CHAPTER 2

HOW THE BRAIN PROCESSES INFORMATION

There are probably more differences in human brains than in any other animal partly because the human brain does most of its developing in the outside world.
— Robert Ornstein and Richard Thompson, *The Amazing Brain*

Chapter Highlights: This chapter presents a modern dynamic model of how the brain deals with information from the senses. It covers the behavior of the two temporary memories, the criteria for long-term storage, and the impact of the self-concept on learning.

While the brain remains largely a mystery beyond its own understanding, we are slowly uncovering more about its baffling processes. Using MRI and PET scans, researchers can display in vivid color the differences in brain cell metabolism that occur in response to different types of brain work. Based on the level of radioactivity in different parts of the brain, a computer constructs a color-coded map indicating what different areas are doing during such activities as learning new words, analyzing tones, doing mathematical calculations, or responding to images. One thing is clear: The brain calls selected areas into play depending on what the individual is doing at the moment. This knowledge encourages us to construct models that explain data and behavior, but models are useful only when they contain some predictability about specific operations.

The Information Processing Model

Several models exist to explain brain behavior. In designing a model for this book, I needed one that would accurately represent the complex research of neuroscientists in such a way as to be understood by educational practitioners. I recognize that a model is just one person's view of reality, and I readily admit that this particular information processing model comes closest to my view of how the brain learns. It differs from other models in that it escapes the limits of the computer metaphor and recognizes that learning, storing, and remembering are dynamic and interactive processes. Beyond that, the model incorporates much of the recent findings of research and is sufficiently flexible to adjust to new findings as they are revealed. I have already made several changes in this model since I began working with it nearly 10 years ago. My hope is that presenting it to classroom teachers may encourage them to reflect on their methodology and decide if there are new insights here that could affect their instruction and improve learning.

Origins of the Model

The precursor of this model was developed by Robert Stahl of Arizona State University in the 1980s. Stahl's more complex model synthesized the research in the 1960s and 1970s on cognitive processing and learning. His goal was to convince teacher educators that they should use this model to help prospective teachers understand how and why learning occurs. He also used the model to develop an elaborate and fascinating learning taxonomy designed to promote higher-order thinking skills.

Usefulness of the Model

The model discussed here (Figure 2.1) is a significantly modified version of Stahl's original. It has been updated and streamlined so that it can be used by the widest range of teacher educators and practitioners. It uses common objects to represent various stages in the process. Even this revised model does not pretend to include all the ways that researchers believe the human brain deals with information, thought, and behavior. It limits its scope to the major cerebral operations that deal with the collecting, evaluating, storing, and retrieving of information—the parts most useful to educators.

The model starts with information from our environment and shows how the senses reject or accept it for further processing. It then explains the two temporary memories, how they operate, and the factors that determine if a learning will be stored or not. Finally, it shows the inescapable impact that experiences and self-concept have on future learning. The model is simple, but the processes are extraordinarily complex. Knowing how the human brain seems to process information and learn can help teachers plan lessons that students are more likely to understand and remember.

Limitations of the Model

Although the explanation of the model will follow items going through the processing system, it is important to note that this linear approach is used solely for simplicity and clarity. Much of the recent evidence on memory supports a model of parallel processing. That is, many items are processed quickly and simultaneously (within limits), taking different paths through and out of the system. Memories are dynamic and dispersed, and the brain has the capacity to change its properties as the result of experience.

While the model may seem to represent learning and remembering as a mechanistic process, it must be remembered that we are describing a *biological process*. Nonetheless, I have avoided a detailed discussion of the biochemical changes that occur within and between neurons since that would not contribute to the understanding necessary to convert the fruits of this research and this model into successful classroom practices, which is, after all, the goal of this book.

Inadequacy of the Computer Model

The rapid proliferation of computers has encouraged the use of the computer model to explain brain functions. This is indeed tempting. Using the analogy of input, processing, and output seems so natural, but there are serious problems with this model. Certainly, the smallest hand-held calculator can out-tally the human brain in solving complex mathematical operations. Larger computers can play chess, translate one language into another, and correct massive manuscripts for spelling and grammatical errors in just seconds. The brain performs slower because of synaptic delays, the time it takes for a nerve impulse to travel along the axon, and because the capacity of working memory is limited. But computers cannot exercise judgment with the ease of the human brain. Even the most sophisticated computers are closed linear systems limited to binary code, the 0s and 1s in linear sequences that are the language of computer operations.

The human brain has no such limitations. It is an open, parallel-processing system continually interacting with the physical and social worlds outside. It analyzes, integrates, and synthesizes information and abstracts generalities from it. It can recognize a face in less than a second—something no computer can do. According to Russell (1979), the entire world's telephone system is equivalent to only one gram of the human brain—a piece the size of a pea! Each neuron is alive and altered by its experiences and its environment. As you read these words, neurons are interacting with each other, reforming and dissolving storage sites, and establishing different electrical patterns that correspond to your new learning. For these and many other reasons, the computer model is woefully inadequate and misleading.

The Model and Constructivism

At first glance, the model may seem to perpetuate the traditional approach to teaching and learning—that students repeat newly learned information in quizzes, tests, and reports. On the contrary, the new research is revealing that students are more likely to gain greater understanding of and derive greater pleasure from learning when allowed to *transform* the learning into creative thoughts and products. This model emphasizes the power of transfer during learning and the importance of moving students through higher levels of complexity of thought. This will be explained further in Chapter 4.

The Senses

Our brain takes in more information from our environment in a single day than the largest computer does in years. That information is detected by our five senses. The senses do not contribute equally to our learning. Over the course of our lives, sight, hearing and touch contribute to about 95 percent of all new learning.

