Memory

7

LEARNING OBJECTIVES

After studying this chapter you should be able to:

1. describe memory and outline the model of information processing
2. describe working memory
3. outline the major types of long-term memory
4. describe how information is encoded and organised in long-term memory
5. explain why remembering, misremembering and forgetting occur.

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7

CONCEPT MAP

Memory

Memory and information processing

- For information to come back to mind after it is no longer present, it has to be represented. ***Sensory representations*** store information in a sensory mode; ***verbal representations*** store information in words.
- The standard model of memory is predicated on the metaphor of the mind as a computer; it distinguishes three memory stores: ***sensory memory***, ***short-term memory (STM)*** and ***long-term memory (LTM)***.

Varieties of long-term memory

- ***Declarative memory*** refers to memory for facts and events; it can be ***semantic*** or ***episodic***. ***Procedural memory*** refers to 'how to' knowledge of procedures or skills.
- ***Explicit memory*** refers to conscious recollection. ***Implicit memory*** refers to memory that is expressed in behaviour.
- ***Everyday memory*** refers to memory as it occurs in daily life.

Encoding and organisation of long-term memory

- To be retrieved from memory, information must be ***encoded***, or cast into a representational form or 'code' that can be readily accessed.
- ***Mnemonic devices*** are systematic strategies for remembering information.
- Knowledge stored in memory forms ***networks of association*** — clusters of interconnected information.
- LTM is organised in terms of schemas, organised knowledge structures or patterns of thought.

Working memory

- ***Working memory*** refers to the temporary storage and processing of information that can be used to solve problems, respond to environmental demands or achieve goals.
- Baddeley and Hitch's (1974) model proposed rehearsal, reasoning and making decisions about how to balance two tasks are the work of a limited-capacity central executive system.
- Most contemporary models distinguish between a visual store (the visuospatial sketchpad) and a verbal store.
- Working memory and LTM are distinct from one another in both their functions and neuroanatomy, but interact to help enhance memory capacities.

Remembering, misremembering and forgetting

- Psychologists often distinguish between the availability of information in memory and its accessibility.
- People make memory errors for a variety of reasons.
- Psychologists have proposed several explanations for why people forget, including decay, interference and motivated forgetting.
- Memories recovered in therapy cannot be assumed to be accurate, but they also cannot be routinely dismissed as false.
- Specific kinds of distortion can also occur within the memories of people whose brains have been affected by illness or injury. ***Anterograde amnesia*** involves the inability to retain new memories. By contrast, ***retrograde amnesia*** involves losing memories from a period before the time that a person's brain was damaged.

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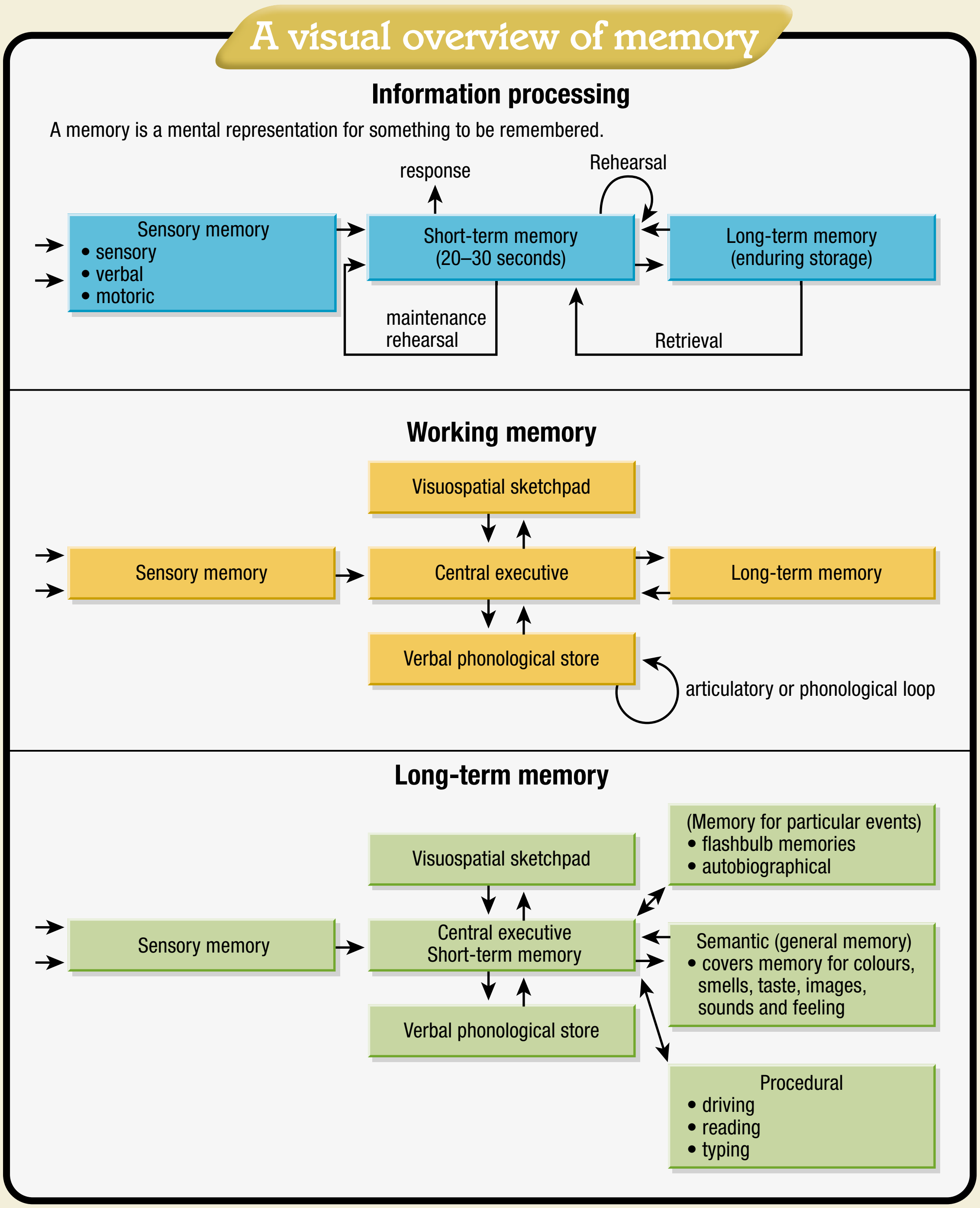

Central questions: what is memory?

- The concept of memory is expanding and we are beginning to see an integration among the differing psychological perspectives.

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Imagine walking into a room to find 300 people you have never met before, seated around tables. You briefly walk around the room, finding out the name of each person. Then, half an hour later, you must go around the room and identify all 300 people by name. That's impossible, you might think. No-one could memorise that many people's names in such a short space of time.

Well, don't tell that to Kerry Domann, an Australian entertainer who regularly amazes dinner functions with his ability to recall the names of up to 300 audience members just minutes after meeting them for the first time. Performing under the stage name 'The Amazing Nigel', Kerry is in demand around the country as an after-dinner speaker who entertains with a mix of comedy and magic. The extremely funny act regularly has the crowd in stitches. But the climax of the stage show occurs when 'Nigel' walks the room naming each of the guests individually, to the amazement of the crowd. His astounding memory is no fluke — and he now also trains people in his techniques for improving memory. So, how is it that The Amazing Nigel can perform feats of memory that to most people would appear impossible? Is there something unique about him and his memory?

But what if your memory disappears altogether? One of Australia's most loved and most enduring entertainment figures has had a number of episodes of amnesia (memory loss), which thankfully have turned out to be temporary. Patti Newton, the wife of television legend Bert Newton, attended the 2012 Logie Awards in Melbourne. Afterwards, Patti went to sleep in her hotel room but then awoke in the middle of the night and could not remember where she was or what she was doing. This followed similar episodes in recent years. After she attended the Sydney premiere of the musical *Wicked* (featuring husband Bert) she flew back to Melbourne, but lost her memory on the drive home from the airport. She stood outside her house staring at it, with no idea where she had been, what she had done or where she was. Similarly, one day in March 2006, Patti took her clothes off in her driveway, thought it was 1950 and could not recognise Bert. While Patti's full memory returned shortly after those episodes and she is otherwise healthy, she is understandably shaken by the experience of losing her identity for those short periods.

So just how does memory work? How can The Amazing Nigel remember the names of 300 people he has just met, while Patti Newton sometimes cannot even remember her own name? Case studies of neurologically impaired patients and experimental studies of normal subjects have demonstrated that memory is not a single function that a person can have or lose. Rather, memory is composed of several systems. Just how many systems, and how independently they function, are questions at the heart of contemporary research.

The previous chapter was dominated by the behaviourist perspective; this one and the next focus primarily on the cognitive perspective. We begin by considering some of the basic features of memory and an evolving model of information processing that has guided research on memory for over three decades. We then explore the memory systems that allow people to store information temporarily and permanently, and examine why people sometimes forget and misremember. Along the way, we consider the implications of memory research for issues such as the accuracy of eyewitness testimony in court and the existence of repressed memories in victims of childhood sexual abuse.

Two questions form the backdrop of this chapter. The first is deceptively simple: What does it mean to remember? Is memory simply the recollection of 'facts'? Or does memory extend to the activation (or reactivation) of goals, emotions and behaviours — as when we effortlessly 'remember' how to drive, even while deeply engrossed in conversation? Second, what is the relationship between the kind of learning described in the last chapter, which emphasised behaviours and emotional responses, and memory?

Central questions

- What does it mean to remember?
- What is the relationship between learning and memory?

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Memory and information processing

Memory is so basic to human functioning that we take it for granted. Consider what was involved the last time you performed the seemingly simple task of remembering a friend's phone number. Did you bring to mind a visual image (a picture of the number), an auditory 'image' (pronouncing a series of numbers out loud in your mind) or simply a pattern of motor movements as you punched the numbers on the phone? How did you bring to mind this particular number, given that you probably have a dozen other numbers stored in memory? Once a number was in your mind, how did you know it was the right one? And were you aware as you reached for the phone that you were remembering at that very moment how to use a phone, what phones do, how to lift an object smoothly to your face, how to push buttons and who your friend is?

This example suggests how complex the simplest act of memory is. Memory involves taking something we have observed, such as a written phone number, and converting it into a form we can store, retrieve and use. We begin by briefly considering the various ways the brain can preserve the past — the 'raw material' of memory — and an evolving model of information processing that has guided psychologists' efforts to understand memory for the last quarter of a century.

MAKING CONNECTIONS

Although olfactory memory is less 'accurate' than visual memory, it is far more emotionally charged. The smell of freshly cut grass can evoke powerful emotional memories from childhood. The scent of a favourite perfume may elicit recognition from grandmother, even in the last stages of Alzheimer's. Thus, **smell** (chapter 4) and **emotion** (chapter 11) are strongly linked by memory.

Mental representations

For a sound, image or thought to return to mind when it is no longer present, it has to be represented in the mind — literally, re-presented, or presented again — this time without the original stimulus. As we saw in chapter 4, a mental representation is a psychological version or mental model of a stimulus or category of stimuli. In neuropsychological terms, it is the patterned firing of a network of neurons that forms the neural 'code' for an object or concept, such as 'dog' or 'sister'.

Representational modes are like languages that permit conversation within the mind (see Jackendoff, 1996). The content of our thoughts and memories — a bird, an angry friend, a beautiful sunset — can be described or translated into many 'languages' — images, sounds, words and so forth — but some languages cannot capture certain experiences the way others can. Fortunately, we are all 'multilingual' and frequently process information simultaneously using multiple representational codes (chapter 3).

Some kinds of representation are difficult to conceptualise and have received less attention from researchers. For example, people store memories of actions, such as how to press the buttons on a phone or how to squeeze the last drops of tomato sauce out of the bottle, which suggests the existence of motoric representations, or stored memories of muscle movements. The most commonly studied representations are sensory and verbal.

Sensory representations

Sensory representations store information in a sensory mode, such as the sound of a dog barking or the image of a city skyline. The cognitive maps discovered in rats running mazes (chapter 6) probably include visual representations. People rely on visual representations to recall where they left their keys last night or to catch a ball that is sailing towards them through the air. Visual representations are like pictures that can be mentally scrutinised or manipulated (Burton, 2003; Burton & Fogarty, 2003; Kosslyn, 1983).

The auditory mode is also important for encoding information (Thompson & Paivio, 1994). Some forms of auditory information are difficult to represent in any other mode. For instance, most readers would be able to retrieve a tune by the Foo Fighters or Guy Sebastian with little difficulty, but would have much more trouble describing the melody than 'hearing' it in their minds.

Fans of pop star Guy Sebastian would likely find it easier to 'hear' one of his songs than to describe it.

Other types of sensory information have their own mental codes as well. People can identify many objects by smell, a finding that suggests that they are comparing current sensory experience with olfactory knowledge (Degel, Piper, & Koster, 2001; Schab & Crowder, 1995). Olfactory

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representations in humans are, however, far less reliable than visual representations in identifying even common objects (de Wijk, Schab, & Cain, 1995). For example, if exposed to the smell of a lemon, people often misidentify it as an orange, whereas people with an intact visual system rarely confuse the two fruits visually. More recent research indicates that two odours need to be presented initially as a mixture, rather than as two separate odours, to increase participants' similarity ratings of the two odours in each pair. This perceptual learning effect is rapid and resistant to interference (Stevenson, Case, & Boakes, 2005).

Interestingly, memories of our past can be evoked by smell. Miles and Berntsen (2011) recently demonstrated that odour can induce participants to remember and relive past events, especially those that occurred in the first 10 years of their lives.

Verbal representations

Although many representations are stored in sensory modes, much of the time people think using ***verbal representations***, or information stored in words. Try to imagine what 'liberty' or 'mental representation' means without thinking in words. Other experiences, in contrast, are virtually impossible to describe or remember verbally, such as the smell of bacon. In fact, using words to describe things about which one has little verbal knowledge can actually disrupt sensory-based memory.

Neuroimaging studies confirm that verbal representations are in fact distinct from sensory representations. Consider what happens when researchers present participants with a string of X's versus a word (Menard, Kosslyn, Thompson, Alpert, & Rauch, 1996). Both stimuli lead to activation of the visual cortex, since both are processed visually. Presentation of the word, however, leads to additional activation of a region at the juncture of the left occipital, parietal and temporal lobes that appears to be involved in transforming the visual representation into a verbal or semantic one.

INTERIM SUMMARY

For information to come back to mind after it is no longer present, it has to be represented. ***Sensory representations*** store information in a sensory mode; ***verbal representations*** store information in words. People also store knowledge about actions as motoric representations.

Information processing: an evolving model

Psychologists began studying memory in the late nineteenth century, although interest in memory waned under the influence of behaviourism until the 'cognitive revolution' of the 1960s. In 1890, William James proposed a distinction between two kinds of memory, which he called primary and secondary memory. Primary memory is immediate memory for information momentarily held in consciousness, such as a telephone number. Secondary memory is the vast store of information that is unconscious except when called back into primary memory, such as the 10 or 20 phone numbers a person could bring to mind if he wanted to call various friends, family members, shops and so forth. James' distinction is embodied in what we will call the standard model of memory. This model has guided research on memory and cognition since the 1960s (Atkinson & Shiffrin, 1968; Healy & McNamara, 1996).

The standard model is predicated on the metaphor of the mind as a computer, which places information into different memory stores (the system's 'hardware') and retrieves and transforms it using various programs ('software'). According to this model (figure 7.1), memory consists of three stores: sensory registers, short-term memory (James' primary memory) and long-term memory (James' secondary memory). Storing and retrieving memories involve passing information from one store to the next and then retrieving the information from long-term memory.

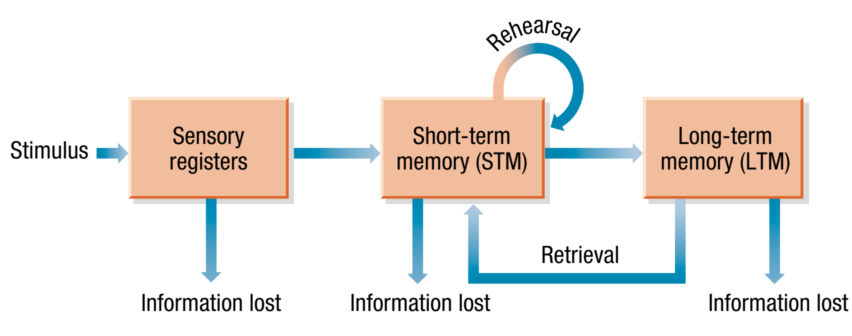

FIGURE 7.1
Standard model of memory. Stimulus information enters the sensory registers. Some information enters STM and is then passed on for storage in LTM. Information can be lost from any of the sensory stores, usually if it is not very important or if a traumatic event has occurred that interferes with memory consolidation or retrieval.

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Sensory registers

Suppose you grab a handful of coins (say, six or seven) from your pocket at the laundromat and, while looking away, stretch out your hand so that all of the coins are visible. If you then glance for a second at your hand but look away before counting the change, you are still likely to be able to report accurately the number of coins in your hand because the image is held momentarily in your visual sensory register. ***Sensory registers*** hold information about a perceived stimulus for approximately half a second after the stimulus disappears, allowing a mental representation of it to remain in memory briefly for further processing (figure 7.2) (Sperling, 1960).

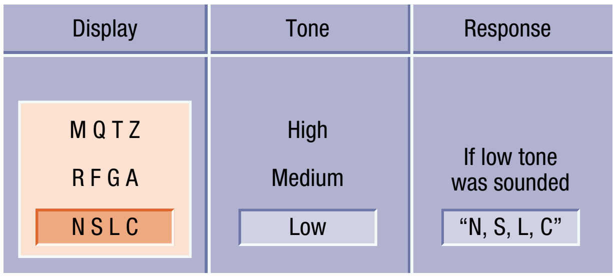

FIGURE 7.2
Visual sensory register. In a classic experiment, participants briefly viewed a grid of 12 letters and then heard a tone after a short delay. They had been instructed to report the top, middle or bottom row, depending on whether a high, medium or low tone sounded. If the tone sounded within half a second, they were 75 percent accurate, by reading off the image in their mind (iconic storage). If the tone sounded beyond that time, their accuracy dropped substantially because the visual image had faded from the sensory register.
Source: Sperling (1960).

