As depicted by the arrows in Figure 9.1, information can enter the short-term store from both the sensory-memory store (representing the present environment) and the long-term-memory store (representing knowledge gained from previous experiences). In this sense, the short-term store is analogous to the central processing unit of a computer. Information can be transmitted into the computer's central processing unit from a keyboard (comparable to input from the mind's sensory store), or it can be entered from the computer's hard drive (comparable to input from the mind's long-term store). The real work of the computer—computation and manipulation of the information—occurs within its central processing unit.

The sensory store and long-term store both contribute to the continuous flow of conscious thought that constitutes the content of the short-term store. *Flow* is an apt metaphor here. The momentary capacity of the short-term store is very small—about seven plus or minus two items (Miller, 1956); only a few items of information can be perceived or thought about at once. Yet the total amount of information that moves through the short-term store over a period of minutes or hours can be enormous, just as a huge amount of water can flow through a narrow channel over time.

Lee Foster/Photoshot

The passing moment The flow of thought through working memory is not unlike the flow of scenery past the window of a moving train.

LONG-TERM MEMORY

Long-Term Memory: The Mind's Library of Information

Once an item has passed from sensory memory into the short-term store, it may or may not then be encoded into ***long-term memory*** (again, see Figure 9.1 on page 322). Long-term memory corresponds most closely to most people's everyday notion of memory. It is the stored representation of all that a person knows. As such, its capacity must be enormous. Long-term memory contains the information that enables us to recognize or recall the taste of an almond, the sound of a banjo, the face of a grade-school friend, the names of the foods eaten at supper last night, the words of a favorite song, and the spelling of the word *song*. We are not conscious of the items of information in our long-term store except when they have been activated and moved into the short-term store. According to the model, the items lie dormant, or relatively so, like books on a library shelf or digital patterns on a computer disk, until they are called into the short-term store and put to use.

As you can see from our brief description, long-term memory and the short-term store are sharply differentiated. Long-term memory is passive (a repository of information), and the short-term store (working memory) is active (a place where information is thought about). Long-term memory is of long duration (some of its items last a lifetime), whereas the short-term store is of short duration (items disappear within seconds when no longer thought about). Long-term memory has essentially unlimited capacity (all your long-lasting knowledge is in it), and the short-term store has limited capacity (only those items of information that you are currently thinking about are in it).

Control Processes: The Mind's Information Transportation Systems

4

In the information-processing model, what are the functions of attention, encoding, and retrieval?

According to the information-processing model presented in Figure 9.1, the movement of information from one memory store to another is regulated by the control processes of *attention, encoding,* and *retrieval,* all indicated in Figure 9.1 by arrows between the boxes. Control processes can be thought of as strategies for moving information through the system and enhancing performance.

Attention, as the term is used here, is the process that controls the flow of information from the sensory store into the short-term store. Because the capacity

ADHD is associated with delays in the development the frontal cortex. For instance, in one study, development of the frontal cortex of 7- to 13-year-old children with ADHD lagged about 3 years behind those of children without ADHD, whereas their motor areas developed slightly earlier (Shaw et al., 2007). This uneven pattern of brain development may account for the increased fidgeting and restlessness seen in children with ADHD.

17
What general roles does the prefrontal cortex play in working memory?

More specific brain regions can also be identified that are associated with particular aspects of executive functions. For example, working-memory tasks involve the anterior portion of each prefrontal lobe. In neuroimaging studies, increased activity in the prefrontal cortex occurs whenever a person is deliberately holding either verbal or visual information in mind (Nee et al., 2008). In one study, neural activity in the prefrontal cortex was significantly greater on trials in which the person successfully kept the information in mind than in unsuccessful trials (Sakai et al., 2002).

Although the relation of the prefrontal cortex to the regulation of behavior has been known at least since the days of Phineas Gage, new neuroimaging techniques are permitting scientists to get a closer look at important brain/cognition relationships. Moreover, as we learn more about how the brain is involved in the control of our thoughts and behaviors, we're bound to discover interesting individual differences. It's very likely that different people take alternative neural routes to achieve similar goals (Braver et al., 2010).

SECTION REVIEW

Executive functions enable regulation of thoughts, emotions, and behavior.

Executive Functions

- Executive functions involve processes of working memory (updating), switching, and inhibition.
- Executive functions (a) show both unity and diversity, (b) have a substantial genetic component, (c) are related to and predictive of important clinical and societal outcomes, and (d) are developmentally stable.

