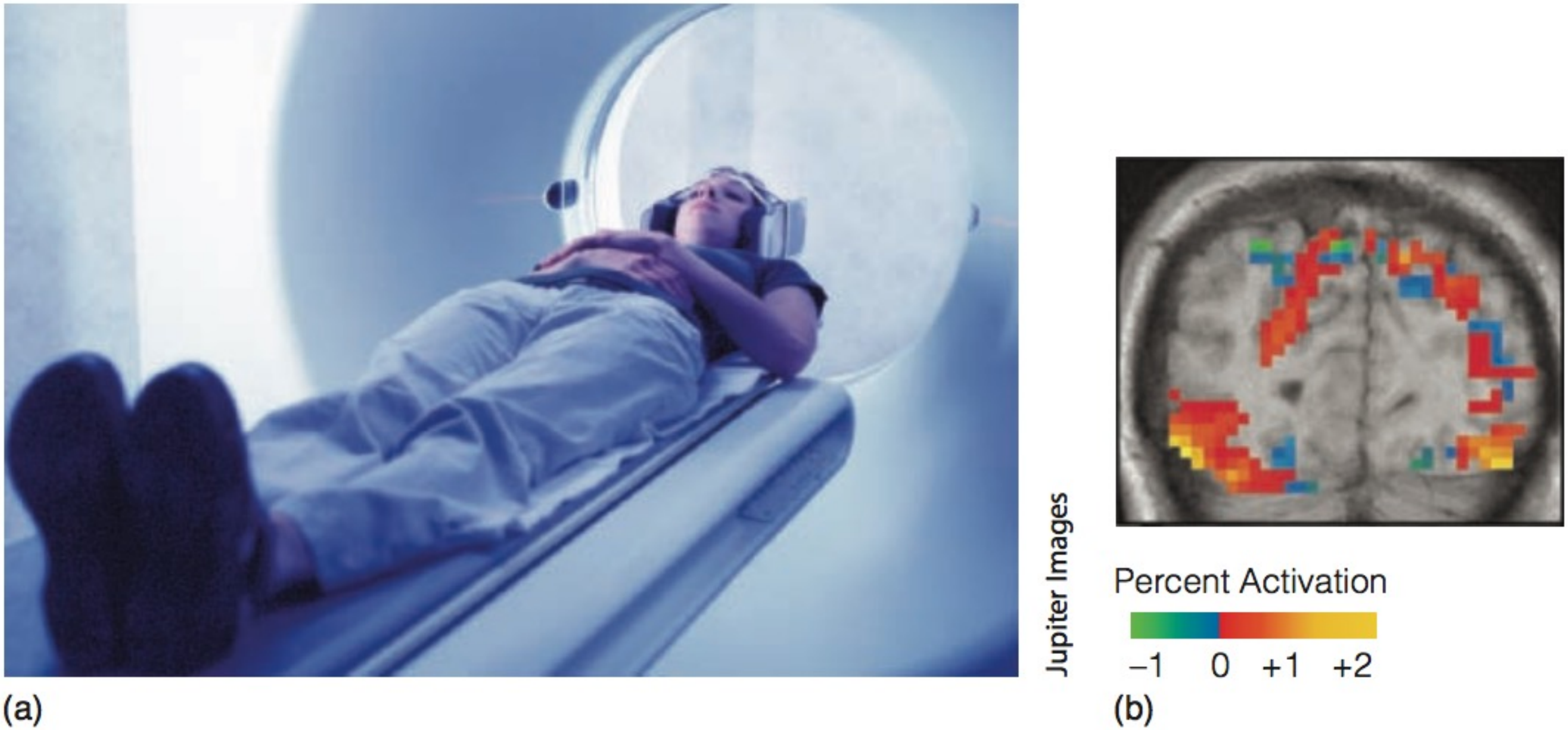
- fMRI uses the fact that haemoglobin, which carries oxygen in the blood contains a ferrous molecule and therefore has magnetic properties. If a magnetic field is presented to the brain, the haemoglobin molecules line up, like many tiny magnets

- fMRI indicates the presence of brain activity because the haemoglobin molecules in areas of high brain activity lose some of the oxygen they are transporting.

- this makes the haemoglobin more magnetic, so those molecules respond more strongly to the magnetic field.

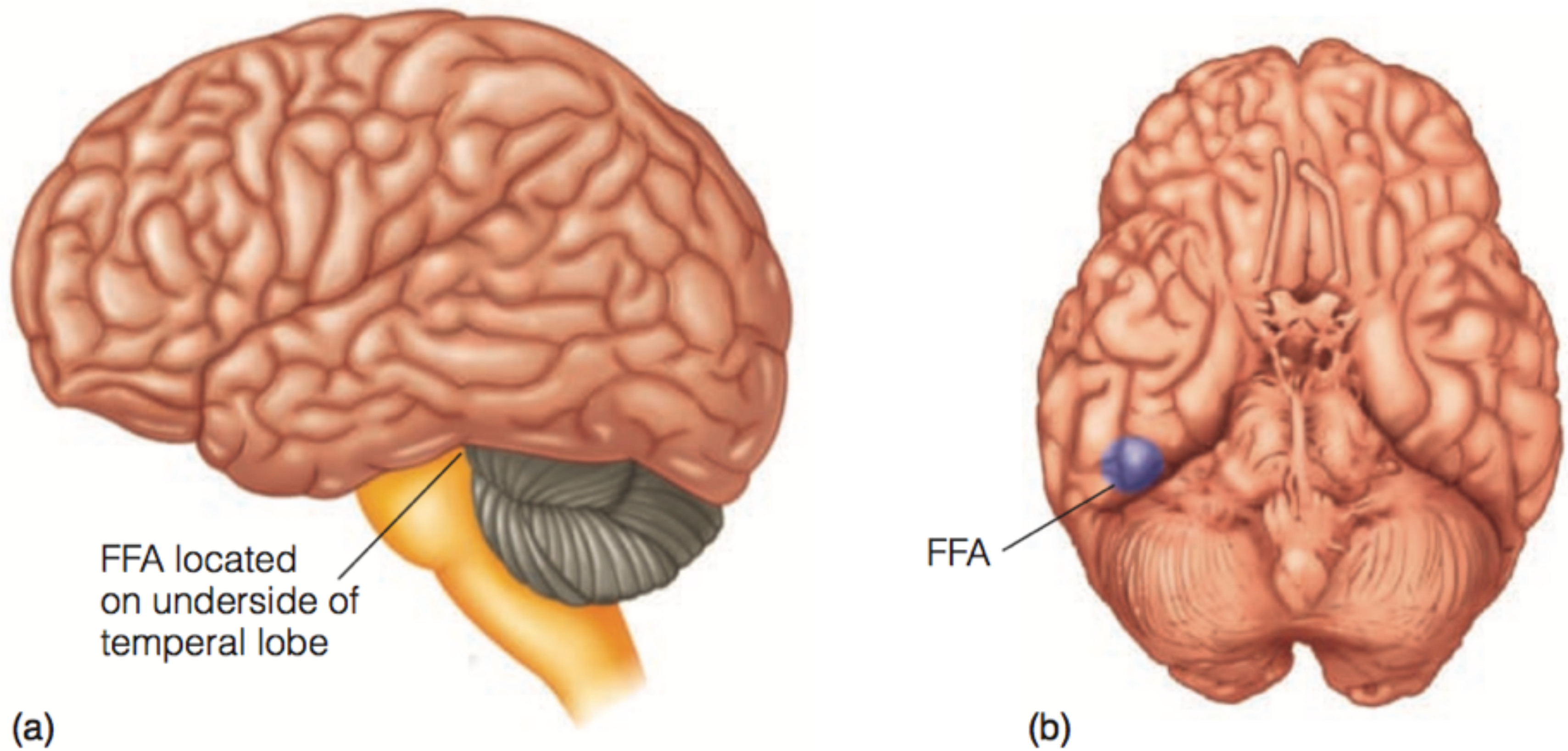
- the fMRI apparatus determines the relative activity of various areas of the brain by detecting changes in the magnetic response of the haemoglobin.

- the subtraction technique is also used for fMRI.



● **FIGURE 2.8** (a) Person in a brain scanner. (b) In this cross section of the brain, areas of the brain that are activated are indicated by the colors. Increases in activation are indicated by red and yellow, decreases by blue and green. (Source: Part b from Alumit Ishai, Leslie G. Ungerleider, Alex Martin, James V. Haxby, "The Representation of Objects in the Human Occipital and Temporal Cortex," *Journal of Cognitive Neuroscience, 12:*2, 2000, pp. 35–51. © 2000 by the Massachusetts Institute of Technology.)

- **Using fMRI**:
  - the **fusiform face area (FFA)** lies in the fusiform gyrus on the underside of the temporal lobe & corresponds to the damaged area in people having prosopagnosia.
  - the **parahippocampal place area (PPA)** is activated by pictures representing indoor and outdoor scenes.
  - the **extra striate body area (EBA)**, is activated by pictures of bodies & parts of bodies (but not by faces).



● **FIGURE 2.10** (a) Side view of the brain. The fusiform face area (FFA) is not visible in this view because it is located on the underside of the brain. (b) Underside of the brain, showing location of the FFA. (Source: B. Goldstein, *Sensation and Perception*, 8th ed., Fig. 13.14, p. 323.

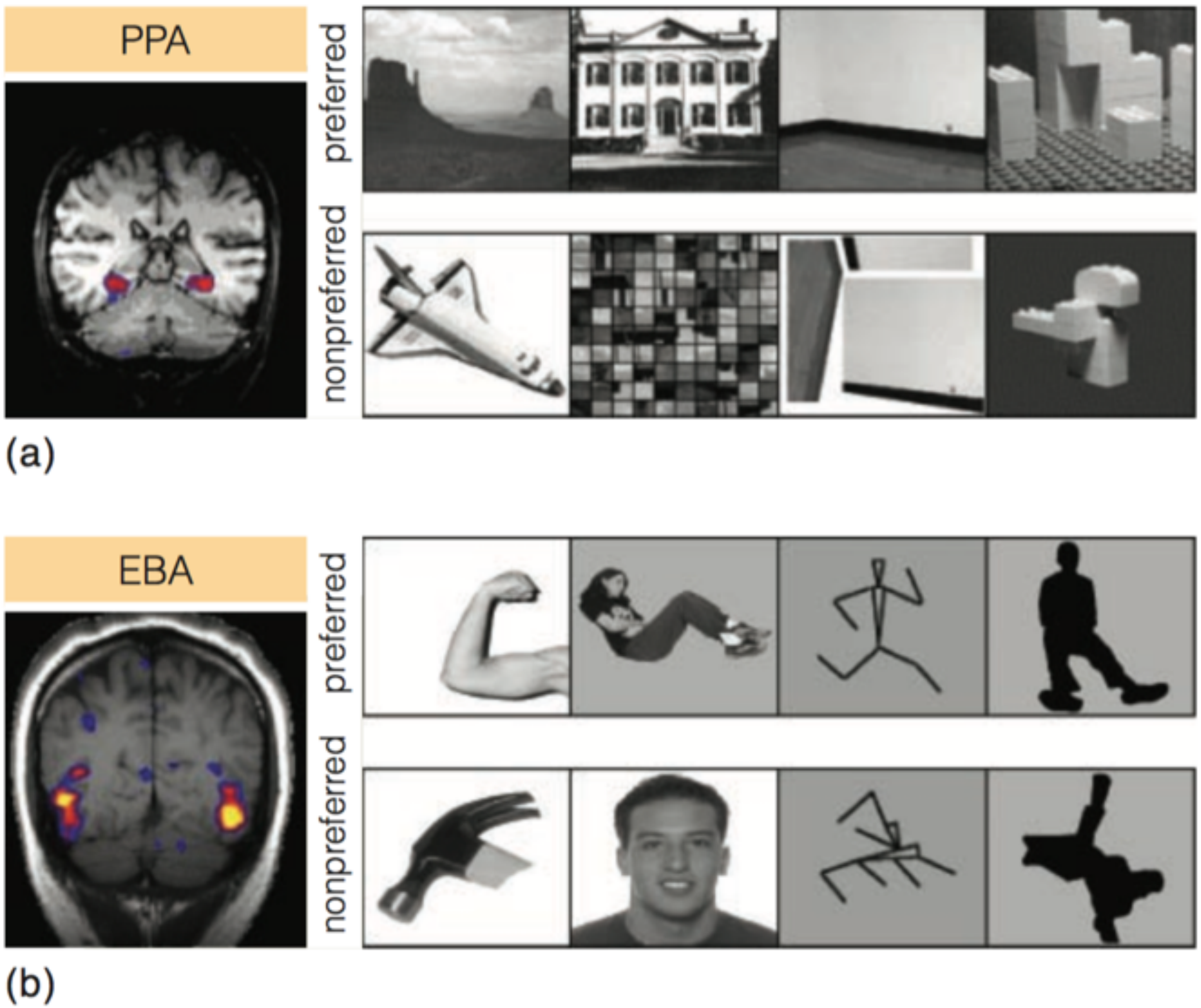


FIGURE 2.11 (a) The parahippocampal place area is activated by places (top row) but not by other stimuli (bottom row). (b) The extrastriate body area is activated by bodies (top), but not by other stimuli (bottom). (Source: L. M. Chalupa & J. S. Werner, eds., *The Visual Neurosciences,* 2-vol. set, figure from pages 1179–1189, © 2003 Massachusetts Institute of Technology, by permission of The MIT Press.)

- **Event Related Potentials (ERP):** The event related potential is recorded with small disc electrodes placed on a person's scalp. Each electrode picks up signals from groups of neurons that fire together.

- When the person (fig 2.13) hears the phrase "The cats won't eat." & ERPs are recorded; you can notice that the signals are very rapid, occurring on a time scale of milliseconds.

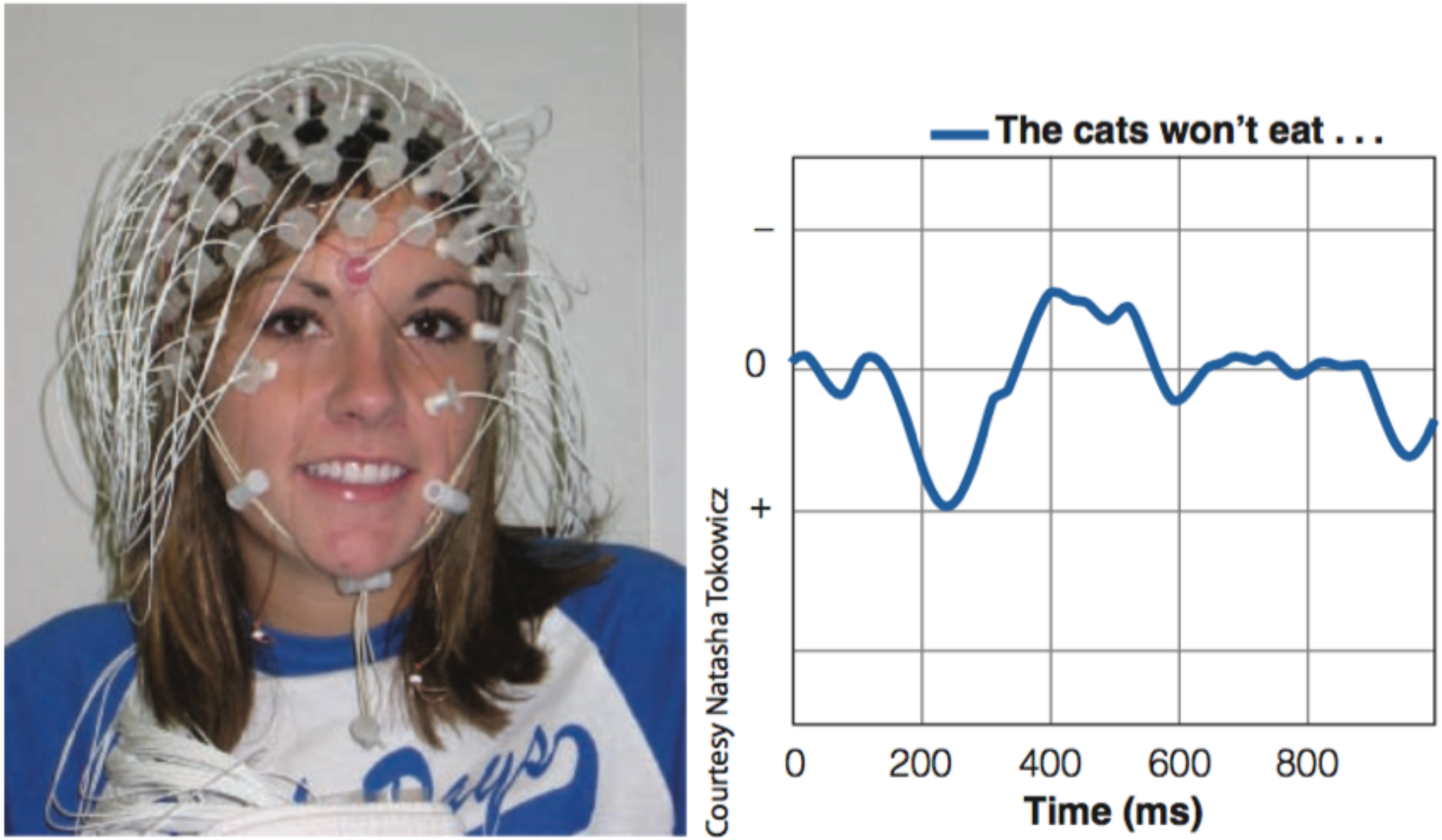
- this makes ERP the ideal technique for investigating a process such as understanding a conversation; in which speakers are saying almost 3 words/sec on an average (Levelt, 1999).