> ***About 95 percent of all new learning during our lifetime is through sight, hearing, and touch.***

Our senses constantly collect bits of information from the environment, even while we sleep. These bits average 40,000 per second![2] This may seem very high, but think about it. The nerve endings all over your skin are detecting the clothes you are wearing. Your ears are hearing sounds around you, the rods and cones in your eyes are picking up this print as they move across the page, you may still be tasting recent food or drink, and your nose may be detecting an odor. Put these bits of data together and it is easy to see how they can add up. Of course, the stimuli must be strong enough for the senses to record them.

The 40,000 bits of data per second is an average count over the course of a day. This number will be higher if you are deeply involved in a multi-sensory learning experience and lower if you are in an unstimulating environment.

Perceptual Register

Imagine if the brain had to give its full attention to all those bits of data at once; we would blow the cerebral equivalent of a fuse! Fortunately, the brain has evolved a structure that screens all these data to determine the importance to the individual. This structure is commonly called the *perceptual* or *sensory register*. The technical name for it is the *reticular activation system* (RAS) and it is located in the brain stem (Figure 1.1). The perceptual register is drawn in the model as the side view of slats, as in Venetian blinds; the reason will become clear later.

The perceptual register monitors the strength and nature of the sensory impulses and, in just milliseconds (a millisecond is one-thousandth of a second), uses the individual's experience to determine the data's degree of importance. Most of the data signals are unimportant, so the perceptual register blocks them and they drop out of the processing system. Have you ever noticed how you can be in a room studying while there is construction noise outside? Eventually, it seems that you no longer hear the noise.

Your perceptual register is blocking these repetitive stimuli, allowing your conscious brain to focus on more important things. This process is called *perceptual filtering* and we are largely consciously unaware of it. One form of autism is believed to occur when an

2. The numbers used in this chapter are averages over time. There are always exceptions to these values as a result of human variations or pathologies.

Information Processing Model

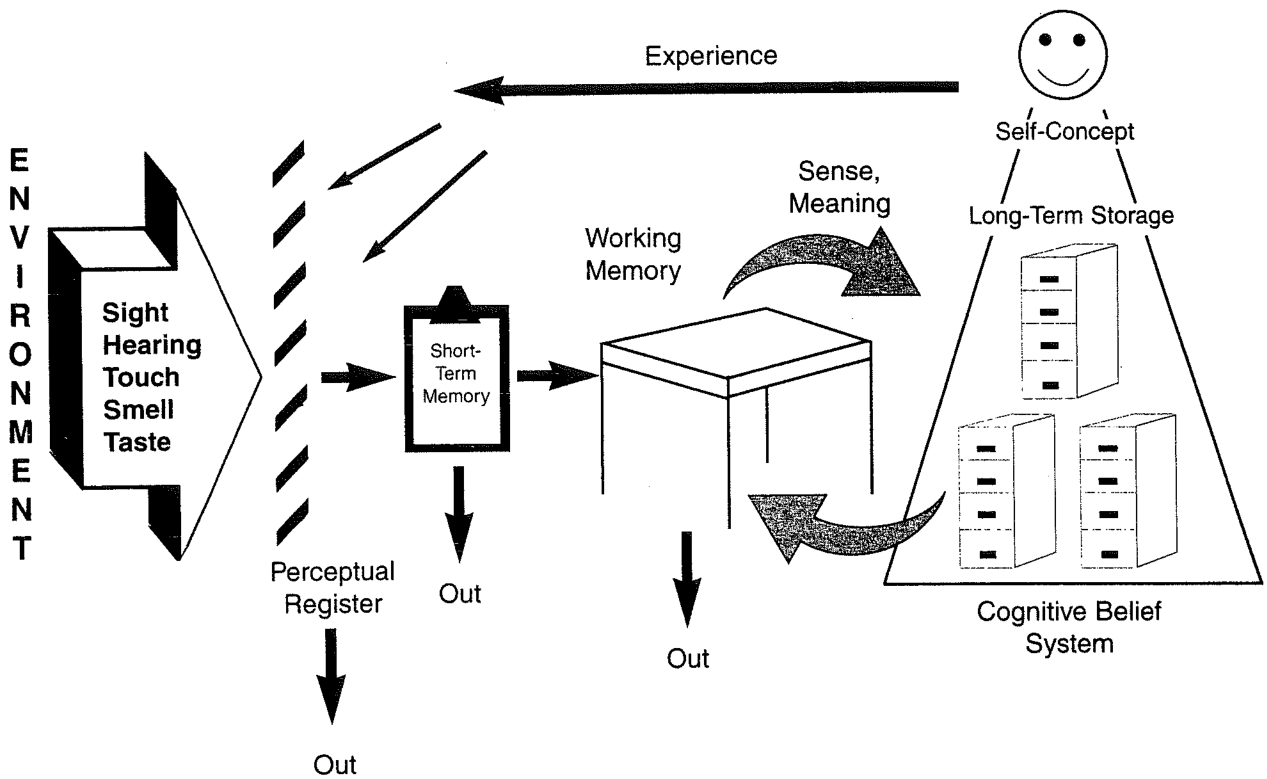

Figure 2.1. The Information Processing Model shows how the brain deals with information from the environment. (Adaptation and enhancement of original model by Robert Stahl.)

individual is unable to filter sensory information. This sensory overload is like living inside a pinball machine, and the brain responds by blocking *all* of it.

Short-Term Memory

If the sensory data are important, or if the perceptual register becomes overloaded, the data are passed on to the first of two temporary memories, called *short-term memory.* If you took a psychology course more than a decade ago, you learned that we had two memories—one short-term (temporary) memory and one long-term (permanent) memory. The idea that we seem to have two temporary memories is recent. It is a way of explaining how the perceptual register deals with an overload of sensory data, and how we can continue to process sensory stimuli subconsciously for many seconds beyond the perceptual register's time limits.

