Alzheimer's Disease and Its Effect on Learning and Memory

By Michelle Xu

Saturday, September 17, 2022

Abstract

The paper investigates the composition of the brain, its functions, and how Alzheimer's Disease affects the structure and function of the brain. The basic foundation of the brain revolves around neurons or nerve cells, which plays an integral role in the interconnectedness of our body systems. However, if damaged by disorders such as Alzheimer's Disease, lasting consequences occur such as memory loss and dysfunction. Further analysis is executed to determine the etymology of this neurologic disorder, including inspection of past case studies executed.

Introduction

The brain is a complex organ that controls thought, memory, emotion, touch, motor skills, vision, and every other process that regulates the body. It contains blood vessels and nerves, including neurons and glial cells, which provide physical and metabolic support to neurons. In the brain, there is gray matter and white matter. Gray matter refers to the darker, outer portion, while white matter describes the lighter, inner section underneath. Gray matter is primarily composed of neuron somas, the round central cell bodies, and white matter is mostly composed of axons, the long stems that connect neurons together; this is all wrapped in myelin, a protective coating. The different composition of neuron parts is why the two appear as separate shades on certain scans. Each of the regions serves a different role: gray matter is primarily responsible for processing and interpreting information, while white matter transmits that information to other parts of the nervous system.

Divisions of the Brain

Moving on from the brain's composition, the three major developmental divisions of the brain are the forebrain, the hindbrain, and the midbrain. The forebrain is by far the largest region, which contains the entire cerebrum and several structures directly within it such as the thalamus, hypothalamus, the pineal gland, and the limbic system. It plays a central role in the processing of information related to complex cognitive activities, sensory and associative functions, and voluntary motor activities. The

hindbrain is located at the lower back part of the brain. It includes most of the brainstem, the cerebellum, the pons, and the medulla oblongata. The brainstem is one of the most important parts of the entire central nervous system, because it connects the brain to the spinal cord and coordinates many vital functions fundamental to survival, such as breathing, motor activity, sleep, wakefulness, and heartbeat. Lastly, located towards the base of your brain is a small but important region called the midbrain, which serves as a vital connection point between the forebrain and the hindbrain or the brain and the spinal cord. It serves important functions in motor movement, particularly movements of the eye, and in auditory and visual processing.

Lobes of the Brain

The cerebral cortex, the outermost layer of the brain, is divided lengthwise into two cerebral hemispheres connected by the corpus callosum. Each of the hemispheres are divided into four lobes: frontal, parietal, parietal, temporal, and occipital. The frontal lobe's higher executive functions include emotional regulation, planning, reasoning, and problem solving. Speech and language production is controlled by the Frontal Lobe's Broca's area and damage to this area can lead to difficulty with fluent speech. The frontal lobe also contains the primary motor cortex, the prime region responsible for voluntary movement. The parietal lobe is responsible for sensory information, including touch, temperature, pressure, and pain. These are the somatic senses, meaning that they come from all over the body. The parietal lobe also plays a role in a person's ability to judge size, shape, and distance. It helps with the interpretation of symbols, which includes those in written and spoken language, mathematical problems, codes and puzzles. The occipital lobe is the visual processing centre in the brain. It contains the primary visual cortex which receives visual information from the eyes. This information is relayed to several secondary visual processing areas, which interpret depth, distance, and the location of seen objects. Last is the temporal lobe which is responsible for hearing, recognising language, and forming memories. Here lies the Wernicke area which contains motor neurons involved in the comprehension of speech. Certain areas in the temporal lobe also make sense of complex visual information including faces

and scenes. Lastly, The medial temporal lobe (area closer to the middle of the brain) contains the hippocampus.

Communication with the Brain

The brain sends and receives chemical and electrical signals throughout the body. Different signals control different processes, and your brain interprets each. Some messages are kept within the brain, while others are relayed through the spine and across the body's vast network of nerves to distant extremities. To do this, the central nervous system relies on billions of neurons or nerve cells. The central nervous system—the brain and spinal cord—is made up of two basic types of cells: neurons and glia. Glia outnumber neurons in some parts of the brain, but neurons are the key components in the brain. Neurons are information messengers. They use electrical impulses and chemical signals to transmit information between different areas of the brain, and between the brain and the rest of the nervous system. Everything we think and feel and do would be impossible without the work of neurons and their support cells. Neurons have three basic parts: a cell body, or soma, and two extensions called an axon and a dendrite. Within the cell body is a nucleus, which controls the cell's activities and contains the cell's genetic material. The axon transmits messages from the cell, and the dendrites receive messages for the cell; this communication can't go both ways. Neurons communicate with each other by sending chemicals, called neurotransmitters—serotonin, norepinephrine, and acetylcholine—across a space called a synapse. Lastly, there is the myelin which is an insulating layer around the nerves. The myelin sheath allows electrical impulses to transmit quickly and efficiently along the nerve cells. If the myelin sheath is damaged, nerve impulses slow or even stop, causing neurological problems or demyelinating diseases.

