CHAPTER 1

Kinds of Memory

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Memory is a single term, but refers to a multitude of human capacities. There are many different kinds of memory. Philosophers have analyzed memory for 2,000 years; psychologists have studied the topic experimentally for 115 years; and neuroscientists have examined the neural bases of memory for the past 70 years. All these attempts have revealed much about phenomena of memory—our understanding has increased in leaps and bounds—but there remains no generally agreed-upon classification of the kinds of memory that exist. Many categorizations do exist, but the difficulty is that experts disagree on which classification is best. Analyzing this problem in 1972, Tulving remarked: “In a recent collection of essays on human memory edited by Norman (1970) one can count references to some twenty-five or so categories of memory, if one is willing to assume that any unique combination of an adjectival modifier with the main term refers to something other than any of the referents of other unique combination” (Tulving, 1972, p. 382). Many more adjective-noun combinations exist in 2002 than in 1972 (implicit memory, flashbulb memory, and working memory, to name just three terms introduced since then), but a universally accepted categorization scheme does not exist. There is no periodic table for types of memory.

The foregoing considerations make it difficult to write a chapter on “varieties of memory.” However, they should not be cause for undue alarm. Yes, the field of inquiry into human memory is in flux and full of healthy disagreement. But to say that there is no universal agreement on a categorization scheme for types of memory is not to say that there is no agreement. In this chapter we present a set of categories that reflect current theorizing for many (and maybe most) psychologists who study human memory. The typology we present is not perfect, as we will see, and some would disagree with it; nonetheless, we see the categorization system we describe here reflected in many articles, chapters, and textbooks. Briefly, we consider types of memory ordered generally by their persistence, beginning with fleeting sensory memories and then moving on to short-term or working memory (holding information in mind and working with it). We finally turn to the many types of long-term retention. This scheme implies sharp boundaries between the length of time information is held by these various types of memory, but in truth the differences are more shades of gray; one type of memory blends into another. Still, the framework is useful.

The chapter begins by considering grounds for distinguishing among types of memory. The next section presents some broad distinctions between different classes of memory or...
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tests of memory, such as explicit and implicit, which have proved useful to the field. Next we consider a brief overview of the typology of sensory, working, and long-term memories. The remainder of the chapter fleshes out these different types of memory.

GROUND FOR DISTINGUISHING TYPES OF MEMORY

We present four different bases for distinguishing among types of memory: phenomenology of memory, differences among memory tests, dissociations between forms of memory, and different neural systems underlying memory.

Phenomenology of Memory

Philosophers have often proposed distinctions among forms of memory chiefly on the basis of the types of experience or the language of expression to which they give rise. For example, the philosopher Gilbert Ryle (1949) distinguished between declarative memory (making declarations about the past) and procedural memory (carrying out actions based on past learning) in part on the basis of different language forms. He argued that these two types of knowledge are accompanied by different verbal expressions. People say “I know that...” when accessing declarative knowledge, but “I know how...” when referring to procedural knowledge: “I know that Ottawa is the capital of Canada,” but “I know how to tie my shoes.”

Similarly, Tulving (1985a) argued that distinct forms of memory are accompanied by different types of mental experience. For example, episodic memory (memory for episodes in specific times and places) is accompanied by the experience of remembering, or mentally traveling back in time and, in a way, re-experiencing the events. Tulving referred to remembering as reflecting autono-

etic (self-knowing) consciousness. Semantic memory (the general knowledge of facts) is, he argued, accompanied by noetic (knowing) consciousness. (We remember salient events of our lives; we know Napoleon was a French emperor). Finally, procedural memory in Tulving’s system is anoetic (not knowing) in its state of conscious experience. That is, complex, practiced procedural skills (riding a bicycle, tying one’s shoes, serving a tennis ball) are executed with little conscious mediation and control once the action has been started.

Other forms of memory, such as flashbulb memories, have also been advanced largely on phenomenological grounds. For example, flashbulb memory refers to the quality of vivid recollection that exists for some memories of particularly highly charged emotional events that are often discussed later in one’s life (Brown & Kulik, 1977).

All these forms of memory and others are supported by differences that most people experience and to which they can relate. However, psychologists have repeatedly found that introspection alone is a poor means for making and defending critical psychological distinctions. Usually, experiential differences are taken, at best, as a starting point for making distinctions among types of memory that need to be verified by other means. For example, Tulving (1985a) proposed a technique that led to a program of research to validate his distinction between remembering and knowing the past (see Gardiner & Richardson-Klavehn, 2000).

Differences among Expressions of Memory

Psychologists have devised a large number of ways to assess a person’s knowledge and to test memory. Of course, there are standardized tests of general knowledge or facts, such as the Scholastic Assessment Test (SAT), and there are other standard tests specifically for
memory of recent experiences such as the Wechsler Memory Scale. However, psychologists studying memory have created a plethora of memory tests for both laboratory study and life that test many different abilities. In the lab, people may study a long series of words or pictures. Tests for these materials can include free recall (recall the items in any order on a blank sheet of paper), cued recall (what presented item was associated with lemon?), serial recall (report the items in order), or recognition (pick old or studied items from new, nonstudied items). There are many other forms of testing for stimuli presented in a laboratory context, as well as tests of knowledge acquired in life, too (such as the test of TV shows that lasted only one season in Squire & Slater, 1975).

No one has ever proposed that all these different tests represent different forms of memory. However, some distinctions proposed to classify types of memory reflect differences observed between tests, such as differences between general knowledge tests (semantic memory) and those for personal experiences (episodic memory). The task, then, is to find out which memory tests behave similarly when certain independent variables are manipulated and which tests respond differently. The next section presents this logic of classifying tests based on whether they produce patterns of results that are similar to or different from one another.

**Dissociations among Memory Measures**

Perhaps the primary method of distinguishing between different types of memory is finding interactions between independent or subject variables and performance on different memory measures. For example, injury to certain parts of the brain (especially the hippocampus and surrounding areas in the medial temporal lobe) renders people amnesic for certain types of information (Squire, 1992). When amnesic patients are examined on tests of memory and compared to control subjects matched on age and education, they typically show impaired retention on certain types of tests but not others (for a review, see Moscovitch, Goshen-Gottstein, & Vriezen, 1994). For example, measures of short-term memory (retention of digits or words over brief periods without distraction) are often comparable to those of healthy control subjects, but certain measures of long-term memory (e.g., free recall of a list of words after a delay of several minutes) are greatly impaired. This outcome leads to the conclusion that, at a minimum, these two different memory tasks (short-term digit memory and long-term free recall) tap different types of memory.

The same sort of outcome can also be obtained between measures of memory in normal, healthy adults by manipulating independent variables. That is, some factor can be varied and be shown to have a strong effect on one measure of memory and either no effect or even an opposite effect on a different measure of memory (see, e.g., Jacoby & Dallas, 1981; Jacoby, 1983). Once again, at a minimum we can conclude that the measures reflect different types of memory capacity.

There are dozens of types of memory tests, and many can be dissociated from one another by manipulating subject, material, or independent variables. Test differences can be useful for attempting to “carve nature at its joints,” but there are so many differences among tests that it is hard to know how to classify them. Although test dissociations are critical in the enterprise of identifying types of memory, most classification systems focus rather arbitrarily on a few test differences while ignoring many others.

**Neural Systems Underlying Memory**

In the past 20 years, much research has been directed towards understanding the neural
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systems underlying memory. Just as perceptual systems can be divided based on differences in function and neural circuitry (the visual system, the auditory system, etc.), so the hope is that memory can be fractionated in similar ways (e.g., Schacter & Tulving, 1994). Most of the data brought to bear on human memory have come either from studies of brain-damaged patients or from experiments that use neuroimaging techniques (positron emission tomography [PET] or functional magnetic resonance imaging [fMRI]). These techniques have been useful for finding differences among types of memory. As already noted, patients with damage to the hippocampus and surrounding areas show great losses on some types of memory tests (such as free recall) but not on others (short-term memory tests and priming on implicit or indirect memory tests). Similarly, neuroimaging techniques often show differences between tests of memory in the component neural processes that underlie the test. These facts may help specify neural differences between tests of memory. Of course, whenever a dissociation occurs between two memory tests at the behavioral level as a function of independent variables, there must be neural differences (Roediger, Buckner, & McDermott, 1999). That is, assuming that the brain is the cause of behavior, if there are differences in behavior, there must be differences in the neural mechanisms causing the behavior. This statement is as true in understanding differences between measures of memory as in understanding any other behavioral phenomena. Therefore, differences in neural underpinnings of memory may help solve the classification problem in some ways, but dissociations among behavioral measures of memory remain fundamental.

Although there is no acid test of any type of memory, researchers look to converging evidence from a variety of sources. The primary types of evidence are those just discussed: phenomenology, test differences, dissociations among measures, and differences in neural underpinnings.

BROAD DISTINCTIONS AMONG TYPES OF MEMORY

In this section we cover important distinctions that have been proposed to cut across a variety of types of memory. Some of these refer to types of memory tests, whereas others are intended to refer to temporal properties of memory or different types of representation.

Declarative/Procedural Memory

As noted above, Ryle (1949) proposed a fundamental distinction between declarative and procedural memory, or “knowing that” and “knowing how.” The modern champion of this distinction has been Squire (e.g., Squire, Knowlton, & Musen, 1993), who originally distinguished between declarative and procedural memory but more recently has preferred to cast the contrast between declarative and nondeclarative categories. Declarative memory, in this typology, is composed of episodic memory and semantic memory. Episodic memory is defined as memory for events (Tulving, 1972); one must retrieve the time and place of occurrence in order to retrieve the event, as in answering the question, “Where did you go on vacation last summer?” The retrieval query specifies the time, but in order to recall the events, the rememberer must retrieve the place where the events occurred. Semantic memory refers to relatively permanent knowledge of the world, or generic knowledge. (Generic memory has been suggested as a substitute for semantic memory because the knowledge may not always be meaningful; Hintzman, 1978). Our knowledge that zebras have four legs, that
the chemical symbol for oxygen is O, and that Joe Dimaggio was a baseball player, as well as thousands of other facts, constitutes our permanent knowledge or semantic memory. One idea about the relationship between episodic and semantic memory is that repeatedly experienced events may become represented in a decontextualized form in semantic memory. That is, the first time you heard “Thomas Jefferson served as president of the United States,” you might have encoded the fact within episodic memory, but after hundreds of exposures you can answer “Who was third president of the United States?” without having to retrieve any specific episode (a particular time or place) in which you heard this fact.

