CHAPTER 17

MEMORY AND FORGETTING

- The meanings of 'memory'
- Storage
- Retrieval
- The multi-store model (MSM)
- Alternatives to the MSM
- Theories of forgetting

INTRODUCTION and OVERVIEW

As we noted in Chapter 11, learning and memory represent two sides of a coin: learning depends on memory for its 'permanence', and memory would have no 'content' without learning. Hence, we could define memory as the retention of learning and experience.

Blakemore (1988) expresses the fundamental importance of memory like this:

> *... Without the capacity to remember and to learn, it is difficult to imagine what life would be like, whether it could be called living at all. Without memory, we would be servants of the moment, with nothing but our innate reflexes to help us deal with the world. There could be no language, no art, no science, no culture. Civilisation itself is the distillation of human memory ...*

Both learning and memory featured prominently in the early years of Psychology as a science (see Chapters 1, 3 and 11). William James was arguably the first to make a formal distinction between *primary* and *secondary memory*, which correspond to *short-term* and *long-term memory* respectively. This distinction is central to Atkinson and Shiffrin's (1968, 1971) very influential *multi-store model* (MSM).

As with other cognitive processes, memory remained a largely unacceptable area for psychological research until the cognitive revolution of the mid-1950s, reflecting the dominance of Behaviourism up until this time. However, some Behaviourists, especially in the USA, studied 'verbal behaviour' using paired–associate learning. This *associationist approach* was (and remains) most apparent in *interference theory*, an attempt to explain forgetting. Other theories of forgetting include *trace decay*, *displacement*, *cue-dependent forgetting* and *repression*.

Several major accounts of memory have emerged from criticisms of the limitations of the MSM. These include Craik and Lockhart's *levels-of-processing* approach, Baddeley and Hitch's *working-memory model*, and attempts to identify different types of long-term memory (e.g. Tulving, 1972). Psychologists are increasingly interested in *everyday memory*, rather than studying it merely as a laboratory phenomenon.

THE MEANINGS of 'MEMORY'

Memory, like learning, is a *hypothetical construct* denoting three distinguishable but interrelated processes:

- *registration* (or *encoding*) – the *transformation* of sensory input (such as a sound or visual image) into a form which allows it to be entered into (or registered in) memory. With a computer, for example, information can only be encoded if it's presented in a format the computer recognises
- *storage* – the operation of *holding* or *retaining* information in memory. Computers store information by means of changes in the system's electrical circuitry; with people, the changes occurring in the brain allow information to be stored, though exactly what these changes involve is unclear
- *retrieval* – the process by which stored information is *extracted* from memory.

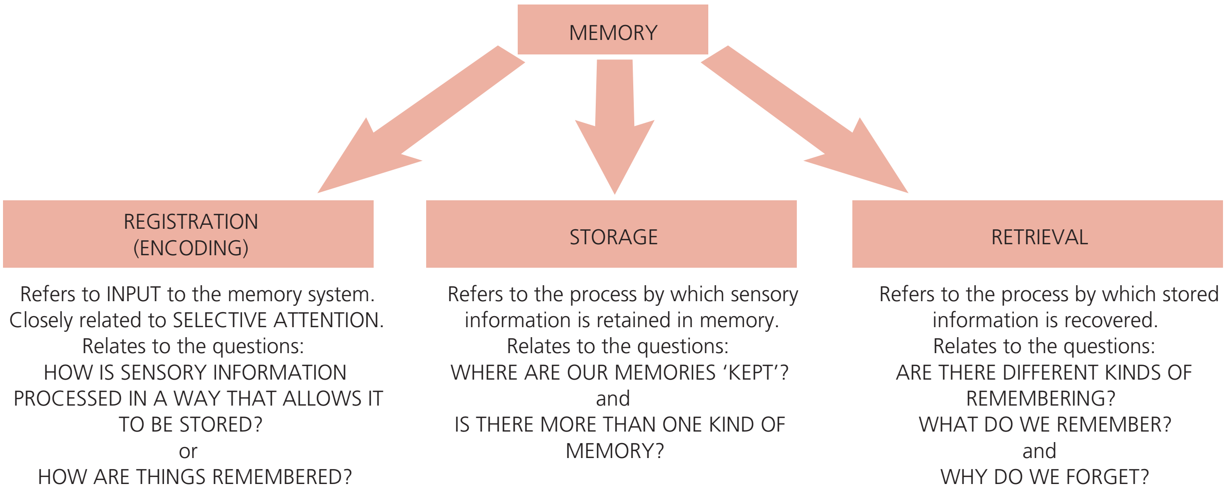

Figure 17.1 The three processes of memory

Registration can be thought of as a necessary condition for storage to take place, but not everything which registers on the senses is stored. Similarly, storage is a necessary, but not sufficient, condition for retrieval: we cannot recover information which hasn't been stored, but the fact that we know it is no guarantee that we'll remember it on any particular occasion. This is the crucial distinction between *availability* (whether or not the information has been stored) and *accessibility* (whether or not it can be retrieved), which is especially relevant to theories of forgetting.

Ebbinghaus (1885), the pioneer of memory research, would have accepted James' distinction between primary and secondary memory. Many Psychologists since James have also made the distinction, including Hebb (1949), Broadbent (1958), and Waugh and Norman (1965). In Atkinson and Shiffrin's (1968, 1971) multi-store model, they're called short-term memory (STM) and long-term memory (LTM) respectively. Strictly, STM and LTM refer to experimental procedures for investigating short-term and long-term *storage* respectively.

STORAGE

Ask Yourself

- Can saying 'I can't remember' mean different things?
- Do you consider yourself to have a 'good/poor' memory? What criteria do you apply in making that assessment?

In practice, storage is studied through testing people's ability to retrieve. This is equivalent to the distinction between learning and performance: learning corresponds to storage, while performance corresponds to retrieval (see Chapter 11). But there are several kinds of retrieval (see below). So, if we're tested by *recall* it may look as though we haven't learned something, but a test of *recognition* may show that we have. For these reasons, it's useful to distinguish between *memory as storage* and *memory as retrieval*. When people complain about having a 'poor memory', they might mean storage or retrieval.

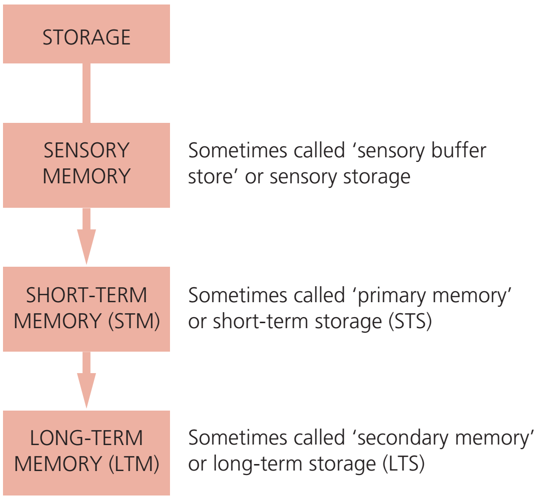

Figure 17.2 The three forms of storage

Sensory memory

Sensory memory gives us an accurate account of the environment as experienced by the sensory system. We retain a 'literal copy' of the stimulus long enough for us to decide whether it's worthy of further processing. Any information we don't attend to or process further is forgotten. It's probably more useful to think of sensory memory as an aspect of perception and as a necessary requirement for storage proper (that is, STM).

There's a definite resemblance between sensory memory (or storage) and Broadbent's sensory 'buffer' store (Eysenck and Keane, 1990: see Chapter 13); Broadbent's *filter model of selective attention* was, in many ways, the main precursor of the multi-store approach to memory (see below).

Short-term memory (STM)

Probably less than one-hundredth of all the sensory information that impinges on the human senses every second reaches consciousness; of this, only about 5 per cent is stored permanently (Lloyd *et al.*, 1984). Clearly, if we possessed only sensory memory, our capacity for retaining information about the world would be extremely limited. However, according to the MSM, some information from sensory memory is successfully passed on to STM.

STM (and LTM) can be analysed in terms of:

- *capacity* – *how much* information can be stored
- *duration* – *how long* the information can be held in storage
- *coding* – *how* sensory input is represented by the memory system.

Capacity

Ebbinghaus (1885) and Wundt (in the 1860s) were two of the first Psychologists to maintain that STM is limited to six or seven bits of information. But the most famous account is given by Miller (1956) in his article 'The magical number seven, plus or minus two'. Miller showed how *chunking* can be used to expand the limited capacity of STM by using already established memory stores to categorise or encode new information.

If we think of STM's capacity as seven 'slots', with each slot being able to accommodate one bit or unit of information, then seven individual letters would each fill a slot and there'd be no 'room' left for any additional letters. But if the letters are chunked into a word, then the word would constitute one unit of information, leaving six free slots. In the example below, the 25 bits of information can be chunked into (or reduced to) six words, which could quite easily be reduced further to one 'bit' (or chunk) based on prior familiarity with the words:

S	A	V	A	O
R	E	E	E	G
U	R	S	Y	A
O	O	D	N	S
F	C	N	E	R

To be able to chunk, you have to know the 'rule' or the 'code', which in this case is: starting with F (bottom left-hand corner) read upwards until you get to S and then drop down to C and read upwards until you get to A, then go to N and read upwards and so on. This should give you 'four score and seven years ago'.

Chunking is involved whenever we reduce a larger amount of information to a smaller amount. This (a) increases the capacity of STM, and (b) represents a form of encoding information, by imposing a *meaning* on otherwise meaningless material. For example:

- arranging letters into words, words into phrases, phrases into sentences
- converting 1066 (four bits of information) into a date (one chunk), so a string of 28 numbers could be reduced to seven dates
- using a rule to organise information: the series 149162536496481100121 (21 bits) is generated by the rule by which 1[squared] = 1, 2[squared] = 4, 3[squared] = 9, and so on. The rule represents a single chunk, and that's all that has to be remembered.

