

Memory is no passive “library of facts.” Instead, human memory is a series of active systems that receive, store, organize, alter, and recover information (Baddeley, Eysenck, & Anderson, 2009). For information to be stored for a long time—like, say, between when you study and when you need to remember for an exam—it must pass through a series of memories: sensory memory, short-term memory, and long-term memory. To pass through each memory, information must be encoded, stored, and retrieved. Encoding is the conversion of information into a form suitable for retention in memory. Once it is encoded, information must be held in memory storage for later use. Finally, retrieval involves the recovery of stored information. If you’re going to remember all of the 9,856 new terms on your next psychology exam, then you must successfully encode them in sensory memory, move them through short-term memory, and eventually retrieve them from long-term memory. These stages are summarized by the Atkinson–Shiffrin model of memory, shown in Figure 32.1 (Atkinson & Shiffrin, 1968; Sternberg, 2017). It is well worth tracing the series of memory events that must occur before you can pass that exam. Let’s start with a quick overview. Figure 32.1 The Atkinson–Shiffrin Model. Successful long-term remembering involves three stages of memory. Sensory memory encodes and stores sensory information for a second or two. Selectively attending to that information encodes small amounts in short-term memory, where it may be processed. Any resulting meaningful information may be encoded in long-term memory, where it may be stored until it is needed, at which time it may be retrieved as needed. It is worth noting that this is a useful, but highly simplified, model of memory; it may not be literally true regarding what happens in the brain.

Sensory Memory Let’s say that you sit down to memorize a few terms from this textbook for your exam next month. As you read, information is first automatically encoded in sensory memory, which can hold an exact copy of what you are seeing for a few seconds or less. We are normally unaware of the functioning of our sensory memories, which store information just long enough for it to be retrieved and encoded into short-term memory (Radvansky, 2011). For instance, look at the next definition in this paragraph and then quickly close your eyes. If you are lucky, a fleeting “photocopy” of the letters will persist. Iconic (eye–KON–ick) memories—visual sensory images—are typically stored for about a half second (Keysers et al., 2005). Similarly, when you hear information, sensory memory stores it for up to 2 seconds as an echoic memory, a brief flurry of activity in the auditory system (Cheng & Lin, 2012). If you are selectively attending (focusing on a selected portion of sensory input) to the terms you are studying, they most likely will be retrieved from sensory memory and encoded in short-term memory. Background events, such as a voice on the television announcing a new episode of American Crime, will not. However, if you are just looking at the words on the page but not paying attention (maybe you are also watching television), that does not bode well for your exam. As your elementary teacher might have commented, reading is more than just passing your eyes over the page.

Short-Term Memory Even though you are usually unaware of your sensory memory, you cannot fail to be aware of your short-term memory. Carefully read the definition contained in the next two sentences. Short-term memory (STM) holds small amounts of information for short periods of time. We are consciously aware of short-term memories for a dozen seconds or so (Jonides et al., 2008). That’s right—what you are aware of right now is in your short-term memory. Back to those definitions you are studying. You pay attention to what you are reading and so become aware of

the definitions when they are encoded in STM. Long-Term Memory If STM is so short-term, how do we remember for longer periods? Information that is important or meaningful is retrieved from STM and encoded in long-term memory (LTM), an unlimited capacity storage system that can hold information over lengthy periods of time. LTM contains everything you know about the world—from aardvark to zebra, math to *The Walking Dead*, facts to fantasy. Yet, there appears to be no danger of running out of room. LTM can store nearly limitless amounts of information. In fact, the more you know, the easier it becomes to add new information to memory. This is the reverse of what we would expect if LTM could be “filled up” (Goldstein, 2015). It also is one of many reasons for getting an education.