These two temporary memories are called short-term memory, which acts simply as an extension of the perceptual register, and *working memory,* where conscious processing occurs. When older literature refers to short-term memory, it really means working memory and not the short-term memory described here.

The short-term memory area is represented in the model as a clipboard, a place where we put information briefly until we make a decision on how to dispose of it. Short-term memory operates subconsciously and holds data for up to about 30 seconds. The individual's experiences determine its importance. If the datum is of little or no importance within this time frame, it drops out of the system. For example, when you look up the telephone number of the local pizza parlor, you usually can remember it just long enough to make the call. After that, the number is of no further importance and drops out of short-term memory. (Note that we have already two major places where information can drop out within just a few seconds of its reception by the senses.)

> ***Test Question No. I:*** *The brain acts more like a sponge than a sieve when processing new information.*
>
> ***Answer:*** *False. The brain acts more like a sieve because there are several early stages where most data are dropped from the system.*

Examples of Short-Term Memory at Work

Here are two other examples to understand how the processing occurs up to this point. Suppose you decide to wear a new pair of shoes to work today. They are snug, so when you put them on, the receptors in your skin send impulses to the perceptual register. For a short time you feel discomfort. After a while, however, as you get involved with work, you do not notice the discomfort signals anymore. The perceptual register is now blocking the impulses from reaching your consciousness. Should you move your foot in a way that causes the shoe to pinch, however, the perceptual register will pass this pain stimulus along to your consciousness and you become aware of it.

Another example: You are sitting in a classroom and a police car with its siren wailing passes by. Experience recalls that a siren is an important sound. It signals the perceptual register to pass these auditory data immediately over to short-term memory. If over the next few seconds the sound of the siren gets fainter, experience signals the short-term memory that the sound is of no further importance and the auditory data are blocked and dropped from the system. All this is happening subconsciously while your attention is focused on something else. If asked about the sound later, you will not remember it. You cannot recall what you have not stored.

Suppose, on the other hand, that the siren sound gets louder and suddenly stops, followed by another siren that gets louder and stops. Experience will now signal that the sounds are important because they are nearby and require your attention. At this point, the now-important auditory data move rapidly through short-term memory and into working memory for conscious processing.

Threats and Emotions Affect Memory Processing

This last example illustrates another characteristic of brain processing: There is a hierarchy of response to sensory input (Figure 2.2). Any input that is of higher priority diminishes the processing of data of lower priority. Thus, data interpreted as posing a threat to the survival of the individual, such as a burning odor, a snarling dog, or someone threatening bodily injury, are processed immediately.

Emotional data also take high priority. When an individual responds emotionally to a situation, the older limbic system (stimulated by the amygdala) takes a major role and the complex cerebral processes are suspended. We have all had experiences when anger, fear of the unknown, or joy quickly overcame our rational thoughts. This override of conscious thought can be strong enough to cause temporary inability to talk ("I was dumbfounded") or move ("I froze"). This happens because the hippocampus is susceptible to stress hormones which can inhibit cognitive functioning and long-term memory. Hart (1983) called this process *downshifting*. Under certain conditions, emotions can enhance memory by causing the release of hormones that stimulate the amygdala to signal brain regions to strengthen memory. Strong emotions can shut down conscious processing during the event while enhancing our memory of it.[3] Emotion is a powerful and misunderstood force in learning and memory.

> ***Threats and emotions inhibit cognitive processing.***

Working Memory

Working memory is the second temporary memory and the place where conscious, rather than subconscious, processing occurs.[4] The information processing model represents working memory as a work table, a place of limited capacity where we can build, take apart, or rework ideas for eventual storage somewhere else. When something is in working memory, it generally captures our focus and demands our attention.

Capacity

Working memory can handle only a few items at once. This functional capacity changes with age. The table on p. 15 shows how the capacity of working memory increases as one passes through the major growth spurts in cognitive development.[5]

3. For more on this phenomenon, see the work of Larry Squires, University of California at San Diego. A summary of his research appeared in *The New York Times*, October 25, 1994, pp. C1 and C11.
4. The older literature calls this area short-term memory. The two terms for the same area will cause confusion until they become standardized in newer writings.
5. For the original research on working memory capacity, see the work of George A. Miller in his article, "The Magical Number Seven, Plus or Minus Two: Some Limits in Our Capacity for Processing Information," *Psychological Review*, 63: 81–97.

