An Introduction to Cognitive Neuroscience

1. Definition

Cognitive neuroscience is the field of study linking the brain and other aspects of the nervous system to cognitive processing and, ultimately, to behavior. The brain is the organ in our bodies that most directly controls our thoughts, emotions, and motivations (Rockland, 2000).

2. Cognition in the Brain: The Anatomy and Mechanisms of the Brain

The brain has three major regions: forebrain, midbrain, and hindbrain. These labels do not correspond exactly to locations of regions in an adult or even a child's head. Rather, the terms come from the front-to-back physical arrangement of these parts in the nervous system of a developing embryo.

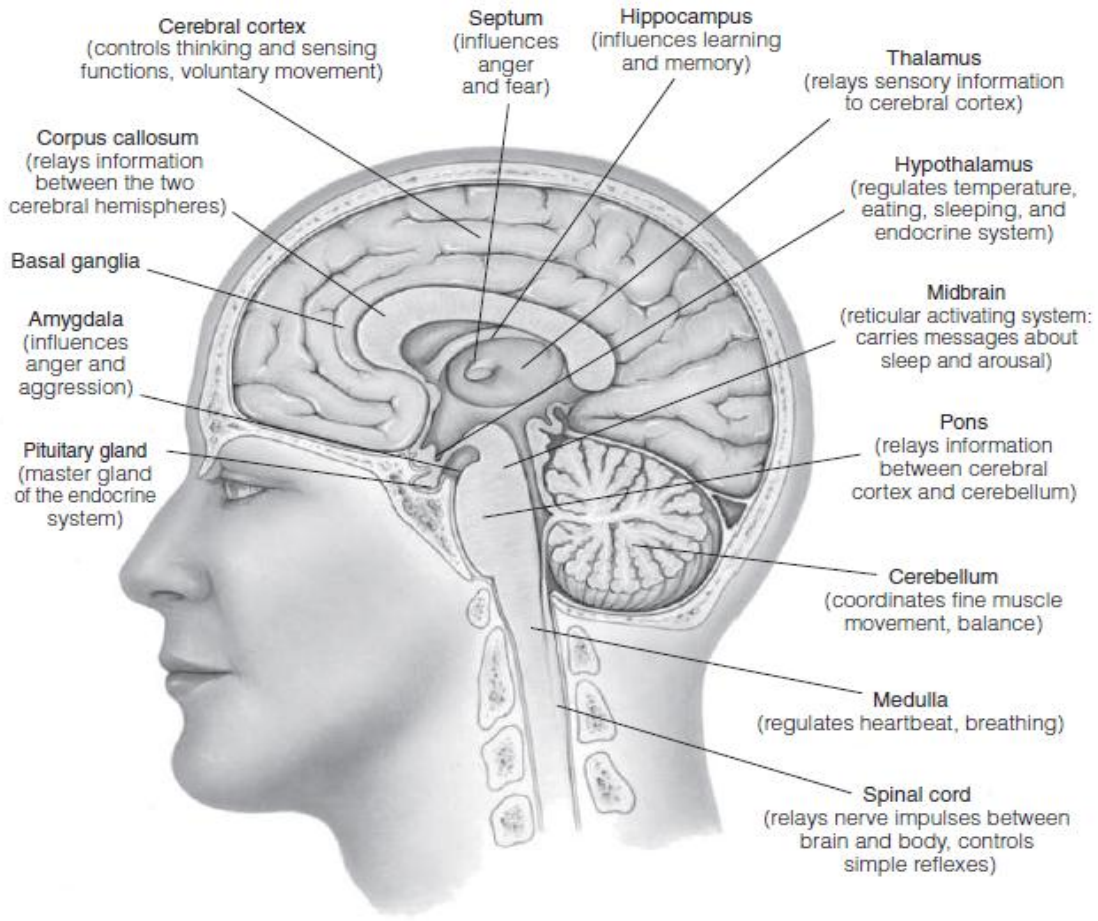

Figure (01): Structures of the Brain (Sternberg, 2000)