The distinction between episodic and semantic memory is clear at a descriptive level, as proposed in the above paragraph, but remains controversial among some researchers. Even those accepting a clear division argue about the relationship between these two systems and other systems, such as procedural memory. Tulving (1985b; 1999) has proposed that procedural memory is oldest in terms of evolution and is shared by all animals. Semantic memory is thought to be a more recent adaptation during the evolution of the brain and neurocognitive systems, and episodic memory is thought to be relatively recent in terms of evolution and perhaps unique to humans. Tulving (1999) has argued that the development of episodic memory was necessary for humans to think about the future as well as the past and was critical for the development of civilizations. Unless one has a concept of the future and can think beyond the here and now, Tulving suggests, there is no reason to farm, to build cities, and so on.

According to Squire (1987), procedural (or non-declarative, to use the later term) memory encompasses a very broad range of human skills and abilities: classical condition-
and procedural memory becomes difficult to defend. Still, in the pure cases (tying one’s shoes versus remembering pictures on a free recall test), the distinction is clearly sensible.

Explicit/Implicit Memory

Graf and Schacter (1985) first proposed the distinction between explicit and implicit memory (for a history of the idea, see Schacter, 1987). The basic distinction is between tests that directly request memories from the past (explicit tests) and those that measure retention indirectly, without subjects necessarily being aware that their responses reflect memory at all. Explicit tests are those such as free recall, cued recall, and recognition in which subjects are required to retrieve events from the recent past. Implicit tests are transfer tests: People are exposed to some material and then later given an ostensibly unrelated task (such as naming picture fragments or completing word fragments such as e,e,h,n.). Sometimes items in a prior study phase may help, or prime, performance on the test. For example, if subjects were to see either a picture of an elephant or the word elephant in the first phase of the experiment, those who saw the picture would be better able to name the fragmented picture of the elephant than would those who saw only the word. Conversely, on the word fragment completion test, studying the word but not the picture would produce a benefit (Weldon & Roediger, 1987).

The measure on implicit memory tests is typically priming, or the benefit of recent exposure to material on a later task that measures transfer.

Explicit memory tests measure conscious recollection, whereas implicit tests reflect retention that has been variously described as automatic, incidental, or even unconscious. Debate swirls around how to characterize performance on implicit memory tests. At least two types of priming occur: perceptual (data-driven) or conceptual (meaning-driven) (Blaxton, 1989; Roediger, 1990). Tests such as completing fragmented words or pictures are perceptual in that basic perceptual manipulations such as modality of study (auditory or visual; symbolic form, i.e., words or pictures) have great effects on perceptual implicit memory tests and little or no effect on conceptual implicit tests (McDermott & Roediger, 1996). On the other hand, conceptual implicit tests (like explicit tests) are often affected by manipulations of meaning, such as levels of processing or the difference between generating material and reading it (Blaxton, 1989; Srinivas & Roediger, 1990).

Conscious/Unconscious Forms of Memory

The term unconscious memory calls to mind the concept of repression and the writings of Sigmund Freud, who popularized the idea in the early 1900s (e.g., Freud, 1917/1982). Briefly, the notion is that painful childhood memories are too threatening to the psyche and so are banished to an unconscious state, or repressed. The memories remain active, creeping out in neurotic symptoms, in slips, and in dreams. The evidence for this form of unconscious memory is scanty (although there is some evidence for it; see Erdelyi, 1996), but the general idea that memories can be outside the realm of consciousness is uncontested. Try to remember the name and face of your sixth grade teacher and you may well succeed. Until you were asked the question, that knowledge was in an unconscious state. By definition, most of our knowledge is unconscious (in this limited sense) at any one point in time.

Conscious recollection in contemporary studies of memory refers to deliberate, effortful remembering in Tulving’s (1985a) sense of traveling back in time and reliving an experience. Unconscious retention typically refers to the automatic display of past experience
on some test such as an implicit memory test. In the very first experiments on memory, Ebbinghaus (1885/1964) proposed a relearning/savings technique for measuring memory because it could potentially detect unconscious knowledge (Slamecka, 1985). Modern implicit memory tests can potentially do the same. In addition, Jacoby (1991) proposed a process dissociation procedure that separates contributions of memory tests into conscious and unconscious components by employing an ingenious combination of experimental conditions.

**Voluntary/Involuntary Retention**

The contrast between voluntary and involuntary retention covers much the same conceptual territory as do the explicit/implicit or conscious/unconscious contrasts. There is a slightly different twist, however. Voluntary retention refers to deliberate, willful recollection; the person actively tries to remember (as on explicit tests). In its purest form, involuntary retention refers to recollection without effort. However, voluntary remembering may reflect automatic processes, and vice versa. For example, if I am trying to remember an event from my childhood and a similar event recently occurred in my experience, I may be primed to remember more easily the childhood event (I might think that I am remembering the childhood event of my own volition, not being aware of the unconscious influence of the recent experience). Similarly, in a case of involuntary or incidental retention, one might try deliberately to use the recent past as an aid. One complaint about implicit memory tests such as completing fragmented words is that subjects may use the cues deliberately to remember the past (e.g., Jacoby, 1991).

An interesting case occurs when conscious recollection follows automatic retrieval—a situation that has been called involuntary conscious recollection (Richardson-Klavehn, Gardiner, & Java, 1996). Briefly, a thought or concept might come to mind unbidden, with no apparent source for the memory. Later, however, the source can be determined, and the rememberer realizes, after some reflection, “Oh, I must have thought of that because of my recent experience.” The study of conscious and unconscious experience is one of the central issues in the contemporary psychology of memory, which uses explicit and implicit memory tests, the remember/know procedure, and the process dissociation procedure.

**Retrospective/Prospective Memory**

Retrospective memory refers to memory for the past—we reflect back and recollect what has happened to us. Thus far we have described only situations involving retrospective memory: Remembering one’s childhood, recognizing a picture studied earlier in an experiment, and completing a word fragment with a recently seen word are all examples of memory for the past. Prospective memory refers to a situation in which the focus is on the future: how we remember to do things in the future. Outside the lab, we face this task all the time—remembering to pick up milk on the way home, remembering to take one’s antibiotic twice a day, and so on. The standard laboratory paradigm for studying prospective memory requires subjects to remember to perform a secondary task (e.g., press a key) when they see a target cue embedded in their primary task (e.g., whenever a specified word occurs in a text; Einstein & McDaniel, 1990). Prospective memory researchers have also used more naturalistic versions of this paradigm such as having participants remember to call the lab on a particular day at a particular time (e.g., Maylor, 1990). Although prospective and retrospective memory refer to clear categories descriptively, it is not yet...
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clear whether the two types of memory tests involve different processes. That is, effects of independent and subject variables may be generally the same for prospective memory tests and retrospective memory tests that are equated on other features.

Code-Specific Memories

A central concept in the study of memory is recoding: Stimuli in the outside world are not copied into the brain, but rather recoded. Psychologists refer to modalities of coding—we can remember events as mental images or verbal descriptions, or perhaps remember the smell and the feel of past events. Psychologists have tended to focus on verbal recoding, the conversion of experience into words or schemas or scripts, with the assumption that verbal coding is ascendant in adult humans (e.g., Glanzer & Clark, 1963). Although language is important, spatial/imaginal representations also underlie much of experience (e.g., Paivio, 1986; Kosslyn, 1995). Memory for odors seems to have special properties, so olfactory coding is also important (Herz & Engen, 1996). Motor coding may be critical at times; performing motor actions to a command makes simple events more memorable than does either hearing the command or imagining performance of the command (see Nilsson, 2000). Therefore, all these coding modalities are ways of representing experience, and each probably has distinct neural substrates.

THE MODAL MEMORY TYPOLOGY: SENSORY, WORKING, AND LONG-TERM MEMORY

The distinctions discussed earlier represent terms that refer to the varieties of memory and memory experience. We now outline one categorization scheme of memories that is based, roughly speaking, on the degree of their persistence. However, we must admit at the outset that attempts to categorize memories by their longevity are fraught with difficulties, as sharp boundaries do not exist. One type of memory usually blends into another. Still, the three main categorizations presented here represent a starting place.

Sensory Memories

Sensations are not coded instantaneously in the brain; rather, the sensations from the receptors (the sense organs) linger in the nervous system as information is being processed by higher cortical centers. This sensory persistence reflects a fleeting memory of the outside world in what is thought to be a relatively faithful, unrecoded form. Although sensory memories are thought to exist for all senses, those most studied are for vision and audition.

Iconic Memories

The sensory memory for vision is referred to as iconic memory. Sperling (1960) developed a standard technique for its study. He presented subjects with arrays of letters for very brief periods (20 ms) and asked them to report parts of the array. The entire array was too large to be reported from a single glimpse, but he reasoned that if the letters were held in a sensory store, people could rescue items when directed to do so. He presented a tone varying in pitch (to direct attention to one line) either just as the array was finished or at various brief times afterward. He wanted to see if subjects could report parts of the array and if this ability would rapidly decrease (as the array faded or was forgotten) from the iconic store. Sperling’s experiments confirmed the existence of the iconic store and estimated its duration at about a quarter of a second, under his conditions. However, other techniques have produced a quite different estimate, at around 100 ms compared with Sperling’s longer estimate (e.g., Haber & Standing, 1970). These
different estimates can be reconciled by assuming that there are really two different brief visual stores with different neural bases in the early visual system (Crowder & Surprenant, 2000). One type of visual persistence seems to correspond to the experience we all have of visual afterimages, such as when a photographic flash persists before our eyes for a brief period after the flash.

**Echoic Memories**

The sensory memory for hearing is called echoic memory for the presumed brief echo that perseveres in the nervous system after information is heard. The existence of echoic memory is supported by an auditory parallel of the Sperling partial-report technique just described (Darwin, Turvey, & Crowder, 1972). Subjects heard briefly presented sounds from three different locations; in the whole-report condition they recalled as much as possible, whereas in the partial-report condition they were cued to recall from just one of the three locations. The partial-report technique led to higher estimates of echoic memory capacity, although this advantage disappeared after the signal to respond was delayed by about 4 s.

As with iconic memory, there seem to be two different forms of brief auditory persistence, one more short-lived than the other. The shorter form lasts only hundreds of milliseconds, but the longer one may last between 2 and 10 seconds (Cowan, 1984). These echoic memories presumably help in comprehending speech and other auditory signals that change rapidly over time (Crowder, 1981).