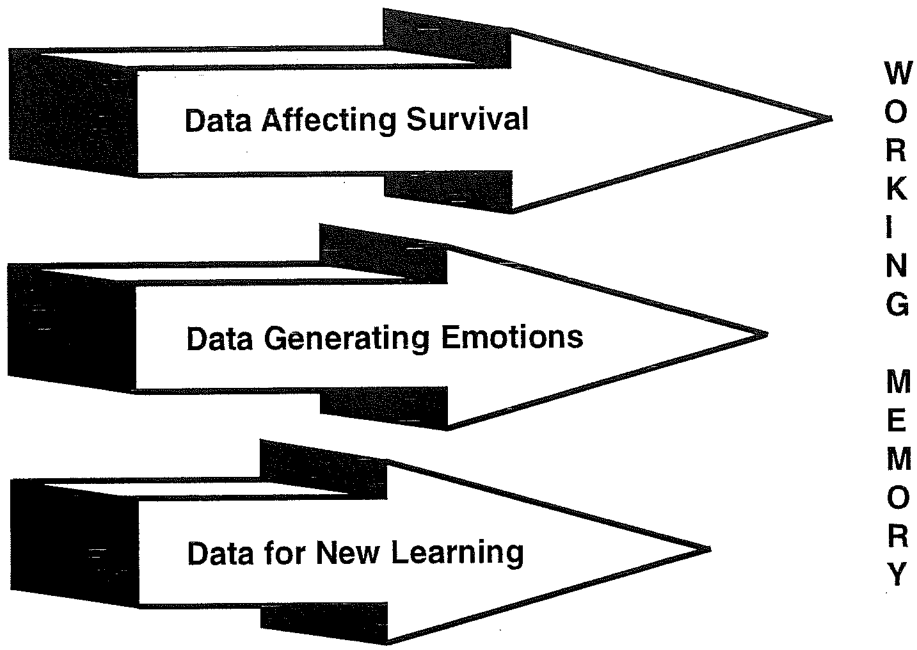

Figure 2.2. *Data for survival and data that generate emotions are processed ahead of data for new learning.*

Pre-school infants can deal with about two items of information at once. Pre-adolescents can handle three to seven items, with an average of five. Through adolescence, further cognitive expansion occurs and the capacity range increases to five to nine, with an average of seven. For most people, that number is constant throughout their lives.

Let's test this notion. Get a pencil and a piece of paper. When ready, stare at the number below for seven seconds, then look away and write it down. Ready? Go.

9217053

Check the number you wrote down. Chances are you got it right. Let's try it again with the same rules. Stare at the number below for seven seconds, then look away and write it down. Ready? Go.

4915082637

Again, check the number you wrote down. Did you get all 10 of the digits in the correct sequence? Probably not. Since the digits were random, you had to treat each digit as a single item, and your working memory just ran out of functional capacity.

This limited capacity explains why we have to memorize a song or a poem in stages. We start with the first group of lines by repeating them frequently. Then we memorize the next lines and repeat them with the first group, and so on. It is possible to increase the number of items within the functional capacity of working memory through a process called chunking. This process will be explained in the next chapter.

CHANGES IN CAPACITY OF WORKING MEMORY WITH AGE			
Approximate Age Range in Years	Capacity of Working Memory in Number of Items		
	Minimum	Maximum	Average
Less than 5	1	3	2
Between 5 and 14	3	7	5
14 and Older	5	9	7

Time Limits

Working memory is temporary and can deal with items for only a limited time. How long is that time? This intriguing question has been clinically investigated for over a century, starting with the work of Hermann Ebbinghaus (1850–1909) during the 1880s. He concluded that we can process items intently in working memory (he called it short-term memory) for up to 45 minutes before becoming fatigued. Because Ebbinghaus mainly used himself as the subject to measure retention in laboratory conditions, the results are not readily transferable to the average high school classroom.

Russell (1979) shows this time span to be much shorter and age dependent. For preadolescents, it is more likely to be 5 to 10 minutes, and 10 to 20 minutes for adolescents and adults. These are average times and it is important to understand what the numbers mean. An adolescent (or adult) normally can process an item in working memory intently for 10 to 20 minutes before fatigue or boredom with that item occurs and the individual's focus drifts. For focus to continue, there must be some change in the way the individual is dealing with the item. For example, the individual may switch from thinking about it to physically using it, or making different connections to other learnings. If something else is not done with the item, it is likely to drop from the working memory.

This is not to say that some items cannot remain in working memory for hours, or perhaps days. Sometimes we have an item that remains unresolved—a question whose answer we seek or a troublesome family or work decision that must be made. These items can remain in working memory, continually commanding some attention and, if of sufficient importance, interfere with our accurate processing of other information.

Criteria for Long-Term Storage

Now comes the most important decision of all: Should the items in working memory move to long-term storage for future recall, or should they drop out of the system? This is an important decision because we cannot recall what we have not stored. Yet teachers teach with the hope that students will retain the learning objective for future use. So, if the learner is ever to recall this information in the future, it has to be stored.

What criteria does the working memory use to make that decision? It seems that the learner's working memory asks just two questions to determine whether an item is saved or rejected. They are: "Does this make *sense*?" and "Does this have *meaning*?" Imagine the many hours that go into planning and teaching lessons, and it all comes to these two questions! Let's review them.

"Does this make sense?" This question refers to whether the learner can understand the item based on experience. Does it "fit" into what the learner knows about how the world works? When a student says, "I don't understand," it means the student is having a problem making sense of the learning.

Sense and meaning are usually required for new learning to be stored.

"Does it have meaning?" This question refers to whether the item is *relevant* to the learner. For what purpose should the learner remember it? Meaning, of course, is a very personal thing and is greatly influenced by our experiences. The same item can have great meaning for one student and none for another. When a student asks, "Why do I have to know this?" it indicates the student has not, for whatever reason, accepted this learning as relevant.

Here are two examples to explain the difference between sense and meaning. Suppose I tell a 15-year-old student that the minimum age for getting a driver's license in his state is 16, but is 17 in a neighboring state. He can understand this information, so it satisfies the sense criterion. But the age in his own state is much more relevant to him, since this is where he will apply for his license. Chances are high that he will remember his own state's minimum age (it has both sense *and* meaning) but will forget that of the neighboring state since it has sense but lacks meaning.

Suppose you are a teacher and you read in the newspaper that the average salary for dock workers last year was $52,000, while the average for teachers was $38,000. Both numbers make sense to you, but the average teacher's salary has more meaning since you are in that profession.

Whenever the learner's working memory decides that an item does not make sense or have meaning, the probability of it being stored is extremely low (see Figure 2.3). If either sense or meaning is present, the probability of storage increases significantly. If both sense *and* meaning are present, the likelihood of storage is very high.

