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Course Title:

Basic Cognitive Processes

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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*.**

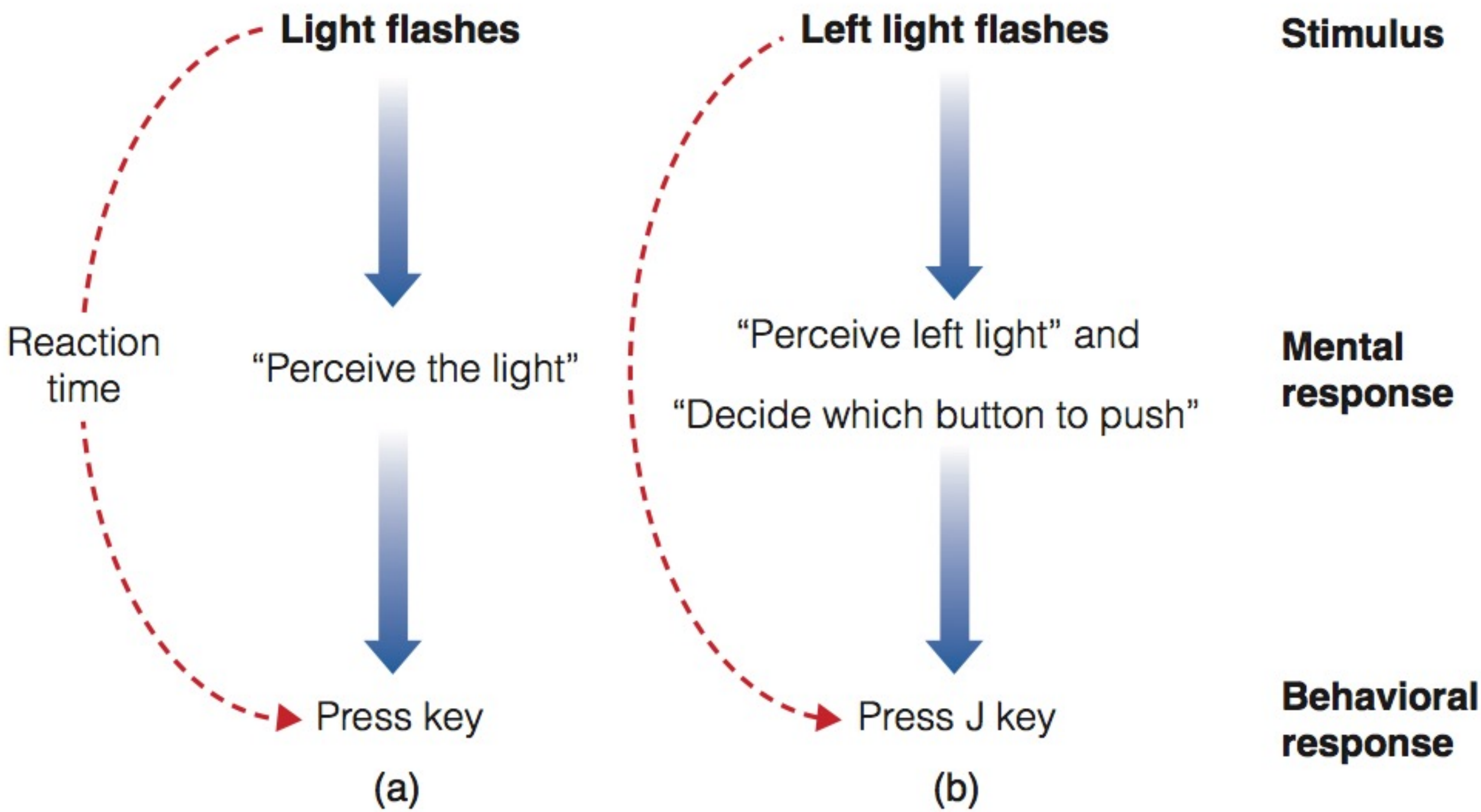
- In the second part of the experiment, he made the task more difficult by presenting two lights, one on the left and one on the right. The participants' task in this part of the experiment was to push one button when the light on the left was illuminated and another button when the light on the right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