Neurological Basis of Executive Functions

- The prefrontal cortex serves as the neural hub for executive functions.
- Patients with damage to the prefrontal cortex have difficulty planning and making decisions, regulating emotions, and inhibiting thought and behavior.

Memory as the Representation of Knowledge

Memory, broadly defined from the perspective of cognitive psychology, refers to all of the information in a person's mind and to the mind's capacity to store and retrieve that information. In this section, we examine memory as the *representation of knowledge*. In the next section, we examine memory as the act of remembering.

When we think of "memories" we typically think of things that have happened to us in the past. In fact, it's not too much of a stretch to say that "we are what we remember." Our memories tell us who we are, who we love, our entire life history. These are all available to consciousness, or self-awareness, and are autobiographical in nature.

But there is more to "memories" than this. Some aspects of our memories are available to consciousness but are not related to our personal histories. Your knowledge of the language you speak, the rules of arithmetic and multiplication, and perhaps basic facts about how the world works (for example, objects fall when they are dropped) are also "memories" of a sort, and although you may remember being taught how to multiply in third grade, your knowledge of the rules is represented differently from your recollection of being instructed in the process. Many of your memories are also nonverbal. You know how to ride a bike, how to throw a ball, and maybe how to ski, but you'd probably have a tough time explaining in words exactly how these skills are performed. Different types of information are represented differently in the brain, and we will examine some of these differences in this section, following mostly from the theorizing of Endel Tulving (2000, 2005).

Explicit and Implicit Memory

18 What are the differences between explicit and implicit memory, and how is each memory type assessed? In what sense are implicit memories more context dependent than explicit memories?

Explicit memory is the type of memory that can be brought into a person's consciousness. It provides the content of conscious thought, and it is highly flexible. Explicit memories can be called to mind even in settings quite different from those in which they were acquired, and they can be combined with other explicit memories for purposes of reflection, problem solving, and planning. Such memory is called *explicit* because it is assessed through explicit tests—tests in which the person is asked to report directly (explicitly) what he or she remembers about a particular entity or event. It is also called *declarative memory* because the remembered information can be declared (stated in words). Tulving referred to episodic memory as *autonoetic,* or "self-knowing," permitting the placement of the self into a particular set of circumstances at a specific time in the past for the purpose of mentally recreating the remembered past at the level of a moment. According to Tulving (2002), "Time's arrow is bent into a loop" (p. 2) by the uniquely human ability to mentally travel in time and consciously transport oneself into the past.

Implicit memory, in contrast, is the type of memory that cannot be verbalized. It consists of all the nonverbal and unconscious means through which previous experiences can influence a person's actions and thoughts. Tulving referred to such knowledge as *anoetic,* or not subject to conscious attention. Such memory is called *implicit* because it is assessed through implicit tests—tests in which the memory is not reported directly but is inferred from behavioral responses. We would test your memory for balancing on a bicycle not by asking you *how* to do it but by asking you *to* do it. Your good performance on the bicycle would imply that you know how to balance on it. Because people do not report in words the relevant information, implicit memory is also called *nondeclarative memory.* Implicit memories are much more closely tied to the contexts in which they were acquired than are explicit memories. Whereas explicit memories can be called forth voluntarily outside of their original context, implicit memories exert their effects automatically in the context of the specific stimuli, tasks, or problems to which they pertain.

In addition to distinguishing between explicit and implicit memories, cognitive psychologists also distinguish among subclasses of each type, along the lines depicted in **Figure 9.11.**

