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SIXTH EDITION

PSYCHOLOGY

A Concise Introduction

Given this finding of its early development, it appears that iconic memory is an essential component of our flexible, multifaceted visual system. We will learn about infants' visual memory in Chapter 7, on developmental psychology.

To get a feel for how iconic memory works in nonlaboratory situations, let's think about seeing a bolt of lightning. It's not really a singular, continuous bolt. It is actually three or more bolts that overlap in our iconic memory and lead to the perception of the single flash of lightning. If you turn off the lights and have a friend quickly move a flashlight in a circular motion, you see a circle of light. Why? Again, iconic memory is at work; it isn't a continuous stream of light, but that's what you perceive. This has larger implications. It is iconic memory that allows us to see the world as continuous and not as a series of unconnected snapshots.

The other sensory registers that have been studied also have large capacities but brief durations. How brief varies with the register. For example, the auditory sensory register (called echoic memory) that processes auditory information has a duration of around four seconds, slightly longer than the duration of iconic memory (Darwin, Turvey, & Crowder, 1972; Glucksberg & Cowen, 1970). The longer duration of echoic memory is due to the nature of auditory information (Radvansky, 2017). Auditory information is not present all at once like visual information. It is stretched out over time. Hence, it must stay in echoic memory longer so that it can be properly analyzed. The only other sensory register that has been adequately studied is the haptic sensory register that processes tactile (touch) information. Its duration is estimated to be less than 2 seconds (Shih, Dabrowski, & Carnahan, 2009). Collectively, the sensory registers make up sensory memory, the first step of information processing in the three-stage memory model. However, when we think about memory, we aren't usually thinking about sensory memory. We're thinking about memory with a much longer duration. So let's take a look at the next major stage of processing in the memory system—short-term memory, which has a longer duration.

Short-Term Memory

Short-term memory (STM) is the memory stage in which the recognized information from sensory memory enters consciousness. We rehearse the information in short-term memory so we can transfer it into more permanent storage (long-term memory) and remember it at some later time. We also bring information from long-term memory back into short-term memory to use it to facilitate rehearsal, solve problems, reason, and make decisions; thus, short-term memory is often thought of as working memory (Baddeley, 2012; Engle, 2002). It is the workbench of the memory system. It is where you are doing your present conscious cognitive processing. What you're thinking about right now as you read this sentence is in your short-term memory. As you work to understand and remember what you are reading, you are using your short-term working memory. The capacity of this

short-term memory (STM) The memory stage with a small capacity (7 ± 2 chunks) and brief duration (< 30 seconds) that we are consciously aware of and in which we do our problem solving, reasoning, and decision making.

type of memory is rather small. Humans just can't process that many pieces of information simultaneously in consciousness. In addition, new information in this stage is in a rather fragile state and will be quickly lost from memory (in less than 30 seconds) if we do not concentrate on it. This is why it is called short-term memory. Now that we have a general understanding of the nature of this stage of memory, let's see how and what researchers have learned about its capacity and duration.

The capacity of short-term memory. To assess the capacity of short-term memory, researchers have used the **memory span task**. In this task, the participant is presented a series of items one at a time and has to remember the items in the order that they were presented. The list items could be any of several types of stimuli such as unrelated letters or words. On each trial, the specific list items change. For example, if words are used, then it is a different list of words on each trial. What have researchers found? George Miller provided the answer in his classic 1956 paper, "The Magical Number Seven, Plus or Minus Two: Some Limits on Our Ability to Process Information." Your **memory span** is defined as the average number of items you can remember across a series of memory span trials. Humans remember 7 ± 2 (5 to 9) chunks of information on memory span tasks. To see what Miller meant by the term *chunk*, let's consider the memory span task.

In the memory span task, different types of items can be used. If the items were unrelated letters, most participants would remember 5 to 9 unrelated letters. But if the items were three-letter acronyms (meaningful abbreviations like ABC or USA) or words (like dog or boy), participants would remember 5 to 9 three-letter acronyms or words (15 to 27 letters). In this latter case, participants remember more letters than in the first case, but they remember the same number of meaningful units. This is what is meant by the term *chunk*. A **chunk** is a meaningful unit in memory. The capacity limit in short-term memory is in terms of chunks, 7 ± 2 chunks. So if the chunks are larger for a particular type of material (words vs. letters), we remember more information but not more chunks. Experts in a particular area, such as chess masters, have larger chunks for information in their area of expertise (Chase & Simon, 1973). In the case of a chess master, for example, several chess pieces on the board form a chunk, whereas for chess novices, each piece is a separate chunk.

