What’s It All About?

- What is cognitive psychology?
- How do we process and store memories?
- How do we build an efficient and accessible knowledge database?
- How does reflection on our own thinking impact learning?

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Chapter 5

Cognitive Learning Theories

Chapter Objectives

- Understand the cognitive perspective.
- Describe memory as a foundation for knowledge.
- Review the information processing model of memory.
- Describe characteristics of sensory memory.
- Describe characteristics of working memory.
- Describe characteristics of long-term memory.
- Describe the organization of knowledge and memory.
- List and explain multiple types of memory.
- Describe how to effectively build knowledge.
- Explain cognitive diversity and its impact on assessment
- Describe metacognitive knowledge.
- Describe metacognitive regulation.
- Describe metacognitive instruction.
- Describe developmental differences in metacognition

Extended Outline

Cognitive Learning Theories

From Today's Headlines

Nathan Burns ◈ **(February 6, 2021)** ◈ ***Tes Magazine***

Metacognition: 5 Remote Self-Regulation Strategies

In this 2021 article for *Tes Magazine*, Nathan Burns reports on metacognitive skills that bring a higher level of success to remote or online learning. According to the article, successful remote learners possess several qualities supporting their achievement. These include being hardworking, independent, confident, accepting of delayed gratification, able to regulate emotions well, and smart about organizing time and efforts. To encourage these qualities in all students, his article reviews five metacognitive strategies that can be taught to support student self-regulation.

First, teachers should strive to teach strategies like planning and evaluation. Such lessons could include planning essays, analyzing exam questions, and how to use knowledge organizers. Second, make sure students know where to go when they need assistance. This includes raising their hand, consulting a teaching assistant or teacher's aide (TA), email, or even chat boards. Such knowledge helps support student independence. Third, use calls to a student's home as an opportunity to reinforce their knowledge of self-regulation skills. Teachers can cover things like delaying gratification, prioritizing work, and monitoring for times of procrastination. Fourth, teachers can try establishing tutoring sessions. These sessions can help students clarify assignments and seek additional assistance. They also support skills associated with working with others. Finally, his fifth suggestion emphasizes instruction on how to become an effective learner. This might include how to create effective revisions, how to take quality and useful class notes, and problem-solving strategies.

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Teachers can encourage metacognitive skills that bring a higher level of success to remote or online learning, including ensuring students know where to go when they need assistance.

Online learning is challenging with its own set of issues. Students who are armed, however, with these suggested metacognitive strategies are in a better position to become successful, independent, and self-regulated learners.

Make the Connection

This chapter will look at some of the fundamental aspects of human thinking that make instruction in metacognition effective. First, we will begin with a general discussion of the cognitive psychological perspective, emphasizing the importance of creating an effective knowledge base through the formation of clear, accessible memories. Then we will look at how our memories build over time to form our knowledge base. We will investigate different types of knowledge and how to create knowledge that is easy to access, accurate, and efficient. Finally, like the article summarized above, we will cover in detail the role of metacognition in creating effective learners.

5.1 Cognition—A Focus on What We Think

In the last chapter, we introduced the concept of learning, defining it as a lasting change in an individual resulting from experience. One of the most debated questions in learning theory, however, is a lasting change in *what*? The behavioral perspective of learning is focused on observable behavior. That is, what is changed during learning is our actual behavior—the things that we *do*. This chapter will continue our look at learning, focusing on cognitive views. Cognitive theorists differ from behaviorists in that they emphasize the way we *think*. For example, if we were to look at your performance on a test of this material, we could examine how certain rewards (good grades or positive comments from friends or instructor) work to alter your behavior (study time and techniques). This would be a typical behavioral approach. Distinguish this type of approach from one attempting to understand your test performance by looking at your thoughts. Perhaps you love the material or see it as vital information to your future success as a teacher. Perhaps you are in the class with a friend and you have a strong desire to perform better. Looking at these factors and their impact on your performance is typical of a cognitive approach to learning. Again, the focus is on what we *think*. In this chapter, we will examine this theoretical perspective in detail.

5.1a Cognitive Perspective

Cognitive perspective

Theories and research related to an understanding of thinking and reasoning

The **cognitive perspective** includes theories and research related to an understanding of thinking and reasoning. This perspective includes research on a wide range of cognitive processes, or mental activities: memory, knowledge, problem-solving, attention, comprehension, and many others. One of the best ways to develop an understanding of the cognitive perspective is to compare it to the behavioral perspective covered in the last chapter.

Interconnections

The behavioral perspective is covered in detail in Chapter 4.

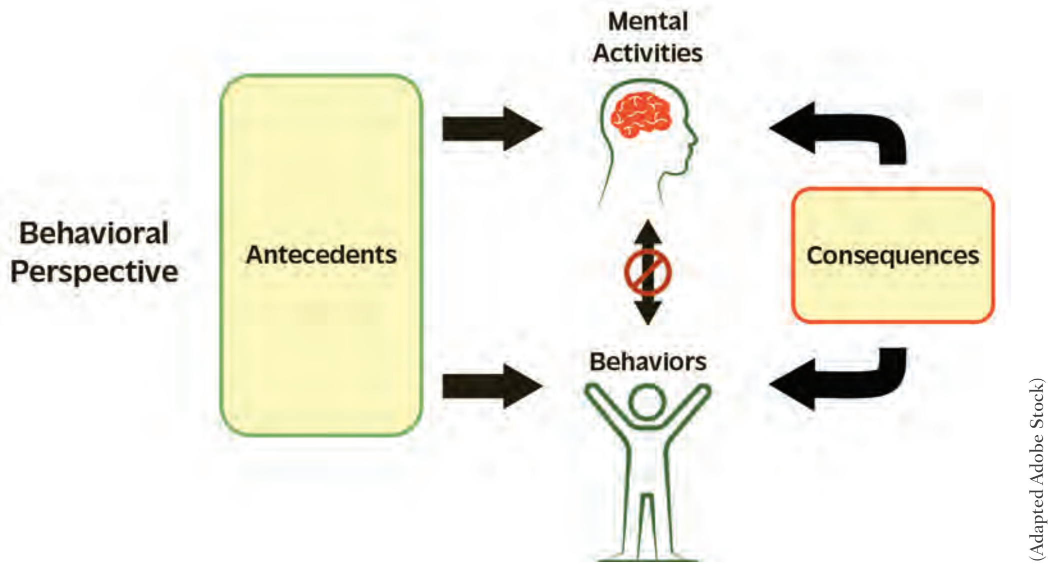
The primary difference between the cognitive and behavioral perspectives in terms of learning is in the interpretation of mental activities (thinking and reasoning). Both perspectives acknowledge that people have an elaborate mental life; however, where the perspectives differ is in the ability of these mental activities to alter our behavior. For example, Markus is an eleven-year-old boy interested in using meditation to improve his basketball skills. His physical education instructor had some tapes of professional basketball players demonstrating various shots that Markus studied diligently. After his review of the tapes, he began daily meditation where he visualized the professional athletes correctly making various shots. By the end of the week, he began working with his physical education teacher on perfecting his technique. The question here is whether meditation is able to improve his basketball performance. Can we improve our performance by thinking about the activity? Do we need actual instruction with a teacher providing appropriate feedback to improve?

The answer to these questions is quite complicated, but it emphasizes a fundamental difference between the cognitive and behavioral perspectives. Cognitive theorists believe that mental activities (such as Markus's meditation) play a direct role in the expression of behavior. This means that although environmental events are important in determining behavior, our *thoughts* can intervene and redirect behavior. Graphically, this idea is represented in Figure 5–1.

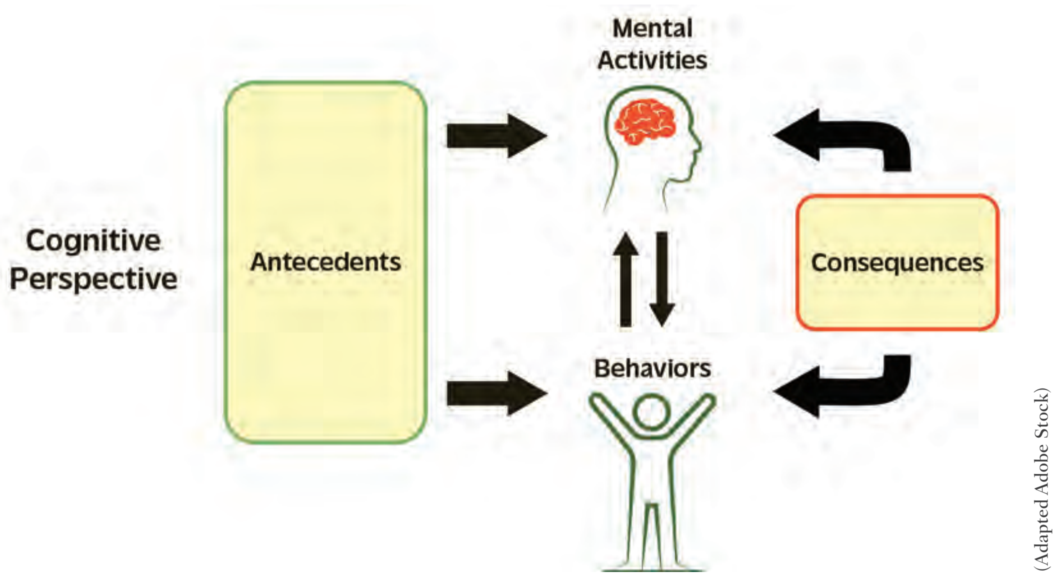
The belief that mental activities influence the expression of behavior makes vastly different interpretations of learning possible. Unlike the traditional behaviorist view of the individual as a passive respondent to environmental changes, cognitive theorists hold that people actively think about their environments and behavior. They engage in mental processes, like planning and goal setting, which have a direct bearing on behavior. This leads to another important point of comparison between behavioral and cognitive perspectives.

Figure 5–1 **Behavioral and Cognitive Perspectives**

The behavioral perspective emphasizes the importance of antecedents, behaviors, and consequences. Antecedents set the stage for behavior to occur, and consequences modify the expression of future behaviors. Mental activities are not considered to be a necessary part of the explanatory equation for behavior.



The cognitive perspective differs from the behavioral perspective in a critical way. It holds that mental activities have a causal relation to behaviors. That is, mental activities can modify or redirect behaviors. This seemingly simple difference places considerable importance on the role of mental activities in the expression of behavior.



Consequences (reinforcement and punishment) under the cognitive perspective do not exclusively determine behavior. Instead, they provide us with feedback about the possible results of our behavior. We are able to consider this feedback and use it to help us decide which type of behavior is best. Again, consequences themselves do not determine behavior according to the cognitive perspective.

When comparing the behavioral and cognitive perspectives, it is important to underscore that both behavioral and cognitive perspectives are theoretical. This means that each perspective is an attempt to explain human behavior. Sometimes students will ask, "Which theory is right?" Both theories have research support that demonstrates their usefulness in certain contexts. At this point, it is not so much whether one perspective is right or wrong but under what circumstances does a particular point of view become useful.

The cognitive perspective began to gain prominence during the latter half of the twentieth century. Feeling like the behaviorists failed to capture the complexity of the human experience, cognitive theorists began to study how thinking impacted behavior. The movement toward a cognitive perspective was also promoted by the advent of the computer. Being able to design machines capable of mirroring some of the complexity of human thinking enabled cognitive theorists to develop specific models for how we accomplish thought processes like knowledge acquisition and memorization.

Early cognitive researchers frequently employed a computer metaphor in the study of human thinking, comparing the way humans think with the way computers operate (Barutta et al., 2011). This "mind as computer" perspective allowed cognition to be conceptualized as an information processing system. This view is based on the many similarities between human thinking and computers. For example, computers and humans both take in information, store this information, process it in some way, retrieve it from memory, and produce an output. In fact, humans build computers and humans write computer programs. It follows that the way computers "think" mirrors the way we think.

(Adobe Stock)

Early cognitive researchers compared the way humans think with the way computers operate.

Researchers using a computer model to study human cognition learned much about the workings of the human mind, paving the way for the cognitive perspective to become a dominant force in psychology. In this chapter, we'll explore this research and the resulting theories regarding the multifaceted nature of human cognition, and we'll discuss topics such as memory, knowledge, and metacognition. We will outline the discoveries of information processing theorists regarding multiple memory stores, and we will also discuss different conceptualizations of knowledge. Throughout the chapter, we will also consider how cognitive research can help us better understand the teaching and learning process, highlighting classroom application of cognitive learning principles. Before we begin this exploration, let's examine the concept of memory, which is the foundation for much of our thinking.

5.1b Memory as a Foundation for Knowledge

Memory

The ability to retain a mental representation of our experiences

Human beings share a remarkable quality with one another: We can retain a mental representation of our experiences. The common term for this mental representation is **memory**. Memory allows us to store life experiences, so we can better adapt to the ever-changing world around us. Imagine what life would be like without the ability to remember events or experiences. Every situation we encountered would be new, as if we had never experienced anything like it before. This would make it very difficult for us to alter our behavior to best suit a particular life circumstance. In fact, our only behavior would be that with which we were born through our genetic endowment. Humans are hardly limited to inborn or genetically driven behaviors. We have a highly developed ability to store new information. For example, an infant recognizes her mother's face, preferring it to others, at around the age of two months (Slater, 2000). When a toddler touches a hot radiator, his memory of the painful event allows him to alter his future behavior to avoid being burned again. A second grader is capable of remembering basic addition, which makes learning and understanding multiplication possible. Not only can we remember people, consequences, and information, as these examples illustrate, but we can also remember events, images, feelings, and coordinated movements. In fact, there are a limitless number of everyday memory examples, and they are a testament to the remarkable complexity of memory as a cognitive process.

Memories, however, would quickly become overwhelming if we did not have an efficient organization technique. Without organization, we would have an enormous store of information, but we would be unable to find relevant memories. The human ability to organize information allows us to find and retrieve memories. This storage of memories in a complex but highly organized reservoir of information is called **knowledge**. Knowledge makes it possible for us to match the face of the person walking across the street to the name "Brent," so that we can call him by name when we say hello. Knowledge allows a physical education teacher to temper her expectations regarding a second-grade basketball game. She knows that young children have a different capacity for motor skills and educates accordingly. Knowledge is far from random or haphazard. Quite the contrary, as you will see in this chapter, the development of knowledge follows a highly organized, yet flexible course.

Knowledge
The accumulation of memories over time into a complex but highly organized body of information

The next section will look more closely at how we form memories. We will explore in detail a popular framework for understanding how we form memories. Afterward, we will return to the concept of knowledge and look at different types of knowledge and varying techniques for building a sound knowledge base.

Summarize and Reflect

1. There are a variety of differences between cognitive and behavioral interpretations of learning. The behaviorist views the individual as a relatively passive respondent to environmental changes. The cognitive theorist views people as actively thinking about their environments and purposefully altering their behavior.
2. Cognitive and behavioral scientists focus on similar scientific methods.
3. Cognitive psychologists began scientifically exploring topics such as memory and specific kinds of knowledge using a computer metaphor to guide their research.
4. Memory is the foundation for knowledge. It is defined as mental representations of experiences.
5. Knowledge is defined as organized sets of accumulated memories.