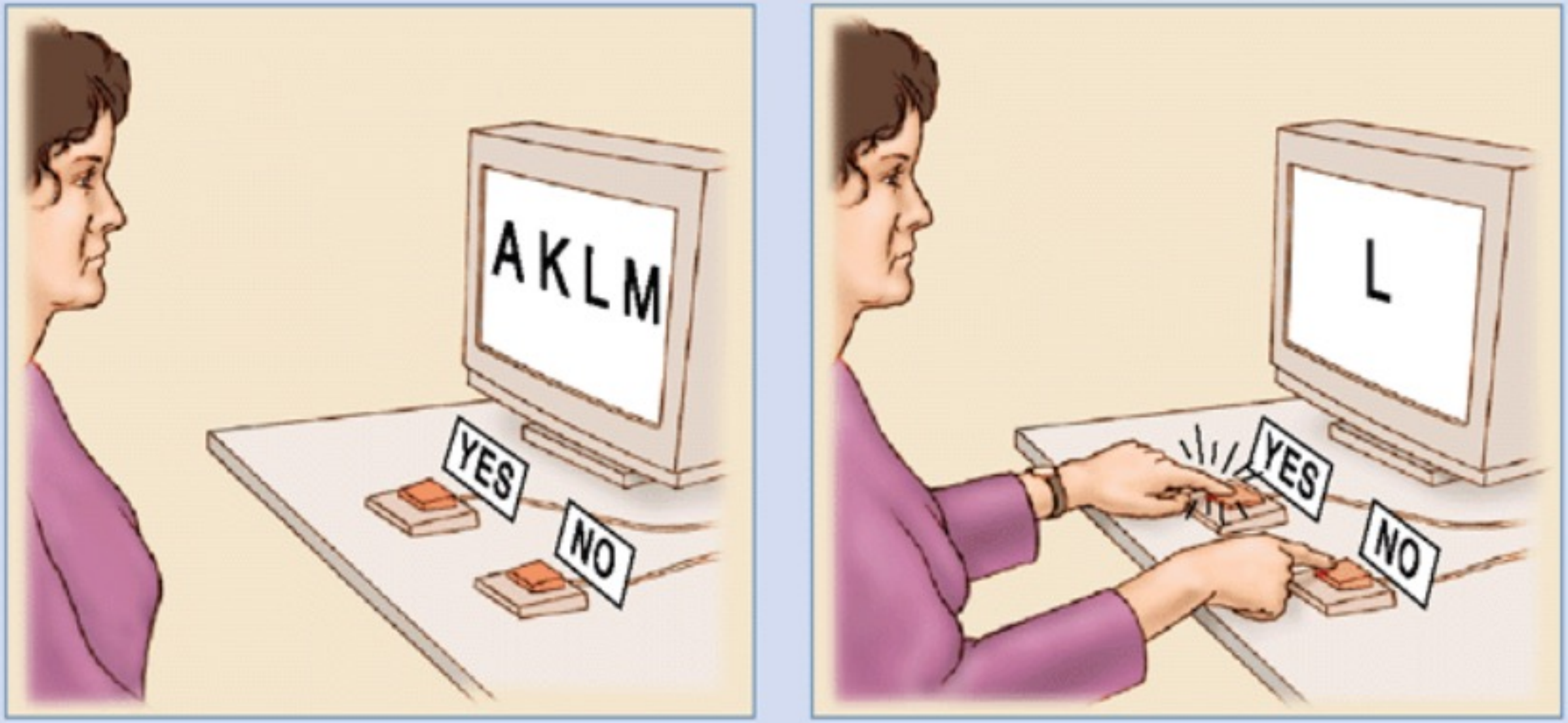
- More specifically, reaction times rise with N, but once N gets large, reaction time no longer increases so much as when N was small.

- 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)

