A MULTIPLICITY OF MEMORY

by Jonathan Schooler

If you listen to people talk about their memory, they usually refer to it as a single thing. Rarely does anyone say "My long-term memory is fine, but my working memory is slipping," or "Mike's explicit memory is much better than his implicit memory." However, when you observe how memory operates, it's clear that considering it as a single "thing" is much too simplistic.

Although memory researchers differ in exactly how they view the divisions of memory, it has become increasingly clear that there are numerous distinct types. One critical dimension by which memories differ is in how long they last. Imagine that you were just introduced to George. You will almost certainly remember George's name long enough to courteously respond, "Nice to meet you, George." This ability to reliably recall information for twenty to thirty seconds involves short-term, or working, memory. Unfortunately, information in short-term memory does not necessarily make it into long-term memory. That is why you may embarrassingly fail to recall George's name five minutes later, when you need to introduce him to a friend.

This division between short-term and long-term memory is only the beginning of the divisions of memory. Other memory types include procedural memory for skills, episodic memory for personal events, semantic memory for knowledge, and prospective memory for intentions, to mention but a few.

How do psychologists identify the varieties of memory? One important source of evidence comes from investigating individuals who have had brain damage that interferes with some memory functions, while leaving others intact. Probably the most studied of all such cases is a former epileptic patient known as "HM." To treat his severe seizures, HM underwent a novel operation in which his *hippocampus*—an area of the brain we now know is important for the formation of enduring memories—was removed.

The operation succeeded in eliminating HM's seizures but it also produced some severe and unexpected side effects. His IQ was fine; he could hold information in memory long enough to respond to it. He could also remember memories for events that occurred prior to the operation. However, HM was simply unable to form new memories that persisted for more than a few minutes.

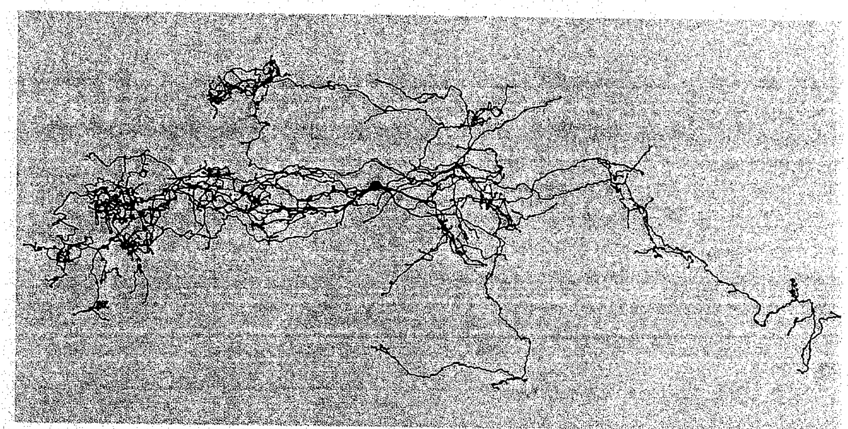
Although a great personal misfortune, HM's disability was one of several critical sources of evidence supporting the distinction between two different kinds of memories—transient, short-term memories that last less than a minute, and more permanent, long-term memories that can persist indefinitely. As a result of his operation, HM seemed to have lost the critical processes that enabled short-term memories to become long-term memories.

Interestingly, although HM was not able to remember events that happened after his operation, he was able to acquire new skills (procedural memory). He learned, for example, how to trace a star while watching his hand in a mirror, even though he had no recollection of learning this skill.

In addition to the selective memory deficits of brain-damaged patients such as HM, evidence for distinct types of memory has also been provided by experiments with normal populations. For example, even people with fully intact brains can be influenced by experiences that they do not explicitly recall. Try to complete the following word fragment: "_ x p _ r _ m _ n t s." If you can do it, it's probably because you recently saw the word "experiments."

Word fragment completion benefits from prior exposure to a word, even if you don't recall

Memories Are Made of This?



This neuron was hand-drawn using a light microscope.

We do not fully understand the neural basis of memory. Still, it appears that a theory proposed in the absence of any neural evidence may hold the key to what memories are made of.

In 1949, Canadian psychologist Donald Hebb suggested that learning might take place at the junctures between neurons, known as *synapses*. To understand Hebb's theory, it may help to look briefly at how nerve cells operate in the brain.

The brain is primarily composed of billions of interconnected cells, called *neurons*, which process information by receiving, integrating, and transmitting electrical impulses. Once an electrical impulse is triggered in a neuron it always travels from its origin (the *dendrite*), through the main cell body (the *soma*), along the equivalent of a well-insulated wire (the *axon*), ending at what are called the *terminal buttons*.

The terminal buttons then release various chemicals, or *neurotransmitters*, into the synaptic space between the sending and receiving neuron. The dendrites on the receiving neuron collect the neurotransmitters at receptor sites. Depending on the type of neurotransmitter, these receptor sites in turn either raise or lower the electrical charge of the receptor cell. If the charge at the receiving cell becomes sufficiently great, it fires, and the process is repeated.