Informed Application

1. Using the cognitive perspective, create an example where a student's mental activities interact with their overt behavior to direct future expression of behavior.
2. Provide an example where a student's behavior is being exclusively shaped by antecedent conditions and subsequent consequences. Explain why mental activities are *not* a necessary explanatory element in your example.

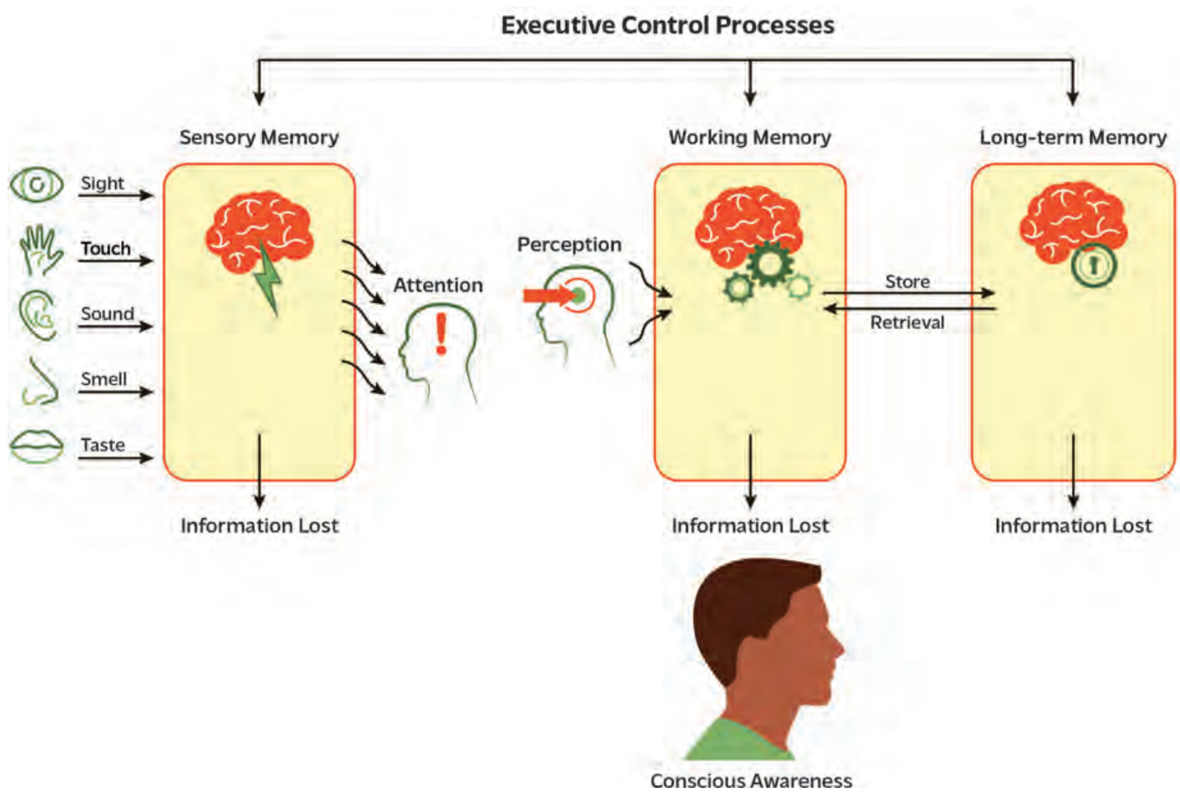
5.2 The Information-Processing Model of Memory

The information-processing model views memory as a process (Halford & Andrews, 2011). This means memorization is not a specific event, but the product of several step-like processes. It is the combination of these steps that results in our ability to retain and recall information. Information-processing models are based on a model proposed by Atkinson and Shiffrin in 1968. The basic steps of the information-processing model are presented graphically in Figure 5–2.

The information-processing model consists of three core components: sensory memory, working memory, and long-term memory. According to this model, information flows in from the environment and is processed by one, two, or all of the components. The outcome of this process will determine the nature of our memories. In addition to the core components, there are also important cognitive processes serving to link the individual components into a single functioning system. These processes are generally referred to as **executive control processes**. These components direct the flow of information through the memory system and impact effectiveness. Let's turn now to a detailed account of each of the information-processing model's main components.

Executive control processes
Memory components that direct the flow of information through the memory system and impact effectiveness

Figure 5–2 Information Processing Model



(Adapted Adobe Stock)

5.2a Sensory Memory

Take a moment to sit very still and concentrate on each of your senses. Starting with vision, begin to notice all the colors, shapes, and objects within your visual field. Continue with each of your other senses. What can you hear, feel, taste, and smell? Did you notice these sensory experiences before you focused your attention on them? Likely, you did not really think about the smell in the room before you were directed to do so. We typically under-appreciate the vast amount of sensory information coming in through our senses every second of the day; yet it is through this sensory information that we come to construct our understanding of the world. What happens to all the sights, smells, and sounds that enter through our senses? Obviously, it would be highly inefficient to try to process all incoming sensory information. The next time you are with a friend, take a quick look around the room and then close your eyes. Have your friend ask you a question about anything in the room. Did you know the answer? Chances are, even though you were just looking at the room, you were unable to answer correctly. The reason lies in the way our sensory memory functions. **Sensory memory** acts as a temporary holding system for incoming sensory information. The memory store appears to have unlimited storage *capacity*, taking in countless sights, sounds, tastes, smells, and physical sensations. Holding this vast amount of sensory information in our memory allows us enough time to select certain information for additional processing. For example, a student listening to a lecture on this chapter is actually taking in other sensory information at the same time. They are sensing the sounds coming from the other students, the feel of their clothing, the image of someone walking by the classroom, etc. It is the sound of the teacher's voice, however, that is most critical; and the sensory memory store allows us to hold all these sensations and pick the voice of the teacher for further processing.

Sensory memory

Memory that acts as a temporary holding system for incoming sensory information

(Adobe Stock)

Some sensory memories, such as the sound of a teacher's voice, are selected for further processing.

What about all the information in which we are not interested? What would life be like if we retained *all* information coming in through our senses? Likely, things would quickly get very confusing. We really don't need to remember what color shirt a student from another class was wearing as they passed by the door or the sound of a wet shoe on the hallway floor. Most of our incoming sensory information is not needed and, therefore, is quickly lost from the sensory memory store, a process known as **sensory decay**. Research shows that the amount of time it takes for a particular sensory memory to decay depends on the particular sense, but sensory memory is always very brief (Cheour et al., 2002). For example, visual memories typically last for about one second and auditory memories for about two to four seconds (Leahey & Harris, 1977; Pashler & Carrier, 1996). The important point to remember is that while sensory memory may have an unlimited *capacity*, it also has a very short *duration*, lasting only a few seconds. Not all sensory memories decay, however. Some of these memories are selected for further processing (like the sound of the teacher's voice in the preceding example) through two mechanisms: attention and perception.

Sensory decay

Refers to the majority of our incoming sensory information that is not needed and therefore is quickly lost from the sensory memory

Attention

Attention is a cognitive resource fundamental to storing memories. **Attention** directs sensory memories toward the next component in the process, working memory. When you attend to the sound of your teacher's voice, for example, you select that memory for additional processing. If you had not paid attention to the sound of the voice, that particular sensory memory would have decayed. Sometimes, directing our attention is easier than others. For example, think about how much effort it takes to pay attention to a really good action/adventure movie.

Attention

That which directs sensory memories toward the next component in the information processing model of memory, working memory

(Adobe Stock)

Externally directed attention is all that is required when watching a good movie.

(Adobe Stock)

Internally directed attention is necessary when having to read one hundred pages of a textbook in one evening.

It probably does not take much effort at all since the movie is very engaging and easily captures our attention. Now, consider how difficult it is to carefully read one hundred pages of your biology textbook in one evening. In this situation, the textbook material is less likely to naturally engage your attention resources. To read the material, you will probably need to constantly refocus your attention to the words as the evening progresses. Reading the biology book requires internally directed attention, while the movie example illustrates externally directed attention.

Allocation of attention resources is extremely important in the classroom. While purposefully directing attention requires effort for all of us, some individuals appear to have better control than others. Classroom environments can also vary substantially in how much they externally mediate a student's attention resources. Even in the most engaging classroom environment, all students will be required to attend to tasks that may not be inherently engaging. If the student can internally direct his attention, he has a better chance of meeting with task success. If he has trouble directing his attention toward less engaging tasks, then important information coming in through his senses will decay, and he will not benefit from the educationally relevant information available to him. Teachers face this situation almost every day. They stand in front of the class, provide directions, and ask the class to begin the task. Almost invariably, at least one student will miss the instructions and not know what to do. What happened? Did the student not hear the teacher's instructions? While this is one possible explanation, another possibility lies in a breakdown in the direction of attention resources.

In all likelihood, the student did "hear" the instructions. At least, the sounds registered in the student's sensory memory. The student was, however, paying attention to an interesting crack on his desk at the time, thus focusing his attention elsewhere. Again, without attention, sensory memories simply decay. This has obvious implications for creating educationally productive environments. Students vary significantly in their ability to purposefully direct attention. In fact, the ability to direct attention can be viewed as a continuum, with some students having excellent control and others having poor control. Teachers who are sensitive to individual differences among students are in a better position to provide appropriate supports. These supports require the teacher to make important classroom information the most engaging aspect of the instructional environment. The supports may be simple, such as repeating instructions one-on-one. They may also require more effort, such as setting up a cueing system or posting written instructions. It should be noted that students who require more substantial support in directing their attention might be at risk for attention-deficit/hyperactivity disorder (ADHD). ADHD is a behaviorally defined diagnosis used to describe children who have a unique set of problems, one of which involves significant difficulty with directed attention. Our focus in this chapter is to help you develop a basic understanding of cognitive processes. We will outline strategies for providing more substantial external supports for children with ADHD in Chapter 11.

Interconnections

Teaching students with attentional deficits is challenging. Instructional strategies are covered in detail in Chapter 11.

Perception

Perception is the cognitive process of assigning meaning to incoming sensory information. Take a look at the symbol below. What letter do you see? Is it an A or an H? Actually, it is neither. The symbol is not a perfect representation of either an A or an H. You may have *perceived* the lines as either an A or an H because you tried to assign meaning to the incoming sensory information.

Perception
The cognitive process of assigning meaning to incoming sensory information

In the early part of the twentieth century, a group of psychologists became interested in the role that perception plays in shaping our understanding of the world. Collectively, these psychologists were called the **Gestalt psychologists**. *Gestalt* is a German word meaning "configuration," and these scientists were so named because they believed that our perception of sensory information depends on the form or configuration of the information. Research conducted by the Gestalt psychologists led to their outlining four basic perceptual processes, presented in Figure 5–3.

Gestalt psychologists
The group of psychologists interested in the role that perception plays in shaping our understanding of the world

Figure 5–3 Four Basic Perceptual Processes

Gestalt principles are important to consider because they help us appreciate the degree to which we actively try to make sense of the world (Gallace & Spence, 2011). Instead of always perceiving the world as made up of individual items, we actively seek patterns, forms, or meaningful configurations.

Along with attention, perception helps sensory memories move into working memory. Attention and perception often work together to determine which information moves into working memory since it is not always enough to just pay attention to something. We may attend to a particular sensory item, but fail to make any sense of it, resulting in the memory being lost through decay. To actively process information, we not only need to pay attention to it, we must also perceive it as meaningful. Recall the symbol presented earlier. We will now alter the context in which this symbol is presented, making it more meaningful and causing you to perceive the lines as both an A and an H. As you can see below, the additional context provided by neighboring letters of the alphabet causes you to *perceive* the same symbol differently in the two words.

The symbol now has meaning, and the information it provides can move on to the working memory store for additional processing. In the classroom, providing a meaningful context for *to-be-learned* information is an important avenue for facilitating learning. Consider the situation of a child in kindergarten presented with the words BAT and HAT. While the child may not be able to read the words when they are presented on flashcards, providing a context by adding pictures above the words allows them to perceive the letter configurations as meaningful so they can "read" the words.

(Adobe Stock)

In first grade, the child might be asked to choose which picture is represented by the word *HAT*. This provides a meaningful perceptual context to facilitate the processing of the information in working memory, encouraging discrimination between the *B* and *H* sounds.

While it is easy to see how important meaningful context is in perception, it is often quite challenging to create such learning environments for all students. A student's cognitive development, level of knowledge, past experiences, or present skill level may not allow them to benefit from a lesson in the way the teacher intended. By asking questions regarding student perceptions and carefully listening to the responses, teachers can develop responsive learning environments that maximize movement of sensory memories into working memory. The important point to remember is that students are actively trying to make sense of the world, and teachers can use this to help students master curricular goals.

Bottom-up processing

Process by which an individual attempts to arrive at a meaningful perception using sensory items to build an appropriate understanding

Top-down processing

Process of using existing knowledge to guide our understanding of new information

Another factor to consider when trying to understand students' perceptions is whether they are building meaning from incoming sensory information or from prior knowledge retrieved from memory. **Bottom-up processing** occurs when an individual attempts to arrive at a meaningful perception by using sensory items to build an appropriate understanding. For example, a child in kindergarten might read a new word, *CAT*, by matching a sound to each letter, blending the sounds together in order, and ultimately recognizing the word, conjuring up an image of her own pet. Meaningful perceptions can also be reached using **top-down processing**, or using existing knowledge, to guide our understanding of new information (Liu et al., 2011). Again, using the kindergarten example of reading the word *CAT*, we might show a picture of a cat with the word printed underneath. In this way, the child can start with something they already know (prior knowledge) and then interpret the incoming visual information (C-A-T) in light of that knowledge. It is important to remember that meaningful interpretations of sensory information may use either bottom-up or top-down processing, and both types of processing have implications for classroom instruction.

Attention and perception are both important components of human information processing, yet most of this work takes place outside our awareness. For example, you didn't have to think about whether you were going to attend or how to interpret the symbols below; you simply looked at the words while you were reading, and your perceptual set allowed you to read them as THE CAT. As soon as you directed your attention to the words and derived meaning from them, the information was immediately transferred to the next phase in the information processing system, working memory.

5.2b Working Memory

What we now call working memory was originally conceived as just another temporary memory store on the way to permanent memory, so it was given the name short-term memory. Later research, however, revealed that both temporary storage and active processing occur in this intermediate store. In fact, our conscious thinking and reasoning occur here. **Working memory** is a term that better describes a memory store where information can be both temporarily stored and consciously processed. The information processed in working memory may come from the sensory store or, as we will see in the next section, from long-term memory. Recall, this information can be understood graphically using the figure at the beginning of this section.

Working memory

A term that better describes a memory store where information can be both temporarily stored and consciously processed

Consider the following example. First, recall your own phone number, including the area code. You weren't thinking about your phone number at all before reading the previous sentence. In fact, it was outside your conscious awareness, housed in the long-term memory store. In order to remember your phone number, you brought the information from long-term memory into your working memory store, and it became *conscious*. Our ability to selectively move information into working memory allows us to maintain a vast unconscious long-term store of information.

Remember that working memory also allows us to process incoming information from sensory memory, to which we assign meaning based on information from long-term memory. In this way, working memory allows us to integrate our sensory experiences with information we have already learned. Extensive research has been conducted to better understand the information processing, which occurs in working memory. Cognitive scientists have explored the duration and capacity of working memory, as well as information transfer from working to long-term memory. We turn now to an exploration of this groundbreaking research regarding human thinking.