The duration of short-term memory. Now let's consider the duration of short-term memory, less than 30 seconds. Why is the duration of short-term memory said to be less than 30 seconds if this type of memory is equivalent to our conscious workspace? If we choose to do so, we could keep information in our consciousness for as long as we want, clearly longer than 30 seconds. The duration estimate refers to how long information can stay in short-term memory if we cannot attend to it. To measure this duration, researchers

memory span task A memory task in which the participant is given a series of items one at a time and then has to recall the items in the order in which they were presented.

memory span The average number of items an individual can remember across a series of memory span trials.

chunk A meaningful unit in a person's memory.

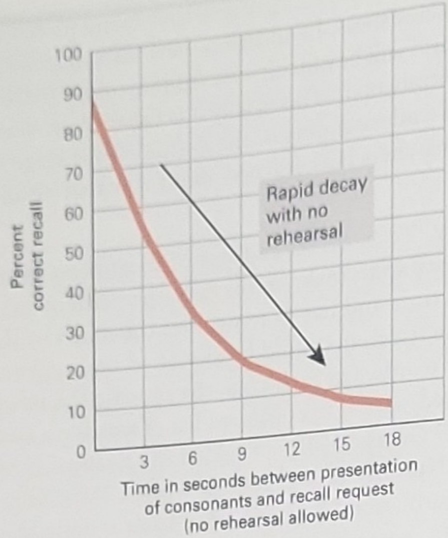


Figure 5.4 | Results for the Short-Term Memory Distractor Task | This figure shows how forgetting in short-term memory occurs over time. As the length of the distractor interval increases, forgetting increases very rapidly. In less than 30 seconds, recall is essentially zero. Information from Peterson, L. R., & Peterson, M. J. (1959). Short term retention of individual verbal items. *Journal of Experimental Psychology, 58*, 193–198.

developed the distractor task (Brown, 1958; Peterson & Peterson, 1959). In the **distractor task**, a small amount of information (three unrelated consonants such as CWZ) is presented, the participant is immediately distracted from concentrating on the information for a brief interval of time, and then the information must be recalled. How is the participant distracted? A number is immediately presented, and the participant has to count rapidly aloud backward by 3s (or by some other interval). Counting backward rapidly occupies the short-term work space and prevents the participant from attending to the three letters. The experimenter varies the length of the distraction period. When the distraction period is over, the participant must try to recall the letters. What happens? Some typical data are presented in Figure 5.4.

As you can see in Figure 5.4, the estimated duration for information in short-term memory is rather brief, less than 30 seconds. To relate this to everyday life, think about what happens when a friend gives you her new cell phone number. She tells you the number. It goes into your echoic memory, and you attend to it and recognize it. It enters your conscious short-term memory. You start to concentrate on it so you can enter the number into your contacts list on your phone. Now what would happen to that number if you heard someone screaming outside and you ran to see what had happened? Chances are that you would forget the phone number (just like participants forget the three consonants in studies using the distractor task), and then have to ask your friend to give you the number again. Information in short-term memory is in a temporary storage state, and we need to concentrate on it to prevent it from being lost. Generally we use

distractor task A memory task in which a small amount of information is briefly presented and then the participant is distracted from rehearsing the information for a variable period of time, after which the participant has to recall the information.

maintenance rehearsal to accomplish this. **Maintenance rehearsal** is repeating the information in short-term memory over and over again in order to maintain it. For example, in the case of the phone number, we rehearse it over and over again to ourselves until we complete the process of entering it into our contacts list.