The following table sums up the major structures of the Brain and their functions

Region of the Brain	Major Structures within the Regions	Functions of the Structures
Forebrain	Cerebral cortex (outer layer of the cerebral hemispheres)	Involved in receiving and processing sensory information, thinking, other cognitive processing, and planning and sending motor information
	Basal ganglia (collections of nuclei and neural fibers)	Crucial to the function of the motor system
	Limbic systems (hippocampus, amygdala, and septum)	Involved in learning, emotions, and motivation (in particular, the hippocampus influences learning and memory, the amygdala influences anger and aggression, and the septum influences anger and fear)
	Thalamus	Primary relay station for sensory information coming into the brain; transmits information to the correct regions of the cerebral cortex through projection fibers that extend from the thalamus to specific regions of the cortex; comprises several nuclei (groups of neurons) that receive specific kinds of sensory information and project that information to specific regions of the cerebral cortex, including four key nuclei for sensory information: (1) from the visual receptors, via optic nerves, to the visual cortex, permitting us to see; (2) from the auditory receptors, via auditory nerves, to the auditory cortex, permitting us to hear; (3) from sensory receptors in the somatic nervous system, to the primary somatosensory cortex, permitting us to sense pressure and pain; and (4) from the cerebellum (in the hindbrain) to the primary motor cortex, permitting us to sense physical balance and equilibrium
	Hypothalamus	Controls the endocrine system; controls the autonomic nervous system, such as internal temperature regulation, appetite and thirst regulation, and other key functions; involved in regulation of behavior related to species survival (in particular, fighting, feeding, fleeing, and mating); plays a role in controlling consciousness (see reticular activating system); involved in emotions, pleasure, pain, and stress reactions
Midbrain	Superior colliculi (on top)	Involved in vision (especially visual reflexes)
	Inferior colliculi (below)	Involved in hearing

Region of the Brain	Major Structures within the Regions	Functions of the Structures
	Reticular activating system (also extends into the hindbrain)	Important in controlling consciousness (sleep arousal), attention, cardiorespiratory function, and movement
	Gray matter, red nucleus, substantia nigra, ventral region	Important in controlling movement
Hindbrain	Cerebellum	Essential to balance, coordination, and muscle tone
	Pons (also contains part of the RAS)	Involved in consciousness (sleep and arousal); bridges neural transmissions from one part of the brain to another; involved with facial nerves
	Medulla oblongata	Serves as juncture at which nerves cross from one side of the body to opposite side of the brain; involved in cardiorespiratory function, digestion, and swallowing

Table (01): Major structures and Functions of the Brain (Sternberg, 2000)

3. Cerebral Cortex and Localization of Function

The cerebral cortex forms the outer layer of the two halves of the brain—**the left** and **right cerebral hemispheres** (Galaburda & Rosen, 2003). Although the two hemispheres appear to be quite similar, they function differently. **The left cerebral hemisphere** is specialized for some kinds of activity whereas **the right cerebral hemisphere** is specialized for other kinds. For example, receptors in the skin on the right side of the body generally send information through the medulla to areas in the left hemisphere in the brain. The receptors on the left side generally transmit information to the right hemisphere. Similarly, the left hemisphere of the brain directs the motor responses on the right side of the body. The right hemisphere directs responses on the left side of the body. **The following figure shows clearly the functional areas of the cortex.**

However, not all information transmission is contralateral—from one side to another (contra-, "opposite"; lateral, "side"). Some ipsilateral transmission—on the same side—occurs as well. For example, odor information from the right nostril goes primarily to the right side of the brain. About half the information from the right eye goes to the right side of the brain, the other half goes to the left side of the brain.

In addition to this general tendency for contralateral specialization, the hemispheres also communicate directly with one another. The corpus callosum is a dense aggregate of neural fibers connecting the two cerebral hemispheres (Witelson, Kigar, & Walter, 2003). It allows transmission of information back and forth. Once information has reached one hemisphere, the corpus callosum transfers it to the other hemisphere.