Capacity and Duration

In 1956, George Miller, a psychologist at Princeton University, claimed to have been "persecuted by an integer." He was haunted, in fact, by the number seven. In the 1950s, researchers studying human mental function had repeatedly found evidence of limits on human processing of sensory information (Garner, 1953; Pollack, 1952), and Miller couldn't help but notice these limits all hovered around the number seven. In his seminal paper, *The Magical Number 7 Plus or Minus 2*, Miller outlined for the first time what has now become standard knowledge in cognitive psychology—the capacity of working memory is around 7 ± 2 items. This limited capacity is easily demonstrated with a simple example. Have a friend write down twenty 2-digit numbers and then read them aloud to you, one per second. After she finishes, quickly write down as many of the numbers as you can. If you were only able to recall seven or so numbers, you are not alone. In fact, research shows that any person who attempts this task will probably be able to recall somewhere around five to nine numbers. Practically, this means we have significant limitations on how many things we can think about at once.

Not only do we have limitations on the number of items we can consider at once, but also on the amount of time items stay in working memory (Gabales & Birney, 2011). In other words, working memory has both a limited capacity and limited duration. The duration of working memory is around thirty seconds. An effective way to demonstrate the duration of working memory is to have a friend tell you his or her parents' phone number, without area code. Repeat it back to ensure it is in working memory. Then immediately start counting backwards by threes from one hundred. Keep counting backwards until you reach zero. After you reach zero, see if you can recall the phone number. Most people will be unable to fully recall the number, particularly if the number is unlike other phone numbers with which they are familiar. The phone number was quickly lost because of the limited duration of working memory.

Get the FACTS!

7 Items

Capacity of working memory is about 7 items.

Miller (1956)

The limited duration and capacity of working memory, however, can be altered. If the 30-second duration and 7 ± 2 capacities were absolute, our thinking would be limited and inflexible. To achieve the incredible flexibility characteristic of human thinking, we need to have a mechanism for maintaining memories in working memory for longer periods of time. We also need a tool to enable us to think about more information at one time. The cognitive mechanisms of chunking and rehearsal help address these issues.

Chunking and Rehearsal

We can increase the amount of information we process in working memory, without increasing its capacity, by changing the way we think. In order to do this, we combine several individual pieces of information into a single meaningful unit, or chunk of information. **Chunking** essentially allows us to expand the amount of information available in working memory without increasing its capacity. For example, if you try to remember the following series of letters, you will exceed the capacity of working memory.

Chunking

Process that essentially allows us to expand the amount of information available in working memory, without increasing its capacity

H P S U C E D T C Y O A G O N O I Y L A L

The twenty-one letters in this sequence will overwhelm your working memory store, causing earlier items to leave the store to make room for the newer items. The trick to easily remembering all these letters is to take certain letters and group them together into smaller chunks of information. Although it may not be obvious, these letters combine to form two words.

E D U C A T I O N A L   P S Y C H O L O G Y

Rehearsal

Refers to the general process of actively thinking about information

Maintenance rehearsal

The specific process of mentally repeating information currently held in working memory

Thinking of these letters as two simple words reduces the load on working memory from a virtually impossible twenty-one items, down to a very manageable two. While the capacity is still limited to 7 ± 2 items, the "items" contain more information. Now that the words "Educational Psychology" are in your working memory, how can you keep them there for more than a few seconds?

The cognitive strategy of **rehearsal**, or repetitively thinking about the information, increases the length of time information stays in working memory without changing the 30-second duration. Essentially, each time you think about a piece of information, the 30-second clock begins. If you think about the information again after twenty-five seconds, the clock starts over. There are two primary types of rehearsal: maintenance and elaborative.


(Adobe Stock)

In process of rehearsal, each time you think about a piece of information, a 30-second clock begins.

Maintenance rehearsal is the process of mentally repeating information currently held in working memory. For example, try to commit the following number sequence to memory: 4-3-2-7-9-6-1. In order to complete this task, you are likely to mentally repeat the number sequence to yourself several times. Similarly, when a physical education teacher asks his students to get a soccer ball out of the storage closet, dribble it the length of the gym, and line up on the west wall of the gym, the students are likely to continue to repeat these instructions to themselves until they are in position along the wall. This repeating of information can maintain information in working memory for an indefinite period of time; however, it requires constant effort. It is also rather inefficient at getting the information into the long-term store. For example, without looking back, what was that number sequence you just tried to remember? While it might not be difficult to keep the list of numbers in memory for a few minutes by using maintenance rehearsal, it is unlikely you were able to commit this meaningless information to long-term memory. It would require much effort and many, many repetitions of the information before it would move into the long-term store. Remember the amount of practice required to commit multiplication facts to long-term memory? While this type of rehearsal will eventually result in information moving into long-term memory, it requires a great deal of practice.

Elaborative rehearsal

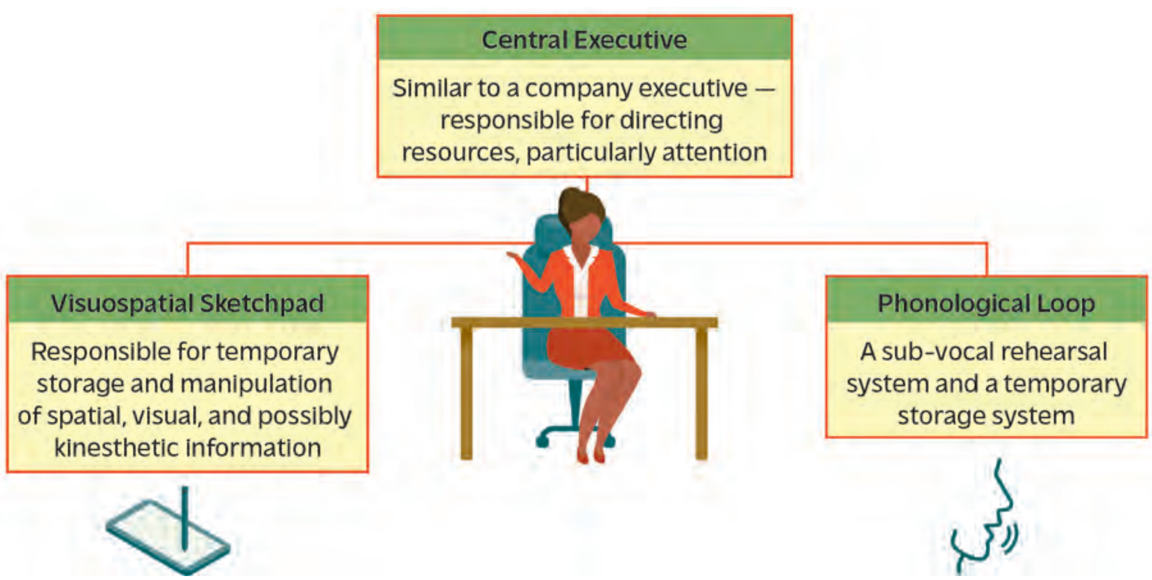
The specific process of taking something you are trying to learn and connecting it to something you already know

A more efficient strategy for moving information from working memory to long-term memory is to use elaborative rehearsal. **Elaborative rehearsal** is the process of taking something you are trying to learn and connecting it to something you already know. If students can create a meaningful association between a new piece of information and something they already know, the new item will be much easier to recall. This is why it is easier to learn about the national deficit in social studies when you realize it is similar to asking your parents for an advance on your allowance. While this example of elaboration is student driven, teachers can also provide elaborative associations to assist students in learning new information, such as using the acronym ROY-G-BIV for learning the color spectrum (red, orange, yellow, green, blue, indigo, violet). Many of us were taught the elaborative association, "spring forward–fall back," to help us remember whether to move the clock forward or backward as a function of daylight savings time. These types of elaborative associations dramatically increase retention of information, moving the storage demand from working memory to the long-term store. Before we turn to a discussion of long-term memory, however, let's take a closer look at the ways different types of information are processed in working memory.

Components of Working Memory

In 1974, Baddeley and Hitch proposed that working memory is not a single entity but actually consists of three different components: a phonological loop for auditory or verbal information, a visuospatial sketchpad for visual information, and a central executive for the management of attentional resources. Newer research has provided considerable support for this interpretation of working memory. Figure 5–4 provides a graphical representation of these concepts.

Figure 5–4 Components of Working Memory



(Adapted Adobe Stock)

Phonological Loop

One of the most extensively studied of these components is the phonological loop. Recall from Chapter 2 that phonology refers to speech sounds. Essentially, the **phonological loop** is the part of working memory that allows us to repeat auditory and verbal information. When we use the maintenance rehearsal strategy of holding information in working memory by silently repeating the information, the phonological loop is in operation. While the phonological loop

Phonological loop
The part of working memory that allows us to repeat auditory and verbal information

is a fairly reliable system, it is susceptible to competition from new information that is phonologically similar. For example, you will have little difficulty remembering a series of words such as *pit, day, cow, soak, pen;* but you are likely to have more difficulty with words such as *man, cat, map, cab, can* (Baddeley, 1966). Research suggests that the reason the second list is more difficult is due to the phonetic similarity of the words. Each word contains the short *a* sound, and each word has at least one other sound present in another word. In effect, we say the words to ourselves in the phonological loop, and we get confused when the sounds of the words are too similar.

The phonological loop also appears to have some important time constraints, which are based on the length of time it takes us to say a chunk of verbal information. Research shows we can only hold as much information in the phonological loop as we can say to ourselves within a 1.5- to 2-second time period. Thus, the processing of information in the phonological loop requires a new constraint on the classically cited five to nine items for working memory. While the capacity of the phonological loop is also five to nine items, these items must take less than about two seconds to say. For example, if you are asked to memorize five to nine digits, you can easily repeat these to yourself within a 2-second timeframe. What if you were asked to memorize five to nine multisyllable words? Repeating a list where each unit of information takes a larger amount of time to say is problematic because the total time exceeds the 1.5- to 2-second limit of the phonological loop (Gray, 2002).

(Adobe Stock)

The phonological loop represents our verbal working memory and is likely influential in learning a spoken language.

The phonological loop represents our verbal working memory, and it is likely influential in learning a spoken language, since sound patterns linked to meaning are required for language learning. It also appears to be important for classroom achievement and is sensitive to memory enhancing instruction (St. Clair-Thompson et al., 2010). Children who experience problems with the functioning of the phonological loop may show speech and language delays (Baddeley et al., 1998). Further, the efficient operation of the phonological loop is often used as an indicator of intellectual potential. The Wechsler intelligence tests, for example, includes a digit span subtest, which measures short-term auditory memory (Wechsler, 1981). Additionally, research on the phonological loop and intellectual ability show that phonological loop performance becomes more impaired as intellectual ability decreases (Schuchardt et al., 2010).

While research shows that children as young as three years old store phonological information in working memory, active and efficient rehearsal within the phonological loop does not develop until later in childhood. It appears this happens around the time children begin to learn to read (Gathercole & Adams, 1993; Waring et al., 2019). In fact, some research suggests that problems with the phonological loop may be related to difficulty with reading acquisition (Gathercole & Baddeley, 1990, 1993). Interestingly, research on the function of the phonological loop and mathematics shows that the phonological loop is more important in mediating performance at earlier ages (Meyer et al., 2010). The visuospatial sketchpad becomes increasing important as children develop. The next section reviews this important component of working memory.

The Visuospatial Sketchpad

The visuospatial sketchpad is the component of working memory responsible for spatial, visual, and possibly kinesthetic (movement) information. Just like the phonological loop system, the visuospatial system has a limited duration and is sensitive to interference from other visual information. For example, if you were to ask students to engage in a visual task such as mentally rotating a figure presented on the board, they would be particularly compromised by other visually oriented information, but not necessarily by incoming auditory information. This is not to say that the visuospatial and phonological systems are completely independent because both systems are constrained by the overall limited capacity and duration of working memory.

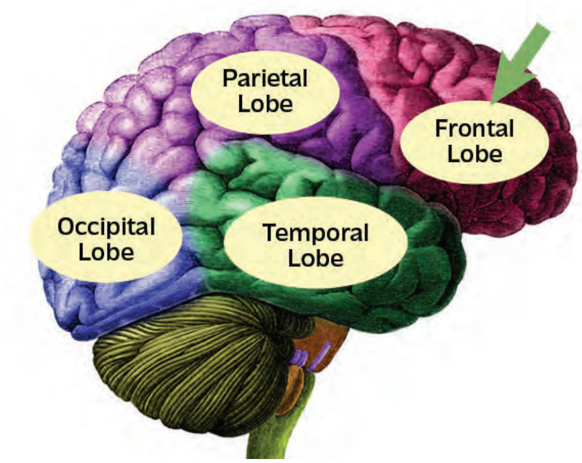
Research regarding the visuospatial sketchpad indicates it also has educational implications. Studies show that the functioning of the visuospatial system is important for maintaining an accurate line track when reading. It is also important for keeping the reader oriented to the text layout on a page (Baddeley, 2003). Further, it has been proposed that the visuospatial sketchpad may help us maintain a representation of the grammatical elements of a sentence from beginning to end so that accurate comprehension is possible (Phillips et al., 2004). Recent research on visuospatial processing indicates, however, that maintaining even a simple visual representation for more than a few seconds is very effortful. Successful representation of the item requires constant refocusing of attention (Baddeley et al., 1999). The purposeful direction of attention places strong demands on the last of our three components of working memory, the central executive.

The Central Executive

The **central executive** is the supervisory system of working memory, managing the allocation of resources. Depending on the nature of the task, the central executive may tap the phonological loop, the visuospatial sketchpad, or both. It also controls the use of information from sensory memory, the retrieval of information from long-term memory, and the integration of such information with reasoning or planning tasks. Its responsibilities are like those of a company executive, taking little part in the actual work of the system but providing much needed direction and overall vision (Baddeley, 1986). The functions of the central executive system are the least understood of the components of working memory, largely because these functions are complex and many. The central executive is responsible not only for directing attention and integrating information from other memory systems but also for planning and directing future thinking and behavior. If we go back to the "mind as computer" metaphor presented earlier, the central executive is like the central processing unit of a computer (CPU). The CPU is responsible for retrieving appropriate information from the hard drive, running the appropriate programs, and producing a usable output.

Central executive

The supervisory system of working memory that manages the allocation of resources



Much evidence points toward the frontal lobes as important in central executive processes.

Researchers have looked extensively for a specific region in the brain where this CPU-like system might be located, and much evidence points toward the frontal lobes as important in central executive processes (Baddeley, 1986; Cohen et al., 1994; Wilkins et al., 1987). In fact, people who have damage to the frontal lobes show significant problems across a wide range of cognitive and behavioral processes, outlined in the *Executive Functioning Skills* list in Section 5.2c Long-Term Memory. Collectively, these processes are known as executive functions. As you can see in the list, problems with any or all of these functions could negatively influence classroom performance. We'll return to the topic of executive function deficits in Chapter 12, when we discuss ADHD in detail. Now, we'll turn our attention to one of the problems with working memory, the ease with which we forget information.

Interconnections

See Chapter 12 for a discussion of executive functions as they relate to Attention-Deficit/Hyperactivity Disorder.

