Indian Institute of Technology Kanpur

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Presents

Course Title:

Basic Cognitive Processes

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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.

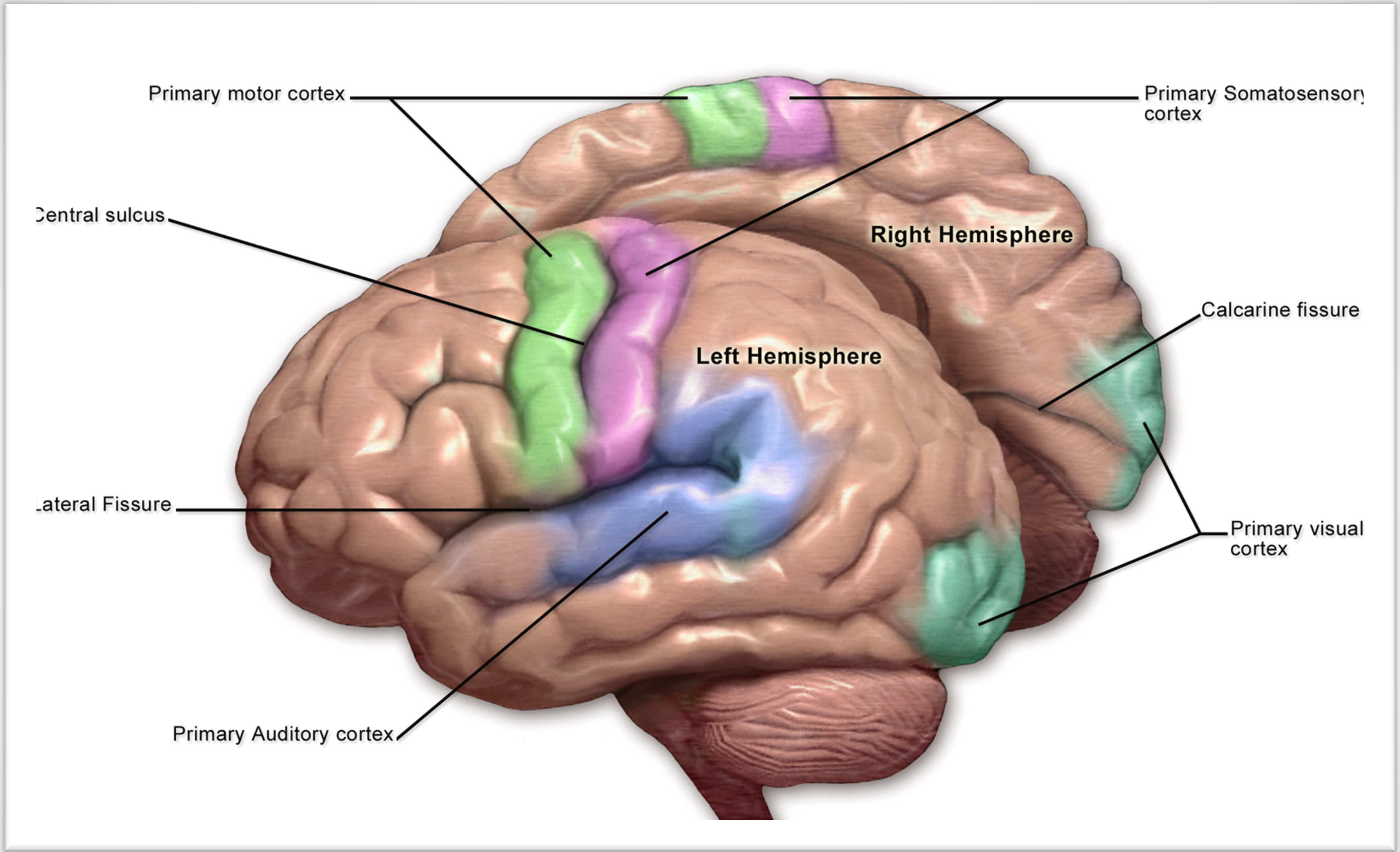
The Cerebral Cortex

- 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.

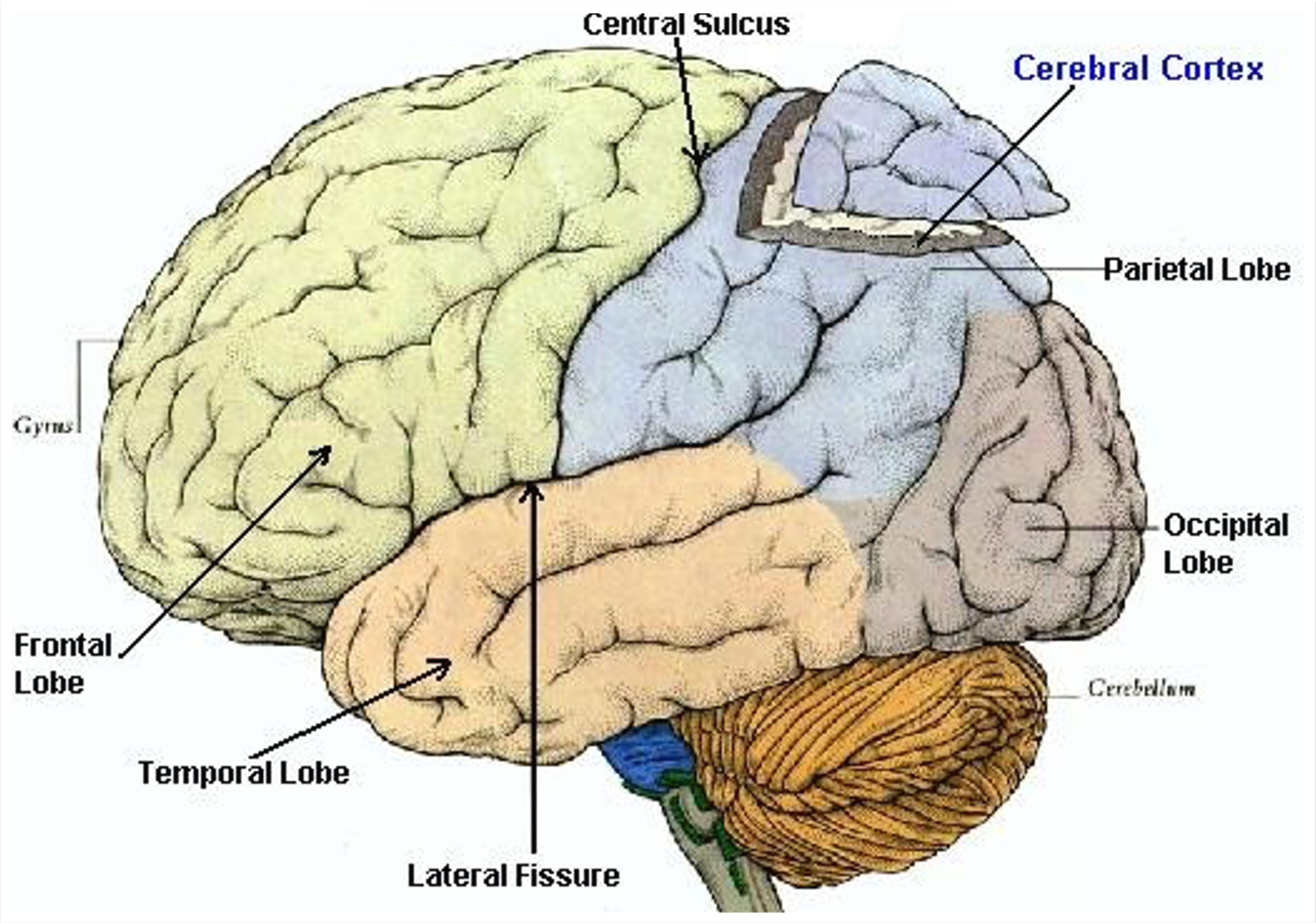
- the cortex is composed of two hemispheres on the left & the right sides of the brain that are connected by a the corpus callosum.