Maintenance rehearsal is just one type of work (processing and manipulating information) performed in short-term memory. As we pointed out earlier, because of all of the various types of work done in short-term memory, it is now commonly referred to as working memory. For our purposes here, you can think of **working memory** as a more detailed description of short-term memory that includes the mechanisms that allow short-term memory to accomplish its tasks. To explain how working memory does this, researchers have proposed differing models of the mechanisms in working memory (Miyake & Shah, 1999). The most influential explanatory model is that of Alan Baddeley (2007, 2012; Baddeley & Hitch, 1974). In brief, Baddeley proposed that there are four components of working memory: (1) a phonological loop, (2) a visuospatial sketchpad, (3) an episodic buffer, and (4) a central executive. The phonological loop allows you to work with verbal information for a short period of time. It is what allows us to repeat the phone number in the maintenance rehearsal example over and over in order to maintain it. Similarly, the visuospatial sketchpad works with visual and spatial information, such as the figures and illustrations on a page in this book, as well as their spatial positions on the page. The episodic buffer integrates information from the phonological loop, the visuospatial sketchpad, and long-term memory, such as the integration of the visual information of your teacher writing on the blackboard, the verbal input from his lecture, and the meaning of all of this input from long-term memory. It is called the episodic buffer because it represents a temporary storage place (a buffer) for the integrated representation of what is happening at any moment in time (an episode). Lastly, the central executive component is responsible for coordinating the activities of and distributing resources to the other three components so that the work (the processing and manipulation of information) can be optimally accomplished. It is also the mechanism for controlling our attention and communicating with long-term memory. In brief, it is the CEO of working memory.

Now that we have a better understanding of short-term memory, we need to think about what our goal is when we are trying to learn. It is not merely to maintain information in short-term memory. Our goal is to put that information into long-term storage so that we can retrieve and use it in the future, and our short-term memory plays a large role in this task. In the last two major sections of this chapter, we will look at the process of encoding information from short-term memory into long-term memory and of retrieving that information from long-term memory back into short-term memory at some later time. But first we need to get an overview of long-term memory, the last memory stage in the three-stage model.

maintenance rehearsal A type of rehearsal in short-term memory in which the information is repeated over and over again in order to maintain it.

working memory A more detailed version of short-term memory that includes the mechanisms that allow short-term memory to accomplish its tasks.

long-term memory (LTM) The memory stage in which information is stored for a long period of time (perhaps permanently) and whose capacity is essentially unlimited.

Long-Term Memory

When we use the word *memory*, we normally mean what psychologists call long-term memory. **Long-term memory (LTM)** allows storage of information for a long period of time (perhaps permanently), and its capacity is essentially unlimited. Remember the trillions of possible synaptic connections in the brain that we discussed in Chapter 2? They represent the capacity of long-term memory. This capacity has been estimated to be around 2.5 petabytes (a million gigabytes). Although human memory does not work like a video recorder, imagining that it does will give you a better understanding of the enormous size of the capacity of long-term memory. If human memory worked like a video recorder, it could hold 3 million hours of television shows (Reber, 2010). You would have to leave the television running continuously for more than 300 years to use up all that storage. Whereas long-term memory has this incredibly large capacity, it definitely does not work like a video recorder (Lilienfeld, Lynn, Ruscio, & Beyerstein, 2010). However, many Americans believe that it does, about 50% according to recent surveys (Simons & Chabris, 2011, 2012). Why this misbelief exists is not clear. What is clear is that our long-term memories are far from exact replicas of what we experience; they are reconstructive and not reproductive. We will discuss both the reconstructive nature of long-term memories and theories of why we forget later in this chapter.

The durations and capacities for all three stages of memory are summarized in Table 5.1. Review these so that you have a better understanding of how these three stages differ. Next, let's consider different types of long-term memories.

Types of long-term memories. Memory researchers make many distinctions between various types of long-term memories (Squire, 2004). The first distinction is between memories that we have to recall consciously and make declarative statements about and those that don't require conscious recall or declarative statements (see Figure 5.5). What if someone asked you, "Who was the first president of the United States?" You would retrieve the answer from your long-term memory and consciously declare, "George Washington." This is an example of

Table 5.1 Durations and Capacities of the Three Memory Stages

Memory Stage	Duration	Capacity
Sensory memory	< 1 sec for iconic memory; 4–5 secs for echoic memory; < 2 secs for haptic memory	Large
Short-term memory	Up to 30 secs without rehearsal	7 ± 2 chunks
Long-term memory	A long time (perhaps permanently)	Essentially unlimited