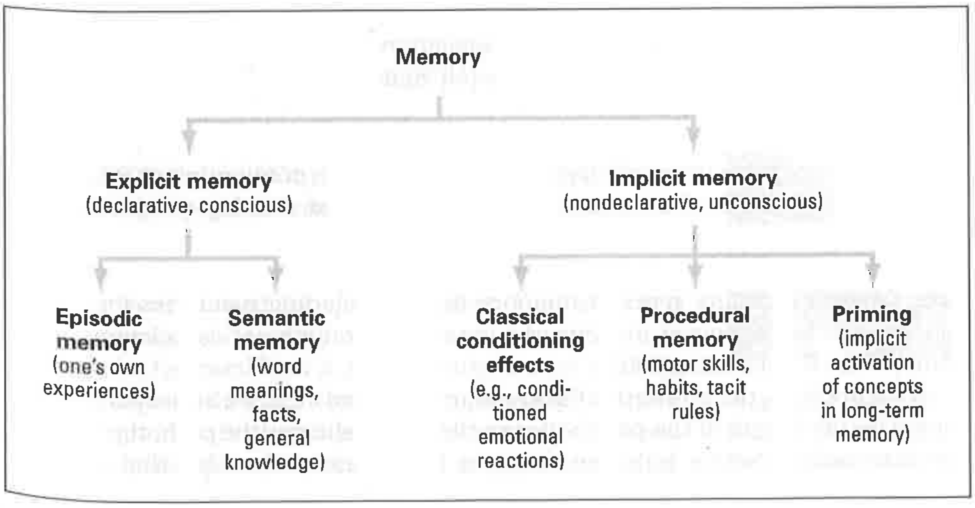


FIGURE 9.11 Types of long-term memory Explicit- and implicit-memory systems follow different rules and involve different neural systems in the brain. The explicit and implicit categories can be further subdivided into narrower memory categories that may also involve different neural systems. (Adapted from Tulving, 1985, and Squire et al., 1993.)

Varieties of Explicit Memory: Episodic and Semantic

19

How do the two subclasses of explicit memory differ from one another?

As shown in Figure 9.11, explicit memory is divisible into two subclasses. ***Episodic memory*** is explicit memory of one's own past experiences. Your memory of what you did and how you felt on your 16th birthday, or of what you ate for dinner last night, or of any other specific episode in your life, is episodic memory. Episodic memories always have a personal quality. An integral part of your episodic memory of an event is your memory of yourself experiencing that event—as participant, witness, or learner. These are sometimes referred to as *autobiographical memories.*

Semantic memory, by contrast, is explicit memory that is not tied mentally to a particular past experience. It includes knowledge of word meanings (which is one definition of semantics) plus the myriad facts, ideas, and schemas that constitute one's general understanding of the world. It also includes knowledge of oneself that is not mentally tied to the re-experiencing of a particular episode in one's life. Your memories that apples are red, that penguins are birds, that you were born on such-and-such a date, and that psychology is the most fascinating of all academic subjects are examples of semantic memory. Of course, all such information had to have been acquired through past experiences in your life, but your memory of the information does not depend on remembering those experiences. To remember your birth date, or that penguins are birds, you do not have to remember anything about the circumstances in which you learned that fact. Although semantic memory is still conscious and within awareness, it is in the domain of temporarily and contextually unspecific pieces of information. Tulving referred to such knowledge as *noetic,* or knowing.

Here is a test question: *What is classical conditioning?* After answering the question, think about *how* you answered it. Did you think back to your experience of reading about classical conditioning in Chapter 4 of this book or to your experience of hearing your professor define classical conditioning and try to reconstruct the definition from your memory of that experience? Or did you just *know* the answer, without having to reflect on any particular past experience? If the first is the case, then your memory of the definition of classical conditioning is an episodic memory (or at least partly so); if the second is the case, it is a semantic memory. In general, episodic memories are more fleeting, and less stable, than semantic memories. Over time, we forget most of our memories of specific past experiences, but the general knowledge that we extract from those experiences often stays with us.

Network Models of Memory Organization

20

What sorts of experimental results was Collins and Loftus's spreading-activation model designed to explain? How does the model expand on the idea that mental associations provide a basis for memory and thought?

Recalling an item from semantic memory is a bit like looking for information in an encyclopedia. To find an item that doesn't come easily to mind, you probe your mind with terms or concepts that have meaningful associations to that item. Many cognitive psychologists today depict the mind's storehouse of knowledge as a vast network of mental concepts linked by associations. **Figure 9.12** illustrates such a model. Allan Collins and Elizabeth Loftus (1975) developed this specific diagram to explain the results of experiments concerned with people's abilities to recognize or recall specific words very quickly after exposure to other words. For example, a person can recognize the word *apple* more quickly if the previous word was *pear* or *red* than if it was *bus*. Collins and Loftus assumed that the degree to which one word speeds up the ability to recognize or recall another reflects the strength of the mental association between the two words or concepts. Similar experiments have shown that many types of memory items—including memories for famous people—can be organized in networks based on strengths of association among them (Stone & Valentine, 2007).

In Figure 9.12, the strength of association between any two concepts is represented by the length of the path between them; the shorter the path, the stronger the association. Notice how the diagram incorporates the idea that common properties of objects often provide a basis for their link in memory. *Roses, cherries, apples, sunsets,* and *fire engines* are all linked to the concept *red,* and through that common tie they are all linked to one another. The model is called a *spreading-activation model* because it proposes that the activation of any one concept initiates a spread of activity to nearby concepts in the network, which primes those concepts so they become temporarily more retrievable than they were before. The spreading activity declines with distance, so concepts that are closely linked with the active concept receive more priming than those that are more distantly linked. Such models are convenient ways to depict the results of many memory experiments, and they help us to visualize the patterns of associations that make up the mind.