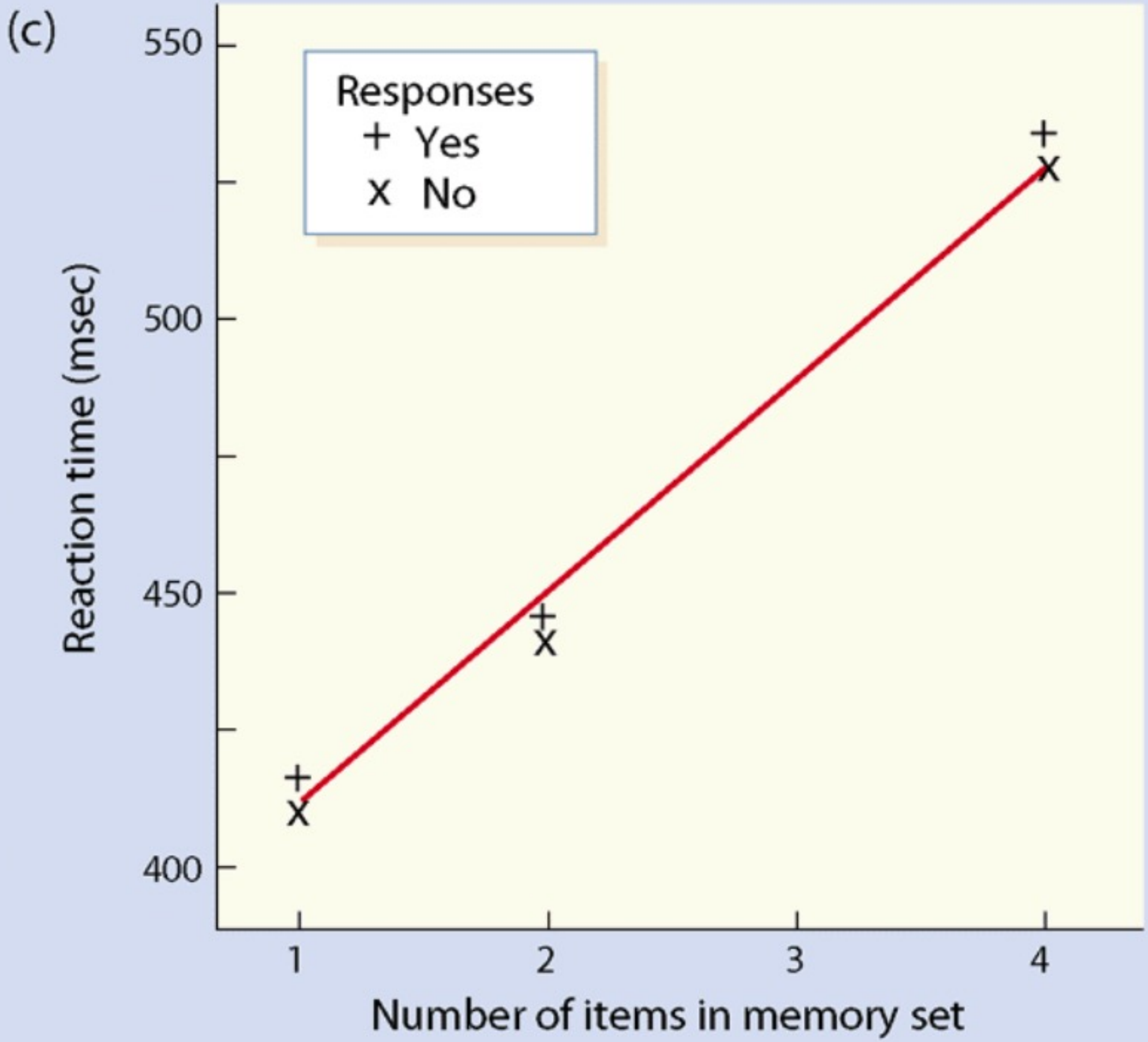
Hypothesized stages

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***

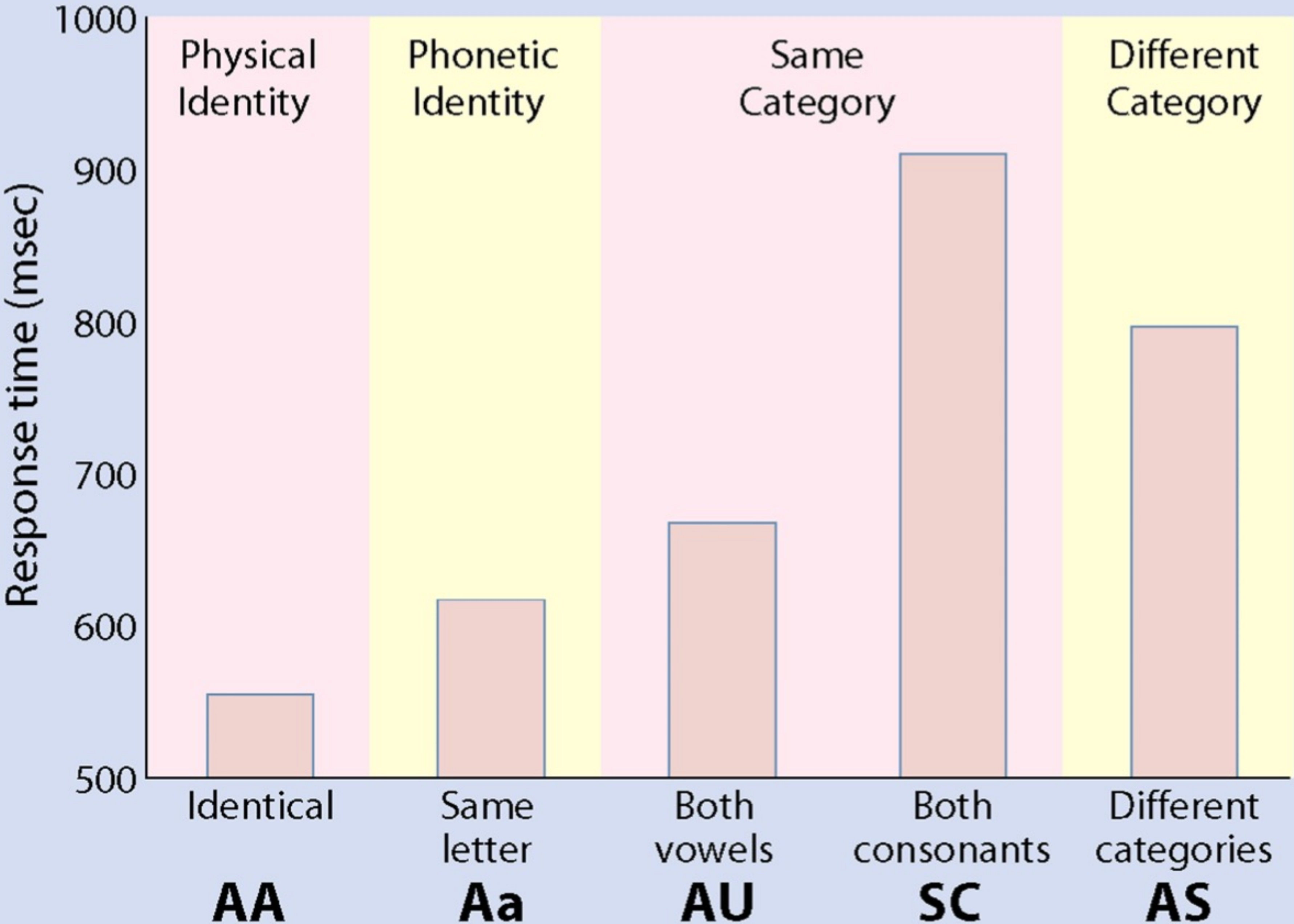
  - Memory retrieval is a serial comparison process between items in memory & those in the world.