- 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

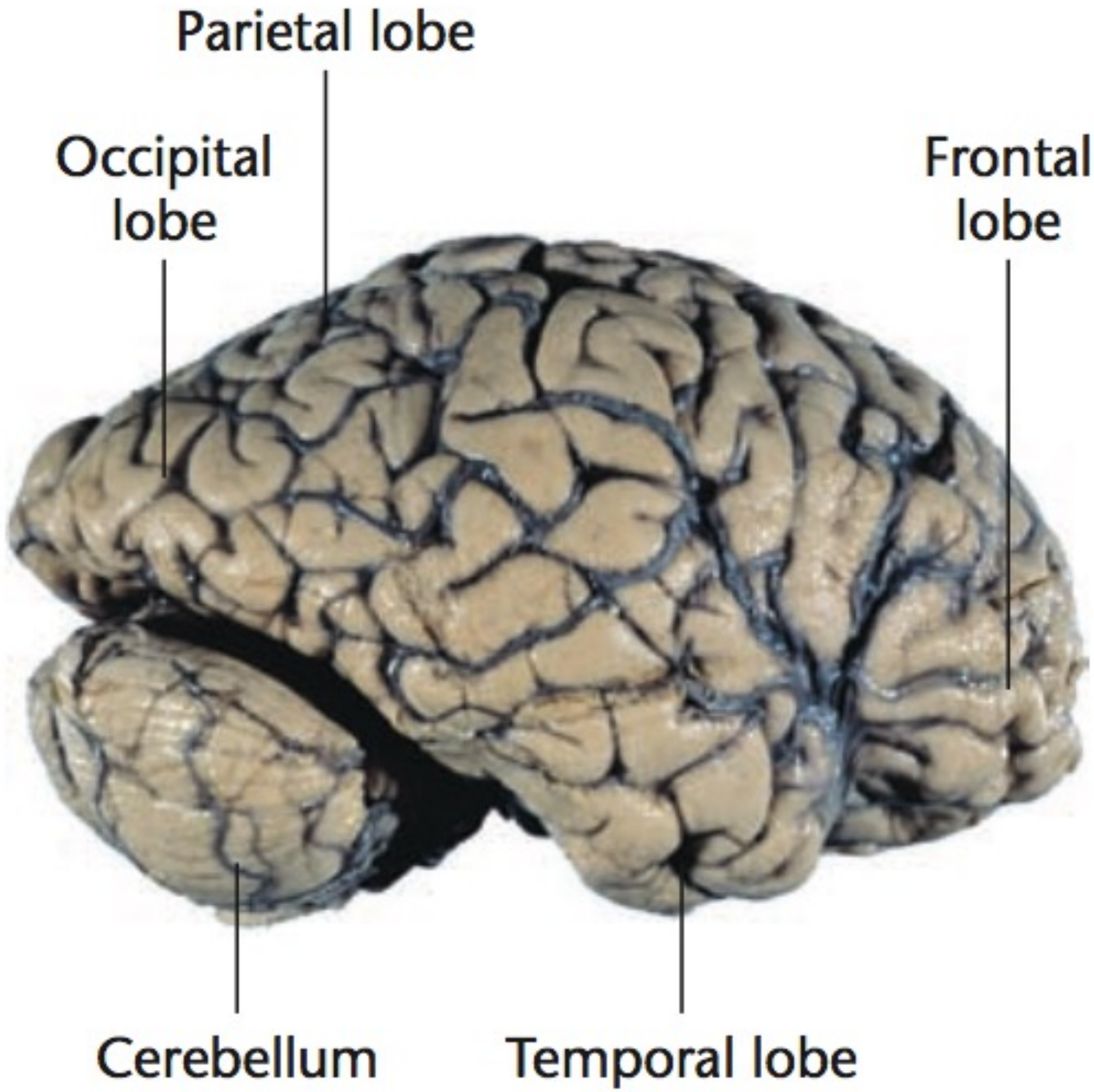


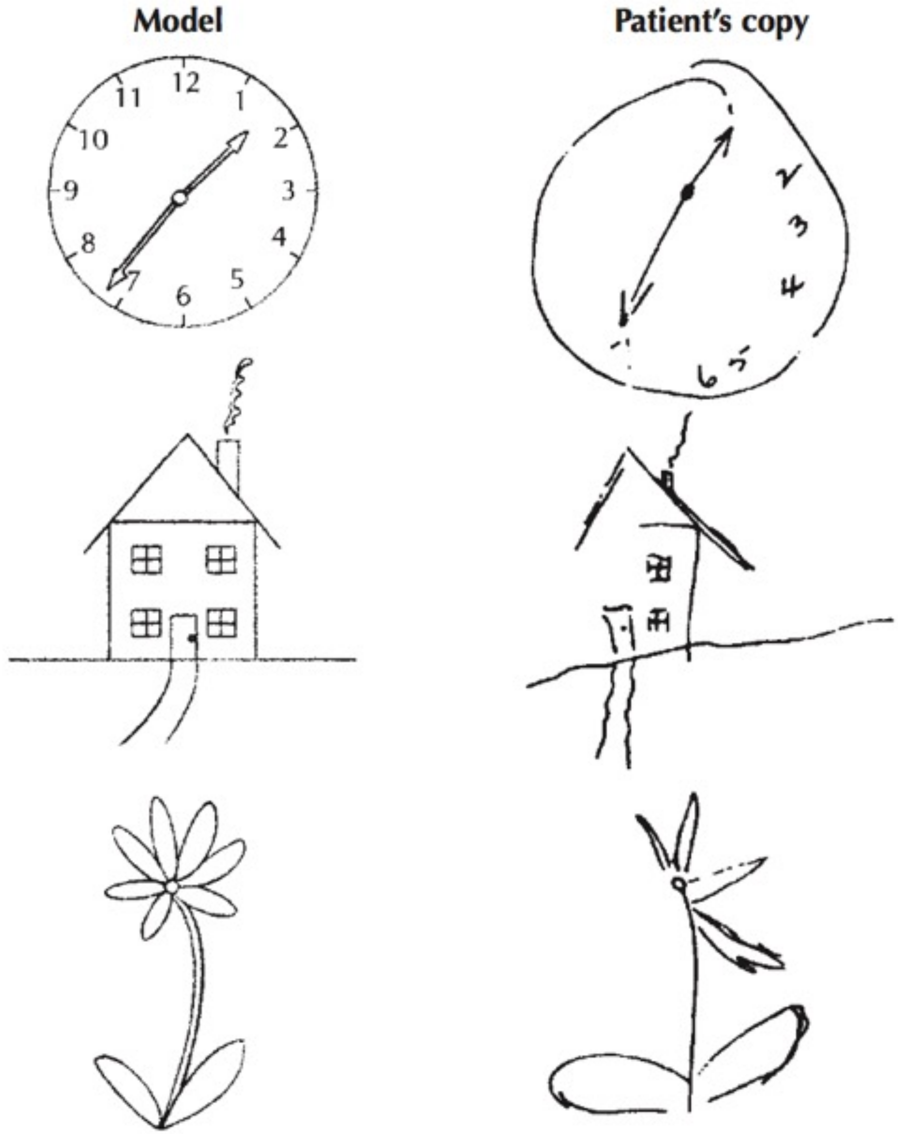
Figure 2.12 **Photograph of human brain.**

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.