Relationship of Sense to Meaning

Sense and meaning are independent of each other. Thus, it is possible to remember an item because it makes sense but has no meaning. If you have ever played *Trivial Pursuit*, you may have been surprised at some of the answers you knew. If another player asked how you knew that answer, you may have replied, "I don't know. It was just there!" This happens to all of us. During our lifetime, we pick up bits of information that made sense at the time and, although they were trivial and had no meaning, they made their way into our long-term storage. Some neuropsychologists estimate that up to 10 percent of what we have in long-term storage may have been acquired in this manner.

It is also possible to remember an item that makes no sense but has meaning. My sixth-grade teacher once asked the class to memorize the nonsense poem from Lewis Carroll's *Jabberwocky*. It begins, *Twas brillig, and the slithy toves did gyre and gimble in the wabe.* The poem made no sense to us sixth graders, but when the teacher said that she would call on each of us the next day to recite it before the class, it suddenly had meaning. Since I didn't want to make a fool of myself in front of my peers, I memorized it and recited it correctly the next day, even though I had no idea what the sense of it was.

Meaning Is More Significant

Of the two criteria, meaning has the greater impact on the probability that information will be stored. Think of all the television programs you have watched that are NOT stored, even though you spent one or two hours with the program. The show's content or story line made sense to you, but if meaning was absent, you just did not save it. It was entertainment and no learning resulted from it. You might have remembered a summary of the show or whether it was enjoyable or boring, but not the details. On the other hand, if the story reminded you of a personal experience, then meaning was present and you were more likely to remember some details of the program.

Now think of this process in the classroom. Every day, students listen to things that make sense but lack meaning. They may diligently follow the teacher's instructions to perform a task repeatedly, and may even get the correct answers, but if they have not found meaning after the learning episode, there is little likelihood of long-term storage. Mathematics teachers are often frustrated by this. They see students using a certain formula to solve problems correctly one day, but they cannot remember how to do it the next day. If the process was not stored, the information is treated as brand new again!

Sometimes, when students ask why they need to know something, the teacher's response is, "Because it's going to be on the test." This response adds little meaning to a learning. Students resort to writing the learning in a notebook so that it is preserved in writing, but not in memory. We wonder the next day why they forgot the lesson.

For the most part, teachers spend the major portion of their planning and instructional time dealing with how to help students make sense of the lesson objective, and devote little time to making it meaningful. Yet, shifting more classroom emphasis to meaning is likely to increase retention of learning. Some suggestions on how to enhance meaning are found in Chapter 3.

> ***Test Question No. 2:*** *Learners who can perform a new learning task well are likely to retain it.*
>
> ***Answer:*** *False. We cannot presume that because a learner performs a new learning well, it will be permanently stored. Sense and meaning must be present to some degree for storage to occur.*

Meaning Present?	Sense Present? No	Sense Present? Yes
Yes	Moderate to High	**Very High**
No	Very Low	Moderate to High

Figure *2.3. The probability of storing information varies with the degree of meaning and sense present.*

> ***Test Question No. 3:*** *Reviewing material just before a test is a good indicator of how much has been retained.*
>
> ***Answer:*** *False. Reviewing material just before a test allows students to enter the material into working memory for immediate use. Thus, this procedure cannot verify that what the learner recalls during the test was from long-term storage.*

Long-Term Storage

Storing occurs when the hippocampus encodes information and sends it to one or more long-term storage areas. The encoding process takes time. While learners may *seem* to have acquired the new information or skill in a lesson, there is no guarantee that there will be permanent storage after the lesson. How do we know if retention has occurred? If the student can accurately recall the learning after a sufficient period of time has passed, we say that the learning has been retained. Since research on retention shows that the greatest loss of newly-acquired information or a skill occurs within 18–24 hours, the 24-hour period is a reasonable guideline for determining if information was transferred into long-term storage. If a learner cannot recall new learning after 24 hours, there is a high probability that it was not stored and, thus, can never be recalled.[6]

6. This point has implications for how we test students for retention of previously-learned material. See the **Practitioner's Corner** at the end of this chapter on how to test whether information is in long-term storage.

Sometimes, we store the "gist" of an experience, not the specifics. This may occur after watching a movie. We store a generalization about the plot, but few, if any, details.

The long-term storage areas are represented in the model as file cabinets—places where information is kept in some type of order. While there are three file cabinets in the diagram for simplicity, we do not know how many long-term storage sites actually are in the brain. Researchers such as Steven Rose (1992) demonstrate that long-term memory is a dynamic, interactive system that activates storage areas distributed across the brain to retrieve and construct memories. We will discuss this more in the next chapter.

Long-Term Memory and Long-Term Storage

This is a good place to explain the difference between the terms *long-term memory* and *long-term storage.* As used here, long-term memory refers to the process of storing and retrieving information. Long-term storage refers to where in the brain the memories are kept. Think of the long-term storage sites as a library and of long-term memory as a librarian who retrieves information and returns it to its proper storage places.

The Cognitive Belief System

The total of all that is in our long-term storage areas forms the basis for our view of the world around us. This information helps us to make sense out of events, to understand the laws of nature, to recognize cause and effect, and to form decisions about goodness, truth, and beauty. This total construct of how we see the world is called the *cognitive belief system.* It is shown in the information processing model as a large triangle extending beyond the long-term storage areas (file cabinets). It is drawn this way to remind us that the thoughts and understandings that arise from the long-term storage data are greater than the sum of the individual items. In other words, one marvelous quality of the human brain is its ability to combine individual items in many different ways. As we accumulate more items, the number of possible combinations grows geometrically.