  - 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.



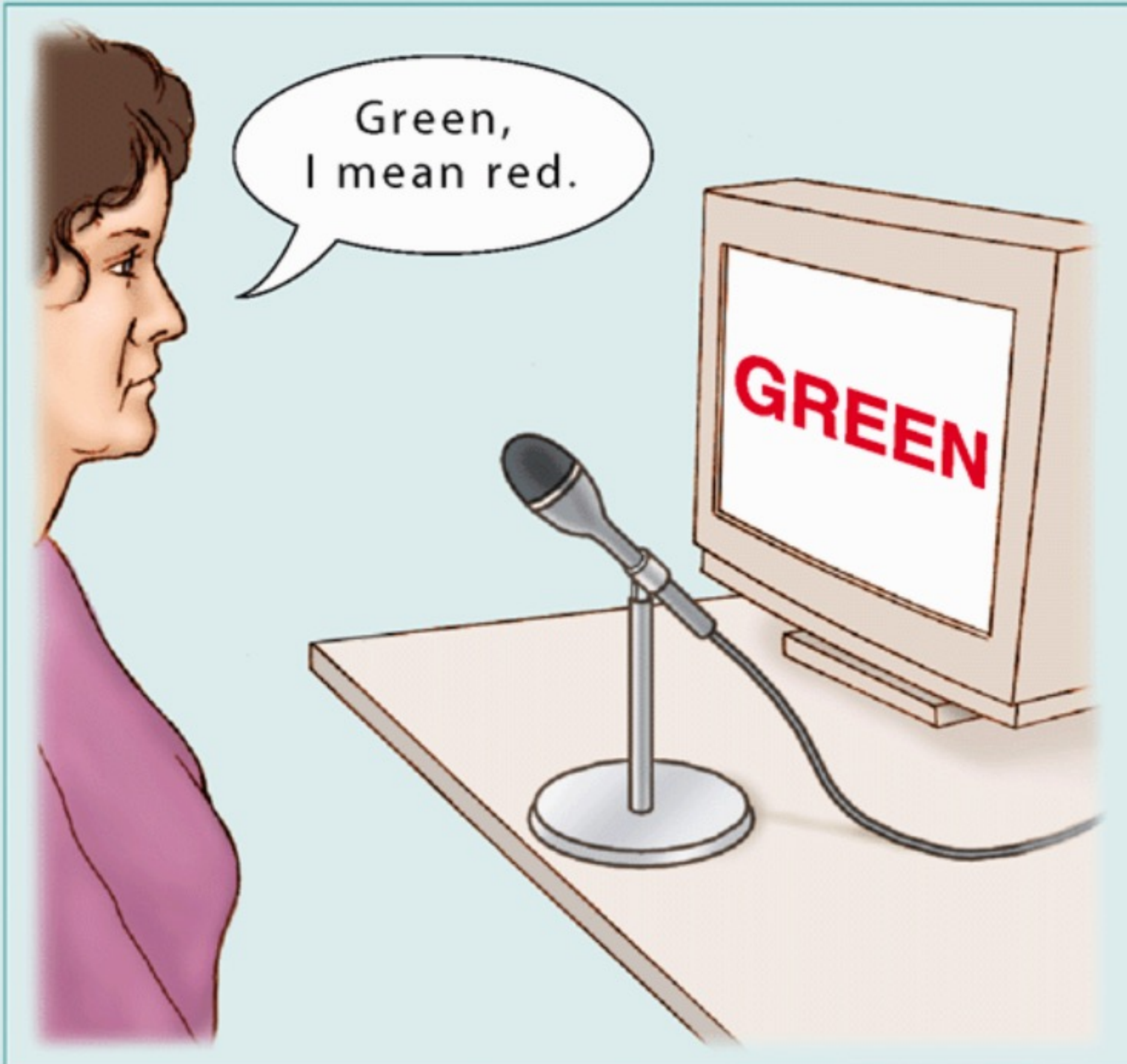
Response time (msec)
1000
900
800
700
600
500
Physical Identity
Phonetic Identity
Same Category
Different Category
Identical
AA
Same letter
Aa
Both vowels
AU
Both consonants
SC
Different categories
AS

- ***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	GREEN
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.