**Working Memory**

The term *working memory* is used to describe a temporary memory system in which information is maintained and manipulated for a short period of time (Baddeley, 2000a). For example, one draws upon working memory when solving an addition problem such as 384 + 743 without a calculator or pencil and paper. In order to accomplish this task, one must temporarily store the addends, add the last digits together, maintain this outcome while adding the next two digits together, and so forth, until the final solution is computed. This notion of working memory is a fairly recent one, and it differs from prior conceptualizations of short-term memory in that it places an emphasis on the active manipulation and use of information, rather than merely on its maintenance or storage. However, both storage and manipulation functions are important. We consider the storage function first and then turn to manipulation.

Within the information-processing tradition that postulated multiple memory stores, the so-called modal model of memory (named by Murdock, 1974) primarily emphasized the storage functions of short-term memory. This model (see Figure 1.1, adapted from Atkinson & Shiffrin, 1971) postulated sensory storage systems through which information flowed to a short-term store that held information briefly. The information could then be transferred more or less well to a long-term store depending on how extensively it was processed while being held in the short-term system. Because only a limited amount of information could be maintained in the short-term store at any given time, new incoming information replaced older information in the store. Depending on the amount of processing already received, this “bumped” information was either forgotten or transferred to the second, long-term store (Atkinson & Shiffrin, 1968).

Several key findings supported the existence of separate short-term and long-term stores. As already noted, some patients with brain damage showed a loss of long-term retention while short-term processes remained intact. In addition, experimental evidence showed different forgetting rates for
short- and long-term stores, as well as different characteristics of retained information, with phonemic coding more probable for short-term verbal memory and semantic coding more likely for long-term verbal memory (Crowder, 1976). In addition, much evidence concerning serial position functions in single-trial free recall also was consistent with two-process theory (e.g., Glanzer & Cunitz, 1966; Glanzer, 1972).

Much of the research in the 1960s and 1970s was concerned with storage characteristics of the short-term store; less emphasis was given to other purposes of short-term retention. That focus changed with the advent of Baddeley and Hitch’s working memory model, which broadened the concept and led to modern notions of working memory.

Baddeley and Hitch (1974) proposed the original model of working memory, which continues to be developed and modified (e.g., Baddeley & Logie, 1999; Baddeley, 2000b). As depicted in Figure 1.2, the Baddeley model of working memory consists of two modality-specific “slave” systems controlled by a higher-level executive system. The idea of modality-specific slave systems grew out of one of the findings not handled gracefully by the Atkinson-Shiffrin model, namely, the finding of relatively little impairment in short-term recall following certain divided-attention tasks (e.g., Brooks, 1968). This finding is easily explained by a model that allows for separate storage systems to handle information-processing demands in different modalities, but not by a model with a single modality-free short-term store.

**The Phonological Loop**

Baddeley and Hitch (1974) hypothesized that working memory is composed of three basic components: the articulatory (phonological) loop, the visuo-spatial sketchpad, and the central executive. According to their model, the phonological loop is responsible for
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maintaining verbal and auditory information, while the visuo-spatial sketchpad maintains visual and spatial information. The central executive coordinates these components and allocates resources to them depending on the demands of the environment. The basic model has evolved over the years to include more detailed descriptions of each component as well as a series of subcomponents. Each of the slave systems works not only to store information passively but also to maintain that information actively.

The most widely studied component of Baddeley’s model, the phonological loop, involves both the passive storage and the active rehearsal of verbal information. Four major experimental findings are cited to support the existence of this slave system; we describe each of these in turn.

The errors people make when recalling words suggest that working memory has a phonological rehearsal component. Baddeley (1966) found that immediate serial recall of a list of items was impaired when the items sounded similar to one another. This phonological similarity effect is thought to occur because the similar phonological codes used for the items are difficult to discriminate from one another during storage or retrieval. Phonological similarity would not matter if the working memory system did not have a phonological rehearsal component.

The finding that the length of words that people are trying to remember affects immediate recall also supports the concept of active phonological rehearsal. A list of longer words shows poorer recall than a list of shorter words when the number of words presented is equated (Baddeley, Thomson, & Buchanan, 1975). Surprisingly, the crucial variable in producing the word-length effect is not the greater number of syllables in the longer words, but rather the actual spoken duration of the words. Baddeley et al. found that memory span is approximately equal to the number of words that can be read aloud in 2 seconds (see also Schweickert & Boruff, 1986). This finding suggests that we subvocally rehearse words, and that the words can only be maintained for about 2 seconds. This constraint on working memory explains why digit spans vary across languages; the memory span (the average number of words that can be accurately recalled in correct order) is shorter in languages (e.g., Welsh) in which words are long (relative to English) and take more time to rehearse (Ellis & Hennelly, 1980). However, memory spans are longer in languages (e.g., Chinese) that have shorter words, thus allowing for the rehearsal of more words in the same time period (Hoosain & Salili, 1988).

Another finding that supports the idea of the phonological loop is the unattended speech effect, which refers to the fact that listening to irrelevant auditory speech impairs recall. That is, if people are hearing words or digits and trying to remember them, having other speech in the background reduces the amount that can be recalled. This effect suggests that the unattended speech obligatorily clogs working memory capacity by engaging the phonological loop and thereby preventing rehearsal of the attended information that people are trying to recall. Again, this effect would not be expected unless there existed a phonological rehearsal process with which the unattended speech interferes (Colle & Welsh, 1976; Salame & Baddeley, 1987, 1989). Critically, the unattended speech effect remains even when the unattended speech is in a foreign language or consists of nonsense syllables. However, the effect does not occur with nonlinguistic materials, such as music.

A final bit of evidence for the importance of phonological rehearsal comes from experiments using articulatory suppression. In this kind of experiment, subjects articulate repeatedly some word or phrase such as “the” or “hiya” while trying to remember information presented visually. Recall is quite
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poor under these conditions when compared with conditions in which subjects are not engaged in articulatory suppression (e.g., Richardson & Baddeley, 1975; Baddeley, Lewis, & Vallar, 1984). This articulatory suppression effect, as it is called, shows that when conditions prevent access of studied material to the phonological loop, recall of that information suffers.

These four lines of evidence (among others) support the concept of the phonological loop as playing a central role in verbal working memory. A comparable slave system exists for nonverbal materials.

The Visuo-Spatial Sketchpad

The second slave system described by Baddeley and Hitch (1974) is the visuo-spatial sketchpad, which is hypothesized to maintain visual and spatial information over short durations and to permit manipulation of this information. The visuo-spatial sketchpad has been further broken down into two sub-components: The visual cache is responsible for passive storage of pattern information, while the inner scribe retains sequences of movement. However, most of the research described here is aimed more at supporting the idea of a separate visual slave system than at elucidating its specific characteristics. In general, much less research has been directed at nonverbal working memory than at verbal working memory.

Brooks (1968) was one of the first to show that maintenance of visuo-spatial information can be independent of storage and manipulation of verbal information. He required people to remember either sentences or visual patterns and then report on them either by talking (verbal output) or pointing (spatial output). His study demonstrated that holding sentences in memory leads to verbal report times that are slower than spatial report times. However, when maintaining spatial patterns in memory, subjects found it quicker and easier to report on them verbally than by pointing. That is, the outcome is not that either pointing or speaking is inherently more difficult, but that it depends on the type of information being held in memory. While people can simultaneously do activities that draw on both the phonological loop and the visuo-spatial sketchpad, they are impaired when attempting to do more than one activity that draws on the same capacity (the phonological loop or the visuo-spatial sketchpad) at the same time. Analogous to the unattended speech effect, unattended visual information disrupts the visuo-spatial sketchpad. Logie (1986) also showed that extraneous visual information selectively disrupted visual learning, again supporting the idea that people can rehearse verbal and visual information in separate systems.

Neurological evidence supports the independence of visual and verbal slave systems, as they draw on different brain areas. McCarthy and Warrington (1988, 1990) reported a single patient who suffered from an abnormality in his left temporal lobe. The patient demonstrated normal ability to comprehend and maintain visual information but could not comprehend auditory/verbal information. Using PET, Smith, Jonides, and Koeppe (1996) provided converging evidence that verbal and spatial working memory tasks involve different areas of the brain. A letter-name recall task (a verbal task) activated regions almost entirely in the left hemisphere, while remembering the positions of three dots (a spatial task) activated only right-hemisphere regions. In short, although the evidence on operation of the visuo-spatial sketchpad is sparser than that on the phonological loop, enough evidence exists to establish the independence of the two slave systems.

The Central Executive

The central executive is the least specified component of Baddeley’s working memory
model and borders on the most fundamental problems in all of cognition: consciousness and control of behavior. The central executive is hypothesized to have control over the allocation of attention, the recruitment of slave systems, and the preparation and use of strategies, as well as other features, such as activating representations in long-term memory (Baddeley, 1996). However, the central executive is thought to have no storage capabilities. The central executive therefore holds most of the power in working memory but is basically relegated to the role of a homunculus. If the central executive has control over the slave systems, what controls the central executive?

The concept of the central executive is similar to the Supervisory Attentional System, proposed by Norman and Shallice (1980). This system oversees and controls certain behaviors, overriding over-learned (automatic) behaviors when necessary.

**Reading Comprehension**

Daneman and Carpenter (1980) argued that typical working memory tasks (e.g., digit span and word span) do not accurately reflect the importance of working memory in comprehension, and that a more appropriate measure is reading span. In this task, subjects read a series of sentences and then recall the last word of each sentence. The number of words that can be reported accurately is the measure of reading span. Although the average number of words correctly recalled was relatively small (just 2 to 5 words in the Daneman and Carpenter sample), this span correlated very highly with performance on questions measuring comprehension of the prose passages. Daneman and Carpenter argued that reading span measured working memory ability, which influenced how well material could be understood. Just and Carpenter (1992) extended this argument and proposed that the important link between reading span and comprehension is working memory capacity, for two main reasons. First, individuals with larger working memory capacities can maintain more information about syntactic constraints within a passage of text, and can use this information to make judgments about the text. Second, a larger working memory capacity facilitates maintenance of more than one interpretation in cases of syntactic ambiguity. This relieves high-capacity individuals of backtracking in the text in order to reinterpret ambiguous sections. The critical point is that a relatively simple measure of working memory (reading span) predicts an important cognitive ability (reading comprehension). Could measures of working memory be tapping some fundamental cognitive capacity?