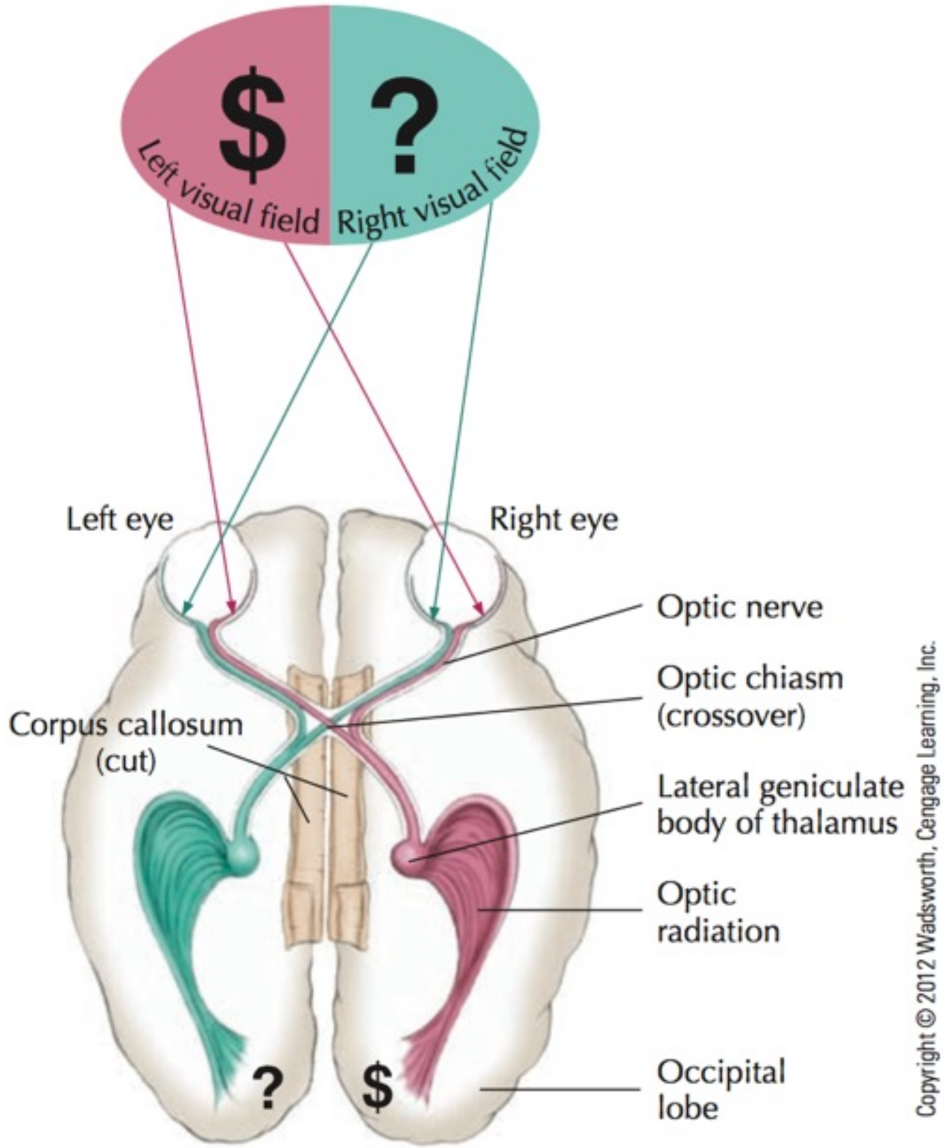
- Interesting scenarios get created with split brain patients: for e.g. when one split brain patient dressed himself, he sometimes pulled his pants up with one hand (that side of his brain wanted to get dressed) & pulled down with the other (while this side did not).

  - 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

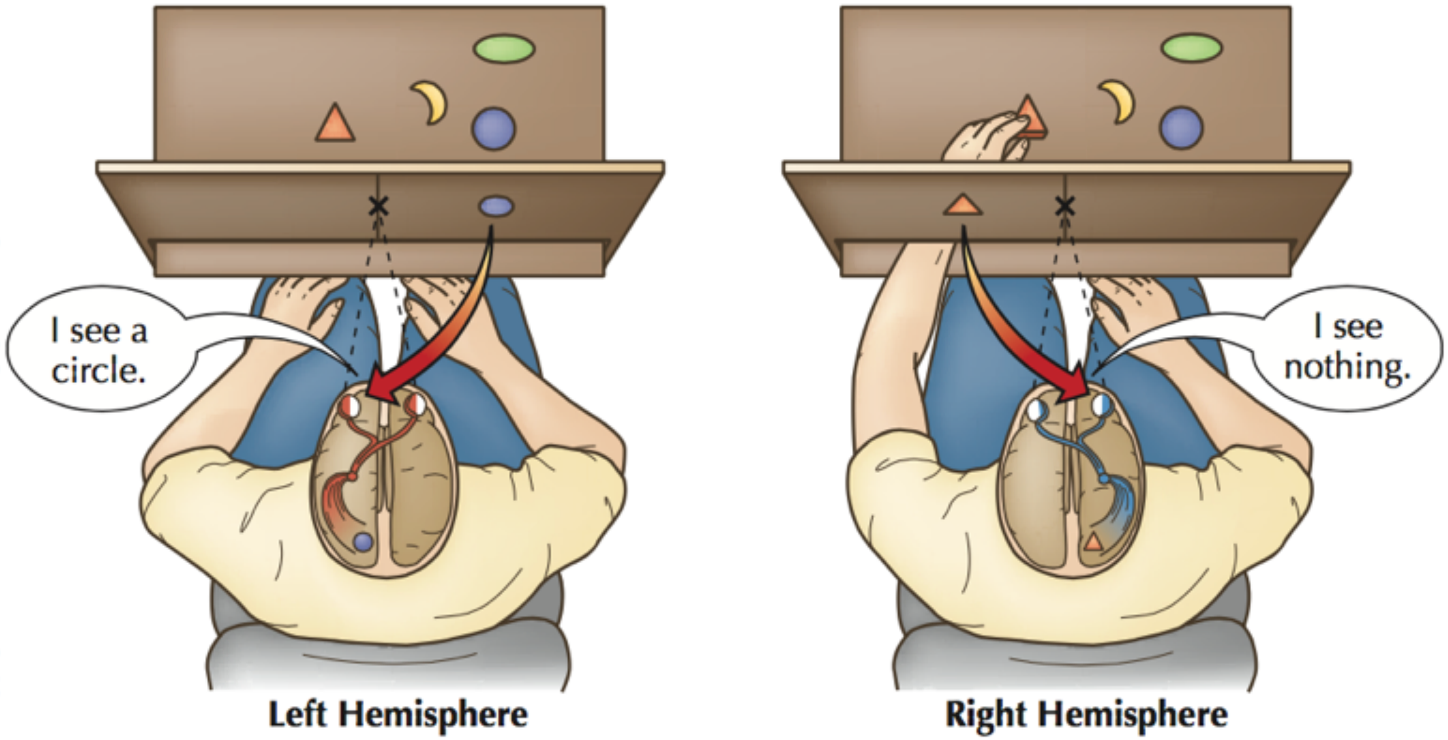


Figure 2.20 A circle is flashed to the left brain of a split-brain patient and he is asked what he saw. He easily replies, "A circle." He can also pick out the circle by merely touching shapes with his right hand, out of sight behind a screen. However, his left hand can't identify the circle. If a triangle 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)

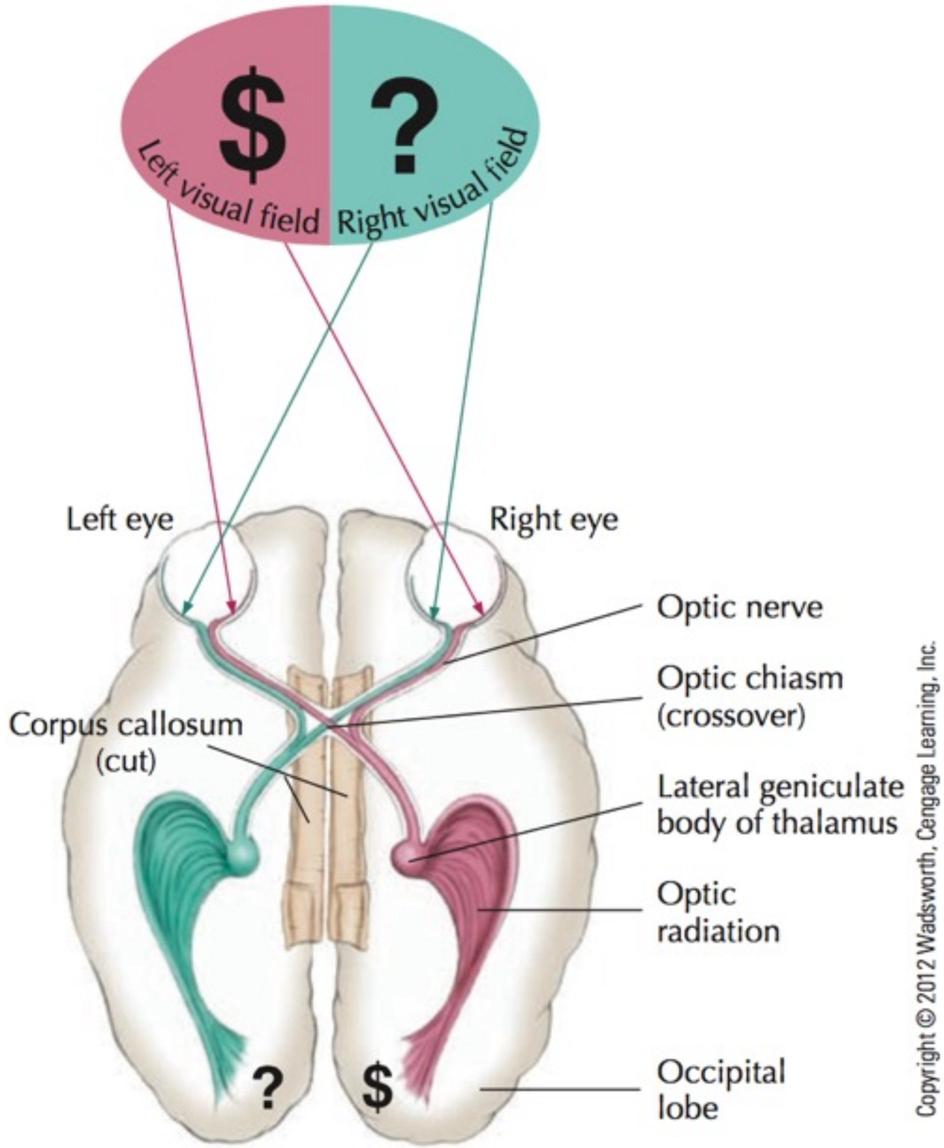
- in contrast, the right hemisphere can produce only the simplest language & numbers.
- however, the right brain is good at perceptual skills, such as recognising patterns, faces & melodies; putting together a puzzle, or drawing a picture.
- the right hemisphere also helps one express emotions & detect 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).



