chapter three

Memory

Key knowledge and skills

This knowledge includes:

- mechanism of memory formation:
  - role of the neuron in memory formation informed by the work of E. Richard Kandel
  - roles of the hippocampus and temporal lobe
  - consolidation theory
  - memory decline over the lifespan
  - amnesia resulting from brain trauma and neurodegenerative diseases including dementia and Alzheimer's disease
- comparison of models for explaining human memory:
  - Atkinson-Shiffrin's multi-store model of memory, including maintenance and elaborative rehearsal, serial position effect and chunking
  - Alan Baddeley and Graham Hitch's model of working memory: central executive, phonological loop, visuo–spatial sketchpad, episodic buffer
  - levels of processing as informed by Fergus Craik and Robert Lockhart
  - organisation of long-term memory including declarative and episodic memory, and semantic network theory.

These skills include the ability to:

- formulate research questions and construct testable hypotheses
- use research literature to demonstrate how psychological concepts and theories have developed over time
- process and interpret information, and make connections between psychological concepts and theories
- apply understanding to both familiar and new contexts
- evaluate the validity and reliability of psychology-related information and opinions presented in the public domain
- analyse issues relating to and implications of scientific and technological developments relevant to psychology.

MEMORY

Models of memory

- Multi-store model (Atkinson and Shiffrin)
  - Maintenance and elaborative rehearsal
  - Serial-position effect
  - Chunking
- Working memory model (Baddeley and Hitch)
  - Phonological loop
  - Visuospatial sketchpad
  - Episodic buffer
  - Central executive
- Levels of processing model (Craik and Lockhart)
  - Shallow processing
  - Intermediate processing
  - Deep processing

Memory formation

- Kandel and the role of neurons
- Temporal lobe and hippocamus
- Consolidation theory
- Memory decline over the lifespan
- Amnesia
  - Retrograde and anterograde amnesia
  - Dementia
  - Alzheimer’s disease

LTM

- Memory types
- Semantic network theory

Memory: Our link to the past, present and future

Imagine what life would be like if most of your memories were wiped out. How would you communicate if you could not remember what words meant or even what you had just said? How would you recognise your family and friends? Your past would be a complete blank.

Now imagine what life would be like if you could remember your past, but could not form new memories of things that happen in the present. This is demonstrated in the film *Memento* (2000), where the character of Leonard Shelby can accurately recall details of his life before his 'accident', yet he cannot remember what happened 15 minutes ago, let alone where he is or where he's going (see Figure 3.1). To remember basic survival information such as 'Where do I live?' or 'Which car is mine?', Leonard relies on a series of annotated Polaroid snapshots and an endless stream of handwritten notes.

Life without a functioning memory would be terrifying and confusing. Memory connects our past and present experiences and provides us with a sense of identity. Memory also helps us to adapt to the constant changes of daily life and to plan for the future. It plays a major role in determining our behaviour, and is crucial for our survival.

Figure 3.1 In the film *Memento*, actor Guy Pearce plays Leonard Shelby, a man unable to form new memories.

ENCODING, STORING AND RETRIEVING INFORMATION

Memory is an active information-processing system that receives, stores, organises and recovers information (Baddeley, 1996).

Memory begins when our senses take in different types of information from our external and internal environments. Because this information cannot be processed in its raw sensory form (for example, light rays or sound waves), it has to be converted into – or represented in – a form (or code) that our brain can work with later. This conversion process is known as encoding.

Encoded information is then stored (held or retained) in the memory system for a period of time – this is known as storage. If stored information is to be used later, it must be retrieved, or taken out of storage. Retrieval involves locating information stored in memory and bringing it into consciousness when needed, to complete a cognitive task.

VIDEO
Understanding memory

This memory process is illustrated in Figure 3.2. View 'Videolink: Understanding memory' to see a presentation of an overview of memory.

memory
An active information-processing system that receives, stores, organises and recovers information

encoding
The process that converts information into a usable form (code) that can be stored and represented in the memory system

storage
The retention of information in the memory system over time

retrieval
The process of locating information stored in memory and bringing it into consciousness when needed, to complete a cognitive task