**Intelligence**

In recent years, some researchers have proposed that working memory is closely related to intelligence as measured by standardized tests. One reason for this claim is that performance on the verbal portion of the SAT is correlated fairly highly with Daneman and Carpenter’s (1980) reading span measure of working memory ($r = .59$). Similarly, Engle, Tuholski, Laughlin, and Conway (1999) showed that performance on working memory tasks that measure the ability to hold and manipulate information (such as reading span) was highly related to measures of fluid intelligence (the ability to solve novel problems and to adapt to new situations). The same relationship does not show up on measures that simply tap storage aspects of short-term memory. Engle et al. argued that the relationship between working memory measures and fluid intelligence exists because both constructs tap the ability to keep a representation active and to manipulate it, despite distractions and interference.

Evidence from fMRI also shows a clear relationship between performance on working memory tasks and measures of fluid
intelligence. In one study (Prabhakaran, Smith, Desmond, Glover, & Gabrieli, 1997) participants solved three different kinds of fluid reasoning tasks from Raven’s Progressive Matrices while in the fMRI scanner. Problems were classified as (a) visuo-spatial, which could be solved primarily by figural analysis; (b) analytical, which required abstract reasoning in addition to figural analysis; and (c) perceptual-motor, which did not require figural or analytic reasoning. The areas activated by these tasks mapped onto those activated by certain working memory tasks. Visuo-spatial reasoning tasks activated the same areas that spatial working memory tasks often activate (e.g., right middle frontal gyrus), and analytical tasks activated areas often implicated in verbal working memory and executive processes (e.g., left middle frontal gyrus and left premotor cortex).

Summary
As with all parts of this chapter, no universally accepted view of the working memory system exists. Baddeley’s (1986) working memory model has provided a fruitful theoretical framework for empirical research in the field; its parsimony and explanatory power continue to motivate research. Of course, several questions remain to be resolved in the future (see, e.g., Miyake & Shah, 1999). Baddeley (2000b) has recently proposed the idea of a fourth component, the episodic buffer. The episodic buffer is hypothesized to integrate (bind) information from the slave systems and long-term memory. New research will address this idea. Another new direction is in terms of neural instantiations of working memory theory, to specify the neural substrates through research with animals and humans. For example, recent neural theories of the mechanisms underlying the central executive have made some progress in avoiding the problem of its resemblance to a homunculus by proposing specific neural mechanisms involved in the central executive (e.g., a dopamine-gating theory of control; Braver & Cohen, 2000). However, the mechanisms of executive control remain largely unexplored.

LONG-TERM MEMORY

The concept of long-term memory is something of a grab-bag because many different types of retention qualify as “long-term memory.” There are names and faces we have known for years; text material studied for exams; our general knowledge or semantic memory for facts; all kinds of motor skills that would include talking, walking, driving cars, playing sports, and so on; and there are the smells (e.g., popcorn) and touches (e.g., silk) that we can instantly recognize. And these examples are but a sample. Everything we retain that did not occur in the last few moments can be considered long-term memory. Here we sample some of the primary concepts that have been used to analyze this huge category, but there is certainly no agreed-upon taxonomy for the various capacities that comprise long-term memory. We could have included many more categories than the ones represented here.

Episodic Memory
As mentioned earlier, episodic memory refers to memory for events (or episodes) and the cognitive and neural mechanisms involved in remembering those events. In order to retrieve such memories, the time and place of occurrence of the events must be specified (explicitly or implicitly) in the retrieval query (Tulving, 1972). Examples of episodic memory tasks include recalling the events experienced last week, recalling the words from a list heard ten minutes ago, or recalling dinner companions from the day before yesterday. Many of the laboratory
techniques developed by psychologists over the years—recall of stories, pictures, or words learned in the lab—test primarily episodic memory. As noted earlier, Tulving (1985a) has argued that episodic memory reflects a special type of awareness—autonoetic (self-knowing) awareness—and that this ability may be unique to humans (Wheeler, 2000). Episodic memory is reflected by performance on explicit memory tests (although some aspects of performance on these tests may reflect contributions from other memory systems, as well). The concept of episodic memory has changed over the years since Tulving (1972) first proposed it, but it remains a central organizing concept in cognitive psychology and cognitive neuroscience (for relatively recent treatments, see Tulving, 1993; Wheeler, 2000).

One important sense in which episodic memory is used is to describe tasks such as the examples just given. The following nine tasks can all be classified as episodic memory tasks because they require subjects to think back to the time that the events in question occurred (Tulving, 1993). (The place is usually given as “in the lab where you are,” but outside the lab the place may need to be specified, too.)

1. **Free recall.** People are exposed to a set of words or pictures and are asked to recall them in any order after a brief delay.

2. **Serial recall.** People are given a series of digits, words, or pictures and are asked to recall them in the order of occurrence. Variations might include giving one item from the series and asking for the item that appeared before or after it.

3. **Paired-associate recall.** People learn pairs of items that might be related (giraffe-lion) or unrelated (tightrope-pickpocket) and are later given one item (e.g., tightrope) and are asked to recall the other item. This task measures the formation of associations.

4. **Cued recall.** People are given a series of words, pictures, or sentences and are then given a cue (often something not presented) and asked to recall a related event from the series. If people study sentences such as “The fish attacked the swimmer,” the word “shark” might be given as a cue. Paired-associate learning is one type of cued recall task, but there are many variations.

5. **Recognition.** These tests, as the name implies, require people to decide whether or not they recognize an item as being from the studied set. In a typical laboratory paradigm, subjects might study a list of 100 words (under various conditions) and then be given a test with 200 words, half studied and half not studied. The task is to select the studied words. If the subjects see the words one at a time, they judge whether each one was studied and respond yes or no. This is called a free choice or yes/no recognition test. If the subjects are tested with pairs of words, one old and one new, they have to pick the word that was studied. This is called a forced choice recognition test. Free and forced choice recognition tests resemble true/false and multiple choice tests (respectively) used in educational assessment. Another variation is the continuous recognition test, in which subjects see a long stream of items and must decide for each item whether or not they have seen it earlier in the series.

6. **Absolute frequency estimation tasks.** Subjects study items such as words or pictures various numbers of times (say, 1–8 times) and then later are presented the item and have to judge how many times they studied it.

7. **Relative recency judgments.** Subjects study items and then are given two and asked which one occurred earlier (or later) in the series.
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8. **Source judgments.** Information is presented from a variety of sources (e.g., spoken or written words, or by a male and a female voice if all items are spoken) and during the later test subjects must identify the source of each (spoken or written? Male or female?).

9. **Metamemory judgments.** Researchers can ask subjects to give other kinds of ratings that are thought to reflect features of episodic memory. Confidence judgments ask for ratings (on, e.g., a 7-point scale) of how confident a person is about whether an event occurred. People can also be asked, for items they recall or recognize, to judge whether they remember the moment of occurrence of the item or rather just know it was presented but cannot remember the moment of actual occurrence (Tulving, 1985a). These kinds of remember/know judgments have been extensively studied (e.g., Gardiner & Richardson-Klavehn, 2000) because remember judgments are thought to reflect a pure manifestation of episodic memory. Subjects can also be asked to evaluate more specifically the sensory, emotional, and contextual characteristics of their retrieved memories (e.g., the Memory Characteristics Questionnaire; Johnson, Foley, Suengas, & Raye, 1988).

All these tests (and others) tap some aspect of episodic memory by requiring subjects to retrieve information from specific times in the past. However, not all performances on the episodic (or explicit) memory tests just listed necessarily reflect “pure” manifestations of episodic memory, as performance from relatively automatic (Jacoby, 1991) or noetic (knowing) states of awareness (Tulving, 1985a) might affect performance as well, especially on tests with strong retrieval cues.

Many variables have been shown to affect episodic memory performance across a range of tests. We consider just a few such variables here—variables manipulated during study or encoding. In general, meaningful processing of events produces better retention than does processing that focuses on more superficial features (Craik & Lockhart, 1972). In such levels-of-processing experiments, as they are called, subjects are exposed to words or other material and are asked to make judgments about them. For example, different groups of subjects given the word “RABBIT” might be asked: Is it in upper-case letters? Does it rhyme with habit? Is it a type of animal? The answer to all three questions would be yes, but the first question requires only a superficial visual examination for an affirmative answer. The second question requires phonemic (or phonological processing) to sound out the word. The third question requires subjects to think about the meaning of the word. Hundreds of experiments have shown that on later tests of recall or recognition, meaningful processing produces retention superior to that afforded by phonemic processing, which in turn provides better recollection than processing of simple visual features such as type font (e.g., Craik & Tulving, 1975). The exact testing conditions for producing the effects do matter, as discussed later, but the levels-of-processing effect is ubiquitous in standard tests of recall and recognition (see Figure 1.3 for an example). However, the interpretation of the effect is still under debate (Roediger & Gallo, in press).

Active involvement in learning, such as generating information rather than reading it, also promotes better retention (Jacoby, 1978; Slamecka & Graf, 1978). This generation effect, as it is called, occurs even under conditions in which the generation seems trivially easy. Jacoby (1978) had students either read word pairs (foot-shoe) or generate the second word from a word fragment (foot-s_e). The fragments were easy (because the words were related), so the target word could almost
always be generated easily. In the test, sub-
jects were given the first word and asked to
respond with the paired word. When they had
generated the second word, they remembered
it much better than when they had read it,
even though the generation process did not
involve much effort. Slamecka and Graf pro-
duced similar results in a somewhat differ-
ent paradigm. Again, this generation effect
can disappear under certain conditions, but
it has fairly wide generality, especially when
the same subjects both read and generate in-
formation (i.e., when the variable is manipu-
lated within subjects; see Begg, Snider, Foley,
& Goddard, 1989; McDaniel, Waddill, &
Einstein, 1988; Slamecka & Katsaiti, 1987).

A third variable that reliably affects epi-
sodic memory tasks is repetition. In general,
and not surprisingly, repeated items are bet-
ter remembered than items presented only
once (the repetition effect; see Crowder, 1976,
Chapter 6). Less intuitively, however, the
spacing of repetitions does matter. Massed
repetition refers to the situation when an event
is studied twice in succession, whereas spaced
repetition refers to the case in which time and
intervening items occur between repetitions.
For tests of long-term retention, spaced repe-
tition almost always leads to better retention
than does massed repetition; furthermore, up
to some limit, the greater the lag or spacing
between two presentations is, the better is re-
tention (e.g., Melton, 1970; Dempster, 1988).
This spacing or lag effect, as it is called,
occurs on practically all tests and under most
conditions. Interestingly, one exception oc-
curs when a test is given very quickly after
the second of two presentations; then massed
repetition leads to better retention than does
spaced repetition (e.g., Balota, Duchek &
Paullin, 1989).