These examples demonstrate how chunking allows us to bypass the seven-bit 'bottleneck'. Although the amount of information contained in any one chunk may be unlimited (e.g. the rule above can generate an infinitely long set of digits), the number of chunks which can be held in STM is still limited to seven plus or minus two.

Duration

A way of studying 'pure' STM was devised by Brown (1958) and Peterson and Peterson (1959), and is called the *Brown–Peterson technique*. By repeating something that has to be remembered (*maintenance rehearsal*), information can be held in STM almost indefinitely. (See Key Study 17.1.)

Coding

Conrad (1964) presented participants visually with a list of six consonants (such as BKSJLR), each of which was seen for about three-quarters of a second. They were then instructed to write down the consonants. Mistakes tended to be related to a letter's *sound*. For example, there were 62 instances of B being mistaken for P, 83 instances of V being mistaken for P, but only two instances of S being mistaken for P. These *acoustic confusion errors* suggested to Conrad that STM must code information according to its sound. Even when information is presented visually, it must somehow be transformed into its acoustic code (see also Baddeley's, 1966, study below).

Critical Discussion 17.1

Is there a magical number after all?

Ask Yourself

- How many capital cities can you name?
- Note any pattern of remembering that occurs.

Broadbent (1975) questioned just how fundamental the number seven actually is. Although people typically remember up to about seven items, perhaps more meaningful was the number of items people could remember *flawlessly* (because, presumably, those items are recalled without relying on a mental strategy that can fail). Memory was nearly flawless for sets of only *three* items: adding a fourth or fifth item resulted in a set that could usually be recalled correctly, and adding more made things more difficult. Broadbent pointed out that when we try to recall items from a category in *LTM*, we tend to do so in bursts of three items.

According to Cowan (2001), across many types of experiment, there exists something like a semi-magical number *four* (plus or minus two, varying across individuals and situations). This applies only to procedures in which the items are well known and in which it's impossible to form larger chunks. Based on a review of recent research, Cowan *et al.* (2007) conclude by saying that the limit of three or four chunks serves as a useful guideline for theory and research.

Key Study 17.1

The Brown–Peterson technique (Peterson and Peterson, 1959)

- In the *Brown–Peterson technique,* participants hear various *trigrams* (such as XPJ). Only one trigram is presented on each trial. Immediately afterwards, they're instructed to recall what they heard or to count backwards, in threes, out loud, from some specified number for 3, 6, 9, 12, 15 or 18 seconds (the *retention interval*). The function of this *distractor task* is to prevent rehearsal. At the end of the time period, participants try to recall the trigram.
- Peterson and Peterson found that the average percentage of correctly recalled trigrams was high with short delays, but decreased as the delay interval increased. Nearly 70 per cent was forgotten after only a nine-second delay, and 90 per cent after 18 seconds.
- In the absence of rehearsal, then, STM's duration is very short, even with very small amounts of information. If a more difficult distractor task is used, it can be made even shorter.

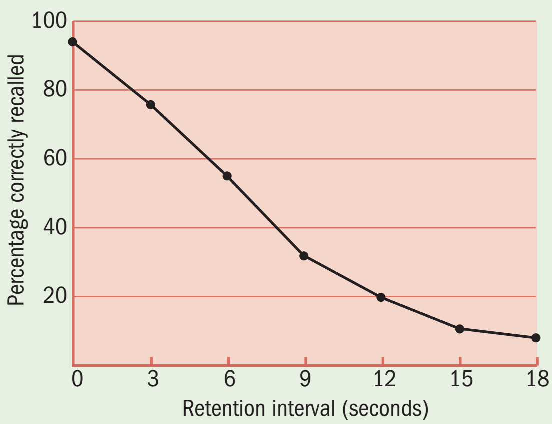

Figure 17.3 The data reported by Peterson and Peterson in their experiment on the duration of STM

Other forms of coding in STM

Shulman (1970) showed participants lists of ten words. Recognition of the words was then tested using a visually presented 'probe word', which was either:

- a *homonym* of one of the words on the list (such as 'bawl' for 'ball')
- a *synonym* (such as 'talk' for 'speak'), or
- *identical* to it.

Ask Yourself

- Shulman found that homonym and synonym probes produced similar error rates.
- What does this tell us about the types of coding used in STM?

If an error was made on a synonym probe, some matching for meaning must have taken place (i.e. *semantic coding*).

Visual images (such as abstract pictures, which would be difficult to store using an acoustic code) can also be maintained in STM, if only briefly.

Long-term memory (LTM)

Capacity and duration

It's generally accepted that LTM has *unlimited* capacity. It can be thought of as a vast storehouse of all the information, skills, abilities and so on, which aren't being currently used, but which are potentially retrievable. According to Bower (1975), some of the kinds of information contained in LTM include:

- a spatial model of the world around us
- knowledge of the physical world, physical laws and properties of objects
- beliefs about people, ourselves, social norms, values and goals
- motor skills, problem-solving skills, and plans for achieving various things
- perceptual skills in understanding language, interpreting music, and so on.

Many of these are included in what Tulving (1972) calls *semantic memory* (see below).

Information can be held for between a few minutes and several years (and may in fact span the individual's entire lifetime).

Coding

With verbal material, coding in LTM appears to be mainly semantic. For example, Baddeley (1966) presented participants with words which were either:

- *acoustically similar* (e.g. 'caught', 'short', 'taut', 'nought')
- *semantically similar* (e.g. 'huge', 'great', 'big', 'wide')
- *acoustically dissimilar* (e.g. 'foul', 'old' and 'deep'), or
- *semantically dissimilar* (e.g. 'pen', 'day', 'ring').

When recall from STM was tested, acoustically similar words were recalled less well than acoustically dissimilar words. This supports the claim that acoustic coding occurs in STM. There was a small difference between the number of semantically similar and semantically dissimilar words recalled (64 and 71 per cent respectively). This suggests that while some semantic coding occurs in STM, it's not dominant.

When an equivalent study was conducted on LTM, fewer semantically similar words were recalled, while acoustically similar words had no effect. This suggests that LTM's dominant code is semantic. Similarly, Baddeley found that immediate recall of the order of short lists of unrelated words was seriously impeded if the words were acoustically similar, but not if they were semantically similar. After a delay, however, exactly the opposite effect occurred.

Does LTM use only semantic coding?

Findings such as Baddeley's don't imply that LTM uses only a semantic code (Baddeley, 1976). Our ability to picture a place we visited on holiday indicates that at least some information is stored or coded visually. Also, some types of information in LTM (such as songs) are coded acoustically. Smells and tastes are also stored in LTM, suggesting that it's a very flexible system, as well as being large and long-lasting.

Table 17.1 Summary of main differences between STM and LTM

	Capacity	Duration	Coding
STM	Seven bits of (unrelated) information. Can be increased through *chunking*	15–30 seconds (unaided). Can be increased by (maintenance) rehearsal	Mainly acoustic. Some semantic. Visual is also possible
LTM	Unlimited	From a few seconds to several years (perhaps permanently)	Semantic, visual, acoustic, and also olfactory (smells) and gustatory (tastes). Very flexible

RETRIEVAL

There are many different ways of recovering or locating information which has been stored; that is, 'remembering' can take many different forms. Likewise, there are also different ways of measuring memory in the laboratory.

How is memory measured?

The systematic scientific investigation of memory began with Ebbinghaus (1885). (See Key Study 17.2.)

Other techniques include the following:

- *Recognition:* This involves deciding whether or not a particular piece of information has been encountered before (as in multiple-choice tests, where the correct answer is presented along with incorrect ones). The sensitivity of recognition as a form of retrieval is demonstrated by Standing (1973). (See Key Study 17.3.)
- *Recall:* This involves participants actively searching their memory stores in order to retrieve particular information (as in timed essays). Retrieval cues are missing or very sparse. The material can be recalled either in the order in which it was presented (*serial recall*) or in any order at all (*free recall*).
- *Memory-span procedure:* This is a version of serial recall: a person is given a list of unrelated digits

Key Study 17.2

Pure memory (Ebbinghaus, 1885)

- To study memory in its 'purest' form, Ebbinghaus invented three-letter nonsense syllables (a consonant followed by a vowel followed by another consonant, such as XUT and JEQ).
- Ebbinghaus spent several years using only himself as the subject of his research. He read lists of nonsense syllables out loud, and when he felt he'd recited a list sufficiently to retain it, he tested himself. If he could recite a list correctly *twice* in succession, he considered it to be learned. After recording the time taken to learn a list, he then began another one.
- After specific periods of time, he'd return to a particular list and try to memorise it again. He calculated the number of attempts (or trials) it took him to relearn the list, as a percentage of the number of trials it had originally taken to learn it (a *savings score*).
- He found that memory declines sharply at first, but then levels off. For example, in one set of experiments involving a series of eight different lists of 13 nonsense syllables, he found savings scores of:
  - 58 per cent, 20 minutes after training
  - 44 per cent, 60 minutes after training
  - 34 per cent, 24 hours after training
  - 21 per cent, 31 days after training.

... Thus, most of the memory loss occurred within the first minutes after training; once the memory had survived this hurdle it seemed much more stable ...
(Rose, 2003)

This finding has subsequently been replicated many times.