Modern brain theories posit that memories for concepts, such as those depicted in Figure 9.12, are stored in overlapping neural circuits in the cerebral cortex (Fuster, 2006; Patterson et al., 2007). Some of the neurons that are part of the circuit for one concept are part of the circuit for other concepts as well. The more overlap there is between the circuits for two concepts, the more closely they are associated in the person's mind. According to these theories, priming occurs because the activation of the circuit for one concept literally does activate part of the circuit for another, making that whole circuit more easily activated than it was before.

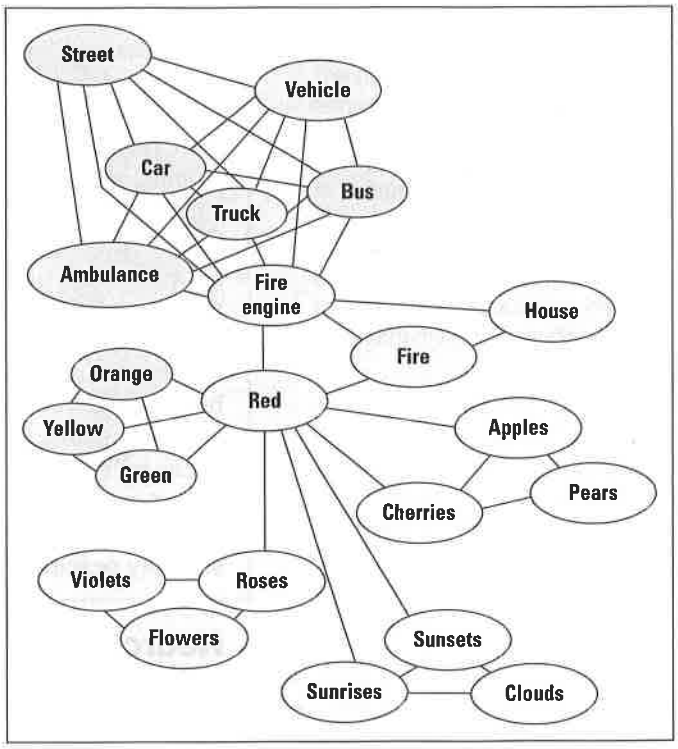


FIGURE 9.12 A network model of memory organization This diagram depicts schematically some of the links, or associations, among a tiny fraction of the thousands of different concepts that are stored in a typical person's long-term semantic memory. (From Collins, A., & Loftus, E. (1975). A spreading-activation theory of semantic processing. *Psychological Review,* 82, 407–428. Figure 1, p. 412. Copyright © American Psychological Association.)

Varieties of Implicit Memory

Implicit memory can also be divided into subclasses, as depicted in the right-hand portion of Figure 9.11. One subclass consists of the memories resulting from classical conditioning—the internal changes that lead a person or animal to respond to conditioned stimuli. Recall that consciousness is not required for classical conditioning to occur. A second subclass is a broad one referred to as ***procedural memory,*** which includes motor skills, habits, and unconsciously learned (tacit) rules. With practice you improve at a skill such as riding a bicycle, hammering nails, or weaving a rug. The improvement is retained (remembered) from one practice session to the next, even though you are unaware of the changes in muscle movements that make the difference. You can even learn to make decisions based on complex rules without ever becoming aware of the rules (Greenwald, 1992), and that phenomenon, too, exemplifies procedural memory.

21

What are some examples of procedural memory, and why are such memories classed as implicit?

Some experiments demonstrating rule-based procedural memories use what are called *artificial grammars* (Frensch & Rünger, 2003; Reber, 1989). The grammars consist of sets of rules specifying which letters may or may not follow certain other letters in strings that are several letters long. For example, one rule might be that an *X* at the beginning of a string must be followed by either another *X* or a *V,* and another rule might be that a *J* anywhere in the middle of a string must be followed by a *B, K,* or *T.* Subjects are not told the rules. Instead, they are shown examples of grammatical and nongrammatical strings, labeled as such, and then are asked to categorize new examples as grammatical or

Procedural memory The learned skill of balancing on a bicycle is retained as implicit procedural memory. You can't say just how you do it, but you don't forget it.

not, on the basis of their "gut feelings." The subjects typically do not learn any of the rules explicitly—they cannot state the rules—yet they learn to make correct categorizations at a rate significantly better than chance. The memories that guide their correct choices are implicit.