If the corpus callosum is cut, the two cerebral hemispheres—the two halves of the brain—cannot communicate with each other (Glickstein & Berlucchi, 2008). Although some functioning, like language, is highly lateralized, most functioning—even language—depends in large part on integration of the two hemispheres of the brain. The following figure shows clearly the functional areas of the cortex.

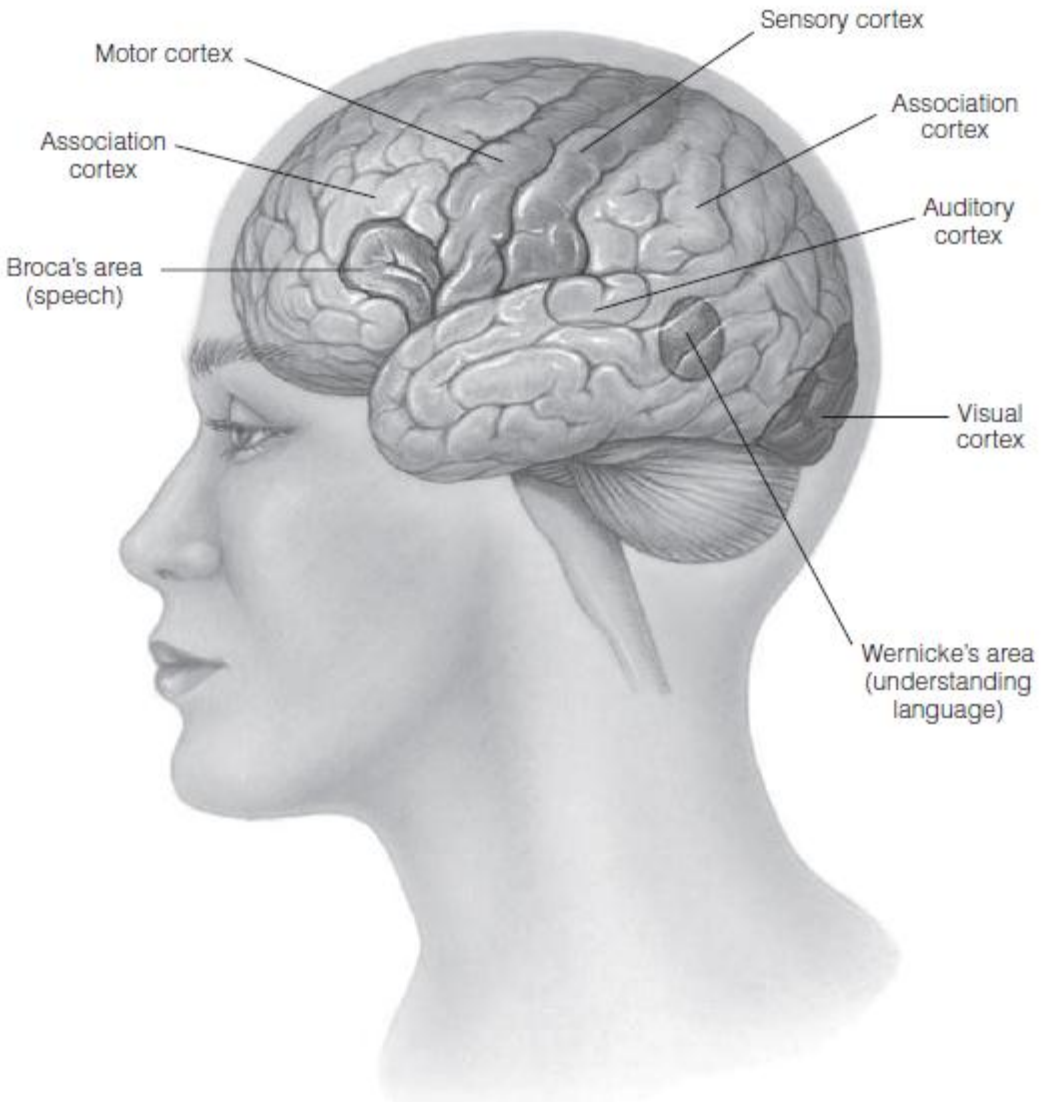

Figure (02): the Functional areas of the Cortex (Sternberg, 2000)

