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Memory

The ability to store and access information that has been acquired through experience. Memory is a critical component of practically all aspects of human thinking, including perception, learning, language, problem solving, and many others. Through its elaborate mechanisms for sorting, organizing, and storing information, memory provides people with the building blocks necessary to structure their knowledge of the world and, ultimately, of themselves. *SEE PERCEPTION; PROBLEM SOLVING (PSYCHOLOGY).*

Stages. Psychologists divide memory into three general stages: sensory memory, short-term memory, and long-term memory. Sensory memory refers to the sensations that briefly continue after something has been perceived. For example, if a person sits in a dark room and then is subjected to a flash of light for just a moment, the image will linger on after darkness returns. Sensory memories occur for all five senses and are usually very similar to the perceptions from which they arise. Short-term memory includes all of the information that is currently being processed in a person's mind, and is generally thought to have a very limited capacity. Memorizing a telephone number just long enough to dial it is an example of a task that involves short-term memory. Long-term memory is the storehouse of the mind, where all the information that may be used at a later time is kept. Childhood memories of the beach as well as what dinner comprised one night ago are examples of long-term memories.

Sensory memory. Psychologists were long aware of sensory memory without being able to experimentally demonstrate its full capacity. For example, after viewing a briefly flashed slide, subjects reported seeing the entire image gradually fade away. However, by the time they tried to describe what they saw, most of their sensory memory had faded. G. Sperling devised a technique known as the partial report test to demonstrate the full extent of sensory memory. Sperling's experiment had two different conditions for reporting the contents of a briefly flashed slide containing three rows of letters. In the full report condition, subjects saw the slide, and then afterward had to name as many of the letters as they could. Subjects in this condition could identify only about a third of the letters. In the partial report condition, Sperling flashed the same slide, but immediately afterward gave subjects a tone indicating which row of letters they were to name. With the partial report technique, subjects could name almost all of the items in any of the three rows. Since subjects did not know which row they would have to name until after the image physically disappeared, they must have had a memory of all of the items in the slide. Subjects in the full report condition probably had the same full memory, but they could name only a few letters before their memory faded. Thus, Sperling's experiment suggested that people have a very detailed sensory memory that lasts only a brief time.

A number of interesting facts are now known about sensory memory, including: (1) sensory memories appear to be associated with mechanisms in the central nervous system rather than at the sensory receptor level; and (2) the amount of attention that a person pays to a stimulus can affect the duration of the sensory memory. Although all of the functions of sensory memory are not understood, one of its most important purposes is to provide people with additional time to determine what should be transferred to the next stage in the memory system, commonly known as short-term memory.

Short-term memory. Information obtained from either sensory memory or long-term memory is processed in short-term memory in order for a person to achieve current goals. In some situations, short-term memory processing simply involves the temporary maintenance of a piece of information, such as remembering a phone number long enough to dial it. Other times, short-term memory can involve elaborate manipulations of information in order to generate new forms. For example, when someone reads 27 + 15, they manipulate the symbols in short-term memory in order to come up with the solution.

One useful manipulation that can be done in short-term memory is to reorganize items into meaningful chunks. For example, it is a difficult task to keep the letters S K C A U Q K C U D E H T in mind all at once. However, if they are rearranged in short-term memory, in this case reversing them, they can be reduced to a single simple chunk: T H E D U C K Q U A C K S. Short-term memory can accommodate only five to seven chunks at any one time. It therefore becomes very important that each chunk includes as much information as possible.

Although, short-term memory holds only a limited number of chunks, the amount of information contained in each chunk is constrained only by one's practice and ingenuity. In one study, an average college student participated in a 20-month program in which he learned to increase his short-term memory span from 7 to 80 random digits. The chunking trick that he used was associating groups of random numbers with familiar track records, an easy task for him since he was a runner. His accomplishment did not represent a general increase in short-term memory capacity (he could still recall only 7 random letters) but rather an improved strategy for organizing random digits. Thus, in order to increase the amount of information that can be kept in short-term memory at one time, people need to develop specific strategies for organizing that information into meaningful chunks.

Not only does manipulating information in meaningful ways increase the capacity of short-term memory, but it also appears to facilitate the transfer of information from short-term to long-term memory. For example, the running student who managed to chunk 80 random digits in his short-term memory was able to recall 80% of those digits days later. Many other studies have also demonstrated that the transfer of information from short-term to long-term memory is much greater when the information is manipulated rather than simply maintained.

Long-term memory. One can keep massive amounts of information in long-term memory. In general, recall from long-term memory simply involves figuring out the heading under which a memory has been filed.