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Objects

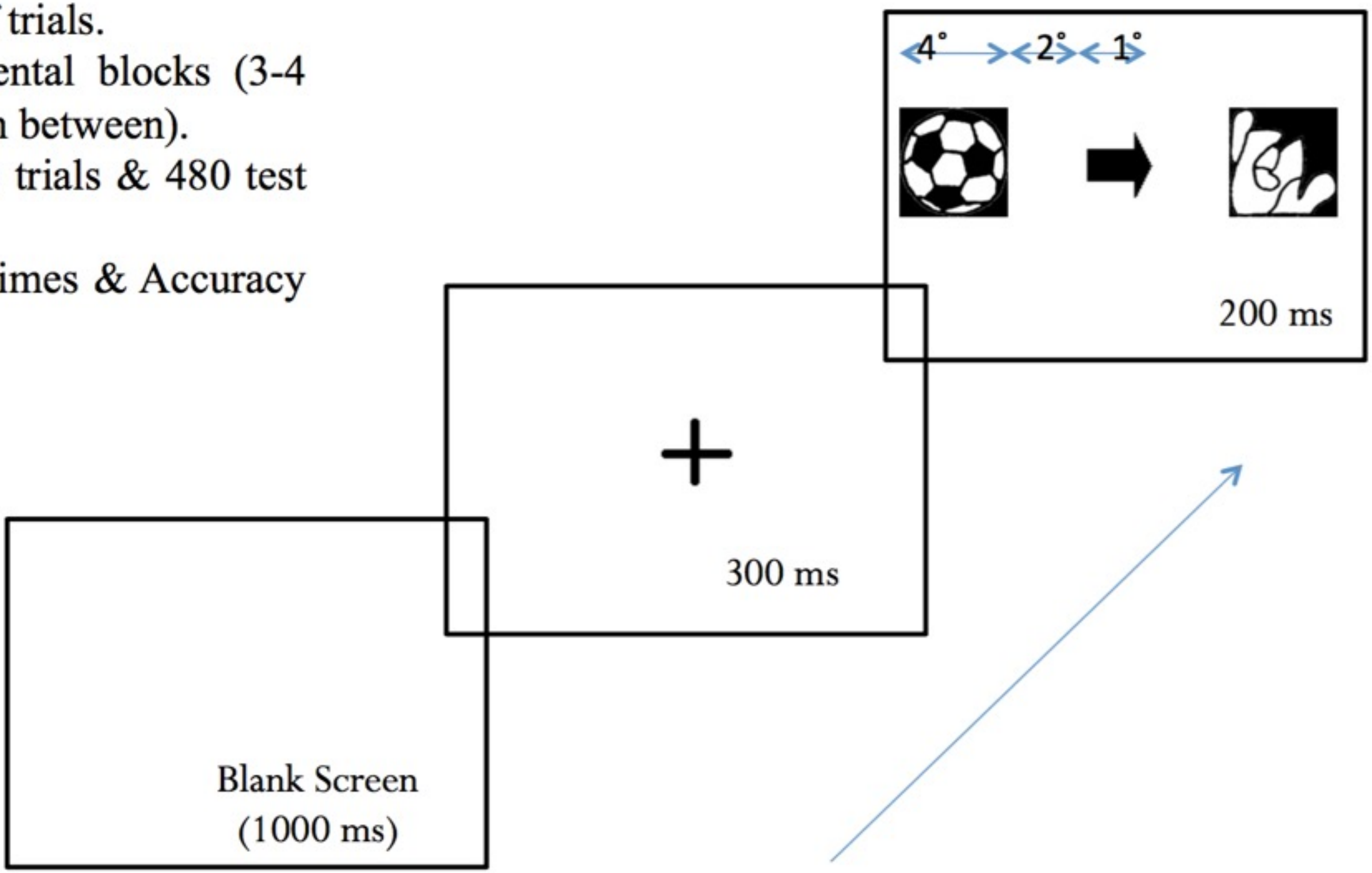
Non-Objects

Tools

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.

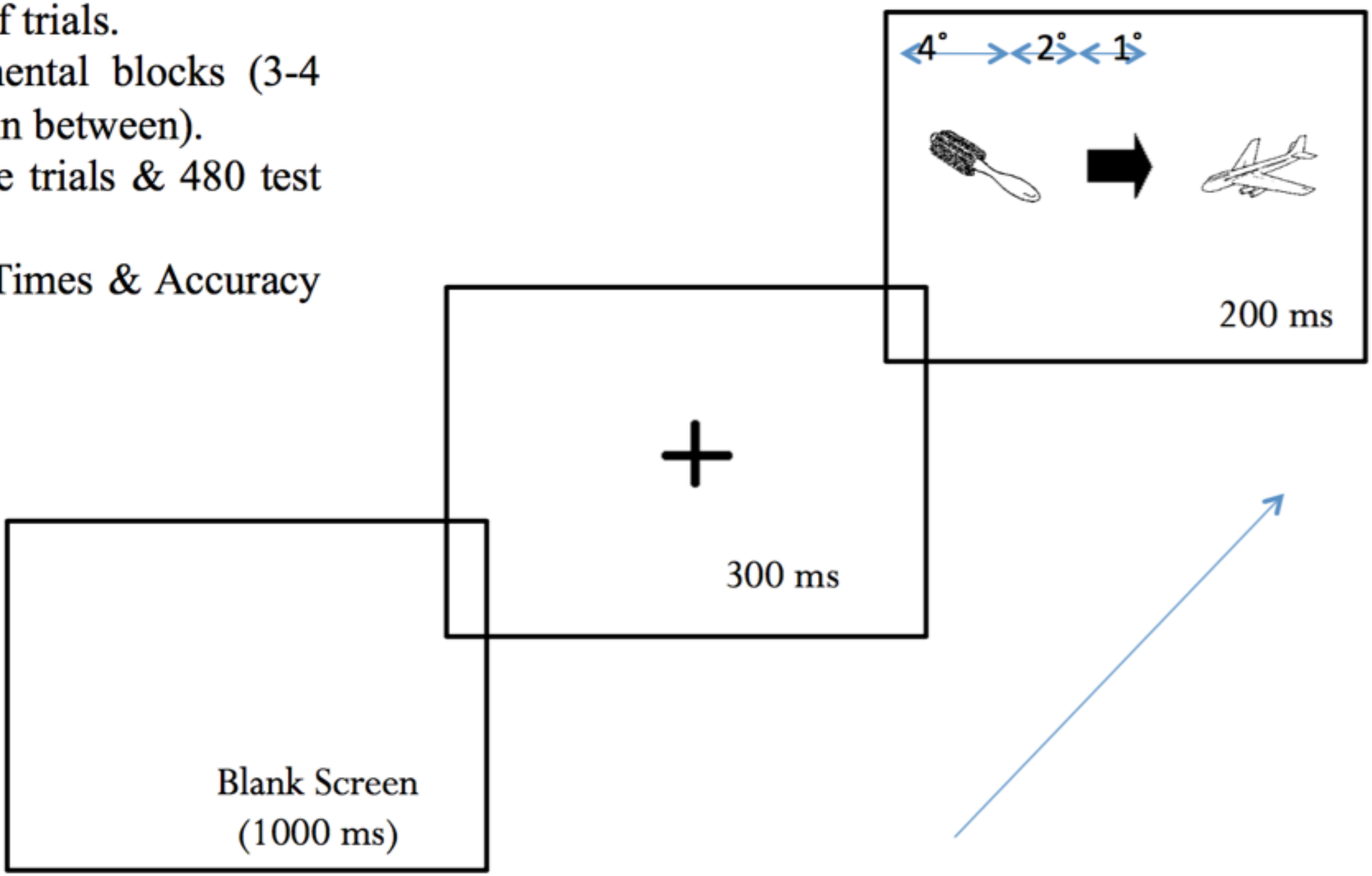
OBJECT RECOGNITION TASK

- 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.