22

Why is priming considered to be implicit memory? What function does priming play in a person's everyday thought?

A third variety of implicit memory is priming (Tulving, 2000). Recall that *priming* is defined earlier in this chapter (on p. 330) as the activation, by sensory input, of information that is already stored in long-term memory. This activation is not experienced consciously, yet it influences subsequent conscious perception and thought and thus provides a link between implicit and explicit memory. Priming helps keep our stream of thought running along consistent, logical lines. When we see or think about an object, event, or idea, those elements of our semantic memory that are relevant to that perception or thought become activated (primed) for a period of time, so they are more easily retrievable into conscious, working memory. Priming is classed as implicit memory because it occurs independently of the person's conscious memory for the priming stimulus. As noted in the discussion of attention, priming can even occur when the priming stimulus is presented in such a way that it is never consciously perceived.

Neuropsychological Evidence for Separate Memory Systems

Further evidence for multiple, distinct memory systems comes from studies of people who have impaired memory resulting from brain damage. Brain damage can destroy one kind of memory while leaving another kind intact. Damage to the hippocampus disrupts that acquisition of new memories, as reflected by the case of H. M.

Implicit Memory Remains Intact in Temporal-Lobe Amnesia: The Case of H. M.

Imagine what life would be like if, as a result of an operation, you became unable to form new explicit (conscious) long-term memories. At any given moment you would be fully aware of your environment and able to think about it, but you would have no idea how you arrived at that moment. You would live first in one moment, then in another, then in another, with no memory of the previous moments. If you made a plan for the future—even the future of just a few minutes ahead—you would forget the plan forever the instant you stopped thinking of it. Your life would be like that of the late Henry Molaison—known for decades in the psychological literature as H. M.—who indeed did lose his ability to form new explicit long-term memories.

In 1953, at age 27, H. M. underwent surgery as treatment for severe epilepsy. A portion of the temporal lobe of the cortex and underlying parts of the limbic system, including the hippocampus, on each side of his brain were removed. The surgery was effective against the epilepsy, but it left him unable to encode new explicit long-term memories. Between the time of his surgery and his death in 2008, H. M. participated in hundreds of memory experiments.

23

How does the case of H. M. support the idea of a sharp distinction between working memory and long-term memory?

Throughout his life, H. M. could remember events that occurred well before the operation. His long-term-memory store was full of knowledge acquired largely in the 1930s and 1940s. He could converse, read, solve problems, and keep new information in mind as long as his attention remained focused on it. He had an excellent vocabulary and was a skilled solver of crossword puzzles (Scotko et al., 2008). But the minute his attention was distracted, he would lose the information he had just been thinking about, and he would be unable to recall it later. To hold information in mind for a period of time, H. M. sometimes used elaborate memory schemes. In one test, for example, he successfully kept the number 584 in mind for 15 minutes, and when asked how he did this, he replied: "It's easy. You

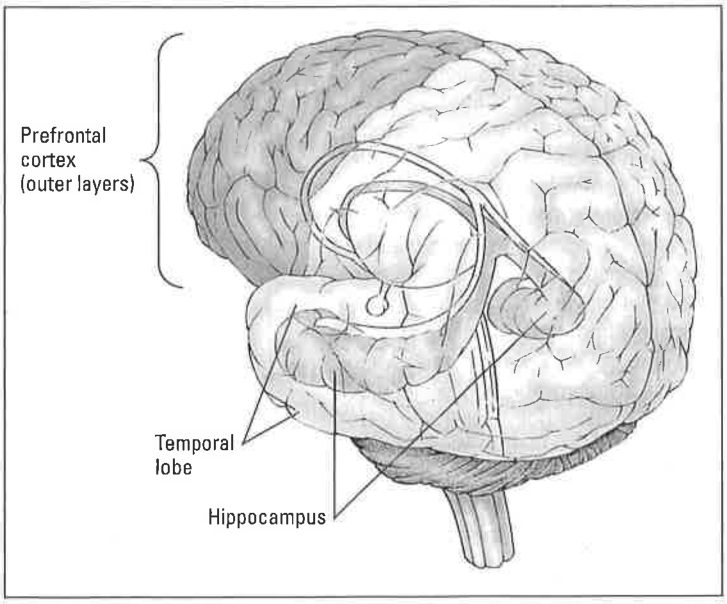


FIGURE 9.13 Brain areas involved in temporal-lobe amnesia The hippocampus, buried within the temporal lobe, is critically involved in long-term memory encoding. The most severe form of amnesia occurs when this structure and some of the surrounding areas of the temporal lobe are destroyed on both sides of the brain. As discussed later in the chapter, the prefrontal cortex is also involved in long-term memory encoding.