Key Study 17.3

Recognising how to ask people to remember (Standing, 1973)

- Participants were shown series of slides of either pictures or words (20 or so per series), each slide for five seconds, and each series at three-minute intervals. Two days later they were shown further series of slides using a double projector. Thus they saw two pictures side by side, one taken from the original series, the other being new. They had to indicate which looked more familiar.
- Amazingly, as the number of images went on increasing up to 10,000, the error rate didn't seem to increase at all with the number of items to be remembered. Standing concluded that, for all practical purposes, there's no upper limit to memory capacity.
- Contrary to the evidence that there are limits to what's transferred from STM to LTM (see text below), it seems that some accessible trace of each item must have been left – enough to enable a new item to be compared with the trace and classified as familiar or unfamiliar. According to Rose (2003):

... On this basis, it could be argued that nothing is forgotten, provided we know how to ask if it is remembered ...

or letters, and then required to repeat them back immediately in the order in which they were heard. The number of items on the list is successively increased until an error is made. The maximum number of items that can consistently be recalled correctly is a measure of *immediate memory span*.

- *Paired-associate recall:* Participants are required to learn a list of paired items (such as 'chair' and 'elephant'). When one of the words (e.g. 'chair') is re-presented, the participant must recall the paired word ('elephant').

THE MULTI-STORE MODEL (MSM)

Atkinson and Shiffrin's (1968, 1971) *multi-store model* (MSM) (sometimes called the *dual-memory model* because of the emphasis on STM and LTM) tried to explain how information flows from one storage system to another. The model sees sensory memory, STM and LTM as *permanent structural components* of the memory system (built-in features of the human information-processing system). In addition, the memory system comprises more *transient control processes*, of which *rehearsal* is key. Rehearsal serves two main functions:

1. to act as a *buffer* between sensory memory and LTM by maintaining incoming information within STM
2. to *transfer* information to LTM.

Information from sensory memory is scanned and matched with information in LTM, and if a match (i.e. *pattern recognition*) occurs, then it might be fed into STM along with a verbal label from LTM. (See Figure 17.4.)

Evidence for the MSM

Three kinds of evidence are relevant here:

1. experimental studies of STM and LTM (sometimes referred to as *two-component tasks*)
2. studies of *coding*
3. studies *of brain-damaged patients.*

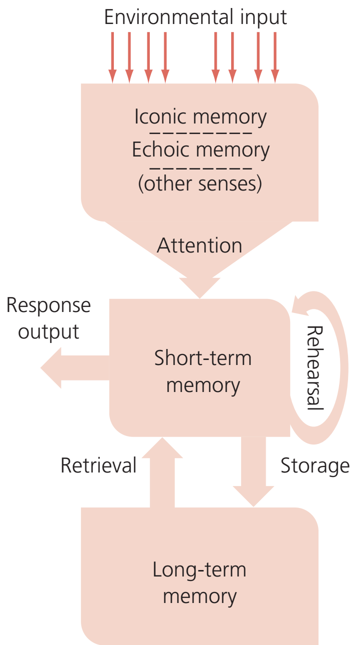

Figure 17.4 The multi-store/dual-memory model of memory proposed by Atkinson and Shiffrin

Experimental studies of STM and LTM

The serial position effect

Murdock (1962) presented participants with a list of words at a rate of about one per second; they were required to free-recall as many of these as they could. The probability of recalling any word depended on its position in the list (its *serial position*).

Participants typically recalled those items from the end of the list first, and got more of these correct than earlier items (the *recency effect*). Items from the beginning of the list were recalled quite well relative to those in the middle (the *primacy effect*), but not as well as those at the end. Poorest recall is for items in the middle. The serial position effect holds regardless of the length of the list (Murdock, 1962).

Ask Yourself

- Using what you already know about STM, LTM and rehearsal, try to explain:
  (a) the primacy and recency effects
  (b) why words in the middle of the list are the least well remembered.

The primacy effect occurs because the items at the beginning of the list have (presumably) been rehearsed and transferred to LTM, from where they're recalled. The recency effect presumably occurs because items currently in STM are recalled from there. Because STM's capacity is limited and can hold items for only a brief period of time, words in the middle are either lost from the system completely, or are otherwise unavailable for recall. The last items are remembered only if recalled first and tested immediately, as demonstrated by Glanzer and Cunitz (1966) in a variation of Murdock's study. (See Key Study 17.4.)

Key Study 17.4

Removing the recency effect (Glanzer and Cunitz, 1966)

- Glanzer and Cunitz presented two groups of participants with the same list of words. One group recalled the material *immediately* after presentation, while the other group recalled *after 30 seconds*. They had to count backwards in threes (the Brown–Peterson technique), which prevented rehearsal and caused the recency effect to disappear.
- The primacy effect was largely unaffected.

Ask Yourself

- Try to account for Glanzer and Cunitz's findings.

It's likely that the earlier words had been transferred to LTM (from where they were recalled), while the most recent words were 'vulnerable' to the counting task (Eysenck, 1993).

Brown–Peterson technique and rehearsal

While the rapid loss of information when rehearsal is prevented using the Brown–Peterson technique is usually taken as evidence for the existence of a STM with rapid forgetting, the concept of rehearsal itself has been criticised as both unnecessary and too general.

Key Study 17.5

Maintenance versus elaborative rehearsal (Craik and Watkins, 1973)

- Craik and Watkins asked participants to remember only certain 'critical' words (those beginning with a particular letter) from lists presented either rapidly or slowly. The position of the critical words relative to the others determined the amount of time a particular word spent in STM, and the number of potential rehearsals it could receive.
- Long-term remembering was unrelated to either how long a word had spent in STM, or the number of explicit or implicit rehearsals it received.
- Based on this and later findings, Craik and Watkins distinguished between:
  - (a) *maintenance rehearsal*, where material is rehearsed in the form in which it was presented ('rote'), and
  - (b) *elaborative rehearsal* (or *elaboration of encoding*), which elaborates the material in some way (such as by giving it a meaning, or linking it with pre-existing knowledge stored in LTM).

It seems that what's important is the *kind* of rehearsal or processing, rather than how much. This has been investigated in particular by Craik and Lockhart (1972), in the form of the levels-of-processing approach (see below).

Studies of coding

Table 17.1 indicates that the major form of coding used in STM is acoustic, while LTM coding is much more flexible and varied. It also suggests that semantic coding is used primarily by LTM; while this is usually taken to support the MSM, not everyone accepts this view.

Chunking, STM and LTM

According to Miller (1956), chunking represents a *linguistic recoding* which seems to be the 'very lifeblood of the thought process'. But this cannot occur until certain information in LTM is activated, and a match made between the incoming items and their representation in LTM.

Miller and Selfridge (1950) gave participants 'sentences' of varying lengths, which resembled (or approximated to) true English to different degrees, and asked them to recall the words in their correct order. The closer a 'sentence' approximated normal English, the better it was recalled. This suggests that knowledge of semantic and grammatical structure (presumably stored in LTM) is used to aid recall from STM.

Clearly, an acoustic code isn't the only one used in STM. According to Wickelgren (1973), the kind of coding might reflect the processing which has occurred in a given context, rather than being a property of the memory store itself.

The study of brain-damaged patients

Anterograde amnesia and the amnesic syndrome

If STM and LTM really are distinct, then there should be certain kinds of brain damage which impair one without affecting the other. One such form of brain damage is *anterograde amnesia*. (See Case Study 17.1.)

Prior to the 1960s, the hippocampus was seen as a direct *storehouse* of memories. Since H.M.'s cortex was undamaged, it made sense that his semantic memories would be intact (see Focus 17.1). Then, in the 1960s, Wickelgren first proposed that the hippocampal region (the *builder*) facilitates the creation of permanent memories in the cortex (the *repository*).

Based on a steady decline in H.M.'s ability to define, spell, find the right words to describe an object, identify line drawings of common objects, and pronounce words familiar to him before his surgery, MacKay (2014, 2017; MacKay and Johnson, 2013) reasoned that the hippocampal region must be involved not just in making new memories, but *preserving old ones*. The hippocampus can craft new memories to replace those that have been degraded or fragmented with time. In H.M.'s case, this hippocampal maintenance system was defunct: he had no way of rejuvenating depleted memories through practice or relearning (Mackay, 2014, 2017); compared with others in their early 70s, his *lexical* memories were dramatically inferior.

An equally dramatic but in many ways more tragic case is that of Clive Wearing. (See Case Study 17.2.)

Ask Yourself

- In what ways do the cases of H.M. and Clive Wearing support the MSM?
- In what ways do they challenge it?

Case Study 17.1

H.M. (MacKay, 2017; Milner *et al.*, 1968)

- H.M. (Henry Molaison) is probably the single most studied amnesic patient in the history of Neuropsychology (Rose, 2003). He'd been suffering epileptic fits of devastating frequency since the age of 16. In 1954 (aged 27), he underwent surgery aimed at alleviating his epilepsy. The anterior two-thirds of his hippocampus, most of his amygdala, plus part of the temporal lobe (on both sides of his brain) were removed (see Chapter 4).
- While this was fairly successful in curing his epilepsy, he was left with severe *anterograde amnesia*: he had near normal memory for anything learned *before* the surgery, but severe memory deficits for events that occurred afterwards.
- He showed preserved STM (e.g. immediate memory span) and episodic memory (see Focus 17.1), could retain verbal information for about 15 seconds without rehearsal, and for much longer with rehearsal. But he couldn't transfer information into LTM or, if he could, was unable to retrieve it. He seemed entirely incapable of remembering any new fact or event.
- He was able to learn and remember perceptual and motor skills, but had to be reminded each day just what skills he possessed.
- He forgot all the news almost as soon as he'd read about it, had no idea what time of day it was unless he'd just looked at the clock, couldn't remember that his father had died or that his family had moved house. He reread the same magazine without realising he'd already read it.
- People he met after the operation remained, in effect, total strangers to him. Brenda Milner knew him for 25 years, yet she was a stranger to him each time they met. He died in 2008.