- The rapid response of the ERP contrasts with the slow response of the brain imaging methods (as PET, fMRI) which takes seconds to develop.

- A disadvantage of the ERP method is that it is difficult to pinpoint the source of these signals.

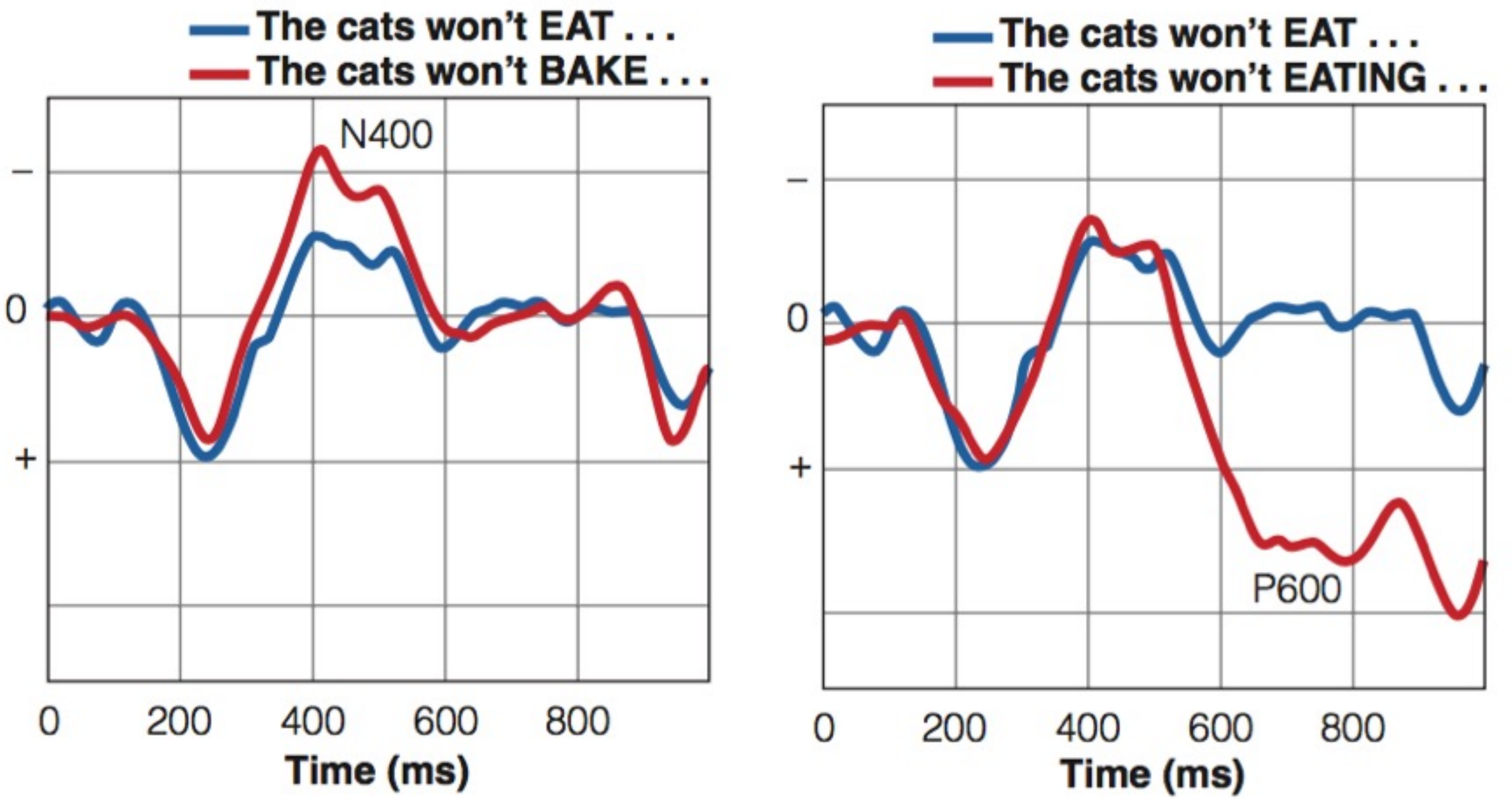
- Still, the ability of the ERP to provide a nearly continuous record of what is happening in the brain from moment to moment makes it particularly suited for studying dynamic processes such as language (Kim & Osterhout, 2005).

- As a method of investigation, ERP is useful in distinguishing between the processing of form & meaning of language.
  - As ERP consists of a number of waves that occur at different delays after a stimulus is presented; these can be linked to different aspects of language.
  - Two components that are known to respond to different aspects of language are the N400 component & the P600 components, respectively.



(a) (b)

FIGURE 2.13 (a) Person wearing electrodes for recording the event-related potential (ERP). (b) An ERP to the phrase "The cats won't eat."



(a) How semantics affects N400

(b) How syntax affects P600

FIGURE 2.14 (a) The N400 wave of the ERP is affected by the meaning of the word. It becomes larger (red line) when the meaning of a word does not fit the rest of the sentence. (b) The P600 wave of the ERP is affected by grammar. It becomes larger (red line) when a grammatically incorrect form is used. (Source: From Osterhout et al., "Event-Related Potentials and Language," in *Trends in Cognitive Sciences,* Volume 1, Issue 6. Copyright © 1997 Elsevier Ltd. Reproduced with permission.)

- An important thing about these results is that they illustrate different physiological responses to two different aspects of language: form & meaning.

- Other experiments have shown that the N400 response is associated with structures in the temporal lobe. for e.g. damage to the areas in temporal lobe reduces the large n400 response that occurs when meanings do not fit in a sentence.

- The P600 response is associated with structures in the frontal lobe, more towards the anterior areas of the brain. damage to the areas in frontal lobe reduces the larger P600 response that occurs when the form of a sentence is incorrect (Osterhout et al., in press).

To Sum Up…

- In this lecture we talked about the various research methodologies used to investigate the functional & neural correlates of mental functions.

  - RT Tasks.
  - Neuroimaging Tasks (PET, fMRI).
  - Electrencephalographic Taks (ERPs)

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National Program on Technology Enhanced Learning (NPTEL)

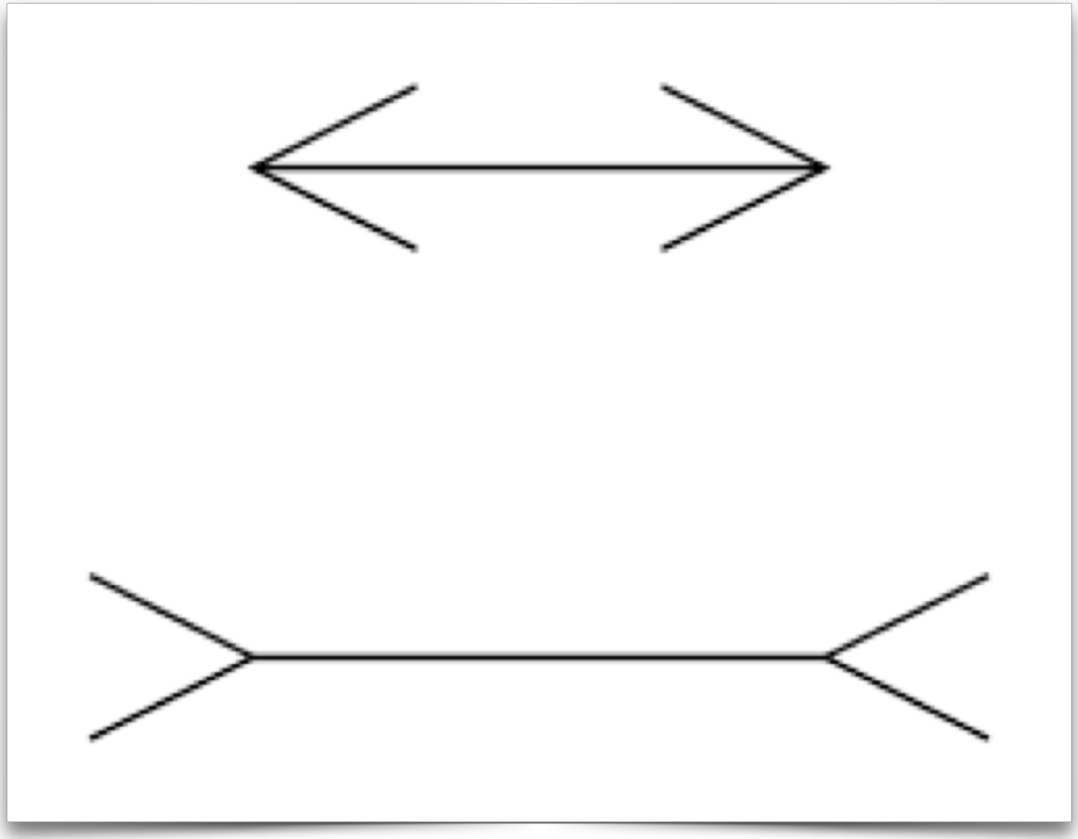
Presents

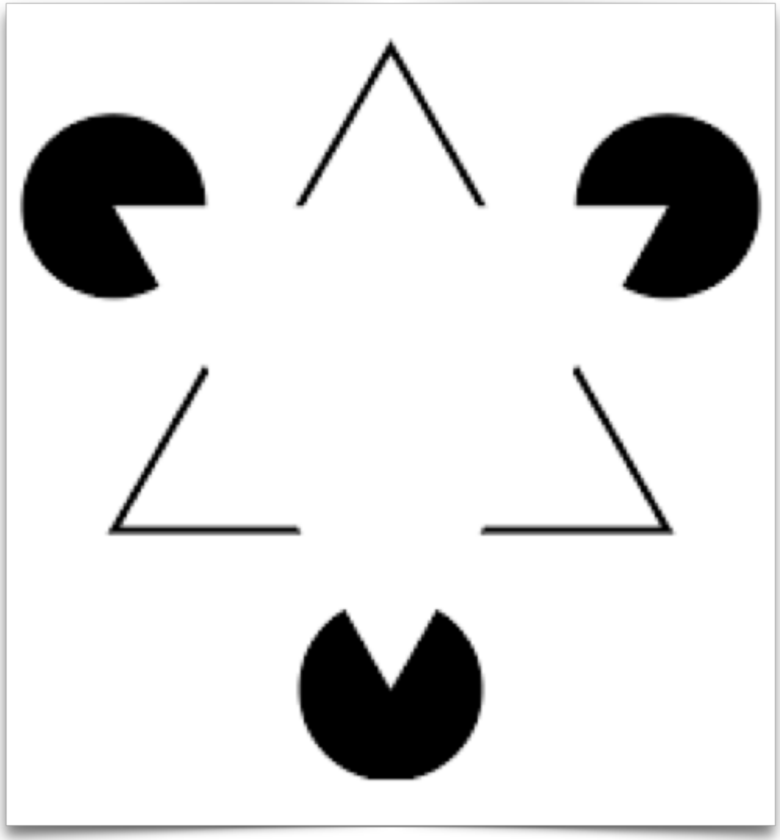
Course Title:

Basic Cognitive Processes

By: Dr. Ark Verma,
Assistant Professor of Psychology,
Department of Humanities & Social Sciences,
IIT Kanpur

Lecture 13: Sensation & Perception





- What did you see in the last few pictures?
- Is it that you made a mistake or is it your senses that befooled you?
- In the latter case, is perception not accurate?

Some basic considerations…

- *"perception is the set of processes by which we recognise, organise, & make sense of the sensations we receive from environmental stimuli* (Goodale, 2000)".
- *"perception is the process by which the cognitive system constructs an internal representation of the outside world."*
- constructs: an active process
- representation: may be different to reality

- Key Issues in Perception

  - “not” an accurate representation of the reality.

  - instead, perception is an “interpretation” of the sensory input.

    - senses may deceive us.
    - senses may be erroneous.

Perception: Various Aspects

- Sensation
- Representation
- Perception
- Influences on Perception

Part I: Sensation

"A question often asked in the some philosophy classes is this: If a tree falls in the forest but nobody hears it, is there a sound?"

The answer is now clear: No!!!

Sound is caused by waves of molecules (a physical event), but the waves themselves are not sound.

Sound is a psychological event and hence depends on a nervous system to transduce the physical energy of the waves to nerve impulses.

Without a brain to register the transduced physical energy, there can be no sound. The situation is exactly analogous to the relationships of wavelength to hue and of amplitude to lightness.

Physical properties lead to psychological events, but they are not the events themselves. The discipline of **psychophysics** charts the relationship between physical events and our experiences of them.

- What comes next?
  - We’ll study some basic concepts in Psychophysics & see how they are used to measure sensation.
  - We’ll talk about how ‘representation’ of information in the external world influences perception.
  - We’ll discuss various approaches to perception.
  - We’ll also talk about theories of object recognition.
  - We’ll talk about various factors that may influence perception.

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Course Title:

Basic Cognitive Processes

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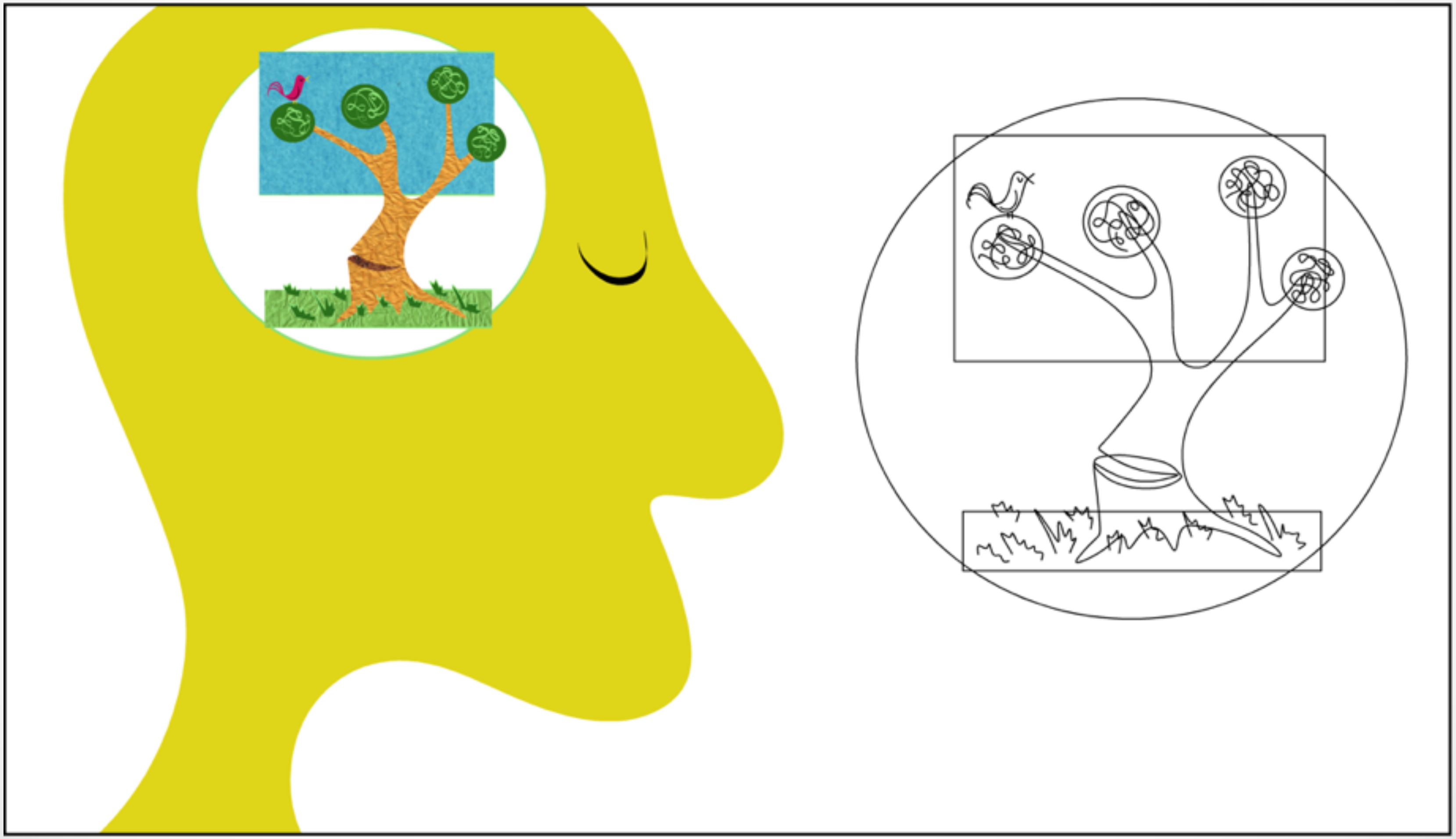
IIT Kanpur

Lecture 14: Basics of Psychophysics

Psycho – physics: Measuring Sensation



What is Psychophysics?