Most research has focused on visual and auditory sensory registration. The term ***iconic storage*** describes momentary memory for visual information. For a brief period after an image disappears from vision, people retain a mental image (or 'icon') of what they have seen. This visual trace is remarkably accurate and contains considerably more information than people can report before it fades (Baddeley & Patterson, 1971). The duration of icons varies from approximately half a second to two seconds, depending on the individual, the content of the image and the circumstances (Neisser, 1976). Recent research indicates that emotional information, particularly visual stimuli evoking fear, is subject to slow decay in iconic storage (Kuhbandner, Spitzer, & Pekrun, 2011). The auditory counterpart of iconic storage is called ***echoic storage***, momentary memory for auditory information (Battacchi, Pelamatti, Umilta, & Michelotti, 1981; Neisser, 1967).

APPLY + DISCUSS

- In what ways is the mind like a computer?
- In what ways does the computer metaphor fail to capture important aspects of human psychological functioning?

Short-term memory

According to the standard model, then, the first stage of memory is a brief sensory representation of a stimulus. Many stimuli that people perceive register for such a short time that they drop out of the memory system without further processing, as indicated in figure 7.1 ('information lost'). Other stimuli make a greater impression. Information about them is passed on to ***short-term memory (STM)***, a memory store that holds a small amount of information in consciousness — such as a phone number — for roughly 20 to 30 seconds, unless the person makes a deliberate effort to maintain it longer by repeating it over and over (Waugh & Norman, 1965). See Nairne (2002) for a review of recent research that identifies the conceptual and empirical problems of the standard model of STM. Nairne argues that STM is cue driven, much like long-term memory, and that neither rehearsal nor decay is likely to explain short-term forgetting.

Limited capacity

Short-term memory has limited capacity — that is, it does not hold much information. To assess STM, psychologists often measure participants' digit span; that is, how many numbers they can hold in mind at once. On average, people can remember about seven pieces of information at a time, with a normal range of from five to nine items (Miller, 1956). That phone numbers in most countries are five to seven digits long is no coincidence.

Hermann Ebbinghaus (1885/1964) was the first to note the seven-item limit to STM. Ebbinghaus pioneered the study of memory using the most convenient and agreeable subject he could find — himself — with a method that involved inventing some 2300 nonsense syllables (such as *pir* and *vup*). Ebbinghaus randomly placed these syllables in lists of varying lengths and then attempted to memorise the lists; he used nonsense syllables rather than real words to try to control the possible influence of prior knowledge on memory. Ebbinghaus found that he could memorise up to seven

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(a) **7638826**
(b) **7638826** (20 seconds later)
(c) **9188326** (25 seconds later)

FIGURE 7.3
Short-term memory. In an experimental task, the participant is presented with a string of seven digits (a). Without rehearsal, 20 seconds later, the representations of the digits have begun to fade but are still likely to be retrievable (b). At 25 seconds, however, the experimenter introduces three more digits, which 'bump' the earliest of the still-fading digits (c).

syllables, but no more, in a single trial. The limits of STM seem to be neurologically based, as they are similar in other cultures, including those with very different languages (Yu et al., 1985).

Because of STM's limited capacity, psychologists often liken it to a lunch counter (Bower, 1975). If only seven stools are available at the counter, some customers will have to get up before new customers can be seated. Similarly, new information 'bumps' previous information from consciousness. Figure 7.3 illustrates this bumping effect.

Rehearsal

Short-term memory is not, however, a completely passive process of getting bumped off a stool. People can control the information stored in STM. For example, after looking up a phone number, most people will repeat the information over and over in their minds — a procedure called ***rehearsal*** — to prevent it from fading until they have dialled the number. This kind of mental repetition in order to maintain information in STM is called ***maintenance rehearsal***.

Rehearsal is also important in transferring information to long-term memory, a finding that will not surprise anyone who has ever memorised a poem or a maths formula by repeating it over and over. As we will see, however, maintenance rehearsal is not as useful for storing information in long-term memory as actively thinking about the information while rehearsing, a procedure known as ***elaborative rehearsal***. Remembering the words to a poem, for example, is much easier if the person really understands what it is about, rather than just committing each word to memory by rote.

INTERIM SUMMARY

The standard model of memory is predicated on the metaphor of the mind as a computer. It distinguishes three memory stores: sensory memory (or sensory registers), short-term memory and long-term memory. ***Sensory registers*** hold information about a perceived stimulus for approximately half a second after the stimulus disappears. From the sensory registers, information is passed on to a limited-capacity ***short-term memory (STM)***, which holds up to seven pieces of information in consciousness for roughly 20 to 30 seconds unless the person makes a deliberate effort to maintain it by repeating it over and over (***maintenance rehearsal***). ***Elaborative rehearsal***, which involves actually thinking about the material while committing it to memory, is more useful for long-term than for short-term storage.

Long-term memory

Just as relatively unimportant information drops out of memory after brief sensory registration, the same is true after storage in STM. An infrequently called phone number is not worth cluttering up the memory banks. More important information, however, goes on to ***long-term memory (LTM)***, in which representations of facts, images, thoughts, feelings, skills and experiences may reside for as long as a lifetime. According to the standard model, the longer information remains in STM, the more likely it is to make a permanent impression in LTM. Recovering information from LTM, known as ***retrieval***, involves bringing it back into STM (which is often used in information-processing models as a synonym for consciousness).

Why did researchers distinguish short-term from long-term memory? One reason was simple: short-term memory is brief, limited in capacity and quickly accessed, whereas LTM is enduring, virtually limitless, but more difficult to access (as anyone knows who has tried to recall a person's name or a term on an exam without success).

Another reason emerged as psychologists tested memory using free-recall tasks. In free-recall tasks, the experimenter presents participants with a list of words, one at a time, and then asks them to recall as many as possible. When the delay between presentation of the list and recall is short, participants demonstrate a phenomenon known as the ***serial position effect***: a tendency to remember information towards the beginning and end of a list rather than in the middle (figure 7.4).

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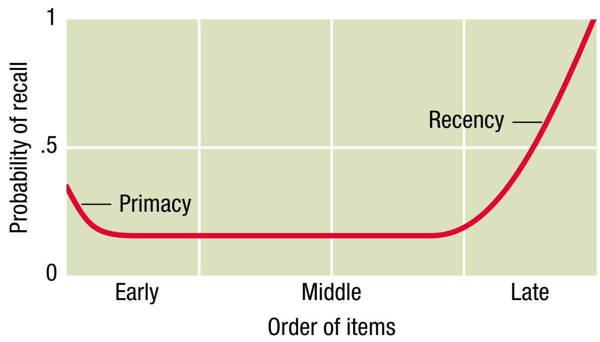

FIGURE 7.4
Serial position effect. Items earlier in a list and those at the end show a heightened probability of recall in comparison to those in the middle.
Source: Atkinson and Shiffrin (1968).

Evolution of the model

Although the standard model provides a basic foundation for thinking about memory, in the last decade it has evolved in four major respects. First, the standard model is a serial processing model: it proposes a series of stages of memory storage and retrieval that occur one at a time (serially) in a particular order, with information passing from the sensory registers to STM to LTM. For information to get into LTM, it must first be represented in each of the prior two memory stores, and the longer it stays in STM, the more likely it is to receive permanent storage in LTM.

Subsequent research suggests that a serial processing model cannot provide a full account of memory. Most sensory information is never processed consciously (i.e., placed in STM), but it can nevertheless be stored and retrieved — an explanation for the familiar experience of finding oneself humming a tune that was playing in the background at a store without ever having noticed consciously that it was playing.

Further, the process of selecting which sensory information to store in STM is actually influenced by LTM; that is, LTM is often activated *before* STM rather than after it. The function of STM is to hold important information in consciousness long enough to use it to solve problems and make decisions. But how do we know what information is important? The only way to decide which information to bring into STM is to compare incoming data with information stored in LTM that indicates its potential significance (Logie, 1996). Thus, LTM must actually be engaged *before* STM to figure out how to allocate conscious attention (chapter 5).

A second major shift is that researchers have come to view memory as involving a set of ***modules*** — discrete but interdependent processing units responsible for different kinds of remembering. These modules operate simultaneously (i.e., in parallel), rather than serially (one at a time) (Fodor, 1983; Rumelhart, McClelland, & the PDP Research Group, 1986). This view fits with neuropsychological theories suggesting that the central nervous system consists of coordinated but autonomously functioning systems of neurons.

For instance, when people simultaneously hear thunder and see lightning, they identify the sound using auditory modules in the temporal cortex and identify the image as lightning using visual modules in the occipital and lower (inferior) temporal lobes (the 'what' pathway), and pinpoint the location of the lightning using a visual–spatial processing module (the 'where' pathway) that runs from the occipital lobes through the upper (superior) temporal and parietal lobes (chapter 4). When they remember the episode, however, all three modules are activated at the same time, so they have no awareness that these memory systems have been operating in parallel.

Similarly, researchers have come to question whether STM is really a single memory store. As we will see shortly, experimental evidence suggests that STM is part of a working memory system that can briefly keep at least three different kinds of information in mind simultaneously so that the information is available for conscious problem solving (Baddeley, 1992, 1995).

Third, researchers once focused exclusively on conscious recollection of word lists, nonsense syllables and similar types of information. Cognitive psychologists now recognise other forms of remembering that do not involve retrieval into consciousness. An amnesic like Jimmie (whose case opened this chapter) who learns a new skill, or a child who learns to tie a shoe, is storing new information in LTM. When this information is remembered, however, it is expressed directly in skilled

APPLY + DISCUSS

At times, we all have trouble remembering certain things, such as a friend's birthday. But, what about remembering to remember? If I put a shirt in the dryer to dry for only 20 minutes, I need to remember in a short time to take the shirt out of the dryer.

- What part of the memory system do you think is related to remembering to remember?
- During the 20-minute interval that the shirt is drying, do most people constantly rehearse in their minds that they need to take the shirt out? Do they use external memory aids, such as a timer?
- How successful are you at remembering to remember?

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behaviour rather than retrieved into consciousness or STM. Further, researchers are now paying closer attention to the kinds of remembering that occur in everyday life, as when people remember emotionally significant events or try to remember to pick up several items at the supermarket on the way home from work.

The fourth change is a shift in the metaphor underlying the model. Researchers in the 1960s were struck by the extraordinary developments in computer science that were just beginning to revolutionise technology, and they saw in the computer a powerful metaphor for the most impressive computing machine ever designed: the human mind. Today, after a decade or more of similarly extraordinary progress in unravelling the mysteries of the brain, cognitive scientists have turned to a different metaphor: mind as brain.

In the remainder of this chapter we will explore the major components of this evolving model. We begin with working memory (the current version of STM) and then examine the variety of memory processes and systems that constitute LTM.

INTERIM SUMMARY

In ***long-term memory (LTM)***, representations of facts, images, thoughts, feelings, skills and experiences may reside for as long as a lifetime. Recovering information from LTM, or ***retrieval***, involves bringing it back into STM. The ***serial position effect*** is a tendency to remember information towards the beginning and end of a list rather than from the middle. Although the standard model still provides a foundation for thinking about memory, in the last decade it has evolved in four major ways. First, the assumption that a serial processing model can account for all of memory no longer seems likely. Second and related, researchers have come to view memory as involving a set of ***modules*** — discrete but interdependent processing units responsible for different kinds of remembering that operate simultaneously (in parallel) rather than sequentially (one at a time). Third, the standard model overemphasises conscious memory for relatively neutral facts and underemphasises other forms of remembering, such as skill learning and everyday remembering. Fourth, the underlying metaphor has changed, from mind as computer to mind as brain.

Working memory

Because people use STM as a 'workspace' to process new information and to call up relevant information from LTM, many psychologists now think of STM as a component of working memory. ***Working memory*** refers to the temporary storage and processing of information that can be used to solve problems, respond to environmental demands or achieve goals (see Baddeley, 1992, 1995; Richardson, 1996a, 1996b).

Working memory is active memory: information remains in working memory only as long as the person is consciously processing, examining or manipulating it. Like the older concept of STM, working memory includes both a temporary memory store and a set of strategies, or control processes, for mentally manipulating the information momentarily held in that store. These control processes can be as simple as repeating a phone number over and over until we have finished dialling it — or as complex as trying to solve an equation in our heads.

Researchers initially believed that these two components of working memory — temporary storage and mental control — competed for the limited space at the lunch counter. In this view, rehearsing information is an active process that itself uses up some of the limited capacity of STM. Researchers also tended to view STM as a single system that could hold a maximum of about seven pieces of information of *any* kind, whether numbers, words or images.

More recent research suggests, instead, that working memory consists of multiple systems and that its storage and processing functions do not compete for limited space. According to one prominent model, working memory consists of three memory systems: a visual memory store, a verbal memory store and a 'central executive' that controls and manipulates the information these two short-term stores hold in mind (Baddeley, 1992, 1995). We begin by discussing the central executive and then examine the memory stores at its disposal.

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Processing information in working memory: the central executive

In 1974, Alan Baddeley and Graham Hitch challenged the view of a single all-purpose working memory by presenting participants with two tasks simultaneously, one involving recall of a series of digits and the other involving some kind of thinking, such as reasoning or comprehending the meaning of sentences. They reasoned that if working memory is a single system, trying to remember seven or eight digits would fill the memory store and eliminate any further capacity for thinking.

The investigators *did* find that performing STM and reasoning tasks simultaneously slowed participants' ability to think. In one study, holding a memory load of four to eight digits increased the time participants took to solve a reasoning task (figure 7.5). However, a memory load of three items had no effect at all on reasoning speed, despite the fact that it should have consumed at least three of the 'slots' in STM. Further, performing the two tasks simultaneously had no impact on the number of errors participants made on the thinking task, suggesting that carrying out processes such as reasoning and rehearsal does not compete with storing digits for 'workspace' in a short-term store.

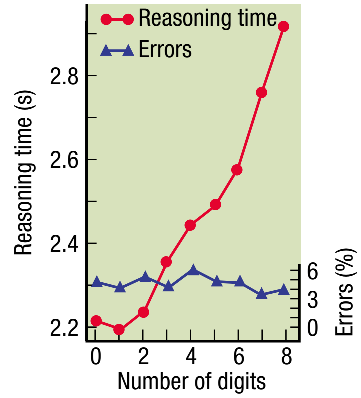

FIGURE 7.5
Speed and accuracy of reasoning as a function of number of digits to remember. Having to remember up to eight digits slowed the response time of participants as they tried to solve a reasoning task, but it did not lead to more errors. Keeping one to three digits in mind had minimal impact on reasoning time or speed.

Source: Adapted from Baddeley, A. 'Working Memory', (1986), Fig 4.5 p. 67, by permission of Oxford University Press.

These and other data led Baddeley and his colleagues to propose that storage capacity and processing capacity are two separate aspects of working memory. Processes such as rehearsal, reasoning and making decisions about how to balance two tasks simultaneously are the work of a central executive system that has its own limited capacity, independent of the information it is storing or holding momentarily in mind. Other researchers have found that working memory as a whole does seem to have a limited capacity — people cannot do and remember too many things at the same time — but working memory capacity varies across individuals and is related to their general intellectual ability (chapter 9) (Baddeley, 2001; Daneman & Merikle, 1996; Just & Carpenter, 1992; Logie, 1996). Indeed, children also demonstrate working memory limitations. For example, Halford and his colleagues at the University of Queensland's Cognition and Human Reasoning Laboratory have investigated the role of learning and information processing limitations in shaping children's cognitions. They have found evidence for a capacity limitation in young infants, and their research indicates that the complexity of information processed by children increases with age (Halford, Maybery, & Bain, 1986; Halford, Wilson, & Phillips, 1998). Similarly, a study of 144 Year 1 children from Queensland state primary schools showed a strong relationship between working memory and children's cognitive functioning (O'Connor, Spencer, & Patton, 2003).

Recent research indicates that children with attention-deficit hyperactivity disorder are likely to have deficits in working memory when compared to their peers (Kasper, Alderson, & Hudec, 2012). For boys, these working memory deficits most likely occur in the area of the central executive (Rapport et al., 2008).

Research suggests there is a strong relationship between working memory and children's cognitive functioning.

Visual and verbal storage

Most contemporary models of working memory distinguish between at least two kinds of temporary memory: a visual store and a verbal store (Baddeley, 1995; Baddeley, Gathercole, & Papagno, 1998). Evidence that these are indeed distinct components comes from several lines of research (figure 7.6, overleaf).

The visual store (also called the visuospatial sketchpad) is like a temporary image the person can hold in mind for 20 or 30 seconds. It momentarily stores visual information such as the location and nature of objects in the environment, so that, for example, a person turning around to grab a mug at the sink will remember where she placed a tea bag a moment before. Images in the visual store can be mentally rotated, moved around or used to locate objects in space that have momentarily dropped out of sight.

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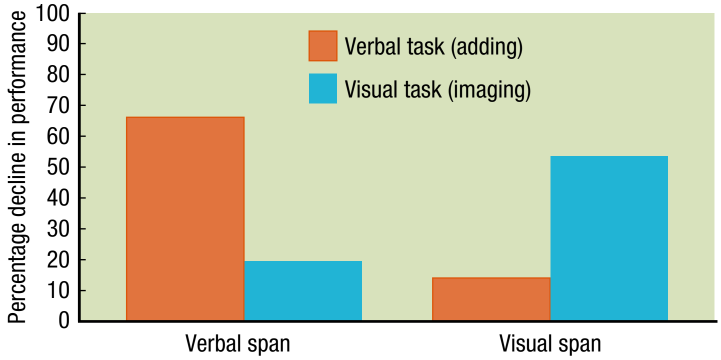
FIGURE 7.6
Independence of verbal and visual working memory storage. In one task, participants had to memorise briefly a sequence of letters ('verbal span'), whereas in another they had to remember the location of an extra grey block on a grid ('visual span'). At the same time, they either had to perform a verbal task (adding) or a visual one (imaging). As can be seen, the visual task interfered primarily with visual span, whereas the verbal task interfered primarily with verbal span.

Source: Adapted from Logie, R., 'The seven ages of working memory', from 'Working memory and Human Cognition' by John T. E. Richardson et al., 1996, Fig 2.4, p. 47, by permission of Oxford University Press.



The verbal (or phonological) store is the familiar short-term store studied using tasks such as digit span. Verbal working memory is relatively shallow: words are stored in order, based primarily on their sound (phonology), not their meaning. Tehan and Humphreys (1995) demonstrated the importance of phonemic codes in working memory by manipulating the strength of phonemic codes in target words. They suggested that phonemic information helps to make items more distinctive and thus easily discriminable from other target items.