Forgetting

Information in working memory is not intended to last for a significant period of time. How then, does information leave working memory, and where does it go? Sometimes, information is moved to the long-term store (which we will discuss in the next section). At other times, information is simply lost or replaced. Multiple theories have been proposed to explain this phenomenon, but the two most investigated are decay theory and interference theory. **Decay theory** asserts that, over time, information not actively rehearsed or transferred to long-term memory will gradually weaken and fade away. Another popular theory about why we easily lose information from working memory is called **interference theory**. This theory maintains that memories do not simply decay over time; instead, the information becomes interfered with by older memories or incoming information (Szmalec et al., 2011). Both processes are likely important determinants of everyday information loss in working memory (Waugh & Norman, 1965). In short, working memory is easily overloaded by our attempts to write and rewrite information in the same mental space and time limited system. Next, we'll turn our attention to the memory store that is virtually impossible to overload, long-term memory.

Decay theory

Belief that, over time, information not actively rehearsed or transferred to long-term memory will gradually weaken and fade away

Interference theory

Belief that memories do not simply decay over time; instead, the information becomes interfered with by older memories or incoming information

5.2c Long-Term Memory

Long-term memory is an important part of the information processing system, as it is responsible for the *relatively* permanent storage of information. This type of storage system allows us to retain memories of our past experiences, which can be brought back into working memory for additional processing. It is because of our long-term store that we can learn from our experiences. The formation of long-term memories (knowledge) has traditionally been the goal of education; yet, moving information into the long-term store and retrieving it on demand is often quite difficult. In the following sections, we'll examine the factors important in storing and retrieving information from long-term memory.

Executive Functioning Skills

- Directing long-term memory storage and retrieval
- Inhibition of reflexive behavioral responses
- Directing attention and filtering extraneous information
- Interrupting and returning to an ongoing activity
- Regulating social behavior, including empathetic responses
- Modifying motor behavior based on feedback
- Shifting cognitive resources based on task demands

Adapted from McCloskey, G. (2011). *Executive Functions: A General Overview.* Philadelphia College of Osteopathic Medicine.

Capacity and Duration

The capacity of long-term memory is similar to sensory memory in that it appears to be virtually unlimited. Investigations of some of the oldest people alive indicate they are still capable of storing new information in the long-term store. This is an impressive feat, given the wealth of information collected over an individual's lifespan. The duration of long-term memory also appears to be unlimited. Again, as we grow old, most of us maintain vivid memories of life experiences across many years. The problems we experience recalling specific information are not based in the capacity or duration of long-term memory. Instead, problems are usually associated with organizational and relational issues. Without sophisticated storage procedures, the vast warehouse of long-term memory would be inaccessible. For example, imagine all the books in the Library of Congress randomly stored throughout the building. Finding a particular book would be nearly impossible.

Elaboration

The linking of new information to information already known

Elaboration, Organization, and Context

In order to keep information from getting lost in long-term memory, we use a variety of tagging and filing techniques. The first strategy we will consider involves attaching new information to something we have already learned, a process called elaboration. Recall that we have already encountered the process of elaboration in our discussion of elaborative rehearsal in working memory. Again, **elaboration** refers to the idea of making connections between material you are trying to learn, and information already known. These "known" memories located within the long-term store basically provide an anchor for the new information you are trying to learn. Making direct attempts to elaborate information you are learning can have dramatic effects on your ability to recall the information. Using elaboration, however, is not always an easy process. In fact, elaboration is a skill; and like all skills, the more time and effort spent practicing, the more expert one becomes. Teachers can help students learn to elaborate through examples, but ultimately it is the student who is in the best position to make connections between new material and the wealth of information they already know.

Teachers who incorporate elaborative techniques into their teaching can greatly assist students in learning specific content. For example, Mr. Ouellette, in his chemistry class, decided to have his students use elaboration to better remember the noble gases. In the past, he typically introduced the topic by reviewing the structure of the periodic table of elements, reminding the students that different chemical groups have a similar configuration of atomic elements. He explained that the noble gases are organized together in a group because each has eight electrons in their outer shell. Mr. Ouellette found that students had significant difficulty at quiz time without requiring the students to think about the noble gases by linking the new information to already known information. Therefore, this year he decided to try a different approach—he required them to use elaboration. In order to help them take the new information on the noble gases and connect it to something known, he formed groups and had each research an everyday use for their assigned noble gas. He then had the students present their findings. The most common uses found were as follows: Krypton—computer monitors; Helium—party balloons; Neon—lights; Argon—incandescent light bulbs; and Xenon—Pyrex glass. This elaborative exercise had very effective results. Every student not only remembered the entire list of noble gases, they also even showed a remarkable improvement in being able to describe the atomic properties they have in common.

By linking new information to knowledge we already have in long-term memory, we create tags or handles by which we can easily grasp the information at a later date. These memory tags are essentially a method of organizing our experiences according to what we already know. Luckily, as we learned back in Chapter 2 in our discussion of Piaget, human beings

Nelson Krackauer

"Should I constantly be trying to make these elaboration connections in all my classes?"

Professor Rainwater

"Yes and no. Elaboration is definitely a powerful tool to help you learn information, but not all information is created equal. When learning some information, like motor skills, you may benefit more from practice and appropriate modeling."

John Forsythe

"As a future teacher, I'm a little intimidated by the thought of having to create these elaborative connections for my students. Any advice?"

Professor Rainwater

"Remember that these elaborations are inherently about the student's own experiences and knowledge base. As a teacher, you don't have to create elaborations for them, as much as provide appropriate activities and guidance for them to develop the connections on their own."


(Adobe Stock)

Teachers who incorporate elaborative techniques into their teaching can greatly assist students in learning specific content.

are incredible organizers. Each new learning situation is almost immediately compared to existing memories for similarities and differences. In other words, much of how we organize information into the long-term store depends on elaborative thinking. We learn about a civil war in another country and recognize similarities to our own civil war. We learn new vocabulary in language arts and immediately notice similar root words. We learn a new sport and realize the necessary skills are very different from any other sport we have played. In this way, we naturally organize our world, creating an integrated body of knowledge.

Sometimes, however, our memory tags get lost in a sea of other information, and we cannot retrieve a memory we know we once had. The ease with which we can access information stored in long-term memory depends on how organized we were learning the information. Remember using the card catalog at the library in elementary school? If you were given a new card to file and you placed it in the correct drawer and in perfect alphabetical order, the odds that you could find the card again would be 100 percent. What would happen if you didn't bother with alphabetical order? What if you saw the author's name began with a B, you pulled the B drawer open, and you haphazardly placed the card in the drawer. What are the odds you could find it again? Well, in the short-term, the task is not too difficult. With the drawer still open, it is relatively easy to remember about where you placed the card. What would happen, though, after you file hundreds of other cards over several days or weeks? Would you remember where you put any particular card? This card catalog example is a good metaphor for what happens when you cram for an exam. Often, we are able to retain enough information to pass the test, but the next week you find you have forgotten most of what you learned. This example is useful in illustrating the distinction between permanent duration and functional access (Broadbent, 1958; Howe, 1970). While long-term memories may be permanent, the information must be organized in such a way that we can find it again. This makes information functional.


(Adobe Stock)

It's important for our long-term memories to be stored in a way that we can retrieve them at a later date, much like a library catalog.

A second strategy to consider makes use of our extraordinary potential for organization. As stated earlier, humans are incredible organizers. If we are presented with information in random order, we will spontaneously organize the information into related groups (Bousfield, 1953). We can also take advantage of preorganized information, learning new material more efficiently when it is presented in an organized manner. Unfortunately, students often disregard the organization of material presented in textbooks and in class when they study. Take, for example, the common study technique of making note cards. Students frequently take information, particularly definition/term information, and create note cards with the term on one side and the definition on the other. Typically, students will study the cards in order and then shuffle the deck to better test their knowledge. What does shuffling the cards mean in terms of organization? Essentially, studying the cards in random order completely divorces the study experience from any type of organization. Most textbooks are highly organized, with much thought going into the progression of ideas. Students who study their note cards in the order the material appears in the chapter take advantage of the organization already present in the textbook. In the same way, briefly previewing the structural elements of a reading (headings, subheadings, etc.) can be used to identify the organization of the material (Robinson, 1970). This can be accomplished by conducting a scan of the bolded heading material, or by reviewing the chapter outline presented at the beginning of the chapter. By explicitly teaching this strategy for promoting organization, teachers can assist students in developing effective study skills (McWhorter, 1996; Wong, 1994).

A final strategy to consider regarding the movement of information into the long-term store is the role of environmental context. When presenting a student with new information, the presentation does not happen in isolation. In fact, the information to be learned is just one of many pieces of information running through working memory at a given point in time. For example, as a teacher presents information on a new topic, other information is also present in the classroom. Perhaps someone makes a quiet joke, passes a note, drops a pencil, or makes a funny noise. All of these incidental events have the potential to be learned, or associated, with the teacher's information because they occur in the same context. A wide variety of environmental cues may become unintentionally associated with the new material. This may make it difficult to access the information if the learning environment differs substantially from the testing environment. In the classroom, for example, teachers frequently create learning environments that are relaxed and more closely match the natural behavior of children. When it comes time to take a test, however, teachers often have students sit in an unusually quiet room, with no interactions or movement allowed. Ideally, the learning environment and the testing environment should be similar to optimize the effects of context. As educators move toward more collaborative and natural learning environments, it should be noted that assessments are still largely conducted in traditional formats. Teachers can facilitate student learning by trying to be more sensitive to how well the learning environment corresponds to the testing environment.


(Adobe Stock)

Small behaviors have the potential to be associated with a teacher's lesson when they occur at the same time.

Forgetting

Carefully elaborating and organizing learning material makes it easier to later recall, but there are still times when we are unable to recall something we have learned. Some theorists have proposed that memories can be lost from long-term memory in the same way they are lost from working memory—through the processes of interference or decay (Anderson, 1983). Others hold that information is not displaced or gone; rather, forgetting occurs due to insufficient retrieval cues to prompt recall (Tulving, 1968). Recall that decay occurs when the memory trace weakens and is lost over time. According to this theory, once a memory has decayed, it is gone from the permanent store and is no longer available for recall. The idea that memories might decay in long-term memory just as they do in short-term memory is supported by the fact that we are more likely to forget with the passage of time. Studies show, however, that once we have learned something such as a list of words, and then forget the list, it is much easier to relearn the same list than it is to learn a new list of words. There is more research support for the idea that interference plays a role in forgetting information in long-term memory (Altmann & Schunn, 2002; Bahrick & Phelps, 1987; Keppel & Underwood, 1962).

Proactive and Retroactive Interference

Recall that interference occurs when a memory is displaced by other information. In the long-term store, either older memories or newly learned information can interfere with recall. For example, let's say you were taking a test on educational psychology and were having difficulty remembering one of Piaget's cognitive stages. In an attempt to recall the first of Piaget's stages (the sensorimotor stage), you inadvertently keep remembering a similar example from another theorist you learned about the semester before in child psychology (Freud's oral stage). In this case, the earlier memory is interfering with your attempts to recall the information from your current class. This type of interference is called **proactive interference** and is illustrated in Figure 5–5. Alternatively, a newly learned piece of information may interfere with the recall of an older memory. Using the same example above, let's say you just learned about Piaget's stages today in your educational psychology class, and later in the week you learn about Freud's stage theory of development in a developmental class. If, when you sit down to take your educational psychology test, you have trouble with questions related to Piaget because you keep remembering the material related to Freud, you are experiencing retroactive interference. **Retroactive interference** occurs when new information interferes with recall of previously learned information and is also illustrated in Figure 5–5. Thus, proactive interference occurs when past learning affects future learning, and retroactive interference occurs when newer learning affects past learning. Both types of interference have been shown to play a significant role in forgetting from the long-term store (Wahlheim & Jacoby, 2011).

Proactive interference

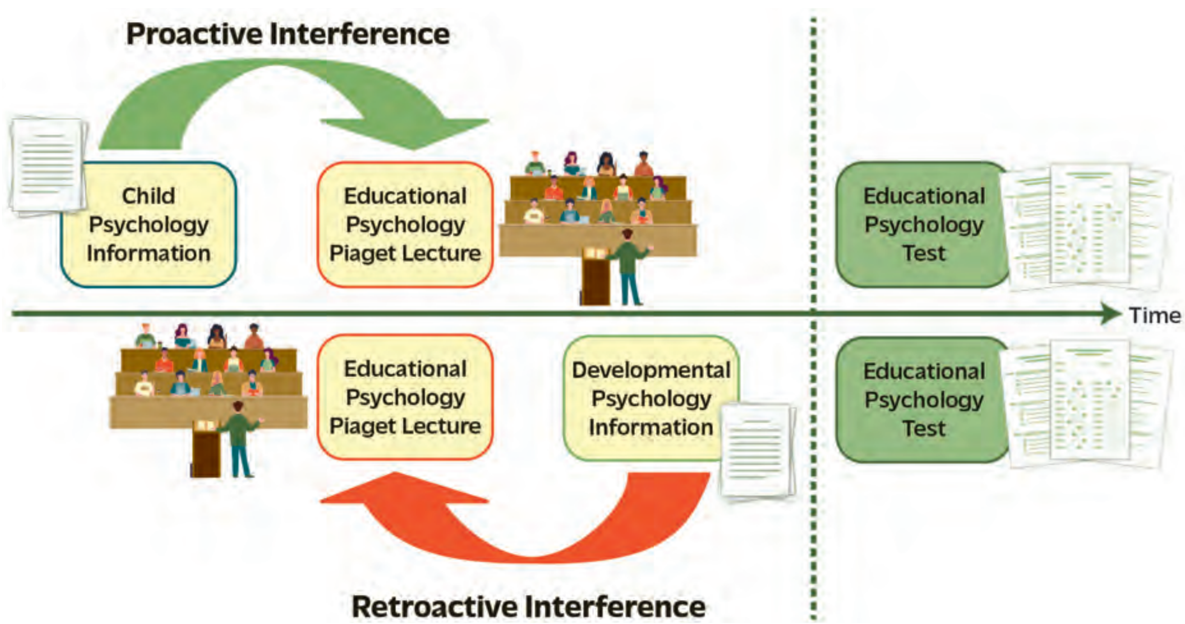
Older memories interfering with your attempts to recall information

Retroactive interference

Newer memories interfering with your attempts to recall information

Figure 5–5 Proactive Interference and Retroactive Interference

Figure 5–5 shows the temporal process involved in the creation of a proactive versus retroactive interference effect. In a proactive interference effect, information mistakenly recalled on a test that was learned before the correct material creates difficulty with appropriate recall. In a retroactive interference effect, information mistakenly recalled on a test that was learned after the correct material creates difficulty with appropriate recall.



(Adapted Adobe Stock)

Retrieval Cues

While interference clearly plays a role in some cases of forgetting, a lack of retrieval cues may also influence whether we are able to recall a specific piece of information (Nairne, 2000). A **retrieval cue** is simply information or some aspect of the environment that helps you recall a memory. Have you ever walked down the hall to get something and then drawn a complete blank about what you are supposed to be looking for? In order to remember, you have to walk

Retrieval cue

Information or some aspect of the environment that helps you recall a memory back to wherever you were, and maybe even reengage in whatever task you had been working on, before you can remember the item. This is an example of what happens when we don't have the appropriate retrieval cues to access specific information. The issue of retrieval cues underscores the importance of developing effective encoding skills. That is, remembering information is strongly related to how we learned the information in the first place. Have you ever had the experience of studying hard for an exam, knowing that you have learned the information, and then being unable to answer the questions on the test? Sometimes, this is due to **encoding specificity**, or memorizing the information in a specific way. For example, what if you memorized the fact that the capacity of short-term memory is around seven items, and then were presented with a multiple-choice question that did not include the number seven anywhere in the answer. In your studying for the test, you used the number seven as your memory tag. In a sense, you filed the memory with the expectation that the retrieval cue of the number seven would prompt your memory, and without it, you are unable to answer the question correctly. Perhaps the answer choices included "five to nine items" instead of 7 ± 2 and you failed to recognize the similarity.