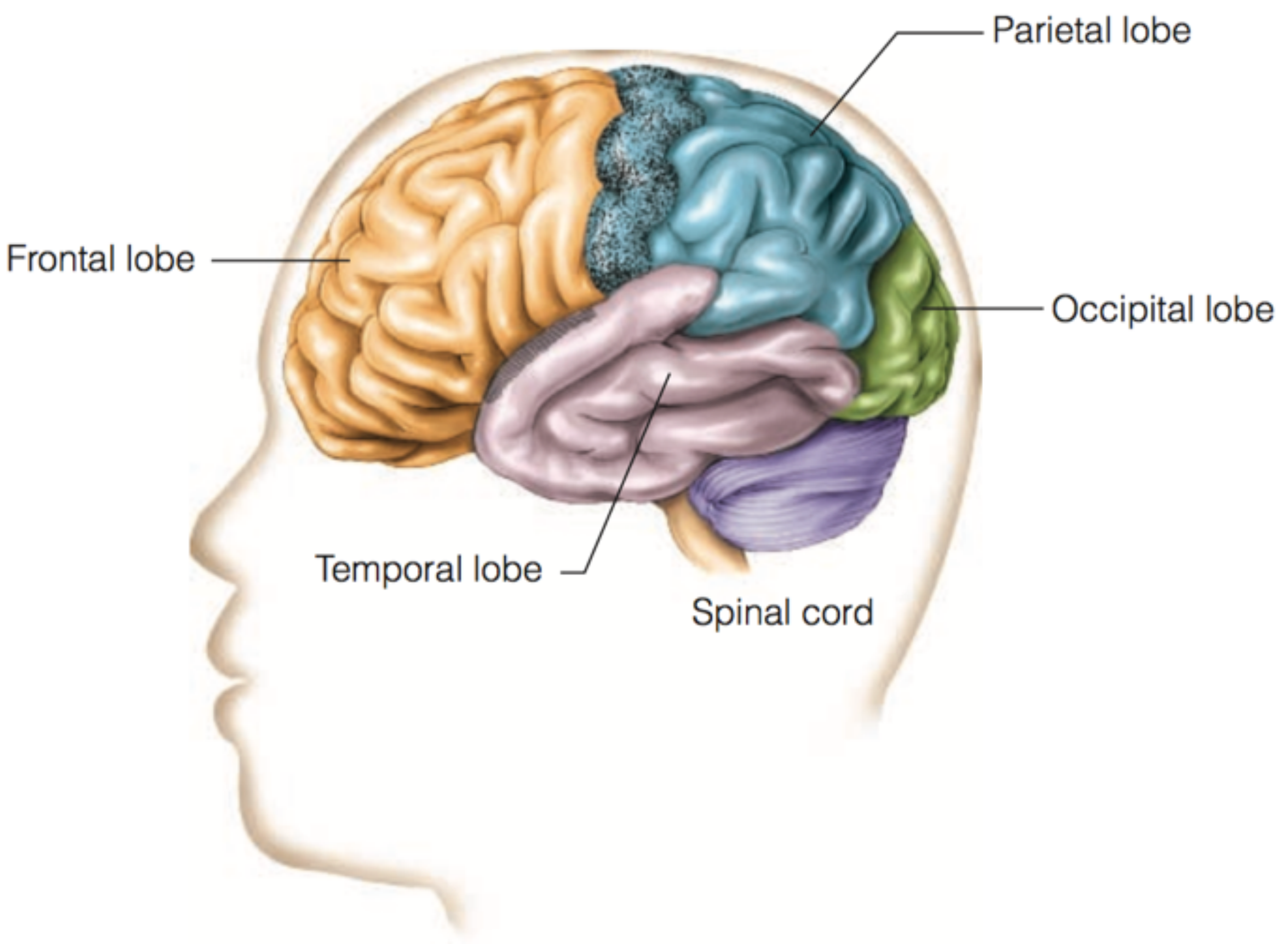
Methods in Cognitive Neuroscience

- 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.

(a) Initial condition—hold object

(b) Test condition—manipulate object

(c) Activity associated with manipulating object

• **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

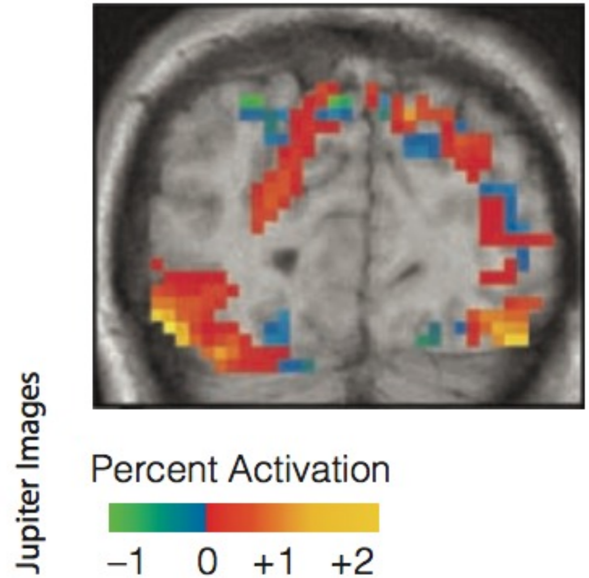
- fMRI indicates the presence of brain activity because the haemoglobin molecules in areas of high brain activity lose some of the oxygen they are transporting.

- 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.

