ISSN ----------
Open Access
Volume 01, Issue 01 - 2024

International Journal of Case Reports and Case Research

Review Article

DOI: http://doi.org/06.2024/IJCRCR/003.

Forgetting mechanism: Neurogenesis as a neurobiological explanation

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Article Info

Received Date: 21 June 2024, Accepted Date: 29 June 2024, Published Date: 02 July 2024

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Citation: Abdulwahab F. Alahmari (2024). "Forgetting mechanism: Neurogenesis as a neurobiological explanation". International Journal of Case Reports and Case Research, 1(1); DOI: http://doi.org/06.2024/IJCRCR/003.

In the Arabic language, a human called (إنسان) pronounced "Ensaan" which means the creature who forgets. This word comes from the verb (نسي) pronounced "Naseaa" which means forgetting. Humans are forgetting creatures by nature for a reason. This paper will highlight the forgetting mechanism and the memory capacity of the human brain.

There are three stages in memory as highlighted below;

Encoding → Storage → Retrieval

Any issue in the encoding stage called "poor attention", any issue in the storage stage called "forgetting", and any issue in the retrieval called "availability or accessibility".

Forgetting in the memory was explained in two ways; fading away or decay of memories, but there is no biological mechanism were used to explain how these memories, get forgotten. The only biological explanation is the documented change that occurs in the hippocampus knew as neurogenesis. Neurogenesis occurs in different parts of the brain, but mainly in the hippocampus.

Hippocampus has the dentate gyrus which generates neurons in mammals, not only humans. This dentate gyrus has a granule cell layer which generates these newborn neurons. The hippocampus is made by many layers folded on each other (i.e. dentate gyrus, cornu ammonis called "CA 1, 2, and 3", subiculum, and entorinal cortex). Also, furthermore, the dentate gyrus has three layers: 1) sub granular zone (i.e. other call it "the hilus or polymorphic layer); 2) granular layer (i.e. with two limbs internal and external); and 3) molecular layer. The new neurons are generated in the granular layer then the neurons axon will extend to the hilus, and their dendrites will reach to the molecular layer. It takes 2 months for a newborn neuron to become an adult neuron. Sometimes these cells die with apoptosis in order to control the number of generated cells.

When a proper stimulus has been received the granular neurons will divide then break off and the new cell will migrate on the dentate gyrus and branch out to the CA3. The new neuron sends signals to other neurons in order to receive signals from them. it is suggested that these new neurons improve human's memory, but that is wrong for many reasons.

When these neurons get destroyed in the process known as neurogenesis, the memories get destroyed as well. The new formed neurons generated without any memories (i.e. clean). With time passing, older neurons get destroyed and a brand-new neuron get formed to take their places. This mechanism of forgetting is an adaptation mechanism to allow humans to let go of bad old memories and get back again to live their lives. The idea of neurogenesis is part of the forgetting mechanism is easy to prove. When patient of Alzheimer's disease has a damage in the hippocampus then the hippocampus get shrinkage, they forget which indicates that these neurons in the hippocampus contains the human memory and when they get damaged the memories get lost. Similarly, in neurogenesis the old painful memories in the hippocampus get deleted with time passing in order to allow the human to function properly. Some claim when two similar memories get mixed up is another mechanism of forgetting or a group of people incorrectly remember the same memory which both are correct, but both are external reasons. But the biological reasons will be internal only.

Donald Thompson argues against eyewitness testimony to incriminates individuals and he present a model;

Leading Question → Source Amnesia → Misinformation Effect

Donald Thompson was a victim of eyewitness testimony when he was brought by the police -for no reason- then he was in line with criminals and a woman picked him. The woman accused him of rape, but Thompson had a good

alibi to be on a TV show speaking about the weakness of eyewitness testimony in the same time that woman was raped and there was a TV showing the show where Thompson was speaking about a relevant topic "eyewitness testimony in crimes". This story is ironic, but it shows how forgetting mechanism can be seen in certain conditions.

Dan Schacter describe the memory's malfunctions as "the seven sins" which are: 1) absent-mindedness; 2) transience; 3) blocking; 4) misattributing; 5) suggestibility; 6) bias; and 7) persistence.

Calcium waves in the brain start when remembering let say a phone number. Neural signal when repeating the number to memorize it, stimulate astrocyte calcium waves which increase the frequency due repetition of the earlier neural firing (Koob, 2009).