Encoding specificity

Storing memories in a specific way which may limit recall to certain situations

Multiple-choice exams provide retrieval cues, which may allow you to recognize the learned information as long as the memory tags you used match the cues provided in the question. Essay-based tests, on the other hand, require you to recall information in long-term memory with fewer retrieval cues. Many students, therefore, perceive recall-based exams as more difficult. This is, in fact, supported by research, which shows performance is often better on recognition tests that provide retrieval cues (Lockhart, 2000). While this may be true in general, some recognition-based test items may be more difficult than others, due to the similarity or degree of correctness of alternative responses. In this way, problems with retrieval cues and interference can work together to make learned information difficult to recall. For example, some alternatives on multiple-choice tests contain correct information, but it just doesn't apply to the particular question. In this case, several of the alternative answers may be recognized as correct, causing recall of information that does not pertain to that particular question to interfere with your memory for the correct response. In the next section, we'll explore the concept of knowledge formation in more detail.

Summarize and Reflect

1. One of the most cited models of memory is the information-processing model of memory. This model conceptualizes memory as a process, with information moving from sensory memory to working memory and finally to long-term memory.
2. According to this model, the roles of attention and perception in moving information from sensory memory to working memory are highlighted.
3. One of the components of this memory model is working memory. Working memory has a very limited capacity and duration.
4. Rehearsal and chunking are important working memory processes for holding information. There are important differences between maintenance and elaborative types of rehearsal.
5. Working memory can be divided into three sub-components: the phonological loop, the visuospatial sketchpad, and the central executive.
6. Long-term memory potentially has an unlimited capacity and duration. The cognitive processes of elaboration, organization, and context form the basis for strategies to keep information from getting lost in the vast expanse of long-term memory.
7. Forgetting is an issue for memories held in the long-term store. There are theories based on decay, interference, and retrieval cue failure.

Informed Application

1. Create an example where you use the concept of perception to explain how a student could pay careful attention to a lecture on how to create a comparative essay, but still fails to include important elements.
2. Develop two examples of a student forgetting the point of an argument they are making. In one example, use decay theory to explain the situation and use interference theory to explain the other situation.

5.3 The Organization of Knowledge and Memory

As we've seen, humans have a remarkable ability to retain information, but the formation of accessible long-term memories is a complicated process requiring the efficient use of a number of cognitive activities. Successful retention of life experiences leads to an accumulation of information over time. This accumulation of information results in **knowledge**.

Knowledge

The accumulation of memories over time into a complex but highly organized body of information

5.3a Multiple Types of Knowledge

Knowledge is formed in a systematic and organized fashion. If all our memories were stored in a simplistic organizational structure, perhaps in the order they were learned, recall would be difficult and extremely time consuming. Think about the memory storage of a typical computer. Most computers simply record information in a sequential fashion, starting at the center of the hard disk and working out toward the edge. Searching such an organizational system is inefficient and usually takes a considerable amount of time. To test this idea, try closing a word processing document and then using the search feature to find it on the hard drive. Although you were just using the file, the search is not likely to be instantaneous although computers are improving at a remarkable rate, becoming more "human-like" every year.

In human terms, conducting a search for information across the entire long-term memory store would be inefficient. Imagine always needing to pause before you are able to answer a friend's question or to recall the necessary steps to take when your car begins to slide in the snow or rain. Luckily, we don't have to search the entire long-term memory store for a specific piece of information; instead, we can store and retrieve memories in a highly organized manner. This section will examine this organization of information, emphasizing the presence of at least three distinct knowledge stores—declarative, procedural, and conditional.

Declarative Knowledge

Declarative knowledge is information that can be stated or declared. For example, if you were asked to define the word *lion*, you would need to access declarative knowledge. Perhaps you would recall that lions are mammals, have large manes, are carnivores, and live in Africa. Think about the information you are learning in this class, the lecture you might someday give in your social studies class on the Civil War, or even the conversation you had with your roommate about your date the previous night. All these situations involve the use of declarative knowledge, things you know and can easily state. Declarative knowledge can be subdivided into two types: episodic and semantic (Tulving, 1993).

Declarative knowledge

Information that can be stated or declared

Episodic knowledge is personal information that is tied to a specific time and place (Conway, 2009; Eichenbaum et al., 2011). For example, your relaying the events of last night's date to your roommate involves an episodic memory. It is a personal memory, grounded in

Episodic knowledge

Personal information that is tied to a specific time and place events, which took place at a specific time and place. Compare this type of information to your definition of the word *lion*. The meaning of the word lion is unlikely to involve episodic memories. For example, let's say you answered the question with the fact that lions were mammals. Where were you when you learned this information—in class, at home, visiting the zoo? Most of us are unable to remember the exact time and place we learned that lions were mammals. The knowledge appears to be disconnected from the episode in which it was learned; therefore, we would not consider the knowledge episodic. This is quite different from the knowledge you have of your daily life events. These episodic memories are a rich documentary of your life and are clearly tied to locations and specific times in your life.

Semantic knowledge is made up of memories for specific facts, regardless of the time and place the facts were learned. For most of us, the knowledge that lions are mammals is a semantic memory. Semantic knowledge allows us to apply meaning to the word *lion*, without basing that meaning on a location or specific time in our lives. Much of our knowledge appears to operate in this manner, and we appear to organize related semantic memories into schema. Recall, we first encountered the term *schema* in our discussion of Piaget in Chapter 2. Piaget used the term **schema** to refer to organized ways of understanding related elements. For example, you probably have a schema for what a college class is like, containing information on lectures, note taking, group work, etc. Research shows that our schemas may actually influence what we think, see, or hear as we go about our lives. For example, one study had students learn a list of words that were all related to bedtime (e.g., nightstand, bed, alarm, moon, etc.). The list consisted of more than twenty words, so students found it difficult to remember all the words due to the limitations of working memory. The words they did recall proved to be quite interesting. In addition to the recall of words presented, participants in the study frequently recalled different words associated with bedtime, such as *pillow*, which were not mentioned in the list. These responses were explained in terms of schemas. The participants appeared to have a schema for bedtime that included some of the stated words, as well as some words not stated. While the students in this experiment made errors in their recall of the list, there is usually practical value to using one's schema in daily life.

Semantic knowledge

Information made up of memories for specific facts, regardless of the time and place the facts were learned

Schema

Organized ways of understanding related elements

Interconnections

The concept of schema was first encountered in Chapter 2 during a discussion of Piaget's developmental theory.

By using existing schema, we can respond to incomplete information in appropriate ways. For example, when a teacher says to his class, "Complete items three to fifteen on page 74," he does not include in his directions some important steps for completing the task. Although the teacher did not explicitly state it, students are expected to locate a piece of paper and a pencil and record their answers to the questions on the paper. They do this without being told because they have a *schema* for answering workbook items. The schema allows them to behave as expected, despite incomplete information. In fact, if asked whether the teacher told them to take out a piece of paper and pencil, many students would probably answer, "Yes."

(Adobe Stock)

Semantic knowledge allows us to apply meaning to the word *lion* without basing that meaning on a location or specific time in our lives.

Building upon schema-based research, knowledge experts and neuroscientists have begun to develop an even more elaborate framework for understanding semantic knowledge called semantic networks. **Semantic networks** are representational structures designed to explain the relation between items within a schema (Goni et al., 2011). Figure 5–6 shows a simple semantic network. A simple model is easier to understand, but complex models better capture the incredible interconnectedness of our semantic knowledge.

Semantic networks

Representational structures designed to explain the relation between items within a schema

Nodes

Specific elements within the semantic network representing concepts

Connectionist network theorists

Theorists who have related knowledge storage and retrieval to the actual functioning of the neuron

The semantic network model assumes that our knowledge is highly interconnected and that recall of any particular item causes a more general activation of all related concepts. Graphically, this activation is represented by a series of interconnected nodes. The **nodes** are specific elements within the semantic network representing concepts like *people* or *world*. The connections represent the activation trends occurring after a particular node is activated. A longer line means it takes a longer period of time to activate the next node. In general, the graphical model is created such that longer connectors mean a weaker connection between the two nodes. To help clarify this process, consider the following studies.

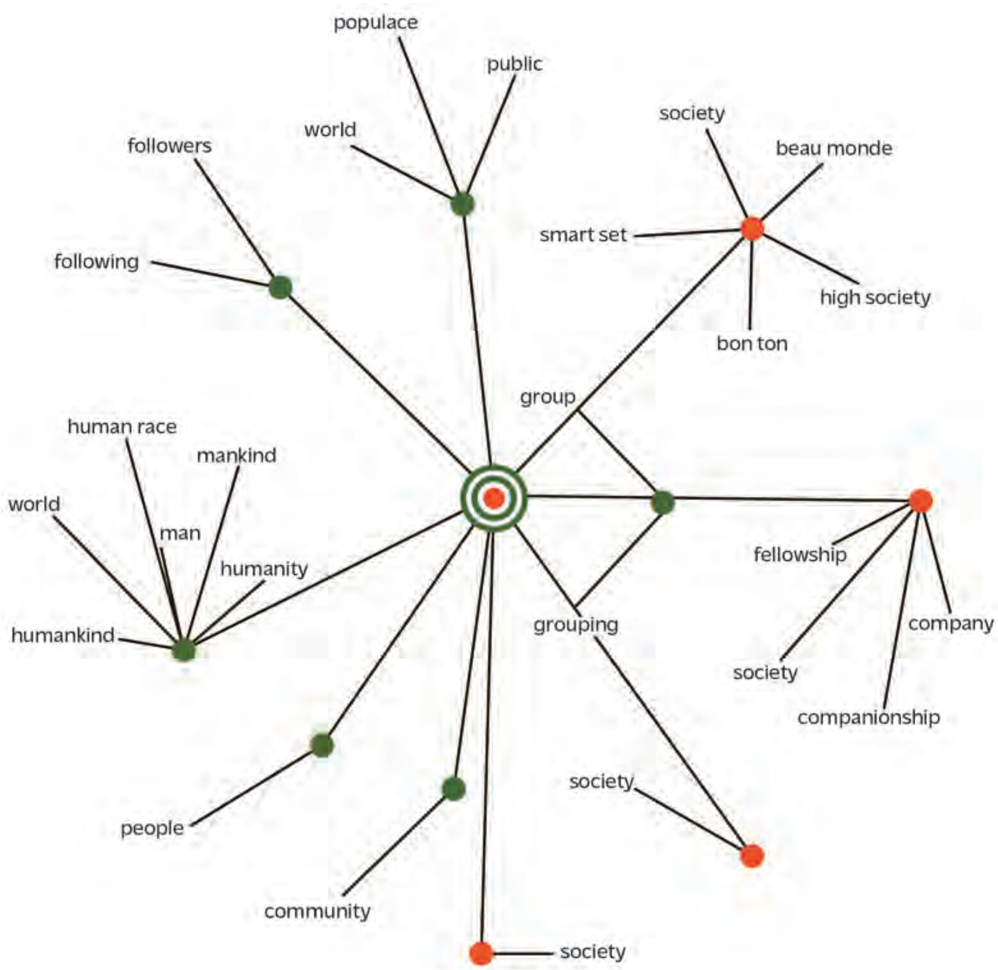
Research examining how long it takes to recall a word following the activation of another word supports semantic network theory. For example, if you were asked the question, "What is a monkey's favorite fruit?" you might respond "banana." This causes the node for banana to become activated, which in turn causes a *spreading activation* to all nodes connected to bananas. Research shows that if you have previously activated the node for banana, you will respond more quickly to any question to which the answer is semantically related. For example, you would respond faster to the question, "What is the traditional gift given from student to teacher?" than the question, "What is the capitol of the United States?" This is because the connector between banana and apple is much shorter (stronger) than the connector between banana and Washington, DC (weaker).

Over time, the conceptual basis for semantic networks has been broadened to incorporate newer research on brain anatomy and physiology. These newer theories have gone beyond theoretical networks and have based knowledge storage and retrieval on our understanding of how the brain actually works. This led to the development of Connectionist Networks and Parallel Distributed Processing theories. **Connectionist network theorists** have related knowledge storage and retrieval to the actual functioning of the *neuron*. As we reviewed in Chapter 2, neurons are the basic building blocks of the brain and function by sending signals to other neurons. There are literally billions of neurons in the brain, and communication across neurons appear to function in a parallel fashion with millions and millions of neurons communicating with each other at the same time. This parallel activity gives rise to our remarkable ability to respond to even extremely complicated environmental stimuli with great speed and flexibility. Consider for example, the simple semantic network presented in Figure 5–6. How is the node for *people* represented at the level of the brain? The theoretical concept of the "people node" is probably a vast collection of interconnected neurons firing in a particular configuration. It is unlikely that a node for *people* actually exists in a particular location in the brain. Instead, it exists as a collection of many brain cells communicating in a unique way. According to this theory, the interconnectedness of the neuronal cells *is* the node for the concept of people. This neural circuit is then connected to other interconnected sets of neurons related to people. As you can see, viewing semantic memories in terms of the way neurons operate is significantly more complicated than even the complex visual depiction of a semantic network illustrates. This model does, however, begin to conceptualize memory in a way that better represents the complexity of human cognition, leaving the computer metaphor far behind.

As you can see, declarative knowledge represents an important part of our knowledge base, but it is only one part. When you first started reading about declarative knowledge, you probably thought all memories were declarative. After all, if you can't say what you know, then you must not really know it. Actually, research supports at least two other knowledge stores that do not lend themselves to verbal declaration: procedural and conditional knowledge.

Figure 5–6 A Simple Semantic Network

Figure 5–6 shows a theoretical representation of a semantic network. As the figure shows, semantic information exists in a highly connected network. According to this theory, knowledge of the meaning of "people" exists in a vast array of interconnected related information sources so that accessing the meaning of "people" immediately activates related knowledge, such as the meaning of humanity, society, public, and group.



Procedural Knowledge

Procedural knowledge is typically referred to as *how to* knowledge because it involves knowledge of how to perform certain actions. Sometimes, we can perform an activity that we cannot describe in words. Consider, for example, something as simple as riding a bicycle. If you were asked to write down a step-by-step guide to riding a bicycle, you would quickly find that verbalizing the procedure is quite difficult. Imagine the complexity of such a guide. You would have to describe how to mount the bicycle, which way to face, how to put your feet on the pedals, and how to balance while you move your feet in an alternating pattern—all the while steering effectively using the handlebars. While these steps are each important for riding a bicycle, do they adequately describe what you must do to ride one? Could someone who has never ridden a bicycle read our description and ride away happily? Obviously, that would not be likely. This difficulty in verbally describing how to ride a bicycle is typical of procedural

Procedural knowledge
"How to" knowledge that involves knowledge of how to perform certain actions

(Adobe Stock)

Procedural knowledge is knowledge of how to perform certain tasks. Sometimes, we are able to perform a task but cannot describe what we did.

knowledge because this type of knowledge is not coded verbally. Instead, it is coded as an automated sequence of actions that have to change as a function of environmental demands, such as having a tree in your biking path. To demonstrate your knowledge of bike riding, you would simply need to get on a bicycle and start riding. In the classroom, many tasks require procedural knowledge, including such activities as cutting, writing, and typing. Procedural knowledge may also be of particular concern for physical education teachers since the coordination of motor skills is required for most activities.