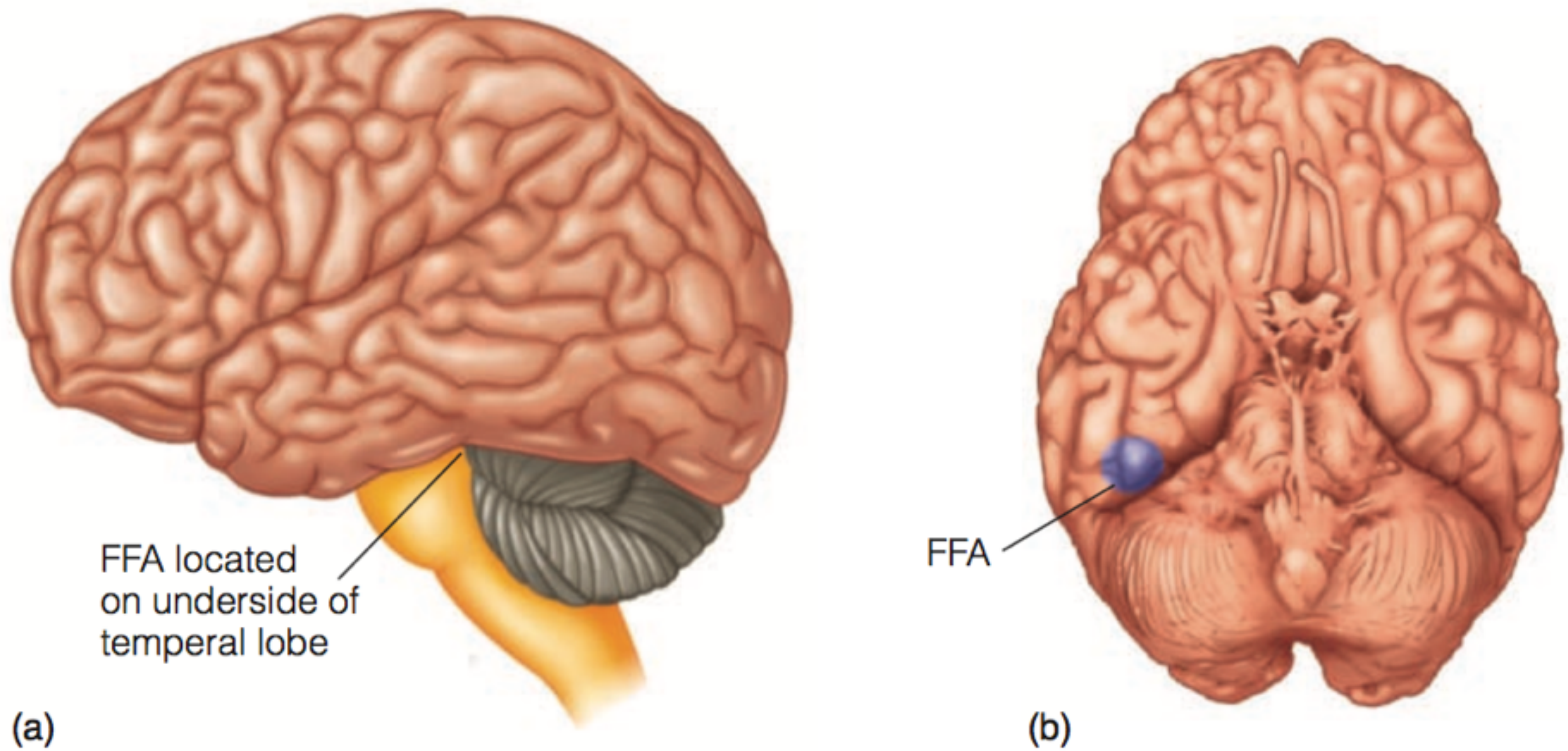
(a)



(b)

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. Copyright © 2010 Wadsworth, a part of Cengage Learning. Reproduced with permission. www.cengage.com/permissions.)