Researchers learned about the 'shallowness' of verbal working memory by studying the kinds of words that interfere with each other (Baddeley, 1986; see also Lange & Oberauer, 2005). A list of similar-sounding words (such as *man*, *mat*, *cap* and *map*) is more difficult to recall than a list of words that do not sound alike. Similarity of meaning (e.g., *large*, *big*, *huge*, *tall*) does not similarly interfere with verbal working memory, but it *does* interfere with LTM. These findings suggest that verbal working memory and LTM have somewhat different ways of storing information.

INTERIM SUMMARY

Many psychologists now refer to STM as ***working memory*** — the temporary storage and processing of information that can be used to solve problems, respond to environmental demands or achieve goals. Working memory includes both a storage capacity and a processing capacity. According to the model proposed by Baddeley and his colleagues, processes such as rehearsal, reasoning and making decisions about how to balance two tasks simultaneously are the work of a limited-capacity central executive system. Most contemporary models distinguish between at least two kinds of temporary memory — a visual store (the visuospatial sketchpad) and a verbal store.

The neuropsychology of working memory

Recently researchers have begun tracking down the neuropsychology of working memory. The emerging consensus is that working memory is 'orchestrated', or directed, by the prefrontal cortex, a region of the brain long known to be involved in the most high-level cognitive functions (Kane & Engle, 2002). When information is temporarily stored and manipulated, the prefrontal cortex is activated along with whichever posterior regions (i.e., regions towards the back of the brain) normally process the kind of information being held in memory, such as words or images (D'Esposito et al., 1997; Faw, 2003; Goldman-Rakic, 1996; Smith, 2000).

Activation of the prefrontal cortex seems to provide access to consciousness to representations normally processed in other parts of the cortex, so that the person can temporarily hold the information in mind and manipulate it. Evidence for the pivotal role of the prefrontal cortex began to accumulate when researchers designed working memory tasks for monkeys and observed the activity of neurons in this region (Fuster, 1989, 1997; Goldman-Rakic, 1995).

Similar studies have now been conducted with humans. In one study, the researchers used fMRI (functional magnetic resonance imaging) to study the activation of different cortical regions while participants tried to remember faces or scrambled faces (a meaningless visual stimulus) (Courtney, Ungerleider, Keil, & Haxby, 1997). The results were striking. Relatively meaningless visual information activated posterior regions of the occipital lobes involved in the early stages of processing visual stimuli. Facial stimuli activated areas of the visual cortex in the occipital and temporal lobes involved in processing and identifying meaningful visual stimuli (and perhaps faces in particular).

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Anterior regions of the frontal lobes, that is, the prefrontal cortex, were most active during the delay period in which the faces and scrambled faces were removed and had to be held in working memory.

Research also demonstrates the independence of different components of working memory. For example, neuroimaging studies confirm that verbal and visual working memory activate different cortical regions (Smith, Jonides, & Koeppe, 1996). A recent neuroimaging study found that gamma band activity readings indicate whether a memory is verbal or visual in nature (Hamamé et al., 2012). Studies even document the existence of two distinct kinds of visual working memory, processed in different areas of the prefrontal cortex: memory for location and memory for objects (Courtney, Petit, Ungerleider, Maisog, & Haxby, 1998; Rao, Rainier, & Miller, 1997). This finding makes sense in the light of research described in chapter 4 that distinguishes between two visual pathways involved in perception, the 'what' pathway (involved in identifying what objects are) and the 'where' pathway (involved in identifying where they are in space). Researchers have even begun tracking down the anatomical location of the central executive.

Using fMRI, one team of researchers identified a region of the prefrontal cortex that may be involved in functions such as managing the demands of two simultaneous tasks (D'Esposito et al., 1997). The researchers presented participants with two tasks that do not involve short-term storage, one verbal (making simple decisions about some words) and the other visual (mentally rotating images).

As expected, the verbal task activated the left temporal cortex, whereas the visual task activated the occipital and parietal cortex. Neither task alone activated the prefrontal cortex. However, when participants had to complete both tasks at the same time, regions of the prefrontal cortex became active — a suggestion that prefrontal working memory circuits are indeed activated when people have to make 'executive decisions' about how to manage the limited workspace in working memory (see also Adcock, Constable, Gore, & Goldman-Rakic, 2000; Bunge, Klingberg, Jacobsen, & Gabrieli, 2000).

APPLY + DISCUSS

Originally, researchers used the term short-term memory (which eventually became working memory) and consciousness as synonyms.

- Are there aspects of consciousness that are not represented in working memory?
- Is everything of which we are consciously aware held in working memory?
- Are there aspects of working memory that are not conscious?

The relationship between working memory and long-term memory

What can we conclude from these various studies about working memory? First, consistent with the original concept of STM, working memory appears to be a system for temporarily storing and processing information, a way of holding information in mind long enough to use it. Second, working memory includes a number of limited-capacity component processes, including a central executive system, a verbal storage system, and at least one and probably two or three visual storage systems (one for location, one for identification of objects and perhaps another that stores both simultaneously). Third, working memory is better conceived as a conscious workspace for accomplishing goals than as a way station or gateway to storage in LTM, because information can be stored in LTM without being represented in consciousness, and information in LTM is often accessed prior to its representation in working memory (Logie, 1996).

How distinct are working memory and long-term memory?

Are working memory and LTM really distinct? In some ways, yes. As we have seen, working memory is rapidly accessed and severely limited in capacity. Imagine if our LTM allowed us to remember only seven pieces of verbal information, seven objects or faces and seven locations!

Some of the strongest evidence for a distinction between working memory and LTM is neurological. Patients like Jimmie with severe amnesia can often store and manipulate information for momentary use with little trouble. They may be able, for example, to recall seven digits and keep them in mind by rehearsing them. The moment they stop rehearsing, however, they may forget that they were even trying to recall digits, an indication of a severe impairment in LTM. Researchers have also observed patients with the opposite problem: severe working memory deficits (such as a memory span of only two digits) but intact LTM (Caplan & Waters, 1990; Shallice & Warrington, 1970).

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Interactions of working memory and long-term memory

Working memory and LTM may be distinct, but much of the time they are so intertwined that they can be difficult to distinguish (Baddeley, 2002; Burgess & Hitch, 2005; Tehan, Hendry, & Kocinski, 2001). For example, when people are asked to recall a sequence of words after a brief delay, their performance is better if the words are semantically related (such as *chicken* and *duck*), presumably because they recognise the link between them and can use the memory of one to cue the memory of the other from LTM (Wetherick, 1975). Similarly, words are more easily remembered than nonsense syllables (Hulme, Maughan, & Brown, 1991; Roodenrys, Hulme, & Brown, 1993). These findings suggest that working memory involves the conscious activation of knowledge from LTM, since without accessing LTM, the person could not tell the difference between words and non-words. More recently, Unsworth, Brewer, and Spillers (2011) demonstrated that participants with high working memory capacity were more efficient in searching their long-term memory than were participants with low working memory capacity. This finding further supports the notion that working memory and long-term memory are not mutually exclusive.

Indeed, from a neuroanatomical standpoint, working memory appears to become engaged when neural networks in the frontal lobes become activated along with (and linked to) networks in the occipital, temporal and parietal lobes that represent various words or images. These mental representations of words or images themselves reflect an interaction between current sensory data and stored knowledge from LTM, such as matching a visual pattern with a stored image of a particular person's face. In this sense, working memory in part involves a special kind of activation of information stored in LTM (see Cowan, 1994; Ericsson & Kintsch, 1995).

APPLY + DISCUSS

On your university course website for this subject, you should be able to access a website that contains many interactive presentations of phenomena in memory and cognition, including verbal rehearsal, elaboration and short-term memory decay, as well as many others.

- How does working memory help us to remember?
- How does rehearsal and/or chunking help us to remember?
- What strategies best help you to remember things?

Chunking

Perhaps the best example of the interaction between working memory and LTM in daily life is a strategy people use to expand the capacity of their working memory in particular situations (Ericsson & Kintsch, 1995). We have noted that the brain holds a certain number of units of information in consciousness at a time. But what constitutes a unit? A letter? A word? Perhaps an entire sentence or idea?

Consider the working memory capacity of a skilled waiter in a restaurant. How can a person take the order of eight people without the aid of a notepad, armed only with a mental sketchpad and a limited-capacity verbal store? One way is to use ***chunking***, a memory technique that uses knowledge stored in LTM to group information in larger units than single words or digits. Chunking is essential in everyday life, particularly in cultures that rely upon literacy, because people are constantly called upon to remember telephone numbers, written words and lists.

Now consider the following sequence of letters: ASXBHPASICSMH. This string would be impossible for most people to hold in working memory, unless they are interested in business and recognise some meaningful chunks: ASX for Australian Securities Exchange; BHP for Broken Hill Proprietary; ASIC for Australian Securities and Investments Commission; SMH for *Sydney Morning Herald*. In this example, chunking effectively reduces the number of pieces of information in working memory from 13 to 4, by putting three or four customers on each stool. People tend to use chunking most effectively in their areas of expertise, such as waiters who know a menu 'like the back of their hands'. Similarly, knowledge of area codes allows people to store 10 or 11 digits at a time, since 61 (the telephone country code for Australia) or 64 (the telephone country code for New Zealand) can become a single chunk rather than two 'slots' in verbal working memory.

MAKING CONNECTIONS

Psychologists once viewed memory as a warehouse for stored ideas. Today, however, many cognitive neuroscientists believe that memory involves the activation of a previously activated network to create a similar experience. Because the activated network is never identical to the original one, however, multiple opportunities for **error** exist (chapter 2).

INTERIM SUMMARY

Working memory and LTM are distinct from one another in both their functions and neuroanatomy because patients with brain damage can show severe deficits on one but not the other. Working memory appears to occur as frontal lobe neural networks become activated along with and linked to networks in the occipital, temporal and parietal lobes that represent various words or images. Working memory clearly interacts with LTM systems, as occurs in ***chunking*** — using knowledge stored in LTM to group information in larger units than single words or digits and hence to expand working memory capacity in specific domains.

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Varieties of long-term memory

Most readers have had the experience of going into the refrigerator looking for a condiment such as mustard. Our first pass at 'remembering' where the mustard is seems more like habit than memory — we automatically look in a particular place, such as the side door, where we have found it many times. If the bottle is not there, we typically employ one of two strategies. The first is to think about where we usually put it, drawing on our general knowledge about what we have done in the past — do we usually put it in the door or on the top shelf? The second is to try to remember a specific episode, namely the last time we used the mustard.

This simple example reveals something not so simple: that LTM comes in multiple forms, such as automatic 'habits', general knowledge and memory for specific episodes. Researchers do not yet agree on precisely how many systems constitute LTM, but developments in neuroimaging over the last decade have made clear that the three different ways of finding the mustard represent three very different kinds of memory, each with its own neuroanatomy. In this section, we explore some of the major types of LTM.

Declarative and procedural memory

In general, people store two kinds of information: declarative and procedural. ***Declarative memory*** refers to memory for facts and events, much of which can be stated or 'declared' (Squire, 1986). ***Procedural memory*** refers to 'how to' knowledge of procedures or skills.

When we think of memory, we usually mean declarative memory: knowledge of facts and events. Remembering that Edmund Barton was the first Prime Minister of Australia and Henry Sewell was the first Premier of New Zealand, or calling up a happy memory from the past, requires access to declarative memory.

Declarative memory can be semantic or episodic (Tulving, 1972, 1987), and the hippocampus and medial temporal lobe are involved in its functioning (see Townsend, Richmond, Vogel-Farley, & Thomas, 2010). ***Semantic memory*** refers to general world knowledge or facts, such as the knowledge that winters are cold in Dunedin or that NaCl is the chemical formula for table salt (Tulving, 1972). The term is somewhat misleading because semantic implies that general knowledge is stored in words, whereas people know many things about objects, such as their colour or smell, that are encoded as sensory representations. For this reason, many psychologists now refer to semantic memory as ***generic memory***.

Episodic memory consists of memories of particular events, rather than general knowledge (Tulving, 2002). Episodic memory allows people to travel mentally through time, to remember thoughts and feelings (or in memory experiments, word lists) from the recent or distant past, or to imagine the future (Wheeler, Stuss, & Tulving, 1997).

In everyday life, episodic memory is often autobiographical, as when people remember what they did on their eighteenth birthday or what they ate yesterday (see Howe, 2000). It is also closely linked to semantic memory (Menon, Boyett-Anderson, Schatzberg, & Reiss, 2002), since when people experience similar episodes over time (such as 180 days a year in school or hundreds of thousands of interactions with their father), they gradually develop generic memories of what those situations were like (e.g., 'I used to love weekends with my father').

Declarative memory is the most obvious kind of memory, but another kind of memory is equally important in daily life: procedural memory, also referred to as skill or habit memory. People are often astonished to find that even though they have not skated for 20 years, the skills are reactivated easily, almost as if their use had never been interrupted. When people put a backspin on a tennis ball, speak grammatically or drive a car, they are drawing on procedural memory. Indeed, Lum, Conti-Ramsden, Page, and Ullman (2012) posited that abnormalities of the brain structures involved in procedural memory may be responsible for specific language impairments in children. Other procedural skills are less obvious, such as reading, which involves a set of complex procedures for decoding strings of letters and words.

Although procedural memories often form without conscious effort (as in conditioning procedures with rats, who presumably do not carefully think out their next move in a maze), at other times procedural memories are 'residues' of prior conscious knowledge and strategies, which have become automatic and highly efficient. For example, when we first learn to type, we study the layout of the

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keyboard, trying to form declarative memories. As we are typing our first words, we also hold in working memory the sequence of keys to hit and knowledge about which fingers to use for each key. Over time, however, our speed and accuracy improve, while conscious effort diminishes. This process reflects the formation of procedural memory for typing. In the end, we think only of the words we want to type and would have difficulty describing the layout of the keyboard (declarative memory), even though our fingers 'remember'. As we will see, this shift from conscious, effortful memory to automatic procedural memory occurs as regions of the cortex 'pass the torch' of memory to subcortical regions in the basal ganglia.

Explicit and implicit memory

For much of the last century, psychologists studied memory by asking subjects to memorise word lists, nonsense syllables or connections between pairs of words and then asking them to recall them. These tasks all tap ***explicit memory***, or conscious recollection. Recently, however, psychologists have recognised another kind of memory: implicit memory (Graf & Schacter, 1987; Roediger, 1990; Schacter & Buckner, 1998). ***Implicit memory*** refers to memory that is expressed in behaviour but does not require conscious recollection, such as tying a shoelace.

Some psychologists use explicit and implicit memory as synonyms for declarative and procedural memory. Although there is clearly some overlap, the declarative–procedural dichotomy refers more to the type of knowledge that is stored (facts versus skills), whereas the explicit–implicit distinction refers more to the way this knowledge is retrieved and expressed (with or without conscious awareness). As we will see, people's knowledge of facts (declarative knowledge) is often expressed without awareness (implicitly). Figure 7.7 provides a model of the different dimensions of LTM.

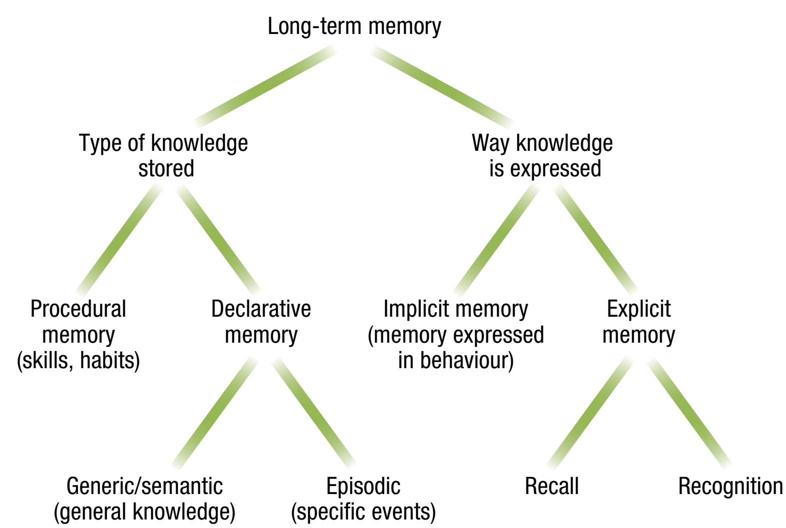

FIGURE 7.7
Key distinctions in long-term memory

Explicit memory

Explicit memory involves the conscious retrieval of information. Researchers distinguish between two kinds of explicit retrieval: recall and recognition. ***Recall*** is the spontaneous conscious recollection of information from LTM, as when a person brings to mind memories of her wedding day or the name of the capital of Egypt. Neuroimaging studies show that recall activates parts of the brain that are also activated during working memory tasks involving the central executive (Nolde, Johnson, & Raye, 1998). This makes sense given that recall requires conscious effort.

Although recall occurs spontaneously, it generally requires effortful use of strategies for calling the desired information to mind. When efforts at recall fail, people sometimes experience the ***tip-of-the-tongue phenomenon***, in which the person knows the information is 'in there' but is not quite able to retrieve it (Brown & McNeill, 1966). Recent research suggests that this phenomenon stems from problems linking the sounds of words (which are arbitrary — a table could just as easily have been called a blah) with their meanings (Merriman, Marazita, Jarvis, Evey-Burkey, & Biggins, 1996). Thus, using the word 'prognosticate' in a conversation with someone who has the word 'pontificate' on the tip of his tongue can lead to sudden recall (and a feeling of relief!).

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Recognition refers to the explicit sense or recollection that something currently perceived has been previously encountered or learned. Researchers often test recognition memory by asking participants whether a word was on a list they saw the previous day. Recognition is easier than recall (as any student knows who has answered multiple-choice items that simply require recognition of names or concepts), because the person does not have to generate the information, just make a judgement about it.

If asked to name the majority of the members of the Melbourne Storm's 2012 NRL premiership winning team (a *recall* task), even ardent rugby league fans may have some difficulty, beyond star players such as Cameron Smith, Billy Slater and Cooper Cronk. If, however, they were shown this team photo (a *recognition* task), many fans would readily and correctly come up with additional names such as Ryan Hoffman, Bryan Norrie, Gareth Widdop and Will Chambers.

