Long Term Memory

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Long-term memory (LTM) is memory in which associations among items are stored, as part of the theory of a dual-store memory model. According to the theory, long term memory differs structurally and functionally from working memory or short-term memory, which ostensibly stores items for only around 20-30 seconds and can be recalled easily. This differs from the theory of the single-store retrieved context model that has no differentiation between short-term and long-term memory.

Dual-store Memory Model

According to Miller (1956), whose paper popularized the theory of the "magic number seven," short-term memory is limited to a certain number of chunks of information, while long-term memory has a limitless store.

According to the dual-store memory model set forth by Atkinson and Shiffrin (1968), memories can reside in the short-term "buffer" for a limited time while they are simultaneously strengthening their associations in long-term memory. When items are first presented, they enter short-term memory, but because it has limited space, as new items enter, old ones leave. However, each time an item is rehearsed while it is in short-term memory, it is also increasing its strength in long-term memory. The longer an item stays in short-term memory, the stronger the association becomes in long-term memory. In long-term store, items are recalled through retrieval cues in a two-step process. First, context is used as a cue to probabilistically select an item to be potentially recalled. Second, that item is probabilistically determined to be recalled or not.

Baddeley and Hitch (1974) proposed an alternative theory to the Atkinson-Shiffrin memory model. According to this theory, short-term memory is divided into different slave systems for different types of input items, and that there is an executive control supervising what items enter and exit those systems. The slave systems include the phonological loop, the visuo-spatial sketchpad, and later Baddeley added the episodic buffer.

Biologically, short-term memory is a temporary potentiation of neural connections that can become long-term memory through the process of rehearsal and meaningful association. Not much is known about the underlying biological mechanisms of long-term memory, but the process of long-term potentiation, which involves a physical change in the structure of neurons, has been proposed as the mechanism by which short-term memories move into long-term storage. The time scale involved at each level of memory processing remains under investigation.

As long-term memory is subject to fading in the natural forgetting process, several recalls/retrievals of memory may be needed for long-term memories to last for years, dependent also on the depth of processing. Individual retrievals can take place in increasing intervals in accordance with the principle of spaced repetition. This can happen quite naturally through reflection or deliberate recall (also known as recapitulation), often dependent on the perceived importance of the material.

Problems with the Dual-store Memory Model

There are several problems with the dual-store memory model. First, an experiment by R. A. Bjork and Whitten (1974) showed that even with a distractor task after the presentation of a list of items, there was still a recency effect. However, if a short-term memory exists, the distraction would replace the items and remove the recency effect. Second, a study by Howard and Kahana (1999) revealed that continual distracters placed intermittently between each list items still resulted in a contiguity effect. However, the existence of short-term memory should destroy the effect because nearby items do not spend time together in short-term memory if there are distracters between them. Third, a study by Craik and Lockhart (1972) revealed that how long an item spends in short-term memory is not the key determinant in its strength in long-term memory. Instead, whether the participant actively tries to remember the item while elaborating on its meaning determines the strength of its store in long-term memory.

Single-store Memory Model

An alternative theory is that there is only one memory store with associations among items and their contexts. According to Howard and Kahana (2002), the context serves as a cue for retrieval. In this model, the recency effect is greatly caused by the factor of context. Immediate and delayed free-recall will have the same recency effect because the relative similarity of the contexts still exist. Also, the contiguity effect still occurs because contiguity also exists between similar contexts.

Encoding of information

Long term memory encodes information semantically for storage, as researched by Baddeley.

Sleep

Some theories consider sleep to be an important factor in establishing well-organized long-term memories. According to Tarnow's theory, long term memories are stored in dream format (reminiscent of the Penfield & Rasmussen's findings that electrical excitations of cortex give rise to experiences similar to dreams). During waking life an executive function interprets long term memory consistent with reality checking (Tarnow 2003).

Types of memory

The brain does not store memories in one unified structure, as might be seen in a computer's hard disk drive. Instead, different types of memory are stored in different regions of the brain. LTM is typically divided up into two major headings: declarative memory and implicit memory (or procedural memory). Computer programs store information similarly with a separate data section and code section.