The Relationship Between STM and LTM Although sensory memory is involved every time we store information, we are most likely to notice STM and LTM. To summarize their connection, picture a small desk (STM) at the front of a huge warehouse full of filing cabinets (LTM). As information enters the warehouse, it is first placed on the desk. Because the desk is small, it must be quickly cleared off to make room for new information. While unimportant items are simply tossed away, meaningful information is placed in the files (Wang & Conway, 2004). When we want to use knowledge from LTM to answer a question, the information is returned to STM. Or, in our analogy, a folder is retrieved from the files (LTM) and moved to the desk (STM), where it can be used. Now that you have a general picture of memory, it is time to explore STM and LTM in more detail. What are the features of short-term (or working) memory? How are short-term memories encoded? Short-term memories can be encoded as images but most often they are encoded phonetically (by sound), especially when it comes to words and letters (Barry et al., 2011). When STM combines with other mental processes, it acts like a sort of “mental scratchpad,” or working memory, in which we do much of our thinking (Chein & Fiez, 2010; Nevo & Breznitz, 2013). Whenever you read a book, do mental arithmetic, put together a puzzle, plan a meal, or follow directions, you are using working memory (Baddeley, 2012; Prime & Jolicoeur, 2010). To experience your short-term memory at work, answer this question: How many doors are in your house or apartment? To answer a question such as this, many people form mental images—mental pictures—of each room and count the doorways they visualize (Ganis, 2013; Shorrock & Isaac, 2010). Stephen Kosslyn, Thomas Ball, and Brian Reiser (1978) provided an interesting example of using images in working memory. Participants first memorized a map like the one shown in Figure 32.2a. They were then asked to picture a black dot moving from one object, such as one of the trees, to another, such as the hut at the top of the island. Did people really form a working memory image to do this task? It seems that they did. As shown in Figure 32.2b, the time that it took to “move” the dot was directly related to actual distances on the map.

Storage and Rehearsal in Short-Term (Working) Memory For how long is a short-term memory stored? That depends, because you can keep sounds active in short-term memory by repeating them over and over, a process called maintenance rehearsal (see Figure 7.1). In a sense, rehearsing information (whether silently or out loud) allows you to “hear” it many times, not just once (Jarrold & Hall, 2013; Tam et al., 2010). You have probably used maintenance rehearsal to keep a phone number active in your mind while looking at your cell phone and dialing it. What if rehearsal is prevented, so a memory cannot be rehearsed? Without maintenance rehearsal, individual memories rapidly decay, or fade from STM. This feature of short-term memory prevents our minds from more permanently storing useless

names, dates, telephone numbers, and other trivia. In one experiment, participants heard meaningless syllables such as “xar,” followed by a number such as 67. As soon as participants heard the number, they began counting backward by threes (to prevent them from rehearsing the syllable). After a delay of between 12 and 18 seconds, their memory for the syllables fell to zero (Peterson & Peterson, 1959).

That’s why, when you are introduced to someone, that person’s name can easily slip out of STM. To avoid embarrassment, pay careful attention to the name, rehearse it several times, and try to use it in the next sentence or two, before it fades away (Radvansky, 2011). You also have likely noticed that STM is very sensitive to interruption, or displacement. You’ve probably had something like this happen: A friend gives you a phone number to call, say to order a pizza. As you start to dial, your friend suddenly asks you a question. You answer and return to dialing, only to find that your memory for the number was displaced by processing the question. Because STM can handle only small amounts of information, it can be difficult to do more than one task at a time (Mercer & McKeown, 2010). Isn’t saying stuff to yourself over and over also a way of studying? It is true that the more times a short-term memory is rehearsed, the greater are its chances of being stored in LTM (Goldstein, 2015; refer to Figure 32.1).

This is rote rehearsal (rote learning)—learning by simple repetition. But rote learning is not a very effective way to study. Elaborative processing, which makes information more meaningful, is a far better way to form lasting memories. When encoding information for the first time, it is best to elaborate on the meaning of the information, especially by forming links between that information and memories that are already in LTM (Raposo, Han, & Dobbins, 2009). As you read, try to reflect frequently. Ask yourself “why” questions, such as, “Why would that be true?” (Toyota & Kikuchi, 2005). Also, try to relate new ideas to your own experiences and knowledge (Karpicke & Smith, 2012). If you do not already recognize this advice, consider (re?)reading Module 1 if only to elaborate on your processing of the idea of elaborative processing.

The Capacity of Short-Term (Working) Memory How much information can be held in short-term memory? It depends on whether the information is comprised of sounds, mental images, or a combination of the two. Read the following numbers once, and then close the book and write as many as you can in the correct order. 8 5 1 7 4 9 3 This is called a digit-span test—a measure of attention and short-term memory (Bowden et al., 2013). Most adults can correctly repeat about seven digits. Now try to memorize the following list, again reading it only once. 7 1 8 3 5 4 2 9 1 6 3 4 This series was likely beyond your short-term memory capacity. Psychologist George Miller (1920–2012) found that short-term memory for sounds is limited to the “magic number” of seven (plus or minus two) information bits (Miller, 1956). A bit is a single meaningful “piece” of information, such as a digit. It is as if short-term memory has seven “slots” or “bins” into which separate items can be placed. A few people can remember up to nine bits, and for some types of information, five bits is the limit. Thus, an average of seven information bits can be stored in short-term memory (Radvansky, 2011). When all of the “slots” in STM are filled, there is no room for new information. Picture how this works at a party: Let’s say your hostess begins introducing everyone who is there, “Chun, Dasia, Sandra, Roseanna, Cholik, Shawn, Kyrene....” Stop, you think to yourself. But she continues, “Nelia, Jay, Frank, Patty, Amit, Ricky.” The hostess leaves, satisfied that you have met everyone. You spend the evening talking with Chun, Dasia, and Ricky, the only people whose names you remember! **Chunking** Before we continue, try your short-