Case Study 17.2

Clive Wearing (based on Baddeley, 1990; Blakemore, 1988; Wearing, 2005)

- Clive Wearing was the chorus master of the London Sinfonietta and a world expert on Renaissance music, as well as a BBC radio producer. In March 1985, he suffered a rare brain infection caused by the cold sore virus (*Herpes simplex*). The virus attacked and destroyed his hippocampus, along with parts of his cortex.
- Like H.M., he lives in a snapshot of time, constantly believing that he's just awoken from years of unconsciousness. For example, when his wife, Deborah, enters his hospital room for the third time in a single morning, he embraces her as if they'd been parted for years, saying, 'I'm conscious for the first time' and 'It's the first time I've seen anybody at all'.
- At first, his confusion was total and very frightening to him. Once he held a chocolate in the palm of one hand, and covered it with the other for a few seconds until its image disappeared from his memory. When he uncovered it, he thought he'd performed a magic trick, conjuring it up from nowhere. He repeated it again and again, with total astonishment and growing fear each time.
- Like H.M., he can still speak and walk, as well as read music, play the organ and conduct. In fact, his musical ability is remarkably well preserved. Also like H.M, he can learn new skills (e.g. mirror-reading), which he performed just as well three months later. Yet for Clive, it's new every time.
- But unlike H.M., his capacity for remembering his earlier life is extremely patchy. For example, when shown pictures of Cambridge (where he'd spent four years as an undergraduate and had often visited subsequently) he only recognised King's College Chapel – the most distinctive Cambridge building – but not his own college. He couldn't remember who wrote *Romeo and Juliet*, and he thought the Queen and the Duke of Edinburgh were singers he'd known from a Catholic church.
- According to Deborah, 'without consciousness he's in many senses dead'. In his own words, his life is 'Hell on earth – it's like being dead – all the bloody time'.
- This illustrates dramatically a *loss of time awareness*, showing how fundamental memory – in particular episodic memory – is to our sense of identity and our ability to function in society (Corballis, 2011).

Atkinson and Shiffrin regard the kind of memory deficits displayed by H.M. and Clive Wearing as 'perhaps the single most convincing demonstration of a dichotomy in the memory system'. According to Parkin (1987), the *amnesic syndrome* (AS) isn't a general deterioration of memory function, but a *selective impairment* in which some functions (such as learning novel information) are severely impaired, while others (including memory span and language) remain intact.

If amnesics do have an intact STM, they should show a similar recency effect (based on STM) but a poorer primacy effect (based on LTM) compared with normal controls. This is exactly what's found (e.g. Baddeley and Warrington, 1970). However, this difference in STM and LTM functioning could mean that:

- the problem for amnesics is one of *transfer* from STM to LTM, which is perfectly consistent with the MSM, or, alternatively
- amnesics have difficulties in *retrieval* from LTM (Warrington and Weiskrantz, 1968, 1970).

Another major implication of cases such as those of H.M. and Clive Wearing is that the MSM's *unitary* LTM is a gross oversimplification (see the next section).

Retrograde amnesia

In *retrograde amnesia,* a patient fails to remember what happened *before* the surgery or accident that caused the amnesia. It can be caused by head injuries, electroconvulsive therapy (ECT: see Chapter 45), carbon monoxide poisoning, and extreme stress (see Chapter 12). As in anterograde amnesia, there's typically little or no disruption of STM, and the period of time for which the person has no memories may be minutes, days or even years. When retrograde amnesia is caused by brain damage, it's usually accompanied by anterograde amnesia. Similarly, patients with Korsakoff's syndrome (caused by severe, chronic alcoholism involving damage to the hippocampus) usually experience both kinds of amnesia.

Retrograde amnesia seems to involve a disruption of *consolidation* whereby, once new information has entered LTM, time is needed for it to become firmly established physically in the brain (see the discussion of forgetting below).

ALTERNATIVES to the MSM

Multiple forms of LTM

Episodic and semantic memory

Despite their brain damage, H.M. and Clive Wearing retained many skills, both general and specific (such as talking, reading, walking, playing the organ). They were also capable of acquiring (and retaining) new skills – although they didn't know that they had them! This suggests very strongly that there are different kinds of LTM. But as far as the MSM is concerned, there's only 'LTM'.

Our 'general' knowledge about, say, computers (part of semantic memory or 'SM') is built up from past experiences with particular computers (part of episodic memory or 'EM'), through abstraction and generalisation. This suggests that, instead of regarding EM and SM as two quite distinct systems within the brain (which is what Tulving originally intended), it might be more valid to see SM as made up from multiple EMs (Baddeley, 1995). (See Focus 17.1.)

Flashbulb memories

Flashbulb memories (FMs) are a special kind of EM, in which we can give vivid and detailed recollections of where we were and what we were doing when we first heard about some major public national or international event (Brown and Kulik, 1977).

Focus 17.1 Episodic and semantic memory (Tulving, 1972)

Episodic memory (EM): an 'autobiographical' memory responsible for storing a record of our past experiences – the events, people, objects and so on which we've personally encountered. EMs usually have a *spatio-temporal context* (e.g. 'What did you have for breakfast this morning?'). They have a *subjective* (self-focused) reality, but most could, in principle, be verified by others.

Semantic memory (SM): our store of general, factual knowledge about the world, including concepts, rules and language, 'a mental thesaurus, organised knowledge a person possesses about words and other verbal symbols, their meanings and referents' (Tulving, 1972). SM can be used without reference to where and when that knowledge was originally acquired. But SM can also store personal information (such as how many siblings we have, or how much we like Psychology).

Ask Yourself

- Where were you and what were you doing when you heard about the Grenfell Tower fire?

Figure 17.5 Grenfell Tower tragedy, 14 June 2017

According to Brown and Kulik (1982), a neural mechanism is triggered by events that are emotionally arousing, unexpected or extremely important, with the result that the whole scene becomes 'printed' on the memory. But how accurate are they? (See Focus 17.2.)

Focus 17.2 FMs: how accurate are they?

- Memories formed under strong emotions are often considerably distorted: they seem so vivid that we have a misplaced confidence in their accuracy (Chen, 2012).
- Hirst *et al.* (2009) surveyed more than 3000 people in New York, Washington and five other US cities one week after the 9/11 terrorist attacks, in subsequent years (and again in 2011). Compared with their initial reports, participants were only 63 per cent correct on the when-where-how details one year later; after that, the decline slowed. Yet they were 'absolutely confident' that their memory was correct.
- Surprisingly, people were least accurate when describing their emotional state on 9/11 (42 per cent accuracy one year later). Initial shock may give way to sadness or frustration over time; we tend to *reconstruct* our emotional past in a way that's consistent with how we're *currently* emotionally reacting. (See Chapters 10 and 21.)
- However, accuracy for the key details, such as the number of hijacked planes and crash sites, was better. This can be explained (at least in part) by the repeated and ongoing media coverage: our memory isn't independent of the larger social context we live in.
- Similarly, Neisser (1982) argues that the durability of FMs stems from their frequent rehearsal and retelling after the event.

Procedural versus declarative memory

Procedural memory (PM) refers to information from LTM which cannot be inspected consciously (Anderson, 1985; Tulving, 1985). For example, riding a bike is a complex skill which is even more difficult to describe. In the same way, native speakers of a language cannot usually describe the complex grammatical rules by which they speak correctly (perhaps because they weren't learned consciously in the first place: see Chapter 19). By contrast, EM and SM are both amenable to being inspected consciously, and the content of both can be described to another person.

Cohen and Squire (1980) distinguish between PM and *declarative memory* (DM), which corresponds to Ryle's (1949) distinction between *knowing how* and *knowing that* respectively (see Figure 17.8). Anderson (1983) argues that when we initially learn something, it's learned and encoded declaratively, but with practice it becomes compiled into a procedural form of knowledge. (This is similar to the distinction between controlled/automatic processing discussed in Chapter 13.)

PM involves more automatic processes, and allows patients to demonstrate learning without the need for

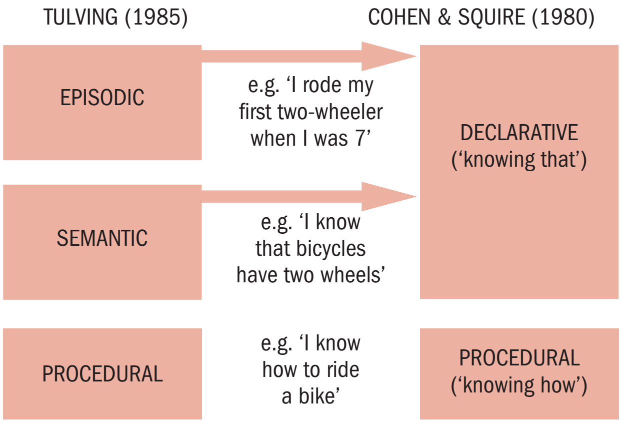

Figure 17.6 Distinctions between different kinds of LTM

conscious recollection of the learning process. But DM involves conscious recollection of the past. Damage to a number of cortical and subcortical areas (including the temporal lobes, hippocampus and mamillary bodies) seriously impairs DM in amnesic patients. PM doesn't appear to be impaired by damage to these areas (Baddeley, 1995).