- Two words: Psychology + Physics
- Psychophysics involves the determination of the psychological reaction to events that lie along a physical dimension. e.g. loudness, lightness, brightness etc.
- G. Boring (1950) claims that the introduction of techniques to measure the relation between internal impressions (the psycho) & the external world (the physics) marked the onset of scientific psychology.

Basic Concepts

- the problem of psychophysics is a seeming paradox:
  - it requires objectification of a subjective experience.
- subjective experience is called **sensation**.

- Now, two issues:
    - measuring sensations is very difficult, because they are not open to public measurement, as light intensity or weight of a stone.
    - the internal judgments are not identical to the amount of physical energy influencing the sensory apparatus.

- Examples:

  - The amplifier or radio - dial that you use to increase the volume (i.e. perceived loudness) of music from your TV, does not bear a one-to-one relation between movements of the dial & increases in physical energy.

  - rather, the dial has to be calibrated so that its movements increase intensity proportional to increments in loudness.

  - thus, doubling the volume level on the dial has to increase physical energy about 10 times to produce a twofold increase in loudness.

- Also, the psychophysical relations between stimulus & judgment depend on the particular sensory modality that is stimulated.

- pain judgments in response to increases in electrical intensity of shocks applied to the skin grow much more rapidly than do loudness judgments in response to increase in sound energy.

- for one shock to be judged twice as painful as another, the intensity of the shock needs to have been increased about one-third.

- Psychophysics tries to solve this problem by closely linking perceptual experience to physical stimuli.
- the basic principle is to use the physical stimuli as a reference system.
- stimulus characteristics are carefully & systematically manipulated & observers are asked to report their perception of the stimuli.
- The art of psychophysics is to formulate a question that is precise & simple enough to obtain a convincing answer.

- " Can you hear the tone?"
  - yes! ***detection***
- "Can you tell which tone?"
  - yes! ***identification***

- Problems arise in case of weak signals or noise in the environment.

- In such cases, the task is one of ***discrimination*** of the stimulus, or signal, from a noisy background, and the task is performed under uncertainty.

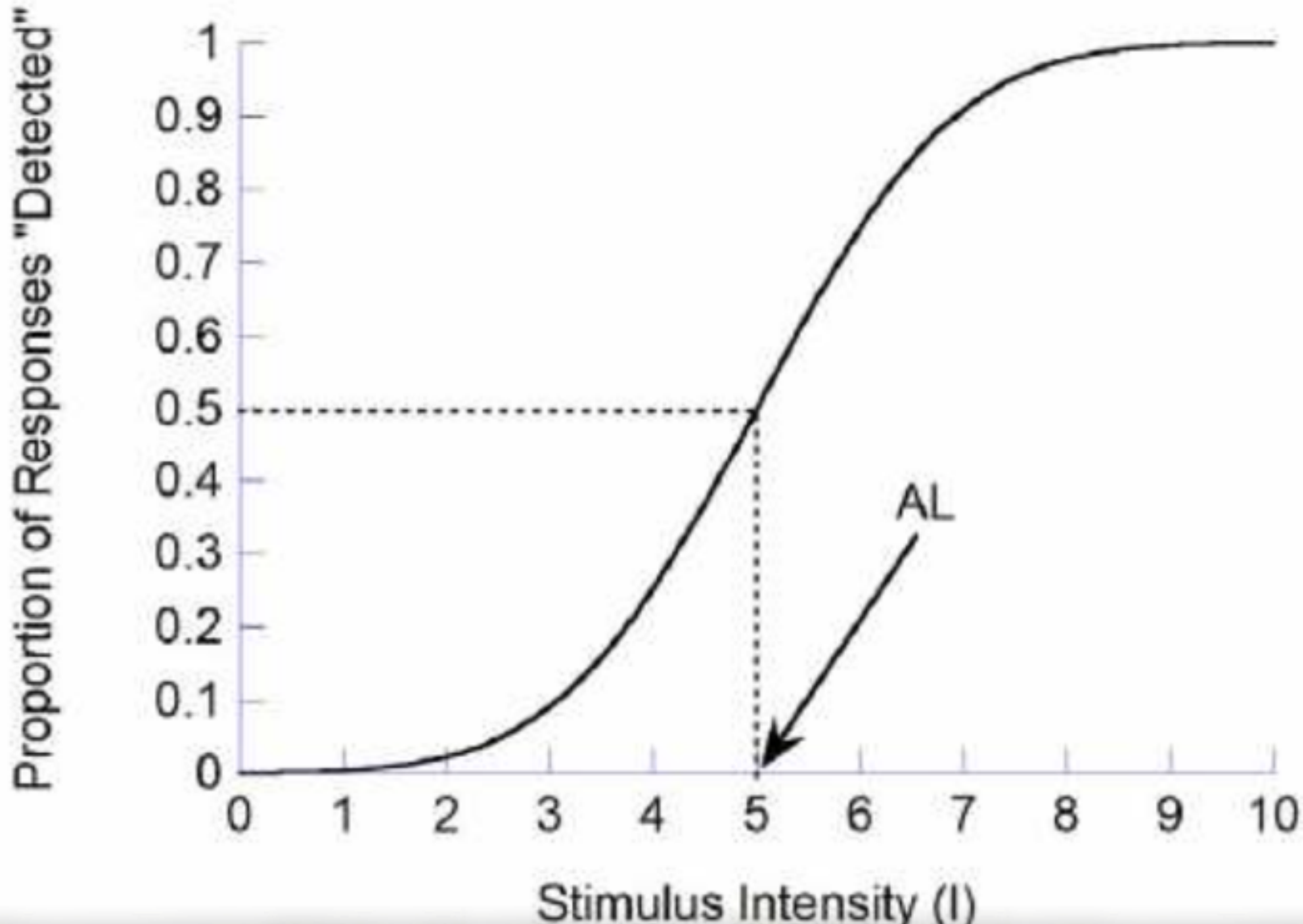
- So, What determines when we can:
- detect a signal.! or
- discriminate a signal from noise!

Sensory Threshold

- the most basic function of any sensory system is to detect energy or changes of energy in the environment.

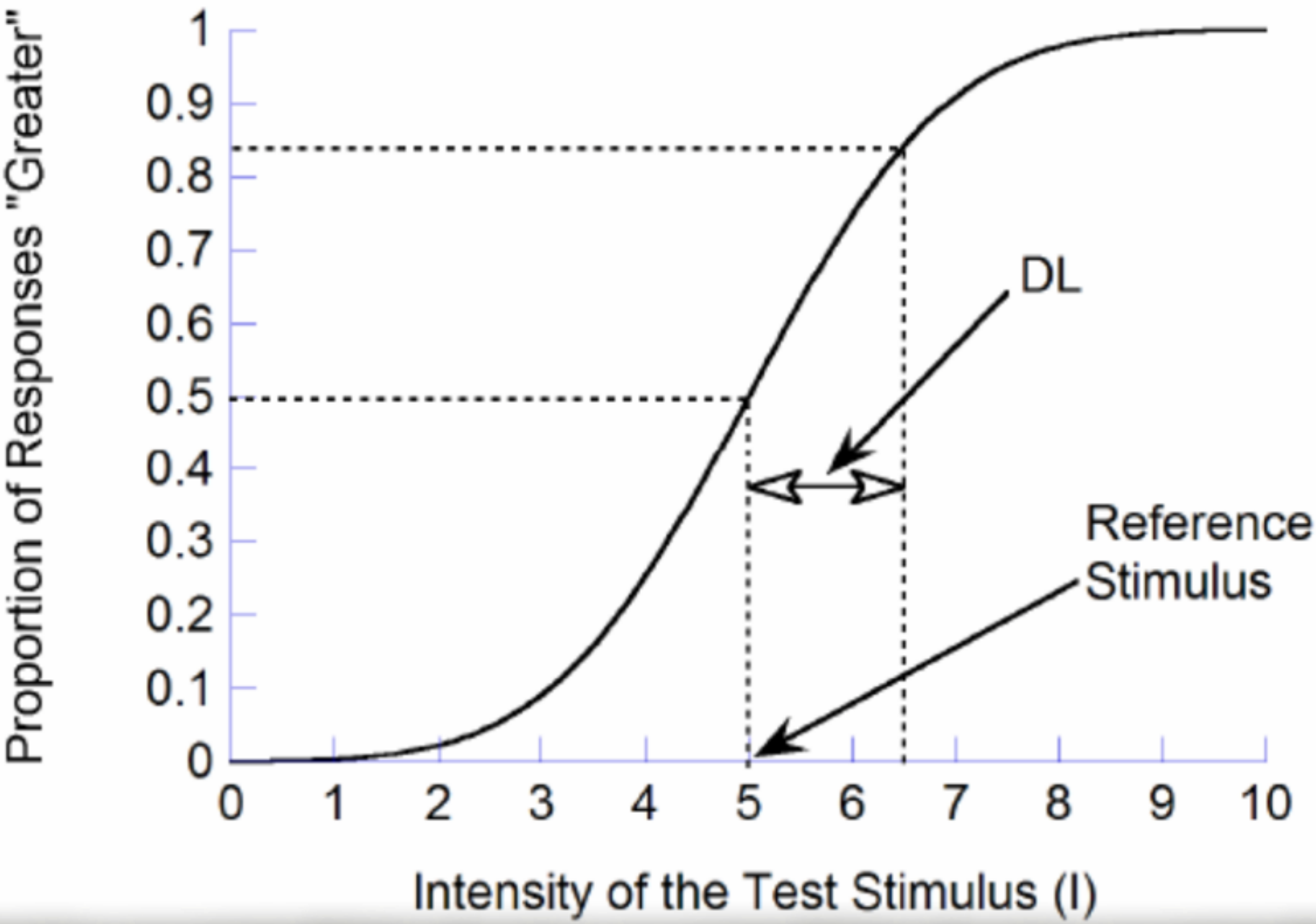
- this energy can consist of chemical (as in taste or smell), electromagnetic (vision), mechanical (audition, proprioception & touch) or thermal stimulation.

- in order to be noticed, the stimulus has to contain a certain level of energy. this minimal amount of energy is called ***absolute threshold***.
- according to Fechner, ***“lifts its sensations over the threshold of consciousness.”***


Proportion of Responses "Detected"
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
AL
0
1
2
3
4
5
6
7
8
9
10
Stimulus Intensity (I)

- the absolute threshold is thus the intensity of the stimulus that an observer can barely detect.

- On the other hand, ***difference threshold,*** refers to the minimum intensity by which a variable *comparison* stimulus must deviate from a constant *standard* stimulus to produce a perceptual difference.


Proportion of Responses "Greater"
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
DL
Reference Stimulus
0
1
2
3
4
5
6
7
8
9
10
Intensity of the Test Stimulus (I)

How do we determine threshold?

- **Method of Adjustment:**
  - the simples & quickest way to determine absolute & difference thresholds is:
    - to let a subject adjust the stimulus intensity until it just noticed or until it becomes just noticeable (when measuring absolute threshold)
    - or appears to be just noticeably different from or to just match a standard stimulus (when measuring difference threshold).

- **Steps**:
  - the observer is typically provided with a control of some sort that can be used to adjust the intensity, say of a sound, until it just becomes audible. (ascending series)
  - this intensity is recorded to provide an estimate of the observer’s threshold.
  - alternatively, the observer can adjust the sound from being clearly audible to just barely inaudible, providing another estimate of the threshold (descending series).
  - Typically the two kinds of adjustments are alternated several times & results are averaged to obtain the threshold estimate.

- **Method of Limits to determine Absolute Threshold**
  - a major difference between the method of adjustment & method of limits is that here one does not allow the observer to control the stimulus directly, rather the experimenter adjusts the intensities.
  - in the method of limits, a single stimulus, say a single light, is changed in intensity in successive, discrete steps and the observer's response to each stimulus presentation is recorded.

- one can start with stimulus which is too weak to be detected, & then increase the intensity in discrete steps till the stimulus is visible (ascending series)
- or one can start from a clearly visible stimulus & then decrease the intensity in discrete steps till the stimulus is not visible (descending series)
- the average of the intensity of the last “seen” & the first “not seen” stimuli in the ascending series & vice-versa in the descending series, is recorded as an estimate of the absolute threshold.

Using the Method of Limits to Determine an Absolute Threshold.

Stimulus Intensity	Response				
	↓		↓		
200			Yes		
180	Yes		Yes		
160	Yes		Yes		
140	Yes	Yes	Yes		
120	Yes	No	No	Yes	
100	Yes	No		No	
80	No	No		No	
60		No		No	
40		No		↑	
20		No			
		↑			
					Mean
Threshold	90	130	130	110	115

Note: In the first series of trials, the experimenter starts with a strong stimulus and decreases its intensity until the observer can no longer detect it. The threshold is the mean of the stimulus intensities that yield the first "no" response and the last "yes" response. In the next series of trials, a weak stimulus is increased in intensity until it is detected. It is customary to start each series at a different stimulus intensity to make it less likely that the observer's responses will be influenced by the length of a series. Stimuli are in arbitrary units—that is, the intensities ranging from 20 to 200 could represent weight or anything else that might vary in intensity.

- **Method of Limits to determine Difference Threshold**
- difference thresholds are based on relative judgments, in which a constant unchanging comparison stimulus is judged relative to a series of changing stimuli.
- the question that is asked is, “How different must two stimuli be before they can be reliably be distinguished?’

- the traditional way to measure is to ask the observer to lift pairs of weights - one constant & the other changing - & to judge if the new weight is heavier, lighter or equal to the standard weight.

- the method is otherwise similar to the last instance:

- one can start from a weight which feels clearly heavier & go till it feels equal & then lighter. or

- one can start from a weight which feels clearly lighter & go till it feels equal & then heavier.

- the upper threshold is the average point at which the observer changes from “heavier” to “equal” &

- the lower threshold is the average point at which the observer changes from “equal” to “lighter”.

- The difference between these two values is called the **interval of uncertainty.**

- The mean of upper & lower thresholds is called the **point of subjective equality**.

-

Using the Method of Limits to Determine a Difference Threshold.

	Comparison Stimulus (grams)	Response				
		↓		↓		
	350			Heavier		
	340	Heavier		Heavier		
	330	Heavier		Heavier		
	320	Heavier	Heavier	Heavier	Heavier	
	310	Equal	Equal	Heavier	Equal	
Standard Stimulus	300	Equal	Equal	Heavier	Lighter	
	290	Equal	Lighter	Equal	Lighter	
	280	Lighter	Lighter	Equal	Lighter	
	270		Lighter	Lighter	Lighter	
	260		Lighter			
					↑	Mean
Upper Threshold		315	315	295	315	310
Lower Threshold		285	295	275	305	290

Interval of Uncertainty = 310 − 290 = 20 grams

Note: For descending series, the upper threshold is the mean of the stimuli leading to the last "heavier" response and the first "equal" response. The lower threshold is the mean of the stimuli producing the last "equal" response and the first "lighter" response. The standard stimulus is always 300 grams. The difference threshold is one-half of the interval of uncertainty (10 grams, in this example).