One of the best ways to ensure that a long-term memory will be found is to memorize it with a very specific file heading. Thus, many tricks for effective retrieval of long-term memories involve associating the memory with another more familiar memory that can serve as an identification tag. This trick of using associations to facilitate remembering is called mnemonics. To make recall easier, a mnemonic called the method of loci may be employed which involves associating to-be-remembered items with series of places (or loci) that are already well fixed in memory. For example, to memorize the presidents of the United States, each president can be associated with a different piece of furniture in the house. By making this association, the furniture can then serve as reminders of the mental file in which the presidents' names can be found. Various other tricks involve associating a familiar memory with an unfamiliar memory. For example, one common way of learning new names is to associate the new person with an old friend or acquaintance with the same name.

Usually people do not make explicit attempts to associate a new memory with an old memory, and yet they are generally reasonably good at accessing long-term memories. This is because long-term memory is organized in a logical manner; that is, long-term memory stores related concepts and incidents in close range of one another. This logical association of memories is indicated by subjects' reaction times for identifying various memories. Generally, people are faster at recalling memories if they have recently recalled a related memory.

Considering that related memories are filed near each other, it is not surprising that one good way to locate a long-term memory is to remember the general situation under which it was stored. Accordingly, techniques that reinstate the context of a memory tend to facilitate remembering. For example, in one study divers learned a list of words underwater and were later tested either underwater or on land. The divers who were tested underwater were able to remember considerably more words. Subjects who learn words while they are in a good mood are also more likely to remember them when they are in a good mood. Similarly, words memorized by subjects under the influence of alcohol are better remembered when again under the influence. In each of these cases, reinstating the context allows subjects to better locate the memories in their long-term memory file.

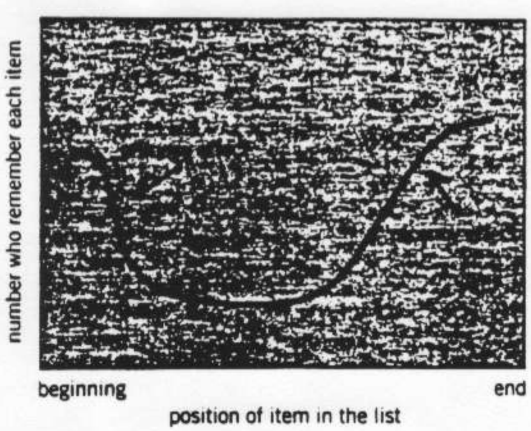
Sometimes information may not have been filed in long-term memory in the first place, or if it has, is inaccessible. In these situations, the long-term memory system often fills in the gaps by using various constructive processes. One common component to memory constructions is a person's expectations. Countless studies have also indicated that memories tend to systematically change in the direction of a prior expectation or inference about what is likely to have occurred.

In addition, a long-term memory often becomes distorted as the result of misleading suggestions. In one study, subjects watched a video tape of an auto accident. Later they were either asked "How fast were the cars going when they hit?" or "How fast were the cars going when they smashed?" On the average, subjects who heard the word "smashed" estimated that the cars were going faster, and were more likely to report having seen nonexistent broken glass. Studies like these indicate that the files in long-term memory are vulnerable to tampering.

Dual memory. The distinction between short- and long-term memory is supported by both physiological and experimental evidence. The experimental support for the distinction comes from a number of sources, including observations of people's recall of words from a memorized word list. When people are given a list of items to remember, the items at the beginning and at the end of the list are remembered well, while items from the middle of the list are remembered less well. The fact that the first few items have a good chance of being remembered is called the primacy effect. The fact that the last few items have a good chance of being remembered is called the recency effect. If a hundred people are given a list to remember, and the number who remember each item is graphed, the classic serial position curve will be seen (see **illus.**). The serial position curve can be explained because of the operation of both short-term and long-term memory. Items at the end of the list are remembered because they are in short-term memory at the moment the list begins to be recalled. These words are likely to be in short-term memory because no later items have displaced them. After they are reported, the contents of long-term memory can be searched. The items at the beginning of the list are more likely to be in long-term memory because they get more attention than do other items. Thus, the dual-memory distinction provides a relatively simple explanation for an otherwise puzzling experimental finding.

A second important source of evidence for the distinction between short-term and long-term memory comes from clinical reports on the memory of brain-damaged individuals. In one famous case, a patient had lesions made in his hippocampus in order to relieve severe epilepsy. After the operation he had perfectly normal memory for experiences that occurred prior to the operation, and he could also perform well on short-term memory tasks. However, there was one major deficit: he could only remember recent experiences as long as he paid attention to them. As soon as he shifted attention, his memory was lost. Apparently, the operation destroyed his ability to transfer information from short-term to long-term memory, thereby preventing him from forming new long-term memories.