4. Lobes of the Cerebral Hemispheres

For practical purposes, four lobes divide the cerebral hemispheres and cortex into four parts. They are not distinct units. Rather, they are largely arbitrary anatomical regions divided by fissures. Particular functions have been identified with each lobe, but the lobes also interact. The four lobes, named after the bones of the skull lying directly over them are: **the frontal, parietal, temporal,** and **occipital lobes**.

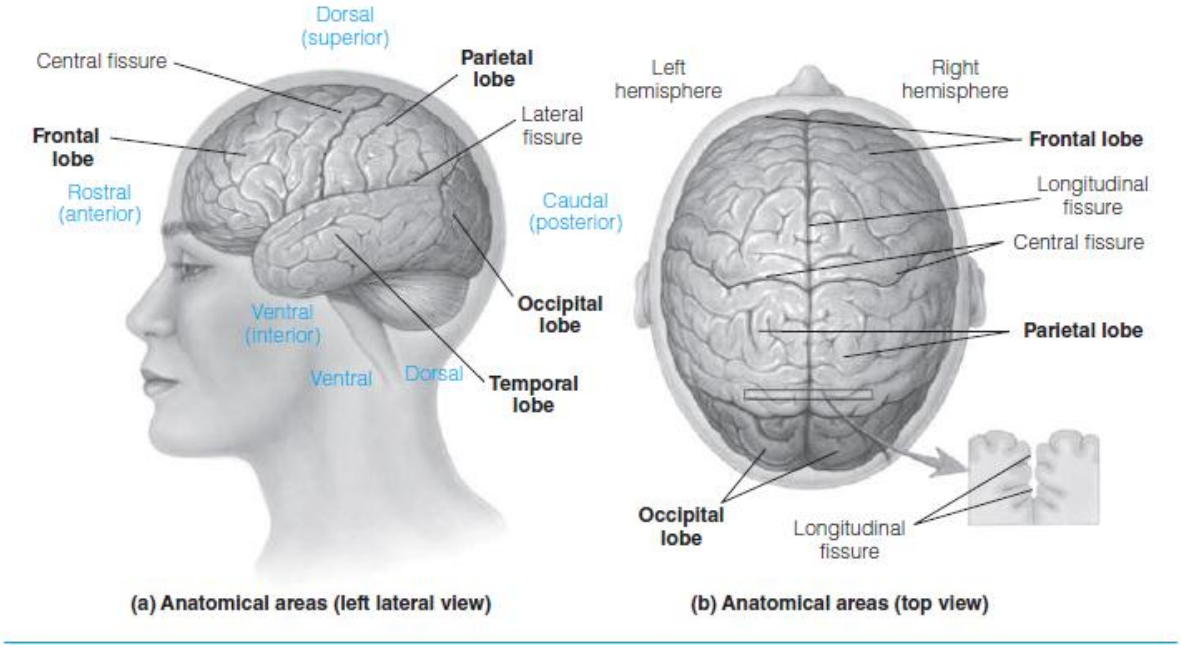

Figure (03): Four Lobes of the Brain (Sternberg, 1998)

4.1. The frontal lobe

It is toward the front of the brain and associated with motor processing and higher thought processes, such as abstract reasoning, problem solving, planning, and judgment (Stuss & Floden, 2003). It tends to be involved when sequences of thoughts or actions are called for. It is critical in producing speech. The prefrontal cortex, the region toward the front of the frontal lobe, is involved in