Fourth, concrete materials generally pro-
duce better retention on episodic memory
tests than do abstract materials. For example,
pictures are better recalled than words (their
names); this is called the picture superiority
effect (Paivio & Csapo, 1973; Paivio, Rogers,
& Smythe, 1968). Words that refer to con-
crete objects (umbrella, fingernail) are better
retained than are abstract words matched on
such qualities as word length, part of speech,
and frequency of occurrence in the language
(Paivio, Yuille, & Rogers, 1969). The same
holds true for prose materials (Paivio & Begg,
1971). To generalize, speakers and professors
who can explain an abstract theory (e.g., the
kinetic theory of gases) by using a concrete
analogy or metaphor (molecules of gas behav-
ing like billiard balls on a pool table) often
can make their subject matter not only eas-
er to understand but also more memorable.
Known since the days of the ancient Greeks
and Romans, mental imagery is one of the old-
est techniques for improving memory, and it
relies on the same principle: The mind gener-
ally grasps and remembers concrete concepts
better than abstract ones.

Finally, distinctive items are generally
better remembered on episodic memory tests.
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(e.g., Hunt, 1995; Hunt & McDaniel, 1993). For example, a picture embedded in a list of words should be better remembered than the same picture embedded in a series of pictures. Distinctiveness has been used to explain superior memory for such items as bizarre sentences (McDaniel, Dunay, Lyman, & Kerwin, 1988), unusual faces (Light, Kayra-Stuart, & Hollander, 1979), atypical category members (Schmidt, 1985), and words with unusual orthographies (Hunt & Elliot, 1980). Distinctiveness may increase attention to and processing of an item at study. Distinctive items also yield excellent retrieval cues, since no other memories are associated with unique events. Distinctiveness may underlie some of the effects just discussed. For example, the better memory associated with pictures and concrete objects may be due to the distinctiveness of their encoding. Similarly, deeper, semantic processing of words leads to more distinctive encoding and retrieval cues than does more shallow, phonological, or orthographic processing.

The various effects just discussed—the levels-of-processing effect, the generation effect, the picture superiority effect, the spacing (or lag) effect, and the distinctiveness effect—represent just a sample of important variables manipulated during encoding or study that affect episodic memory performance. However, just because these variables are manipulated during learning does not mean that they only affect encoding of memories. Retrieval processes are critically important in the study of episodic memory.

A common experience is forgetting some bit of information—the name of an acquaintance, where you left your keys—and then suddenly retrieving the information later. Sometimes the recovered memory seems to occur spontaneously, but in other cases it is prompted by cues. Such recovered memories show that forgetting is not necessarily due to loss of information from memory (e.g., degraded memory traces) but rather that the information was available in memory, but not accessible. Tulving and Pearlstone (1966) first formally distinguished between information that is available in memory (is stored) and information that is accessible (is retrievable under a particular set of conditions). Psychologists may wish for a perfect measure of what is stored in memory, but they will never have one; all measures reveal the information accessible under a particular set of conditions. The study of retrieval processes is therefore a key to understanding episodic memory (Roediger & Guynn, 1996; Roediger, 2000; Tulving, 1974).

Even when we restrict our view to the study of episodic memory measures, we find that all tests do not reveal the same pattern of results. For example, words that occur in the language with high frequency are typically better recalled on a free recall test than are words that occur with less frequency (e.g., Hall, 1954). So, we might conclude that high-frequency words simply produce stronger or more durable memory traces than do low frequency words. However, this simple idea is ruled out by recognition experiments. When high- and low-frequency words are presented and then retention is measured by recognition, low-frequency words are better recognized than are high-frequency words (Kinsbourne & George, 1974; Balota & Neely, 1980). That different patterns of outcome are often obtained when different memory tests are used is a fundamental fact that must be understood.

Two general ideas that have been forwarded to explain encoding/retrieval interactions are the encoding specificity principle (Tulving & Thomson, 1973) and the principle of transfer appropriate processing (Morris, Bransford, & Franks, 1977; Roediger, 1990). Both principles maintain that retention is best when the conditions of retrieval match (complement, overlap,
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recapitulate) the conditions of learning. Within terms of the encoding specificity framework, the idea is that features of experience are encoded and that retrieval cues are effective to the extent that features extracted from the cue match or complement those in the memory trace (e.g., Flexser & Tulving, 1978). The transfer appropriate processing principle states that experiences during learning transfer to a test to the extent that the test requires appropriate cognitive operations to permit expression of what was learned. Tests may be more or less appropriate to tap what was learned. These two principles are not meant to be opposites; rather, they are somewhat different statements of what is fundamentally the same idea. Much evidence agrees with these principles in episodic memory research (see Roediger & Guynn, 1996, for a review) and perhaps across all memory tests (Roediger & McDermott, 1993). We shall return to these principles when we consider evidence for implicit memory tests.

The study of episodic memory is a huge topic, and we can barely scratch the surface in this section. Tulving’s (1983) book, *Elements of Episodic Memory*, is a good starting place for further study of this critical topic. Much episodic memory research has been laboratory-based. A somewhat different tradition of research, but one that is also concerned with personal experiences, goes under the rubric of autobiographical memory, to which we turn next.

**Autobiographical Memory**

Autobiographical memory refers to one’s personal history. Memories of the first week of college, of learning to drive, and of a friend’s phone number are all autobiographical to some extent. As these examples demonstrate, one’s autobiographical knowledge consists of many different types of knowledge: episodes, procedures, and facts. Autobiographical memory is an amalgam of varieties of memories tied together by their importance to one’s sense of self and one’s life history. In some sense, then, it does not represent a distinct category of memory (like episodic and semantic memory are assumed to be), but rather a distinct research tradition within the field. Still, consideration of autobiographical memory serves to bring out many of the core concepts of memory as considered by most people who are not psychologists.

The problem of defining autobiographical memory has been discussed elsewhere in depth (e.g., Conway, 1990). Brewer (1986) suggested distinguishing among personal memories, autobiographical facts, and generic personal memories. Personal memories, such as memories of one’s wedding, are described as memories for specific life events accompanied by imagery. These would be episodic memories. Autobiographical facts, such as memories for phone numbers, are memories for self-relevant facts and are unaccompanied by imagery or spatio-temporal context (like semantic memories, as defined by Tulving, 1972). Other knowledge, such as knowledge of how to drive, consists of abstractions of events and is unaccompanied by specific images. These could be considered procedural memories, but Brewer refers to them as generic personal memories. In this section, we focus on personal memories, with some attention to generic personal memories.

**Vivid Memories of Life Events**

Clearly, people have access to many vivid personal memories. People can retrieve detailed, emotional memories in response to a wide variety of retrieval cues, from across the life-span and following long delays. What, then, leads to the unique, vivid personal memories that characterize our sense of the past?

Historically, psychologists made surprisingly few attempts to capture autobiographical memory. Galton (1879) conducted the
first attempt to study personal memories; he retrieved and dated personal memories in response to each of a set of 20 cue words. Other early research included Colegrave’s (1899) collection of people’s memories of hearing the news of Lincoln’s assassination as well as Freud’s clinical investigations into childhood memories (Freud, 1917/1982). However, experimental psychologists conducted little research on autobiographical memory until the 1970s. At that time, the pendulum swung in favor of more naturalistic research, partly in response to Neisser’s famous charge that “If X is an interesting or socially significant aspect of memory, then psychologists have hardly ever studied X” (Neisser, 1978, p. 4). In addition, the 1970s brought the publication of three important methods and ideas: Linton’s (1975) diary study of her own memories for six years of her life, the idea that surprising events imprint vivid “flashbulb memories” on the brain (Brown & Kulik, 1977), and the rediscovery of the Galton word-cueing technique (Crovitz & Schiffman, 1974). Urged on by these results and the changing zeitgeist, experimental psychologists turned to the tricky problem of understanding how people come to hold such vivid memories of their own lives.

Results from Diary Studies

Beginning in 1972, Marigold Linton spent six years recording descriptions, dates, and ratings of 5,500 events from her own life. She tested herself for recognition of a semirandom sample of events each month. While Linton was primarily interested in her ability to date these personal events (e.g., Linton, 1975), she did preliminary analyses of the characteristics associated with remembered versus forgotten events. She argued that remembered events were salient, emotional, and relatively distinctive, and that there was some tendency for positive events to be better remembered (Linton, 1982).

Both White (1982) and Wagenaar (1986) followed up Linton’s results, conducting diary studies aimed more specifically at remembering details of events rather than dates. Wagenaar collected 2,400 events over a period of 6 years; he recorded the most salient event each day, and coded it with four cues: who, what, when, and where. He also rated the salience (distinctiveness) of the event, as well as its pleasantness and his emotional involvement. White recorded one event per day for a year; he haphazardly selected both salient and nonsalient events. For each event, he recorded a description and chose adjective descriptors. He rated each event on a number of dimensions, including the degree to which he participated in the event, its importance to him, its frequency, and its emotionality and physical characteristics (e.g., sights, sounds, smells). Overall, the results from the two studies corresponded well with Linton’s observations: Recalled events were unique, and, at least in Wagenaar’s study, more emotional. Both studies presented some evidence for the better recall of pleasant events.

Converging Results

While diary studies provide a rich source of autobiographical memories, such richness comes with methodological costs. Diary studies typically involve only the experimenter as subject; the events to be remembered are not randomly selected; and the very act of recording the events probably changes the way they are encoded. Two different paradigms have been developed to deal with these problems. In one study, Thompson (1982) recruited 16 undergraduates to participate in a diary study; the twist was that the participants recorded events not only from their own lives but from their roommates’ lives as well. All 32 participants later attempted to retrieve the recorded events and used a 7-point scale to rate how well they remembered them. The critical finding was that memory did not differ between
the recorders and their roommates, even though the recorders had selected and recorded the events and had knowledge of the upcoming memory test.

In another clever study, Brewer (1988a) dealt with the event-selection issue by recruiting subjects to carry pagers and record their ongoing events whenever the alarm sounded. Participants also rated their emotional state as well as the frequency, significance, and goal of the event. In the test, subjects were given one of five different types of retrieval cues (time, location, both time and location, thoughts, or actions) and were asked to recall the event in question. Correctly recalled events were rated as being more associated with remembered sensory details, emotions, and thoughts. Consistent with the results of earlier diary studies (Wagenaar, 1986; White, 1982), correct recall was associated with exciting, infrequent events occurring in atypical locations. Similar results were also obtained in another beeper study in which the memory test involved recognition rather than cued recall (Brewer, 1988a, 1988b). As in laboratory studies of episodic memory, distinctive events are well remembered.