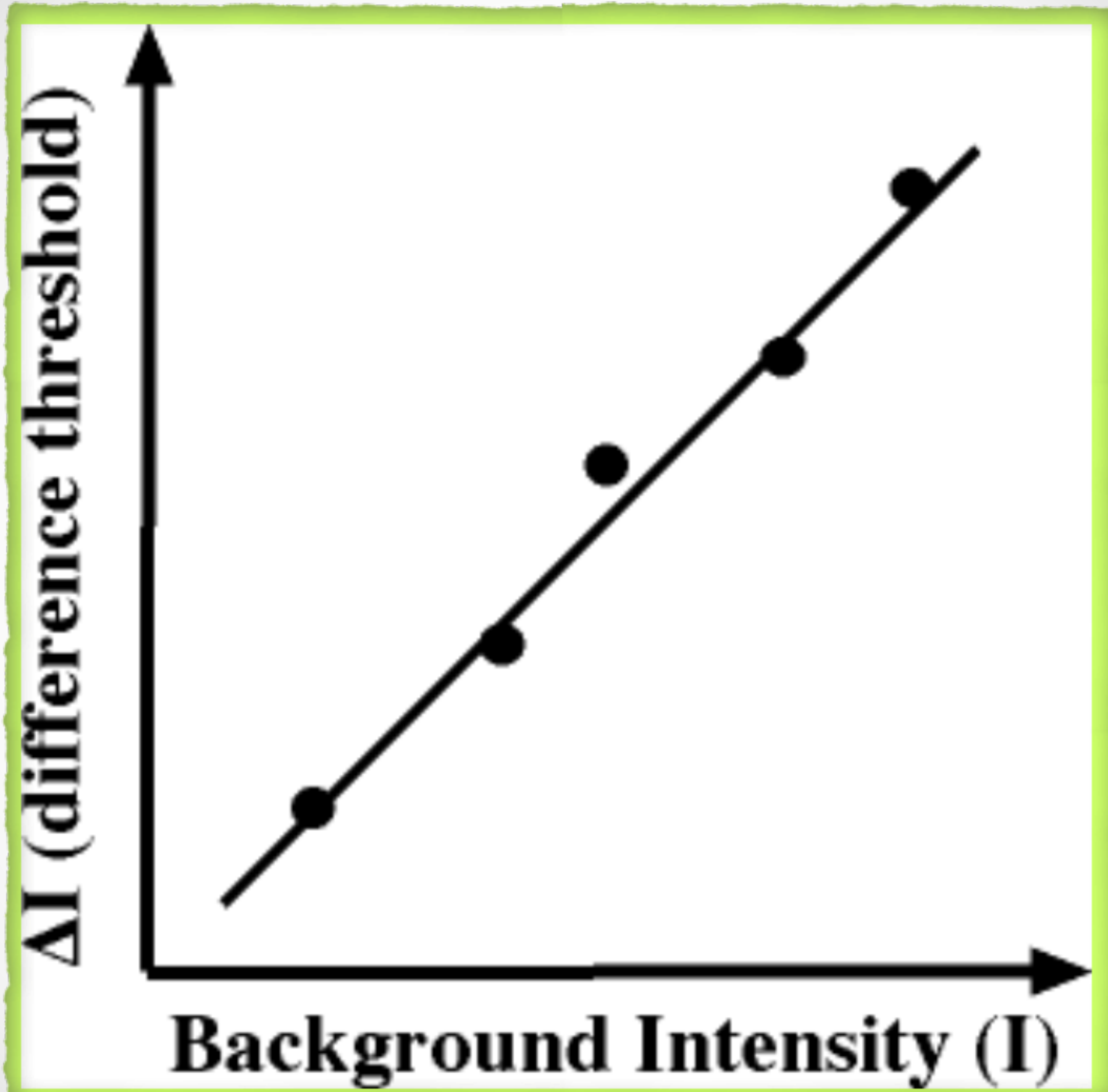
Moving Further…

- Ernst Heinrich Weber (1795 - 1878) discovered some important properties of the difference threshold.
  - the magnitude of difference threshold increases with the increase in the magnitude of the standard stimulus.
  - e.g. he found that for a standard weight of 300 grams the difference threshold is 10 grams; while for a standard weight of 600 grams the difference threshold is 20 grams.

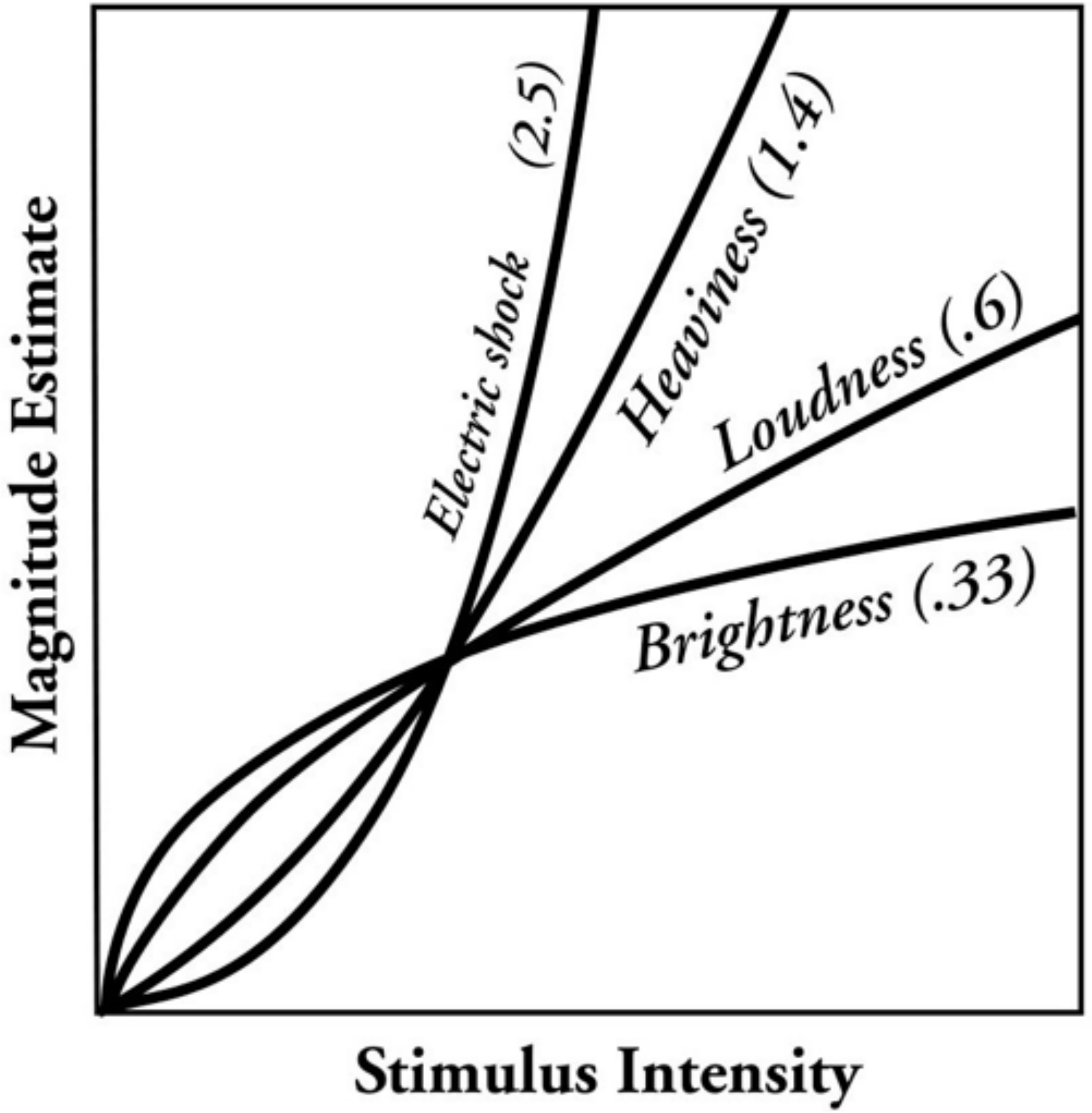
- the second property was, *for a particular sensory modality, the size of the difference threshold relative to the standard stimulus is constant*.

- So, the ratio of 10 grams to 300 grams is the same as that of 20 to 600 grams or 40 to 1200 grams.

- Gustav Fechner called the relative constancy of the difference threshold as **Weber’s Law.**
  - **Weber’s Law: (delta)I/I = K.**
- where **I** refers to the magnitude of the standard stimulus**, (delta)I,** is the difference threshold**, & K** is the symbol for constancy**.**


ΔI (difference threshold)
Background Intensity (I)

- Weber's Law or Weber Fraction varies in size for different senses. for e.g. it is somewhat larger for brightness than it is for heaviness.
- Weber also discovered that the value of the difference threshold is about 2% of the magnitude of standard stimulus intensity.


Magnitude Estimate
Electric shock (2.5)
Heaviness (1.4)
Loudness (.6)
Brightness (.33)
Stimulus Intensity

- **Method of Constant Stimuli**

  - here, the experimenter chooses a number of stimulus values (usually from 5 to 9 values) which, on the basis of previous exploration are likely to encompass the threshold value.

  - this fixed set of values is presented multiple times in a quasi - random order that ensures each will occur equally often.

- after each stimulus presentation, the observer reports whether or not the stimulus was detected (absolute threshold) or whether its intensity was weaker or stronger than that of a standard (difference threshold).

- once each value has been presented multiple times (~20), the proportion of "detected" & "not detected" ("weaker" or "stronger") responses is calculated for each stimulus level.

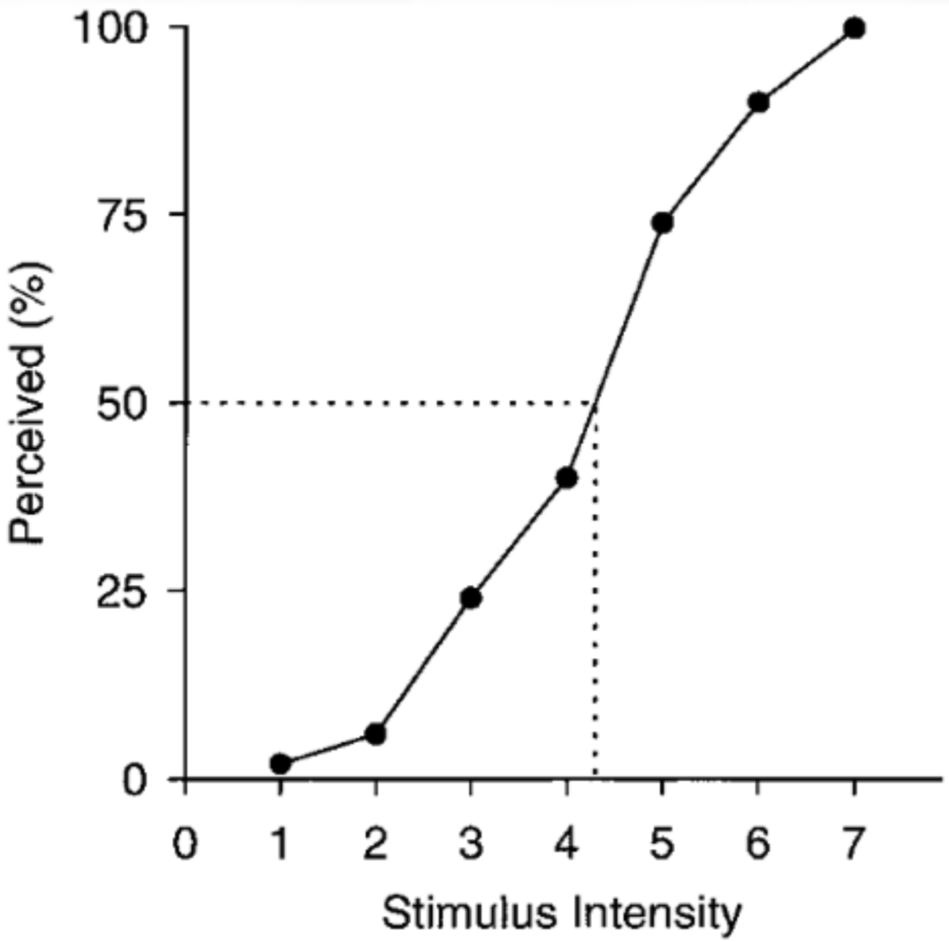
- the data are then plotted with stimulus intensity along the x-axis & the percentage of perceived stimuli along the y-axis.

- the resulting graph represents the so called **psychometric function**.

Table 2. Method of Constant Stimuli (50 Presentations for each Stimulus Intensity)

Stimulus Intensity (arbitrary units)	1	2	3	4	5	6	7
Frequency of Perceived Stimuli	1	3	12	20	37	45	50
Percentage of Perceived Stimuli	2	6	24	40	74	90	100

Fig. 3. Psychometric function which shows the relationship between the percentage of times that a stimulus is perceived and the corresponding stimulus intensity. The threshold is defined as the intensity at which the stimulus is detected 50 percent of the time.



- Note that, if there were a fixed threshold for detection, the psychometric function should show an abrupt transition from “not perceived” to “perceived”.

- however, psychometric functions are generally Sigmoidal (S- shaped) curves, that reflect that lower stimulus intensities are detected occasionally and higher values more often; intensities in the middle are detected sometimes & sometimes not.

- other reasons why we get a S-shaped curve here could be the continuous fluctuations in the sensitivity of the various biological systems (due to spontaneous activity or internal noise).

- these inherent fluctuations mean that an observer must detect activity elicited by external stimulation against a background level of activity.

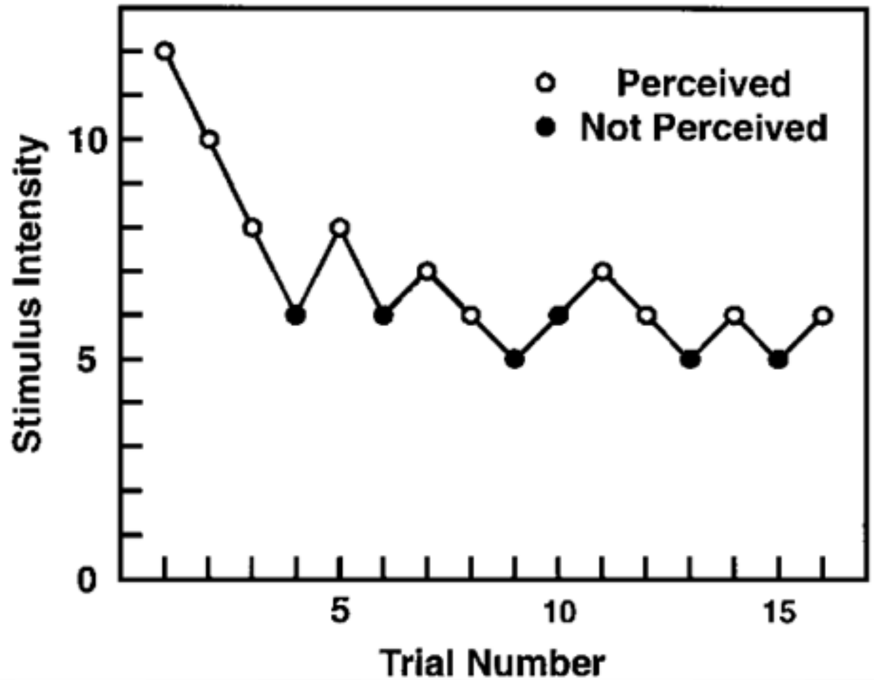
- so, the threshold occurs with a certain probability and its intensity value must be defined statistically.
- by convention, the absolute threshold measured with the method of constant stimuli is defined as the intensity value that elicits “perceived” responses on around 50% of the trials.
- in Table 2., this comes between levels 4 & 5.

- **Staircase Method**
  - adaptive testing procedures are used to keep the test stimuli close to the threshold by adapting the sequence of stimulus presentations according to the observer's response.
  - since a smaller range of stimuli need to be presented, such methods are more efficient. an example being the **staircase method**.

- the staircase method is a modification of the Method of Limits.
- an observer may start from a ascending or descending series of stimuli.
- each time the observer says “yes” the intensity is changed (increased/decreased) by one step.
- this continues until the stimulus becomes too weak to be detected.
- at this point, we reverse the direction of the series by one step; & continue till the response changes from “yes” to “no” or vice-versa.