just remember 8. You see, 5, 8, 4 add to 17. You remember 8; subtract from 17 and it leaves 9. Divide 9 by half and you get 5 and 4, and there you are—584. Easy." Yet a few minutes later, after his attention had shifted to something else, he could not remember the number or the memory scheme he had used, or even that he had been given a number to remember (Milner, 1970).

H. M.'s memory impairment made it impossible for him to live independently. He had to be accompanied wherever he went and needed constant reminders of what he was doing (Hilts, 1995). He was aware of his memory deficit and once described it in the following way (Milner, 1970): "Right now, I'm wondering, have I done or said anything amiss? You see, at this moment everything looks clear to me, but what happened just before? That's what worries me. It's like waking from a dream. I just don't remember."

There have been many other studies of people who have a memory loss like H. M.'s, though usually not as complete, after strokes or other sources of brain damage. Any loss of long-term memory, usually resulting from some sort of physical disruption or injury to the brain, is referred to as *amnesia*. H. M.'s particular disorder is called ***temporal-lobe amnesia,*** and the areas of destruction most strongly correlated with it are the *hippocampus* (the limbic-system structure buried within the temporal lobe, depicted in **Figure 9.13,** and introduced in Chapter 5) and cortical and subcortical structures closely connected to the hippocampus in both halves of the brain (Gold & Squire, 2006; Squire, 1992).

24

What evidence indicates that the hippocampus and temporal-lobe structures near it are involved in encoding explicit long-term memories?

Neuroimaging studies complement the evidence from brain-damage research. When people with intact brains are presented with new information to memorize, they manifest increased activity in the hippocampus and adjacent parts of the temporal lobe, and the degree of that increase correlates positively with the likelihood that they will recall the information successfully in a later test (Otten et al., 2001; Reber et al., 2002). Apparently, activity in the hippocampus is essential for the formation of at least some types of long-term memories.

H. M.'s deficits had to do entirely with explicit memory. Such patients generally behave normally on all sorts of implicit-memory tests. If classically conditioned to blink their eyes in response to a conditioned stimulus, they show the conditioned response as strongly in subsequent tests as do subjects who do not have amnesia (Daum et al., 1989). If given practice with a new motor skill, such as tracing a pattern that can be seen only in its mirror image, they show normal improvement from session to session and retain the effects of previous learning

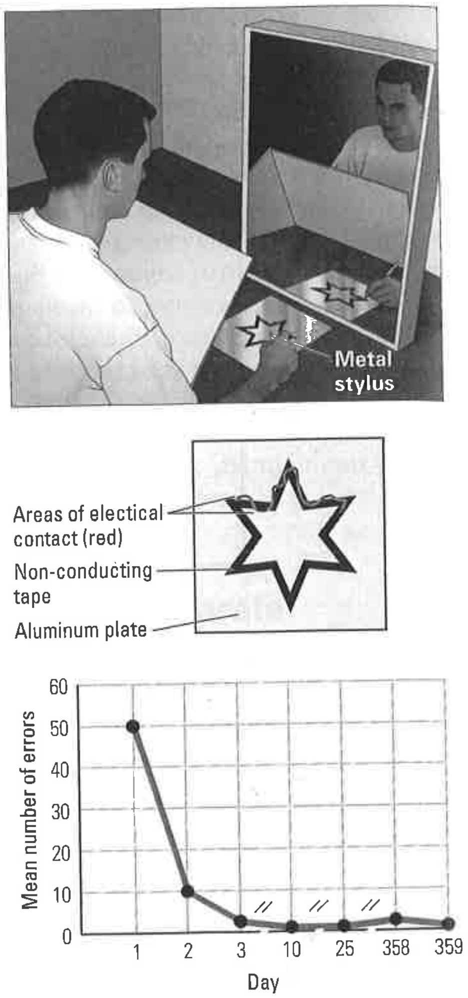


FIGURE 9.14 Implicit memory without explicit memory As shown in the graph, H. M., the patient with temporal-lobe amnesia, improved from session to session in a mirror-tracing task, even though at each session he could not remember having performed the task before. The task was to trace a star under conditions in which the star and hand could be seen only in a mirror so that movements had to be made oppositely from the way in which they appeared. An error was counted whenever the stylus moved off the star's outline. The data points on the graph represent the average number of errors per trial for the seven trials that occurred in each session. Sessions occurred on three successive days and then after delays of 1 week, 15 days, and nearly a year.
(Based on data from Gabrieli et al., 1993.)