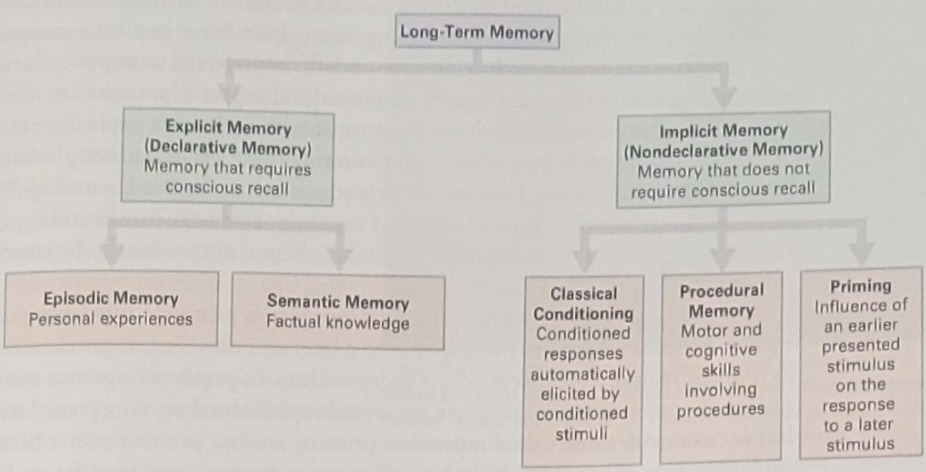


Figure 5.5 | Types of Long-Term Memory | Memory researchers make a distinction between two major types of long-term memory—explicit memory, which requires conscious recall, and implicit memory, which does not. Each of these two major types of long-term memory is further subdivided into more specific types of long-term memory, as defined in the figure.

what is called **explicit (declarative) memory**—long-term memory for factual knowledge and personal experiences. Explicit memory requires a conscious explicit effort to remember.

Tulving (1972) made a further distinction in explicit memory between **semantic memory**, memory for factual knowledge, and **episodic memory**, memory of your personal life experiences (the episodes in your life). Remembering that George Washington was the first president of the United States (semantic memory) is very different than remembering your first kiss (episodic memory). Semantic and episodic memories blend together in autobiographical memory (Williams, Conway, & Cohen, 2008). Autobiographical memories obviously include episodic memories of your past personal experiences, but they can also be about factual, semantic aspects of your personal history, such as remembering your birth date or what high school you attended.

Explicit memory is contrasted with **implicit (nondeclarative) memory**. Implicit memory is long-term memory that influences our behavior but does not require conscious awareness or declarative statements. Implicit memory happens automatically, without deliberate conscious effort. For

explicit (declarative) memory Long-term memory for factual knowledge and personal experiences. This type of memory requires a conscious effort to remember and entails making declarations about the information remembered.

semantic memory Explicit memory for factual knowledge.

episodic memory Explicit memory for personal experiences.

implicit (nondeclarative) memory Long-term memory for procedural tasks, classical conditioning, and priming effects. This type of memory does not require conscious awareness or the need to make declarations about the information remembered.

example, you remember how to drive a car and you do so without consciously recalling and describing what you are doing as you drive. Some implicit memories (like driving a car, typing, or hitting a tennis ball) are referred to as **procedural memories** because they have a physical procedural aspect (the execution of an ordered set of movements) to them. In contrast with declarative explicit memories, procedural implicit memories are like knowing "how" versus knowing "what." Not all implicit memories, however, are procedural memories (see Figure 5.5). We learned about another type of implicit memory, classical conditioning, in Chapter 4. Classically conditioned responses elicited automatically by conditioned stimuli are also implicit memories.

Another type of nonprocedural implicit memory is priming. In **priming**, an earlier stimulus influences the response to a later stimulus. Priming is classified as implicit memory because it occurs independent of a person's conscious memory for the priming stimulus. There are several experimental priming procedures, but let's consider one called repetition priming so that you can gain a better understanding of how priming works. In repetition priming, a person first studies a list of words and then at some later time is asked to complete a list of word fragments with the first word that comes to mind for each fragment. For example, the fragment *s _ c _ _ _* might be presented. The likelihood that the person answers "s o c i a l" (the primed word because the word *social* was on the earlier word list) is much higher than for unprimed words, such as *s o c c e r* or *s o c k e t*, that fit the fragment but were not on the list. Such priming occurs even when people had not recognized the list word on an earlier recognition test (Tulving, Schacter, & Stark, 1982). Thus, priming occurs when explicit memory for the word does not, which means that priming is an involuntary, nonconscious implicit process. Graf, Squire, and Mandler (1984) provided further evidence that priming is an implicit, nonconscious type of memory. They found that **amnesics**, people with severe memory deficits following brain surgery or injury, who had no explicit memory for new information could perform as well as normal adults on a repetition priming-word fragment task even though the amnesics had no conscious memory of having seen the words before.