Since no two of us have the same data in our long-term storage (not even identical twins raised in the same environment have identical data sets), no two of us see the world in exactly the same way. There are many different ways that people can put the same data together. To be sure, there are areas of agreement: Gravity, for example (few rational people would dispute its effects), or inertia, since most people have experienced the lurch forward or backward when a moving vehicle rapidly changes speed. There can be strong disagreement, however, about what makes an object or person beautiful, or an act justified. The persistent debates over abortion and capital punishment are testimony to the wide range of perspectives that people have over any issue. These differences reflect the ways individuals use the experiences in their long-term storage areas to interpret the world around them.

The cognitive belief system is our view of the world around us and how it works.

Here is a simple example of how experiences can interpret the same information differently. Suppose I ask you to form the mental image of an "old bat." What picture comes to mind? For some baseball fans, it might be a marred wooden club that has seen too many games. A zoologist, however, might picture an aging fruit bat as it flies haltingly among the trees. Still others might recall an old hag whose complaining made their lives unpleasant. Here are at least three very different images generated by the same two words, each one formed by individuals whose experiences are different from the others.

Self-Concept

Deep within the cognitive belief system lies the *self-concept.* While the cognitive belief system portrays the way we see the world, the self-concept describes the way we view *ourselves* in that world. I might conceptualize myself as a good softball player, an above-average student, or a poor mathematician. These and a long list of other descriptions form part of a person's self-concept.

The self-concept is represented in the model as a face and is placed at the apex of the triangle to emphasize its importance. Self-concept is used here as a neutral term that can run the gamut from very positive to very negative (Figure 2.5). The face on the diagram has a smile, indicating a positive self-concept, but for some people, the face might have a frown since they may not see themselves as positive beings in their world. Emotions play an important role in forming a person's self-concept.

Self-Concept and Experiences

Our self-concept is shaped by our experiences. Some of our experiences, such as passing a difficult test or getting recognition for a job well-done, raised our self-concept. Other experiences, such as getting a reprimand or failing to accomplish a task, lowered our self-concept. These experiences produced strong emotional reactions that the brain's amygdala encoded and stored with the cognitive event. These emotional cues are so strong that we often re-experience the emotion each time we recall the event.

Accepting or Rejecting New Learning

Remember that the perceptual register and short-term memory use experience as the criterion for determining the importance of incoming data to the individual. Thus, if an individual is in a new learning situation and experience signals the perceptual register and short-term memory that prior encounters with this information were successful, then the information is very likely to pass along to working memory. The learner now consciously recognizes that there were successes with this information and focuses on it for further processing. But if experiences produced failure, then the self-concept signals the perceptual register to block the incoming data, just as Venetian blinds are closed to block light. The learner resists being part of the unwanted learning experience and re-

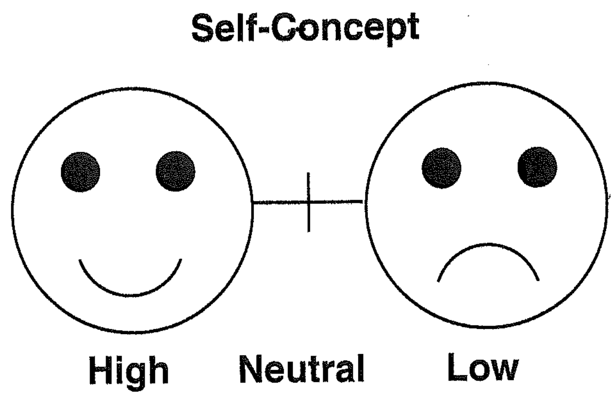

Figure 2.5. Self-concept describes how we see ourselves in the world. It can range from very high to very low and vary with different learning situations.

sorts to some other cerebral activity, internal or external, to avoid the situation. In effect, the learner's self-concept has closed off the receptivity to the new information. As mentioned earlier in discussing the hierarchy of data processing, when a concept struggles with an emotion, the emotion almost always wins. Of course, it is possible for reason to override emotions, but that takes time and conscious effort.

Let us use an example to explain this important phenomenon. Someone who was a very successful student in mathematics remembers how that success boosted self-concept. As a result, the individual now feels confident when faced with basic mathematical problems. On the other hand, if this person was a poor mathematics student, the lack of success lowered the self-concept. Consequently, the individual will avoid dealing with mathematical problems whenever possible. People will participate in learning activities that have yielded success for them and avoid those that have produced failure.

Dealing with Self-Concept

Students who experience this self-concept shutdown in the classroom often give signals of their withdrawal—folding their arms, losing themselves in other work, or causing distraction. Too often, teachers deal with this withdrawal by reteaching the material, usually slower and louder. But they are attacking the problem from the front end of the information processing system, and this is rarely successful. It is the equivalent of putting a brighter light outside the closed Venetian blinds, hoping the light will penetrate. If the blinds are fully closed and effective, no light will get through, regardless of how bright it may be.

> ***Self-concept can greatly affect how an individual responds to a new learning situation.***

The better intervention is to deal with the learner's emotions that are affecting the self-concept, that is, to convince the learner to allow the perceptual register to open the blinds and pass the learning along. But since the self-concept controls the blinds, the learner must believe that participating in the learning will produce new successes rather than repeat past failures. When teachers provide these successes, they encourage students to open the perceptual register and, ultimately, to participate and achieve in the once-avoided learning. In short, the self-concept is an important participant in controlling the feedback loop and in determining how the individual will respond to almost any new learning. Recognizing this connection gives teachers new insight on how to deal with reluctant learners.

This completes our trip through the information processing model. Remember that the brain is a parallel processor and deals with many items simultaneously. While it rejects much data, it stores some. The next chapter will examine the nature of memory and the factors that determine and help in the retention of learning.

PRACTITIONER'S CORNER

Sensory Preferences and Learning Style

Although we use all five senses to collect information from our environment, they do not contribute equally to our knowledge base. Most people do not use sight, hearing, and touch equally during learning. Just as most people develop a left or right-handed preference, they develop preferences for certain senses as they gather information from their environment.