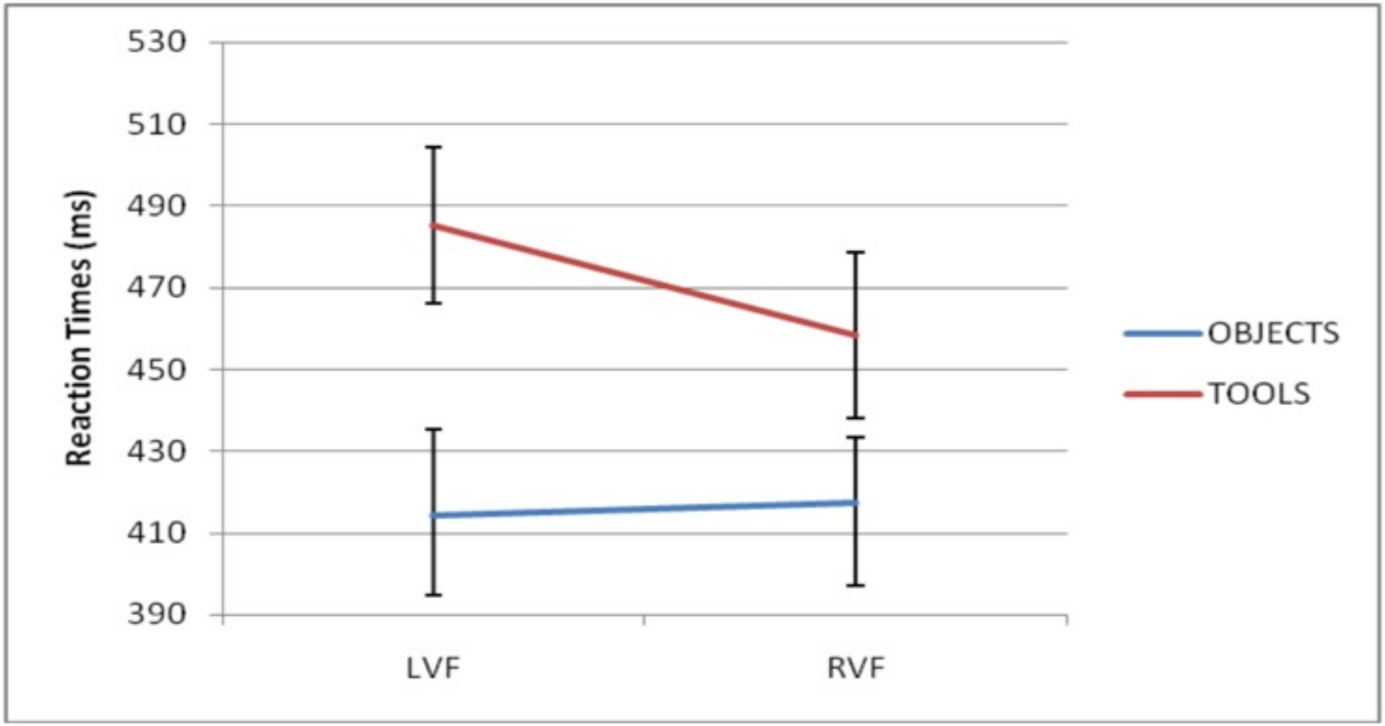
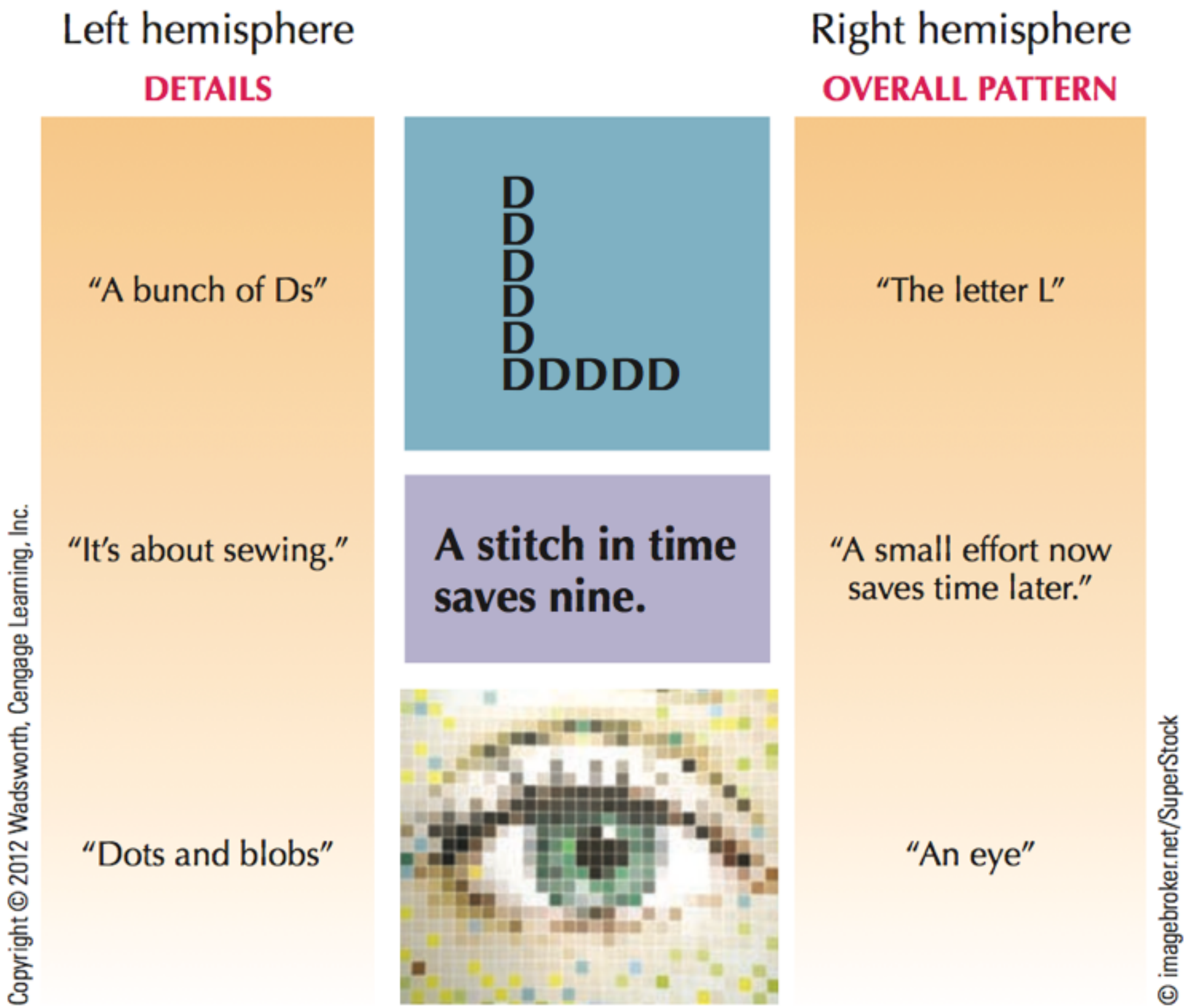


Figure: **Showing significant RVF (17ms) facilitation for tools, while no such facilitation is seen for objects.**

- 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.