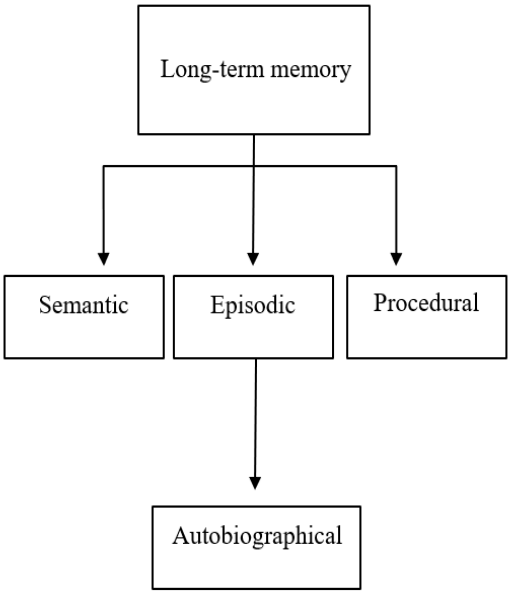

Diagram 1. *Tulving's model of long-term memory.*

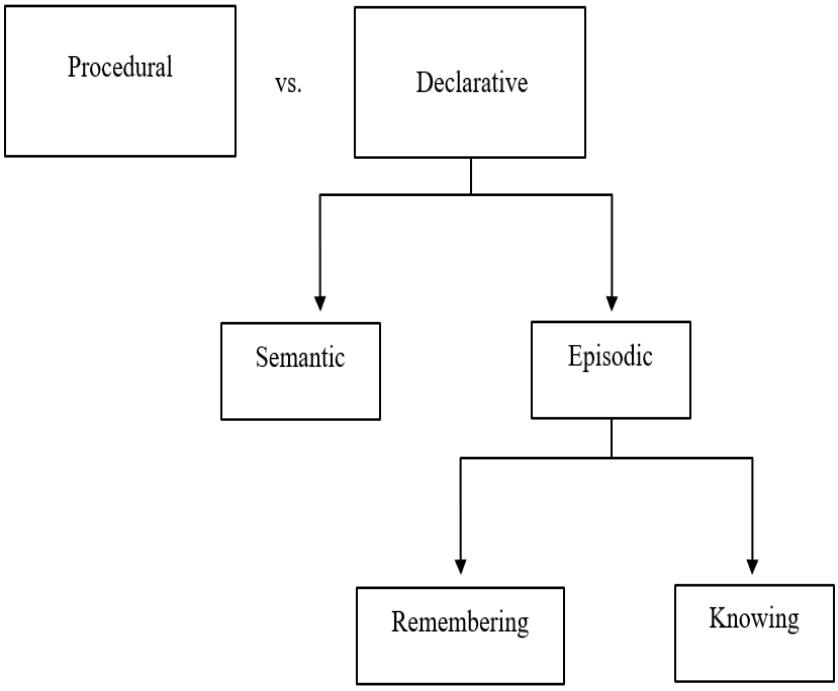

Diagram 2. *Squire's model of the explicit memory.*

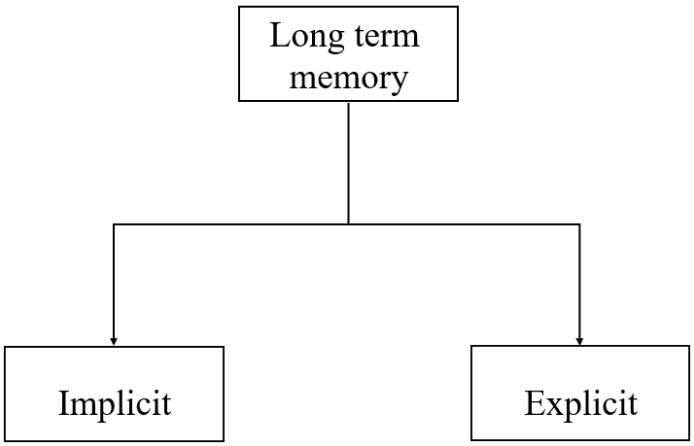

Diagram 3. Warrington and Weiskrantz (1974) who described the implicit memory and Endel Tulving (1972) who described the explicit memory. Both described parts of the long-term memory.