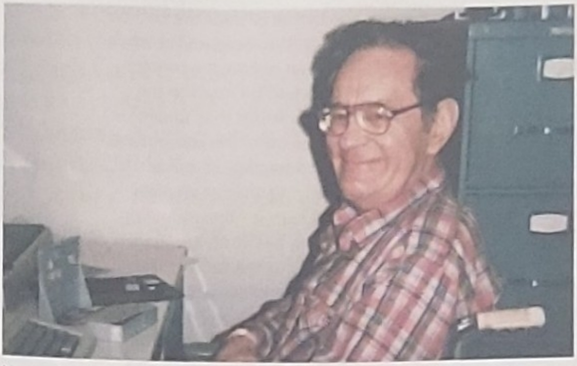
Next we'll see how other memory research with amnesics has allowed us to further differentiate explicit and implicit memory and even discover what parts of the brain seem to be involved in each type of memory.

procedural memory Implicit memory for cognitive and motor tasks that have a physical procedural aspect to them.

priming The implicit influence of an earlier presented stimulus on the response to a later stimulus. This influence is independent of conscious memory for the earlier stimulus.

amnesic A person with severe memory deficits following brain surgery or injury.

Amnesia, the loss of long-term memories. There is some evidence from the studies of amnesics that explicit and implicit memories are processed in different parts of the brain. We will focus our discussion of amnesics on the most studied amnesic in psychological research, H. M., whom we discussed briefly in Chapter 1. When H. M. was 7 years old, he was hit by a bicyclist and suffered a brain injury that later led to severe epileptic seizures in his teens (Hilts, 1995). In



Henry Molaison, shown above, is often referred to as the best known and most studied individual in the history of neuroscience. He died in 2008 at the age of 82. For confidentiality purposes while he was alive, only his initials, H. M., were used to identify him in the hundreds of studies that he participated in for over 5 decades. Following his death, his brain was sliced into 2,400 razor-thin histological sections for preservation and digital imaging, allowing researchers to create a virtual 3-D digital model of his brain (Annese et al., 2014).

Jenni Ogden.

1953 at the age of 27, H. M. had his hippocampus and surrounding temporal lobe areas removed with the hope of reducing his epileptic seizures (Corkin, Amaral, Gonzalez, Johnson, & Hyman, 1997). The seizures were reduced, but the operation drastically affected his long-term memory. Before the operation, he had normal short-term memory and long-term memory. After the operation, he had normal short-term memory, above-average intelligence, and no perceptual or language deficits, but he didn't seem able to store any new information in long-term memory (Scoville & Milner, 1957). For example, H. M. could read the same magazine over and over again and think it was a new magazine each time. He could no longer follow the plot of a television show because the commercials would interfere with his memory of the story line. If he did not know someone before his operation and that person introduced herself to him and then left the room for a few minutes, he would not know the person when she returned. Even Brenda Milner and Suzanne Corkin, the two neuroscientists who studied H. M. for decades, had to introduce themselves anew each time they met with him.

H. M. had **anterograde amnesia**—the inability to form new explicit long-term memories following surgery or trauma to the brain. Anterograde amnesia is contrasted with **retrograde amnesia**—the disruption of memory for the past, especially episodic information for events before, especially just before, brain surgery or trauma. Such amnesia is typical in cases of brain concussions. H. M. had some retrograde amnesia, especially for the several days preceding the surgery, but this was mild compared with his severe, pervasive anterograde amnesia.

Remember, as we just learned, amnesics have shown implicit repetition priming effects. So what about H. M.? Although he didn't form any new explicit long-term memories (but see O'Kane, Kensinger, & Corkin, 2004; Skotko et al., 2004), did he form new implicit memories? The answer is a resounding "yes" (Corkin, 2013). Let's briefly consider some of the experiments demonstrating this. H. M. demonstrated implicit procedural memory on a mirror-tracing task. In this task, you have to trace a pattern that can be seen only in its mirror image, which also shows your tracing hand moving in the direction opposite to its actual movement. This is

anterograde amnesia The inability to form new explicit long-term memories for events following surgery or trauma to the brain. Explicit memories formed before the surgery or trauma are left intact.

retrograde amnesia The disruption of memory for the past, especially episodic information for events before, especially just before, surgery or trauma to the brain.