Memory: Neurobiological mechanisms and assessment

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Received: 11 April 2021
Revised: 29 May 2021
Accepted: 22 July 2021
Published: 22 October 2021

ABSTRACT

Memory is the process of retaining of knowledge over a period for the function of affecting future actions. It can be divided into declarative and procedural types. The process of memory consolidation is done in the hippocampus. The long-term memories are spread among various areas of the cerebrum depending on the different perceptual properties. The process of long-term potentiation and molecular changes occurring during memory formation are discussed in detail below. The steps involved in memory formation include encoding, storage, and recall (retrieval) in that order. Amnesia is a phenomenon in which there is the problem in memory formation which can be due to trauma to the brain, certain diseases, or stressors. While the assessment of memory has greatly improved, we are only beginning to understand the underlying mechanisms.

Keywords: Amnesia, declarative/explicit memory, encoding, long-term potentiation, memory, neural plasticity, procedural/implicit memories, recall, retrieval, storage

Memory is the process of retaining of knowledge over a period for the function of affecting future actions. From a historical standpoint, the area of memory research from 1870 to 1920 was focused mainly on human memory. The book: The Principles of Psychology written by famous psychologist William James suggested that there is a difference between memory and habit. The case of Henry Molaison was first described as a result of research of two main researchers, namely William Beecher Scoville and Brenda Milner. The findings have contributed a lot to our understanding of memory. Since then, a lot of research has been done in the field of memory and led to many advancements. The Nobel Prize in Physiology or Medicine in the year 2000 was given to Eric Richard Kandel for his contribution in understanding the physiological basis of memory storage in neurons. The prize was shared with Arvid Carlsson and Paul Greengard.

CLASSIFICATION OF MEMORY

Memory was classified into two types-declarative (explicit) and procedural (implicit) memories by Anderson. Explicit memory can be defined as the information regarding places, things, people, and events, etc., It can be recollected by conscious effort. It is stored in the medial part of the brain.
temporal lobe of the cerebrum and hippocampus. It may be subdivided into episodic memory which is also called autobiographic memory and semantic memory. Episodic memory recalls personal events and experiences. Whereas semantic memory recalls facts which can be general or autobiographical. Since Implicit memory is recollected unconsciously it is called nondeclarative. It is stored in various regions of the brain like the cerebellum, the neocortex, the striatum, the amygdala, etc.

**NEUROBIOLOGY**

Research suggests that the hippocampus plays an important role in memory consolidation. It was proved by experiments, wherein lesions were applied to rat hippocampi at various times after learning. Looking from the molecular and cellular point of view two proteins involved are calcium calmodulin-dependent protein kinase II (CaMKII) and protein phosphatase 1 (PP1). During the formation of memory, there is Ca2+ influx after which CaMKII goes through autophosphorylation process which changes it into an activated kinase. Since PP1 has an inhibitory effect on memory it returns the CaMKII to its resting state. This opposite relationship involving CaMKII and PP1 characterizes a push-pull system actually has an important part in memory formation. Hence, a balance maintained between remembering and forgetting the memories which are stored. Consolidation of short-term memories however requires a functional change after which gene transcription and protein synthesis should occur.

During any learning process, persistent stimulation causes sustained activation of two pathways namely the protein kinase A (PKA) and MAP kinase Erk (MAPK) pathways. PKA causes phosphorylation as well as the activation of CREB1a which is a transcriptional activator, whereas MAPK causes phosphorylation and inactivation of CREB2, a transcriptional repressor.

The most unique characteristic of our brain is the facility to acclimatize to the ever-changing surroundings and to increase its functioning by learning through experience. Learning and memory formation involves a remarkably interesting phenomena of neuroplasticity. During learning there occurs a structural change at the synapse which includes a change in the power of old synapses and changes in the quantity of synaptic connections in particular pathways. Synaptic associations that are less used become weaker over a period and ultimately perish. The ones which are used a lot become stronger with each use and in due course boost in number. Studies suggest that long-term memory (LTM) storage may be preserved by DNA methylation or prions.