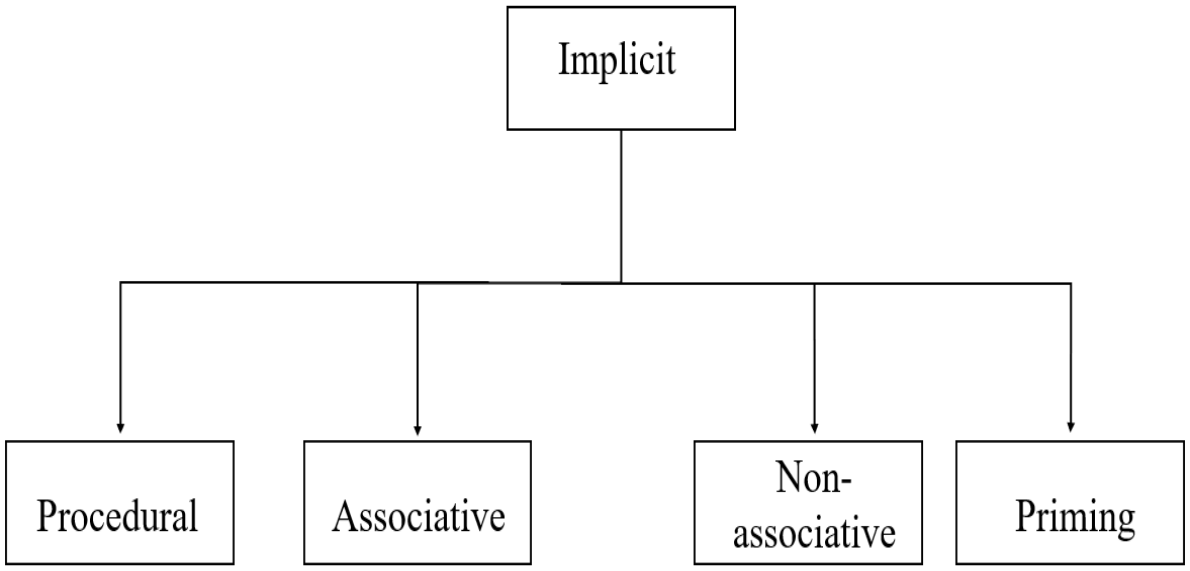

Diagram 4. Warrington and Weiskrantz (1974) who described the implicit memory.

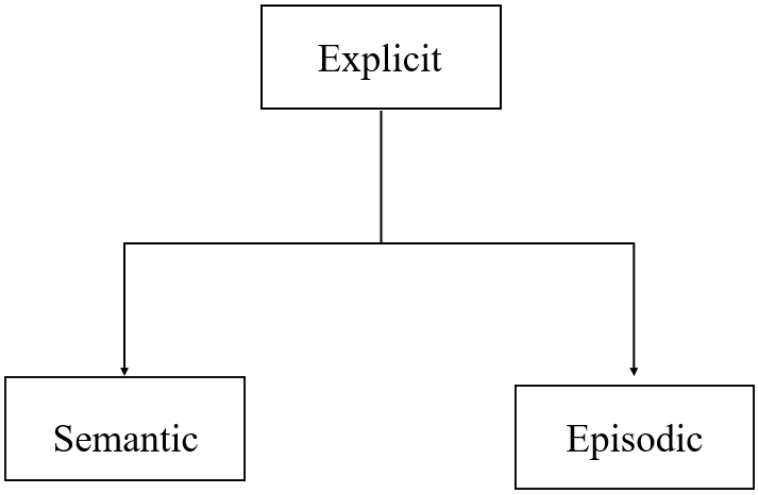

Diagram 5. Endel Tulving (1972) who described the explicit memory.

The prefrontal cortex, the hippocampus, the cerebellum, and the amygdala are the primary brain regions involved in memory. Declarative, episodic, and recognition memory are all linked to the hippocampus. The amygdala plays a role in fear and memories of terror. Processing procedural memories is mediated by the cerebellum. It indicates that remembering semantic activities involves the prefrontal cortex.

Miller law in 1950s which indicates that the short-term memory is typically composed of 7 ± 2 items. The location of brain damage will reflect on which type of amnesia the patient will have whither anterograde vs. retrograde amnesia (Foster, 2008). Functional imaging is used to evaluate guilt or innocence of a potential convict. This is done by examining the ability of remembering that event which means the human personal memory privacy is at danger (Alahmari, 2021; Foster, 2008). Micro-disorientation in memory happens when someone forget their dreams which is common which a mechanism by the brain to allow the brain to focus on the reality (Fosse, 2001).

Infantile amnesia happens when young children do not remember previous life before 4 years of age which explained by the biological process as the maturity of hippocampus in 3-5 years of age (Goldman-Rakic, 1987). Even though, (Foster, 2008) claim it could be due to the shift in state of dependence, biological processes, or all of them together.

Mathematical Analyses

There is no equivalent between brain's memory capacity and computer's memory capacity, so the scientists came with an idea that 1 bit = 1 synapse which is questionable. The brain has 250 trillion synapses which means 250 trillion bits. This means the brain capacity is 31.25 terabytes.