Some people have a preference for learning by sight. They are called *visual* learners. Others who use hearing as the preferred sense are known as *auditory* learners. Still others who prefer touch or whole-body involvement in their learning are called *kinesthetic* learners. Sensory (also called *modality*) preferences are an important component of an individual's learning style. Teachers need to:

- **Understand** that students with different sensory preferences will behave differently during learning, and

- **Recognize That They Tend To Teach the Way They Learn.** A teacher who is a strong auditory learner will prefer this modality when teaching. Students who also are strong auditory learners will feel comfortable with this teacher's methods, but visual learners will have difficulty in maintaining focus. They will doodle or look at other materials to satisfy their visual craving.

- **Note**, similarly, that students with auditory preferences will want to talk about their learning and will become frustrated with teachers who use primarily visual strategies. Strong kinesthetic learners require movement while learning or they become restless—tapping their pencils or feet, squirming in their seats, or finding reasons to walk around the room.

- **Avoid** misinterpreting these variations in learning style behavior as inattention or as intentional misbehavior. They may, in fact, represent the natural responses of learners with different and strong preferences.

- **Understand** that teachers' own learning styles and sensory preferences can affect learning and teaching. They should design lessons that include activities to address all preference styles.

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Developing a Classroom Climate Conducive to Learning

Nearly all learning that occurs in schools involves complex cerebral processing. This occurs more easily in environments free from threat or intimidation. Whenever a student detects a threat, the cerebrum downshifts and thoughtful processing gives way to emotion or survival reactions. Experienced teachers have seen this in the classroom. Under pressure to give a quick response, the student begins to stumble, stabs at answers, gets frustrated, angry, and may even resort to violence.

There are ways to deal with questions and answers that reduce the fear of giving a wrong answer. The teacher could:

- Supply the question to which the wrong answer belongs: "You would be right if I had asked ... "
- Give the student a prompt that leads to the correct answer.
- Ask another student to help.

Threats to students loom continuously in the classroom. The teacher's capacity to humiliate, embarrass, reject, and punish all constitute perceived threats to students. Many students even see grading more as a punitive than as a rewarding process. Students perceive threats in varying degrees, but the presence of a threat in *any* significant degree impedes learning. One's thinking and learning functions operate fully only when one feels secure.

Teachers can make their classrooms better learning environments by avoiding threats (even subtle intimidation) and by establishing democratic climates in which students are treated fairly and feel free to express their opinions during discussions. In these environments students:

- Develop trust in the teacher
- Exhibit more positive behaviors
- Are less likely to be disruptive
- Show greater support for school policy
- Sense that thinking is encouraged and nurtured.

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Increasing Processing Time Through Motivation

Motivational factors can increase the time that working memory deals with information. Wlodkowski and Jaynes (1990) and Hunter (1982) suggest a few that teachers can use:

- **Generate Interest**. If the learner is interested in the item, then the processing time can be extended significantly because the learner is dealing with the item in different ways and making new connections with past learnings that once were also of interest. The working memory is seeking ways to use this new learning to enhance the usefulness of the past learning. We all know students who won't give us five minutes of their undivided attention in class, but who spend hours working on a stamp collection or repairing a carburetor.

  Teachers can identify these interests by having their students complete interest inventories at the beginning of the school year. The information gathered from these surveys can help teachers design lessons that include references to student interests as often as possible. Guidance counselors have more information on the types and sources of interest inventories.

- **Establish Accountability**. When learners believe they will be held accountable for new learning, processing time increases. High school students have little difficulty staying on task in driver education classes. Not only do they have interest, but they know they will be legally accountable for their knowledge and skills long after they complete the license tests.

- **Provide Feedback**. When students get prompt, specific, and corrective feedback on the results of their thinking, they are more likely to continue processing, making corrections, and persisting until successful completion. Many brief quizzes that are carefully corrected and returned promptly are much more valuable learning tools than the unit test, and are much more likely to help students be more successful. This success will improve self-concept and encourage them to try more difficult tasks. Computers are motivating because they provide immediate and objective feedback and allow students to evaluate their progress and understand their level of competence.

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Increasing Processing Time Through Motivation – Continued

Another effective strategy suggested by Hunter (1982) for increasing processing time through motivation is called *level of concern*. This refers to how much the student cares about the learning. We used to think that if the students had anxiety about learning, then little or no learning occurred, but there is helpful anxiety (desire to do well) and there is harmful anxiety (threats). Having anxiety about your job performance will usually get you to put forth more effort to obtain positive results. When you are concerned about being more effective (helpful anxiety), you are likely to learn and try new strategies.

Students also need a certain level of concern to stimulate their efforts to learn. When there is no concern, there is little or no learning. If there is too much concern, anxiety shuts down the learning process and emotions take over. The teacher then has to seek the level of concern that produces the optimum processing time and learning. Hunter offers four ways to raise or lower the level of concern in a learning situation.

- **Consequences**. Teachers raise the level of concern when they say "This is going to be on the test" and lower it with "Knowing this will help you learn the next set of skills more easily."
- **Visibility**. Standing next to a student who is off task will raise that student's concern; moving away from an anxious student will lower it. Telling students their work will be displayed can also raise concern.
- **Amount of Time**. Giving students only a little time to complete a learning task will raise concern; extending the time will lower it.
- **Amount of Help**. If there is little or no help available to students while completing a learning task, concern rises. On the other hand, if they have quick access to help, concern lowers. This can be a problem. If students can always get immediate help to solve a problem, they may become dependent and never learn to solve it for themselves. There comes a time when the teacher needs to reduce the help and tell the students to use what they have learned to solve the problem on their own.