The working-memory (WM) model: rethinking STM

In their MSM, Atkinson and Shiffrin saw STM as a system for temporarily holding and manipulating information. However, Baddeley and Hitch (1974) criticised the model's concept of a *unitary* STM. While accepting that STM rehearses incoming information for transfer to LTM, they argued that it was much more complex and versatile than a mere 'stopping-off station' for information. Instead of a single, simple STM, Baddeley and Hitch proposed a more complex, *multi-component* WM. This comprises a *central executive*, which is in overall charge of *sub-* or *slave systems*. These are the *articulatory* (or *phonological*) *loop* and the *visuospatial scratch* (or *sketch*) *pad*. Later, Baddeley (2000) added a fourth component, the *episodic buffer*.

The central executive

This is thought to be involved in many higher mental processes, such as decision-making, problem-solving and making plans (see Chapter 20). More specifically, it may co-ordinate performance on two separate tasks, and attend selectively to one input while inhibiting others (Baddeley, 1996). Although capacity-limited, it's very flexible and can process information in any sense modality (it's *modality-free*). It resembles a pure attentional system (Baddeley, 1981: see Chapter 13).

The articulatory (or phonological) loop

This is probably the most extensively studied component of the model. It was intended to explain the extensive evidence for acoustic coding in STM (Baddeley, 1997). It can be thought of as a *verbal* *rehearsal loop* used when, for example, we try to remember a telephone number for a few seconds by saying it silently to ourselves. It's also used to hold words we're preparing to speak aloud. It uses an *articulatory/phonological code*, in which information is represented as it would be spoken (the *inner voice*).

Its name derives from the finding that its capacity isn't limited by the number of items it can hold, but by the length of time taken to recite them (Baddeley *et al.*, 1975). Lists of words that took longer to pronounce weren't recalled as well as lists of the same number of words that could be pronounced more quickly. Similarly, the faster you recite something into a microphone, the more words you can record on a short loop of recording tape (Groome *et al.*, 1999).

The visuospatial scratch (or sketch) pad

This can also rehearse information, but deals with visual and/or spatial information as, for example, when we drive along a familiar road, approach a bend, and think about the road's spatial layout beyond the bend (Eysenck, 1986). It uses a visual code, representing information in the form of its visual features such as size, shape, and colour (the *inner eye*).

The scratch pad appears to contain separate visual and spatial components. The *more active spatial component* is involved in movement perception and control of physical actions, while the *more passive visual component* is involved in visual pattern recognition (Logie, 1995).

The episodic buffer

One weakness of the original version of the WM model is that least was known about the most important component, namely the central executive (Hampson and Morris, 1996). It could apparently carry out an enormous variety of processing activities in different conditions, making it difficult to describe its precise function. It was like a *homunculus* ('little man': see Chapter 4) who sits there in the model and can be conveniently called upon whenever the theorist is unsure how to explain something. But if any result can be explained, how do you test and develop the theory? (Baddeley, 2008).

Baddeley's answer is that you try to chip away gradually at the tasks the homunculus is required to perform. In this context, the original assumption that the central executive was a purely attentional system and couldn't itself store information was questioned: how did the phonological loop and visuospatial sketchpad work together if they don't have a common code or language? And how could the whole system interface with LTM?

The *episodic buffer* (EB) was proposed as the answer to these questions. As shown in Figure 17.10, it sits between the slave systems, LTM, and the central executive. It's a limited-capacity (about four episodes or chunks) system that provides temporary storage of information held in a *multimodal code*, which is capable of combining information from the slave systems, and from LTM, into a unitary episodic representation (Baddeley, 2000). So, the EB acts as a buffer between these other parts of WM: when you try to form a mental image of a person's face or voice, all these conscious experiments are assumed to be represented within the EB. At first, it was thought of as being accessible through conscious awareness (it's the stage at which conscious mental action occurs); but it's now seen as an essentially *passive* store:

> *... a television screen rather than a stage, in which the hard work goes on elsewhere, but which depends on the buffer for its display. (Baddeley, 2008)*

Evaluation 17.1

The WM model

- It's generally accepted that (a) STM is better seen as a number of relatively independent processing mechanisms than as the MSM's single unitary store, and (b) attentional processes and STM are part of the same system (they're probably used together much of the time in everyday life). Indeed, Baddeley (e.g. 2007) identified the central executive with the *supervisory attentional system* (SAS) proposed by Norman and Shallice (1980: see Chapter 13).
- The idea that any one slave system (such as the phonological loop) may be involved in the performance of apparently very different tasks (such as memory span, mental arithmetic, verbal reasoning, and reading) is a valuable insight.
- An important *theoretical* development is to ask: why has the phonological loop evolved? (See Focus 17.3.)

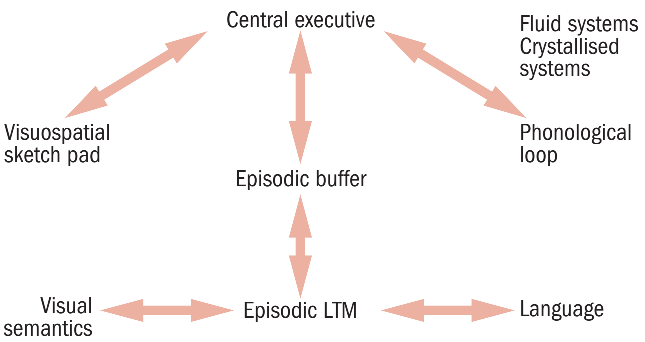

Figure 17.7 The working memory model, showing the central executive and its subsystems

Focus 17.3 Evolution and the phonological loop

- As Baddeley (2008) wittily points out, the phonological loop presumably didn't evolve because nature was preparing us for telephone numbers!
- He tested a patient who, following a stroke, had developed a pure deficit in her phonological STM. After being given a telephone number of more than two digits, she'd immediately forget it. Although her language skills were normal, she had great difficulty in learning new words (such as Russian words). This led Baddeley to suggest that the loop might have evolved for *language learning*.
- Further evidence to support this hypothesis came from the study of 8-year-old children with *specific language impairment.* They had normal general intelligence, but the language development of 6-year-olds. When given non-words (such as *prindle, skiticult* and *contramponist*) to repeat back, they performed like 4-year-olds; as the non-word length increased, so did their failure rate.
- Baddeley also found a correlation between level of vocabulary development in young normal children and their capacity to repeat back non-words; this is what would be expected if the loop had evolved for new word learning.

The levels of processing (LOP) model

Rehearsal and the MSM

As we noted above, the MSM sees rehearsal as a key control process which helps to transfer information from STM to LTM. There's also only one type of rehearsal as far as the model is concerned, what Craik and Watkins (1973) call *maintenance* (as opposed to *elaborative*) rehearsal (see Key Study 17.5). This means that what matters is *how much* rehearsal occurs. But maintenance rehearsal may not even be necessary for storage. Jenkins (1974) found that participants could remember material even though they weren't expecting to be tested – and so were unlikely to have rehearsed the material. This is called *incidental learning*.

According to Craik and Lockhart (1972), what matters is the *kind* of rehearsal or processing; they also considered that the MSM's view of the relationship between structural components and control processes was, essentially, the wrong way round.

Ask Yourself

- How does the MSM see the relationship between structural components and control processes?

Critical Discussion 17.2

Intermind: How Google is changing our memory

- According to Wegner and Ward (2013), the internet is not just replacing other people as sources of memory and someone to share information with, but also our own cognitive faculties, undermining the impulse to ensure that some important, just-learned facts get inscribed into our biological memory banks (the *Google effect*).
- Sparrow *et al.* (2011) asked participants to copy 40 memorable factoids (e.g. 'An ostrich's eye is bigger than its brain') into a computer. Half were told their work would be saved on the computer; the other half were told that it would be deleted. In addition, half of each group was asked to remember the information, regardless of whether it was being saved.
- Those participants who believed the computer had saved their work were much *worse* at remembering; this tendency persisted when they were explicitly asked to keep the information in mind.
- The internet comes to mind quickly when we don't know the answer to a question: our first impulse is to think of our all-knowing 'friend' that can provide the information we need.
- Research has shown that participants who have just found answers on a website experience the illusion that their *own* mental capacities had produced this information – not Google. Using Google gives people the sense that the internet has become part of their own cognitive tool set.

... The advent of the 'information age' seems to have created a generation of people who feel they know more than ever before – when their reliance on the internet means that they may know ever less about the world around them. (Wegner and Ward, 2013)

- For now, technology seems to be tweaking rather than replacing our capacity for memory – but in the future there may be a much greater merging of the interface between us and machines; our brain will begin to adapt to this and we may become increasingly dependent on that interface (Thomson, 2018). One such human-machine interface is a cyborg, a being (organism) with restored – or enhanced – functions and abilities due to the insertion/addition of some artificial (*biomechatronic*) body part(s) into its original ('natural') body (Gross, 2019).

According to the MSM, the *structural components* (sensory memory, STM and LTM) are fixed, while *control processes* (such as rehearsal) are less permanent. Craik and Lockhart's *levels-of-processing* (LOP) model *begins* with the proposed control processes. The structural components (the memory system) are what results from the operation of these processes: memory is a *by-product of perceptual analysis*. This is controlled by the central processor, which can analyse a stimulus (such as a word) on various levels:

- at a *superficial* (or *shallow*) level, the *surface features* of a stimulus (such as whether the word is in upper or lower case) are processed
- at an *intermediate* (*phonemic* or *phonetic*) level, the word is analysed for its *sound*
- at a *deep* (or *semantic*) level, the word's *meaning* is analysed.

The level at which a stimulus is processed depends on both its nature and the processing time available. The more deeply information is processed, the more likely it is to be retained.

Consistent with the LOP model is the *production effect* (Farrin and MacLeod, 2017). (See Key Study 17.6.)

THEORIES of FORGETTING

To understand why we forget, we must recall the distinction between *availability* (whether or not material has been stored) and *accessibility* (being able to retrieve what's been stored). In terms of the MSM, since information must be transferred from STM to LTM for permanent storage:

- *availability* mainly concerns STM and the transfer of information from STM into LTM
- *accessibility* has to do mainly with LTM.