Implicit memory

Implicit memory is evident in skills, conditioned learning and associative memory (i.e., associations between one representation and another). It can be seen in skills such as turning the wheel in the correct direction when the car starts to skid on a gravel road (which skilled drivers in country regions do before they have even formed the thought 'I'm skidding') as well as in responses learned through classical and operant conditioning, such as avoiding a food that was once associated with nausea, whether or not the person has any explicit recollection of the event.

Implicit associative memory emerges in experiments on ***priming effects***, in which prior exposure to a stimulus (the prime) facilitates or inhibits the processing of new information. Participants in memory experiments show priming effects even when they do not consciously remember being exposed to the prime (Bowers & Schacter, 1990; Tulving, Schacter, & Stark, 1982). For example, they might be exposed to a list of words that are relatively rarely used in everyday conversation, such as assassin. A week later, they may have no idea whether assassin was on the list (a test of explicit recognition memory), but if asked to fill in the missing letters of a word fragment such as A--A--IN, they are more likely to complete it with the word assassin than control participants who studied a different list the week earlier. Priming effects appear to rely on activation of information stored in LTM, even though the person is unaware of what has been activated.

INTERIM SUMMARY

Types of LTM can be distinguished by kind of knowledge stored (facts versus skills) and the way this knowledge is retrieved and expressed (with or without conscious awareness). People store two kinds of information, declarative and procedural. ***Declarative memory*** refers to memory for facts and events; it can be ***semantic*** (general world knowledge or facts) or ***episodic*** (memories of particular events). ***Procedural memory*** refers to 'how to' knowledge of procedures or skills. Knowledge can be retrieved explicitly or implicitly. ***Explicit memory*** refers to conscious recollection, whereas ***implicit memory*** refers to memory that is expressed in behaviour. Researchers distinguish between two kinds of explicit retrieval: ***recall*** (the spontaneous retrieval of material from LTM) and ***recognition*** (memory for whether something currently perceived has been previously encountered or learned). Implicit memory is evident in skills, conditioned learning and associative memory (associations between one representation and another).

FROM BRAIN TO BEHAVIOUR

Long-term memory and neuropsychology

How distinct are these varieties of long-term memories? Are researchers simply splitting hairs, or are they really 'carving nature at its joints', making distinctions where distinctions truly exist?

Some of the most definitive data supporting distinctions among different types of memory are neuroanatomical studies, including case studies of patients with neurological damage, brain imaging with normal and brain-damaged patients and experimental studies with animals (Gabrieli, 1998; Gluck & Myers, 1997; Squire, 1992, 1995). Researchers discovered the distinction between implicit and

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explicit memory in part by observing amnesic patients who have trouble storing and retrieving new declarative information (such as their age or the name or face of their doctor) but show minimal impairment on implicit tasks (Schacter, 1995a). Consider the case of H. M., who had most of his medial temporal lobes (the region in the middle of the temporal lobes, including the hippocampus and amygdala) removed because of uncontrollable seizures (figure 7.8). Following the operation, H. M. had one of the deepest, purest cases of amnesia ever recorded, leading to the conclusion that medial temporal structures play a central role in the consolidation (i.e., encoding and 'solidification') of new explicit memories. Despite his inability to store new memories, however, H. M. was able to learn new procedural skills, such as writing words upside down. Each new time H. M. was asked to perform this task, his speed improved, but he had no recollection that he had ever performed it before. Sadly, H. M. died on 2 December 2008, aged 82. His survival of ill-conceived brain surgery enabled researchers to identify how and where memories are formed in the brain. His form of anterograde amnesia prevented him from collecting any new memories and he lived in a pre-1953 world. H. M. is to be remembered and saluted for all that he has contributed to the scientific community.

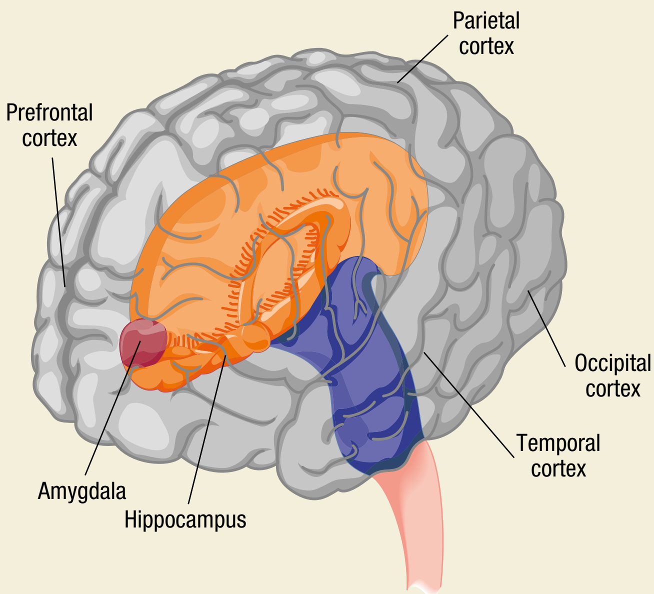

FIGURE 7.8
Anatomy of memory. The medial temporal region (inside the middle of the temporal lobes), particularly the hippocampus, plays a key role in consolidation of explicit, declarative information. The frontal lobes play a more important role in working memory, procedural memory and aspects of episodic memory, such as dating memories for the time at which they occurred. Posterior regions of the cortex (occipital, parietal and temporal cortex) are involved in memory just as they are in perception, by creating mental representations.

Lesion research with monkeys and imaging research with humans have demonstrated that the hippocampus and adjacent regions of the cortex are central to the consolidation of explicit memories (Eichenbaum, 1997; McGaugh, 2000; Squire & Zola-Morgan, 1991). In contrast, the fact that amnesics like H. M. often show normal skill learning and priming effects suggests that the hippocampus is not central to implicit memory.

In daily life, of course, implicit and explicit memory are often intertwined. For example, people learn through conditioning to fear and avoid stimuli that are painful, but they are also frequently aware of the connection between various stimuli or behaviours and their effects. Thus, a child might learn by touching a stove that doing so is punishing (conditioning) but also might be able explicitly to recall the connection between the two events: 'If I touch the stove, I get an ouchie!'

Neurologically speaking, however, implicit and explicit memory rely on separate mechanisms (Bechara et al., 1995). For example, fear conditioning and avoidance learning require an intact amygdala. In a classical conditioning procedure in which a particular sound (the conditioned stimulus or CS) is paired with an electric shock (the unconditioned stimulus or UCS), patients with an intact hippocampus but a damaged amygdala can explicitly state the connection between the CS and the UCS — that is, they consciously know that the tone is associated with shock. However, their nervous system shows no signs of autonomic arousal (e.g., increased heart rate) or behavioural expressions of fear when exposed to the CS. They *know* the connection but cannot *feel* it. In contrast, patients with an intact amygdala but a damaged hippocampus may have no conscious idea that the CS is associated with electric shock — in fact, they may have no recollection of ever having encountered the stimulus

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before — but nonetheless they show a conditioned fear response to it, including autonomic arousal (see chapters 3 and 6).

Subsystems of implicit and explicit memory

Implicit and explicit memory are themselves broad categories that include neurologically distinct phenomena. The two kinds of explicit memory, semantic and episodic, rely on different neural mechanisms. Patients with damage to the frontal lobes have little trouble retrieving semantic knowledge but often show deficits in episodic memory (Shimamura, 1995; Wheeler, Stuss, & Tulving, 1995, 1997). They may, for example, have trouble remembering the order of events in their lives (Swain, Polkey, Bullock, & Morris, 1998), or they may vividly recall events that never occurred because they have difficulty distinguishing true from false memories of events (Schacter, 1997). Positron emission tomography (PET) studies show greater activation of prefrontal regions when recalling episodic rather than semantic information (Nyberg, 1998). However, other studies have since failed to replicate this finding (see Menon et al., 2002).

Implicit memory also likely comprises at least two systems. Patients with damage to the cortex caused by Alzheimer's disease may have normal procedural memory but impaired performance on priming tasks. In contrast, patients with Huntington's disease, a fatal, degenerative condition that affects the basal ganglia, show normal priming but impaired procedural learning (Butters, Heindel, & Salmon, 1990).

Brain imaging data on normal participants have provided insight into the way knowledge that at first requires considerable effort becomes procedural, as the brain essentially transfers the processing of the task from one network to another (see Poldrack, Desmond, Glover, & Gabrieli, 1998). For example, after practice at reading words backwards in a mirror, people show *decreased* activity in visual pathways but *increased* activity in verbal pathways in the left temporal lobe. This switch suggests that they are more rapidly moving from the visual task of mentally turning the word around to the linguistic task of understanding its meaning.

INTERIM SUMMARY

Implicit and explicit memory are neuroanatomically distinct. The hippocampus and adjacent regions of the cortex are centrally involved in consolidating explicit memories. Amnesics with hippocampal damage often show normal skill learning, conditioning and priming effects, suggesting that the hippocampus is not central to implicit memory. Different kinds of explicit memory, notably episodic and semantic, also appear to constitute distinct memory systems. The same is true of two types of implicit memory, procedural and associative.

Everyday memory

In designing studies, researchers have to strike a balance between the often conflicting goals of maximising internal validity — creating a study whose methods are sound and rigorous and can lead to clear causal inferences — and external validity — making sure the results generalise to the real world (chapter 2). Since Ebbinghaus' studies in the late nineteenth century, memory research has tended to emphasise internal validity, by measuring participants' responses as they memorise words, nonsense syllables and pairs of words, to try to learn about basic memory processes. Increasingly, however, researchers have begun to argue for the importance of studying ***everyday memory*** as well; that is, memory as it occurs in daily life (Ceci & Bronfenbrenner, 1991; Herrmann, McEvoy, Hertzod, Hertel, & Johnson, 1996; Koriat, Goldsmith, & Pansky, 2000; Rogoff & Lave, 1984).

In the laboratory, the experimenter usually supplies the information to be remembered, the reason to remember it (the experimenter asks the person to) and the occasion to remember it (immediately, a week later etc.). Often the information to be remembered has little intrinsic meaning, such as isolated words on a list. In contrast, in daily life, people store and retrieve information because they need to for one reason or another, the information is usually meaningful and emotionally significant, and the context for retrieval is sometimes a future point in time that itself must be remembered, as when a

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person tries to remember to call a friend later in the day. Thus, researchers are choosing to study everyday memory in its naturalistic setting — such as people's memory for appointments (Andrzejewski, Moore, Corvette, & Hermann, 1991) — as well as to devise ways to bring it into the laboratory. For example, Unsworth, Brewer, and Spillers (2012) showed that laboratory tests of attention and memory accurately predict everyday memory failures.

Everyday memory is functional memory

In their daily lives, people typically remember for a purpose, to achieve some goal (Anderson, 1996; Gruneberg, Morris, & Sykes, 1988). Memory, like all psychological processes, is functional. Of all the things we could commit to memory over the course of a day, we tend to remember those that affect our needs and interests.

The functional nature of memory was demonstrated in a set of studies that examined whether men and women would have better recall for stereotypically masculine and feminine memory tasks (Herrmann, Crawford, & Holdsworthy, 1992). In one study, the investigators asked participants to remember a shopping list and a list of travel directions. As predicted, women's memory was better for the shopping list, whereas men had better memory for the directions.

Does this mean that women are born to shop and men to navigate? A second study suggested otherwise. This time, some participants received a 'shopping list' to remember whereas others received a 'hardware list'. Additionally, some received directions on 'how to make a shirt' whereas others received directions on 'how to make a workbench'. In reality, the grocery and hardware lists were identical, as were the two lists of 'directions'. For example, the shopping list included items such as *brush*, *oil*, *chips*, *nuts* and *gum* that could just as easily be interpreted as goods at a supermarket as hardware items. The 'directions' were so general that they could refer to almost anything (e.g., 'First, you rearrange the pieces into different groups. Of course, one pile may be sufficient . . .').

As predicted, women were more likely to remember details about shirt making and grocery lists. The biases in recall for directions for men were particularly strong (figure 7.9). Apparently, 'real men' do not make shirts. These findings demonstrate the importance of non-cognitive factors such as motivation and interest in everyday memory: what men define as not relevant, not interesting or threatening to their masculinity does not make a lasting impression on their memory (Colley, Ball, Kirby, Harvey, & Vingelen, 2002).

Other research links some forms of everyday memory to the hippocampus. Researchers tested London taxi drivers' knowledge of the streets of their city. Drivers showed more activation in the hippocampus for a navigation task that required their expertise than for several other memory tasks (Maguire, Frackowiak, & Frith, 1997). In fact, the size of the activated regions of the hippocampus was strongly correlated with the number of years they had been driving, a suggestion that the brain devotes more 'room' in the hippocampus for frequently used information, just as it does in the cortex (Maguire, Mummery, & Buechel, 2000). More recently, research has used virtual reality to further examine the role of the hippocampus in spatial navigation and episodic memory (see Burgess, 2002).

MAKING CONNECTIONS

Research from the Australian National University has challenged the myth that pregnant women and mothers become forgetful. This short-term memory loss is often described as 'baby brain' or 'placenta brain' and has been contested by Professor Christensen and her team in a 20-year population study on health and ageing. Christensen, Leach, and Mackinnon (2010) analysed the memory and cognitive speed of a group of women before and during pregnancy and in the early stages of motherhood, and found no support for the notion that pregnancy and motherhood are related to persistent cognitive deterioration. Their research indicates that memory lapses can happen to any one of us, pregnant or not, and that **cognitive decline** varies across individuals (see chapter 12).

Prospective memory

Most studies of memory have examined ***retrospective memory***, that is, memory for things from the past, such as a list of words encountered 20 minutes earlier. In everyday life, an equally important kind of memory is ***prospective memory***, or memory for things that need to be done in the future, such as picking up some items at the corner shop after work (Brandimonte, Einstein, & McDaniel, 1996; Einstein & McDaniel, 1990; McDaniel, Robinson-Riegler, & Einstein, 1998; Smith, 2003). Prospective memory has at least two components: remembering to remember ('be sure to stop at the corner shop after work') and remembering *what* to remember (e.g., a loaf of bread and milk). In other words, prospective memory requires memory of intent as well as content (Kvavilashvili, 1987; Marsh, Hiscks, & Bink, 1998). Experimental studies suggest that intending to carry out certain acts in the future leads to their heightened activation in LTM (Goschke & Kuhl, 1993, 1996).

The study of prospective memory is a growing area of research (Dismukes, 2012). Failures in prospective memory have been linked to illicit polydrug use (Hadjiefthyvoulou, Fisk, Montgomery, &

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Bridges, 2011), binge-drinking (Heffernan, Clark, Bartholemew, Ling, & Stephens, 2010), and autism spectrum disorders (Jones et al., 2011).

Although prospective memory is probably not itself a memory 'system' with its own properties, it does have elements that distinguish it from other kinds of memory (see McDaniel, 1995). One is its heavy emphasis on time. Part of remembering an intention is remembering when to remember it, such as at a specific time (e.g., right after work) or an interval of time (tonight, tomorrow, sometime over the next few days).

Another unique feature of remembered intentions is that the person has to remember whether they have been performed so they can be 'shut off'. This facet of prospective memory is more important with some tasks than with others. Inadvertently hiring a DVD that you already watched a month ago is clearly less harmful than taking medication you did not remember taking an hour earlier.

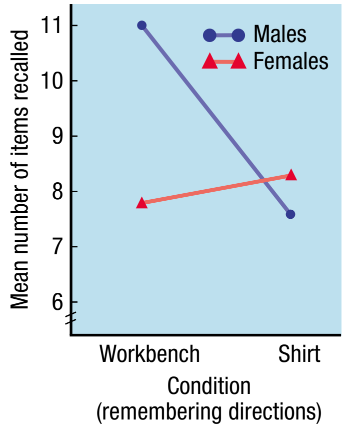

FIGURE 7.9
Gender and everyday memory. The figure shows men's and women's memory, following a distracter task, for a list of directions that they thought were for making either a workbench or a shirt. Women recalled slightly more items when they thought they were remembering sewing instructions. Men's performance was dramatically different in the two conditions: men were much more likely to remember the 'manly' instructions for the workbench.
Source: From Herrmann et al. (1992).

INTERIM SUMMARY

Everyday memory refers to memory as it occurs in daily life. Everyday memory is functional, focused on remembering information that is meaningful. One kind of everyday memory is ***prospective memory***, memory for things that need to be done in the future.

Encoding and organisation of long-term memory

We have now completed our tour of the varieties of memory. But how does information find its way into LTM in the first place? And how is information organised in the mind so that it can be readily retrieved? In this section, we explore these two questions. The focus is on the storage and organisation of declarative knowledge, since it has received the most empirical attention.

Encoding

For information to be retrievable from memory, it must be ***encoded***, or cast into a representational form, or 'code,' that can be readily accessed. The manner of encoding — how, how much and when the person tries to learn new information — has a substantial influence on its accessibility (ease and ability of retrieval — i.e., how readily it can be accessed).

Levels of processing

Anyone who has ever crammed for a test knows that rehearsal is important for storing information in LTM. As noted earlier, however, the simple, repetitive rehearsal that maintains information momentarily in working memory is not optimal for LTM. Usually, a more effective strategy is to attend to the meaning of the stimulus and form mental connections between it and previously stored information.

Some encoding is deliberate, such as studying for an exam, learning lines for a play or theatre production or trying to remember a joke. However, much of the time encoding simply occurs as a by-product of thought and perception — a reason why people can remember incidents that happened to them 10 years ago even though they were not trying to commit them to memory.

Deep and shallow processing

The degree to which information is elaborated, reflected upon and processed in a meaningful way during memory storage is referred to as the depth or ***level of processing*** (Craik & Lockhart, 1972; Lockhart & Craik, 1990). Information may be processed at a shallow, structural level (focusing on physical characteristics of the stimulus); at a somewhat deeper, phonemic level (focusing on simple characteristics of the language used to describe it); or at the deepest, semantic level (focusing on the meaning of the stimulus).

For example, at a shallow, structural level, a person may walk by a restaurant and notice the type face and colours of its sign. At a phonemic level, she may read the sign to herself and notice that

MAKING CONNECTIONS

As the philosopher of science Thomas Kuhn argued, a **paradigm** (or perspective in psychology) includes a set of propositions that constitute a model, an underlying metaphor, and a set of agreed-upon methods (chapter 1). In the last few years, all these have changed in cognitive psychology. We have moved from three sequential memory stores to multiple-memory systems operating in parallel; from a computer metaphor to a brain metaphor; and from a set of methods (such as memorising word pairs) that tended to study memory divorced from meaning to more diverse methods, including those that can examine memory in its natural habitat — everyday life.

