# LEARNING AND MEMORY

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**Contents**



**Summary**

Learning and memory influence thinking, planning and particularly decision making. The acquisition and storage of information enable the organism to repeat successfully and to avoid failures by utilizing its past experience. Two principal types of learning process are recognized, classic and operant conditioning (passive and active learning). During active learning, subject exerts a considerable degree of voluntary control over the *learning* process. The gradual diminution of response to a specific stimulus, which is given several times, is known as habituation. The nervous system evidently elaborates a succession of adjusting filters that are particularly tuned to the particular stimulus under those circumstances.

At the behavioral level, habituation and conditioning to the arousal value of various stimuli are common and everyday human experiences. The opposite reaction of habituation is sensitization. When this occurs, repeated stimulus produces a greater response. Most of the recent investigators have accepted the concept that the establishment of a memory trace takes place in two stages: an initial stage in which the memory trace is evanescent and easily disrupted, and a later, more stable state, which is the “permanent” memory trace. Sensory memory refers to that brief period when information has reached receptors and is about to be sent on to the central nervous

system. Primary memory has small capacity, short duration and storage, whereas long term memory has large capacity, long duration and organization. Rehearsal and codifying are involved in consolidation of long term memory.

Integrity of the limbic system is essential for long term memory. Bilateral damage to certain parts of the hippocampus, fornix, mammillary body, medial hypothalamus or those parts of the thalamus connected with the mammillary bodies, causes severe and persistent disorder of memory, called amnesia. Patients with damage to the hippocampal system seem largely to be incapable of adding new information to their long-term store (anterograde amnesia). A similar type of amnesia is shown by some chronic alcoholics (Korsakoff psychosis). Following head injuries (damage to the thalamus), patients often lose their memory of events which occurred before the injury; this is called retrograde amnesia.

## 1. Introduction

Learning and memory are probably the most evolutionarily advantageous developments in neurophysiology. The acquisition of information, learning, and its storage in memory enable an organism to repeat successfully and avoid failure by utilizing its past experience. In humans the education and learning periods are long, but learning phenomena can be observed also in simple animals like the giant marine snail *Aplysia*, which has served as a model of many studies. We remember, however, little of our past; about 1% of our experience is stored in the long term memory. This process is important to prevent us being overwhelmed by information. It seems that the amount already stored and the information acquired after a fact has been added to our memory determine its likelihood of being retained.

Learning is defined as an alteration of behavior or modification of innate responses by experience and training. The ability to learn is a fundamental characteristic of man and most of the animals. The capability of learning lies wholly within the nervous system and may be considered to reside in a sort of "functional plasticity" of this complex system where physiochemical modifications can occur as the result of experience.

It is quite clear that the activities of the nervous system can be formed by experience in such a way that responses to various stimuli can be altered considerably.

One particularly enigmatic feature that is shared in common by the learning as well as the memory process is the temporal scale upon which these events take place. Thus the majority of neurophysiologic processes have a duration lasting for a few milliseconds or perhaps a few seconds. Learned information may take considerably longer to "store", and once committed to memory the information may be retained for many years, during which time probably all the atoms and molecules have been replaced by new ones.

It is frequently assumed that the learning process is an exclusive function of the cerebral hemispheres. Primitive forms of "learning" can readily be demonstrated to take place in many species including, for example, insects and worms. Furthermore, "learning" phenomena have been demonstrated to occur in mammals at subcortical as well as spinal levels of the central nervous system. For example, posttetanic potentiation, which is the facilitation observed to take place in a synaptic pathway after repeated stimulation, is an excellent example of this kind of subcortical learning phenomenon. In birds the subcortical area has an important role in the control of behavior. For example the pigeon is able to learn quite rapidly a number of highly complex and sophisticated visual discriminations and navigate its way home over long distances.

Despite the facts summarized above, the more highly advanced learning processes that take place in humans require the participation of the cerebral cortex, even though the brain stem is also involved. The structural changes that have been observed to take place after a period of learning are discussed later.