Although the dual-memory view is widely accepted, there are some theorists who argue that differences between alleged short- and long-term mem-



Serial position curve.

ories can be attributed to differences in how information is processed. One alternative to the dual-memory distinction is known as the levels-of-processing approach. It posits that memories differ only with respect to how "deeply" they have been processed. According to this argument, shallowly processed information will be quickly forgotten, while information that receives a deeper processing will be better remembered. The primary evidence for this view comes from incidental learning situations in which subjects participate in some task involving words. Later, to their surprise, the subjects are asked to recall the words that they previously worked with. Generally, incidental tasks involving "deep" processing (for example, determining the meaning of a word) are associated with better word recall then tasks involving "shallow" processing (for example, determining whether a word is in upper- or lowercase). Both the dual processing and the depth of processing concepts have something to offer. Specifically, depth of processing is an important factor in determining if a memory will last a long time. It is convenient to say that the resulting enduring memory is stored in long-term memory; certain physiological studies support this idea. *See Information processing (psychology).*

Physiology. A number of physiological mechanisms appear to be involved in the formation of memories, and the mechanisms may differ for short-term and long-term memory. There is both direct and indirect evidence suggesting that short-term memory involves the temporary circulation of electrical impulses around complex loops of interconnected neurons. A number of indirect lines of research indicate that short-term memories are eradicated by any event that either suppresses neural activity (for example, a blow to the head or heavy anesthesia) or causes neurons to fire incoherently (for example, electroconvulsive shock). More direct support for the electric circuit model of short-term memory comes from observing electrical brain activity. By implanting electrodes in the brain of experimental animals, researchers have observed that changes in what an animal is watching are associated with different patterns of circulating electrical activity in the brain. These results suggest that different short-term memories may be represented by different electrical patterns. However, the nature of these patterns is not well understood. *See Electroencephalography.*

Unlike short-term memories, long-term memories appear to involve some type of permanent structural or chemical change in the composition of the brain. This conclusion is derived both from general observations of the imperviousness of long-term memories and from physiological studies indicating specific changes in brain composition. Even in acute cases of amnesia where massive deficits in long-term memory are reported, often, with time, all long-term memories return. Similarly, although electroconvulsive therapy (shocking the brain in order to produce convulsions) is known to eliminate recent short-term memories, it has practically no effect on memories for events occurring more than an hour prior to shocking. Thus the transfer from a fragile short-term memory to a relatively solid long-term memory occurs within an hour. This process is sometimes called consolidation.

The nature of the "solid" changes associated with long-term memories appears to involve alterations in both the structural (neural connections) and chemical composition of the brain. One study compared the brains of rats that had lived either in enriched environments with lots of toys or in impoverished environments with only an empty cage. The cerebral cortices of the brains of the rats from the enriched environment were thicker, heavier, endowed with more blood vessels, and contained significantly greater amounts of certain brain chemicals (such as the neurotransmitter acetycholine). Another study demonstrated that the brains of goldfish that were forced to learn a difficult swimming task had undergone significant changes in ribonucleic acid (RNA).

Theories of how long-term memories are represented in the brain are, however, only speculative. Compositional brain changes associated with learning may be due to some other aspect of the learning activity. For example, the goldfish that had to learn a difficult way of swimming had to swim much harder; therefore a question remains as to whether it was the learning or the swimming that caused the changes in brain RNA. Thus, understanding the physiological mechanisms underlying memory is constrained both by the elusive qualities of the memory trace and by the experimental difficulties involved in singling out what the changes mean.

Forgetting. In addition to investigating the mechanisms affecting memory, researchers have put considerable effort into determining how and why people forget. Forgetting has been associated with three major causes: decay, interference, and motivation.

Decay of memory traces. Decay theories of forgetting assume that memories fade and will gradually be lost if they are not occasionally refreshed. Although this model of forgetting seems intuitively sensible, and is in fact probably the source of some forgetting, there are a number of reasons why it can not fully explain forgetting. First, many memories do not fade even though they have not been recalled for a very long time. Memories for motor skills, such as riding a bicycle, usually remain quite strong indefinitely. A second problem with decay theories of forgetting is that they are very difficult to distinguish from other theories. It is impossible for time to pass without the brain engaging in some type of activity. Consequently, theorists can never be sure whether forgetting is simply due to the passage of time or whether it is due to some activity in that time.

Interference. According to interference theories, forgetting occurs when one memory replaces or becomes confused with another memory. Evidence for interference comes from studies showing that some activities cause greater forgetting than others. Sleeping and being awake, for example, probably involve different levels of interference. If people learn a word list and are then tested 8 hours later, they will recall considerably more words than if they sleep during those 8 hours. Presumably, sleeping reduces the amount of information that people encounter, and consequently reduces the amount of interferences with memory.