Forgetting can occur at the encoding, storage or retrieval stages.

One way of looking at forgetting is to ask what prevents information staying in STM long enough to be transferred to LTM (some answers are provided by *decay* and *displacement theories*). Some answers to the question about what prevents us from locating the information that's already in LTM are offered by *interference theory, cue-dependent forgetting* and *motivated forgetting* (or *repression*: this is discussed in Chapter 21).

Decay theory

Decay (or *trace decay*) *theory* tries to explain why forgetting increases with time. Clearly, memories must be stored somewhere, the most obvious place being the brain. Presumably, some sort of structural change (the *engram*) occurs when learning takes place. According to decay theory, metabolic processes occur over time which cause the engram to degrade/break down, unless it's maintained by repetition and rehearsal. This results in the memory contained within it becoming unavailable.

Hebb (1949) argued that while learning is taking place, the engram which will eventually be formed is very delicate and liable to disruption (the *active trace*). With learning, it grows stronger until a permanent engram is formed (the *structural trace*) through neurochemical and neuroanatomical changes.

Decay in STM and LTM

The active trace corresponds roughly to STM, and, according to decay theory, forgetting from STM is due to disruption of the active trace. Although Hebb didn't apply the idea of decay to LTM, other researchers

Key Study 17.6

Read out loud if you want to remember (Farrin and MacLeod, 2017)

- 75 student participants were recorded reading aloud 160 words; they knew they'd be returning to the lab in two weeks' time (but didn't know why).
- On their return, they studied 80 words from the original word list in preparation for an imminent memory test, in four different ways:
  - (i) They read 20 of the words silently to themselves.
  - (ii) They heard a recording of someone else reading 20 of the words aloud.
  - (iii) They heard the earlier recording of themselves saying 20 more of the words.
  - (iv) They read the last 20 words out loud.
- The memory *recognition* test involved the 80 words they'd just studied, plus the other 80 used two weeks earlier. For each word, the participants had to indicate whether or not it was one they had just studied.

Ask Yourself

- Which revision method produced the highest memory score?
- Why?

- Method (iv) produced the highest average recall (77 per cent), followed by (iii), (ii) and (i) (65 per cent).
- The memory advantage obtained from reading aloud – the *production effect* – is likely caused through the combined advantage of (a) *motor processing* (reading aloud makes it a more *active* process); (b) *visual processing* (reading may produce *deeper learning* compared with just listening); and (c) *self-reference* (reading aloud – '*I* said it') can make the information more *salient* (Farrin and MacLeod, 2017).

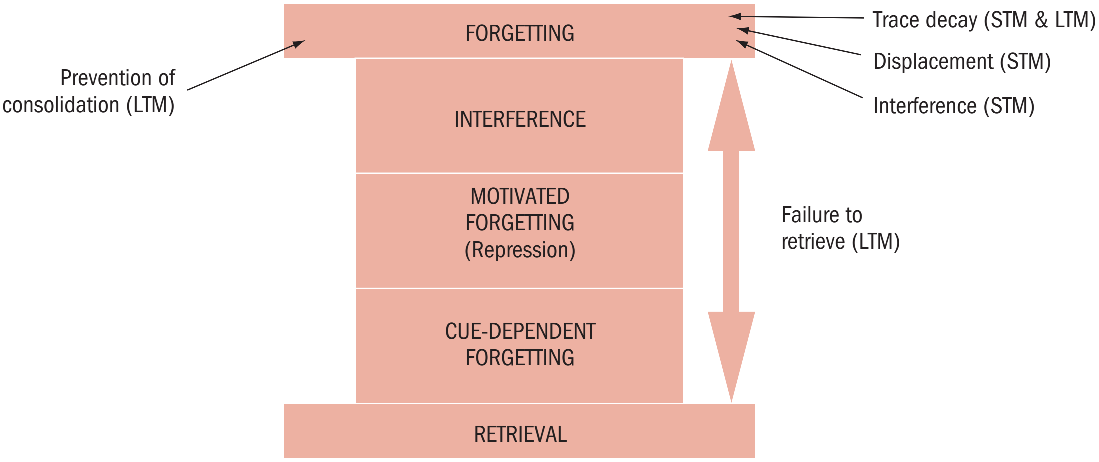

Figure 17.8 Different theories of forgetting, including retrieval failure

have argued that it can explain LTM forgetting if it's assumed that decay occurs through disuse (hence, *decay-through-disuse theory*). So, if certain knowledge or skills aren't used or practised for long periods of time, the corresponding engram will eventually decay away (Loftus and Loftus, 1980).

Ask Yourself

- Try to think of skills/knowledge that, contrary to decay-through-disuse theory, aren't lost even after long periods of not being used/practised.

Is forgetting just a matter of time?

Peterson and Peterson's (1959) experiment (see Key Study 17.1) has been taken as evidence for the role of decay in STM forgetting. If decay did occur, then we'd expect poorer recall of information with the passage of time, which is exactly what the Petersons reported.

The difficulty with the Petersons' study in particular, and decay theory in general, is that other possible effects need to be excluded before we opt for a decay-based account. The ideal way to study the role of decay in forgetting would be to have people receive information and then do nothing, physical or mental, for a period of time. If recall was poorer with the passage of time, it would be reasonable to suggest that decay had occurred. Such an experiment is, of course, impossible.

However, Jenkins and Dallenbach (1924) were the first to attempt an approximation to it. In their now classic experiment, participants who were allowed to sleep following the learning of a list of nonsense syllables showed little forgetting when re-tested, compared with those who stayed awake for the same amount of time (one, two, four or eight hours) and went about their normal activities. If decay is a natural result of the passage of time alone, then we should have expected equal forgetting in *both* groups. The results suggest that it's what happens *in between* learning and recall that determines forgetting, not time as such. Jenkins and Dallenbach concluded that forgetting is a matter of '*interference*, inhibition or obliteration of the old by the new'.

Although some data exist suggesting that neurological breakdown occurs with age and disease (such as Alzheimer's disease), there's no evidence that the major cause of forgetting from LTM is neurological decay (Solso, 1995). Indeed, the case of H.M. shows that the intact hippocampus helps to repair weak or damaged memories throughout life, and recent research suggests that even Alzheimer's patients' memories may *not* be wiped (but instead become harder to access).

SLEEP, CONSOLIDATION and RECONSOLIDATION

While Jenkins and Dallenbach's study illustrates that sleep facilitates learning/remembering by preventing interference, it doesn't make any claims for the benefits of sleep in its own right. The last 20 years has seen an explosion of research showing that sleep participates in memory processing (Stickgold, 2017: see Chapter 7).

In keeping with Hebb's view of memory, a long-held view of new memories is that they're quite fragile until they go through a process of *consolidation*, which transforms them into a stable, permanent form. But more recent research has shown that memories retain the ability to change even *after* consolidation. Indeed, the *reactivation* of a memory can return it to its original unstable state, requiring *reconsolidation*; this allows originally accurate information to become 'corrupted' and inaccurate information to be corrected. This has led researchers to talk about memory *evolution*, rather than consolidation – especially in the context of sleep-dependent memory processing (Stickgold, 2017).

So, are consolidated memories not necessarily permanent after all?

Based on their study using rats, Nader *et al.* (2000) concluded that every time a memory is recalled, it becomes unstable again – just as if it were a new memory being laid down. This means that memories *aren't* permanent after all; rather, they're constructed anew every time we recall them (*reconsolidation*). This is a view of memory as dynamic and modifiable. Nader *et al.*'s insights suggested the possibility of removing unwanted emotional memories, such as those found in PTSD and depression, by deliberately interfering with the reconsolidation process.

Indeed, Kroes *et al.* (2014) succeeded in manipulating the memories of people with severe depression who were undergoing electroconvulsive therapy (ECT) (see Chapter 45). A week after being presented with two stories with unpleasant narratives – a car crash and an assault – just before their scheduled ECT session, the participants were given a brief reminder of one of the stories in order to reactivate the memory. When asked to recall the stories 24 hours after their ECT – long enough for reconsolidation to have occurred – they couldn't do so for the memory that been reactivated (their recall was no better than chance).

Ask Yourself

- What serious ethical issues might be raised by this (potential) kind of meddling with memories?

Conversely, research by Perusini *et al.* (2017) suggests that Alzheimer's may *not,* as long believed, completely erase memories, destroying the neurons that store them. Research by Lulu Xie *et al.* (2013) using mice suggests that instead of being 'lost', memories can become *inaccessible* (they're still *available*). Of course, it's dangerous to generalise from mice to humans; however, there's other evidence consistent with these findings, such as the ability of music to help reawaken memories in Alzheimer's patients (Stickgold, 2017).

Displacement theory

In a limited-capacity STM system, forgetting might occur through *displacement*. When the system is 'full', the oldest material in it would be displaced ('pushed out') by incoming new material. This possibility was explored by Waugh and Norman (1965) using the *serial probe task*. Participants were presented with 16 digits at the rate of either one or four per second. One of the digits (the 'probe') was then repeated, and participants had to say which digit followed the probe. Presumably:

- if the probe was one of the digits at the beginning of the list, the probability of recalling the digit that followed would be small, because later digits would have displaced earlier ones from the system
- if the probe was presented towards the end of the list, the probability of recalling the digit that followed would be high, since the last digits to be presented would still be available in STM.

When the number of digits following the probe was small, recall was good, but when it was large, recall was poor. This is consistent with the idea that the earlier digits are replaced by later ones.

