Review Article

MEMORY AND ITS MECHANISM

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Abstract : Memory; a higher intellectual function is ability to store experiences and information and to recall these voluntarily and involuntarily. Explicit or declarative memory is associated with consciousness. It is of two types; episodic (memory of events) and semantic (memory of words, rules and language. It involves hippocampus, amygdala and diencephalon. Implicit or skill or habits memory is the memory of skilled behavior and it does not require conscious understanding; for example riding a bicycle and playing basket ball. Parts of the brain involved in this memory are parts of sensorimotor cortex, basal nuclei and cerebellum.

Memory can be short term, intermediate long term and long term. Short term memory lasts for seconds to a few minutes. Short term memory is consolidated to long term memory by rehearsal or active practice. Minimum consolidation occurs in 5-10 minutes while strong consolidation requires 1 hour or more. Long term memory involves protein synthesis and permanent facilitation of synapses. Those sensory experiences are stored into memory that are accompanied by either reward or punishment.

Keywords: Explicit or declarative, implicit or skill memory, short term, long term, consolidation, reward, Punishment.

Introduction

Memory is one of the higher intellectual functions. It is ability to store experiences and information and to recall these consciously and unconsciously. The brain processes, stores and retrieves information in different ways to suit the need. The term memory encoding defines the neural processes that convert an experience into the memory.[1] It involves cellular or molecular changes specific to different memories.[2] Memory can be classified into two categories according to the type of information that is stored; declarative or explicit or precognitive memory and procedural or implicit or skill memory.[3]

Declarative or Explicit or Precognitive Memory:

It is associated with consciousness or at least awareness. It is memory of events (episodic memory) and memory of words, rules and language etc (semantic memory). It is the retention and recall of conscious experiences that can therefore be put into words (declared). One example is the memory of having perceived an object or event and, therefore, recognizing it as familiar and may be even knowing the specific time and place when the memory originated. Another example would be one's general knowledge of the world, such as names and facts.[3]

Procedural Or Skill Or Implicit Memory:

It is the memory for skilled behaviors and it does not require any conscious understanding, as for example, riding a bicycle. Individuals can suffer severe deficits in declarative memory but have intact procedural memory. One case study describes a pianist who learned a new piece to accompany a singer at a concert but had no recollection the following morning of having performed the composition. He could remember how to play the music but could not remember having done so. The category of procedural memory also includes learned emotional responses, such as fear of spiders, and the classic example of Pavlov's dog that learned to salivate at the sound of a bell after the bell had previously been associated with food. Implicit memory does not involve awareness, it includes skills, habits and conditioned reflexes. However explicit memory is initially required for activities such as riding a bicycle, it can become implicit once the task is thoroughly learned.[2] Our brain receives a lot of sensory information but the brain has capability to ignore information that is not useful. This capability results from inhibition of synaptic pathways through habituation and that is called negative memory. Useful information are stored as positive memory through facilitation of the synaptic pathways. The neural change responsible for retention or storage of knowledge is called-memory trace.[1] Some memories last for only a few seconds whereas others last for hours, months or years, so there is a common classification of memories that divides memories into three types; short term memory, intermediate long term memory and long term memory.[1,4]

Short Term Memory:

It registers and retains incoming information for a short time, a matter of seconds to minutes after its input. It is the memory that we use when we keep

information consciously in mind. For example a person looks a number in the telephone book and remembers it only long enough to walk across the room and dial it. Usually a telephone number of 7 to 10 digits can be retained for a short time. Short term memory is produced by continual neural activity resulting from nerve signals that travel around and around a temporary memory trace in a circuit of reverberating neurons. Other possible mechanisms are presynaptic facilitation or inhibition. This occurs at synapses that lie on terminal nerve fibrils immediately before these fibrils synapse with a subsequent neuron. The neurotransmitters secreted at such terminals cause facilitation or inhibition lasting for seconds upto several minutes.[1] During short term memory, the memory traces are subject to disruption by trauma and various drugs; whereas long term memory traces are remarkably resistant to disruption. Short term memory is also known as working memory. Working memory keeps incoming information available for a short time.[5]