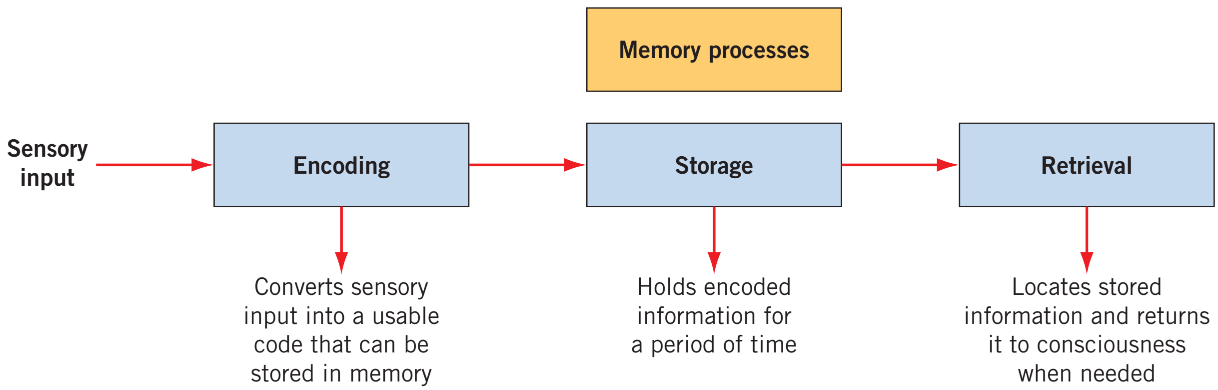


Figure 3.2 Memory is an active system that processes sensory information by *encoding*, *storing* and *retrieving* it.

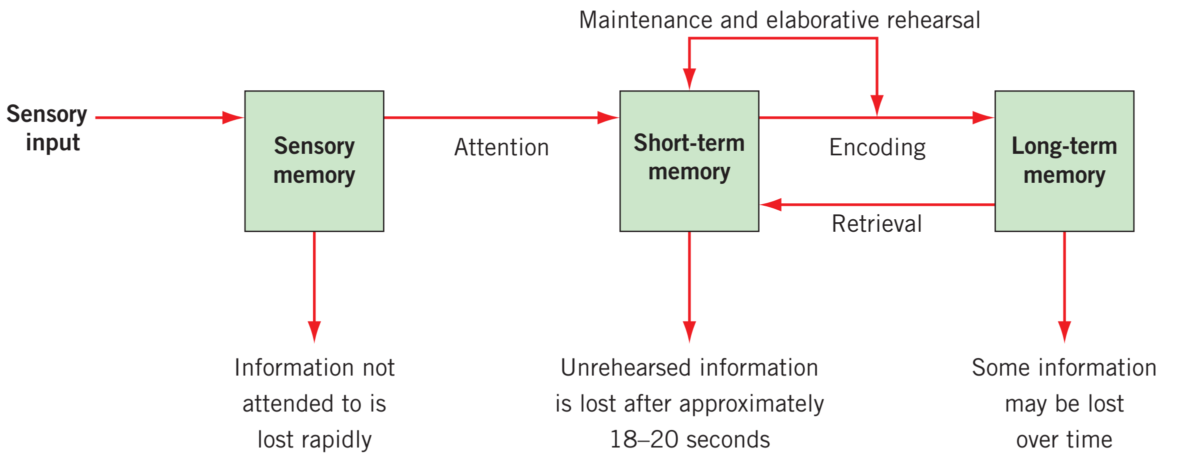


Figure 3.3 The multi-store model of memory: According to Atkinson and Shiffrin, human memory consists of three separate but interrelated memory stores through which a stream of data flows for processing.

Atkinson and Shiffrin's multi-store model of memory

Atkinson and Shiffrin's (1968) multi-store model of memory visualises memory as a system consisting of multiple memory stores, through which a stream of data flows for processing (Atkinson & Shiffrin, 1968). This model emphasises the storage structures, and suggests that if information is to be stored for a long time, it must pass through three memory stores: *sensory memory*, *short-term memory (STM)* and *long-term memory (LTM)* (see Figure 3.3). Each store operates independently, but all operate at the same time and their control processes are interrelated. We will examine these memory stores next.

SENSORY MEMORY

New sensory information – in the form of sight, sound, taste, smell and touch – enters memory when it is registered in sensory memory (see Figure 3.4).

Figure 3.4 All the information you process about what you see, hear, smell, taste and feel in the busy environment is initially registered in your sensory memory.

Sensory memory stores information briefly – for up to a few seconds only. However, while duration is brief, psychologists believe the capacity of sensory memory is unlimited.

Although we have no conscious control over sensory memory, we are not overwhelmed by incoming data because we do not select all of it for attention. Information is held just long enough to encode it into a usable form and transfer it to the STM store for further processing (Neath, 1998). If we ignore information that enters our sensory memory, it fades rapidly.

Psychologists believe sensory memory contains a sensory register for each of our senses. The registers hold the information as an exact copy of its original sensory form (for example, visual information is held as an image; auditory information is held as an echo). There are two main sensory registers for memory, which we will now explore.

Iconic memory

Iconic memory is the sensory register for visual information – such as shape, size and colour – which it stores in the form of an icon for about 1/3 to 1/2 of a second. For example, if you look at a flower and then close your eyes, an *icon* (a fleeting mental image with picture-like qualities) of the flower will persist in your consciousness. The intensity of the visual stimulus (for example, its brightness) determines how long the icon will last, but most last no longer than half a second – just long enough for encoding to begin. Because visual information changes constantly, we must deal with it quickly (see Figure 3.5). If we held images for longer than we do, we might miss important new information. If we held it for shorter periods, images would succeed one another so quickly that we would perceive our world as a blur (see Figure 3.6).