With this in mind, let's consider Hebb's account of memory. Hebb suggested that memory could result from changes in the ease with which adjacent neurons cause each other to fire. Specifically, he hypothesized that the connection between sending and receiving neurons might be strengthened following situations in which they fire together, which could happen if they were simultaneously stimulated by a neuron adjacent to them both. As a result of this paired firing, Hebb hypothesized the next time the sending neuron was fired, it would be more likely to prompt the firing of the receiving neuron. You might say the essence of this mechanism—known as *Hebbian plasticity*—is "cells that fire together, wire together."

At the time that Hebb proposed this mechanism, it was viewed as an intriguing but entirely unsubstantiated hypothesis. However, Hebb's theory has gained increasing support recently. Subsequent studies have offered further evidence that Hebb's theory does provide the neural foundation for memory. For example, researchers have found that changes resulting from stimulating neural pathways have been proven to be long lasting—a necessary requirement to account for the durability of many memories. The changes are also exclusively limited to the stimulated pathway, thereby enabling the very specific neural associations that would be required to capture our seemingly endless number of distinct memories. Additional research has even begun to pin down specific neurotransmitter-receptor site combinations that provide the critical "glue" for enabling these paired associations.

Although there are other neural mechanisms that contribute to the manner in which neurons learn, Hebbian plasticity appears to be a fairly universal process that mediates learning in various brain regions.

—Jonathan Schooler

having seen it. This provides important evidence for a general distinction between two types of long-term memory: explicit memory (memories that you are aware of accessing) and implicit memory (memories that influence performance without your realizing they have been accessed). Recently, there has been a flurry of research demonstrating the surprising variety of situations in which you are influenced by—but unaware of—implicit memories.

Research has also been important in demonstrating the divisions of short-term, or working, memory. English psychologist Alan Baddeley proposed that working memory involves a "central executive system" that serves as the mental workspace for processing and manipulating information, and two supporting auxiliary systems: the "articulatory loop," which maintains auditory information, and the "visual-spatial sketch pad," which holds visual representations.

One source of evidence for the articulatory loop is the finding that the number of words remembered depends on how quickly they are said. This demonstrates that it is the amount of auditory information, and not the number of words, which determines the limits of the articulatory loop. Evidence for the visual-spatial sketch pad comes from the finding that the ability to maintain images in your mind is disrupted when you simultaneously try to attend to visual, as compared to auditory, information, in the same way that plugging too many appliances into one circuit can blow a fuse.

The notion that memories can be divided by sensory modality also applies to long-term memories. For example, there is considerable evidence that long-term memory includes distinct visual and verbal representations. This is why you are better at remembering concrete words (e.g., thorn, truck) than abstract words (e.g., thought, truth). Concrete words are easily visualized and produce both a verbal and a visual memory, whereas abstract words are difficult to visualize and so only produce verbal memories.

Although visual and verbal memories often complement one another, sometimes they can be at odds. For example, in my research at the University of Pittsburgh's Learning Research and Development Center, my colleagues and I have found that asking people to describe visual memories that are difficult to verbalize, such as a face, can actually impair their memory of the face. Such "verbal overshadowing" of visual memories illustrates that some things really are better left unsaid!

In addition to verbal and visual long-term memories, people also appear to possess distinct memories for touch, sound, and—perhaps most interestingly of all—odor, which has a unique relationship with memory. As French writer Marcel Proust observed, the experience of an odor from childhood (in Proust's case, the smell of a madeleine biscuit dipped in linden tea) can trigger a flood of feelings and memories.

More recent research has confirmed Proust's observations. For example, psychologist Rachel Herz compared the effectiveness of odors to other cues in eliciting memories. In one study, people saw paintings that were either paired with different odors (e.g. the smell of peppermint) or different odor names ("peppermint smell"). She then provided either the odor or the word, and asked people to recall the painting that was paired with it. Interestingly, odors were no more likely than words to remind people of the paintings. However, they were much more likely to remind people of the emotional experience they had had. In a subsequent study, Herz compared odor cues with visual and tactile cues, and once again found that odor prompted the most emotional memories.

One explanation of why odor is particularly apt to trigger emotional memories is that the olfactory system is the only sensory system that directly connects with the *amygdala* (a center for emotional memories) and the hippocampus (a center for explicit long-term memories). This direct connection to the emotional and explicit memory centers of the brain may give odor-triggered memories their unique emotional punch.

Not only do we have numerous different types of memory, we also have a great variety of kinds of recollective experiences. For example, how often have you recognized someone but have not remembered where you know them from? It turns out that the experience of familiarity (knowing that something has been seen before) is readily distinguishable from the experience of actually remembering (specifically recalling where it was seen).

There are even differences between states of not remembering. For example, even when you can't remember a word, you sometimes know you'd recognize it, whereas other times, you have no sense that the word is on the tip of your tongue. Such differences illustrate the subtle varieties of memory experiences, and highlight the value of our own subjective awareness in understanding memory processes.