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it sounds Italian. Processing material deeply, in contrast, means paying attention to its meaning or significance, noticing, for instance, that this is the restaurant a friend has been recommending for months.

Processing information at a deep, semantic level is also positively related to academic success in first-year studies, with a shallow learning approach predicting poor achievement (Burton, Taylor, Dowling, & Lawrence, 2009). In a related Australian study, results from 134 pre-service teacher education students at a rural university in New South Wales indicated that modifications to teaching methods, task requirements, and assessment processes can help minimise a shallow learning approach and encourage in students a deep learning approach (Gordon & Debus, 2002).

Different levels of processing activate different neural circuits. As one might guess, encoding that occurs as people make judgements about the meaning of words (such as whether they are concrete or abstract) leads to greater activation of the left temporal cortex, which is involved in language comprehension, than if they attend to qualities of the printed words, such as whether they are in upper- or lowercase letters (Gabrieli et al., 1996). Deliberate use of strategies to remember (such as remembering to buy bread and bottled water by thinking of a prisoner who is fed only bread and water) activates regions of the prefrontal cortex involved in other executive functions such as manipulating information in working memory (Kapur, Tulving, Cabeza, & McIntosh, 1996). Subsequent research has even shown that the amount of activity in the prefrontal and temporal cortices predicts the extent to which participants are likely to remember studied material successfully (Brewer, Zhao, Desmond, Glover, & Gabrieli, 1998; Wagner et al., 1998). Otten, Henson, and Rugg (2001) further extended this finding, showing that episodic encoding for words in a semantic task involves a subset of the regions activated by deep processing.

Australian actress Cate Blanchett's prefrontal cortex was activated when she used deliberate techniques to learn her lines for her role as Galadriel in *The Hobbit* film series.

Encoding specificity

Advocates of depth-of-processing theory originally thought that deeper processing is always better. Although this is generally true, subsequent research shows that the best encoding strategy depends on what the person later needs to retrieve (see Anderson, 1995). If a person is asked to recall shallow information (such as whether a word was originally presented in capital letters), shallow encoding tends to be more useful.

The fact that ease of retrieval depends on the match between the way information is encoded and later retrieved is known as the ***encoding specificity principle*** (Tulving & Thomson, 1973). For example, a student who studies for a multiple-choice test by memorising definitions and details without trying to understand the underlying concepts may be in much more trouble if the lecturer decides to include an essay question, because the student has encoded the information at too shallow a level.

Why does the match between encoding and retrieval influence the ease with which people can access information from memory? According to several theorists, memory is not really a process distinct from perception and thought; rather, it is a by-product of the normal processes of perceiving and thinking, which automatically lay down traces of an experience as it is occurring. When people remember, they simply reactivate the same neural networks that processed the information in the first place (Crowder, 1993; Lockhart & Craik, 1990). If the circumstances at encoding and retrieval are similar, the memory is more easily retrieved because more of the neural network that represents it is activated. To put it another way, a new thought, feeling or perception is like a bushwalker who has to create a new trail through the bush. Each time another traveller takes that path, that is, each time a similar event occurs, the trail becomes more defined and easier to locate.

Context and retrieval

According to the encoding specificity principle, the contexts in which people encode and retrieve information can also affect the ease of retrieval. One study presented scuba divers with different lists of words, some while the divers were under water and others while they were above (Godden & Baddeley, 1975). The divers had better recall for lists they had encoded under water when they were

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under water at retrieval; conversely, lists encoded above water were better recalled above water. An Australian study (Pearse, Powell, & Thomson, 2003) also found context is important in recall for young children. The study participants took part in the same staged event four times, with some details varied each time (e.g., the colour of a coat). Three days later, the children were asked to recall those details. During the interview process, contextual cues were given to some of the children — such as a different person undertaking one of the tests, or a new watch that the interviewer wore. Those children who were given a contextual cue performed better in recalling details of the events. However, opponents of the encoding specificity principle suggest that the diagnostic value of the retrieval cue is a better predictor of memory performance than the context (see Goh & Lu, 2012, for a full review).

The same phenomenon appears to occur with people's emotional state at encoding and retrieval, a phenomenon called state-dependent memory: being in a similar mood at encoding and retrieval (e.g., angry while learning a word list and angry while trying to remember it) can facilitate memory, as long as the emotional state is not so intense that it inhibits memory in general (see Bower, 1981; Keenly, 1997). Having the same context during encoding and retrieval facilitates recall because the context provides ***retrieval cues***, stimuli or thoughts that can be used to facilitate recollection.

APPLY + DISCUSS

Research in New Zealand (Harper, 2000; Parkes & White, 2000; White & Ruske, 2002) into the effect of drugs that decrease acetylcholine activity in the brain suggests that memory loss is related to a problem at the initial encoding of the stimulus rather than to a problem with later recall.

- Is information processed at a deep level easier to retrieve than information processed at a shallow level?
- When might shallow information be more useful than deep processing?
- Why is a memory more easily retrieved when the circumstances at encoding emulate those at retrieval?

Spacing

Another encoding variable that influences memory is of particular importance in educational settings: the interval between study sessions. Students intuitively know that if they cram the night before a test, the information is likely to be available to them when they need it the next day. They also tend to believe that massed rehearsal (i.e., studying in one long session or several times over a short interval, such as a day) is more effective than spaced, or distributed, rehearsal over longer intervals (Zechmeister & Shaughnessy, 1980). But is this strategy really optimal for long-term retention of the information?

In fact, it is not (Bruce & Bahrick, 1992; Dempster, 1996; Ebbinghaus, 1885/1964). Massed rehearsal seems superior because it makes initial acquisition of memory slightly easier, since the material is at a heightened state of activation in a massed practice session. In the long run, however, research on the ***spacing effect*** — the superiority of memory for information rehearsed over longer intervals — demonstrates that spacing study sessions over longer intervals tends to double long-term retention of information.

In one study, the Bahrick family tested the long-term effects of spaced rehearsal on the study of 300 foreign language vocabulary words (Bahrick, Bahrick, Bahrick, & Bahrick, 1993). The major finding was that, over a five-year period, 13 training sessions at intervals of 56 days apart increased memory retention rates compared to 26 sessions spaced at 14-day intervals (figure 7.10). These results are robust across a variety of memory tasks, even including implicit memory (Perruchet, 1989; Toppino & Schneider, 1999). More recently, Callan and Schweighofer (2010) found that the left frontal operculum — known to facilitate the transfer of information into LTM — shows increased activity during spaced rehearsals.

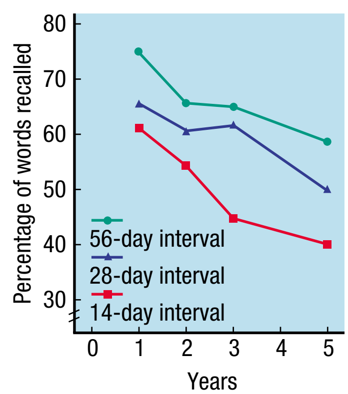

FIGURE 7.10
Impact of spacing on memory retention over five years. Longer intervals between rehearsal sessions for English–foreign language word pairs predicted higher long-term retention of the information one, two, three and five years after the last training session.
Source: Bahrick et al. (1993).

These and related findings have important implications for students and teachers (Bruce & Bahrick, 1992; Herbert & Burt, 2004; Rea & Modigliani, 1988). Students who want to remember information for more than a day or two after an exam should space their studying over time and avoid cramming. Medical students, law students and others who intend to practise a profession based on their course work should be particularly wary of all-nighters.

Moreover, much as students might protest, cumulative exams over the course of a semester are superior to exams that test only the material that immediately preceded them. Cumulative exams require students to relearn material at long intervals, and the tests themselves constitute learning sessions in which memory is retrieved and reinforced. In fact, research on spacing is part of what led the authors of this text to include both interim summaries and a general summary at the end of each chapter, since learning occurs best with a combination of immediate review and spaced rehearsal.

Representational modes and encoding

The ability to retrieve information from LTM also depends on the modes used to encode it. In general, the more ways a memory can be encoded, the greater the likelihood that it will be accessible for later

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APPLY + DISCUSS

- What are the best ways to study material so that it 'sinks in'?
- What forms of rehearsal and spacing are likely to lead to long-term retention of information?
- Are the same methods useful in procedural learning? What methods would be most useful in remembering a new tennis serve, or learning to type?

retrieval. Storing a memory in multiple representational modes — such as words, images and sounds — provides more retrieval cues to bring it back to mind (see Paivio, 1991).

For instance, many people remember phone numbers not only by memorising the digits but also by forming a mental map of the buttons they need to push and a motoric (procedural) representation of the pattern of buttons to push that becomes automatic and is expressed implicitly. When pushing the buttons, they may even be alerted that they have dialled the wrong number by hearing a sound pattern that does not match the expected pattern, suggesting auditory storage as well.

INTERIM SUMMARY

For information to be retrievable from memory, it must be ***encoded***, or cast into a representational form that can be readily accessed from memory. The degree to which information is elaborated, reflected upon and processed in a meaningful way during memory storage is referred to as the depth or ***level of processing***. Although deeper processing tends to be more useful for storing information for the long term, ease of retrieval depends on the match between the way information is encoded and the way it is later retrieved, a phenomenon known as the ***encoding specificity principle***. Similar contexts during encoding and retrieval provide ***retrieval cues*** — stimuli or thoughts that can be used to facilitate recollection. Aside from level of processing, two other variables influence accessibility of memory, the ***spacing*** of study sessions and the use of multiple representational modes.

Mnemonic devices

The principles of encoding we have just been describing help explain the utility of many ***mnemonic devices*** — systematic strategies for remembering information (named after the Greek word *mneme*, which means 'memory'). People can use external aids (such as note taking or asking someone else) to enhance their memory, or they can rely on internal aids, such as rehearsal and various mnemonic strategies (Harris, 1980a). Most mnemonic devices draw on the principle that the more retrieval cues that can be created and the more vivid these cues are, the better memory is likely to be. Generally, mnemonic devices are most useful when the to-be-remembered information lacks clear organisation.

Method of loci

One mnemonic strategy is the ***method of loci***, which uses visual imagery as a memory aid. The ancient Roman writer Cicero attributed this technique to the Greek poet Simonides, who was attending a banquet when he was reportedly summoned by the gods from the banquet hall to receive a message. In his absence, the roof collapsed, killing everyone. The bodies were mangled beyond recognition, but Simonides was able to identify the guests by their physical placement around the banquet table. He thus realised that images could be remembered by fitting them into an orderly arrangement of locations (Bower, 1970).

To use the method of loci, you must first decide on a series of 'snapshot' mental images of familiar locations. For instance, locations in your bedroom might be your pillow, your wardrobe, the top of your dresser and under the bed. Now, suppose that you need to do the following errands: pick up vitamin C, buy milk, return a book to the library and make plans with one of your friends for the weekend. You can remember these items by visualising each in one of your loci, making the image as vivid as possible to maximise the likelihood of retrieving it. Thus, you might picture the vitamin C pills as spilled all over your pillow, a bottle of milk poured over the best outfit in your wardrobe, the book lying on top of your dresser and your friend hiding under your bed until Friday night. Often, the more ridiculous the image, the easier it is to remember. While you are out doing your errands, you can mentally flip through your imagined loci to bring back the mental images.

SQ4R method

A strategy specifically developed to help students remember information in textbooks is called the ***SQ4R method***, for the six steps involved in the method: survey, question, read, recite, review and

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write (Martin, 1985; Robinson, 1961). The SQ4R method fosters active rather than passive learning while reading. In brief, the steps of this method are as follows.

Recital is a key component of the SQ4R method.

- *Survey.* Skim through the chapter, looking at headings and the summary. This will help you organise the material more efficiently as you encode.
- *Question.* When you begin a section, turn the heading into a question; this alerts you to the content and makes reading more interesting. For example, for the subheading, 'Long-term memory systems', you might ask yourself, 'What evidence could demonstrate the existence of separate memory systems? Could patients with different brain lesions have one kind of LTM intact and another disrupted?'
- *Read.* As you read, try to answer the questions you posed.
- *Recite.* Mentally (or orally) answer your questions and rehearse relevant information before going on to the next section.
- *Review.* When you finish the chapter, recall your questions and relate what you have learned to your experiences and interests.
- *wRite.* As you read or listen to lectures, actively write answers to questions and take notes.

INTERIM SUMMARY

Mnemonic devices are systematic strategies for remembering information. The ***method of loci*** associates new information with a visual image of a familiar place. The ***SQ4R method*** helps students study textbook material efficiently by encouraging them to survey, question, read, recite, review and write.

Networks of association

One of the reasons mnemonics can be effective is that they connect new information with information already organised in memory. This makes the new information easier to access because a 'trail' blazed in the neural woods by prior knowledge can be more easily spotted than a new, barely worn path. As William James proposed over a century ago (1890, p. 662, italics deleted):

> The more other facts a fact is associated with in the mind, the better possession of it our memory retains. Each of its associates becomes a hook to which it hangs, a means to fish it up by when sunk beneath the surface. Together, they form a network of attachments by which it is woven into the entire tissue of our thought. The 'secret of a good memory' is thus the secret of forming diverse and multiple associations with every fact we care to retain.

James' comments bring us back once again to the concept of association, which, as we saw in chapter 6, is central to many aspects of learning. Associations are crucial to remembering because the pieces of information stored in memory form ***networks of association***, clusters of interconnected information. For example, for most people the word *dog* is associatively linked to characteristics such as barking and fetching (figure 7.11, overleaf). It is also associated, though less strongly, with *cat* because cats and dogs are both household pets. The word or image of a dog is also linked to more idiosyncratic personal associations, such as an episodic memory of being bitten by a dog in childhood.

Each piece of information along a network is called a ***node***. Nodes may be thoughts, images, concepts, propositions, smells, tastes, memories, emotions or any other piece of information. That one node may have connections to many other nodes leads to tremendously complex networks of association. One way to think of a node is as a set of neurons distributed throughout the brain that fire together (see chapter 3). Their joint firing produces a representation of an object or category such as dog, which integrates visual, tactile, auditory, verbal and other information stored in memory. To search through memory means you go from node to node until you locate the right information. In this sense, nodes are like cities, which are connected to each other (associated) by roads (Reisberg, 1997).

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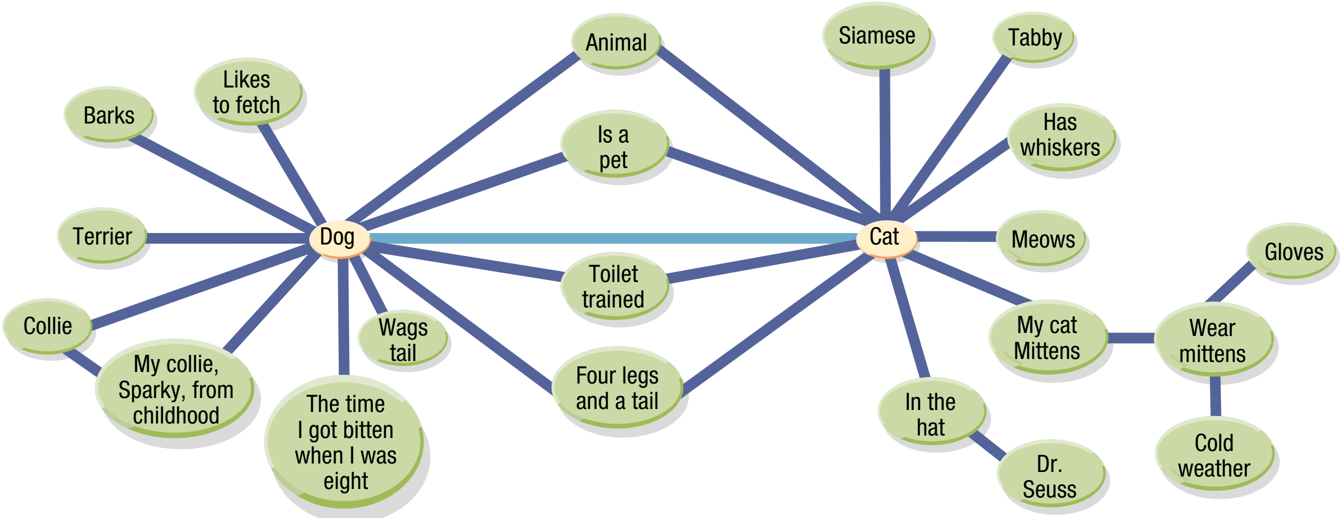

FIGURE 7.11
Networks of association. Long-term knowledge is stored in networks of association, ideas that are mentally connected with one another by repeatedly occurring together.

Not all associations are equally strong; *dog* is more strongly connected to *barks* than to *cat* or *animal*. To return to the cities analogy, some cities are connected by superhighways, which facilitate rapid travel between them, whereas others are connected only by slow, winding country roads. Other cities have no direct links at all, which means that travel between them requires an intermediate link. The same is true of associative networks: in figure 7.11 *cat* is not directly associated to *cold weather*, but it is through the intermediate link of *my cat Mittens*, which is semantically related to *wear mittens*, which is in turn linked to the *cold weather* node.

From a neuropsychological perspective, if two nodes without a direct link become increasingly associated through experience, a 'road' between them is built; and if the association continues to grow, that road will be 'widened' to ensure rapid neural transit between one and the other. If, on the other hand, a neural highway between two nodes falls into disuse because two objects or events stop occurring together (such as the link between the word *girlfriend* and a particular girlfriend months after the relationship has ended), the highway will fall into disrepair and be less easily travelled. The old road will not likely disappear completely: occasionally a traveller may wander off the main road down the old highway, as when a person accidentally calls his new girlfriend by his old girlfriend's name.

MAKING CONNECTIONS

The neural processes underlying memory involve synaptic activity. No pun intended, but memories are formed by neurons making connections, or by breaking connections. Those **synapses** that are used repeatedly retain and strengthen their dendritic spines (site of synaptic connections), whereas others develop but are lost if not used frequently (chapter 3).

Spreading activation

One theory that attempts to explain the workings of networks of association involves spreading activation (Collins & Loftus, 1975; Collins & Quillian, 1969). According to ***spreading activation theory***, activating one node in a network triggers activation in closely related nodes. In other words, presenting a stimulus that leads to firing in the neural circuits that represent that stimulus spreads activation, or energy, to related information stored in memory.