- usually six to nine such reversals are taken to estimate the threshold, which is defined as the average of all the stimulus intensities at which the observer’s response changed; i.e. the transition points.

Fig. 4. Adaptive testing technique using a single staircase procedure. This example shows a descending staircase for which stimulus intensity is decreased when the stimulus is perceived and increased when it is not perceived.



To Sum Up

- We talked about the concept og sensation vs. perception.

- We also talked about how abstract experiences can be quantified using psychophysics.

- We also talked about the various possible methods in psychophysics that are used to put numbers to sensations.

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Course Title:

Basic Cognitive Processes

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Lecture 15: Signal Detection Theory

Signal Detection Theory

- What if we do not need to determine threshold?
  - according to the **theory of signal detection**, our perception in general is controlled by evidence & decision processes.

- a signal or stimulus creates (hypothetical) evidence that depends on the intensity of the signal and the acuity of the observer, which partly determines a “yes” response.
- there could also be other factors, that influence the willingness of an observer to say “yes”.
- these response - bias influences include the payoff for being accurate, the frequency of the signal & so on.

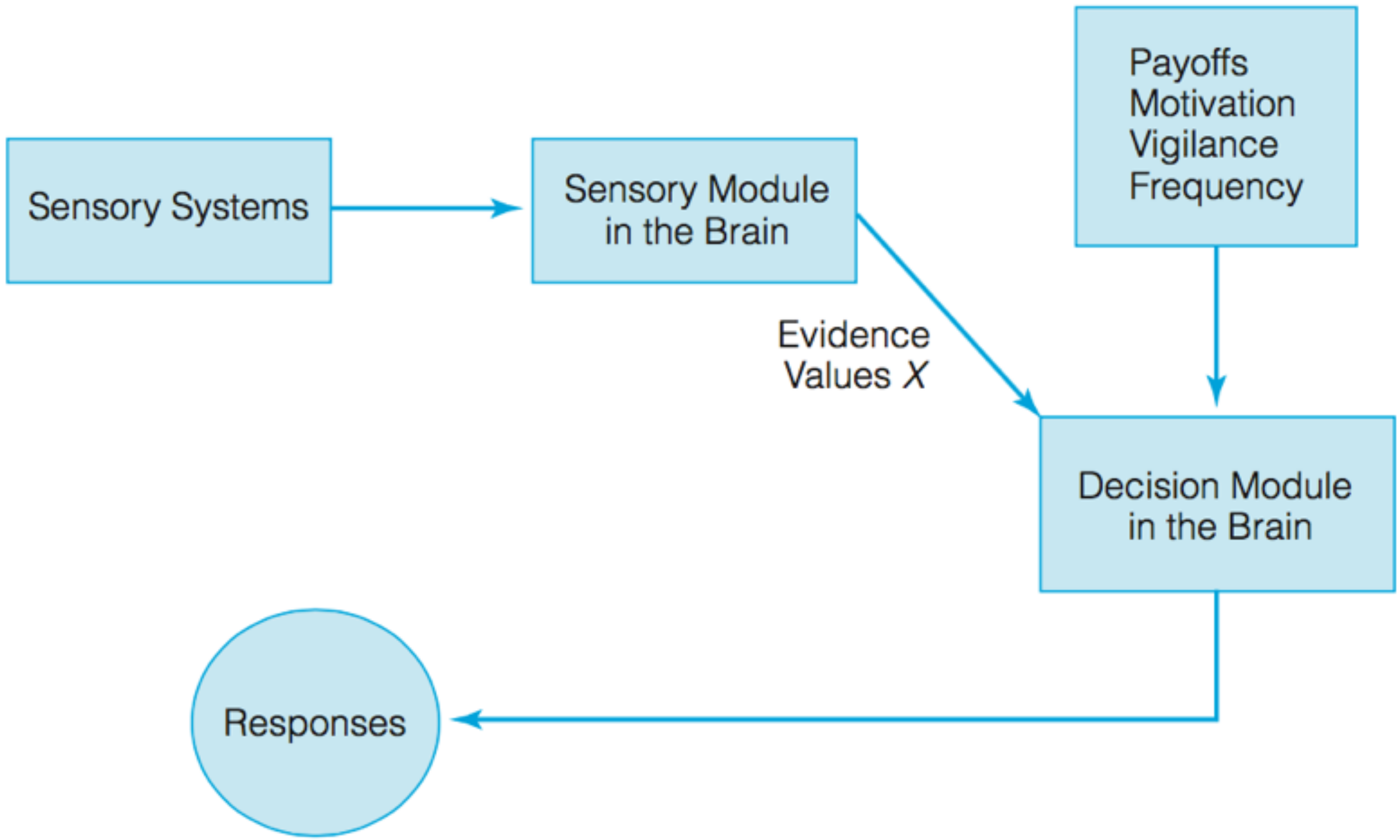


FIGURE 6.3

A Theoretical Look at What Happens in Signal Detection. Sensory analysis sends evidence values (*X*) to the decision module. The values of *X* are a function of signal strength and the acuity of the observer. The payoffs, motivation, and attention processes send response bias information to the decision module. Together, the sensory and bias components determine the response of the observer. The *X* evidence values are on the abscissa of Figures 6.4 and 6.5. The payoffs and so on determine the position of the criterion.

- examples: imagine your friend has set up a blind date for you. The costs (a wasted evening) are probably less than the possible benefits (an exciting evening now & many in future).

- in such scenarios, where the (perceived) costs are less than the (perceived) benefits, a highly likely response is a "yes" response.

- the decision would be based on costs & benefits, since information about the stimulus is lacking.

- however, if the decision has high costs (accepting or offering a marriage proposal).

- people would be very careful/conservative.

- in terms of decision theory, most of us are conservative decision makers when costs are higher relative to benefits (costs of an unsatisfactory marriage vs. cost of a bad date).

- the sensory process transmits a value to the decision process.

- if the value is high, the decision process is more likely to yield a “yes” response, once costs & benefits are considered.

- if the value is low, the decision process is more likely to yield a “no” response, once again taking into account costs & benefits.

- What determines the quality of the signal?
  - signal detection theory assumes that **noise,** a disturbance that can be confused with signals, is always present when a human attempts to detect signals.
  - e.g. environmental changes, equipment changes, spontaneous neural activity, & direct experimental manipulations.

- An Experiment
  - Imagine sitting in a soundproof booth, wearing headphones.
  - On each of several hundreds of trials, you must decide whether you heard a faint tone combined with white noise or only white noise itself.

- a trial might begin by the presentation of a flashing light, to get you ready.
- then you hear a burst of white noise, which may or may not contain the faint tone signal.
- you say "yes" if you think a tone signal was present & "no" if you think it was not.

- Signal detection theory assumes that any stimulus, even noise, produces distribution of evidence.

- the evidence on each trial is only one point & the distributions are built up from many trials, each occurring at a different point in time.

- since evidence cannot be directly observed, the distributions for stimulus trials & noise trials are hypothetical.

- the evidence for the trial for which noise only occurred will tend to be small, so that over many trials, a hypothetical distribution with a small mean will be established.

- when a signal plus noise is presented, the evidence will be larger & a greater mean will be formed over many trials.

- so, two distributions will be generated: one for noise only & one for the signal plus noise.
- since the two distributions will overlap in the middle, some values of evidence are ambiguous.

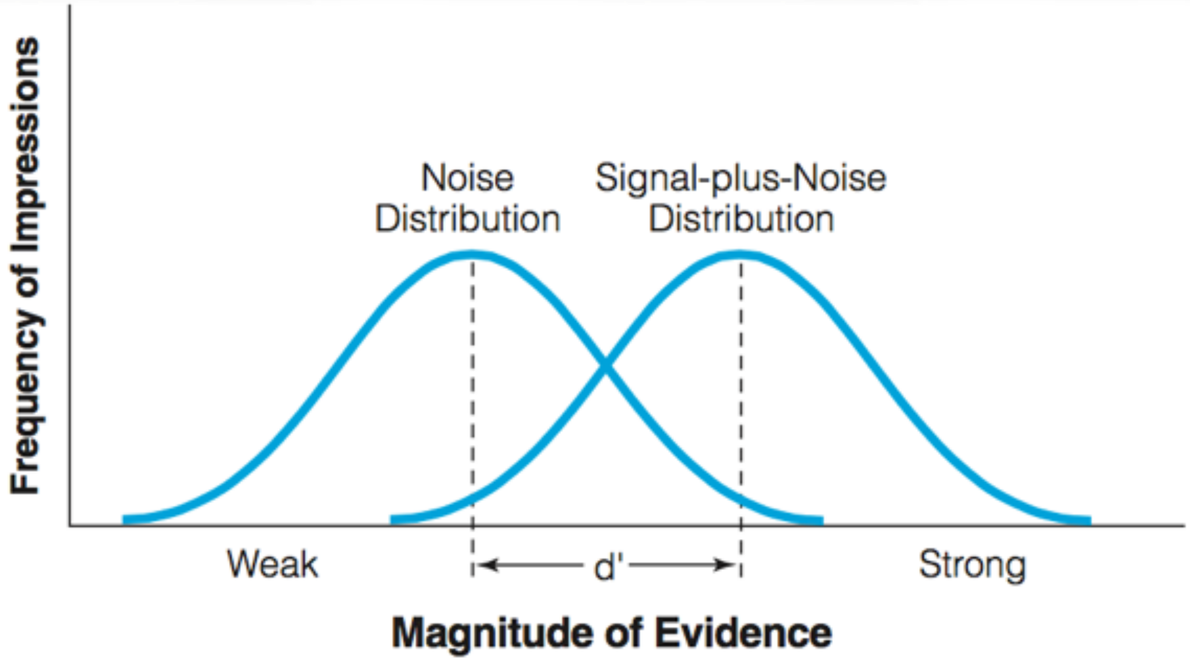
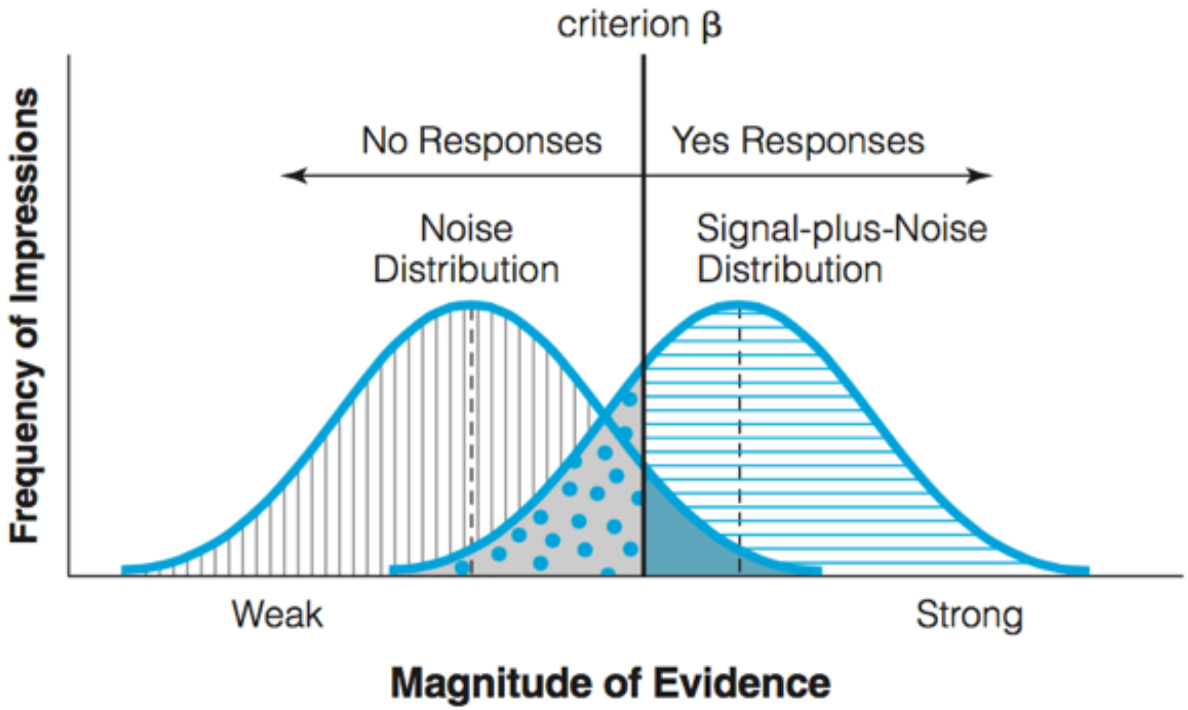


FIGURE 6.4

Hypothetical Distributions of the Evidence Resulting from Noise and Signal Plus Noise. The frequency of the impressions is the *Y*-axis and the magnitude of evidence is the *X*-axis. The strength of the signal and the sensory acuity of the observer determine the amount of overlap of the two distributions. A stronger signal or a more sensitive observer would move the signal-plus-noise distribution to the right (toward the strong end of the *X*-axis). The dashed vertical lines are the mean (average) of each distribution, and the distance between the two means is called d'.

- a criterion therefore, must be set to determine whether a response will be “yes” or “no”.
- the position for this criterion is set by the decision process.
- if costs & benefits favor a liberal decision policy, the criterion will be set far to the left, so that most responses will be “yes”.
- if a conservative decision policy is used, the criterion moves to the right, so that most responses will be “no”.



▼ FIGURE 6.5

Hypothetical Distributions of "Yes" or "No" Responses as a Function of the Criterion and the Magnitude of the Evidence. The decision criterion (β) determines whether a "yes" or "no" response will be made. Strong evidence to the right of the criterion will lead to "yes" responses, and weak evidence to the left will lead to "no" responses. Correct detection of the signal ("yes" responses in the horizontally striped area) are called hits. Correct "no"responses when noise occurs (the vertically striped portion) are called correct rejections. Misses occur when a "no" response occurs to weak signals to the left of the criterion (the dotted portion of the signal-plus-noise distribution). False alarms are incorrect "yes" responses to noise that is to the right of the criterion (the black portion of the noise distribution).

- either way, some errors of judgment are bound to happen.
- correctly detecting a signal when it is present is called a **hit**.
- incorrectly responding “yes”, when only noise is present is called a **false alarm.**
- With a liberal decision strategy there will be high number of hits & false alarms.
- With a conservative decision strategy there will be low number of hits & false alarms.

- If we plot hits as a function of false alarms, as the criterion moves from conservative to liberal, we get the following figure.

- This is the ***receiver – operating characteristic (ROC)*** function.

    - Both hits & false alarms are infrequent (conservative criterion) at the lower left of the curve.

    - As the criterion gets more liberal, both hits & false alarms get more frequent & the ROC curve moves upward to the right.