even if months elapse between one session and the next (see **Figure 9.14**; Gabrieli et al., 1993; Milner, 1965). Similarly, they can learn and retain artificial grammars and tacit rules for grouping objects into categories (Knowlton et al., 1992; Poldrack & Foerde, 2008), and they show as much activation of long-term semantic memories in response to priming stimuli as do normal subjects (Gabrieli, 1998; Levy et al., 2004).

In all these examples the implicit memory is manifested even when the subjects with amnesia cannot consciously remember anything at all about the learning experience. In one experiment, a patient with severe amnesia learned to program a computer over a series of sessions. At each session, his programming ability was better than it was in the previous session, even though he had no explicit memory of ever having programmed a computer before (Glisky et al., 1986).

Semantic Memory Without Episodic Memory in Some Patients with Amnesia

The most severe cases of temporal-lobe amnesia, like that of H. M., entail loss of both episodic- and semantic-memory encoding. H. M. not only failed to remember anything about his own experiences that occurred after his surgery (in 1953) but also failed to remember almost all factual information that he had experienced after that date (Corkin, 2002). He could not name new world leaders or entertainers, and if asked to draw a car or a radio from memory, he would draw a 1940s or early 1950s version (Milner, 1984). But patients with less severe forms of amnesia typically manifest a greater deficit in episodic memory than in semantic memory (Bayley et al., 2008; Tulving, 2002).

The most extreme differentiation between episodic and semantic memory is found in patients who suffer from a rare disorder called *developmental amnesia*. These people have bilateral damage to the hippocampus, but not to structures surrounding it, caused by temporary loss of blood flow to the brain at the time of birth or in early childhood. The hippocampus is more susceptible to permanent damage caused by lack of oxygen than is the rest of the brain. Faraneh Vargha-Khadem and her colleagues (1997, 2002; Gardiner et al., 2008) have identified and studied several young people who suffer from this disorder. All these individuals have severe deficits of episodic memory. If asked what happened a few hours ago or yesterday or at their last birthday party, they can recount little or nothing. Yet, despite this, they developed speech, reading, vocabulary, and other verbal capacities within the normal range. They all attended mainstream schools and learned and remembered facts well enough to perform passably on school tests. When they were presented with new factual information in controlled studies, they later remembered a good deal of that information but did not remember the episodic experience of learning it. Their abilities are consistent with other evidence that the hippocampus is essential for episodic-memory encoding but not for semantic-memory encoding (Eichenbaum, 2003). Patients with amnesia, such as H. M., who lose the ability to encode new semantic as well as episodic memories, have damage not just to the hippocampus but also to other portions of the temporal lobes.

25

What is some evidence that semantic memory can occur in the absence of episodic memory and that the hippocampus is more important for the latter than the former?

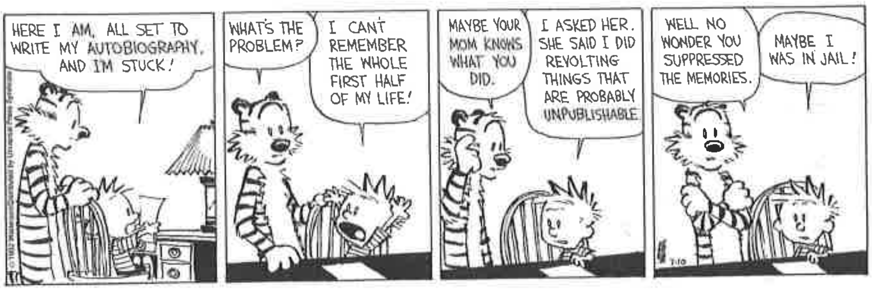
Other Evidence of Semantic Memory Without Episodic Memory

It may at first seem surprising that people can remember new information without remembering the experience of learning that information. Yet, with a little poking around in your own semantic store, you will find many facts that you yourself know but can't relate to any episodes in your life (though it probably took you longer to forget the episodes than patients with amnesia would take). I (Peter Gray) know that kumquats are a kind of fruit, but I can't recall any instance in my life of ever seeing, reading about, or hearing of kumquats.