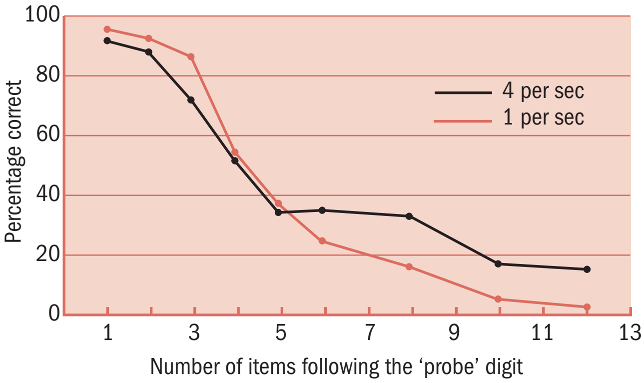

Figure 17.9 Data from Waugh and Norman's serial probe experiment

Ask Yourself

- Waugh and Norman also found that recall was generally better with the faster (four per second) presentation rate. How does this support decay theory?

Since less time had elapsed between presentation of the digits and the probe in the four-per-second condition, there would have been less opportunity for those digits to have decayed away. This makes it unclear whether displacement is a process distinct from decay.

Retrieval-failure theory and cue-dependent forgetting

According to *retrieval-failure theory*, memories cannot be recalled because the correct retrieval cues aren't being used. The role of retrieval cues is demonstrated by the *tip-of-the-tongue phenomenon* (TOT), in which we know that we know something but cannot retrieve it at that particular moment in time (Brown and McNeill, 1966).

Tulving (1974) used the term *cue-dependent forgetting* to refer jointly to *context-dependent* and *state-dependent forgetting*. (See Table 17.2.)

Interestingly, when Godden and Baddeley (1980) repeated their 'underwater' experiment using *recognition* as the measure of remembering, they found no effect of context. They concluded that context-dependent forgetting applies only to *recall*. According to Baddeley (1995), large effects of context on memory are found only when the contexts in which encoding and retrieval occur are *very* different.

Table 17.2 Cue-dependent forgetting

Context-dependent forgetting	State-dependent forgetting
Occurs in absence of relevant environmental or contextual variables. These represent *external* cues.	Occurs in absence of relevant psychological or physiological variables. These represent *internal* cues.
Abernathy (1940): One group had to learn and then recall material in the same room, while a second group learned and recalled in different rooms. The first group's recall was superior.	Clark *et al*. (1987): Victims' inabilities to recall details of a violent crime may be due at least partly to the fact that recall occurs in a less emotionally aroused state. (See Chapter 21.)
Godden and Baddeley (1975): Divers learned lists of words either on land or 15 feet under water. Recall was then tested in the same or a *different* context. Those who learned and recalled in different contexts showed a 30% *deficit* compared with those who learned and recalled in the same context.	McCormick and Mayer (1991): The important link may be between mood and the sort of material being remembered (e.g. we're more likely to remember happy events when we're feeling happy).

Interference theory

According to *interference theory*, forgetting is influenced more by what we do before or after learning than by the mere passage of time. (See Key Study 17.6.)

- In *retroactive interference/inhibition* (RI), *later* learning interferes with the recall of *earlier* learning.
- In *proactive interference/inhibition* (PI), *earlier* learning interferes with the recall of *later* learning.

Interference theory has been extensively studied in the laboratory using *paired-associate lists*. The usual procedure for studying interference effects is shown in Figure 17.13.

Usually, the first member of each pair in list A is the same as in list B, but the second member of each pair is different in the two lists.

- In RI, the learning of the second list interferes with recall of the first list (the interference works *backwards* in time).
- In PI, the learning of the first list interferes with recall of the second list (the interference works *forwards* in time).

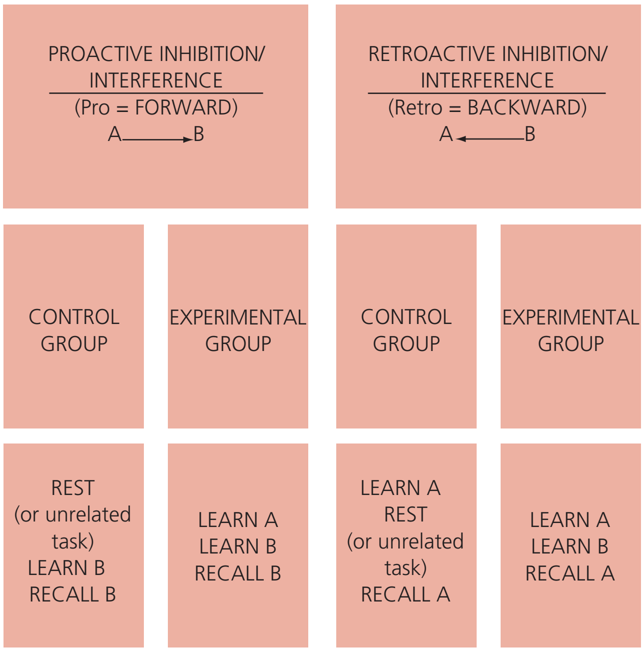

Figure 17.10 Experimental procedure for investigating retroactive and proactive interference

Limitations of laboratory studies of interference theory

- In the laboratory, learning is artificially compressed in time, which maximises the likelihood that interference will occur (Baddeley, 1990). Such studies therefore lack *ecological validity*.
- Laboratory studies tend to use nonsense syllables as the stimulus material. When meaningful material is used, interference is more difficult to demonstrate (Solso, 1995).
- When people have to learn, say, the response 'bell' to the stimulus 'woj', the word 'bell' isn't actually learned in the laboratory, since it's already part of SM. What's being learned (a specific response to a specific stimulus in a specific laboratory situation) is stored in EM. SM is much more stable and structured than EM, and so is much more resistant to interference effects. No amount of new information will cause someone to forget the things they know that are stored in their SM (Solso, 1995).
- However, in support of interference theory, it's generally agreed that if students have to study more than one subject in the same time-frame, these should be as *dissimilar* as possible.

Ask Yourself

- Think of examples of subjects that (a) should definitely *not* be studied together in the same time-frame, and (b) *could* be studied together without much risk of interference.

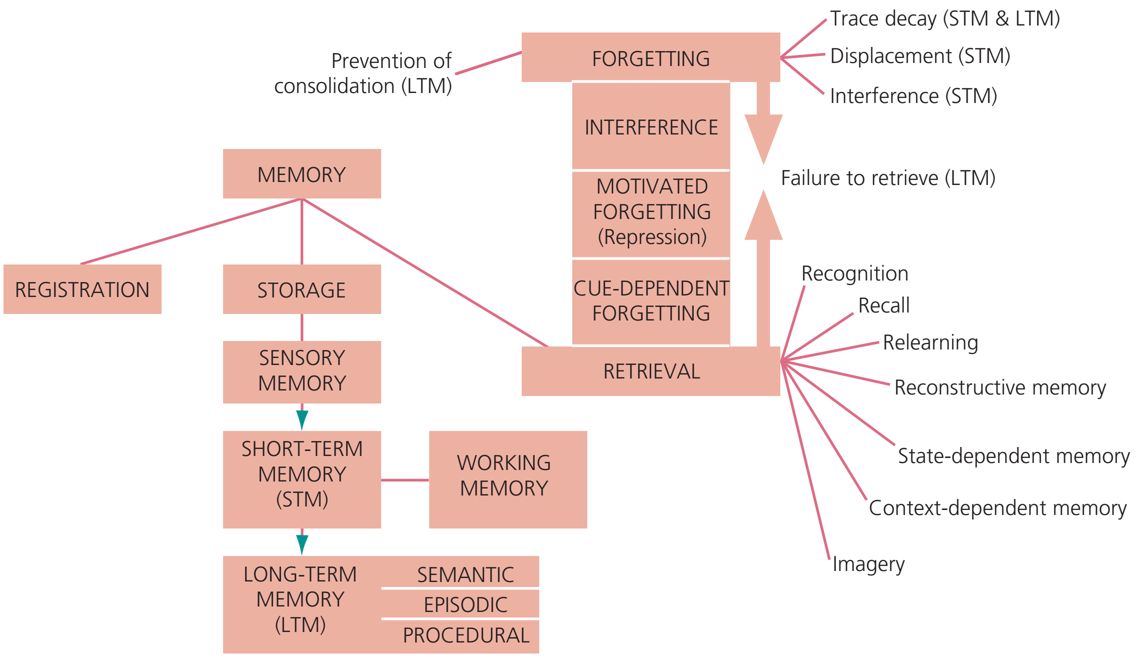

Figure 17.11 A summary of the three components of memory and theories of forgetting

According to Schacter (2002), efficient forgetting is a crucial part of having a fully functioning memory. When we forget something useful, the pruning system is working just a little too well. In his book *The Seven Sins of Memory* (2001), Schacter describes several ways that we forget, including:

- *Transience* is a strategy whereby we discard information that's out of date (such as old telephone numbers or what we had for lunch last week).
- *Absent-mindedness* might involve failing to properly encode information about where we put our keys because our attention is tied up elsewhere (see Chapter 13).
- *Blocking* refers to the brain holding back on one memory in favour of a competing memory, so that we don't get muddled (this prevents interference).

Each of these strategies has an adaptive purpose, preventing us from storing mundane, confusing or out-of-date memories. (See Case Study 17.3.) Explaining HSAM is more difficult than describing it; it's possible that it relies not just on how information is encoded but also on how it's retrieved (Marshall, 2008).