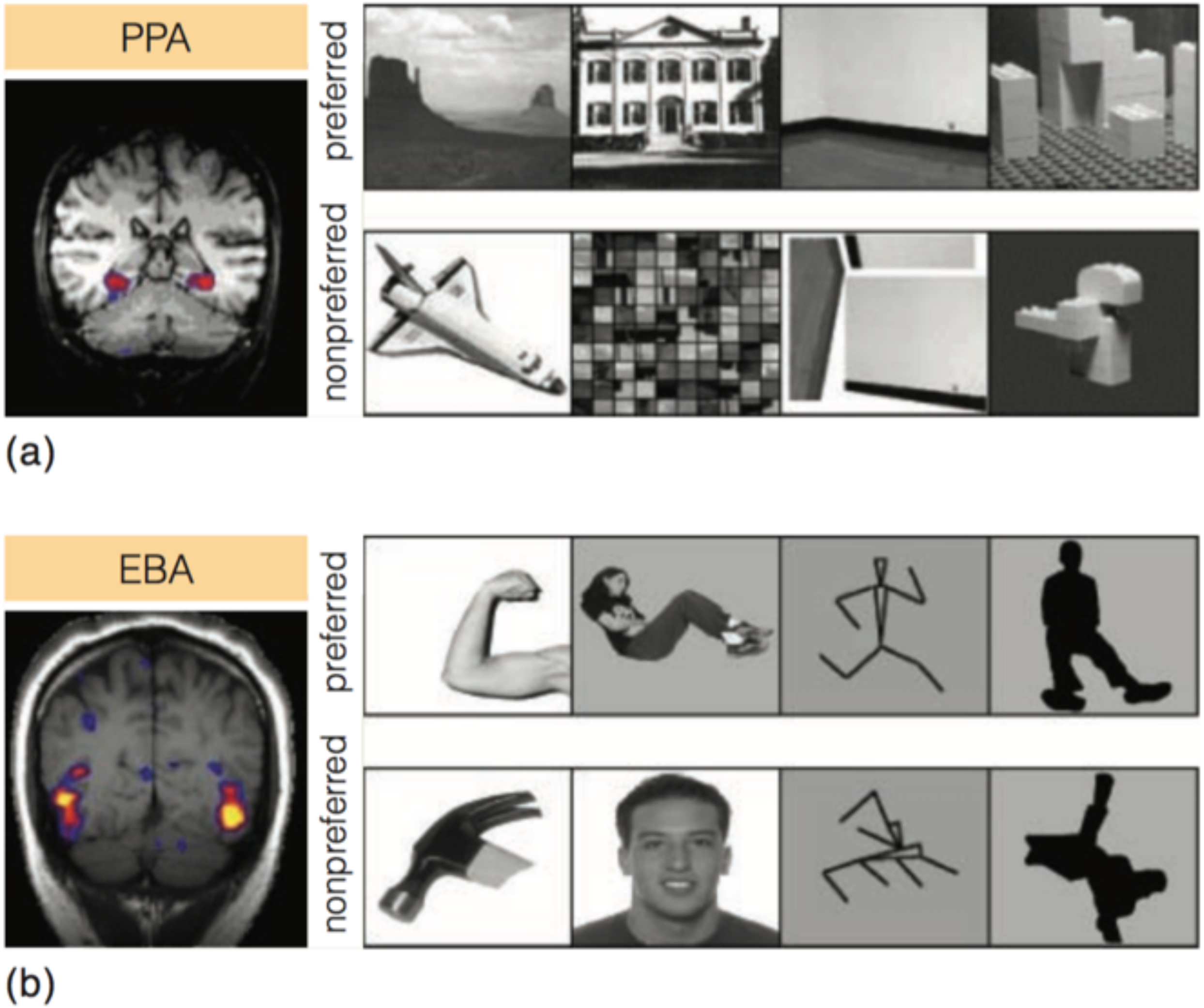


FIGURE 2.11 (a) The parahippocampal place area is activated by places (top row) but not by other stimuli (bottom row). (b) The extrastriate body area is activated by bodies (top), but not by other stimuli (bottom). (Source: L. M. Chalupa & J. S. Werner, eds., *The Visual Neurosciences,* 2-vol. set, figure 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.

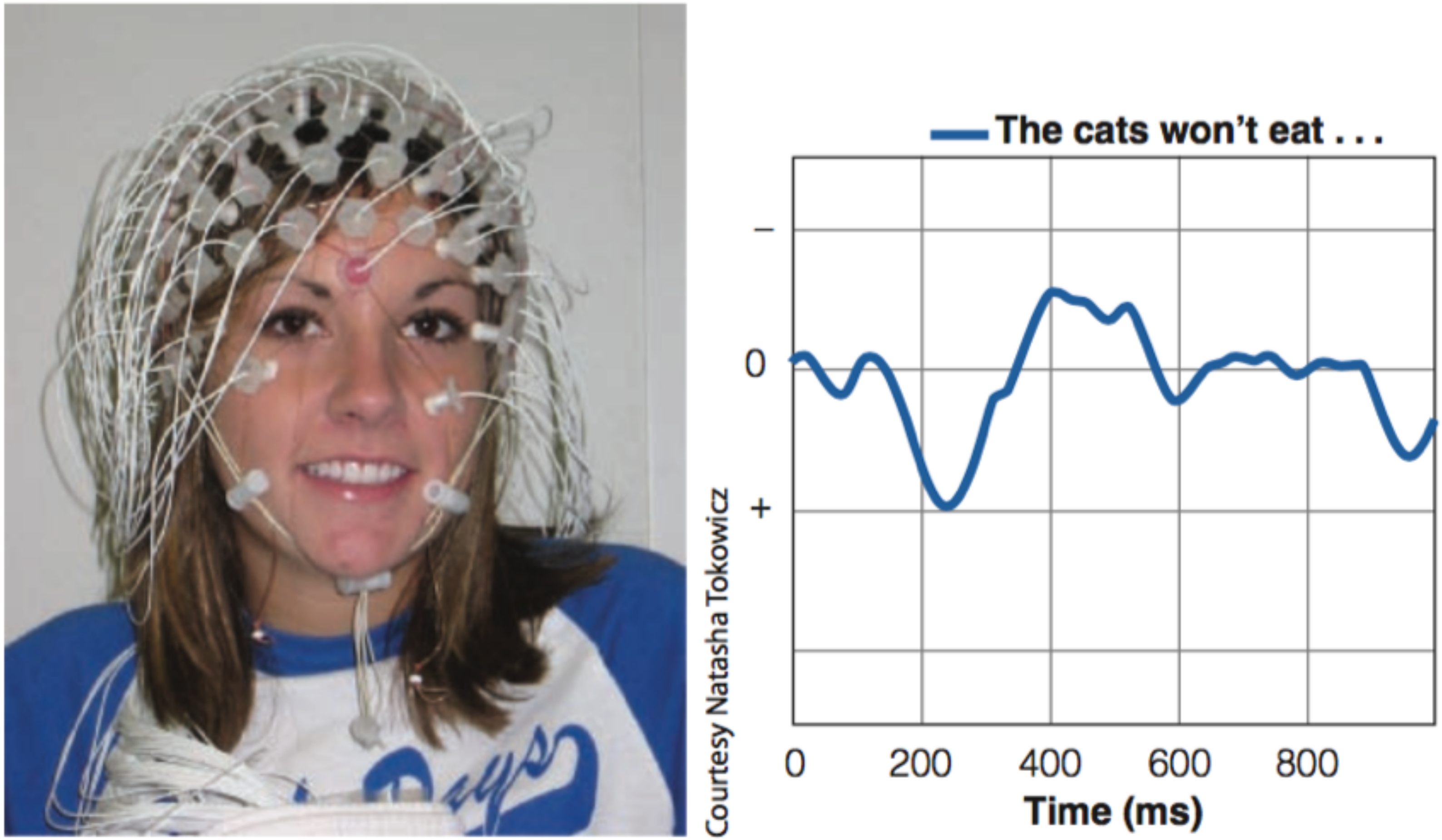
- A disadvantage of the ERP method is that it is difficult to pinpoint the source of these signals.