Spreading activation does not always start with a stimulus such as a spoken word. Activation may also begin with a thought, fantasy or wish, which in turn activates other nodes. For example, a psychotherapy patient trying to decide whether to divorce his wife found the song *We can work it out* coming to mind on days when he leaned towards reconciliation. On days when he was contemplating divorce, however, he found himself inadvertently singing a different tune, *Fifty ways to leave your lover*.

Considerable research supports the theory of spreading activation. In one study, the experimenters presented participants with word pairs to learn, including the pair *ocean–moon* (see Nisbett & Wilson, 1977). Later, when asked to name a laundry detergent, participants in this condition were more likely to respond with Tide than control participants, who had been exposed to a different list of word pairs. You would expect similar findings if you replaced Tide with Surf in a comparative sample of Australian participants — Surf is a popular laundry detergent in Australia — although the connection would probably not be as strong.

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The researchers offered an intriguing explanation (figure 7.12): the network of associations that includes *ocean* and *moon* also includes *tide*. Priming with *ocean–moon* thus activated other nodes on the network, spreading activation to *tide*, which was associated with another network of associations, laundry detergents.

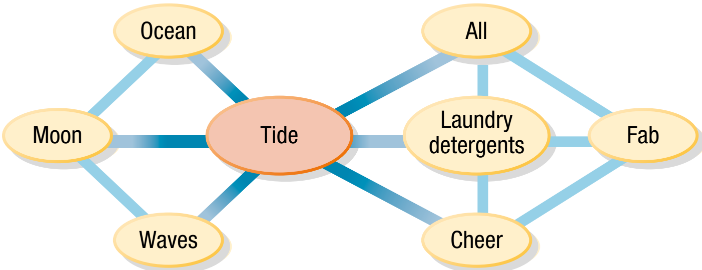


FIGURE 7.12
Spreading activation. Tide stands at the intersection of two activated networks of association and is thus doubly activated. In contrast, other brands only receive activation from one network. (This experiment, of course, only works in places where Tide has a substantial market share.)

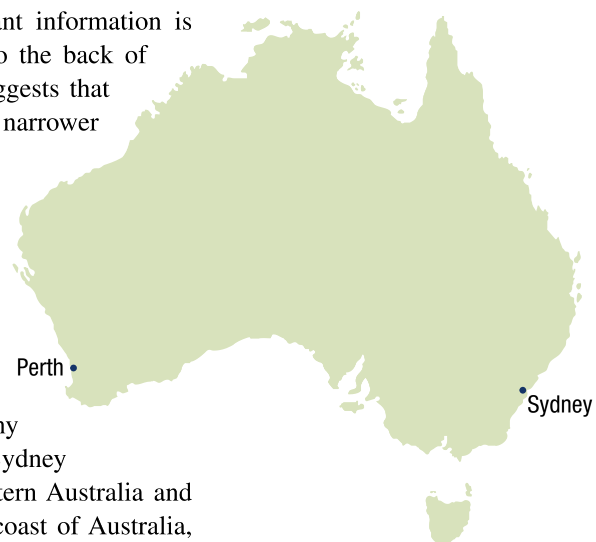
According to many contemporary models, each time a thought or image is perceived, primed or retrieved from memory, the level of activation of the neural networks that represent it increases. Thus, two kinds of information are likely to be at a high state of activation at any given moment: recently activated information (such as a news story seen a moment ago on television) and frequently activated information (such as a doctor's knowledge about disease). For example, a person who has just seen a documentary on cancer is likely to identify the word *leukaemia* faster than someone who tuned in to a different channel; a doctor is similarly likely to identify the word quickly because *leukaemia* is at a chronically higher state of activation.

Hierarchical organisation of information

Although activating a *dog* node can trigger some idiosyncratic thoughts and memories, networks of association are far from haphazard jumbles of information. Efficient retrieval requires some degree of organisation of information so that the mind can find its way through dense networks of neural trails. Research suggests that people with the thought disorder schizophrenia experience an abnormal increase in the spread of activation in semantic memory (Kreher, Holcomb, Goff, & Kuperberg, 2008), making it difficult for them to link ideas together.

Some researchers have compared LTM to a filing cabinet, in which important information is kept towards the front of the files and less important information is relegated to the back of our mental archives or to a box in the attic. The filing cabinet metaphor also suggests that some information is filed hierarchically; that is, broad categories are composed of narrower subcategories, which in turn consist of even more specific categories.

For example, a person could store information about *animals* under the subcategories *pets*, *farm animals* and *wild animals*. Under *farm animals* are *cows*, *horses* and *chickens*. At each level of the hierarchy, each node will have features associated with it (such as knowledge that chickens squawk and lay eggs) as well as other associations to it (such as roasted chicken, which is associated with a very different smell than is the generic 'chickens').



Hierarchical storage is generally quite efficient, but it can occasionally lead to errors. For instance, when asked, 'Which is farther north, Perth or Sydney?' many people say Sydney. In fact, Perth is farther north. People mistakenly assume that Sydney is north of Perth because they go to their general level of knowledge about Western Australia and New South Wales. They remember that Perth is right at the bottom of the west coast of Australia, while Sydney is a significant distance up the east coast. In reality, the east coast of Australia extends much further south than the west coast.

INTERIM SUMMARY

Knowledge stored in memory forms ***networks of association*** — clusters of interconnected information. Each piece of information along a network is called a ***node***. According to ***spreading activation theory***, activating one node in a network triggers activation in closely related nodes. Some parts of networks are organised hierarchically, with broad categories composed of narrower subcategories, which in turn consist of even more specific categories.

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Schemas

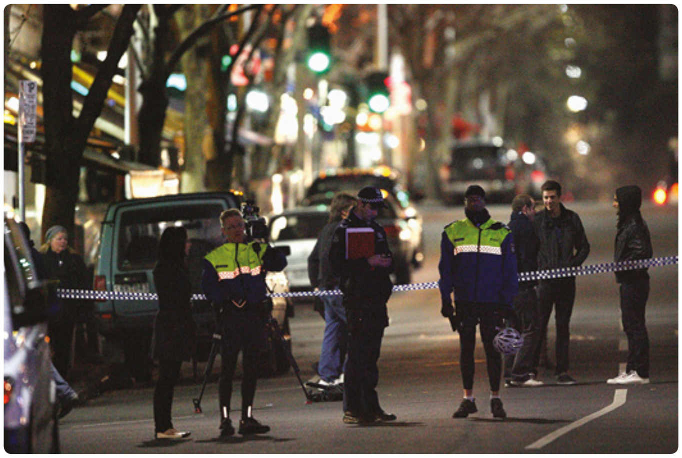
The models of associative networks and spreading activation we have been discussing go a long way towards describing the organisation of memory, but they have limits. For example, psychologists have not yet agreed on how to represent propositions like 'The dog chased the cat' using network models, since if *dog* and *cat* are nodes how is the link between them (*chased*) represented? Further, activation of one node can actually either increase or inhibit activation of associated nodes, as when a person identifies an approaching animal as a dog and not a wolf and hence 'shuts off' the *wolf* node.

Psychologists have argued for over a century about the adequacy of principles of association in explaining memory (Bahrick, 1985). Some have argued that we do not associate isolated bits of information with each other but instead store and remember the 'gist' of facts and events. They note that when people remember passages of prose rather than single words or word pairs, they typically remember the general meaning of the passage rather than a verbatim account.

According to this view, when confronted with a novel event people match it against schemas stored in memory. Schemas are patterns of thought, or organised knowledge structures, that render the environment relatively predictable. When students walk into a classroom on the first day of class and a person resembling a professor begins to lecture, they listen and take notes in a routine fashion. They are not surprised that one person has assumed control of the situation and begun talking because they have a schema for events that normally transpire in a classroom. Proponents of schema theories argue that memory is an active process of reconstruction of the past. Remembering means combining bits and pieces of what we once perceived with general knowledge that helps us fill in the gaps. In this view, memory is not like taking snapshots of an event; it is more like taking notes.

Schemas affect the way people remember in two ways: by influencing the information they encode and by shaping the way they reconstruct data that they have already stored (Davidson, 1996; Rumelhart, 1984).

APPLY + DISCUSS



- If people's memories for events are, in part, driven by schemas, what implications would this have for people recalling details of crime scenes (Tuckey & Brewer, 2003)?
- Might their memory for those details be influenced by a 'crime schema'?
- What role would such schemas play in eyewitness testimony?

Schemas and encoding

Schemas influence the way people initially understand the meaning of an event and thus the manner in which they encode it in LTM. Harry Triandis (1994) relates an account of two Englishmen engaged in a friendly game of tennis in nineteenth-century China. The two were sweating and panting under the hot August sun. As they finished their final set, a Chinese friend sympathetically asked, 'Could you not get two servants to do this for you?' Operating from a different set of schemas, their Chinese friend encoded this event rather differently than would an audience at Wimbledon.

Schemas and retrieval

Schemas not only provide hooks on which to hang information during encoding, but they also provide hooks for fishing information out of LTM. Many schemas have 'slots' for particular kinds of information (Minsky, 1975). A person shopping for a DVD player who is trying to recall the models she saw that day is likely to remember the names Sony and Pioneer but not Paul Collins (the salesman at one of the stores). Unlike Sony, Paul Collins does not fit into the slot 'brand names of DVD players'. Recent fMRI studies suggest that new information that fits an established schema is likely to be more quickly assimilated in neocortical networks, and that the medial prefrontal cortex may facilitate this process (Van Kersteren, Rijpkema, Ruiter, & Fernández, 2010).

The slots in schemas often have default values, standard answers that fill in missing information the person did not initially notice or bother to store. When asked if the cover of this book gives the authors' names, you are likely to report that it does (default value = yes) even if you never really noticed, because the authors' names normally appear on a book cover. In fact, people are generally unable to tell which pieces of information in a memory are truly remembered and which reflect the operation of default values.

One classic study demonstrated the reconstructive role of schemas using a visual task (Brewer & Treyens, 1981). The experimenter instructed university student participants to wait (one at a time)

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in a 'graduate student's office' similar to the one depicted in figure 7.13 while he excused himself to check on something. The experimenter returned in 35 seconds and led the student to a different room. There, he asked the participant either to write down a description of the graduate student's office or to draw a picture of it, including as many objects as could be recalled.

The room contained a number of objects (e.g., bookshelves, coffeepot, desk) that would fit most participants' schema of a graduate student's office. Several objects, however, were conspicuous — or rather, inconspicuous — by their absence, such as a filing cabinet, a coffee cup, books on the shelves, a window, pens and pencils, and curtains. Many participants assumed the presence of these default items, however, and 'remembered' seeing them even though they had not actually been present.

Without schemas, life would seem like one random event after another, and efficient memory would be impossible. Yet as the research just described shows, schemas can lead people to misclassify information, to believe they have seen what they really have not seen and to fail to notice things that might be important.

FIGURE 7.13
Influence of schemas on memory. Participants asked to recall this graduate student's office frequently remembered many items that actually were not in it but were in their office schemas.
Source: Brewer and Treyens (1981).

INTERIM SUMMARY

One way psychologists describe the organisation of LTM is in terms of schemas, organised knowledge about a particular domain. Proponents of schema theories argue that memory involves reconstruction of the past, by combining knowledge of what we once perceived with general knowledge that helps fill in the gaps. Schemas influence both the way information is encoded and the way it is retrieved.

Cultural models and memory

Throughout this chapter, we have described memory as if it occurs in isolated information processors (see Cole, 1975). However, ***cultural models***, or shared cultural concepts, organise knowledge and shape the way people think and remember (chapter 19; D'Andrade, 1992; Moore & Mathews, 2001; Strauss & Quinn, 1997). Imagine, for example, how much more difficult the task of remembering how a neuron works might be for someone whose culture lacked the concept of cells.

Now is the time for all good men to to come to the aid of their countrymen.

The extra 'to' at the beginning of the second line is easily overlooked because of the schema-based expectation that it is not there. Students often fail to notice typographical errors in their papers for the same reason.

Years ago, Frederic Bartlett (1932) demonstrated the impact of cultural models on retrieval. British participants read a North American Indian folk tale, waited 15 minutes and then attempted to reproduce it verbatim. Their errors were systematic: participants omitted or reworked unfamiliar details to make the story consistent with their own culturally shaped schemas.

INTERIM SUMMARY

Across and within cultures, people tend to remember information that matters to them, and they organise information in memory to match the demands of their environment. Shared cultural concepts, or ***cultural models***, also shape the way people think and remember.

Remembering, misremembering and forgetting

We could not do without our memories, but sometimes we wish we could. According to Daniel Schacter (1999), who has spent his life studying memory, human memory systems evolved through natural selection, but the same mechanisms that generally foster adaptation can regularly cause memory failures. He describes 'seven sins of memory' that plague us all:

- *transience* (the fact that memories fade)
- *absent-mindedness* (the failure to remember something when attention is elsewhere)
- *misattribution* (misremembering the source of a memory — something advertisers rely on when they tell half-truths about competing brands and people remember the half-truth but forget its source)

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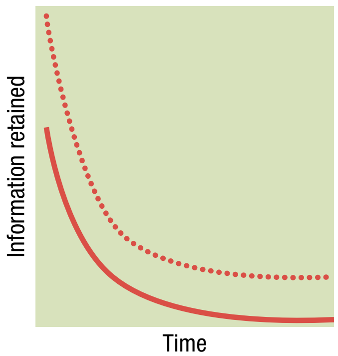

FIGURE 7.14
Rate of forgetting. Forgetting follows a standard pattern, with rapid initial loss of information followed by more gradual later decline. Increasing initial study time (the dotted line) increases retention, but forgetting occurs at the same rate. In other words, increased study shifts the curve upward but does not change the rate of forgetting or eliminate it.

- *suggestibility* (thinking we remember an event that someone actually implanted in our minds)
- *bias* (distortions in the way we recall events that often tell the story in a way we would rather remember it)
- *persistence* (memories we wish we could get rid of but which keep coming back)
- ***forgetting*** (the inability to remember).

Although at first glance these 'sins' all seem maladaptive, many stem from adaptive memory processes that can go awry. For example, if memory were not transient or temporary, our minds would overflow with irrelevant information.

Perhaps the cardinal sin of memory is forgetting. Over a century ago, Ebbinghaus (1885/1964) documented a typical pattern of forgetting that occurs with many kinds of declarative knowledge: rapid initial loss of information after learning and only gradual decline thereafter (figure 7.14). Researchers have since refined Ebbinghaus' forgetting curve slightly to make it more precise — finding, in fact, that the relation between memory decline and length of time between learning and retrieval is logarithmic and hence predictable by a very precise mathematical function (Wixted & Ebbesen, 1991). This logarithmic relationship is very similar to Stevens' power law for sensory stimuli (chapter 4).

This forgetting curve seems to apply whether the period of time is hours or years. For example, the same curve emerged when researchers studied people's ability to remember the names of old television shows: they rapidly forgot the names of shows cancelled within the last seven years, but the rate of forgetting trailed off after that (Squire, 1989).

How long is long-term memory?

When people forget, is the information no longer stored or is it simply no longer easy to retrieve? And is some information permanent, or does the brain eventually throw away old boxes in the attic if it has not used them for a number of years?

The first question is more difficult to answer than the second. Psychologists often distinguish between the availability of information in memory — whether it is still 'in there' — and its accessibility — the ease with which it can be retrieved. The tip-of-the-tongue phenomenon, like the priming effects shown by amnesics, is a good example of information that is available but inaccessible.

In large part, accessibility reflects level of activation, which diminishes over time but remains for much longer than most people would intuitively suppose. Memory for a picture flashed briefly on a screen a year earlier continues to produce some activation of the visual cortex, which is expressed implicitly even if the person has no conscious recollection of it (Cave, 1997). And most people have vivid recollections from their childhood of certain incidents that occurred once, such as the moment they heard the news that a beloved pet died. But what about the other hundreds of millions of incidents that they cannot retrieve? To what degree these memories are now unavailable, rather than just inaccessible, is unknown.

Studies of very long-term memory suggest, however, that if information is consolidated through spacing over long learning intervals, it will last a lifetime, even if the person does not rehearse it for half a century (Bahrick & Hall, 1991). Eight years after having taught students for a single semester, university lecturers will forget the names and faces of most of their students (sorry!), but 35 years after graduation people still recognise 90 percent of the names and faces from their high school yearbook.

The difference is in the spacing: the lecturer teaches a student for only a few months, whereas high school students typically know each other for at least three or four years. Similarly, people who take university mathematics courses that require them to use the knowledge they learned in high school algebra show nearly complete memory for algebra 50 years later even if they work as artists and never balance their chequebook. People who stop at high school algebra remember nothing of it decades later.

How accurate is long-term memory?

Aside from the question of *how long* people remember is the question of *how accurately* they remember. The short answer is that memory is both functional and reconstructive, so that most of the time it serves us well, but it is subject to a variety of errors and biases.

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For example, the normal associative processes that help people remember can also lead to memory errors (see Robinson & Roediger, 1997; Schacter, Verfaellie, Anes, & Racine, 1998). In one set of studies the researchers presented participants with a series of words (such as *slumber*, *nap* and *bed*) that were all related to a single word that had *not* been presented (*sleep*). This essentially primed the word 'sleep' repeatedly (Roediger & McDermott, 1995). Not only did most participants remember having heard the multiply primed word, but the majority even remembered which of two people had read the word to them. Some participants refused to believe that the word had not been presented even after hearing an audiotape of the session!

Emotional factors can also bias recall. The investigators in one study asked university student participants to recall their maths, science, history, English and foreign language grades from high school and then compared their recollections to their high school transcripts (Bahrick, Hall, & Berger, 1996). Students recalled 71 percent of their grades correctly, which is certainly impressive.

More interesting, however, was the pattern of their errors (figure 7.15). Participants rarely misremembered their As, but they rarely correctly remembered their Ds. In fact, a D was twice as likely to be remembered as a B or C than as a D. Approximately 80 percent of participants tended to inflate their remembered grades, whereas only 6 percent reported grades lower than they had actually achieved. (The remaining 14 percent tended to remember correctly.)

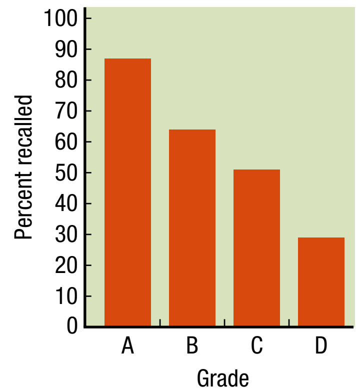

FIGURE 7.15
Distortion in memory for high school grades. The lower the grade, the less memorable it seems to be, demonstrating the impact of motivation and emotion on memory.
Source: Adapted from Bahrick et al. (1996).