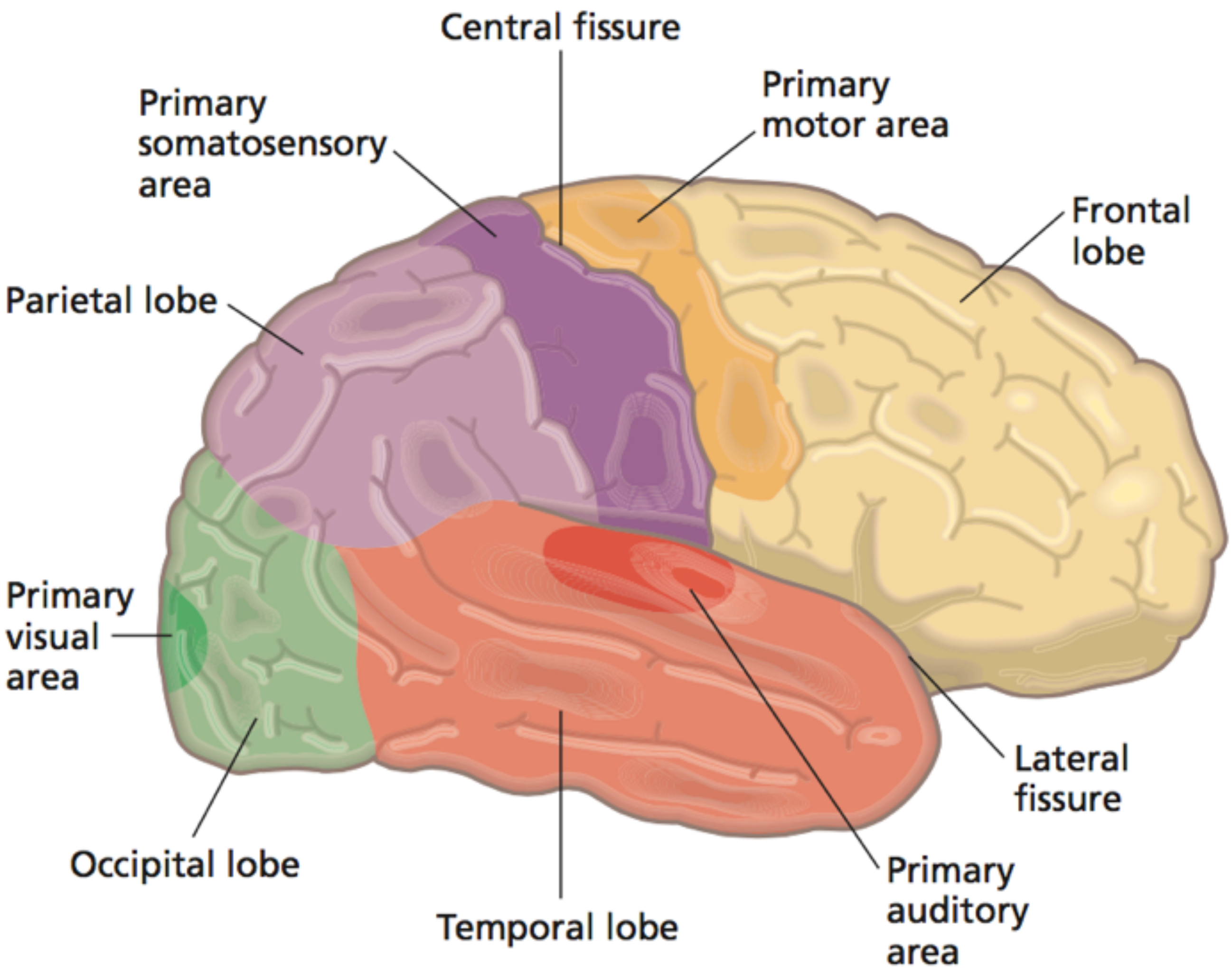


Figure 2.13a Cerebral cortex. *(a) Lateral view*

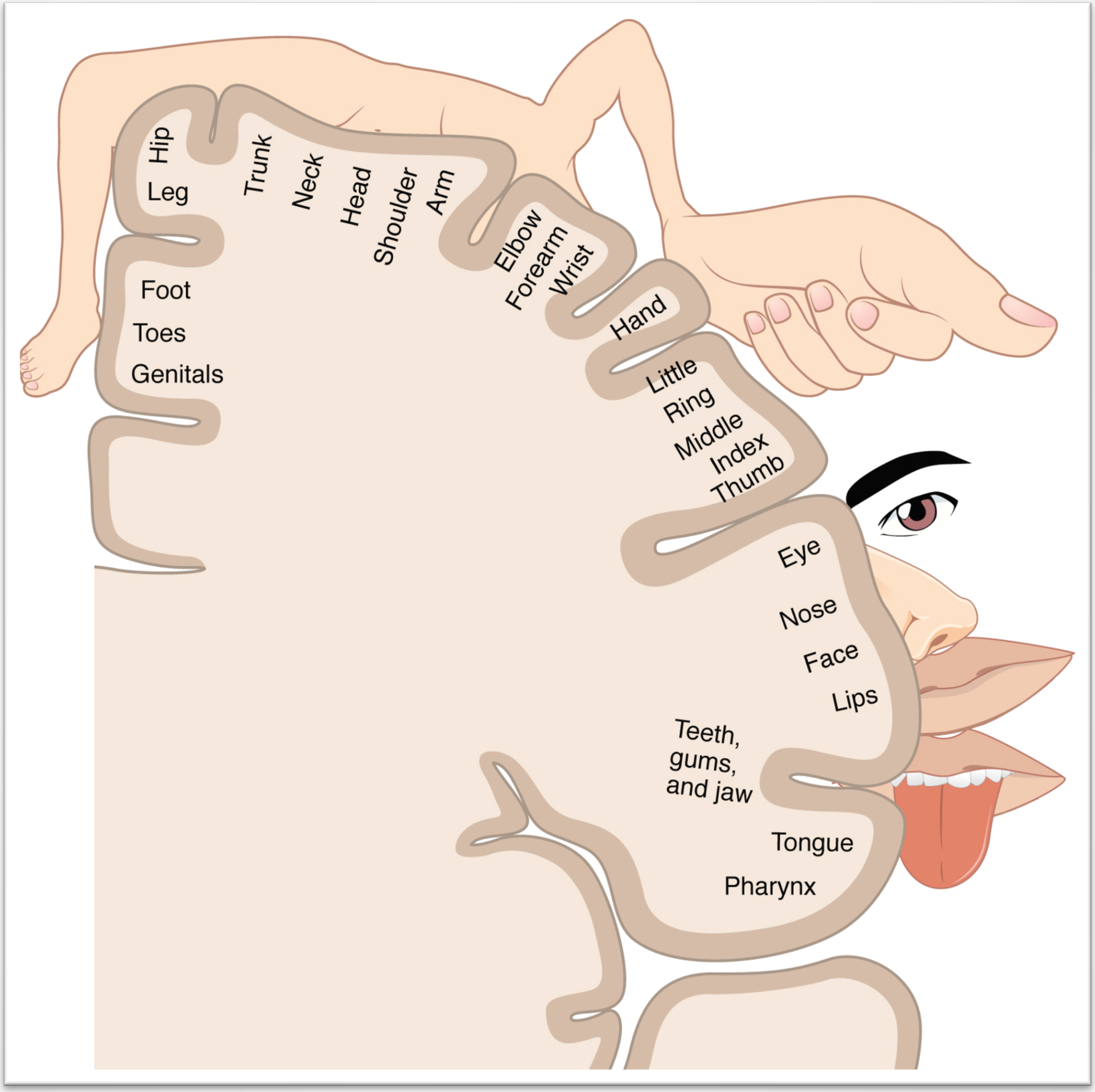
Figure

- ***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.