Fundamentally two principal types of learning process are recognized, depending upon whether or not the subject plays a passive or active role. During *classic conditioning*, the subject plays a relatively involuntary or passive role; hence this type of learning is considered to represent a relatively “primitive“, “simple” or “generalized” learning process. On the other hand, during *operant conditioning* (trial-and-error learning) the subject exerts a considerable degree of voluntary control over the learning process so that this type of conditioning is considered to represent learning at a much “higher” level than either classic conditioning.

## 2. Learning by Classic Conditioning

Classic conditioning results in the formation of learned responses called conditioned reflexes. A conditioned reflex in turn is an automatic response to a stimulus, which previously did not evoke a response. This effect is produced by repeatedly pairing the stimulus, which does not produce the response (the conditioned stimulus, CS) with a second stimulus, which normally produces a specific and innate response (the unconditioned stimulus, US). When the unconditioned and conditioned stimuli are applied in the correct temporal sequence and for a sufficient number of times, then ultimately the presentation of the conditioned stimulus alone will evoke the response which originally could be elicited only by the unconditioned stimulus.

Among the classic experiments performed by Ivan Pavlov, salivation was induced in the dogs in response to placing meat in the mouth (the unconditioned stimulus). If a bell was rung immediately before the meat was placed in the mouth, and this process was repeated a number of times, then eventually ringing the ball (i.e. the conditioned stimulus) alone was sufficient to evoke salivation.

In order for conditioning of this type to take place, the conditioned stimulus must precede the unconditioned stimulus. If the conditioned stimulus is applied after the unconditioned stimulus, no conditioned reflex develops. The conditioned response follows the conditioned stimulus by a time interval, which is practically identical to that which separated the conditioned stimulus and the unconditioned stimulus during the training period. This delay between stimulus and response may range from a second or so up to 1.5 minutes, and when a considerable time such as this elapses between the application of the conditioned stimulus and the development of the conditioned response, the latter is called a delayed conditioned reflex.

When first developed, a conditioned reflex can be elicited not only by the conditioned stimulus but also by similar stimuli, e.g. by ringing bells having slightly different tones to evoke salivation in the example mentioned above. If only one particular conditioned stimulus (i.e. a bell having one specific tone) is reinforced by repetition, whereas the similar stimuli are not repeated, then an animal can learn to discriminate between the different stimuli with amazing accuracy. This process is called discriminative conditioning. Such conditioning stimuli are an exceedingly useful tool for studying color vision and pitch discrimination, among other sensory modalities, in various subhuman species.

Once a conditioned reflex becomes established, if the conditioned stimulus is applied a sufficient number of times in the absence of the unconditioned stimulus, eventually the conditioned response disappears. The process whereby this effect takes place is called extinction. On the other hand, if the animal is distracted or disturbed by an external stimulus, which is presented immediately following the conditioned stimulus, the conditioned reflex may not take place, and this effect is called external inhibition. If, however, the conditioned reflex is reinforced occasionally by pairing the unconditioned and conditioned stimuli, the conditioned response will remain unaltered for extremely long periods of time.

Instrumental conditioning, which is important to establishing learning and memory, can be activated with relative ease. On the other hand an unconditioned stimulus must be coupled to either a pleasant or unpleasant affect.

To analyze what is pleasant or unpleasant learning, one can take various parameters. Learning of any event which gives pleasant rewards like food, sexual gratification or any happy feeling could be called “pleasant” learning, whereas any stressful condition like electrocutaneous shock or nociceptive stimuli could be called “unpleasant” learning.

It is clear that unpleasant learning remains for a longer time than pleasant. This learning could be one reason, why it is a common observation in conditioning experiments, that animals take a long time to be conditioned, in response to pleasant learning whereas unpleasant learning develops readily. For instance a person who has Kluver Bucy Syndrome (where a lesion in the temporal lobe along with hippocampus and amygdala are common) loses his social sense with excessive oral tendencies and hyper sexuality, which could be interpreted as the person retained the pleasant part of those experiences tending to forget the unpleasant part.