Flashbulb memories

If remembering is more like consulting an artist's sketch than a photograph, what do we make of ***flashbulb memories***, that is, vivid memories of exciting or highly consequential events (Brown & Kulik, 1977; Conway, 1995; Winograd & Neisser, 1993)? Many people can recall precisely where and when they first heard the news of the September 11 attacks on the United States in 2001, almost as if a camera had recorded that moment in time. People report similarly vivid memories of the announcement that Sydney had been awarded the 2000 Olympic Games, as well as personal events such as the death of a loved one or a romantic encounter (Rubin & Kozin, 1984).

Flashbulb memories are so clear and vivid that we tend to think of them as totally accurate; however, considerable evidence suggests that they are often not of snapshot clarity or accuracy and can even be entirely incorrect (Neisser, 1991). For example, on the day following the *Challenger* space shuttle disaster in the United States in 1986, people reported where they were when they heard the space shuttle had disintegrated. Three years later when they were again asked where they were, not a single person recalled with complete accuracy where they had been, and a third of the respondents were completely incorrect in their recall (McCloskey, Wible, & Cohen, 1988; Neisser & Harsch, 1992).

Do you remember where you were when you heard that Crocodile Hunter Steve Irwin had died?

Emotional arousal and memory

In trying to understand 'flashbulb' memories, Cahill, Prins, Weber, and McGaugh, (1994) designed an elegant experiment that manipulated both the emotional content of the material to be remembered and adrenalin (the fight-or-flight hormone, chapter 3) (see figure 7.16). First, they developed two series of 12 slides depicting a little boy leaving for school, having an unusual experience and then returning home. In the middle section of slides, the unusual experience differed for the two series. In the control or neutral condition, the little boy goes on a field trip to the hospital and sees a disaster drill. In the experimental or arousal condition, the little boy is in a tragic accident in which his feet are severed from his legs and a concussion leads to bleeding in the brain. Miraculously, the doctors are able to reattach the boy's feet and control the brain bleeding.

Half the participants were shown the neutral slide series; the other half were shown the arousal slide series. The second manipulation, that of adrenalin activity, was created by giving a drug that antagonises the actions of adrenalin (propranolol) to half the participants in each group. The propranolol blocked any effect of adrenalin that the arousal slides produced. In this two-by-two design, two factors were studied: (1) neutral or arousal slide versions, and (2) placebo drug or the adrenalin antagonist propranolol. Thus, there were four groups (see figure 7.16) — NPl: neutral, placebo drug; NPr: neutral, propranolol; APl: arousal, placebo drug; and APr: arousal, propranolol.

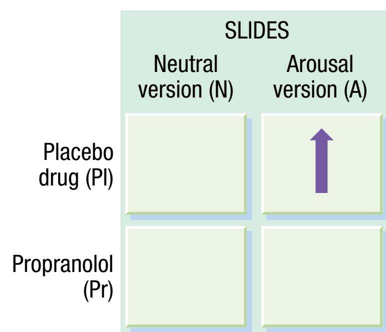

FIGURE 7.16
In an investigation of the relationship between emotional arousal and memory, researchers found that memory was higher for participants in the arousal condition who had not received propranolol, relative to the other three conditions.

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The researchers hypothesised that the memory for all groups, when tested one week later, would be the same, except for the APl group, for which memory of the middle set of slides (when the boy was in the accident) would be better than the other groups. That is, they hypothesised that the emotionally arousing slides, which triggered adrenalin release, would lead to enhanced memory of those slides. Neither of the neutral groups would have any adrenalin release (thus, the propranolol would not have any adrenalin to antagonise) and the arousal group whose adrenalin activity was antagonised by propranolol would not have enhanced memory, even though they saw the arousing slides. The results supported their hypothesis.

These results support the notion that our 'flashbulb' memories for emotionally arousing events are dependent on the fight-or-flight hormone, adrenalin. It is important to note that memory was enhanced *only* for the arousal slides, not for the neutral beginning and ending slides. Thus, emotional arousal, via adrenalin activity in the brain, can lead to enhanced memory. However, recent research demonstrates that if people are in a state of alarm at the time they receive information to be encoded and stored in memory, the truthfulness of this memory may be affected by reconstructive processes (Lanciano, Curci, & Semin, 2010).

ETHICAL DILEMMA

A seven-year-old boy witnesses a brutal assault on his mother by a home invader in the early hours of the morning. The house is dark and the attacker leaves unaware of the child's presence. The boy is the only witness to the assault and has to come to the aid of his mother after the assault. The police later arrest a suspect and need evidence to secure a conviction when the case goes to trial. Eyewitness testimony identifying the culprit would certainly help.

- Should the young boy be allowed to testify at trial? Why or why not?
- How accurate is the child's testimony likely to be?
- Discuss the ethical issues most relevant to this case.

Eyewitness testimony

Research on the accuracy of memory has an important real-life application in the courtroom: how accurate is eyewitness testimony (see Melinder, Scullin, Gunnerod, & Nyborg, 2005; Schacter, 1995b; Sporer, Malpass, & Koehnken, 1996; Wells et al., 2000; Wells & Olson, 2003)? Numerous studies have explored this question experimentally, usually by showing participants a short film or slides of an event such as a car accident (Wells & Loftus, 1984; Zaragosta & Mitchell, 1996). The experimenter then asks participants specific questions about the scene, sometimes introducing information that was not present in the actual scene, asking leading questions or contradicting what participants saw.

These studies show that seemingly minor variations in the wording of a question can determine what participants remember from a scene. One study simply substituted the definite article *the* for the indefinite article *a* in the question 'Did you see the/a broken headlight?' Using *the* instead of *a* increased both the likelihood that participants would recall seeing a broken headlight and their certainty that they had, even if they never actually observed one (Loftus & Palmer, 1974; Loftus & Zanni, 1975).

One Australian study (Dietze & Thomson, 1993) explored the accuracy of child witness testimony by showing participants a film and then asking them questions about it under three conditions — first, where the film was being viewed at the time; second, using a series of specific questions; and third, using free recall. The correctness of recall was better when the film was being viewed in context or when specific questions were asked, as compared to free recall. Thus retrieval of memories was affected by the way in which the participants were asked to recall details of a past event.

A more recent Australian study by Tuckey and Brewer (2003) examined how schemas, or expectations, for a crime influenced the types of information eyewitnesses remembered and forgot over time. Their results showed that when a witness reports details that are common to that type of crime (i.e., which are expected of that crime), the schema-consistent details are likely to be accurate and recalled at subsequent interviews.

These findings have clear implications both in the courtroom and in the way police interrogate witnesses. However, individuals vary in their susceptibility to misleading information (Loftus, Levidow, & Diensing, 1992; see also Melinder, Goodman, Eilertsen, & Magnussen, 2004). Further, some aspects of a memory may be more reliable than others. The emotional stress of witnessing a traumatic event can lead to heightened processing of (and hence better memory for) core details of the event but less extensive processing of peripheral details (Christianson, 1992). A sharp barrister could thus attack the credibility of a witness's entire testimony by establishing that her memory of peripheral details is faulty, even though she clearly remembers the central aspects of the event. Consequently, an emerging field is the study of methods for evoking and assessing traumatic memories. The aim is to better determine the processes and contents of memory retrieval in traumatised individuals (see Hopper & van der Kolk, 2001).

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Should we be worried when a senior complains about their memory?

By Professor Craig Speelman, Edith Cowan University

Human memory is a fallible storage device. Even when our memory of an experience feels clear, comparison with objective information will reveal that our memory is prone to gaps, distortions and illusions. There are countless times when we notice that we have forgotten something and yet we do not assume that our memory is faulty. Forgetting is a normal feature of memory. Nonetheless, memory performance does tend to decline as we age, particularly memory for episodic information.

Memory decline with age is a normal occurrence, although some changes in memory performance are more severe than others and could be a sign of dementia. At what point should we be concerned about a change in memory performance or complaints from seniors that their memory is failing? Around two-thirds of seniors (those over 70 years old) living in the community report memory difficulties (Slavin et al., 2010); however, there is only a weak association between self-reported memory difficulties and observable memory performance (Reid & MacLullich, 2006). Research indicates that this relationship is stronger when age and IQ are taken into account (Merema, Speelman, Kaczmarek, & Foster, 2012).

Importantly, the likelihood of someone reporting memory complaints is related to whether or not they suffer from depression (Merema et al., 2012). This relationship has been reported many times before. However, new research has found that depression exhibits little relationship with memory complaints, beyond what can already be explained by personality characteristics (predominantly neuroticism) (Merema, Speelman, Foster, & Kaczmarek, 2013). What this suggests is that depression may not be directly related to memory complaints but, rather, the relationship is mediated through characteristics of personality. For example, high levels of neuroticism are typically associated with more frequent or severe memory complaints as well as an increased risk of depressive symptoms, which would generate an indirect association between them. This suggests two important clinical implications.

1. Older adults complaining of memory problems likely exhibit an ongoing risk for depression. Such complaints are associated with higher levels of neuroticism, a known risk factor for depression.
2. Memory complaints are often associated with an increased risk of subsequent dementia, despite generally being a poor predictor of concurrent memory performance. The higher rates of dementia in older adults complaining of memory problems may be partially attributable to this increased vulnerability to depression (Byers, Covinsky, Barnes, & Yaffe, 2011), as well as the relationship between neuroticism and dementia risk (Low, Harrison, & Lackersteen, 2013).

So, should we be concerned when seniors complain about their memory? Yes — not necessarily because their memory is failing, but because of other issues the complaints may suggest, such as depression. The results discussed here underline the great extent to which our mental faculties — memory and personality — are interrelated.

INTERIM SUMMARY

The flipside of memory is ***forgetting***. Many kinds of declarative knowledge show a similar forgetting curve, which is initially steep and then levels off. Psychologists often distinguish between the availability of information in memory — whether it is still 'in there' — and its accessibility — the ease with which it can be retrieved. People tend to make memory errors for a variety of reasons, some cognitive and some emotional. ***Flashbulb memories*** — vivid memories of exciting or highly consequential events — are sometimes extremely accurate but sometimes completely mistaken. Eyewitness testimony is also subject to many biases and errors.

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Why do people forget?

The reconstructive nature of remembering — the fact that we have to weave together a memory from patches of specific and general knowledge — leaves memory open to a number of potential errors and biases. But why do people sometimes forget things entirely? Psychologists have proposed several explanations, including decay, interference and motivated forgetting.

Decay theory

Decay theory explains forgetting as a result of a fading memory trace. Having a thought or perception produces changes in synaptic connections, which in turn create the potential for remembering if the neural circuits that were initially activated are later reactivated. According to decay theory, these neurophysiological changes fade with disuse, much as a path in the forest grows over unless repeatedly trodden. The decay theory is difficult to corroborate or disprove empirically. However, it fits with many observed memory phenomena. Further, some studies do show a pattern of rapid and then more gradual deactivation of neural pathways in the hippocampus (which is involved in memory consolidation), which suggests a possible physiological basis for decay (see Anderson, 1995).

APPLY + DISCUSS

Most people cannot explicitly remember events before about age four, a phenomenon known as childhood amnesia.

- What is your earliest memory?
- Why might we be unable to retrieve memories from before age three or four? What aspects of the way we represent, store and retrieve information might affect our capacity to recall early memories?
- What neurological factors might limit access to early episodic memories?

Interference theory

A prime culprit in memory failure is ***interference***, the intrusion of similar memories on each other, as when students confuse two theories they learned around the same time or two similar-sounding words in a foreign language. Finding the right path in the neural wilderness is difficult if two paths are close together and look alike. Or to use the filing cabinet metaphor, storing too many documents under the same heading makes finding the right one difficult. Cognitive psychologists distinguish two kinds of interference. ***Proactive interference*** refers to the interference of previously stored memories with the retrieval of new information, as when a person calls a new romantic partner by the name of an old one (a common but dangerous memory lapse). In ***retroactive interference***, new information interferes with retrieval of old information, as when people have difficulty recalling their home phone numbers from past residences. One reason children take years to memorise multiplication tables, even though they can learn the names of cartoon characters or classmates with astonishing speed, is the tremendous interference that is involved, because every number is paired with so many others (Anderson, 1995).

Motivated forgetting

Another cause of forgetting is ***motivated forgetting***, or forgetting for a reason. People often explicitly instruct themselves or others to forget, as when a person stops in the middle of a sentence and says, 'Oops — forget that. That's the wrong address. The right one is . . .' (Bjork & Bjork, 1996). At other times, the intention to forget is implicit, as when a person who parks in a different parking space every day implicitly remembers to forget where she parked the day before so it does not interfere with memory for where she parked today (Bjork, Bjork, & Anderson, 1998).

Experimental evidence suggests that goal-directed forgetting requires active inhibition of the forgotten information, which remains available but inaccessible. Researchers have demonstrated this by using directed forgetting procedures: participants learn a list of words but are told midway to forget the words they just learned and remember only the last part of the list. This procedure reduces recall for the words in the first part of the list and decreases proactive interference from them, so that participants can more easily remember words in the last half of the list. This outcome suggests that the procedure is in fact inhibiting retrieval of the to-be-forgotten words. This procedure does not, however, decrease recognition of, or implicit memory for, the to-be-forgotten words, and they remain available, just less accessible.

Other studies show that instructing a person not to think about something can effectively keep the information from consciousness, but that deliberately suppressing information in this way creates an automatic, unconscious process that 'watches out' for the information and hence keeps it available

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(Wegner, 1992). For example, when people are instructed to suppress an exciting thought about sex, they remain physiologically aroused even while the thought is outside awareness. In fact, they remain just as aroused as participants instructed to think about the sexual thought (Wegner, Shortt, Blake, & Page, 1990). In a sense, goal-directed forgetting is like a form of prospective memory, in which the intention is to forget something in the future rather than to remember it. In this situation, forgetting is actually a form of remembering! In real life, people often try to inhibit unpleasant or anxiety-provoking thoughts or feelings (chapter 11). They often forget things they do not want to remember, such as 'overlooking' a dentist appointment.

False memories and repressed memories

The concept of repression has always been controversial in psychology (Holmes, 1990), but it is now the centrepiece of controversy (Sivers, Schooler, & Freyd, 2002). It is at the heart of claims of childhood sexual abuse and counterclaims of false memories raised by alleged perpetrators. The alleged perpetrators claim that the charges of sexual abuse against them have been invented by incompetent clinicians who have convinced their patients of the existence of events that never occurred (Del Monte, 2001; Howe, 2000; Pezdek & Banks, 1996).

The question of implanting false memories is exceedingly difficult to address scientifically for a number of reasons. First, distinguishing true from false allegations is difficult in all legal circumstances, but it is even more difficult when the events may have occurred 15 years ago. Second, a cardinal feature of sexual abuse is that the perpetrator does everything possible to maintain secrecy (including threatening the victim) and to discredit the victim if she or he ever tells the story — a situation not unlike what often occurs with rape, political torture and genocide (Herman, 1992). Third, some number of innocent people are unfairly accused: divorcing parents sometimes accuse former spouses as a tactic in custody disputes, and some poorly trained therapists look for (and 'find') abuse whenever an adult female patient steps into their office complaining of anxiety or depression (Loftus, 1993).

Evidence of false memories

Data from numerous laboratory studies suggest that people can sometimes be led to create compelling memories of things that did not happen (Loftus, 1997a; Payne, Nevschate, Lampien, & Lynn, 1997). As we have seen, presenting people with a series of words semantically related to a target word that was not presented can produce high rates of false recognition of the target, and people can be quite firm in their beliefs about these false memories. Women reporting a recovered memory of childhood sexual abuse are more likely than other women to recognise a target word (*sweet*) mistakenly as having been present in an earlier list of related words (*sugar*, *candy*, *honey*) (Clancy, Schacter, McNally, & Pitman, 2000). Women who report remembering abuse all along (as opposed to recovering it) do not show this bias.

In another experimental design that bears on false memories, researchers obtain detailed information from parents of university students about events that actually occurred when their children were younger and then present the students with several real memories and one false one, such as getting lost in a shopping centre at age five and being found by an elderly woman (Loftus, 1997b). The investigators then interview participants about each event, ask them if they remember it, and ask them to recall what they remember. In these studies, roughly 15 to 25 percent of participants can be induced to recall a false memory over the course of two or three interviews. More recent research from New Zealand indicates that drawing things related to false information while being questioned may promote false memories in children (see Strange, Garry, & Sutherland, 2003). Furthermore, Sharman, Manning, and Garry (2005) found that asking adults to explain earlier events inflated their confidence and memory for those events. Other research has demonstrated the role of sociolinguistic cues on memory. For example, Vornik, Sharman, and Garry (2003) found that people are likely to be misled by an inaccurate narration if the narrator is high (rather than low) on social attractiveness.

For most people, however, the vulnerability to recall false memories is not without limit. When one researcher tried to induce memories more like those of sexual abuse victims (in this case, memory of a rectal enema in childhood), none of the participants created a false memory (Pezdek, cited in Loftus, 1997b). There is obviously a need for caution in extending the findings of these experimental studies to the creation of false memories of sexual abuse, a highly traumatic and evocative event.

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Evidence of repressed memories

Other studies call into question the charge that most psychotherapy patients who believe they have been sexually abused invent these memories. The majority of victims of repeated or severe sexual abuse in childhood have at least some memories of the abuse prior to psychotherapy, although their memories are often fragmented (Herman, 1992). Their recollection of childhood events tends to have gaps of months or years, and the memories of traumatic experiences they do recall frequently come to them in flashbacks, in physical forms (such as the sensation of gagging that initially attended the experience of being forced to perform oral sex), or in nightmares. Such intrusions and flashbacks experienced by trauma survivors and those who have experienced post-traumatic stress disorder are linked to an inability to selectively control episodic memory (Zwissler et al., 2012).

Several studies document that periods of amnesia for sexual abuse are common (see Briere & Conte, 1993; Loftus, Polonsky, & Fullilove, 1994), just as in other traumatic events such as combat or rape (Arrigo & Pezdek, 1997). Perhaps the clearest empirical evidence for repressed memories comes from a study that tracked down women who had been treated at a hospital for sexual molestation when they were children (Williams, 1994). Seventeen years after their documented abuse, 38 percent were amnesic for the incident. When asked if any family members had ever gotten into trouble for their sexual behaviour, one participant, who denied sexual abuse, reported that before she was born an uncle had apparently molested a little girl and was stabbed to death by the girl's mother. Examination of newspaper reports 17 years earlier found that the participant herself had been one of the uncle's two victims and that the mother of the other victim had indeed stabbed the perpetrator.