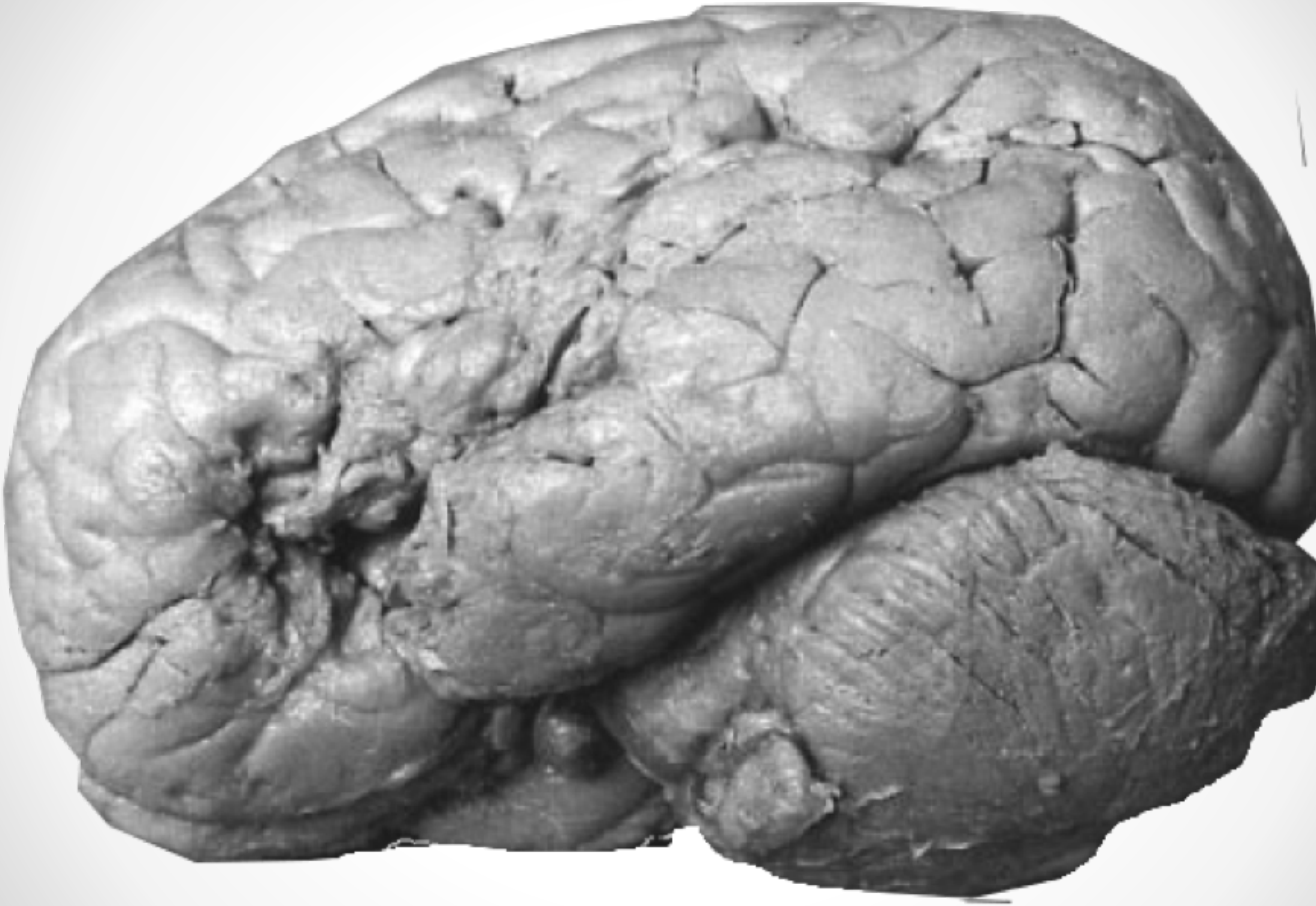


Hip
Leg
Foot
Toes
Genitals
Trunk
Neck
Head
Shoulder
Arm
Elbow
Forearm
Wrist
Hand
Little
Ring
Middle
Index
Thumb
Eye
Nose
Face
Lips
Teeth,
gums,
and jaw
Tongue
Pharynx

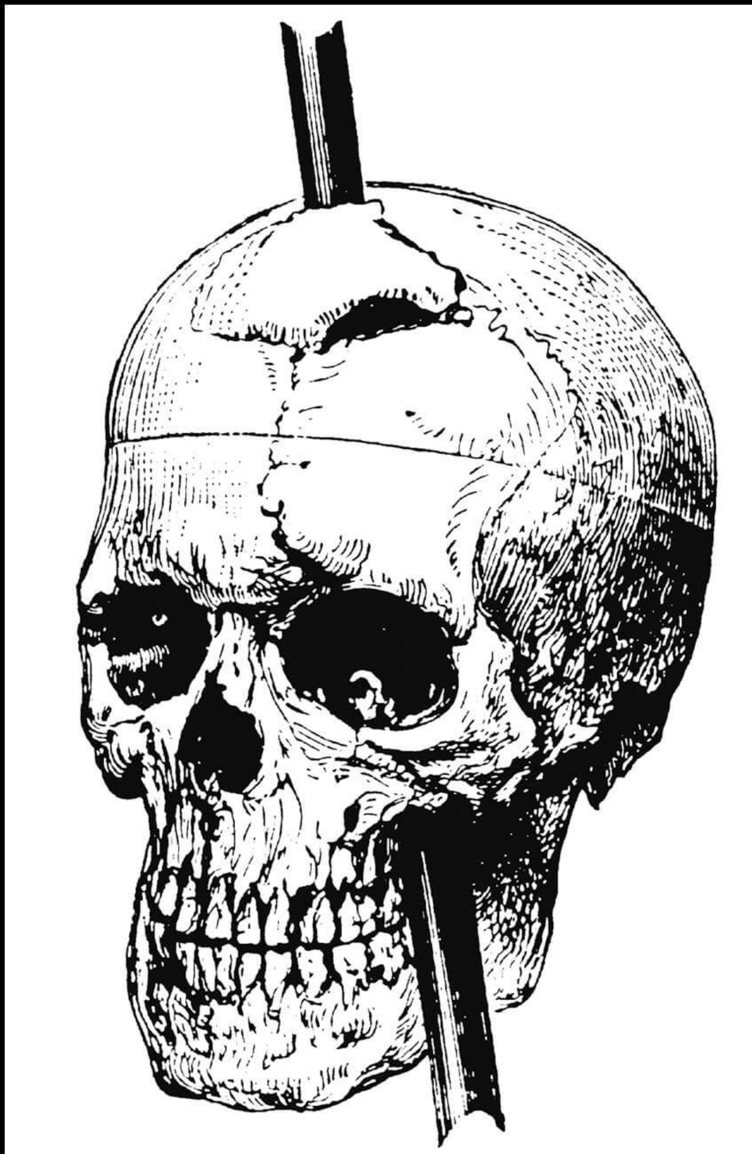
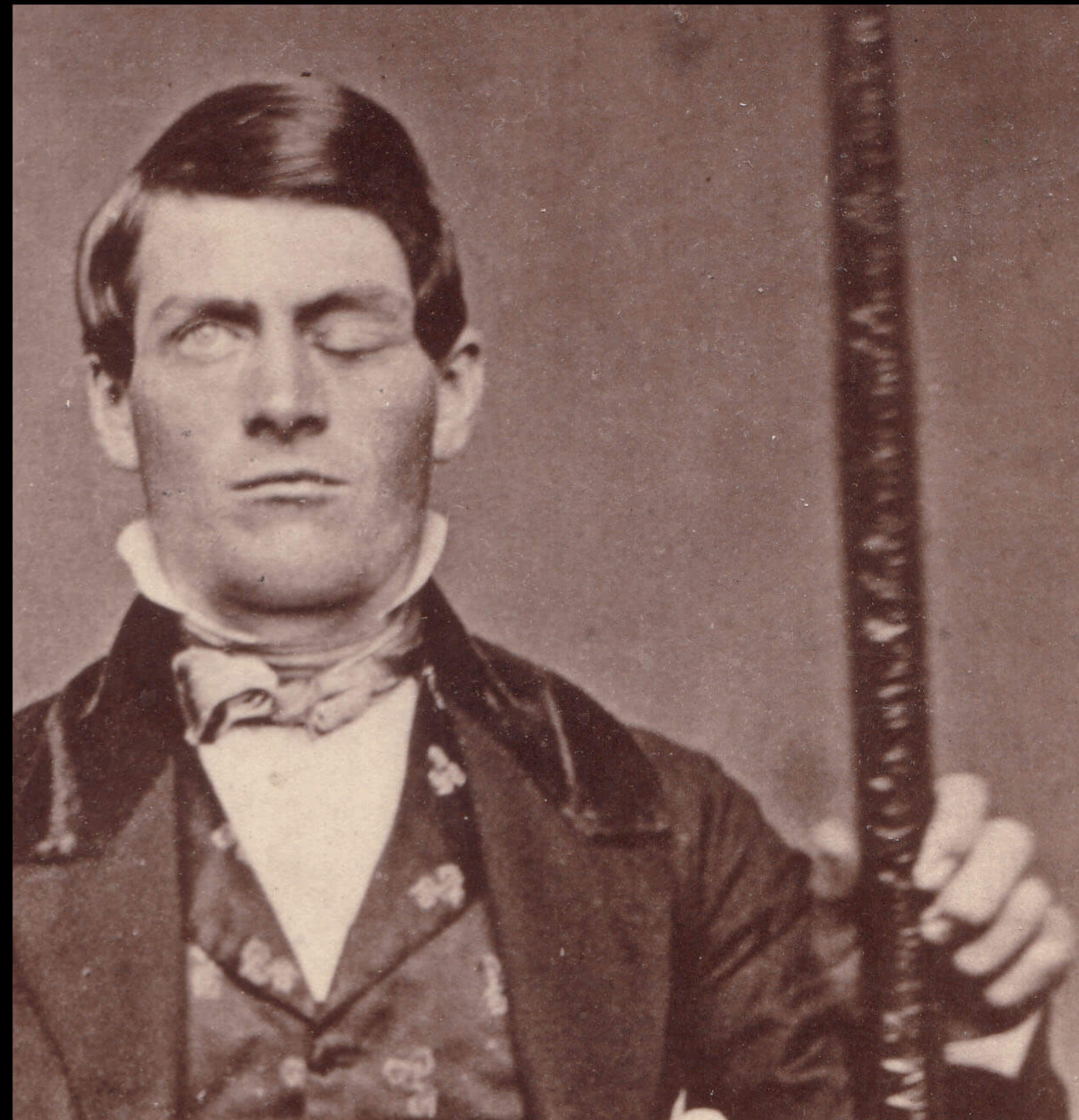
- the rest of the frontal lobes are often referred to as *frontal association areas*. i.e. only a small portion of the cerebral cortex directly controls the body or receives information from the senses;