Communication Process

Neurons have a negative concentration gradient most of the time, meaning there are more positively charged ions outside than inside the cell. This regular state of a negative concentration gradient is called resting membrane potential. However, if the absolute threshold, the minimum amount of

stimulus that receptors can actually detect, is exceeded, the neuron is triggered and an impulse gets sent along its axon—this is called an action potential. A portion of the axon nearest the cell body then depolarizes, which means that the cell undergoes a shift in electric charge distribution, resulting in less negative charge inside the cell compared to the outside. This change triggers depolarization in the section of the axon next to it, and so on, until the rise and fall in charge has passed along the entire length of the axon. After each section has fired, it enters a brief state of hyperpolarization, which increases the stimulus required to move the membrane potential to the action potential threshold, meaning it is less likely to be triggered again immediately. Most often, it is potassium (K+) and sodium (Na+) ions that generate the action potential. Ions move in and out of the axons through voltage-gated ion channels and pumps which is illustrated in the image below. The sodium-potassium pump sets the membrane potential of the neuron by keeping the concentrations of Na+ and K+ at constant disequilibrium. Once a signal reaches a synapse, it triggers the release of chemicals neurotransmitters into the gap between the two neurons; this gap is called the synaptic cleft. The neurotransmitter diffuses across the synaptic cleft and interacts with receptors on the membrane of the postsynaptic neuron which is the neuron that receives the information, triggering a response and making the postsynaptic neuron either more or less likely to fire its own action potential.

The Hippocampus

The hippocampus is an extension of the temporal part of the cerebral cortex. It can be distinguished externally as a layer of densely packed neurons, which curls into a S-shaped structure. The hippocampus plays a vital role in regulating learning, memory encoding, memory consolidation, and spatial navigation. The anatomy of the hippocampus is extremely important to its function. The hippocampus receives input from and sends output to the rest of the brain via a structure known as the entorhinal cortex, which is located beneath the anterior region of the hippocampus. The hippocampal formation itself is composed of several subregions, which include the cornu ammonis (CA1–4), the dentate gyrus, and the subiculum. In particular, the dentate Gyrus is a deep region within the

hippocampus and is surrounded by cornu ammonis (CAs). This plays a crucial role as a processor of information from Entorhinal cortex to CA3. It has been shown to play an important role in pattern separation, learning, and memory. The anterior hippocampus is preferentially connected to the amygdala and orbitofrontal cortex which sits just above the eye sockets and is thought to be involved mainly in the regulation of emotion and stress. The posterior hippocampus is connected to the retrosplenial and posterior parietal cortices which control navigation and spatial attention and eye movements and is thought to be involved mainly in cognitive and spatial processing.

Learning and Memory

Memories aren't stored in just one part of the brain. Different types are stored across different, interconnected brain regions. Implicit memories, such as motor memories, rely on the basal ganglia and cerebellum. For explicit or declarative memories—which are episodic, as well as semantic—there are three important areas of the brain: the hippocampus, the neocortex and the amygdala. Specifically, the formation of new episodic memories requires the medial temporal lobe, a structure that includes the hippocampus. Without the medial temporal lobe, one is able to form new procedural memories but cannot remember the events during which they happened. Another reason why the hippocampus is so important to learning and memory is that short-term memories, which are memories that are brief—about 30 seconds—are converted into long-term memories in this structure with constant rehearsal and retrieval. These memories are then stored elsewhere in the brain.

Damage and Injury

If a part of the hippocampus is damaged, the person can experience a loss of memory and a loss of the ability to make new, long-term memories. They may be unable to remember some things that happened shortly before the damage, but they may still remember things that happened long ago. This is because the long-term memories are stored in another part of the brain once they become long-term.

Patient H.M.