Perhaps the moral of the story is that psychologists should always attend both to the phenomenon they are studying — in this case, repressed memories — and to their own needs, fears and cognitive biases. For example, research demonstrates that people with abuse histories are more likely to see or hear themes of abuse in ambiguous situations (Nigg, Lohr, Westen, Gold, & Silk, 1992). Thus, clinicians with painful memories of their own childhood should be particularly careful to avoid jumping to conclusions or subtly influencing patients with leading questions.

On the other hand, researchers who may have had little or no exposure to real sexual abuse victims should be circumspect about overstepping the limits of their vantage point. Researchers and clinicians alike need to look carefully at their own cognitive and motivational biases before attempting to rewrite — or write off — the life histories of others.

COMMENTARY

Memory

By Professor Rick Richardson, The University of New South Wales

The idea of *memory erasure* has attracted considerable interest, both scientifically and in popular culture (e.g., the movie *Eternal Sunshine of the Spotless Mind*). One reason for this interest has to do with the possibility of erasing trauma-related memories that often underlie anxiety disorders (e.g., post-traumatic stress disorder is due to persistent, vivid, traumatic memories that adversely impact on an individual's ability to function normally). While treatments like cognitive–behavioural therapy are undoubtedly effective in treating many anxiety disorders, they are not perfect, with some patients not improving and others relapsing after successful completion of treatment (McNally, 2007). What would happen if the underlying memory could be erased?

The idea of memory erasure has been raised in several areas of research. For example, some researchers have lesioned just those neurons that were active at the time of memory encoding and found a selective loss of memory (e.g., Han et al., 2009). Although very exciting, this approach is not currently possible in humans. However, other researchers have examined the concept of memory erasure in settings that can be applied to humans.

It has been suggested that *extinction* of fear can involve the unlearning, or erasure, of the original memory underlying the fear, at least in certain circumstances (Quirk et al., 2010). In a typical extinction experiment, animals (either humans or non-humans) first learn to fear a stimulus, often through Pavlovian conditioning (see chapter 6). Extinction training then involves repeated presentations of the fear-eliciting conditioned stimulus (CS) by itself, which leads to a gradual loss of fear. Extinction usually results in the formation of a competing memory that inhibits the original memory

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(Todd, Vurbic, & Bouton, in press), which allows for the possibility of the original memory returning (i.e., relapse).

There is evidence that adding particular pharmacological treatments to extinction reduces the occurrence of relapse (see Graham, Langton, & Richardson, 2011), and that it might even lead to the erasure of the original fear memory (Graham & Richardson, 2011). Although much more research is needed in this area, the pharmacological modification of extinction is particularly exciting as extinction is the empirical basis for exposure-based therapy, which is the most effective treatment for anxiety disorders.

There is also evidence that *reactivating* a memory (i.e., such that the person/animal is currently thinking about it) may make it susceptible to being erased. In some studies, participants given extinction training shortly after a fear memory had been reactivated exhibited much less relapse compared to participants merely given extinction training (Monfils, Cowansage, Klann, & LeDoux, 2009; Schiller et al., 2010; see Xue et al., 2012, for an example of this finding with drug-related cues). The typical interpretation of this finding is that the reconsolidation of the original memory was disrupted in the reactivation–extinction condition, leading to memory erasure. While this is a very exciting finding, some have failed to replicate it (e.g., Chan, Leung, Westbrook, & McNally, 2010; Kindt & Soeter, 2013), while others have replicated the basic effect but have raised questions about how it should be interpreted (Baker, McNally, & Richardson, 2012). More research in this area is clearly needed.

Whatever the outcome of this future research, the types of research described in this section hold great promise for not only enhancing our understanding of memory, but also for improving the efficacy of treatments for a variety of psychological disorders.

INTERIM SUMMARY

The ***decay theory*** explains forgetting as a result of a fading memory trace; disuse of information leads to a gradual decrease in the strength of neural connections. ***Interference*** of similar information is another cause of forgetting. ***Proactive interference*** refers to the interference of previously stored memories with the retrieval of new information, whereas ***retroactive interference*** refers to the interference of new information with retrieval of old information. Another cause of forgetting is ***motivated forgetting***, or forgetting for a reason. The final word has not yet been written about repressed memories of childhood sexual abuse, although the data suggest caution on both sides: memories recovered in therapy cannot be assumed to be accurate, but they also cannot be routinely dismissed as false.

Disordered memories

We have seen that distortion can occur within the memories of people with normal brain function. Specific kinds of distortion can also occur within the memories of people whose brains have been affected by illness or injury. These are called disordered memories. There are two main types of disordered memories — anterograde and retrograde.

Anterograde amnesia

Anterograde amnesia involves the inability to retain new memories. This amnesia is typically caused by damage in the temporal lobe, particularly in the hippocampus and subcortical region (Mishkin & Appenzeller, 1987). People with this condition often have no problem retrieving memories stored before their brains were damaged, but cannot learn anything new (Gleitman, Fridlund, & Reisberg, 1999). The brain simply does not retain or retrieve fresh information. Anterograde amnesia is a symptom that is typically associated with Alzheimer's disease (chapter 12).

Retrograde amnesia

By contrast, ***retrograde amnesia*** involves losing memories from a period before the time that a person's brain was damaged. Brain tumours and strokes often cause this form of amnesia. Severely depressed or manic patients may also experience a brief period of retrograde amnesia following electroconvulsive

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therapy (Andreason & Black, 1996) — they have no memory of the treatment or of the events directly preceding it (chapter 16). Commonly the amnesia covers only a short period (although this can be up to several years) before the injury or illness damaged the brain — older memories and new memories are not affected. The reasons why this occurs are still being debated (see Squire, 1987).

INTERIM SUMMARY

Specific kinds of distortion can also occur within the memories of people whose brains have been affected by illness or injury. ***Anterograde amnesia*** involves the inability to retain new memories. By contrast, ***retrograde amnesia*** involves losing memories from a period before the time that a person's brain was damaged.

Central questions revisited

◆ What is memory?

We began this chapter with a central question: what is the nature of memory? Is memory the recollection of facts? Or are the feelings that return with the episodic memory of our first kiss (or the procedural memory of *how* to kiss after a long dry spell!) rightly considered memory phenomena? And what is the relationship between learning and memory?

To answer these questions requires a consideration of the perspectives that have guided our inquiry into memory. We have focused in this chapter primarily on the cognitive perspective, just as the previous chapter on learning focused on the behaviourist perspective. But as the concept of memory has expanded to include phenomena such as implicit memory, we are beginning to see an integration of perspectives that would have seemed unimaginable just 10 years ago, as cognitive psychologists move into terrain traditionally viewed as the 'turf' of other perspectives.

Take, for example, the relationship between learning and memory. Whatever happened to classical and operant conditioning in the standard model of memory? Surely an animal must be remembering something when it produces an adaptive response based on prior experience? But behaviourists emphasised that these forms of learning do not require conscious attention (that is, retrieval into STM) and often involve emotional learning (as when a rat learns to avoid situations associated with fear-inducing stimuli). A preliminary answer has begun to emerge: conditioning is a form of associative memory that is expressed implicitly rather than retrieved as explicit, declarative memory.

Our expanding understanding of memory has also begun to narrow the gulf between cognitive, psychodynamic and evolutionary approaches. The standard model assumed that information had to be processed consciously (in STM) before being stored in LTM and that remembering required conscious retrieval. Psychoanalysis, in contrast, proposed that most mental processes occur outside awareness, are processed in parallel and can be expressed in behaviour without ever becoming conscious. Freud, like most contemporary cognitive theorists, was schooled in classical associationist thought, and he proposed a network theory of the mind and a mechanism similar to spreading activation a century ago (see Erdelyi, 1985; Freud, 1895/1966; Pribram & Gill, 1976). He argued that networks of association operate unconsciously, leading people to think, feel and behave in ways they may not understand. Freud and later psychodynamic theorists thus developed an approach to treating psychological problems that involves trying to map these networks, so that the person can begin to recognise the implicit triggers for ideas, feelings and behaviour patterns that lead to problems such as repeated struggles with bosses or other authority figures.

Finally, the standard model viewed the capacity for memory and thought as essentially independent of content; that is, as applying to any kind of information. The mind was a general information-processing machine that could take almost any input, manipulate it and remember it with appropriate encoding and rehearsal. But an increasingly modular conception of the brain and memory systems has made contemporary cognitive models more compatible with a view of cognition emerging in evolutionary circles. This view maintains that the brain has evolved content-specific mechanisms that facilitate the remembering and processing of very particular kinds of information (Tooby & Cosmides, 1992). It is no accident that we have the capacity to perceive and recognise faces that differ in what are objectively some incredibly trivial ways. (To a possum, we all look alike.) Knowing who we are

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dealing with is incredibly important from an adaptive perspective, so it is perhaps not surprising that we are born with specialised neural circuits that help us recognise faces.

In sum, as cognitive neuroscience has expanded the domain of memory, it has led to an unforeseen potential for integration among cognitive, behavioural, psychodynamic and evolutionary perspectives. Perhaps someday we will not remember the differences among them so clearly.

SUMMARY

1 Memory and information processing

- Case studies of neurologically impaired patients and experimental studies of normal participants have demonstrated that memory is composed of several systems.
- For information to return to mind after it is no longer present, it has to be put into a mental code, or representation. The major forms of representations studied by psychologists are ***sensory representations*** and ***verbal representations***. People also store memory for actions as motoric representations.
- The standard model of memory views the mind as a computer, which stores, transforms and retrieves information processing. It includes three sequential memory stores or stages of memory. The first is the ***sensory register***, the split-second mental representation of a perceived stimulus that remains very briefly after that stimulus disappears. ***Iconic storage*** describes visual sensory registration; ***echoic storage*** describes auditory sensory registration.
- ***Short-term memory (STM)*** stores information for roughly 20 to 30 seconds, unless the information is maintained through ***rehearsal*** (repeating the information again and again). This form of rehearsal, which merely maintains information in STM, is called ***maintenance rehearsal***. ***Elaborative rehearsal*** — thinking about and elaborating on the information's meaning — tends to be superior for storing information in long-term memory.
- Important information is passed along to ***long-term memory (LTM)***, where representations may last as long as a lifetime. Recovering information from LTM, or ***retrieval***, brings it back into STM, or consciousness.
- In recent years, this model has been changing substantially. Instead of viewing memory exclusively in terms of serial processing (which assumes that information passes through a series of stages, one at a time and in order), researchers now view memory as involving a set of ***modules*** that operate simultaneously (in parallel) rather than sequentially (one at a time). Researchers now recognise that not all remembering is expressed by retrieving information into consciousness, or STM, and they rely less on the metaphor of mind as computer than mind as brain.

2 Working memory

- Psychologists now refer to STM as ***working memory***, the temporary storage and processing of information that can be used to solve problems, respond to environmental demands or achieve goals. According to one prominent model, control processes such as rehearsal, reasoning and making decisions about how to balance two tasks simultaneously are the work of a limited capacity central executive system; whereas storage involves at least two limited-capacity systems, a visual store (also called the visuospatial sketchpad) and a verbal store.
- The existence of neurological patients who show deficits in either working memory or LTM but not both suggests that these memory systems are neurologically distinct, although in everyday life they work together, as frontal working memory networks provide a special form of activation to networks in the posterior parts of the cortex that represent current perceptions and information stored in LTM. One way to expand the capacity of working memory in particular domains is ***chunking***; that is, grouping information into larger units than single words or digits. The roughly seven pieces of information stored in visual or auditory working memory can represent larger, more meaningful pieces of information.

3 Types of long-term memory

- Types of long-term memory can be distinguished by the kind of knowledge stored and the way this knowledge is retrieved and expressed. People store two kinds of information, declarative and procedural. ***Declarative memory*** refers to memory for facts and events and is subdivided into ***semantic*** or ***generic memory*** (general world knowledge or facts) and ***episodic memory*** (memories of particular events). ***Procedural memory*** refers to 'how to' knowledge of procedures or skills.
- Information can be retrieved either explicitly or implicitly. ***Explicit memory*** refers to conscious recollection, expressed through ***recall*** (the spontaneous retrieval of material from LTM) or ***recognition*** (memory for whether something currently perceived has been previously encountered or learned). ***Implicit memory*** is expressed in behaviour rather than consciously retrieved.
- Neurological data suggest that different kinds of memory form discrete memory systems. The hippocampus and adjacent regions of the cortex are central to the consolidation of explicit memories but do not appear to play an important role in either implicit memory or working memory.
- ***Everyday memory*** — memory as it occurs in daily life — tends to be functional (focused on remembering information that is meaningful) and emotionally significant. ***Prospective memory*** is memory for things that need to be done in the future.

4 Encoding and organisation of long-term memory

- For information to be retrievable from memory, it must be ***encoded***, or cast into a representational form, or 'code,' that can be readily accessed from memory.
- Among the factors that influence later accessibility of memory are the degree to which information is elaborated, reflected upon and processed in a meaningful way during encoding (***level of processing***); the presence of ***retrieval cues*** (stimuli or thoughts that can be used to facilitate recollection); the ***spacing*** of study sessions (with longer intervals between rehearsal sessions tending to be more effective); and the use of multiple and redundant representational modes to encode the information, which provides more cues for its retrieval. ***Mnemonic devices***, or systematic strategies for remembering information, can also be useful for remembering, as can external memory aids such as notes.
- Information stored in memory forms networks of association — clusters of interconnected units of information called ***nodes***. According to spreading activation theory, activating one node in a network triggers activation in closely related nodes. Some information is

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organised hierarchically, with broad categories composed of narrower subcategories, which in turn consist of even more specific categories.

- Schemas are organised knowledge about a particular domain. According to schema theory, memory is an active, reconstructive process that involves reactivation of both the initial representations of an event and general knowledge that helps fill in the gaps. Schemas facilitate memory by organising information at both encoding and retrieval.
- Many schemas are shaped by culture, from beliefs about foods that are appropriate to eat to beliefs about the meaning of life. Across cultures, people tend to remember what matters to them.

5 Remembering, misremembering and forgetting

- Ebbinghaus discovered a forgetting curve that applies to many kinds of declarative memory, in which considerable information is initially lost but ***forgetting*** then tapers off.
- Memory is a reconstructive process that mingles representations of actual experiences with general knowledge. Although memory is functional and tends to work well most of the time, misremembering is common, even in ***flashbulb memories*** (vivid memories of exciting or highly consequential events) and eyewitness testimony, which can be biased by even seemingly minor changes in the way questions are asked.
- Three theories attempt to account for forgetting: ***decay theory*** (which explains forgetting as a result of a fading memory trace); ***interference*** of new and old information with retrieval of the other; and ***motivated forgetting*** (forgetting for a reason, which leads to inhibition of retrieval).
- Specific kinds of distortion can also occur within the memories of people whose brains have been affected by illness or injury. ***Anterograde amnesia*** involves the inability to retain new memories. By contrast, ***retrograde amnesia*** involves losing memories from a period before the time that a person's brain was damaged.

KEY TERMS

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chunking *p.* 258
cultural models *p.* 273
decay theory *p.* 278
declarative memory *p.* 259
echoic storage *p.* 251
elaborative rehearsal *p.* 252
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REVIEW QUESTIONS

1. Describe the characteristics of working memory, short-term memory and long-term memory.
2. Distinguish between procedural, declarative, explicit and implicit memories, and between the two kinds of explicit retrieval.
3. Explain how information is encoded in long-term memory using deep and shallow processing.
4. Describe techniques for retrieving information from long-term memory.
5. Outline the seven characteristics of human memory systems that can regularly cause memory failures.

DISCUSSION QUESTIONS

1. How are working memory and long-term memory related?
2. Is the eyewitness on trial when giving evidence in legal cases?
3. How accurate are repressed memories?

APPLICATION QUESTIONS

1. Test your understanding of the different memory types discussed in this chapter by matching each of the scenarios listed here with one of the following: declarative memory, episodic memory, explicit memory, implicit memory, flashbulb memory, everyday memory, procedural memory, prospective memory, retrospective memory and semantic memory.
   (a) Although it has been quite a few years since George had ridden his bike, he is able to pedal down the road after a bit of a wobbly start.
   (b) In a tutorial, Yin can recognise a number of word pairs she memorised from a word list that was provided in the lecture.
   (c) While going through some old honeymoon photos, Tricia recalls how beautiful and blue the ocean looked in the full moonlight.
   (d) Antonio shuts down his computer before leaving work for the day.

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(e) Carla intends to stop at the nursery and buy some trees and shrubs to plant in the garden this weekend.
(f) Goran recalls with confidence that Sir Edmund Barton was the first Prime Minister of Australia.
(g) Rodney reminds himself to phone his friend Himesh to wish him a happy birthday.
(h) Maria is 80 years old but clearly recalls the fond memory of her first kiss, as though it happened yesterday.
(i) Sharon recalls precisely where and when she was when she first heard the news of Princess Diana's death in 1997.
(j) Chris was introduced to Russell, Abdul and Mischa at a conference but cannot remember their names when he runs into them at another function the next day.

2. Test your understanding of why forgetting occurs by identifying the theory of forgetting in each of the following scenarios. Choose from decay theory, proactive interference, retroactive interference and motivated forgetting.
(a) Jung does not like presenting in front of others and forgets when she is scheduled to give a class presentation.
(b) Michelle has just moved house and is constantly confusing her old home phone number with her new one.
(c) Matthew flicks through his baby album on his twenty-first birthday and is amazed by how much he has forgotten about his early milestones. His earliest remaining memory is that he loved riding his tricycle when he was three years old.
(d) Six-year-old Sharif goes to swimming lessons and learns the freestyle kick, shortly followed by the butterfly kick. At swimming lessons the next day, he confuses the butterfly kick with the freestyle kick.

The solutions to the application questions can be found at the end of the book.

MULTIMEDIA RESOURCES

iStudy featuring Cyberpsych is a multimedia resource to accompany this textbook to further develop your understanding of many key psychology concepts. It contains a wealth of rich media content and activities, and for this chapter includes:

- video case studies on unforgettable memories and eyewitness testimony
- interactive modules on declarative versus procedural memory, amnesia and enhancing memory.

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