Psychologists have identified two different types of interference. Consider the situation of traveling in Europe, where one must learn the same phrases (hello, thank you, how much is the bill) in a number of different languages. If these phrases are learned first in French and later in German, learning them in German will interfere with the ability to recall the earlier learned French words. This situation, in which information that is learned later interferes with information that was learned earlier, is known as retroactive interference. In another type of interference, after having learned a number of phrases in French, it will be more difficult to learn those same words in German. Situations in which old memories inhibit the learning of new memories constitute proactive interference.

Motivated forgetting. The notion that people forget certain things because they want to is a central theme in Freud's psychoanalytic theory. Freud believed that unacceptable or anxiety-provoking thoughts are repressed by the unconscious in order to avoid confronting them directly. Although the processes involved in such motivated forgetting are far from being understood, it is clear that people do forget very disturbing events such as violent crimes of great passion or horrendous automobile accidents. *SEE PSYCHOANALYTIC THEORY.*

Less dramatic unpleasant experiences are also often forgotten with time. As time passes, people become increasingly more likely to recall the pleasant aspects of an event. In addition, with time people tend to distort various other types of memories in a manner that makes them and their lives appear more worthwhile. For example, people may recall having better-paying jobs, voting more frequently, and donating more to charity than records indicate. Thus, selective forgetting allows memories to be shaped to better fit what a person would like the world to be. *SEE MOTIVATION.*

Permanence. Some widely cited physiological research by W. Penfield was thought to suggest that many seemingly lost memories can be reactivated by direct electrical stimulation. Penfield stimulated particular areas of the brain in patients who were undergoing brain surgery. The patients, who were only under local anesthesia, often reported "reliving" various episodes from earlier times in their life. These observations led Penfield and many other psychologists to conclude that all experiences are kept in memory, and that forgetting simply involves an inability to find a particular memory.

Subsequent consideration of Penfield's findings, however, have shed doubt on this interpretation. Specifically, the experiences that people reported were never verified, so it is not certain that they were really memories at all. The patients might have been experiencing a process like dreaming, involving very lifelike qualities that do not actually correspond to real events. Thus, the question of the permanence of memory is still an open one.

Photographic memory. A rare type of memory that is sometimes associated with young children, and very occasionally with adults, involves the ability to image very vivid "picture" memories. People who experience this type of memory, known as eidetic imagery, report being able to recall remarkable visual details. For example, when remembering a book they claim that they can actually read from the pages in their mind. People with this gift are quite rare and are difficult to study experimentally. Only one adult has been conclusively shown to have eidetic imagery. In this study, the subject was shown a dot pattern containing 10,000 dots. Later she was shown a second pattern of dots. The two patterns were designed so that when they were superimposed, a three-dimensional cube would be visible. In fact, when asked to imagine the two patterns of dots together, this subject "saw" the three-dimensional cube, thereby demonstrating the remarkable detail of her eidetic images.

Hypnosis and memory. Hypnosis is often used as a means of unlocking unavailable memories. Exactly how hypnosis achieves results is not completely understood. One possible explanation is that it may be simply an effective way to induce relaxation and concentration. Although it sometimes is quite useful, hypnosis does not always improve memory, and in fact sometimes it makes memory worse. Under hypnosis, subjects occasionally recall details that were not originally remembered; sometimes the additional memories are accurate, but just as often they are fabrications. Upon awaking from the hypnotic state, subjects believe in the truth of these fabrications. Thus, paradoxically, hypnosis can simultaneously improve and distort memories.

Future research. Psychology has made major advances in the understanding of how memory operates. These findings have been used in various applied settings. Knowledge about short-term memory has been important for the development of codes that people will remember. For example, telephone numbers are broken up into parts in order to facilitate the formation of chunks. Knowledge about the importance of deep processing has been incorporated into the development of better teaching techniques. Knowledge about the ways in which memory can be distorted has helped jurors to more accurately assess the credibility of eyewitnesses.

Despite the advances in the field, and the consequent benefits, much is still unknown. For example, understanding of the physiological mechanisms of memory is primitive. In addition, very little is known about how the files in long-term memory are organized. In particular, more research is needed to understand the strategies that enable people to search through their vast memories in order to find some small detail. *SEE LEARNING, NEURAL MECHANISMS OF.*

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Mendelevium

A chemical element, Md, atomic number 101, the twelfth member of the actinide series of elements. Mendelevium does not occur in nature; it was discovered and is prepared by artificial nuclear transmutation of a lighter element.

In 1955 A. Ghiorso, B. G. Harvey, G. R. Choppin, S. G. Thompson, and G. T. Seaborg performed a series of classic experiments which constituted the