We mention here only one of the many other studies that support the idea that vivid memories tend to be for life events that were unique, important, and emotional. Rubin and Kozin (1984) collected data on vivid memories using two paradigms. First, they asked participants to describe their three most vivid memories and then rate them on a number of scales (e.g., national and personal importance, surprisingness, consequentiality, etc.). Overwhelmingly, participants provided memories of events such as personal injuries or romantic episodes that were rated high in personal but not in national importance (see also Robinson, 1976). Second, participants retrieved autobiographical memories in response to 20 national (e.g., the night President Nixon resigned) and personal (e.g., your 13th birthday) cues. These cues naturally varied in their ability to elicit vivid memories; vivid memories tended to be associated with consequentiality, surprise, emotional change, and rehearsal (repeated retrieval after the event).

Thus, vivid personal memories tend to be associated with exciting, emotional, unique, and even surprising life events. We turn now to the question of what is forgotten.

Forgetting Life Events

Some researchers claim to find less forgetting of life events than might be expected given the high forgetting rates in many laboratory tasks, but of course such comparisons are fraught with difficulty. (No one really measures forgetting of the thousands of trivial activities that occur in our lives.) Both Linton (1978) and Wagenaar (1986) reported forgetting less than 1% of recorded events after a year delay, but of course they had only recorded one event per day, and the act of recording would make events more memorable. Forgetting rates do increase when events to be remembered are not selected to be memorable; White (1982) forgot about 40% of his events, and the participants in Brewer’s beeper studies failed even to recognize almost one third of events after five months.

As in laboratory studies of words and pictures, forgetting of autobiographical events increases over time (Linton, 1978). It is critical to note, however, that estimates of forgetting are dependent on the type of retrieval cue used. Emotion words are not good retrieval cues (e.g., Robinson, 1976), and temporal cues are not as strong as content cues such as “what,” “who,” and “where” (Wagenaar, 1988; but see Pillemer, Goldsmith, Panter, & White, 1988).

We have already noted that unique events are more likely to be remembered (e.g., Wagenaar, 1986). When evaluating forgotten (non recognized) events, Linton (1982) classified many as the “failure to distinguish” the target event from other similar events in
memory. Once-salient events became less memorable as Linton experienced more and more similar life events, corresponding to how the study of related material in laboratory experiments increases interference effects (e.g., Underwood, 1957) and leads to an abstraction of the gist of events or a schema for the events (e.g., Bartlett, 1932). Although participants may lose access to specific event memories, they may retain more generic personal memories covering a class of related life events (Brewer, 1986). Barsalou (1988) found that students asked to recall the events from their summer vacations most commonly responded with summaries of events (e.g., “I watched a lot of TV”). Only 21% of responses were classified as corresponding to specific events (e.g., “we had a little picnic”).

As already noted, forgetting of life events increases with the passage of time. Crovitz and Schiffman (1974) had college students recall and date life events in response to a series of cue words using Galton’s technique. Briefly, subjects were asked to jot down a few words describing the first memory that came to mind for each of 20 cue words. They were then asked to go back over the list of memories and date each as accurately as possible. Crovitz and Schiffman counted up the numbers of memories occurring in each of a series of temporal categories. As expected, subjects recalled the most things from their recent pasts and the fewest from their distant pasts (see also Rubin, 1982). However, a more complicated pattern emerges when retention across the entire life span is examined. First, the decline is accelerated for memories from early childhood. Memories from the first and second year of life are almost nonexistent, and memories from the first five years of life are infrequent (e.g., see Wetzler & Sweeney, 1986). This phenomenon is called childhood amnesia (Howe & Courage, 1993). Second, a different function occurs for older adults than for college students. When older adults recall and date memories in response to word cues, they still report fewer memories from more distant time periods, and disproportionately few memories from early childhood. However, they also show what is called the reminiscence bump (see Figure 1.4); given the rest of the distribution, a greater proportion of retrieved memories are dated to the periods of late adolescence and early adulthood than would be expected (e.g., Rubin & Schulkind, 1997). Numerous reasons have been suggested to account for the so-called reminiscence bump, including a preponderance of “firsts” occurring during the 20-something time period, the importance of that time period for identity formation, and

![Figure 1.4 Distribution of autobiographical memories across the lifespan. In four studies, represented by the lower four curves in the figure, 50-year-old subjects remembered and dated life events in response to cue words. The top curve collapses over studies and sums over the lower four curves. Subjects recalled a disproportionate number of events from adolescence and early adulthood (reminiscence bump). Source: Rubin et al., 1986. Reprinted with the permission of Cambridge University Press.](image-url)
greater rehearsal frequencies for the types of events occurring during one’s 20s. The exact reason for the bump remains uncertain.

**Dating Autobiographical Memories**

On what date did you hear about the attempted assassination of Ronald Reagan? On what date did you receive your acceptance letter from the college that you eventually attended? We suspect that our readers will be unlikely to answer these questions quickly or accurately. Numerous studies have shown that people have difficulty in dating their autobiographical memories (for a review, see Friedman, 1993), and that this difficulty increases with the passage of time from the target event (Linton, 1975).

As introspection quickly reveals, however, it is not that autobiographical memory lacks all temporal information, which “would be like a jumbled box of snapshots” (Friedman, 1993, p. 44). While the “snapshots” may lack explicit time-date stamps, we are quite capable of relating, ordering, and organizing the “snapshots” into a coherent story. The same subjects who cannot date a series of events within a month of their occurrence (3% correct; Brown, Rips, & Shevell, 1985) can determine the temporal ordering of the events (rank order correlation of .88; Brown et al., 1985). There is an entire literature on how people accomplish this; due to space constraints, we describe only a few of the strategies people use to reconstruct when events occurred. In general, people make use of what little temporal information was encoded originally. At least two types of temporal information in memory appear relevant: the temporal cycles that regularly occur in people’s lives, and temporal landmarks. First, natural temporal structures or cycles are encoded that later guide memory; examples include the academic calendar (Kurbat, Shevell, & Rips, 1998; Pillemer, Rhinehart, & White, 1986) and the weekday-weekend cycle (Huttenlocher, Hedges, & Prohaska, 1992). Second, people have a better sense of the dates of consequential landmark events, and thus both public and private landmarks can be used to guide date reconstruction (e.g., Brown, Shevell, & Rips, 1986; Loftus & Marburger, 1983; for a review, see Shum, 1998). Such information about temporal and event boundaries, combined with knowledge of some specific dates, can be used to place a date on a target event. However, people’s reconstructed dates tend to be too recent (Loftus & Marburger, 1983).

Other biases come into play when dating autobiographical memories; we mention just two here. Similar to the availability bias found in decision making (see Chapter 10), memories for which people have more knowledge are dated as more recent (the accessibility principle; Brown et al., 1985). People also may make rounding errors when they use inappropriately precise standard temporal units (e.g., days, weeks, months; see Huttenlocher, Hedges, & Bradburn, 1990).

**Inaccuracies in Autobiographical Memories**

Retrieval times for remembering autobiographical events tend to be slow and variable, suggesting that remembered events are reconstructed. Although diary studies have suggested that people are good at recognizing and remembering events that happened to them, they do not show that people’s memories are accurate. A study by Barclay and Wellman (1986) makes this point nicely. In their study, students took a recognition test on previously recorded life events that included four types of items: duplicates of original diary entries, foils that changed descriptive (surface) details of the original events, foils that changed reactions to original events, and foils that did not correspond to recorded events. Participants were good at recognizing original diary entries (94% correct), but they also accepted a large number of the foils. They
incorrectly accepted 50% of modified descriptions and 23% of novel events. These effects increased over a delay such that after a year subjects were accepting the majority of both semantically related and unrelated foils.

More naturalistic data also support the idea that participants’ autobiographical memories may not be accurate, even if they seem vivid and are confidently held. Perhaps most famous is the case of John Dean, a witness in the Watergate hearings who appeared to have an incredible memory for meetings with Nixon—at least until the appearance of the Presidential Transcripts, actual recordings of Oval Office conversations. Neisser (1982) provided a fascinating comparison of Dean’s memory with the transcripts, revealing that sometimes Dean’s memories reflected not the truth but rather his fantasies and beliefs about what should have been. For example, on 15 September 1972 John Dean assured Nixon that ”nothing is going to come crashing down to our surprise” (p. 146). When recalling this meeting nine months later, Dean remembered that “I also told him there was a long way to go before this matter would end and that I certainly could make no assurances that the day would not come when this matter would start to unravel” (p. 147).

Numerous laboratory experiments have since demonstrated that people remember their personal histories as consistent with what they believe should have happened, rather than with what did happen. Ross (1989) has argued that people use their current status as benchmarks and then reconstruct the past based on whether or not they think changes should have occurred over time. For example, people believe that attitudes and political beliefs remain consistent over time, so they often overestimate the consistency of the past with the present. In one study, subjects’ attitudes towards toothbrushing were manipulated; people exposed to a pro-brushing message overestimated previous brushing reports, whereas participants in an antibrushing condition underestimated their previous reports (Ross, McFarland, & Fletcher, 1981). Likewise, people may mistakenly remember a nonexistent change if one was expected. Participants who took a bogus study skills group (leading to no improvement) misremembered their prior skills as being worse than they actually were (Conway & Ross, 1984).

Even the most emotional, unique memories are not immune from distortion. While it was initially argued that unexpected events (e.g., hearing of an assassination) triggered a special mechanism leading to capture of all event details in a very accurate memory trace (Brown & Kulik, 1977), a spate of research has appeared arguing to the contrary. The so-called flashbulb memories may be particularly vivid, rehearsed at high frequencies, and confidently held, but they are prone to inaccuracies just as are memories of less emotional events. Early investigations of flashbulb memories were retrospective only, meaning that they did not assess the consistency of participants’ stories over time (e.g., Yarmey & Bull, 1978). A different picture emerged from studies that involved the comparison of initial reports to later memories. For example, Neisser and Harsch (1993) compared initial reports of having learned about the space shuttle Challenger’s explosion to those collected 32 to 34 months later. Even though their subjects reported high confidence in their memories, only three subjects’ accounts contained only minor discrepancies. Twenty-two subjects were wrong on two out of three major memory attributes (location, activity, and who told them); the remaining eleven subjects were wrong on all three. Other similar studies of disasters such as bombings and assassinations have confirmed that what characterizes flashbulb memories is the confidence with which they are held (e.g., Weaver, 1993) rather than their consistency and accuracy over time (e.g., Christianson, 1989).
Not only may memories be distorted in detail, but entire events may be misremembered as well. Loftus (1993) created a procedure to convince people that nonexistent events actually occurred: A trusted confederate (normally a relative) asked the subject to recall repeatedly five childhood events for a class experiment; unbeknownst to the subject, one of the events had never occurred. Over a series of sessions, subjects were willing to describe detailed recollections of the false event, such as being lost in a shopping mall (e.g., see Loftus, 1993). Similar data have been reported by Hyman and Pentland (1996), who found that participants who imagined knocking over a punch bowl at a wedding were more likely to create false memories for having done so. Consistent with the other memory errors described thus far, however, a person is more likely to accept a false memory when it is plausible and consistent with the rest of his or her history. For example, participants are more likely to accept a false memory for a religious event when the ritual is of their own faith (Pezdek, Finger, & Hodge, 1997).