Explicit memory/Declarative memory refers to all memories that are consciously available. These are encoded by the hippocampus, entorhinal cortex, and perirhinal cortex, but consolidated and stored elsewhere. The precise location of storage is unknown, but the temporal cortex has been proposed as a likely candidate.

Declarative memory also has two major subdivisions:

Episodic memory refers to memory for specific events in time
Semantic memory refers to knowledge about the external world, such as the function of a pencil.

Implicit memory/Procedural memory refers to the use of objects or movements of the body, such as how exactly to use a pencil or ride a bicycle. This type of memory is encoded and probably stored by the cerebellum and the striatum. There are various other categorizations of memory and types of memory that have captured research interest. Prospective memory (its complement: retrospective memory) is an example.

Emotional memory, the memory for events that evoke a particularly strong emotion, is another. Emotion and memory is a domain that can involve both declarative and procedural memory processes. Emotional memories are consciously available, but elicit a powerful, unconscious physiological reaction. They also have a unique physiological pathway that involves strong connections from the amygdala into the prefrontal cortex, but much weaker connections running back from the prefrontal cortex to the amgydala.

Disorders of memory

Minor everyday slips and lapses of memory are fairly commonplace, and may increase naturally with age, when ill, or when under stress (Reason J.). Some women may experience more memory lapses following the onset of the menopause. More serious problems with memory generally occur due to traumatic brain injury or neurodegenerative disease.

Everyday memory problems

The everyday experience of memory problems is the problem of failed recall, forgetting. The tip-of-the-tongue phenomenon is particularly frustrating because the person trying to remember feels that the memory is available. In physical terms your neurons are firing, but your receptors aren't catching. Failing to remember something in the situation in which it would have been useful leads to regret.

Traumatic brain injury

The majority of findings about memory have been the result of studies that lesioned specific brain regions in rats or primates, but some of the most important work has been the result of accidental or inadvertent brain trauma. The most famous case in recent memory studies is the case study of HM, who had parts of his hippocampus, parahippocampal cortices, and surrounding tissue removed in an attempt to cure his epilepsy. His subsequent total anterograde amnesia and partial retrograde amnesia provided the first evidence for the localization of memory function, and further clarified the differences between declarative and procedural memory.

Neurodegenerative diseases

Many neurodegenerative diseases can cause memory loss. Some of the most prevalent (and consequently, most intensely researched) include Alzheimer's Disease, Dementia, Huntington's Disease, Multiple Sclerosis, Parkinson's Disease, and Schizophrenia. None act specifically on memory; instead memory loss is often a casualty of generalized neuronal deterioration. Currently, these illnesses are irreversible, but research into stem cells, psychopharmacology, and genetic engineering holds much promise.

Biological underpinnings at the cellular level

Long term memory, unlike short term memory, is dependent upon the construction of new proteins. This occurs within the cellular body, and concerns particularly transmitters, receptors, and new synapse pathways that reinforce the communicative strength between neurons. The production of new proteins devoted to synapse reinforcement is triggered after the release of certain signaling substances (such as calcium within hippocampal neurons) in the cell. In the case of hippocampal cells, this release is dependent upon the expulsion of magnesium (a binding molecule) that is expelled after significant and repetitive synaptic signaling. The temporary expulsion of magnesium frees NMDA receptors to release calcium in the cell, a signal that leads to gene transcription and the construction of reinforcing proteins. For more information, see long-term potentiation (LTP).

One of the newly synthesized proteins in LTP is also critical for maintaining long-term memory. This protein is an autonomously active form of the enzyme protein kinase C (PKC), known as PKMζ. PKMζ maintains the activity-dependent enhancement of synaptic strength and inhibiting PKMζ erases established long-term memories, without affecting short-term memory or, once the inhibitor is eliminated, the ability to encode and store new long-term memories is restored. Also, BDNF is important for the persistence of long-term memories.