Conditional Knowledge

Conditional knowledge

Knowledge about the appropriate application of procedural and declarative information

A final type of knowledge to consider is **conditional knowledge**, or knowledge about the appropriate application of procedural and declarative information. For example, think about how you speak to children versus how you speak to your peers. In all likelihood, you make substantial changes to both the content and structure of your speech, depending on the audience. How do you know to do this? Similarly, when you must figure out how to put a set of fifty chairs into five rows, how do you know whether to multiply or divide? Conditional knowledge allows you to know which conditions necessitate the use of specific actions.

A teacher's conditional knowledge is highly important for effective teaching. When students experience difficultly with a particular lesson, for example, how does the teacher know how to help them? Perhaps the students simply misunderstood the lesson, and all the teacher needs to do is repeat the original explanation. Perhaps they need a few minutes of independent practice, to watch a model solve the problem, or to work with a more knowledgeable peer. Teachers often need to consider a multitude of different educational approaches to find the one appropriate for the given student. Finding the correct approach accomplishes two important things. First, it helps the students' progress and supports their learning. Second, it also helps to facilitate the teacher's conditional knowledge base. The teacher now knows how to provide appropriate instructional support for this particular problem or misunderstanding. Over time, successful teachers build a conditional knowledge base of teaching techniques that work for children with very different individual learning needs over a variety of situations. Advancement of this type of knowledge helps novice teachers move toward becoming expert teachers.

As we have seen in this section, our declarative, procedural, and conditional knowledge stores are comprised of different types of information and are important for different cognitive and behavioral tasks. We have not yet explored, however, how these different types of knowledge develop. In the next section, we will discuss the development of each type of knowledge, as well as techniques for improving students' ability to use these knowledge stores effectively.

5.3b Building Knowledge and Improving Memory

Earlier in the chapter, we outlined the important roles of elaboration, organization, and context in learning new information, describing how this information accumulates over time forming our knowledge base. In this section, we will further explore the development of knowledge, focusing on techniques for increasing and optimizing declarative, procedural, and conditional knowledge.

Mnemonics

Mnemonics (ni-'mä-niks) is an unusual word generally applied to a wide variety of techniques used to improve memory. Mnemonics are used to enhance recall of memories from our declarative knowledge base. As we discussed earlier, we naturally organize our memories when we transfer them to long-term memory. This organization, however, varies widely in quality and effectiveness. Like most skills, we can learn to organize information in such a way as to make it more accessible later. Mnemonics are techniques that organize information via specific forms of elaboration. Recall elaboration is the process of connecting new information to information already well learned. The particular type of elaboration varies according to the mnemonic used. For example, the most common mnemonic is the **acronym approach**. This approach works well with simple lists. To help memorize the information, the first letter of each item on the list is taken and rearranged to form a familiar word. In keeping with the notion of elaboration, the idea is that the word you form is very familiar to you and difficult to forget. If you can create a strong association between the acronym and the list, the familiarity with the word will help you recall the list. For example, when memorizing the sequence of operations to perform in an algebra problem, the acronym FOIL (First, Outer, Inner, Last) can be very useful and is difficult to forget.

Mnemonics

Term generally applied to a wide variety of techniques used to improve memory

Acronym approach

A mnemonic where the first letter of each item on the list is taken and rearranged to form a familiar word

The difficulty with the acronym approach is that this type of elaboration does not require a very meaningful association between the material to be learned and the information in long-term memory. In the FOIL example, the word is completely unrelated to algebra. This may make the approach less effective for learning conceptual types of information. Similarly, anatomy students are familiar with learning the names of the cranial nerves by using the acronym *On Old Olympus' Towering Tops, A Finn And German Viewed Some Hops* (olfactory, optic, oculomotor, trochlear, trigeminal, abducens, facial, acoustic, glossopharyngeal, vagus, spinal accessory, hypoglossal). While this is effective for memorizing the names of the cranial nerves, it is not really helpful in learning the function or position of each of the nerves.

(Adobe Stock)

The most common mnemonic is the acronym approach.

Mnemonics that use visual imagery are also very effective in facilitating recall (Paivio, 1986). Visual mnemonics create a visual code for the information being learned, in addition to the more common auditory code. This dual code approach enhances elaboration and facilitates recall. One common type of visual mnemonic is the **method of loci**. This is a memorization approach that is excellent for learning items that can be visualized (Cornoldi & de Beni, 1991). The process begins with the individual imagining a familiar location, such as a path from home to work or a specific room. Once a clear image of the location is created, the individual then proceeds to create visual images of the new information and imbeds these images along the well-known path. For example, if you wanted to remember the colors of the rainbow you might create a mental image of your bedroom and then systematically "paint" the room the appropriate colors. Begin the process at a specific location, perhaps to the right of the door, and proceed to imbed the colors in some way along the edges of the room until you are back at the left side of the door. Perhaps you begin by painting the dresser to the right of the door a bright red. With the method of loci, it helps if you make the image unusual, so imagine the paint can as being ten times larger than normal and sitting in the center of the dresser dripping with paint. Continue to imbed the images around the room, one after the other, until you reach the left side of the door. Once this is accomplished, all you need to do is take a mental walk around your room. To recall the information, start with the desk to the right of the door and simply "see" the first item you are trying to recall in the imbedded image. As with the acronym method, this technique typically works well for concrete nouns, which are easy to imagine, and need to be recalled in a specific order.

Method of loci

A memorization approach that is excellent for learning items that can be visualized

Keyword method

A mnemonic that is particularly useful if you are trying to use a visualization technique for remembering more abstract words

Another popular visual technique is the **keyword method**. This mnemonic is particularly useful if you are trying to use a visualization technique for remembering more abstract words. To use this approach, you first think of an easily visualized word that sounds like the abstract word you are trying to remember. This easily visualized word becomes the *keyword*, acting as the key or gateway to the phonetically similar abstract word. Next, you relate the definition of the abstract word to the keyword. At this point, recall of the keyword should lead to the associated definition. For example, let's say you are trying to remember the definition for the word *exigent* (which means demanding). An appropriate keyword would be *exit*, because it is like the first part of the word. Now, imagine a door with a large exit sign and standing at the door is your professor *demanding* your research paper. The next time you see the word exigent, you will probably remember the keyword exit, the exit sign and door, and the professor demanding the paper. This process led you to the definition, "demanding." This mnemonic has been shown to be particularly effective for learning foreign language words (Bellezza, 1996). Other mnemonics involving embedding to-be-learned information in a familiar visual image have also shown promise in learning foreign language alphabet letters (Shmidman & Ehri, 2010).

Automating Knowledge

Another way to improve memory and build a solid knowledge base is to create automated sources of knowledge. This is particularly true for procedural memories. Recall that procedural knowledge consists of how-to memories, like *how to* ride a bicycle. The development of procedural knowledge, however, takes practice before it becomes automatic. Often, we need to break complex activities into smaller parts so that students can practice individual steps before being able to perform a complex activity (Hong et al., 2019). Consider writing in cursive, for example. We can't just tell students how to write neatly and legibly in cursive. Instead, we teach them how to write each individual cursive letter, and they need a significant amount of practice before they can reliably form the letters correctly. As is often the case with procedural learning, observing a model actually performing the desired behavior and then having time to practice is an important component in teaching handwriting (Torriero, et al.).

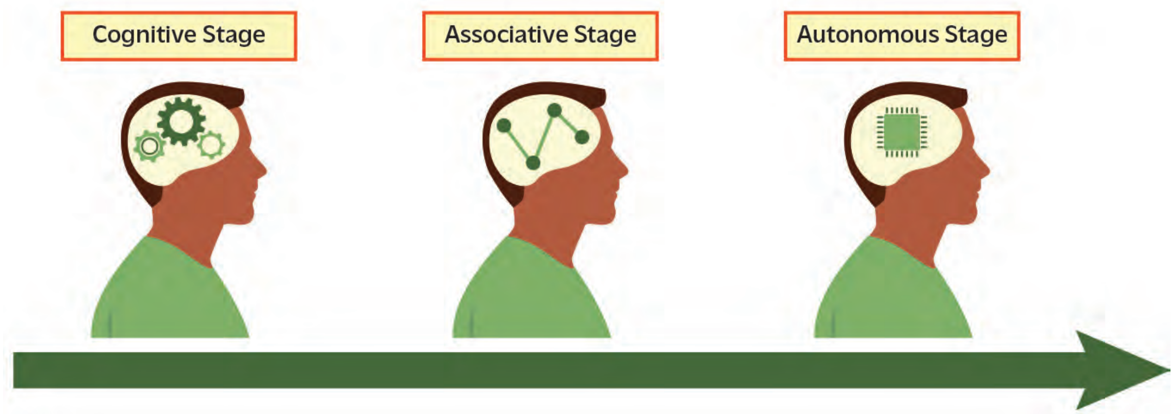
While cursive writing is at first slow and laborious, with practice it becomes an automatic process that requires little thought. The same is true for other types of procedural knowledge, from dribbling a basketball to typing on a keyboard. Thus, accessing procedural knowledge becomes automatic over time, leaving more of our limited cognitive resources available for other tasks. Think about how often you engage in a procedural activity, like driving a car, while simultaneously engaging in another task, like carrying on a conversation or reading a map for navigation. It is relatively easy for most individuals to think about a wide range of things while riding a bike or driving a car because these activities do not require active cognitive resources. In other words, you are able to use your procedural knowledge without having to actively think about it.

(Adobe Stock)

For most people it is relatively easy to perform multiple tasks at the same time, such as driving a car and reading a navigation system.

The path to automation of procedural memories begins with the *cognitive stage* (see Figure 5–7). At this point in the process, each step of the procedure still requires active cognitive resources. That is, we still must think about each step in the procedure. Let's go back to the example of learning to write. When a child first begins to write, he must really think about how to hold the pencil correctly, requiring a significant portion of his cognitive resources. These thoughts directly compete with other thoughts, making it difficult to think about other aspects of the writing process. Over time and with repeated practice, holding the pencil correctly begins to become more automatic. Then, the child can pick up the pencil and write whole words correctly, without even thinking about how the pencil feels in his hand or having to look at model letters. He does, however, have to pay close attention to the spaces he puts between words. This is the *associative stage* of automating his procedural knowledge of writing. At this point, parts of the overall process have become automatic; however, he still has to actively think about the next step at certain key points, like when he finishes or begins a new word.

Figure 5-7 **Procedural Memory**



(Adapted Adobe Stock)

The final step in this process is the *autonomous stage*. This stage is the final integration of the whole process into one cohesive unit. When a child can write fluidly—without having to think about holding the pencil, forming the letters, or spacing the words—his procedural knowledge of writing has reached the autonomous stage. Now that writing is an automated script, he can think about the development of the ideas he wants to express more freely.

These automated scripts occur quite frequently as we go about our daily lives. Think about the last time you drove a car. What exactly were you doing while driving? How many traffic lights did you pass? Did you use your turn signal every time you changed direction? Chances are you have very little recollection of these specifics because your driving behavior is automated. In the same way, we develop automated knowledge of our daily routines. Have you ever noticed that at the beginning of the semester you must check your schedule several times a day? Soon, you really won't have to look to see when or where you have class, as the routine becomes automated. In the same way, many students in a classroom may feel overwhelmed at the beginning of the school year, finding it difficult to manage a new, complicated daily routine. Teachers can assist students in developing automated knowledge regarding the daily routine by breaking the day into steps or component parts and making sure they deviate as little as possible from the set routine during the initial stages of learning. Automatization allows students to divert more cognitive resources toward their studies and daily activities, instead of having to focus on what is supposed to be happening next.

In the Classroom

Applying Theory

Procedural Knowledge

Theory Basics

As discussed in the textbook, procedural knowledge is *how-to* knowledge. It is that aspect of knowledge that allows us to ride a bike or drive a car. The development of procedural knowledge is difficult, typically requiring significant mental effort as you begin to learn the skill. This necessity to actively think about each step in the overall process starts to fade as parts of the skill are learned and performed more automatically. Ultimately, the individual can participate in the activity with little conscious effort, freeing them to think about other things.

Classroom Application

Educators typically overlook research on the development of procedural knowledge. Often it is difficult to recognize situations where well-developed procedural knowledge can help curricular goals. One type of educational environment, however, is a natural place to emphasize this important aspect of knowledge. Physical education has enjoyed increased attention as our nation realizes the importance of maintaining a healthy and active lifestyle. Physical fitness goals, however, are often difficult to maintain over time. Part of the problem stems from a failure to learn exercises properly. This leads to a struggle with the mechanics of the exercise program in addition to other barriers to success, like allocating time, establishing consistency, and avoiding injury.

Teachers Help students develop procedural automaticity, which in turn helps students engage in more productive physical activities.

To apply theories on the development of procedural knowledge, it is important for the educator to recognize the overall process. Students are likely to become frustrated at the beginning of a learning task because they must think about each step. This is often magnified when teachers demonstrate a skill. They see how the teacher performs the skill with relative ease, which serves to highlight their difficulty. The demonstration is important, but it is also important for the teacher to help the student understand the overall process. Emphasize that everyone must "think" about the skill in the beginning. It is a necessary step toward the overall goal. Next, try to break the skill down into to smaller parts that are more manageable and help the student to appreciate when these smaller steps become more fluid and automatic. This helps motivate students as they realize they are indeed making progress. Continue to provide many opportunities for practice, and eventually you will have your students enjoying their new skills. They will be able to complete them with less cognitive effort, which allows them to fully enjoy the benefits of being active.


(Adobe Stock)

Providing many opportunities for practice will help students enjoy their new skills.

When and Where to Apply Knowledge

The third type of knowledge we introduced above was conditional knowledge, or knowledge about when and how to use declarative and procedural knowledge. Like declarative and procedural knowledge, conditional knowledge develops over time. Specifically, conditional knowledge builds as a series of condition-to-action rules (Anderson, 1995). In other words, we develop rules for ourselves regarding how to respond to specific situations or events, and we form these rules based upon our experience with the world. We try different behaviors and are met with differing levels of success. These experiences help us develop a pool of knowledge regarding the appropriateness of various actions across a wide range of conditions.

Teachers can help students develop this knowledge base by providing consistent feedback regarding behavior. Students need appropriate feedback across many situations to begin to appreciate the situational specificity of their actions. Knowing when to add or subtract when given a word problem, for example, depends on conditional knowledge. Without feedback regarding correct and incorrect performance on word problems, students have great difficulty learning to execute the appropriate manipulations. Classroom behavior also depends on conditional knowledge. Most students develop an understanding of what actions are appropriate in the classroom in the early grades. Even first graders know, for example, that bringing out a soccer ball during class and starting a game is inappropriate. Teaching students how to raise their hand to speak, wait in line, or ask for assistance can be more challenging, as these require a conditional knowledge store regarding a number of more ambiguous conditions.