**MULTI-STORE MODEL OF MEMORY**

Richard Atkinson and Richard Shiffrin put forth a model of memory which is known as “The multi-store model or modal model.” It states that memory consists of three distinct elements: “a sensory register, a short-term store, and a long-term store.” The data from the environment and our senses goes into the memory via the sensory register. The short-term store, otherwise known as working memory or short-term memory (STM), receives and holds input from both the sensory register and the long-term store. Finally, if the information is rehearsed in the short-term store then it goes in the long-term store, wherein it is held indefinitely. Memory consists of the following steps-encoding, storage, and recall (retrieval). Encoding is the process of altering the material reaching our nervous system into a mode that the system can manage so that it can be easily stored. There are various methods through which knowledge can be encoded is via visual, acoustic, semantic coding. The STM is encoded mainly via acoustic coding. The LTM however usually involves semantic coding. Nonetheless, data in LTM can also be encoded both via visual and acoustic coding. When it comes to acquiring data out of storage, the process of retrieval comes into the picture. Unable to remember information can be due to the inability to retrieve that piece of information. Retrieval helps us understand the dissimilarities among STM and LTM. STM is stored and retrieved chronologically. The storage and retrieved of LTM on the other hand occur via association. Thus, the organization of information can facilitate the process of retrieval.

Sensory memory consists of three types. The first is the iconic memory. It is a quickly declining storage of visual data. It stores an image for a small duration which has been perceived by the person briefly. The second is the echoic memory. It is described as storage of sounds for short durations that have been heard briefly. Moreover, haptic memory characterizes a database for touch stimuli.

**WORKING MEMORY MODEL**

The “working memory model” was put forward by Baddeley and Hitch. According to them, working memory comprises the following: “the central executive, the phonological loop, and the visuospatial sketchpad” along with a multimodal episodic buffer.

Working memory and STM are often used interchangeably. In his paper, “the magical number 7 ± 2,” George A. Miller proved that the store of STM was 7 ± 2 items. However, contemporary approximations of the capability of STM
FORGETTING

Forgetting was classified under various types by Paul Connerton: They are-prescriptive forgetting, planned obsolescence, formation of the new identity, repressive erasure, structural amnesia, annulment, and humiliated silence.[10]

Retroactive interference can be defined as the phenomenon when new information or memories disturb the old information. Whereas proactive interference happens when old information disturbs the retrieval of new memories.[17] Trace decay elucidates memories that are stored in STM and LTM with the assumption that memories leave a trace in the central nervous system. Herman Ebbinghaus in 1913 proposed a forgetting curve. It theorizes the deterioration of memory retention over a period. It represents a curve showing how memory is lost over a period if there is no effort to preserve it.

AMNESIA

Amnesia is a phenomenon in which there is the problem in memory formation which can be due to trauma to the brain, certain diseases, or stressors.[18] It can be subdivided into retrograde amnesia and anterograde amnesia.

Retrograde amnesia is the lack of ability to recover information that was attained before a specific time, typically before an accident or surgery.[19] Anterograde amnesia is the lack of ability to allocate new information from the short-term to the long-term store. It is observed that suffering from extended periods of amnesia after a trauma can be a prognostic indicator and that the improvement from the symptoms of concussion may take more than usual.[20]

ASSESSMENT

A scale consisting of 30 questions which is employed to gauge impairment inmemory is the Mini-Mental State Examination.[21] Another scale employed for detecting mild and early memory problems is the Montreal Cognitive Assessment.[22] Also utilized to detect memory issues is Addenbrooke’s Cognitive Examination.[23] A scale consisting of 50 questions is the test of memory malingering. It is a visual memory recollection test that differentiates between true memory impairment and malingering. It has two learning trials and a retention trial after a delay which is optional.[24] The Wechsler Memory Scale segregates clinical categories. It can differentiate between the various clinical categories.[25]

CONCLUSION

Advances in knowledge have resulted in the realization that memory is a very complex system. While the assessment of memory has greatly improved, we are only beginning to understand the underlying mechanisms.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

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