Older people are especially familiar with the phenomenon of knowing without knowing how they know. In old age, the capacity to form new episodic memories generally declines more rapidly than does the capacity to form new semantic memories (Johnson et al., 1993). Young children also show excellent semantic memory and poor episodic memory. During their first 4 years of life, children acquire an enormous amount of semantic information—including word meanings and facts about their world—that will stay with them throughout their lives. But children under 4 are relatively poor at recalling specific episodes in their lives, and none of us in adulthood can recall much about our own childhood prior to about age 4 (West & Bauer, 1999). Apparently the human ability for episodic-memory encoding develops more slowly and unravels more quickly than that for semantic-memory encoding.

The inability to remember events from infancy and early childhood is not just due to the length of time between experiencing the event and trying to recall it. Even 4- and 5-year-old children fail to remember events in their lives from just 1 and 2 years earlier. The inability to remember events from infancy and early childhood is called ***infantile amnesia*** and marks the beginning of true autobiographical memory—personal and long-lasting memories that are the basis for one's personal life history (Nelson, 1996). Yet, some people can provide one or two vivid memories of life as an infant, including one of your authors (David Bjorklund):

> My memory is of me as a sick baby. I had the croup (something like bronchitis). When I recall this memory I can feel the congestion in my chest, hear the vaporizer whir, smell the Vicks VapoRub, and see the living room of my grandparents' house while looking through the bars of my crib. The memory is like a multisensory snapshot. I have no story to tell,



Most people cannot remember anything from the first few years of their lives, but this does not mean that this information is being repressed.

> only the recall of an instant of my life as a sickly baby. My mistake was relating this vibrant and personally poignant memory to my mother. She listened carefully and then told me that I had never had the croup; my younger brother Dick had the croup as an infant. I was about 4 years old at the time. My "memory" was a reconstruction—and of an event I had only *observed*, not one I had actually *experienced*. (Bjorklund, 2012, p. 302)

Most people who have recollections from infancy and early childhood can be explained as mine was—a reconstruction based on what one heard, experienced, or imagined later.

26
What is responsible for the off-set of infantile amnesia around the age of 4?

Why can't we remember events from early childhood? There have been several explanations, but most modern ones focus on how early memories were encoded and represented and how we try to remember them years later (Howe et al., 2009). For instance, Gabrielle Simcock and Harlene Hayne (2002) showed 27- to 39-month-old children a sequence of actions in their homes about a "Magic Shrinking Machine." They then interviewed the children 6 and 12 months later and asked them to remember as much as they could about the novel (and seemingly memorable) event. The children's memory for the earlier event was related to their level of vocabulary development *at the time of the original experience.* Children with higher verbal scores at the initial testing were able to remember aspects of the event 6 and 12 months later, whereas children of the same age but with poorer language skills were not. According to the authors, "children's verbal reports were frozen in time, reflecting their verbal skill at the time of encoding, rather than at the time of test" (p. 229). Overall, the research evidence indicates that infantile amnesia reflects important changes that occur during early childhood—changes that permit autobiographical memory and that separate our species from all others.

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How might the relative lack of episodic memory in early childhood and old age be explained? How does episodic memory seem to distinguish us from other species?

The relatively poor episodic memory at both ends of the life span may be related to prefrontal cortical functioning (Li et al., 2005; Wheeler et al., 1997). The prefrontal cortex develops more slowly in childhood and tends to suffer more damage in old age than does the rest of the brain. People with prefrontal cortical damage typically experience a much greater loss in episodic-memory encoding than in semantic-memory encoding (Wheeler, 2000). This brain area, which is much larger in humans than in other species and is crucial for planning and complex thought, may be essential for our sense of self, including our sense of our own past experiences. We are not only a conscious species but also a self-conscious species. We—unlike any other animal, or at least much more so than any other animal—reminisce about our past, think about our position in the present, and project ourselves into the future as we make plans and contemplate their consequences. In fact, one explanation for infantile amnesia is that, until about age 4, children do not have a well-developed sense of self (Howe et al., 2009). Such abilities are intimately tied to our capacity to form episodic memories (Schacter et al., 2007). This evolutionarily recent addition to the mammalian cognitive machinery is apparently more fragile—more destructible by aging and injuries—than is the more ancient semantic-memory system or the still more ancient implicit-memory system (Tulving, 2002; Wheeler et al., 1997).