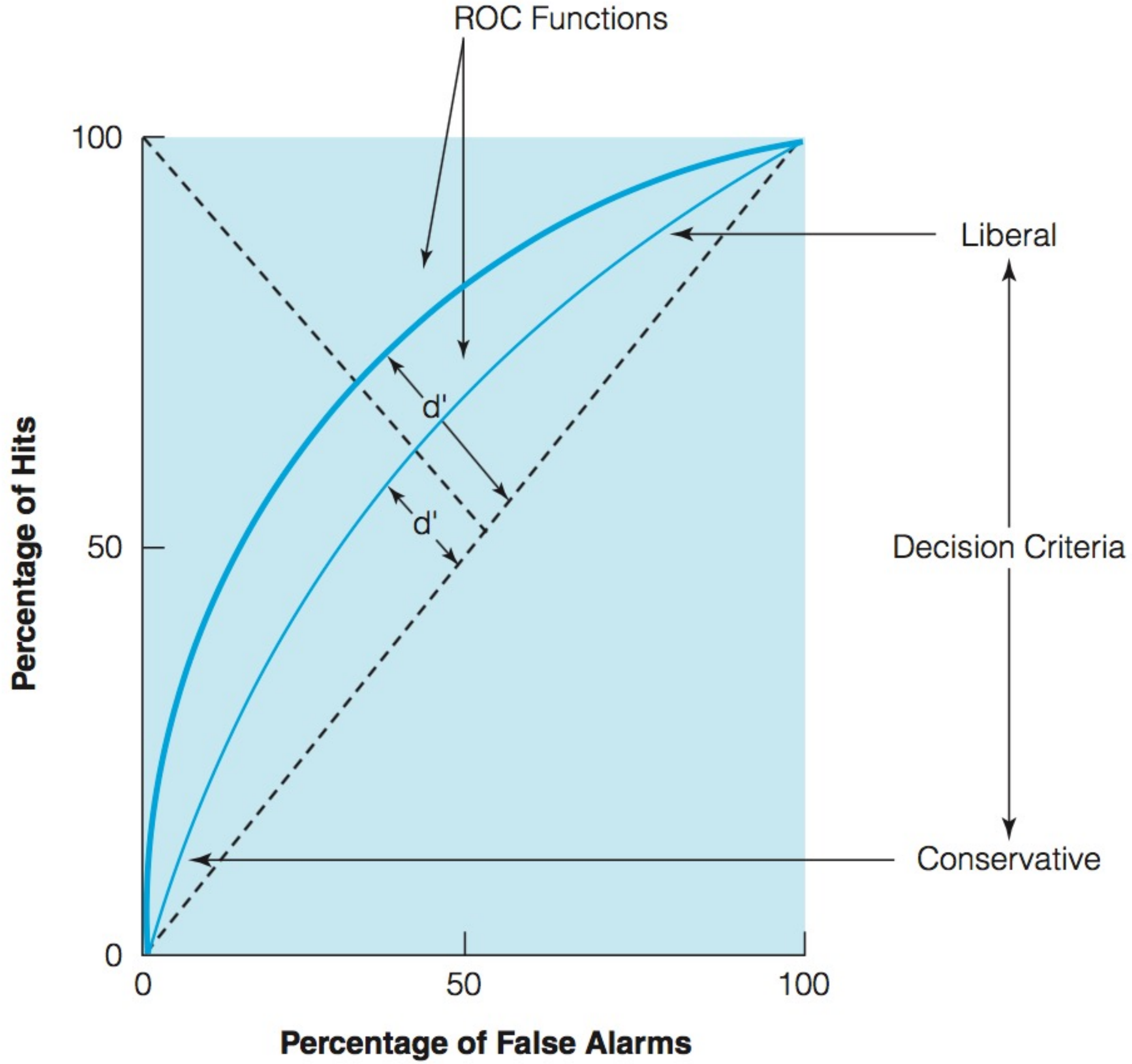


FIGURE 6.6

ROC Functions. The distance from the diagonal to the center of the curve is proportional to d'. The diagonal represents chance performance, with the observer guessing about the presence or absence of a signal. Thus, the percentage of hits equals the percentage of false alarms along this "guessing" diagonal. The heavy ROC function is farther away from the diagonal than is the lighter ROC function, which means that d' is greater for the heavy curve than for the light one. A larger d' can result from a stronger signal or a more acute observer.

- The slope of the ROC function tells us the crietrion.:
    - The flat slopes reveal a liberal decision criterion (generally, the upper right curve) &
    - The steep slopes reveal a conservative criterion (usually, the lower left of the curve).
- The slope of curves such as the ROC function is determined by the slope of a line that is drawn tangent to a particular point on the function and intersects one of the axes of the graph.

- The distance from the diagnoal to the ROC curve tells us how far apart the noise & signal – plus – noise distributions of Fig 6.4 lie.

  - When two distributions are far apart, indicating either a more discernible signal or a more acute observer, the ROC curve moves upward to the left, away from the diagonal, as shown by the heavy ROC function.
  - When the signal is less detectable or when the observer is less acute and the two distributions are close together, the ROC curve moves closer to the diagonal.

- Thus, the ROC function tells us about both the sensory processes (d′, i.e. distance between signal plus noise & noise only distributions) and the decision process (β, the slope).

- ***Advantage of Signal Detection Methods***

    - a major advantage of signal – detection methods over a classical psychophysical procedure, such as the method of limits, is the ability to measure both sensitivity and response bias.

        - In many areas of applied psychology, the ability to distinguish between these two processes is very important.

    - Let us take an example: To determine how analgesics work, Clark and colleagues (Clark, 1969; Clark & Yang, 1974) conducted a number of experiments on pain analgesia.

- They decided to use a signal – detection procedure instead of a classical psychophysics one; so that both changes in sensitivity & decision processes could be assessed.

- In these experiments a dolorimeter was used to evoke pain by means of thermal stimulation.

- Initially, Clark found that analgesics such as aspirin reduced d’, which means that the drug lowered the acuity of the sensory system with the outcome being that the aspirin reduced the ability of the people to distinguish between painful & non – painful stimuli.

- He, then went onto investigate whether placebos & accupuncture altered d′ or whether placebos and accupuncture changed the willingness of the subjects to report pain.

- In both experiments, Clark found that placebos & accupuncture & placebos elevated the subject's decision crietrion, so that stronger stimuli than before were required to elicit a detection response.

  - This does not mean that placebos & accupuncture do not work, rather they change the decision threshold for reporting the pain that has been experienced.

- Drawing from the work done earlier by Hardy & colleagues (1952); it was found using method of limits that suggestion altered absolute threshold.

- Given, the signal – detection results found by Clark, it is reasonable to suppose that suggestion changed the absolute threshold by altering the decision criterion of subjects.

- The same could be true for few other occurrences like, "Why do naive observers have a lower pain threshold?".

- We could not have determined the cause of the same without using a signal – detection analysis/procedure.

To Sum Up

- Signal detection measures are a departure from the classical psychophysical methods as they take into account both the sensitivity of the observer, the evidence provided by the stimulus & the decision processes.

- They have an advantage over the classical methods because they help us understand the decision process of experiencing & reporting sensations.

References

- Kantowitz, B. H., Roediger, H. L., & Elmes, D. G. (2008) Experimental Psychology. 9th Ed. *Wadsworth Cengage Learning.*

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Lecture 15: Physiology of Visual Perception

Visual Perception: The Beginning

- The precondition for vision is light, i.e. electromagnetic radiation that can be described in terms of wavelength.
- Humans can perceive only a small range of wavelengths that exist: the visible wavelengths are from 380 - 750 nm.

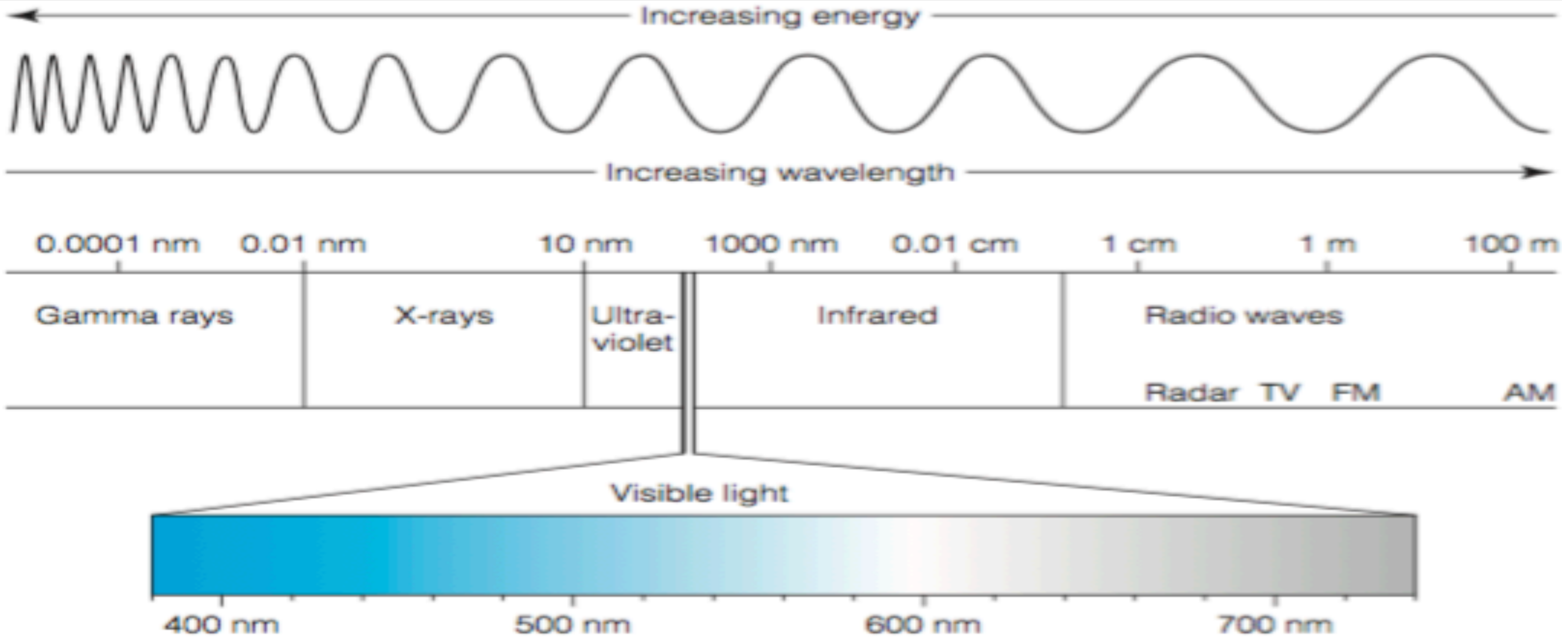


Figure 3.6 The Electromagnetic Spectrum.
This image shows the different wavelengths that light comes in, and the small array of wavelengths that is actually visible to humans.

Image: Sternberg & Sternberg (2011). Cognitive Psychology. *Wadsworth Publishing*. 6th Ed. (Fig 3.6, p. 92).

- Vision begins when light passes through the protective covering of the eye, i.e. the **cornea**, which is a clear dome that protects the eye.

- Light, then passes through **the pupil**, i.e. the opening in the center of the **iris.**

- It continues through the crystalline lens and the vitreous humor, which is a gel - like substance that comprises the majority of the eye.

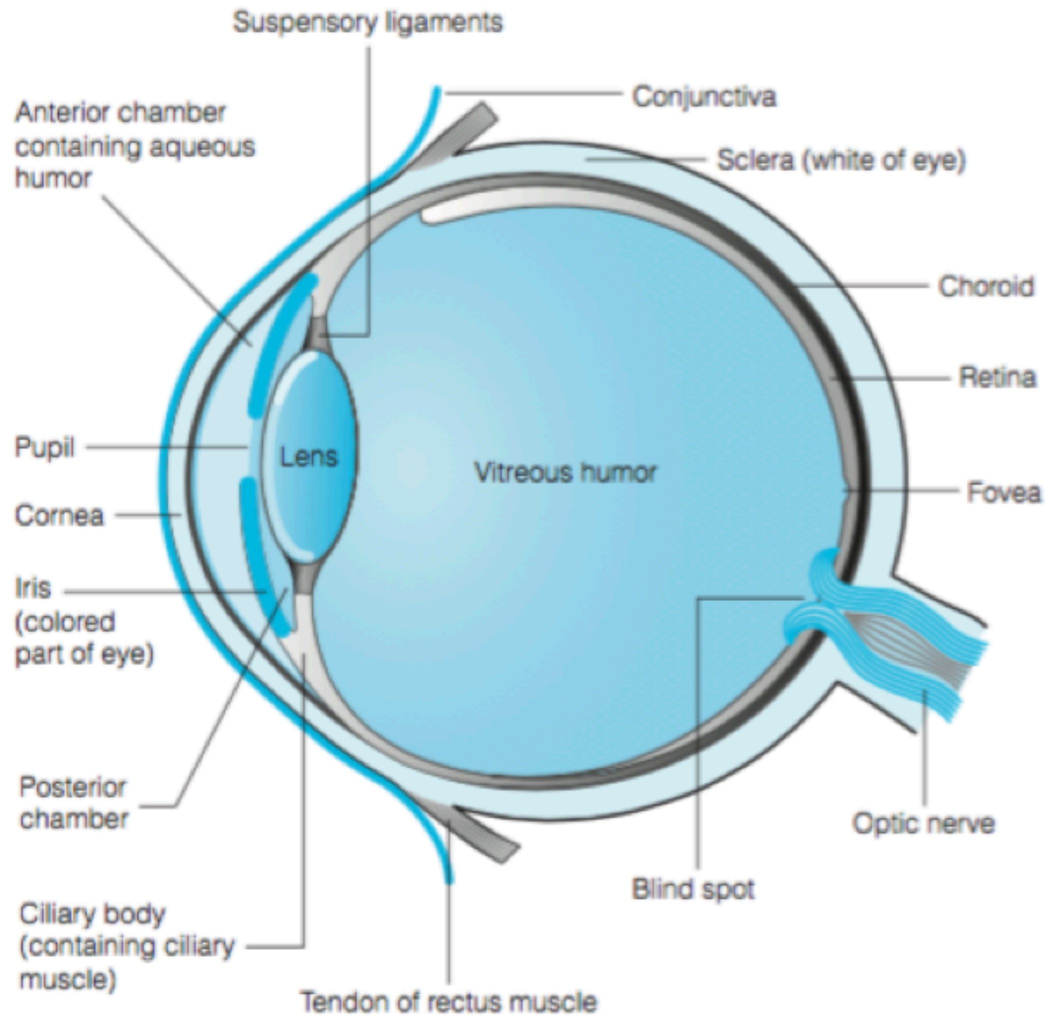


Figure 3.7 **The Human Eye.**
The composition of the human eye.

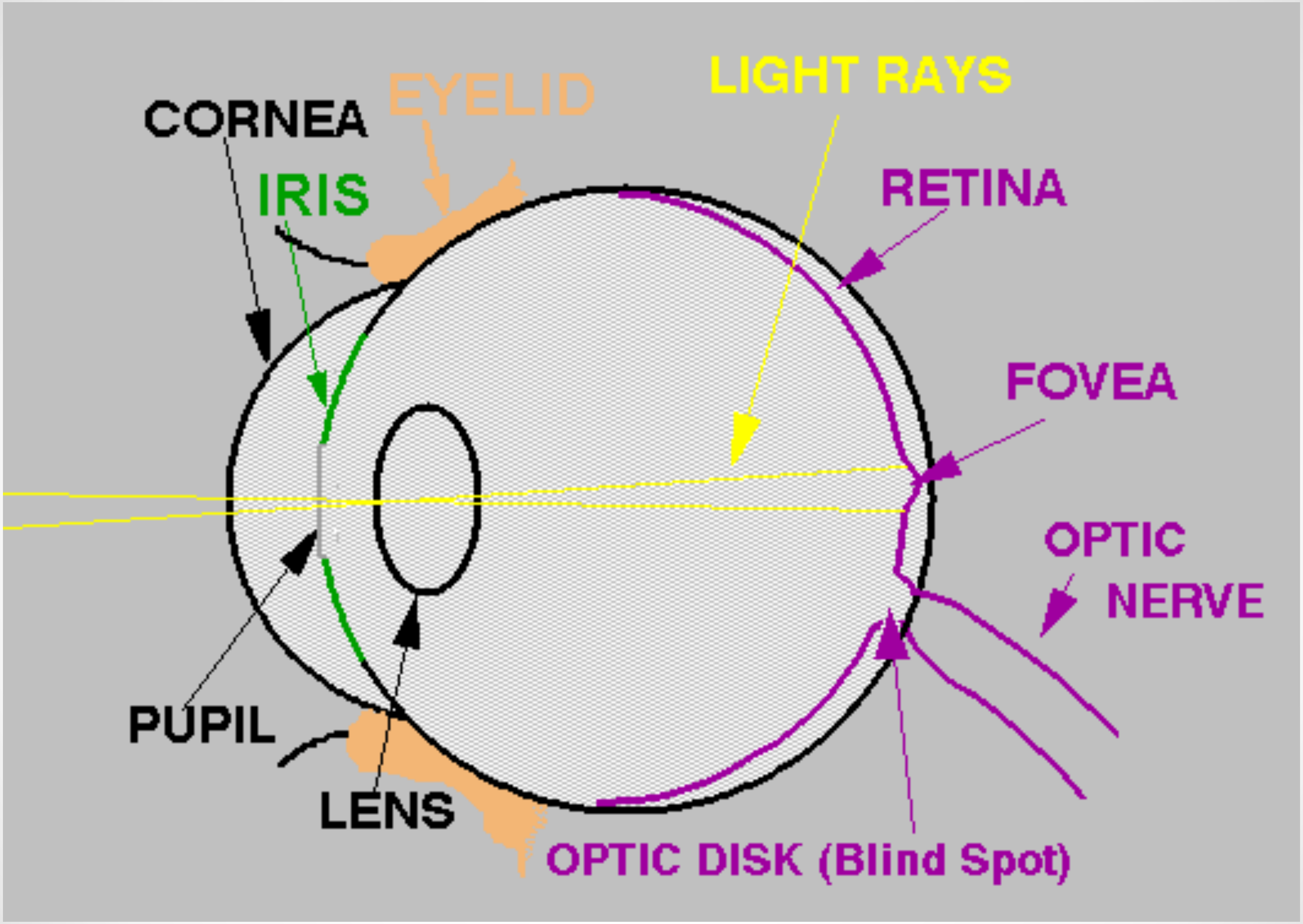
Image: Sternberg & Sternberg (2011). Cognitive Psychology. *Wadsworth Publishing*. 6th Ed. (Fig 3.7, p. 93).