5.3c Cognitive Diversity and Assessment

A final topic to consider when examining how we process information to create knowledge concerns cognitive diversity. **Cognitive diversity** is defined as differences in thinking patterns, analysis, perception, and point of view (Jones & Dovidio, 2018). This definition reflects the fact that most of our thinking tools develop depending on our interactions with the world around us. These interactions are unique to each individual, but there are also generalizations that can be made to groups with common history, culture, biology, or perspective. For example, some have conceptualized autism with the following tendencies: adherence to well-tried routines, avoiding change, a narrow range of interests, development of irrational fears and anxieties, having no sense of danger, and bizarre behaviors and mannerisms (Belek, 2019). The author of this article is quick to note that the realization of any of these qualities in a particular individual with autism depends on their particular life circumstances, social environment, cultural context, and personality traits. Approaching this list as possibilities rather than necessary defining characteristics, we can get a sense of how cognitive diversity manifests within the context of autism. The current trend is to work on supporting these cognitive differences and ensure teaching and assessment are developed in such a way as to give individuals with autism the chance to participate fully in the educational experience. The same is true for all dimensions of diversity.

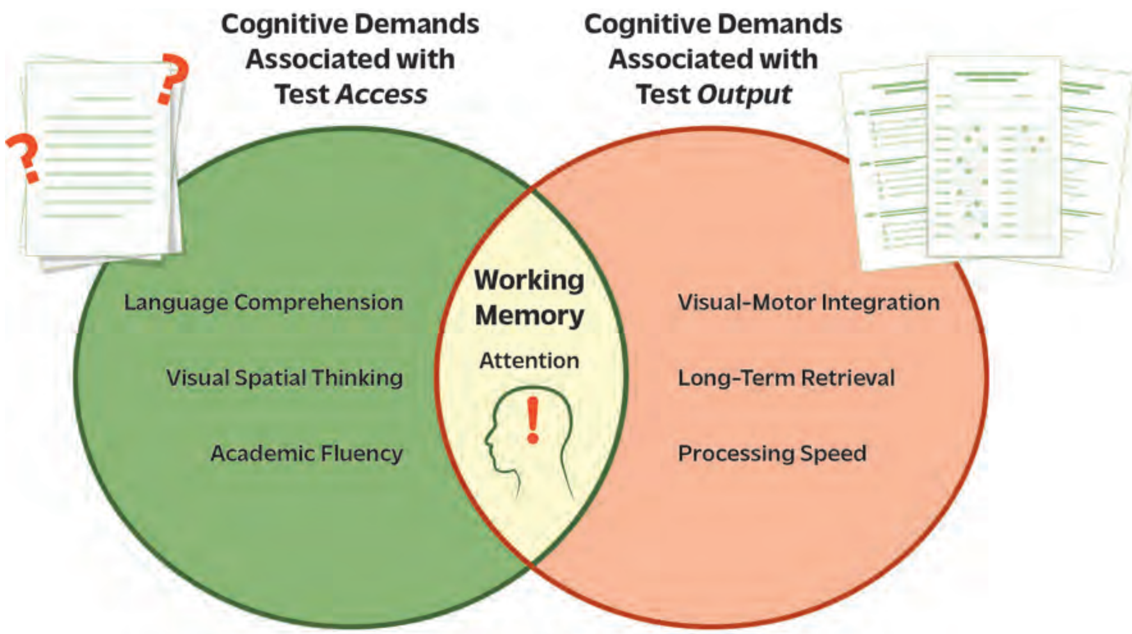
Cognitive diversity
Defined as differences in thinking patterns, analysis, perception, and point of view

One of the most directly related and comprehensive articles on the topic of cognitive diversity and the design of classroom tests for all learners is by Shinn and Ofiesh (2012). The general focus of their article is on delineating the various cognitive demands made by tests. This is followed by a review of different dimensions of cognitive diversity and the associated challenges with meeting cognitive test demands. We will consider both in turn.

Let's start by looking at what kind of cognitive skills a typical classroom test demands of students. First, it is important to organize cognitive demands around the practical consideration inherent in the making and giving of most tests. Important test components include how the student accesses the test, how the student generates an output to the test questions, and those demands related to both access and output. The typical cognitive demands associated with each testing component are presented in Figure 5–8.

Figure 5–8 **Cognitive Demands Associated with Testing Components**

As you can see in the figure, cognitive demands associated with test access include language comprehension, visual spatial thinking, and academic fluency. Language comprehension refers to our ability to make sense of spoken words and written language. Students need to satisfactorily meet this demand to understand test directions as well as the meaning of individual test items. Visual spatial thinking demands of the student the ability to make sense of visually presented work.



(Adapted Adobe Stock)

Adapted from: Shinn, E., & Ofiesh, N. S. (2012). Cognitive Diversity and the Design of Classroom Tests for All Learners. *Journal of Postsecondary Education and Disability,* 25(3), 227–245. Used with permission.

Tests are more commonly presented in a visual format, rather than read to the student, requiring them to be able to work with different test layouts, accompanying figures and graphs, and general pattern recognition. Test access also demands a certain degree of academic fluency. This refers to relative ease and speed a student brings to working on academic material. This test demand is directly influenced by earlier history with print work, leading to familiarity and ease with tests and other academically related tasks. Cognitive demands associated with test output include visual-motor integration, long-term memory retrieval (see Section 5.2c), and processing speed. Visual-motor integration in a testing context is the ability to successfully apply fine-motor skills (e.g., handwriting, bubbling in a Scantron sheet) to a visually presented response form. Processing speed is an important cognitive demand in testing because most tests are limited to a particular time frame (e.g., a class period). A couple of final cognitive demands associated with taking tests are those demands affecting both test access and output. These involve working memory (see Section 5.2b). Finally, attention is important for maintaining focus on the task at hand while ignoring internal and external factors leading to distractions. Failure to maintain attention can result in misunderstood questions or an inability to finish the test within the allotted time.

As mentioned, the Shinn and Ofiesh (2012) article goes on to present different dimensions of cognitive diversity and the associated challenges with the cognitive demands detailed above. The following types of cognitive diversity are reviewed: learning disability (see Chapter 10), attention-deficit/hyperactivity disorder (ADHD) (see Chapter 11), language disorders (see Chapter 10), anxiety, depression, post-traumatic stress disorder (PTSD), linguistic diversity, poverty, and age (see Table 5–1).

Table 5–1 Cognitive Diversity and Associated Testing Challenges

Diversity Dimension	Potential Challenges to Meeting Test Demands
Learning disability	Academic fluency Working memory
Attention-deficit/hyperactivity disorder	Attention Working memory Long-term retrieval Processing speed
Language disorders	Language comprehension
Anxiety	Long-term retrieval
Working memory	Processing speed
Depression	Long-term retrieval
Post-traumatic stress disorder	Processing speed Short-term memory Long-term memory
Linguistic diversity	Language comprehension
Poverty	Language comprehension Academic fluency
Age	Short-term memory

Adapted from Shinn, E., & Ofiesh, N. S. (2012). Cognitive Diversity and the Design of Classroom Tests for All Learners. *Journal of Postsecondary Education and Disability,* 25(3), 227–245.

As you can see from the table, each of the diversity dimensions are associated with cognitions requiring special care when faculty members make assessments. Faculty members are in a position to create tests that are sensitive to the various types of cognitive diversity, leading to more inclusive tests. There are many testing factors available for modification. They typically include things like test presentation and visual design (e.g., font, spacing, and organization), test output (e.g., handwriting, typing, drawing, or speaking), and test content (e.g., clarity of individual test items aligned to course objectives). The ultimate hope here is that faculty, fluent in the demands tests place on students, coupled with an understanding of the ways different types of students process and respond to assessments, will lead to creative, clear, and meaningful tests. Tests should measure a student's knowledge of the material without capturing error brought on by tests failing to address potential challenges inherent in their students' unique ways of thinking. Faculty who take cognitive diversity into consideration when designing instruction and assessments are in the best position to inclusively meet the demands of our emerging societal diversity (Popkess & Frey, 2015).

Summarize and Reflect

1. Knowledge is the organized accumulation of information in memory.
2. There are three distinct knowledge stores: declarative, procedural, and conditional knowledge.
3. The declarative store consists of verbal memories, which can be stated or declared, differentiating between episodic and semantic memories.
4. The semantic network model of memory includes the connectionist and parallel distributed processing theories of memory, which use the way neurons are organized and operate in the brain as a model for memory.
5. Procedural knowledge is knowledge of how to perform actions. This type of knowledge is nonverbal and automated, which makes it difficult to verbalize.
6. Conditional knowledge is knowledge about the situationally appropriate application of procedural and declarative knowledge.
7. Mnemonics are used for enhancing declarative memory. The acronym, method of loci, and keyword approaches were highlighted, giving classroom examples.
8. Improving procedural learning emphasizes the importance of breaking complex procedural activities into individual steps and providing opportunities for practice. The path to automatization of procedural memories starts with the cognitive stage, moves through the associative stage, and finally reaches the autonomous stage.
9. Conditional knowledge is a series of rules about how to respond to specific situations or events. These rules are based on experiences with the world. It is important for teachers to give appropriate feedback regarding correct and incorrect student performance to encourage the development of conditional knowledge.
10. An appreciation of cognitive diversity can help educators create assessments for a more inclusive audience.

Informed Application

1. You are a physical education teacher working on developing pitching skills during a unit on baseball. What steps can you take to support your students' knowledge in this area?
2. A student is given an assignment to write an essay on the drawbacks of technology integration into twenty-first century life. Describe how a well-developed conditional knowledge base will help you succeed on the assignment.

5.4 Metacognition

Metacognition

Broadly defined as thinking about one's own thought processes

Metacognition refers to a mental process everyone uses in their daily life—thinking about one's own thinking. What exactly does *thinking about thinking* mean? Consider the following example. Jared is a tenth-grade student studying for his geometry test. Since he is having difficulty with the material, he stays after school to work with his teacher. His teacher decides that Jared understands the problems conceptually, but he does not check his work for accuracy. This leads him to get off track midway through a problem, and he ends up correctly solving the wrong problem. To address this issue, his teacher instructs Jared to ask himself the following question when he is halfway through a problem: *"How can I check to make sure I am on track?"* Upon the completion of each geometry problem, Jared is instructed to ask himself, *"What can I do to check the accuracy of my answer?"* These questions require Jared to think about his own thinking when it comes to solving geometry problems. He might, for example, reflect on techniques such as working the problem backward or rechecking his math to confirm his answer.

By asking himself these questions, Jared is using metacognitive knowledge, which helps him think and reflect on his own thought processes. This is like an individual observing a conversation between two friends. In a sense, he is putting himself in the position of being an outside observer of his own thinking and critically examining his thinking about geometry problems for appropriateness and effectiveness. Metacognition has traditionally been subdivided into at least two distinct processes: metacognitive knowledge and metacognitive regulation, which often work together.

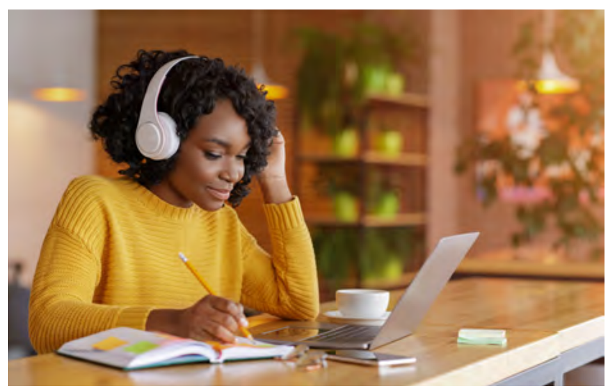
5.4a Metacognitive Knowledge

Flavell, in 1979, proposed that metacognitive knowledge was a distinct component of metacognition. **Metacognitive knowledge** is information that we acquire about how thinking occurs. Perhaps you have learned that studying in a lunchroom or common area is distracting, making it difficult for you to focus. When you study, you use this knowledge about your own cognitive processes to choose an appropriate environment for studying. This knowledge about your own thinking is only one sub-component of metacognitive knowledge. Metacognitive knowledge can be further subdivided into three areas: knowledge about how we think, knowledge about the nature of a given task, and knowledge about what strategy to use for a given task (Flavell, 1979, 1987).

Metacognitive knowledge

Information we acquire about how thinking occurs

The *first* subcomponent of metacognitive knowledge is knowledge about how we think. For example, perhaps you know that you learn best visually. This knowledge is metacognitive, allowing us to think about our own thinking and set up the environmental conditions we know are effective. This aspect of metacognitive knowledge can be important for increasing learning, allowing us to recognize our own cognitive strengths and act accordingly. Usually, this occurs naturally, and we begin to structure our environments to maximize learning. For example, you may know that your approach to math tends to be haphazard, resulting in multiple errors, so you make sure that you always check your work. Similarly, you may recognize that writing seems to come naturally to you, so you choose a paper over an oral report.


(Adobe Stock)

Metacognition refers to our contemplation of our own thinking. It allows us to keep ourselves on track with specific tasks.

Sometimes, however, students do not easily develop metacognitive knowledge regarding their own learning, requiring direction in evaluating and building on cognitive strengths. Eight-year-old Steven, for example, has excellent verbal skills, but he has significant difficulty with math. He becomes frustrated when working only with numbers and symbols; yet, he does very well with word problems. Given this cognitive profile, Steven's teacher helps him interpret numbers as real-life representations. Later, as his math skills become automated, Steven's verbal interpretation of the numbers will no longer be required

The *second* subcomponent of metacognitive knowledge is knowledge about specific task variables, such as having the knowledge that spelling sentences will take much longer to complete than a reading worksheet. This type of metacognitive knowledge allows students to allocate their time more effectively. In the same way, we know that we can read a popular magazine cover to cover in less time than it takes to read a chapter of a textbook. Without this knowledge regarding the specific task demands, we would have considerable difficulty managing our daily assignments.

The *third* component of metacognitive knowledge relates to strategy use. Metacognitive strategies involve our awareness of available strategies for completing a task or solving a

(Adobe Stock)

By using the mnemonic "Please Excuse My Dear Aunt Sally," (Parentheses, Exponents, Multiplication/Division, Addition/Subtraction) when solving equations, the student employs a metacognitive strategy to direct the process.

problem. Consider, for example, a student who frequently becomes confused regarding the appropriate sequence of steps in solving an algebraic equation. By using the mnemonic "**P**lease **E**xcuse **M**y **D**ear **A**unt **S**ally," (Parentheses, Exponents, Multiplication/Division, Addition/Subtraction) when solving equations, she employs a metacognitive strategy to direct the process. Essentially, this strategy is a predetermined plan for helping solve the problem.

5.4b Metacognitive Regulation

Metacognitive regulation involves evaluating the outcome of our efforts to use metacognitive strategies (Livingston, 1997). This aspect of metacognition is essential for overseeing these processes and ensuring that a particular goal has been achieved. For example, the questions used by Jared in the beginning of this section represent his attempts to govern his geometry problem solving. The questions presented help him govern his thinking and move him closer to achieving his goal. Metacognitive regulation is an important part of the learning process. Without regulation, learning would be inefficient, with individuals having little control over the effectiveness of their learning. Metacognitive regulation typically involves planning a learning strategy, monitoring progress, and evaluating the effectiveness of the process (Brown, 1987; Nelson, 1996). Research has documented that our ability to plan, monitor, and evaluate our learning develops over time as we become better able to direct our own learning (Cotterall & Murray, 2009).