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Creating Meaning in New Learning

Meaning refers to the relevancy that students attach to new learning. Meaning isn't inherent in content, but rather the result of how the students relate it to their past learnings and experiences. Questions like "Why do I need to know this?" reveal a learner who is having difficulty determining the relevancy of the new topic. Here are a few ways teachers can help students attach meaning to new learning.

- **Modeling**. Models are examples of the new learning that the learner can perceive in the classroom rather than relying on experience. Models can be concrete (a model of an engine) or symbolic (a map). To be effective, a model should:
  - Accurately and unambiguously highlight the critical attribute(s) of new learning. A dog is a better example of a mammal than a whale.
  - Be given first by the teacher to ensure that it is correct during this period of prime time when retention is highest.
  - Avoid controversial issues that can evoke strong emotions and redirect the learner's attention.
- **Examples from Students' Experience**. Examples from students' experiences allow them to bring previous knowledge into working memory to accelerate making sense and attaching meaning to the new learning. Make sure that the example is clearly relevant to the new learning. This is not easy to do on the spot, so examples should be thought out in advance when planning the lesson.
- **Creating Artificial Meaning**. When it is not possible to identify elements from student experience for examples, we can resort to other devices to develop meaning. Mnemonic devices are ways to associate material so students can remember it. Examples are HOMES to remember the Great Lakes, and "Every good boy does fine" for the musical notes *e, g, b, d,* and *f*. (See Chapter 3.)

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Using Closure To Enhance Sense and Meaning

Closure describes the covert process whereby the learner's working memory summarizes for itself its perception of what has been learned. It is during closure that a student often completes the rehearsal process and attaches sense and meaning to the new learning, thereby increasing the probability that it will be retained in long-term storage.

- **Initiating Closure**: To initiate closure, the teacher gives directions that focus the student on the new learning, such as "I'm going to give you about two minutes to think of the three causes of the Civil War that we learned today; be prepared to discuss them briefly." In this statement, the teacher is providing adequate quiet time for the cerebral summarizing to occur and has included a following overt activity (discussion) for student accountability. During the discussion, the teacher can assess the quality and accuracy of what occurred during closure and make any necessary adjustments in teaching.

- **Closure is Different from Review**. In review, the teacher does most of the work, repeating key concepts that were made during the lesson and re-checking student understanding. In closure, the student does most of the work by mentally rehearsing and summarizing those concepts and deciding whether they make sense and have meaning.

- **When to Use Closure**. The teacher can use closure at various times in a lesson.

  It can start a lesson: "Think of the two causes of the Civil War we talked about yesterday and be prepared to discuss them."

  It can occur during the lesson (called *procedural closure*) when the teacher moves from one sub-learning to the next: "Review those two rules in your mind before we learn the third rule."

  It should also take place at the end of the lesson (called *terminal closure*) to tie all the sub-learnings together.

Taking time for closure is an investment that can pay off dramatically in increased retention, thereby furthering student understanding and achievement.

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Testing Whether Information Is in Long-Term Storage

Information that the learner processes during a lesson remains in working memory where it eventually will be dropped out or saved for long-term storage. Stahl (1985) notes that just because students *act* as if they have learned the new information or skill doesn't mean it will be transferred to long-term storage at the end of the lesson. Extensive research on retention indicates that 70–90 percent of new learning is forgotten 18–24 hours after the lesson. Consequently, if the new learning survives this time period intact, it is probably in long-term storage and will not deteriorate further.

This time requirement confirms that the processing and transfer between working memory and long-term storage needs adequate time for the encoding and consolidation of the new information into the storage networks. Thus, tomorrow is the earliest reliable time we can confirm that what was learned today has been indeed retained.

How To Test. If teachers want to test whether information actually has been transferred to long-term storage, what type of test should they give? Using what we know about retention, the test:

- Should be given no sooner than 24 hours after the learning.
- Should test on precisely what should have been retained.
- Should come as a surprise to the learner, with no warning or preparation time.

Rationale. If the learners have warning about the test, they are likely to review the material just before the test. In this case, the test may determine the amount of information the learners were able to cram and hold in working memory and *not* what they have recalled from long-term storage. While testing without warning may seem insensitive, it is the only way teachers can be sure that long-term storage was the source of the test information that the learners provided. Unannounced quizzes, then, should help students assess what they have remembered, rather than be a classroom management device to get students back on task.

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Testing Whether Information Is in Long-Term Storage – Continued

Misuse of Tests. Some teachers use unannounced tests as punishment to get students back on task. This is a misuse of a valuable tool. Teachers should:

- **Establish** sense and meaning to increase the probability that retention will occur.

- **Explain** to students that unannounced tests or quizzes help them see what as well as how much they have retained and learned over a given period of time.

- **Ensure** that the test or quiz matches the rehearsal when it was first taught. If the learning required essentially rote rehearsal, give a rote type of test. If it required elaborate rehearsal, use a test that allows the students more flexibility in their responses.

Using the Test Results. It is important that teachers:

- **Analyze** immediately the results of the test to determine what areas need to be untaught or practiced. If some students forgot parts, consider forming cooperative learning groups that focus on reteaching the forgotten areas.

- **Decide** whether memory strategies such as concept maps, mnemonics, or chunking (see following chapters) can help in retention.

The analysis might also reveal areas of the curriculum that might need to be reworked or updated for relevance or it might show that the lesson should be retaught in a different way. A task analysis on a failed lesson is a good way to detect false assumptions about learning that the teacher may have made, and it recasts the lesson into a new presentation that can be more successful for both students and teacher.

Using tests as tools to help students to be right, rather than to catch them being wrong, will create a supportive learning climate that results in improved student performance.