There is a strong correlation between working memory and standard measures of intelligence. The specific memory deficit that occurs in early stages of Alzheimer's disease, a condition marked by dementia and serious memory loss, may be in this attention focusing component of working memory. The hormones released during stress such as epinephrine, glucocorticoids and vasopressin affect the retention of learned experiences. Coma, deep anesthesia, electroconvulsive shock and insufficient blood supply to the brain interfere with working memory.[2]

Intermediate Long Term Memory:

Intermediate long term memories may last for many minutes or even weeks. These are eventually lost unless the memory traces are activated enough to become more permanent. These memories result from temporary chemical or physical changes, or both, in either the presynaptic terminals or the postsynaptic membrane .These changes can persist for minutes upto several weeks.[1]

Long Term Memory:

It may last for years or even for the whole life such as knowledge of alphabets, basic facts and names of near relatives. The process of transferring and fixing short term memory traces into long term memory stores is known as consolidation **Fig-I** [6,7]. It is through active practice or rehearsal. Short term memory fades quickly unless consolidated into long term memory. Long term memory involves permanent functional or structural changes between existing neurons such as formation of new synapses, synthesis of new proteins. The process of consolidation requires 5-10 minutes for minimal consolidation and 1 hour or more for strong consolidation Rehearsal enhances the transfer of short term memory into long term memory. Long term memory results from actual structural changes at synapses instead of only chemical changes.[1] Long term potentiation is involved in the memory mechanism, in which certain synapses undergo a long lasting increase in their effectiveness when these are heavily used.[2] These structural changes will not occur if a drug is given that blocks DNA stimulation of protein replication in the presynaptic neuron and permanent memory trace will not develop. The most important physical structural changes are.[1]

1- Increase in number of transmitter vesicles released.
2- Increase in vesicle release sites for secretion of transmitter substance
3- Increase in number of presynaptic terminals.
4- Changes in structures of the dendritic spines that permit transmission of stronger signals.

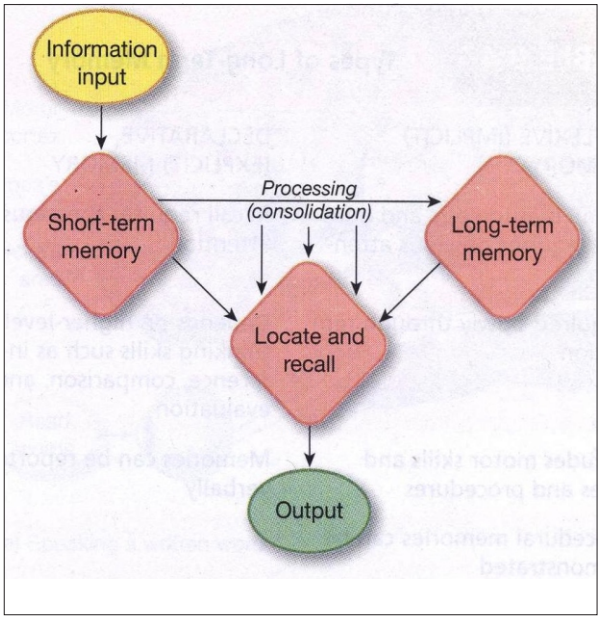

Fig-1: Consolidation of short term memory into long term memory.[7]

Long-term memories are believed to consist of some kind of structural changescalled engramsin the cerebral cortex. Widely accepted today is the theory that an engram consists of some kind of permanent change in the synapses in a specific circuit of neurons. It may represent an increase in the number of presynaptic axon terminals or an increase in the

number of receptor proteins in the postsynaptic neuron's membrane. Changes in second messenger systems and protein synthesis occur during long term memory.[2] There may be changes in the average concentration of neurotransmitters at certain synapses or changes in the functions of astrocytes. Whatever the changes are, these somehow facilitate impulse transmission at the synapses. The storage capacity of the long term memory bank is more extensive than the capacity of short term memory. Visual memories are stored separately from anditory memories. Some long term memories (information or skills) of daily use are never forgotten such as names of near relatives or alphabets. Remembering is the process of retrieving specific information from memory stores. Forgetting is the inability to retrieve stored information.[6]

Retrograde (going backward) amnesia is the inability to recall recent past events. It usually follows concussion or stroke. Anterograde (going forward) amnesia is inability to store memory on long term basis. It is associated with lesion of medial temporal lobe, these patients cannot establish new permanent memories. They can recall things they learned before the onset of their problems.[6]