Case Study 17.3

The Case of A.J. (Parker *et al.*, 2006)

- A 42-year-old woman from California, A.J. (real name, Jill Price) remembers every day of her life since her teens in extraordinary detail. Mention any date since 1980, and she's immediately transported back in time, picturing where she was, what she was doing, and what made the news that day. She can also identify the day of the week for any date since 1980 and give the correct date for apparently insignificant events.
- She's locked in a cycle of remembering that she describes as 'running a movie that never stops'. She describes her constant recall as 'non-stop, uncontrollable and totally exhausting' and as a 'burden' of which she's both warden and victim.
- Parker *et al*. coined the term 'hyperthymestic syndrome' (from the Greek 'thymesis' = 'remembering'). It's also referred to as highly superior autobiographical memory (HSAM) (McGaugh and Le Port, 2014).
- MRI and PET scans of the brains of other people with HSAM have identified two memory-related regions, the *uncinate fascicle* (a nerve tract linking the temporal and frontal cortex) and the *parahippocampal gyrus*.
- Independent evidence shows that injury to the uncinate fascicle impairs autobiographical memory (McGaugh and Le Port, 2014). HSAM is quite different from the memory of 'S', made famous by Luria (1968) in *The Mind of a Mnemonist* (see Rolls, 2010).

CONCLUSIONS: WHAT IS MEMORY FOR?

According to Rose (2003):

> *… Memory defines who we are and shapes the way we act more closely than any other single aspect of our personhood …*

Whatever happens to us (including losing a limb), we're still, in an important sense, recognisably ourselves provided our memories are intact. However:

> *… Lose your memory and you, as you, cease to exist … (Rose, 2003)*

Paradoxically, Schacter (2001) argues that memory is about the future, not the past. We have evolved memory systems not so that we can reminisce but so we can use prior experience to enhance our future performance. George (2018) cites the case of KC, who was left with an impaired EM following a motorcycle accident: he could remember faces but not personal experiences – this stopped him from imagining the future.

If we cannot recall past events and preferences, our ability to make sound decisions also crumbles: decision-making involves drawing on past choices and existing knowledge to assess options and imagine how they might turn out (George, 2018). Children are unable to imagine themselves in the future (*episodic future thinking*: Atance and O'Neill, 2005; or *episodic foresight*: Suddendorf, 2010) before the age of 5 (Dickerson *et al.*, 2018).

According to Mahr and Csibra (2018), the key difference between human and non-human animal memory is that we don't just recall an event – we also remember how we came to know about it: having first-hand experience of something gives us authority, making us more accurate and convincing. This is a vital part of managing our social interactions and belief systems: without it, we couldn't justify social entitlements and obligations, such as promises, which often involves explicit reference to past events.

Consistent with this argument is the finding that when someone tells you about, say, a movie they've seen, the pattern of brain activity in your brain as you listen – and imagine the scenes – matches that of the person describing it (Chen *et al.*, 2016). A key implication of this finding is that for specific memories we share distinct brain patterns, almost like fingerprints, with other people. This evolved to enable us and our evolutionary ancestors to instantly understand and empathise with one another, essentially implanting memories in each other's brains by recounting stories and information crucial to survival (Chen *et al.*, 2016).

EM's dual ability to reach back into the past and forward into the future is referred to as *mental time travel* (MTT), a uniquely human ability (Corballis and Suddendorf, 2007). While other animals react to what's happening in their immediate environment, humans can transcend time: our behaviour can be influenced by both our past and our (imagined) future.

Chapter Summary

- **Memory** can be defined as the **retention of learning** or **experience**. Learning and memory are **interdependent** processes.
- Ebbinghaus began the systematic study of memory, using **nonsense syllables**. He showed that memory declined very rapidly at first, then levelled off.
- Memory is now studied largely from an **information-processing approach**, which focuses on **registration/encoding**, **storage**, and **retrieval**. Storage corresponds to **availability**, retrieval to **accessibility**.
- Techniques for measuring memory include **recognition**, **recall** (**serial** or **free**), **paired associates recall**, and the **memory-span procedure**.
- James' distinction between **primary** and **secondary** memory corresponds to that between **short-term memory** (**STM**) and **long-term memory** (**LTM**).
- **Sensory memory** is probably best thought of as an aspect of **perception** and as a prerequisite for storage proper (i.e. STM).
- The limited capacity of STM can be increased by **chunking**, which draws on LTM to encode new information in a meaningful way. **Rehearsal** is a way of holding information in STM almost indefinitely, and the primary code used by STM is **acoustic**. But semantic and visual codings are also used.
- LTM probably has an **unlimited capacity,** and information is stored in a **relatively permanent** way. Coding is mainly – but not exclusively – **semantic.**
- Atkinson and Shiffrin's **multi-store model** (**MSM**) sees sensory memory, STM and LTM as **permanent structural components** of the memory system. Rehearsal is a **control process**, which acts as a **buffer** between sensory memory and LTM, and helps the **transfer** of information to LTM.
- The **primacy effect** reflects recall from LTM, while the **recency effect** reflects recall from STM. Together they comprise the **serial position effect**.
- Studies of **brain-damaged, amnesic patients** appear to support the STM–LTM distinction. While STM continues to function fairly normally, certain aspects of LTM functioning are impaired.
- LTM isn't unitary, but comprises **semantic** (**SM**), **episodic** (**EM**), and **procedural memory** (**PM**). **Autobiographical memory** (**AM**) and **flashbulb memories** are two kinds of EM. An overlapping distinction is that between PM and **declarative memory/learning**.
- Baddeley and Hitch's **working-memory** (**WM**) **model** rejected the MSM's view of STM as unitary. Instead, STM is seen as comprising a **central executive**, which controls the activities of the **phonological loop** (**inner voice**), and **visuospatial scratch pad** (**inner eye**).
- A passive, limited capacity **episodic buffer** sits between the slave systems, LTM and central executive, providing temporary storage of information held in a **multimodal code.**
- Craik and Watkins' distinction between **maintenance** and **elaborative rehearsal** implies that it's not the amount but the **kind** of rehearsal or processing that matters.
- According to Craik and Lockhart's **levels-of-processing** (**LOP**) **model**, memory is a **by-product of perceptual analysis**, such that STM and LTM are the consequences of the operation of control processes.
- The more deeply information is processed, the more likely it is to be retained. **Semantic** processing represents the **deepest** level.
- **Decay/trace decay theory** attempts to explain why forgetting increases over time. STM forgetting is due to **disruption** of the **active trace**, and **decay through disuse** explains LTM forgetting.
- **Displacement theory** is supported by data from Waugh and Norman's **serial probe task**. However, displacement may not be distinct from decay.
- According to **retrieval-failure theory**, memories cannot be recalled because the correct **retrieval cues** are missing (as demonstrated by the **tip-of-the-tongue** (**TOT**) **phenomenon**).
- **Cue-dependent forgetting** comprises **context-dependent** and **state-dependent** forgetting, which refer to **external** and **internal cues** respectively.
- According to **interference theory**, forgetting is influenced more by what we do before/after learning than by the mere passage of time. **Retroactive interference/inhibition** (**RI**) works **backwards** in time, while **proactive interference/inhibition** (**PI**) works **forward**s in time.
- Laboratory studies of interference lack **ecological validity**, and interference is more difficult to demonstrate when meaningful material is used.
- The need to forget redundant information is a fundamental aspect of a fully functioning memory; this is lacking in people with **hyperthymestic syndrome** (or **highly superior autobiographical memory**/HSAM).

Links with Other Topics/Chapters

Chapter 13 → Broadbent's filter model of selective attention was, in many ways, the precursor to Atkinson and Shiffrin's MSM, and sensory memory is very similar to Broadbent's concept of a sensory 'buffer' store

Chapter 3 → The case study method, in practice at least, often involves unusual or abnormal behaviour. While this can shed light on 'normal' behaviour, critics argue that we cannot generalise from such cases, making it unscientific

Chapter 42 → Traditional science adopts a *nomothetic* ('law-like') approach, while the case study is central to the *idiographic* ('uniqueness') approach

Chapter 39 → Rose (2003) argues that cases like those of H.M. and Clive Wearing involve brain damage that is clinically unique, making it impossible to generalise as can be done from patients with Korsakoff's syndrome or Alzheimer's disease

Chapter 13 → The distinction between PM and declarative memory is similar to that between controlled and automatic processing

Chapter 20 → Chess masters' phenomenal STM only for non-random board positions demonstrates an important difference between how people and computers 'think' and solve problems

Chapter 40 → A.J. and other people with hyperthymestic syndrome display obsessive qualities similar to those of autistic individuals (such as an unusual interest in dates)

Chapters 7 and 44 → The need to forget is considered important for people suffering from post-traumatic stress disorder (PTSD) and is the central concept in Crick and Mitchison's reverse learning theory of dreaming

Recommended Reading

Baddeley, A. (1997) *Human Memory: Theory and Practice* (revised edition). Hove: Psychology Press.
Baddeley, A. (1999) *Essentials of Human Memory.* Hove: Psychology Press.
Draaisma, D. (2004) *Why Life Speeds Up As You Get Older.* Cambridge: Cambridge University Press. Also relevant to Chapters 6, 21, and 40.
Gross, R. (2008) *Key Studies in Psychology* (5th edition). London: Hodder Education. Chapter 5.
Parkin, A.J. (1987) *Memory and Amnesia: An Introduction.* Oxford: Blackwell.
Rose, S. (2003) *The Making of Memory: From Molecules to Mind* (revised edition). London: Vintage. Also useful for Chapter 49.

Useful Websites

http://memory.uva.nl/index_en (Memory Psychology for a general audience: University of Amsterdam)
www.exploratorium.edu/memory/index.html (Memory exploratorium)
www.york.ac.uk/res/wml (Centre for Working Memory and Learning: University of York)
www.livescience.com/38280-what-is-deja-vu.html (Some very useful links to other aspects of memory)