term memory again, this time on letters. Read the following letters once, and then look away and try to write them in the proper order. T V I B M U S N Y M C A Notice that there are 12 letters, or “bits” of information. If you studied the letters one at a time, this should be beyond the seven-item limit of STM.

However, you may have noticed that some of the letters can be organized, or chunked, together. For example, you may have noticed that NY is the abbreviation for New York. If so, the two bits N and Y became one chunk. Chunking, then, is the process of grouping similar or meaningful information together. Does chunking make a difference? Chunking recodes (reorganizes) information into units that are already in LTM. In a classic experiment that used lists like this one, people remembered best when the letters were read as familiar meaningful chunks: TV, IBM, USN, YMCA (Bower & Springston, 1970).

If you recoded the letters this way, you organized them into four chunks of information and probably remembered the entire list. If you didn’t, go back and try it again; you’ll notice a big difference. Chunking suggests that STM holds about five to seven of whatever units we are using. A single chunk could be made up of numbers, letters, words, phrases, or familiar sentences. Picture STM as a small desk again.

Through chunking, we combine several items into one “stack” of information. This allows us to place seven stacks on the desk, whereas before there was room for only seven separate items. While you are studying, try to find ways to link two, three, or more separate facts or ideas into larger chunks, and your short-term memory will improve. In fact, some psychologists believe that STM may actually hold only four items, unless some chunking has occurred (Jonides et al., 2008; Mathy & Feldman, 2012). The clear

message is that creating information chunks is the key to making good use of your short-term memory (Gilchrist, Cowan, & Naveh-Benjamin, 2009; Jones, 2012). This means, for example, that it is well worthwhile to find or create meaningful chunks when you study. The Multimedia Principle

How about short-term memory for images? Unlike the digit span test, there is, as yet, no standard way of measuring short-term memory span for mental images. What we do know, however, is that people process words and mental images together better than they do words alone. This is the multimedia principle (Overson, 2014). When it comes to short-term memory, this means that adding mental images

to short-term memory interferes less with memory for words already in STM than adding more words. If the friend who gave you the phone number of the pizza joint grinned at you and gave you a thumbs up signal instead of asking you a question as you dialed the number, chances are your memory for the number would not suffer. (See Module 36 to see how the multimedia principle can be put to good use designing memorable presentations.) Are long-term memories also encoded as images or sounds?

They can be. But long-term memories are typically encoded on the basis of meaning. For example, try to memorize this story: He looked outside from cramped quarters. Many unknown objects moved swiftly in blackness. Fearless companions manipulated buttons while reading complex patterns. Flat familiar homeland resembled a rubber ball. Everyone knew that only lifeless things would be found among cold mountains surrounding barren valleys. But important papers anxiously awaited their arrival for no man had ever made such big news. (Adapted from Dooling & Lachman, 1971.) This odd story emphasizes the impact that meaning has on memory encoding. You can, of course, memorize the words without understanding their meaning. But people given the title of the story find it much more meaningful, and memorable, than those not given a title. See if the title helps you as much as it did them: “The First

Space Trip to the Moon.” In the “cramped quarters,” the rest of the crew is at the controls of the space ship. The “rubber ball” is the appearance of earth from space and the “important papers” are the newspapers waiting to report on the moon landing. Back to your psychology exam: If you make an error in LTM, it probably will be related to meaning. For example, if you are trying to recall the phrase test anxiety, you are more likely to mistakenly write down test nervousness or test worry than text anxiety or tent anxiety. One important way to gain meaning is to link information currently in STM to knowledge already stored in LTM. This makes it easier to encode in LTM and, hence, remember. For example, if you can relate the definition of test anxiety to a memory of a time when you or a friend was nervous about taking a test, you are more likely to remember the definition. Culture also affects the encoding of long-term memories (Ross & Wang, 2010). For example, American culture emphasizes individuals, whereas Chinese culture emphasizes membership in groups. In one study, European-American and Chinese adults were asked to recall 20 memories from any time in their lives. As expected, American memories tended to be self-centered: Most people remembered surprising events and what they did during the events. Chinese adults, in contrast, remembered important social or historical events and their own interactions with family members, friends, and others (Wang & Conway, 2004). Thus, in the United States, personal memories tend to be about “me”; in China they tend to be about “us” (Wang, 2013).