An example of what can happen to the loss of a working hippocampus is Henry Molaison, known widely as Patient H.M. He was an American who had a bilateral medial temporal lobectomy. His hippocampus and amygdala were removed in an attempt to cure his epileptic seizures, which were believed to be caused by a bicycle accident that occurred in his childhood. And although the surgery was successful in controlling his epilepsy, a severe side effect was that he became unable to form new memories. He could remember some things such as scenes from his childhood and historical events that occurred before his surgery but he was unable to form new memories. For example, if he met someone who then left the room, within minutes he had no recollection of the person or their meeting. In short, H.M had lost his explicit memory, but his unconscious implicit memory remained intact. Given the damage to his hippocampus in surgery, researchers concluded from tasks such as these that the hippocampus must play a role in declarative but not procedural memory.

Alzheimer's Disease

Alzheimer's disease is a brain disorder that slowly destroys memory and thinking skills and, eventually, the ability to carry out the simplest tasks. Those with the late-onset type symptoms first appear in their mid-60s. Early-onset Alzheimer's occurs between a person's 30s and mid-60s and is very rare. The brain typically shrinks to some degree in healthy aging but does not lose neurons in large numbers. In Alzheimer's disease, however, damage is widespread as many neurons stop functioning, lose connections with other neurons, and die. At first, Alzheimer's disease typically destroys neurons and their connections in parts of the brain involved in memory, including the entorhinal cortex and hippocampus. It later affects areas in the cerebral cortex responsible for language, reasoning, and social behavior. Eventually, many other areas of the brain are damaged. Many molecular and cellular changes take place in the brain of a person with Alzheimer's disease, including amyloid plaques and neurofibrillary tangles. The beta-amyloid protein involved in Alzheimer's comes in several different molecular forms that collect between neurons. It is formed from the breakdown of a larger protein, called amyloid precursor protein.

One form, beta-amyloid 42, is thought to be especially toxic. In the Alzheimer's brain, abnormal levels of this protein clump together to form plaques that collect between neurons and disrupt cell function. The amyloid plaques first develop in the areas of the brain concerned with memory and other cognitive functions. Neurofibrillary tangles are abnormal accumulations of a protein called tau that collect inside neurons. Healthy neurons, in part, are supported internally by structures called microtubules, which help guide nutrients and molecules from the cell body to the axon and dendrites. In healthy neurons, tau normally binds to and stabilizes microtubules. In Alzheimer's disease, however, abnormal chemical changes cause tau to detach from microtubules and stick to other tau molecules, forming threads that eventually join to form tangles inside neurons. These tangles block the neuron's transport system, which harms the synaptic communication between neurons.

References

Brain Anatomy and How the Brain Works. (n.d.). Johns Hopkins Medicine. Retrieved September 17, 2022, from https://www.hopkinsmedicine.org/health/conditions-and-diseases/anatomy-of-the-brain

Brain Basics: The Life and Death of a Neuron | National Institute of Neurological Disorders and Stroke. (2022, September 27). National Institute of Neurological Disorders and Stroke. Retrieved September 17, 2022, from https://www.ninds.nih.gov/health-information/patient-caregiver-education/brain-basics-life-and-death-neuron

forebrain | Definition, Function, Structures, Diagram, & Facts. (n.d.). Encyclopedia Britannica. Retrieved September 17, 2022, from https://www.britannica.com/science/forebrain

Hammond, N. (2020, May 26). *Parietal lobe: Definition, function, diagrams, and linked conditions*. Medical News Today. Retrieved September 17, 2022, from https://www.medicalnewstoday.com/articles/parietal-lobe#function

Hammond, N., Kelly, S., & Railton, D. (n.d.). *Hippocampus: Function, size, and problems*. Medical News Today. Retrieved September 17, 2022, from https://www.medicalnewstoday.com/articles/313295#current-research

The hindbrain - Queensland Brain Institute - University of Queensland. (n.d.). Queensland Brain Institute. Retrieved September 17, 2022, from https://qbi.uq.edu.au/brain/brain-anatomy/hindbrain

Hippocampus in health and disease: An overview. (n.d.). NCBI. Retrieved September 17, 2022, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3548359/

Lobes of the brain - Queensland Brain Institute - University of Queensland. (n.d.). Queensland Brain Institute. Retrieved September 17, 2022, from https://qbi.uq.edu.au/brain/brain-anatomy/lobes-brain

Squire, L. R. (n.d.). *The Legacy of Patient H.M. for Neuroscience*. NCBI. Retrieved September 17, 2022, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2649674/

What Happens to the Brain in Alzheimer's Disease? (2022, October 27). National Institute on Aging. Retrieved September 17, 2022, from https://www.nia.nih.gov/health/what-happens-brain-alzheimers-disease