> **Metacognitive regulation**
> Evaluating the outcome of our efforts to use metacognitive strategies

5.4c Metacognitive Instruction

Like most skills, there is variation in the degree to which individuals naturally engage in metacognition. Most individuals engage in metacognition without explicit awareness of the process (Perner, 2000); however, providing explicit instruction in metacognition may prove effective (Schneider, 2008; van de Kamp et al., 1993). Typically, programs to enhance metacognitive abilities center on developing the ability to think in new and unique ways, to develop different strategies for approaching a task, and to better reflect on one's thinking. In addition to providing knowledge about how to use metacognitive thinking, it is also important to provide ample practice. Providing strategies without a structured program requiring practice typically results in less efficient cognitive control (Livingston, 1996). It is important to remember that metacognition is a natural process, which can be facilitated by explicit instruction, helping less successful students become more aware of, and thereby better able to regulate, their own learning processes.

Metacognitive instruction was the topic of a review study of over fifty articles on teaching metacognition and student outcomes. Perry et al. (2019) found strong support for positive student outcomes from appropriately taught metacognition. The researchers report there is no specific definition for what metacognitive strategies are taught by educators; however, as mentioned above, they typically include strategies that help students monitor, plan, and evaluate their performance on a task. This is especially true for novel tasks. Tanner (2012) provided suggestions for questions students can be taught to ask themselves when they are taking an exam or quiz (see Figure 5–9). This kind of support helps students develop an understanding of how metacognition can play a direct role this important area of their academic lives.

Figure 5–9 **Sample Self-Questions to Promote Student Metacognition about Learning on a Quiz or Exam**

Planning	Monitoring	Evaluating
■ What strategies will I use to study (e.g., study groups, problem sets, evaluating text figures, challenging myself with practice quizzes, and/or going to office hours and review sessions)? ■ How much time do I plan on studying? Over what period of time and for how long each time I sit down do I need to study? ■ Which aspects of the course material should I spend more or less time on, based on my current understanding?	■ To what extent am I being systematic in my studying of all the material for the exam? ■ To what extent am I taking advantage of all the learning supports available to me? ■ Am I struggling with my motivation to study? If so, do I remember why I am taking this course? ■ Which of my confusions have I clarified? How was I able to get them clarified? ■ Which confusions remain and how am I going to get them clarified?	■ What about my exam preparation worked well that I should remember to do next time? ■ What did not work so well that I should not do next time or that I should change? ■ What questions did I not answer correctly? Why? How did my answer compare with the suggested correct answer? ■ What questions did I not answer correctly? Why? What confusions do I have that I still need to clarify?

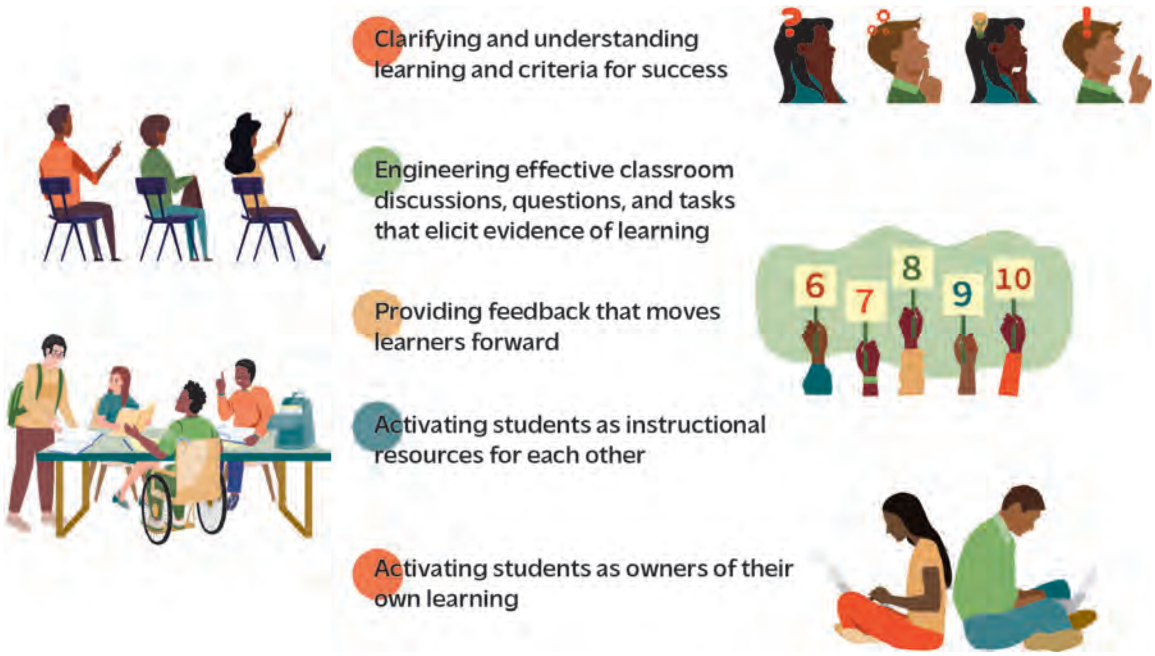
Source: Tanner, K. D. (2012). Promoting student metacognition. *CBE Life Sciences Education, 11*(2), 113–120. https://doi.org/10.1187/cbe.12-03-0033

Metacognitive strategies are enhanced when they are taught within the context of the Assessment for Learning (AFL) instructional focus (Baas et al., 2015; Perry et al., 2019). AFL is a teaching approach using assessment feedback to support, inform, and promote learning. The five key strategies of AFL are presented in Figure 5–10 (Wiliam, 2011). Research results indicate that when students are taught metacognition with accurate assessment through AFL, the potential for academic success is high. Additionally, academic success is further enhanced by teaching metacognition through cooperative work groups (Aydin & Dincer, 2022; Dignath & Gerhard, 2008; Perry et al., 2019).

5.4d Early Development of Metacognition

There has been considerable debate over the years regarding the developmental progression of metacognitive ability. As mentioned above, John Flavell was a pioneer in the field of metacognition and provided some of the earliest evidence regarding its developmental progression. Eleonora Papaleontiou-Louca (2019) conducted a review of research on metacognitive awareness in preschoolers summarizing four of Flavell's main findings. First, she reported on evidence supporting very poor recall of the content of young children's own thinking. Second, young children were poor at identifying when someone was thinking and what they were thinking about. Third, young children were poor at detecting the presence of inner speech in themselves. Fourth, five-year-old children were poorer than seven- to eight-year-old children at reporting their recent thoughts. Taken collectively, this summary of Flavell's findings support the notion that young children have limited access and understanding of their own thoughts and a commensurate limitation in making constructive changes to their thinking process.

Figure 5-10 **Typical Assessment for Learning (AFL) Strategies**



(Adapted Adobe Stock)

Newer studies employing different methodologies have reached alternative conclusions regarding the metacognitive abilities of young children. Fridman et al. (2020) conducted a study to examine emerging inquiry, metacognitive strategic awareness, and self-regulation capabilities among preschoolers during play-based scientific exploration in 215 children with an average age of five. Regarding inquiry capabilities, the study demonstrated that given the opportunity, children exhibited inquiry capabilities during situated scientific exploration: They asked questions, planned, hypothesized, used tools, drew conclusions, and were able to explain their conclusions. Regarding metacognitive strategic awareness and self-regulation capabilities, findings indicated that the young participants exhibited capabilities of metacognitive strategic awareness, self-regulation, and high levels of attention, persistence on task, and engagement. Another study by Köksal et al. (2021) similarly showed that young children can engage in metacognitive processes beyond what was originally thought. They studied sixty five- and six-year-old children on their understanding of metacognitive awareness. The children were asked to evaluate and explain both confounded and unconfounded evidence that was presented to them. The results indicate many of the children responded with multiple causes when explaining confounded evidence. Overall, the researchers concluded that young children could reason explicitly about how much information can be deduced from different sources of evidence. Further research in this area will certainly continue to elaborate and extend our understanding of how metacognition develops.

Summarize and Reflect

1. Metacognition is the higher-level process of thinking about our thoughts and decision-making processes.
2. This important aspect of human thinking can be divided into two distinct processes: metacognitive knowledge and metacognitive regulation.
3. Metacognitive knowledge consists of three important areas: knowledge of how we think, knowledge about the nature of a given task, and knowledge about what strategy to use for a given task.
4. Metacognitive regulation involves evaluating the outcomes of efforts to use cognitive and metacognitive strategies.
5. Metacognition is an important part of learning. Most individuals engage in metacognition without explicit awareness of the process.
6. Research on effective instruction in metacognitive strategies in the classroom illustrates that teaching metacognitive skills can help students become more aware of, and better regulate, their own learning.
7. Research on the development of metacognition has evolved over the years. Current findings generally show that even young children can engage in metacognitive processes.

Informed Application

1. A first-grade class received instruction on double-digit addition. They are then placed into small groups to work on several problems. Specifically using the double-digit addition task, provide an explanation of what kind of metacognitive capabilities are likely to be demonstrated by the students.

The Chapter in Review

In this chapter, we explored cognitive views of learning. We started out by comparing the cognitive and behavioral perspectives on learning, emphasizing that both use scientific methods to explore answers to different questions. We discussed memory and knowledge as the foundation for cognitive research, and we reviewed research and theory regarding the basic processes involved in human memory and thinking. We outlined the information-processing model of human memory, which conceptualizes human memory as involving multiple stores. We took an in-depth look at sensory, working, and long-term memory stores, outlining cognitive processes involved in moving information from one store to another. We discussed research on getting information into long-term memory, as well as retrieval. We discussed the importance of organization of memories into specialized knowledge stores, exploring declarative, procedural, and conditional knowledge in detail. We described the importance of each of these types of knowledge in the classroom and discussed strategies for increasing and optimizing declarative, procedural, and conditional memory. We also stressed the importance of considering cognitive diversity when creating assessments. Finally, we discussed metacognition and the importance of students' thinking about their own thinking in the learning process, highlighting research on the teaching of metacognitive strategies to increase learning and the early development of these skills.

Interdisciplinary Case Focus

Student/Teacher Case Focus

Jack, Student

Interdisciplinary Team

- Parent
- Fellow Educator—Third Grade Teacher
- Psychologist

Referral Question

Dramatic decline in academic engagement in math.

Meet Jack Johnson

Jack Johnson, a third grader in Mrs. Klein's classroom, is a creative and curious child, who has always excelled academically. At the beginning of the year, he showed a significant strength in his conceptual understanding of multiplication. In fact, Mrs. Klein often had Jack work collaboratively using manipulatives with other children who were having more difficulty. Manipulatives is a general term referring to any object the student can manipulate or handle (e.g., blocks) that helps them conceptualize a task. Recently, however, Jack has begun having trouble finishing his math assignments on time. Instead of looking forward to math time, as he did at the beginning of the year, Jack appears to try to avoid it. Mrs. Klein sits down with Jack as he works a set of simple multiplication practice sets, trying to figure out the nature of his problem. It quickly becomes apparent that Jack has not memorized his multiplication facts, working each problem by adding the numbers quietly. In fact, she notices that he actually counts on his fingers. Obviously, he never memorized his addition facts either. She initially thinks he must not have spent any time working to memorize the math facts since he easily commits information to memory in other subjects, such as social studies. She asks Jack if he has practiced at home with the flash cards they made in class earlier in the year. Jack becomes very upset, saying that he "hates those dumb cards" and starts to cry. Mrs. Klein decides to talk to Jack's parents regarding his attempts to memorize the multiplication facts, recognizing that this task has been quite difficult for him. She also seeks advice from several colleagues regarding ideas for helping to reduce Jack's newfound frustration with math.

✦ Parent

Jack's mother, Rita Johnson, tells Mrs. Klein that Jack has spent hours practicing with the flash cards. While he always came up with the right answer, it was never automatic. She could tell that he was "doing the math" in his head each time, so she tried using a time limit for each fact, moving on to the next card after ten seconds. This was very frustrating for Jack; and since he didn't seem to be having any problems finishing his math homework, they stopped working with the flashcards. She figured that he would just memorize the multiplication facts on his own after having to use them over and over again in class.

✦ Teacher

Dena Schefler, Mrs. Klein's colleague, who has been a third-grade teacher for fifteen years, tells her that this problem is not uncommon. Many children, in her opinion, never memorize math facts completely, resulting in slower problem solving. She says that depending on the degree of memorization failure, this can become a much larger problem as students move on toward more complicated math problems. She recently attended a workshop on alternative strategies for teaching information traditionally learned via rote memorization, and suggested using mnemonics, visual imagery, music, and/or movement for increasing memorization success. She refers Mrs. Klein to the website, www.multiplication.com, for ideas regarding these strategies.

✦ Psychologist

Charles Farrell, the school psychologist, helps explain why Jack has trouble committing math facts to memory. He explains that when children try to memorize multiplication facts they usually have to do so without any elaborative cues. In other words, it's difficult to relate 8 3 4 5 32 to other memories they already have, since the math fact doesn't really have meaning except as a numerical operation. In contrast, information in social studies or reading is inherently more meaningful since the ideas are easy to imagine, sequence, and relate to a child's own experiences. He says that it is not impossible to strategically attach meaning to multiplication facts, however, and that there are many commercial packages for purchase. He knows of one, for example, which sets the multiplication tables to music. He encourages Mrs. Klein to read about strategies such as these on the website recommended by Ms. Schefler since many of them can be implemented without having to purchase a commercial product.

Mrs. Klein takes the advice of her colleagues and seeks out alternative strategies for helping Jack (and quite a few of the other children) to more easily memorize the multiplication tables. She finds a number of easy "tricks" to help students relate the facts to other meaningful information, including a number of simple rhymes, such as:

$2 \times 2 = 4$

Two shoes kicked the door, two times two equals four.

$3 \times 4 = 12$
One–two–three–four, One–two is three times four.

$3 \times 8 = 24$
A tree on skates fell on the floor, three times eight is twenty-four.

$5 \times 5 = 25$
Two fives jump off the high dive, five times five is twenty-five.

$6 \times 8 = 48$
Six asked eight for a date, six times eight is forty-eight.

$7 \times 7 = 49$
7×7 is 49, you are cool; you are fine!

$7 \times 8 = 56$
Five–six–seven-eight, fifty-six is seven times eight.

She also finds a number of games to play with the students that are easy and fun, and they really seemed to help Jack. One of the most successful of these activities involved pinning a multiplication fact to each child's shirt and pretending their name for the day was the answer to the problem. Jack's shirt said $8 \times 4 =$, so he was 32 for the day. By calling each of the children by their "answer name" for a whole day, the entire class participated in the exercise and reinforced everyone's learning.

Finally, the website that Ms. Schefler recommended not only had information regarding alternative memorization strategies but also games and techniques for helping children visualize and understand the concept behind multiplication. She began to use these activities in class, and she sent home a newsletter for parents, suggesting specific activities to try at home.

Key Terms

Acronym approach 195
Attention 175
Bottom-up processing 178
Central executive 183
Chunking 180
Cognitive diversity 199
Cognitive perspective 170
Conditional knowledge 194
Connectionist network theorists 192
Decay theory 184
Declarative knowledge 190
Elaboration 185
Elaborative rehearsal 180
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