- 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.

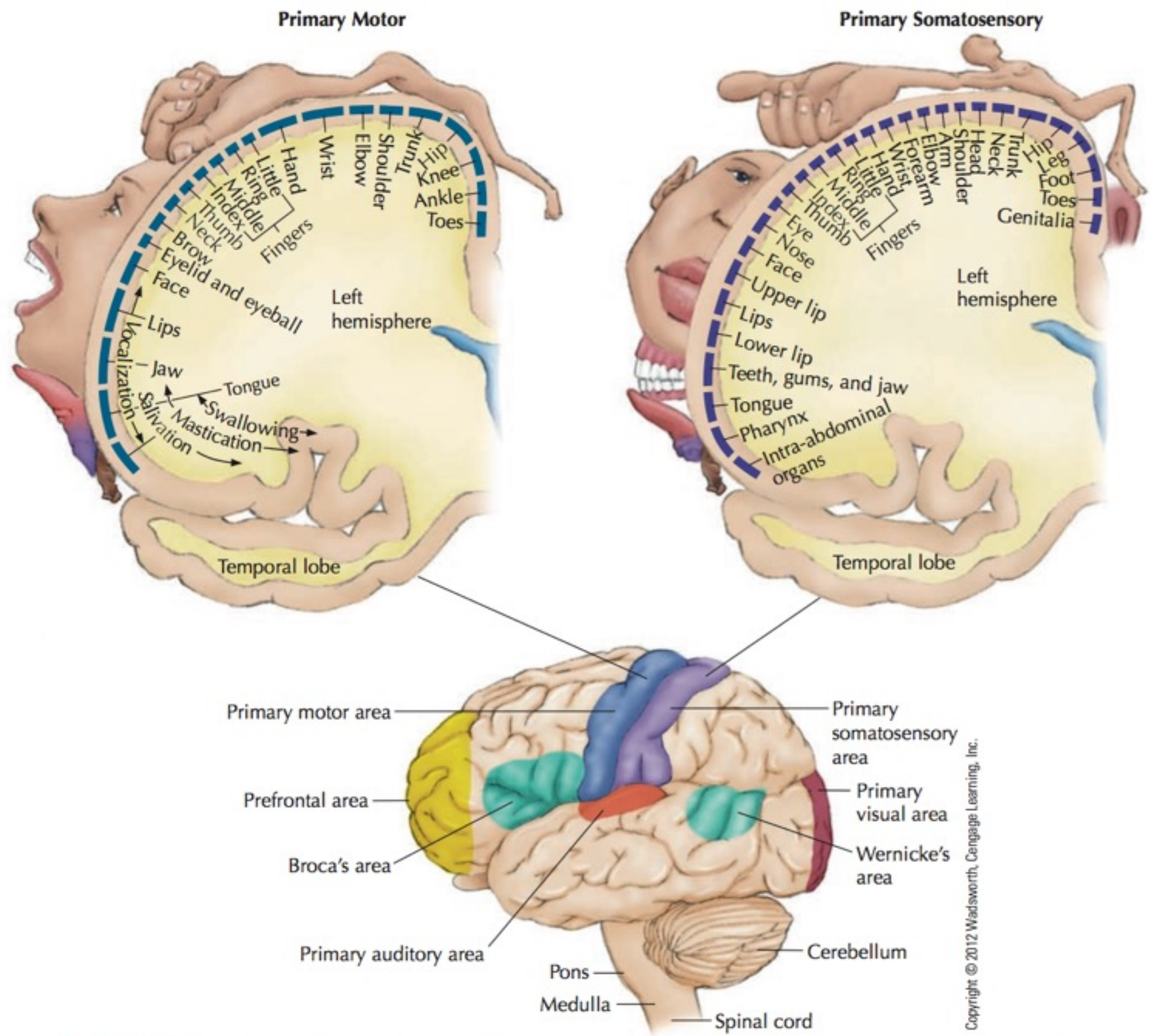
- some association areas also contribute to the higher mental abilities, such as language. e.g. a person with damage to association areas in the left hemisphere may suffer *aphasia,* i.e. an impaired ability to use language (speak). e.g. Broca's aphasia.



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

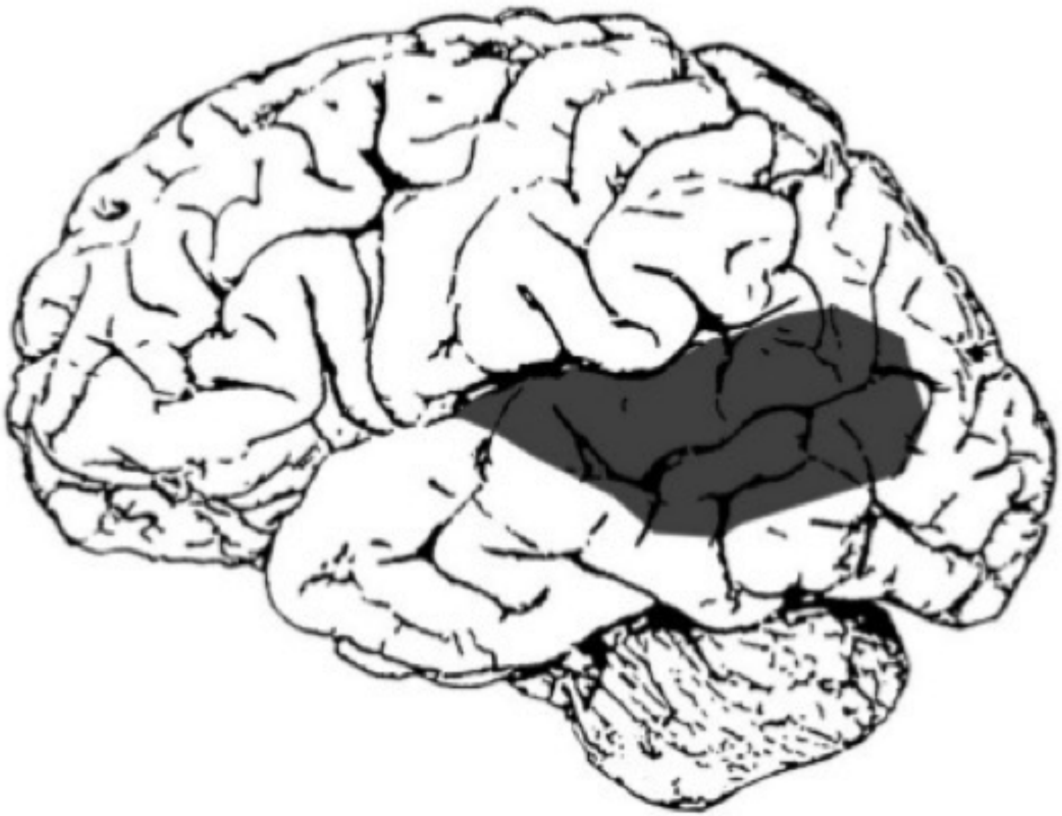
- ***The Temporal Lobes***: the temporal lobes are located on each side of the brain.

    - 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.
    - o how do the visual areas represent vision?
    - o 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.