- Eventually, the light focuses on the **retina**, where electromagnetic light energy is transduced i.e. converted - into neural electrochemical impulses (Blake, 2000).

- Vision is most acute in the **fovea**, which is a small, thin region of the retina, of the size of the head of a pin.

- The retina contains of three main layers of neuronal tissue:

    - ganglion cells
    - amacrine, horizontal & bipolar cells
    - photoreceptors: rods & cones


CORNEA
EYELID
LIGHT RAYS
IRIS
RETINA
FOVEA
OPTIC
NERVE
PUPIL
LENS
OPTIC DISK (Blind Spot)

- the first layer of neuronal tissue - closest to the front, outward facing surface of the eye - is the layer of ganglion cells; whose axons constitute the **optic nerve.**

- the second layer consists of three kinds of interneuron cells:

  - **Amacrine cells** & **horizontal cells** make single lateral connections among the adjacent areas of the retinal in the middle layer of cells.
  - **Bipolar cells** make dual connections forward and outward to the ganglion cells, as well as backward & inward to the third layer of retinal cells.

- the third layer of the retina consists of the **photoreceptors,** which convert light energy into electrochemical energy that is transmitted by neurons to the brain.
  - there are two kinds of photoreceptors - **rods** & **cones**.

- Each eye contains roughly around 120 million rods & 8 million cones.

- Rods & cones differ not only in shape but also in their compositions, locations & responses to light.

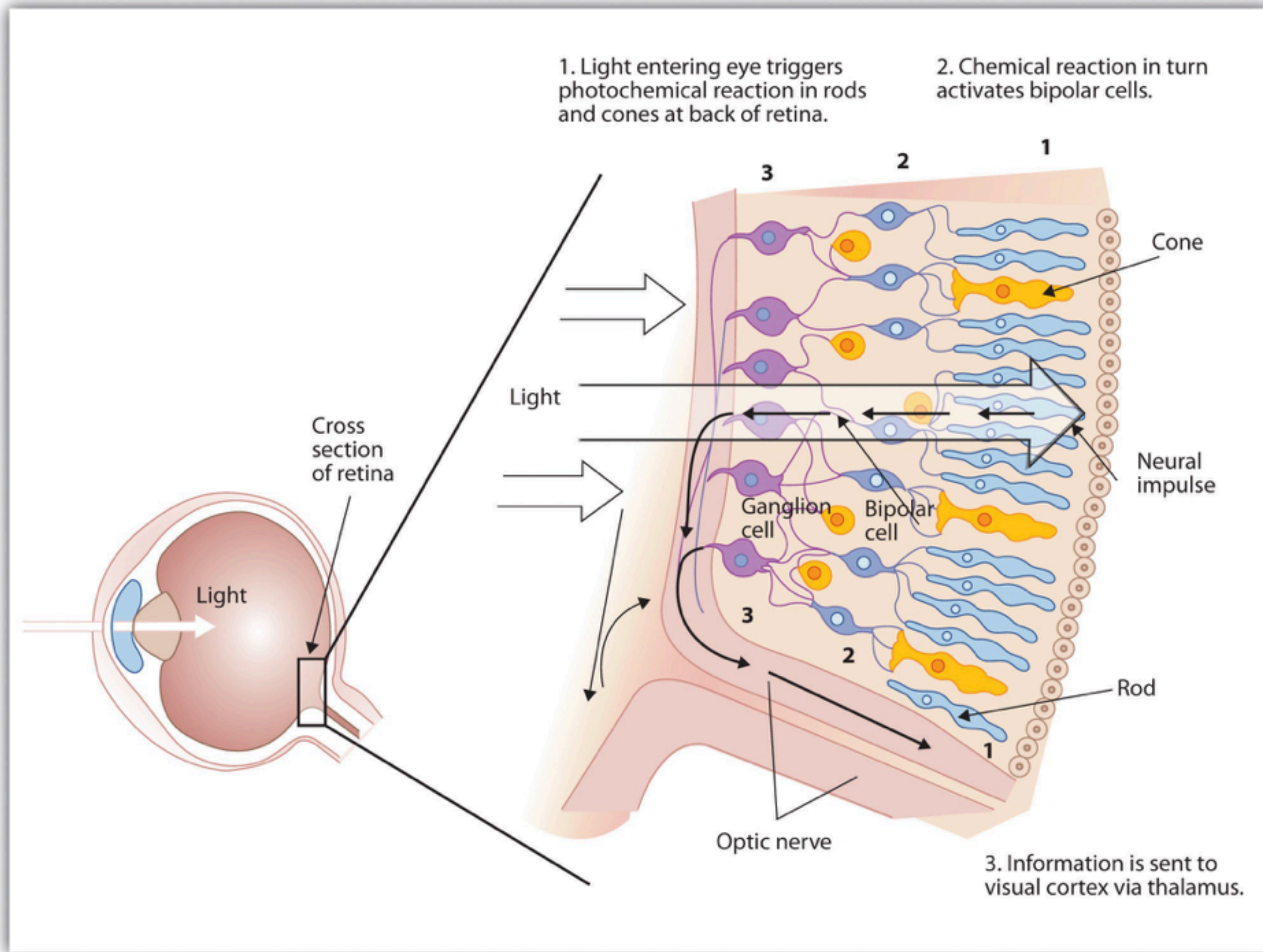


Image: Stangor (2010) Introductin to Psychology. *Flat World Knowledge.* (p. 180 Under creative commons license)

- Within the rods & cones are **photopigments,** i.e. chemical substances that react to light and transform physical electromagnetic energy into an electrochemical neural impulse that can be understood by the brain.

- The rods are long & thin photoreceptors; more highly concentrated in the periphery of the retina than in the foveal region. are responsible for night vision and are sensitive to light & dark stimuli.

- The cones are short & thick photoreceptors and allow for the perception of colour. are highly concentrated in the foveal region than in the periphery of the retina.

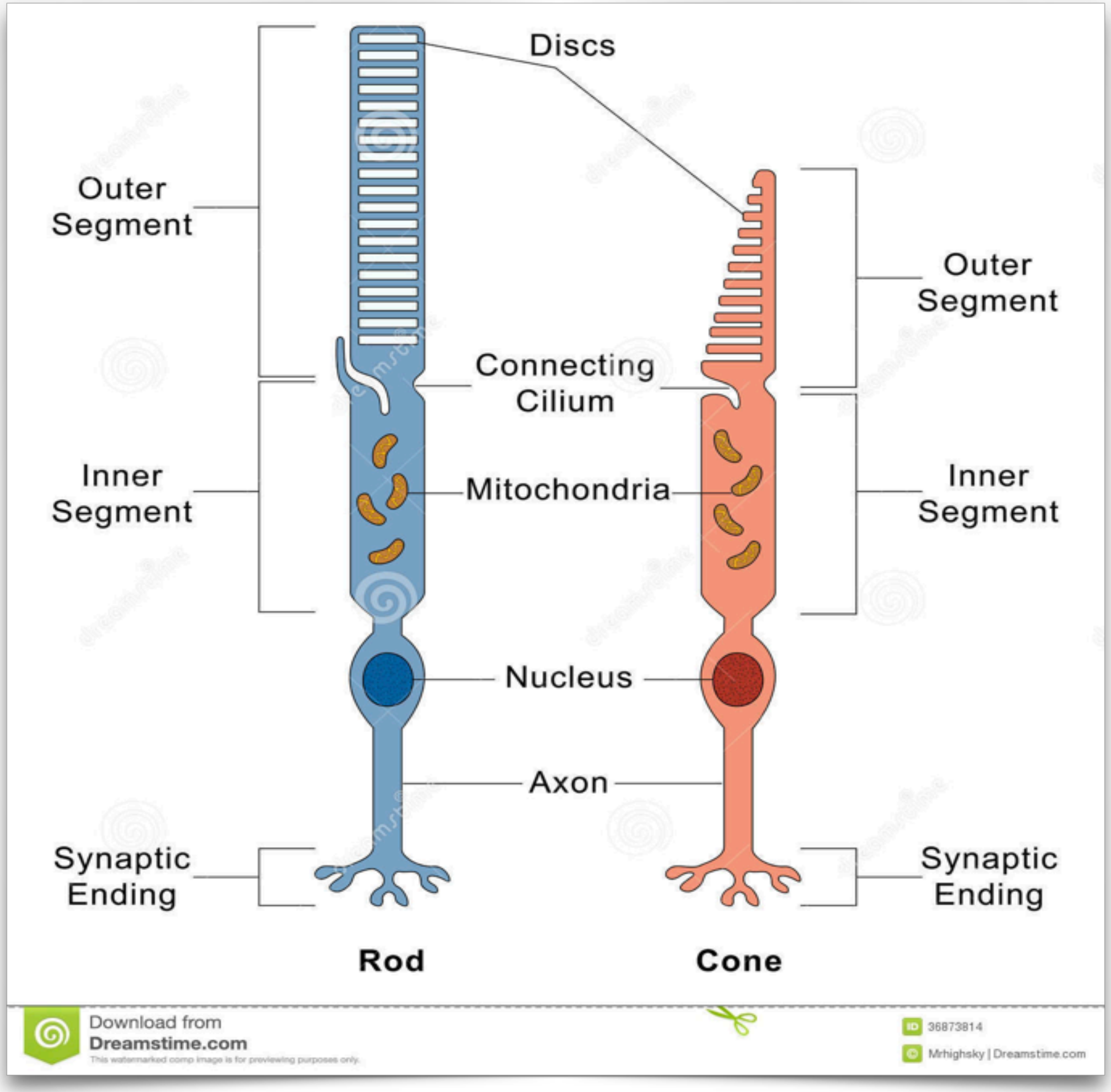


Image: [https://ghr.nlm.nih.gov/art/large/rod-and-cone-cells.jpeg?ow]

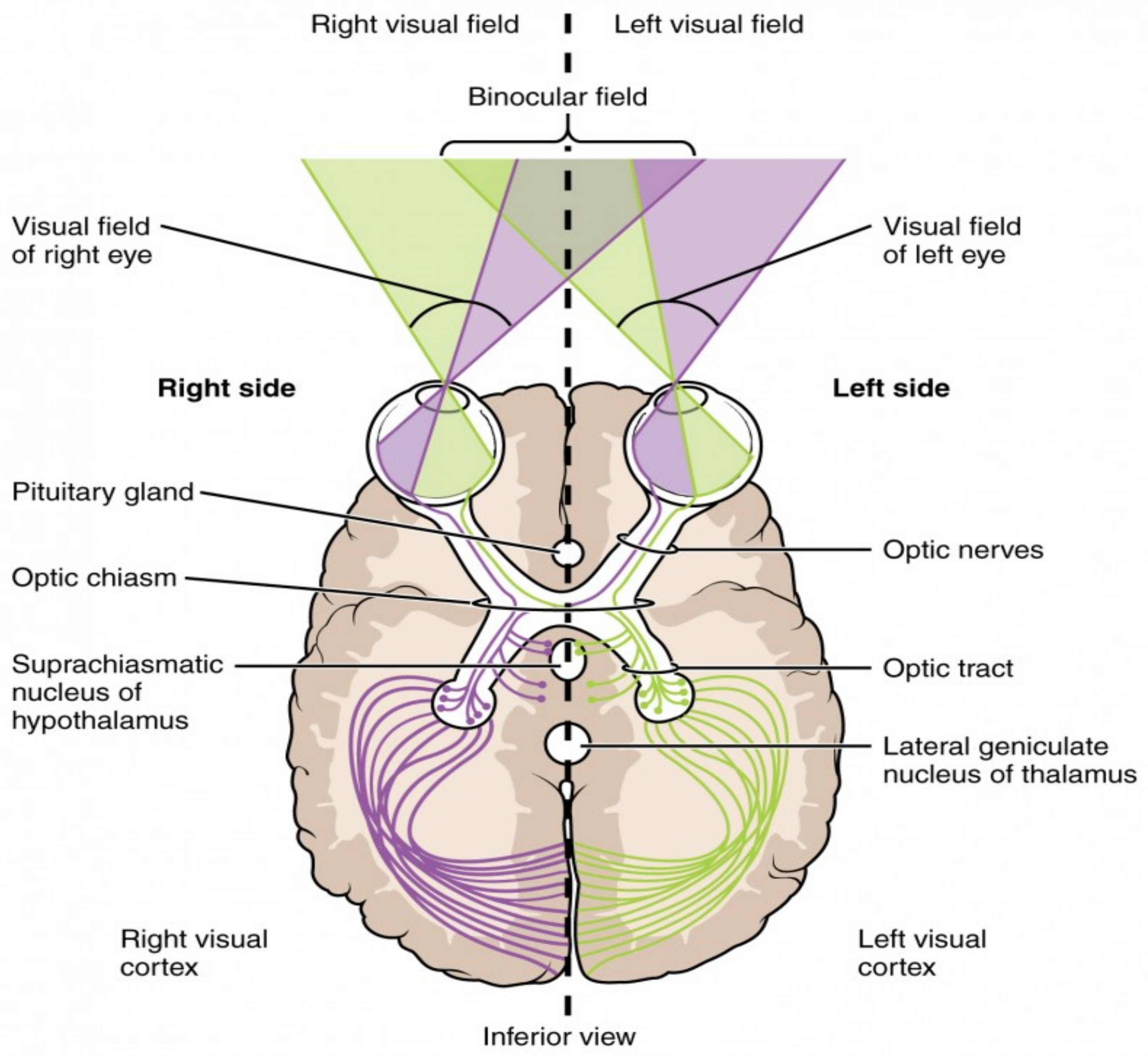
- The rods, cones & photo pigments could not do their work were they not somehow hooked up to the brain.
- The neurochemical messages processed by the rods & cones of the retina, travel via the bipolar cells to the ganglion cells.
- the axons of the ganglion cells in the eye collectively form the optic nerves for that eye.

- The optic nerve of the two eyes join at the base of the brain to form the **optic chiasm.**

- at this point, the ganglion cells from the inward or nasal, part of the retina - cross through the optic chiasm and extend to the opposite hemispheres of the brain.

- the ganglion cells form the outward, or temporal area of the retina goes to the hemisphere on the same side of the body.

- the lens of each eye inverts the image of the world as it projects the image onto the retina.
- After being routed through the optic chiasm, about 90% of the ganglion cells then go to the **lateral geniculate nucleus** of the **thalamus**.
- From the thalamus, the neurons carry information to the primary visual cortex (V1 or the striate cortex) in **the occipital lobe** of the brain.
- The **visual cortex** contains several processing areas; each handling different kinds of visual information, relating to intensity & quality, including colour, location, depth, pattern & form.