## 2.1. Habituation

When the stimulus evokes neither a pleasant nor an unpleasant affect, repetition produces progressively less and less response in the subject, and the subject learns to ignore the stimulus completely. The gradual diminution in the behavioral response, which is produced by the repeated application of a stimulus without reinforcement, is known as habituation. When a human or animal is exposed to a new (or novel) sensory stimulus, the subject becomes alert, and actively pays keen attention to the stimulus. The electroencephalography (EEG) exhibits a diffuse arousal pattern, the evoked secondary electric responses become clearly evident in many parts of the brain and most of the information input to the cerebral cortex is established. During habituation, all these behavioral reactions disappear.

This is associated with decreased release of neurotransmitters from the presynaptic terminal, because a gradual inactivation of $Ca^{2+}$ channels decreases intracellular $Ca^{2+}$ into this terminal. It can be short-term, or it can be prolonged if exposure to the benign stimulus is repeated many times.

At a behavioral level, habituation and conditioning to the arousal value of various stimuli are common and everyday human experiences. For example, one can become habituated very rapidly to commercial advertisements, which are presented visually or orally. Unless such stimuli produced a particular effect, they will be totally ignored.

Habituation generally develops after the stimulus has been applied only a few times. It occurs in many species. Therefore it has been used experimentally as a model of plasticity in the nervous system. Many investigators showed that so called CA3 neurons of hippocampus indicated specific “habituation” property, even in sliced preparations which was necessary for the registration of new information—an essential component for learning and memory processing.

## 2.2 Sensitization

Sensitization is in a sense the opposite reaction to habituation. A repeated stimulus produces a greater response, if it is coupled one or more times with an unpleasant or a pleasant stimulus. It is common knowledge that intensification of the arousal value of stimuli occurs in humans. For example, a mother who sleeps through many kinds of noise wakes promptly when her baby cries.

Sensitization may occur as a transient response, or if it is reinforced by additional pairings of the noxious stimulus and the initial stimulus, it can exhibit features of short-term or long term memory. The short-term prolongation of sensitisation is due to a $Ca^{2+}$ mediated change in adenylyl cyclase that leads to a greater production of cyclic AMP. Long-term potentiation also involves protein synthesis and growth of the presynaptic and postsynaptic neurons and their connections.

As mentioned above, the learning process itself is poorly understood, but it can be studied experimentally at the synaptic level in isolated slices of mammalian brain or in the nervous systems of simpler invertebrates. Synapses subjected to repeated presynaptic neuronal stimulation show changes in excitability of postsynaptic neurons, including facilitation of neuronal firing, changes in the patterns of neurotransmitter release, changes in second messenger formation, and, in intact organisms, evidence that learning occurred.

The phenomenon of increased excitability and altered chemical state on repeated stimulation of synapses is known as long-term potentiation (LTP)—a condition that persists beyond cessation of electrical stimulation.

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**Biographical Sketch**

**Dr. Hojjatallah Alaei** was born in Esfahan, Iran in 1955. He was awarded a Doctor of Pharmacy from the University of Esfahan (1982) and PhD of Neurophysiology from University of Sheffield in U.K (1990). His field of research is function of neurotransmitters in the brain. He tries to evaluate serotonin, norepinephrine and cholinergic system of the EEG and somatosensory evoked potentials. Some behavioral studies such as morphine addiction and memory also have been evaluated. He is also doing some experiments to find relationship between memory addiction and nuclei in the brain and any changes in the concentration of neurotransmitters using microdialysis methods. Dr. Alaei has been teaching memory and learning about 10 years for medical, pharmacy and dentist students.

Dr. Alaei has published more than 30 articles on memory, learning and sleep. He has also written two books about function of nervous systems such as memory and sleep.

He is member of editorial board of Iranian Journal of Physiology and he was president of the Iranian Physiology and Pharmacology Society from 1994 to 1996.

He is currently working as chairman of the Department of Physiology in Esfahan University.