Autobiographical memories refer to people’s retention of personal experience. But we all know much more than that—knowledge we share with many other people. We turn now to that topic, our general knowledge.

Semantic Memory

As noted earlier, Tulving (1972) distinguished between episodic and semantic memory, with the latter term referring to general knowledge of the world. Facts accessed from semantic memory do not require one to retrieve the original time or place of learning (e.g., Who was President during the U.S. Civil War? Did Virginia or Nevada first become a U.S. state? and so on through thousands of common facts). Semantic memory includes not only memories of facts and concepts, but high-level knowledge structures such as schemas and scripts as well. Tulving described semantic memory as “a mental thesaurus, organized knowledge a person possesses about words and other verbal symbols, their meanings and referents, about relations among them, and about rules, formulas, and algorithms for the manipulation of the symbols, concepts, and relations” (p. 392).

Representations of new facts may initially be episodic in that they are linked to their original context of learning. For example, in one study subjects who learned fictional facts about famous people were later aware that they had learned these facts during the experimental session, although they were unsure about which of two experimental sources had imparted particular facts (Schacter, Harbluk, & McLachlan, 1984). With time, however, such representations of new facts may become “sourceless” and thus qualify as semantic as opposed to episodic memories.

As shown in Figure 1.5, one way of conceptualizing semantic memory for words and concepts is as a large network in which related items (nodes) are linked, and the activation of one item spreads to other associated items (e.g., Collins & Quillian, 1969; Collins & Loftus, 1975). Accordingly, subjects are faster and more accurate when recognizing a word if it was preceded by a related word; for example, recognition of doctor would benefit from the prior presentation of nurse or hospital but not unrelated concepts such as butter (Meyer & Schvaneveldt, 1971). Still under debate is how to best conceptualize the nature of the nodes in the network; nodes could represent features, prototypes, or exemplars of concepts (see Chapters 5 and 10). Similarly, the nodes in the network could represent specific facts. For example, the “George Washington” node would then be linked to what one knows about the man, such as knowledge about his role in the American Revolution and his first presidency. Accordingly, Lewis and Anderson (1976) found that
learning new, unrelated information about famous people slowed retrieval of already-known information, presumably because an increase in the number of an item’s associations reduces the amount of activation spreading to any one associate. This outcome is called the fan effect, because it is assumed that the more facts that are attached to (or fan off of) a node, the slower will be retrieval of any one fact.

Such a conceptualization of semantic memory, however, leads to a “paradox of the expert.” Experts know huge sets of facts about their topics of expertise, and often have speedy access to them. How can this be explained? A network representation of an expert’s semantic memory would be characterized by a large number of information nodes. For example, chess experts have stored on the order of 50,000 chess patterns (Chase & Ericsson, 1982). However, if these huge amounts of information are stored in semantic memory in network representations, this fact should lead to the counterintuitive prediction that expertise should slow information retrieval due to reduced activation reaching any one particular node. Yet expert knowledge is characterized not only by its quantity
but also by its interrelatedness (e.g., Chi & Koeske, 1983), and this fact may help account for the speed with which experts access their knowledge. Consistent with this idea, Smith, Adams, and Schorr (1978) found that learning new, related information did not interfere with retrieval of previously known facts. For example, subjects who studied only two sentences like “Marty did not delay the trip” and “Marty broke the bottle” were faster at accessing information in these two sentences than were subjects who studied those two sentences plus the third sentence “Marty painted the old barn.” This is the fan effect. However, when the third sentence was related to one of the first ones, such as “Marty christened the ship,” the speed at which subjects could retrieve information did not slow down.

People use the contents of semantic memory in ways other than directly retrieving a fact to be remembered. Participants can reason about the contents of semantic memory, indicating what would be plausible given their knowledge of the facts (e.g., Reder, 1982). People can also sometimes retrieve partial information about the fact to be remembered. For example, a person who cannot retrieve the answer to a trivia question can predict quite well whether or not she will recognize it (Hart, 1967) and whether she will recall the answer given its first letter (Gruneberg & Monks, 1974). Similarly, subjects in a tip-of-the-tongue state are able to describe characteristics of the word to be remembered, such as its first letter, its number of syllables, and other words it sounds like (Brown & McNeill, 1966). Such results support the idea that multiple features of facts are represented in semantic memory.

How long do facts, concepts, and other forms of knowledge stay in semantic memory? The question of the long-term retention of knowledge is important but difficult to tackle given methodological issues. In one ambitious study, Bahrick (1984) examined participants’ knowledge of Spanish words, idioms, and grammar following retention intervals of up to 50 years, for which participants reported very little use of Spanish. Figure 1.6 shows the data on grammar recall, which are representative of the results with the other measures of retention. There are three distinct components to the retention function. First, consistent with forgetting in traditional episodic and autobiographical memory tasks, participants experienced a drop in knowledge of Spanish over the first 3 to 6 years of the retention interval. Second, scores remained stable over the next 20 to 30 years. Finally, scores dropped off again as the retention interval continued to increase, possibly reflecting the declines often associated with aging. The most interesting data involve the middle, flat part of the retention function, in which participants showed relatively stable knowledge of Spanish years after learning occurred; Bahrick labeled this component of the curve as reflecting the permastore. Thus, semantic memory appears to contain semipermanent information, relatively immune to forgetting, with the result that participants retain a large
amount of information without rehearsal. This description of semantic memory holds across different amounts of initial Spanish training, and across different levels of original mastery of the language.

The study of semantic memory per se has not been pursued as vigorously over the years as has the study of episodic memory. However, semantic memory borders on the issue of how concepts and categories are represented and accessed, and this topic has received great attention (see Chapters 10 and 11). If it is defined somewhat more broadly to encompass these topics, semantic memory has occupied cognitive psychologists to a great degree over the past 30 years.

Implicit Memory

Implicit memory tests are indirect measures of the retention of past experience (Schacter, 1987; see also Roediger, 1990). In terms of the procedures used to study implicit memory, the encoding phase is like that of a standard episodic (or explicit) memory experiment, whereas the test phase is like that of a standard semantic memory test. That is, during a first (encoding) phase subjects are usually exposed to a series of words or pictures (either with or without instructions to learn the material). However, during the test phase subjects are asked to complete a task based on their past knowledge to the best of their abilities, as in a semantic memory test, but no specific mention is made of using recently presented information from the earlier phase of the experiment. The implicit test is therefore thought to measure incidental retrieval of past experiences (Jacoby & Witherspoon, 1982; Roediger & McDermott, 1993).

Several standard tests of implicit memory involve accessing lexical knowledge, or knowledge of the forms of words. If subjects have studied the word elephant in a long list of words, they might later be given a number of fragmented forms of words and asked to name the first word that pops to mind that fits the clue. For example, ele____ or e_e_h_n.might be given; these tests are called word stem completion and word fragment completion, respectively. If subjects have recently studied the word elephant, they are more likely to complete the stem (which could be completed several ways—element, electric, elective, etc.) or the fragment (which can only be completed one way) with elephant. The measure of interest in implicit memory tests is priming, or the difference in probability (or speed) of completing the stem or fragment with a target when it has been recently studied relative to when it has not. Therefore, some items are not studied but are tested to get the base rate against which to measure priming from past experience. It is possible to conduct the same experiment with pictures that are studied and picture fragments that are used as test items, as well as with other types of material and procedures.

Implicit memory tests have revealed a number of startling outcomes about human memory, in that standard variables that seem well understood in other arenas either have no effect or opposite effects on standard implicit memory tests such as word fragment or word stem completion. As noted earlier, the study of implicit memory began with the observation that even densely amnesic patients, who showed dismal performance relative to control subjects on explicit tests such as free recall, showed intact priming on implicit tests (Warrington & Weiskrantz, 1968; see also Graf, Squire, & Mandler, 1984). This outcome shows that “amnesic patients” are amnesic only for certain types of memory; in addition, standard explicit tests do not measure the only type of memory. Implicit memory tests require different processes and rely on different memory systems than do explicit tests (Tulving & Schacter, 1990; Roediger, Buckner, & McDermott, 1999).
The difference between standard explicit and implicit memory tests extends far beyond work with brain-damaged patients. In the section on episodic memory we reviewed four different powerful effects of manipulating variables during study—(the levels-of-processing effect, the generation effect, the picture superiority effect, and the repetition effect). Those outcomes generalize reasonably well across episodic memory tests (free recall, cued recall, standard recognition tests); but on the kind of verbal implicit memory tests described earlier (word stem and word fragment completion), all four of these effects either disappear (there is no effect of the variable) or actually reverse. For example, Jacoby and Dallas (1981) first showed that the levels-of-processing effect that is so powerful in recognition and recall did not occur on a verbal implicit memory test akin to those discussed here. This outcome has been replicated, but some have reported small effects of levels of processing. Even when they occur, they are tiny compared to effects on explicit tests. Similarly, Jacoby (1983) and Blaxton (1989) found that words that are read produce more priming in naming visually degraded or fragmented words than do words that are generated during study. Therefore, the generation effect on standard explicit tests reverses on these kinds of implicit tests. Some have reported no differences between generating and reading on certain types of implicit tests (e.g., Masson & MacLeod, 1992), but that is still quite different from the standard positive effect obtained on explicit tests. The picture superiority effect also reverses on verbal implicit memory tests (Weldon & Roediger, 1987), and sometimes no priming whatsoever from pictures occurs on verbal tests (Srinivas, 1993). The repetition effect also does not occur on implicit memory tests; Challis and Sidhu (1993) showed that 16 massed repetitions of a word produced priming equivalent to one presentation!