Parts of the brain involved:

There is no single "memory center" in the brain. Neurons involved in memory traces are widely distributed in the cortical and subcortical regions of the brain.[5] The regions of brain most extensively involved in memory include the hippocampus, medial temporal lobes, limbic system, cerebellum and prefrontal cortex.[6,8] The temporal lobes appear to be particularly important for memory because bilateral removal of the hippocampus severely and permanently disrupts recent memory. Short-term and long-term memories are unaffected, but new long-term memories can no longer be stored. Thus, patients with such deficits remember events before their surgery but fail to recall new events, even with multiple exposure, and must be reintroduced to their therapists repeatedly. This is a loss of declarative memory involving the conscious recall of personal events, words and their meanings, and general history. Such patients, however, can still learn some tasks because they retain procedural memory, the ability to acquire problem-solving, association, and motor skills. If patients are given a complex task to perform (e.g., mirror writing), they will not only improve during the first training session but will also perform better on subsequent days despite their denial of having any experience with the task.[5] The hippocampus, amygdala and diencephalon play an important role in short term memory and declarative memory. The cerebellum, basal ganglia and regions of sensorimotor cortex play an essential role in procedural memories involving motor skills gained through repetitive training. The prefrontal cortex is involved in the complex reasoning skill associated with working memory Working memory areas are connected to the hippocampus and adjacent parahippocampal portions of the medial temporal cortex **Fig- II.**[2]

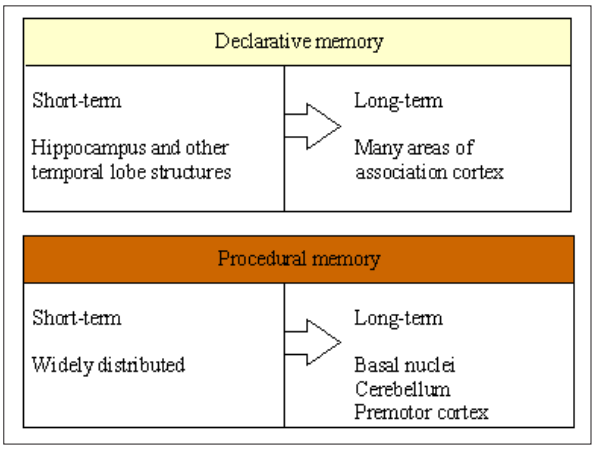

Fig-2: Brain areas involved in encoding and storage of declarative and procedural memories.[2]

The key to memory is alteration in the strength of selected synaptic connections which involves protein synthesis and activation of genes. This occurs during the change from short term memory to long term memory. Long term memory leads to activation of genes that produces increases in synaptic contacts. In humans, bilateral destruction of the ventral hippocampus, or Alzheimer's disease and similar disease process that destroys its neurons cause marked defects in short term memory. Human with such destruction have intact working memory and remote memory. Their implicit memory processes are generally intact. The connections of the hippocampus to especially mamilliary bodies and anterior thalamic nuclei are also involved in memory. Long term memories are stored in various parts of the neocortex. Once long term memories have been established, these can be recalled or accessed by a large number of different associations. For example, the memory of a vivid scene can be evoked by a sound or smell associated with the scene.[5]

Many research findings indicate that the cerebrum's limbic systemthe "emotional brain"plays a key role in memory.

To mention one role, when the hippocampus (part of the limbic system) is removed, the patient loses the ability to recall new information. Personal experience substantiates a relationship between emotion and memory.[7] Sensory experiences that are not accompanied by reward or punishment are hardly remembered. An animal builds up strong memory traces for sensation that are either rewarding or punishing.[1] The absolute amount of REM sleep has been correlated with intellectual functioning in the elderly.[9] REM sleep levels are shown to be diminished in Alzheimer's patients.[10]

Hormal control of memory:

Certain hormones like adrenocorticotrophic hormone (ACTH), epinephrine and vasopressin released during stressful or even mild stimulating condition, affect memory. Enkephalin and endorphin interfere with learning and memory during painful experiences because these decrease emotional (fear, anxiety) components of the painful experience associated with learning, there by reducing the motivation necessary for learning.[11]

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