Storage in Long-Term Memory An electrode touched the patient’s brain. Immediately, she said, “Yes, sir, I think I heard a mother calling her little boy somewhere. It seemed to be something happening years ago. It was somebody in the neighborhood in which I live.” A short time later, the electrode was applied to the same spot. Again the patient said, “Yes, I hear the same familiar sounds. It seems to be a woman calling, the same lady” (Penfield, 1958). A woman made these statements while she was undergoing brain surgery. The brain has no pain receptors, so the patient was awake while her brain was electrically stimulated (Figure 32.3). When activated, some brain areas seemed to produce vivid memories of long-forgotten events (Jacobs, Lega, & Anderson, 2012).

False Memories There’s another reason to doubt that all our experiences are permanently recorded. Although elaborative processing is helpful when you’re making meaningful connections between new information and what you already know, it also can lead to memories of things that never happened (Jou & Flores, 2013). Gaps in memory, which are common, may be filled in by logic, guessing, or new information (Schacter, 2012). The result is often the storage of new long-term memories as older memories might be revised or even lost (Baddeley, Eysenck, & Anderson, 2009). To illustrate this point, Elizabeth Loftus and John Palmer (1974) showed people a filmed automobile accident. Afterward, some participants were asked to estimate how fast the cars were going when they “smashed” into one another. For others, the words “bumped,” “contacted,” or “hit” replaced “smashed.” One week later, each person was asked, “Did you see any broken glass?” Those asked earlier about the cars that “smashed” into one another were more likely to say yes, even though no broken glass was shown in the film. The new information (“smashed”) was incorporated into the original memories, elaborating them and producing a false memory. Such “memories” can seem accurate, but they never happened (such as remembering broken glass at an accident when there was none) (Loftus, 2003; Weinstein & Shanks, 2010).

Organizing Memories Long-term memory stores huge amounts of information during a lifetime. How are we able to quickly find specific memories? The answer

is that each person's "memory index" is highly organized. Does that mean that information is arranged alphabetically, as in a dictionary? Not usually. Information in LTM may be arranged according to rules, images, categories, symbols, similarity, formal meaning, or personal meaning (Baddeley, Eysenck, & Anderson, 2009). Psychologists believe that a network model best explains the structure, or organization, of memories. Memory structure refers to the pattern of associations among items of information. According to this view, LTM is organized as a network of linked memories.

Summary 32.1 In general, how does memory work?

32.1.1 Memory is an active system that encodes, stores, and retrieves information.

32.1.2 The Atkinson–Shiffrin model of memory includes three stages of memory (sensory memory, short-term or working memory, and long-term memory) that hold information for increasingly longer periods.

32.1.3 Sensory memories are encoded as iconic memories or echoic memories.

32.1.4 Selective attention determines what information moves from sensory memory, which is exact but very brief, on to STM.

32.1.5 While we are normally unaware of sensory memory, we are conscious of the contents of short-term memory, which can function as a working memory, or "mental scratchpad."

32.1.6 Long-term memories are encoded by meaning.

32.2 What are the features of short-term (or working) memory?

32.2.1 Short-term memories tend to be encoded by sound, are sensitive to interruption or displacement, and, although brief, can be prolonged through maintenance rehearsal.

32.2.2 STM has a capacity of about five to seven bits of verbal information, but this limit can be extended by chunking.

32.2.3 For transferring information to LTM, rote rehearsal is less effective than elaborative processing.

32.3 What are the features of long-term memory?

32.3.1 Long-term memories are relatively permanent. LTM seems to have an almost unlimited storage capacity.

32.3.2 Remembering is an active process. Elaborative processing can have the effect of altering memories. Our memories are frequently lost, altered, revised, or distorted.

32.3.3 LTM is organized into memory networks.

32.3.4 In redintegration, memories are reconstructed as one bit of information leading to others, which then serve as cues for further recall.

32.3.5 LTM contains procedural (skill) and declarative (fact) memories. Declarative memories can be semantic or episodic.