In short, the “laws of memory” seem quite different on these verbal tests involving fragmentary visual clues that challenge the perceptual system. The types of implicit memory tests discussed thus far are called perceptual or data-driven tests; they present fragmentary data to the perceptual system and require subjects to produce a response. The fact that standard effects on explicit tests (e.g., levels of processing) vanish or reverse on these implicit tests can be understood through the principle of transfer appropriate processing. These tests challenge the perceptual system but do not require much analysis of meaning. Therefore, as long as subjects have read the word forms during study, they will show a benefit on a later test. Deeper processing adds other processes (meaningful ones) to the reading, but this will not help a subject complete a word fragment or word stem. Similarly, it is better for subjects to have read the word than to have generated it, because in the former condition they have practiced the skill they will need at the test (i.e., reading the word from a brief or fragmentary clue). In the case of studying pictures, the word form is not presented at all, and hence there is little or no priming on a word fragment completion test. The skills and systems needed for priming on implicit memory tests are different from those required by standard explicit tests (which are usually meaning-based), so patterns of outcome are quite different (Roediger & McDermott, 1993).

As noted toward the beginning of this chapter, there are two types of implicit memory tests: perceptual and conceptual. Conceptual tests also reveal intact priming in amnesic patients (Shimamura, 1986), but in other ways they are similar to standard (meaning-based) explicit tests, probably because conceptual tests are themselves meaning-based. Examples of conceptual implicit memory tests include free associating to words for 30 seconds (tusk: ???), generating members of categories
for 30 seconds (animals: ???), or answering general knowledge questions (What animal did Hannibal use to help scale the mountains in his attack on Rome?). In each of these cases, having previously studied the word *elephant* would lead to priming on these tests, relative to the case in which the word had not been studied. However, for these types of tests there is a positive effect of levels of processing on priming, as well as of generating (e.g., Srinivas & Roediger, 1990). Again, this pattern is interpretable in terms of transfer appropriate processing ideas, because both these manipulations are conceptual in nature. However, data from some experiments fail to conform to the transfer appropriate processing ideas. McDermott and Roediger (1996) and Weldon and Coyote (1996) both found that presentation of pictures during an encoding phase produces equivalent levels of priming as words, despite the greater conceptual elaboration thought to be involved in processing pictures. This puzzle and others await future resolution.

### Procedural Memory

Procedural memory involves memory for cognitive and motor skills. Skiing, reading, driving, and typing are all examples of procedural memory. Such knowledge is generally acquired slowly via practice. As described earlier, procedural or nondeclarative knowledge often cannot be verbalized; in fact, people may not even be aware that learning has occurred. Their behavior is characterized by “knowing how” to do something rather than “knowing that” they know it. Consistent with this, amnesic patients show intact procedural memory on a variety of tasks, including rotary pursuit (Brooks & Baddeley, 1976) and solving the tower of Hanoi problem (Wilson & Baddeley, 1988). If the skill is acquired after the brain injury that rendered the patient amnesic, the patient will often learn the skill and yet deny knowledge of the task.

### Acquisition of Procedures

Singly and Anderson (1989) did an in-depth analysis of the acquisition of text-editing skills by secretarial students trained in typing but not word processing. Over 6 days, students practiced making corrections to a word-processing document. As shown in Figure 1.7, time per page decreased from a mean of 8 min on the first day to 2 min by the last day. Singly and Anderson classified subjects’ time as either thinking time or keystroking time. As all subjects were experienced typists, keystroking time remained fairly constant across the 6 days. However, thinking time decreased dramatically across the 6 days as subjects became more experienced with word processing. Even the slight decrease in keystroking time was due to the elimination of keystrokes rather than to increases in the speed of key pressing. These results are explainable within Anderson’s (1982) framework for skill acquisition, in which people’s
initial knowledge is declarative and is translated into automatic procedures via practice. On day one, subjects’ knowledge of word processing was in a declarative state, meaning that they looked up and used specific production rules for different editing situations (e.g., “to make this change, first I need to highlight this passage with the mouse, press the delete key, and then type the new words”). Time per page decreased as subjects automatized procedures, made fewer errors, and eliminated unnecessary rules.

“Knowing That” versus “Knowing How”
As noted already, people can demonstrate procedural learning even when they are unaware of it themselves. Curran and Keele (1993) examined subjects’ awareness of their learning of a visuo-spatial sequence. They were instructed to press keys corresponding to particular spatial locations of visual signals on a computer screen; sometimes the sequence of signals followed a repeating spatial pattern that subjects could learn. Over the course of the experiment, their behavior showed learning as they responded more quickly in blocks of trials that followed the sequence than in blocks of trials that were randomly arranged. Subjects who had been informed about the nature of the repeating sequences showed the most learning \((M = 210 \text{ ms})\), but uninformed subjects also showed learning. Based on results of a postexperiment questionnaire, uninformed subjects were divided into those who were more or less aware of the repeating sequences. All uninformed subjects showed learning, although more learning occurred in more-aware \((M = 189 \text{ ms})\) than in less-aware subjects \((M = 118 \text{ ms})\) (Curran & Keele, 1993, Experiment 1).

Such unawareness of procedural learning can occur even when the skill is of a cognitive nature. In a classic study by Berry and Broadbent (1984), the subject’s task was to learn how to control the output of a hypothetical sugar factory so that production amounted to 9,000 tons of sugar. The factory produced 6,000 tons of sugar at the beginning of the experiment; to change that output, subjects were able to manipulate the size of the work force. The relationship between work force and sugar output was not a direct one, so they could not reach the desired output simply by multiplying the work force by 1.5. Rather, sugar output \((P)\) was computed by the formula \(P = 2 \times W - P_1\), where \(W\) was the work force in hundreds and \(P_1\) was the previous output in tons. Subjects manipulated sugar production for 60 trials, and by the end of the experiment they were very good at controlling output \((M = 8675\text{ in Experiment 1})\). However, on a postexperiment questionnaire they showed little explicit knowledge of the relationship between sugar production and work force. Procedurally, the subjects knew how to get the sugar production in the right range, but they were unable to state what the rule was relating work force and sugar output.

Specificity of Skill Learning: Applying Transfer Appropriate Processing Ideas
As described earlier, subjects’ episodic memories may be tied to the context of their original learning. People retrieve more information when in the same mood, place, or state as that of original learning. A similar thing occurs for procedural memory; subjects show better retention on tests of procedural memory when they can use the same procedures in the test as at learning (Kolers & Roediger, 1984). Kolers demonstrated procedure-specific memory in a series of studies in which participants practiced reading geometrically inverted (i.e., upside down) text. The task became less cognitively demanding with practice, leading to a decrease in reading time and also a decrease in retention for the inverted sentences (Kolers, 1975). After a delay of more than a year, subjects showed savings in relearning
the skill by showing reduced reading times relative to their initial reading speeds in the first phase of the experiment (Kolers, 1976). Critically, however, savings were greater for text that had been read the previous year than for new text. Presumably subjects were able to use the same procedures to reread the previously seen text, whereas slightly modified procedures had to be used for the novel texts. Similarly, recognition memory benefits from a match in procedures at study and in the test. Kolers and Ostry (1974) had students read normal and inverted sentences at study, and then tested recognition memory with normal and inverted sentences. Both types of sentences were best recognized when the test allowed students to use the same procedures to parse the sentences as at study; recognition was best for sentences both studied and tested in the same format (normal or inverted).

**Expertise Revisited**

We discussed earlier how experts have more interconnected knowledge in addition to more domain-specific knowledge. Our discussion of procedural memory adds to the picture of experts by endowing them with highly practiced, domain-specific skills. The chess expert moves quickly early in the game because he or she often has a memorized rule for the best possible move, and thus thinking time is greatly reduced. The secretary has automatized typing; the student is highly practiced at reading. Thus, expert knowledge is best characterized as consisting of domain-specific procedures in addition to a large amount of domain-specific declarative knowledge.

**CONCLUSION**

The theme of this chapter is that the single term memory does not do justice to the underlying concepts it represents. Memories come in multifarious forms, and within each form the diverse kinds of memory are multifaceted. Philosophers, psychologists, and neuroscientists have all made important contributions to the understanding of these varieties of memory. This chapter represents a progress report on our understanding at the turn of a new century.

At the same time, however, this chapter comments on the usefulness of applying classification schemes to memory. Noticeably absent from our chapter is the memory researcher’s analog to the biologist’s taxonomic tree or the chemist’s periodic table—namely, a figure depicting the best way to subdivide memory into types. While it may be tempting to present a figure for the classification system of memory, there is no such easy solution for memory researchers. Rather, as we have argued throughout the chapter, there are multiple dimensions one could use to subdivide memory into types, including (but not limited to) how long the memory trace lasts, phenomenological differences in accessing different kinds of memory, performance on different memory tests, and the neurological systems underlying performance on these tests. We organized our discussion of memory around how long the memory trace lasts; if we had chosen a different criterion, we would have ended up with a different overall framework. While this admission may be discouraging to the student of memory who is looking for the correct answer to how various types of memory should be classified, we believe our chapter is an appropriate characterization of the current state of the study of human memory.

We wish to make one other caveat regarding classification systems. The urge to tie all research to a classification scheme sometimes leads to under-appreciation of some memory research. Although this chapter is probably too long, we omitted many topics that could be considered varieties of memory and included in this chapter. Unfortunately,
research that does not fit nicely with one of the classifications may be ignored or relegated to an “other topics” category. For example, our chapter has been relatively silent on the important issue of social and collective aspects of memory. While we are very interested in research on topics such as collaborative remembering (for an excellent summary, see Weldon, 2001), such topics do not fit easily within the classification scheme we have described. Consider, for example, the broad topic of collective memory (e.g., Wertsch, in press), which may be loosely defined as the common memories of a group of people about their society, culture, and history. For example, people in the United States have the common experience of learning American history and, for recent history, of living through the events. For people who are in their 50s (or older) in the year 2001, the Vietnam War is a living memory. Even if people did not participate in it, they still lived through those turbulent times, so new foreign excursions might be shaped by the thought that “we might be entering a new Vietnam.” For American college students of 2001, the war resides in memory only from second-hand sources (history, novels, movies, recollections of family members, etc.), and the impact is probably different. The Vietnam war (and World War II or the Civil War) and other major national events shape our historical identity, and our personal identity as Americans. The same process is true in every country and every society, with important commonalities and important differences (e.g., consider how Black and White college students in the southern United States might remember and be shaped by the Civil War). These questions of collective memory are fascinating and clearly a type of memory (a part of semantic memory?), but they are just beginning to be explored empirically. We have not included this category and several others that could plausibly have been considered under the title of “varieties of memory.”

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