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Visual Cortices

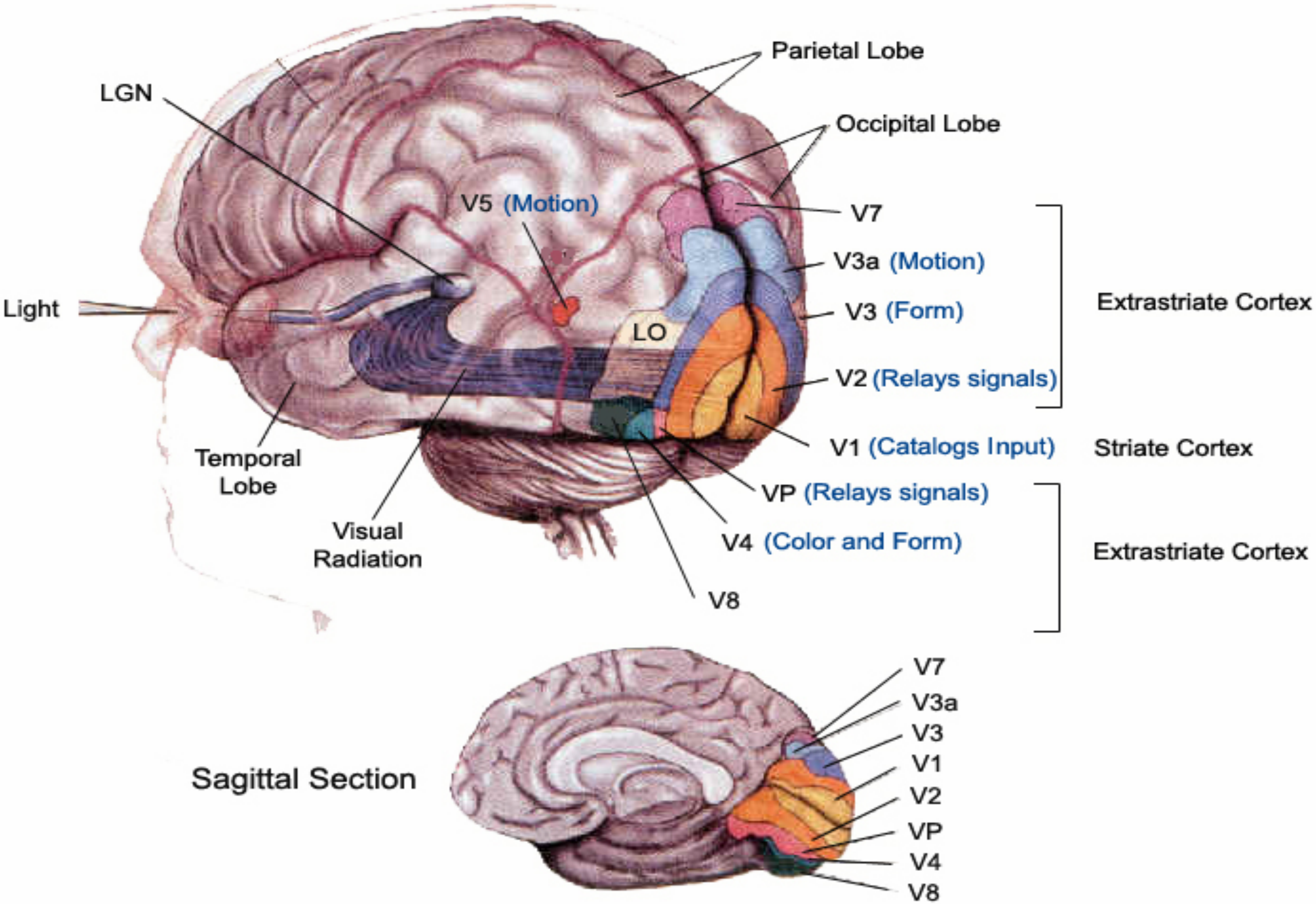

Image:[http://mikeclaffey.com/psyc170/notes/images/vision-v-areas.jpg]

To Sum Up

- We understood the basic physiology of visual perception.
- We talked about the passage of light from the environment through the various parts of the eye.
- We talked about transduction & how information about the environment is relayed from eye via the optic nerve to areas in the visual cortex.

References

- Sternberg & Sternberg (2011). Cognitive Psychology. *Wadsworth Publishing*. 6th Ed.

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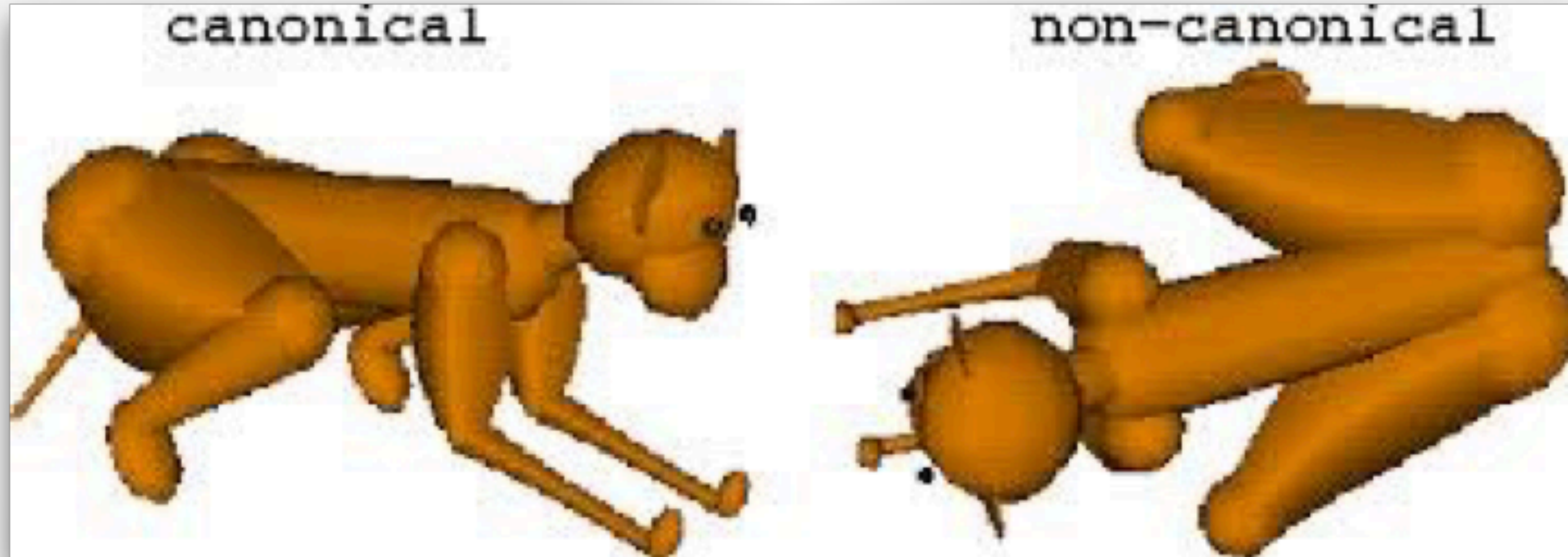
Lecture 15: Representation in Perception

Representation: The Currency of Cognition

- An important aspect of all cognition, or more precisely the INPUT to the functional architecture of the human MIND.
- A *mental representation* is anything that allows us to think about, visualise & make judgments concerning physical objects or scenes in their absence.
- It is important to refer to the **function** of the mental representation, when talking about it. for e.g. recognition.

- Consider this example:
  - To solve the problem of recognition, which includes (identification, categorisation & discrimination; Liter & Bulthoff, 1998); one has to principally rely on the encoding of spatial information derived through perceptual experience (Wallis & Bulthoff, 1999).
  - Recognition is only successful if a mental representation can be matched with current contents of perceptual experience.
  - One of the requirements of this process is that it should be flexible.
    - A flexible mental representation of objects/scenes must be insensitive to variations in illumination, viewing conditions & other factors.



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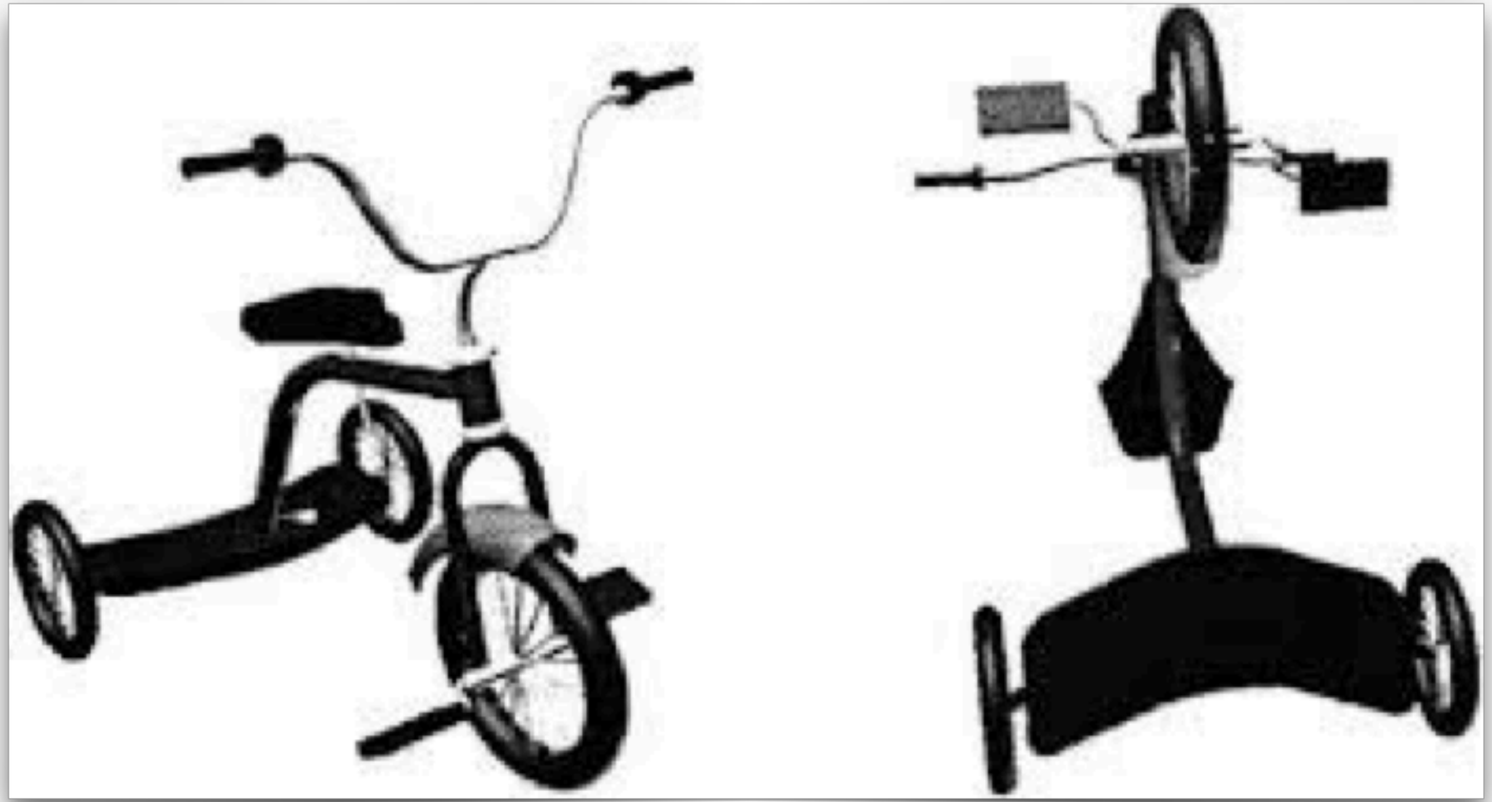

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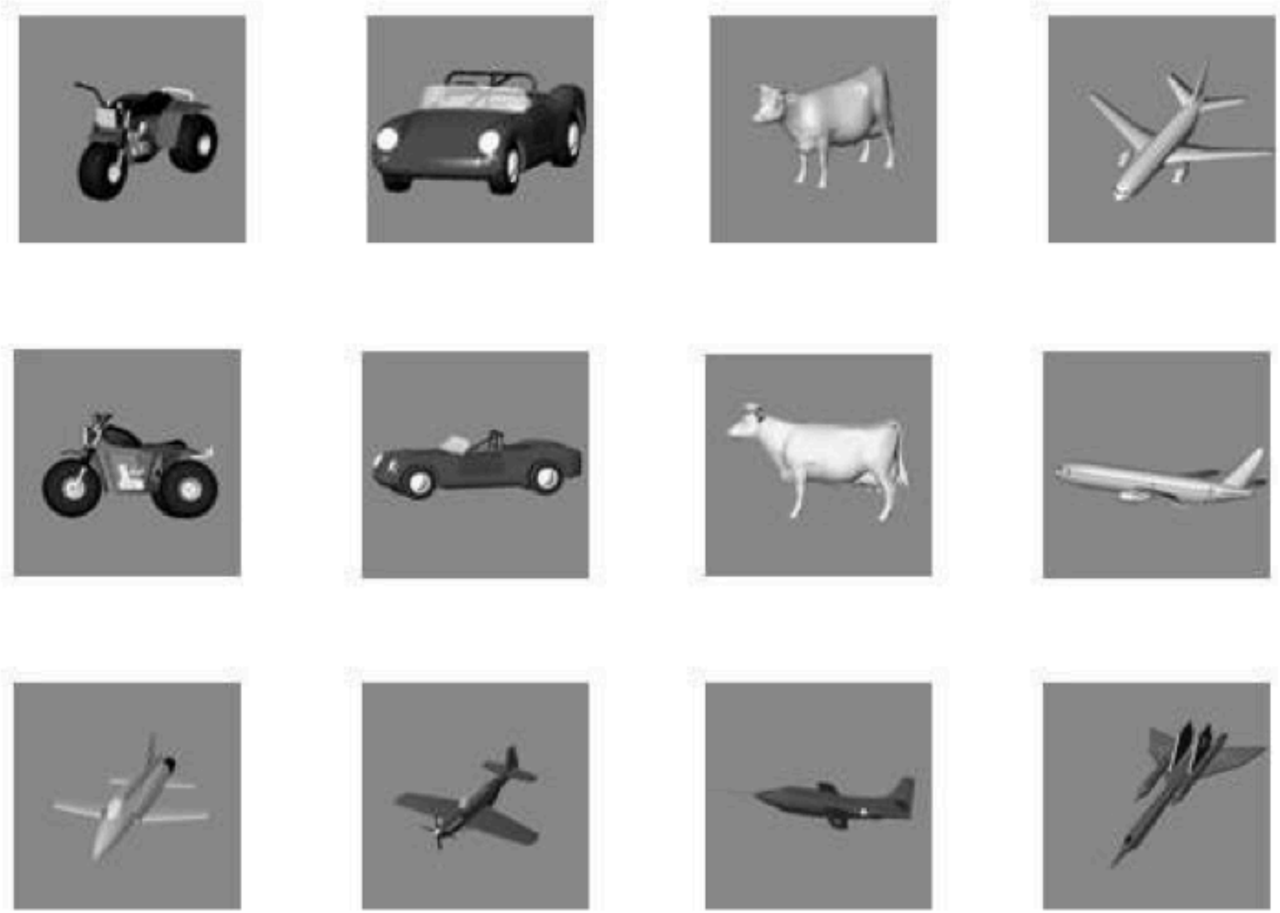

Image: [http://4.bp.blogspot.com/_W34dGUlLgO8/Supvm_LcwzI/AAAAAAAAAKs/Wm29yzKtJ6w/s400/canonical.jpg]

- Such flexibility may theoretically be achieved either by a transformation of the representation to match the contents of perceptual encoding or

- by a transformation of perceptual encoding to match the representation.

- Which of the two transformations is more prominent in human recognition?

- While empirical philosophers like John Locke tried to solve by proposing the existence of of both simple ideas (yellow, hot, sweet) and complex ideas (conjunctions of simple ideas) & deducing that:
    - all knowledge is based on experience and complex entities or objects are essentially combinations of qualities derived through sensory experience.

- Another possible example is evident in David Marr's theory of object encoding.
  - In Marr's view the final (3D) representation of an object is a product of a so called 2.5D sketch that only specified the depth distances & orientation changes directly visible to the observer.
  - Furthermore the 2.5D sketch is formed from a combination of even more basic detail derived from visual cues such as stereopsis, motion parallax, kinetic depth cues etc.
  - Eventually, the 2.5D sketch is used to form a complete 3D representation of an object.

- Final words on representation:
  - If we begin with the assumption that the content pf the representation is determined by qualities of sensory experience; &
  - that, perception is contained to lie within certain invariant bounds (of sensory experience);
  - then these boundaries may be reflected by the properties of representation & consequently recognition performance.

- There are two possibilities to consider here:
  - If no processing of sensory experience occurs; then the representation is tied to the sensory properties of the retinal image or optical array that brought about the representation.
  - Or, perception may be an analytical process wherein, symbolic descriptions of what we see are actively produced.

- The ability to generalize or to overcome variations in appearance during identification & recognition will depend on the extent of processing that occurs during perception and the kinds of information extracted.
  - there is also a possibility that during recognition a stored representation is adjusted to form a match with a current stimulus.

- A possible solution:
  - Neither, retinal images always form the basis of mental representation nor perception is always analytical.
    - there is a middle path:
  - mental encoding need not be elaborated to the extent that the true nature of 3D objects are faithfully represented and that the limitations of perception may be reflected in the nature of spatial encoding.

To Sum Up

- We talked about the notion of representation in cognition in general and perception in particular.
- We talked about how the representations might be built, i.e. via sensory experience or analytical processes.
- We discussed the consequences of either approach towards representation.