Figure 3.5 Because the image of this sparkler persists briefly in iconic memory, when the sparkler is moved fast enough, the blending of after-images causes people to see a continuous circle instead of a succession of individual points.

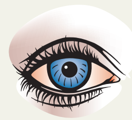
Figure 3.6 If iconic memory did not clear quickly, we would see the world as a blur, as in this photograph. You may not be able to guess that this is an image of two people on a motorbike.

Echoic memory

Echoic memory is the sensory register for auditory information. Storage time (duration) is temporary and sounds remain as an *echo* (a brief continuation of activity in the auditory system after the stimulus has ended) for up to three or four seconds. This is long enough for the sounds to be encoded and selected for attention. If duration was shorter, language would sound like a series of distinct sounds instead of whole words or phrases we can understand. For instance, if someone says 'aeroplane' you hear 'aeroplane' because 'aero' is held in your echoic memory until you hear 'plane'. Echoic memory provides us with a smooth, integrated and continuous experience of auditory information.

Table 3.1 gives an overview and comparison of iconic and echoic memory. To discover why psychologists believe in the existence of sensory memory, read 'Focus on research: Evidence in support of sensory memory'.

Table 3.1 Overview of iconic and echoic memory

	ICONIC MEMORY 	ECHOIC MEMORY 
What it holds	Exact replica of visual information (an icon)	Exact replica of auditory information (an echo)
Duration stored	Approximately 1/3–1/2 of a second	Approximately 3–4 seconds
Storage capacity	Relatively unlimited	Relatively unlimited

FOCUS ON RESEARCH

Evidence in support of sensory memory

George Sperling (1960) was the first psychologist to suggest the existence of sensory memory. In one experiment to test for iconic memory, Sperling showed participants slides containing sets of 12 letters (such as that shown in Figure 3.7) for about 1/20 of a second. Sperling chose only consonants so that participants were not able to group and interpret the letters as words.

Most participants could recall four or five letters from each set, as if the letters were still physically present, for up to a 1/3 of a second after the slide had been taken away.

Continued

multi-store model of memory
The memory model that visualises memory as a system consisting of multiple memory stores through which a stream of data flows for processing

sensory memory
The first stage of the multi-store model of memory; it receives and stores an unlimited amount of sensory information for up to a few seconds

sensory register
A subsystem of sensory memory that receives and stores specific sensory information received from a sense organ

iconic memory
The subsystem of sensory memory that receives and stores an unlimited amount of visual information in the form of a visual image for approximately 1/3 to 1/2 of a second

echoic memory
The subsystem of sensory memory that receives and stores an unlimited amount of auditory information in the form of an echo for up to 3–4 seconds

Participants also stated that they actually held an image of all the letters but they were only able to recall up to four or five of them.

To test whether *all* the letters were actually held for a period of time, Sperling conducted a second experiment. In it he sounded a tone just after the slide of letters was shown. When the *high* tone sounded after the slide, participants were instructed to report only the letters from the top row. When the *medium* tone sounded, they were to report letters from the middle row. When the *low* tone sounded, they were to report letters from the bottom row only. Participants did not know which tone was going to sound, so they did not know which row to focus on, meaning they had to focus on the entire grid.

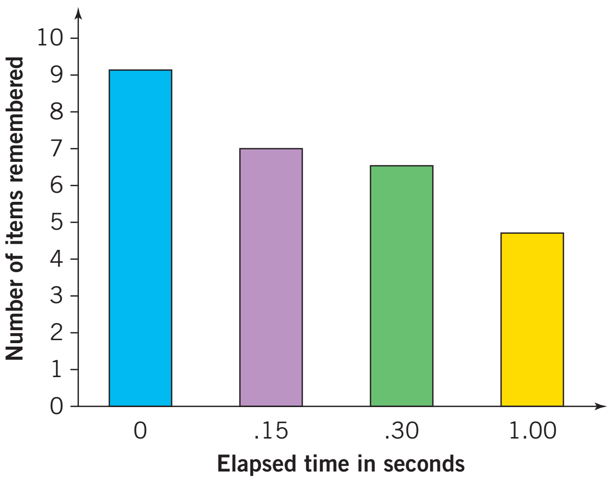
G	K	B	L
M	V	X	P
R	W	Z	C

Figure 3.7 An example of the slides shown during Sperling's experiments

When tested, participants could recall the letters from the row required, which led Sperling to conclude that they stored an image of the whole pattern of letters in memory after the pattern left the screen.