In neuroscience there is a concept of "distributed representation" which means no single neuron have a memory for information, but neurons have information coded inside it as in the DNA. Why storing of information in a single neuron is not possible? Let's say the distributed representation is true, how this distributed representation will give explanation of the forgetting mechanism? It does not give any answer and it will never be able to do it. The distributed representation could explain the foggy memory when the neuron that have information dies some parts of it's information might still in the surrounding neurons which will give a foggy memory about a certain event.

But in other papers, they found that some cells called "place cells" when a rat run in maze, different cells fire to different part of the maze. This proves that memory of different places are stored in different cells which indicates that each neuron have memories of it's own.

In one study, a mean of calculation of the numbers of neurons in 10 normal hippocampi show the average normal hippocampus contains 45.5×10^5 neurons which means 48,500,000 (Šimić et al., 1997). The human brain contains two hippocampi which means $(45.5 \times 10^5) \times 2 = 97{,}000{,}000$ is the average number of neurons in normal adults. The average volume of a normal hippocampus is 3.267 cm^3 in one study, while another study reports 3.244 cm^3 (Šimić et al., 1997; Mondragón et al., 2017). The average of these two studies is 3.2555 cm^3. The brain memory capacity in normal adult human for information. One neuron can store only 1 bit. The human memory capacity is 2.5 petabytes (Reber, 2024). By following the previous numbers, the following calculation can be done.

In order to know how many neurons in 1 mm^3 of the hippocampal formation tissue the volume change from cm to mm which is 3255.5 mm^3. Then the number 48,500,000 of neurons is divided on 3255.5 mm^3. The result will be 14,897.86 neurons in one mm^3. Then these neurons each one will have one bit which means 1862.2325 bytes. If 1 mm^3 get damaged or shrink of the hippocampus then 1862.2325 bytes of information will be lost. The two hippocampi will have the capacity of 1,2125,000 bytes which is 0.012125 gigabytes. By this simple calculation, which show the hippocampi are not the only memory areas in the brain.

If we convert the 2.5 petabytes to bytes it will be 2,814,749,767,106,560 bytes then we divide this number on the number neurons in both hippocampi it will show that the memory capacity is 29,018,038.83 bytes per neuron which is 29.01 megabytes which is a small part of CD (i.e. 6.7%). Since one Compact Disc (CD) is 700 megabytes. This shows that this is does not seem logical calculations for being too high.

The total number of neurons in the brain is 86 billion neurons (Herculano-Houzel, 2009). If we divide the memory capacities in bits (232144310.64) on the whole number of neurons in the brain 86 billion neurons then each neuron will have the memory capacity of 0.00269935244 bits (i.e. less than one bit). This calculation does not seem right for being too low.

If we calculate the total numbers neurons in the 4 locations in the brain that are responsible for memory which are prefrontal cortex, the hippocampus, the cerebellum, and the amygdala. The total number of neurons the prefrontal cortex is 1,280,000,000 neurons (Gabi, 2016). The total number neurons in the cerebellum is 69,000,000,000 (Herculano-Houzel, 2009). The total number of neurons in two hippocampi is 97,000,000 neurons (Šimić et al., 1997). The total number of neurons in one amygdala is 12.75 million then the number is multiple by 2 for having two amygdala in the brain that make 25,500,000 neurons. The total number of neurons is 70,402,500,000 cells. If we divide 2,814,749,767,106,560 bytes by total number of neurons in the 4 for mentioned area (i.e. 70,402,500,000) will equal 39,980.82 bytes per cell. This means one neuron will have the capacity of 39.98 kilobytes. The capacity of one neuron is near half of the first floppy disc ever invented which has size of 80 kilobytes.

In the human's memory, when a cell dies that is losing a small part of the bit of information. When there is a bigger loss of neurons, then bits combine to form a byte (1 byte consists of 8 bits). Then memory get lost.

There is a hypothesis called "the frontal lobe hypothesis" (West, 1996). This hypothesis suggests that the

degeneration of the frontal lobe cause age related memory loss (Foster, 2008), which indicates that there are other storage areas of memories outside the hippocampi. The frontal lobe matures late around 20 years of age and the frontal lobe deteriorate early in adults which result in affecting the strategic and organizational aspect of memory. Decline in brain capacity has a hallmark as frontal lobe atrophy which results in Mild Cognitive Impairment (MCI). It has been postulated that MCI could be specific amnestic MCI or multiple cognitive domain MCI.

According to Koob (2009), the cortical memory is abolished by blocking the glutamate reuptake. Yet researchers were not able to know how the cortex contains information (Koob, 2009).

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