- 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.

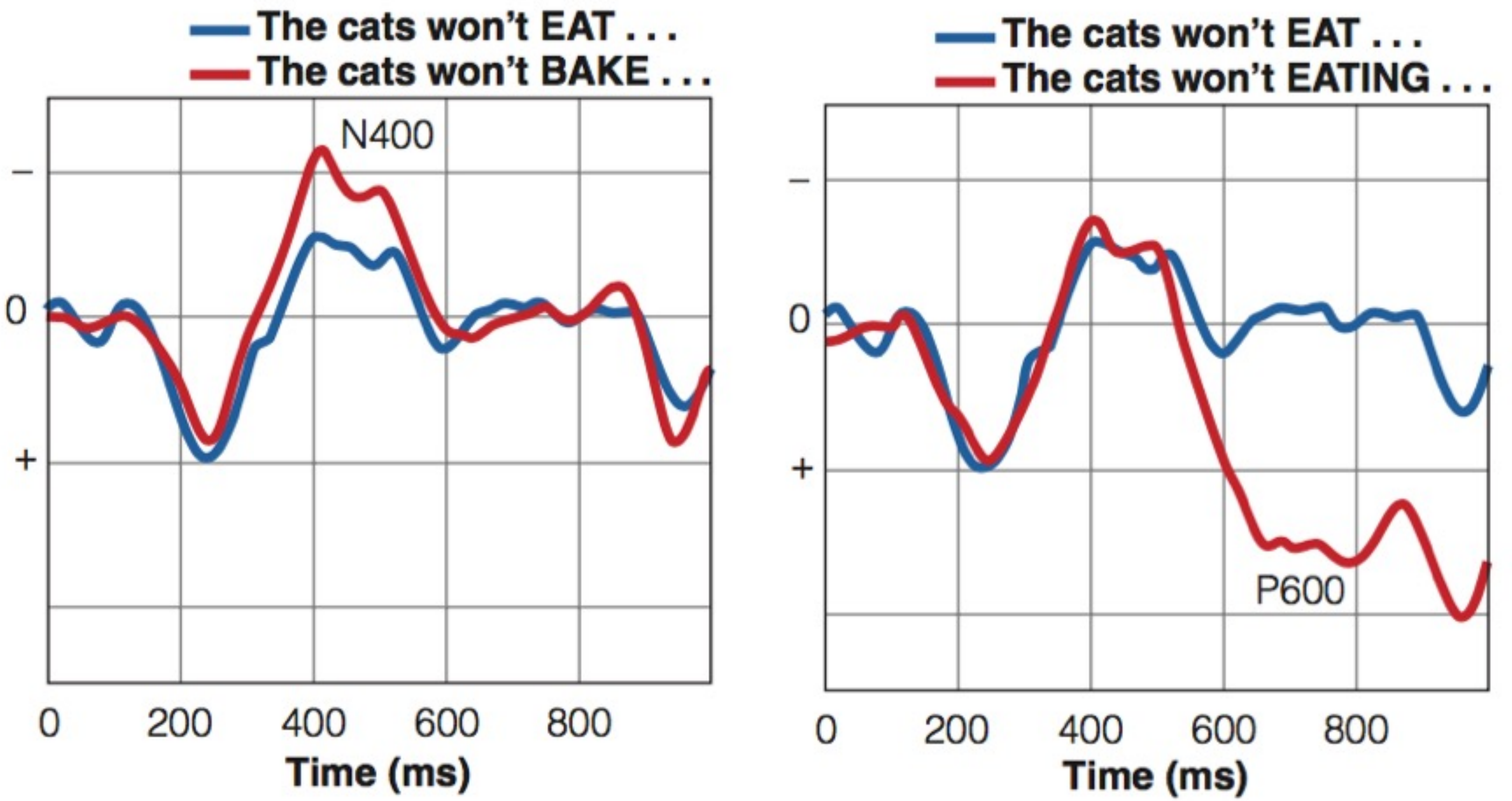
  - As ERP consists of a number of waves that occur at different delays after a stimulus is presented; these can be linked to different aspects of language.

  - 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)