Sperling was also interested in the amount of time that iconic memory retains a visual image, so he continued his original experiment focusing on the 12 letters, but delayed the time between showing the image and asking for the recalled letters. The time was delayed for increasingly longer periods, ranging from 1/15 of a second to 1 second. As he lengthened the time delay, Sperling found that participants' abilities to recall letters declined (see Figure 3.8).

The results of his tests for iconic memory led Sperling to conclude that iconic memory does exist, and that it has an unlimited capacity but its duration is brief (up to three or four seconds).



Source: Sperling (1960), adapted by Kagan, Segal & Havemann (2004, p. 184)

Figure 3.8 As this graph shows, the amount of information held in iconic memory is large to begin with, but declines rapidly.

QUESTIONS

1 Write an operational hypothesis for the final part of Sperling's experiment.
2 Identify the independent variable.
3 Identify the dependent variable.
4 State the results of the experiment.
5 What conclusions did Sperling draw, based on these results?

SHORT-TERM MEMORY (STM)

Short-term memory (STM) stores a limited amount of information for a brief period, unless the information is rehearsed. STM holds all the thoughts, information and experiences that you are aware of at any given point in time.

STM receives information from two sources: sensory memory and long-term memory (LTM). When you encounter something new (for example, a distinctly-coloured bird), information such as shape, colour, texture and sound that was registered in sensory memory is sent to STM. To give this information meaning, your STM immediately starts comparing it to the existing information about birds that you have gained from past experience and have stored in LTM. In this way, STM also manages the retrieval of information from LTM.

If information is not attended to, it simply drops out of the system. If it is attended to, further processing and encoding occurs.

STM capacity

STM has a limited storage capacity and can hold only small amounts of information. Psychologist George Miller (1956) found that an average adult's STM is limited to the magic number 7 (+ or – 2) – that is, approximately seven single items (give or take one or two) of unrelated information at one time (Miller, 1956). To demonstrate this, read the following number set once. Then close the book and write as many of the numbers as you can in the correct order.

8 5 1 7 4 9 3

If you were able to correctly reproduce seven digits, you have an average STM capacity. Now try the same again using the following number set, which is probably beyond your STM's capacity.

7 1 8 3 5 4 2 9 1 6 3 4

If you were able to correctly recall all of these numbers, your STM is extraordinary!

When STM is full, new single items can be added only by dropping (displacing) some of the old ones. This limited capacity means that STM is very sensitive to interruption, making it very difficult for STM to do more than one task at a time (Anderson, Reder & Lebiere, 1996).

INCREASING STM'S CAPACITY: CHUNKING

Can our STM ever hold more than 7 (+ or – 2) single items of information at once? Although STM's storage capacity is limited, if we group separate items of information so they form a larger single item, we can effectively increase STM's normal storage capacity. This process is known as chunking. An information 'chunk' can be made up of numbers, letters, words, phrases or familiar sentences.

Try reading the following letters once, then look away and write the letters in the order you read them: TV IBM NFL VIC. Note that there are 11 letters, or 11 items of information. This amount

Source: Adapted from Kagan, Segal & Havemann, 2004, p. 195

Figure 3.9 A classroom demonstration of chunking; a) Seven groups of seven letters are shown. How many of the total 49 letters might students remember, even after looking at the board for several minutes? b) The task of remembering has become much easier now that the 49 separate letters have been made into seven chunks of meaningful words.

should be beyond the seven-item (plus or minus 2) capacity of most people's STM. However, because the letters are presented as four single information chunks, you were probably able to remember them.

Chunking is also more effective when single items are arranged into chunks that are similar to information already stored in LTM. For example, you may have noticed that in the previous letter list the three separate items 'V', 'I' and 'C' form one chunk to become 'VIC', which, as you know, is the abbreviation for 'Victoria'. The abbreviations 'TV', 'IBM' and 'NFL' would also be familiar to you.

Figure 3.9 shows a classroom demonstration of chunking.

TRY IT YOURSELF 3.1

Chunking: Increase your STM's capacity

You will need:

- a partner
- paper
- a pen.

1 Read aloud each of the following number sets to your partner, giving a two-second pause between each number. After reading each set, allow your partner time to write the number set in the correct order.

   a 9-7-5-4
   b 3-5-2-6
   c 5-6-7-0-8
   d 6-4-3-2-1
   e 3-5-0-2-1-7
   f 9-5-3-7-8-1
   g 8-5-3-8-9-1-2
   h 2-3-4-1-5-7-8-0
   i 8-4-3-7-8-2-9-1-6

2 Note the last number-set your partner remembered correctly. What does this suggest about the limit to STM storage capacity?

3 Now, repeat the same procedure using the following number sets (allow a two-second pause between each chunk within the sets).

   a 604-575
   b 492-342
   c 111-133-9
   d 983-251-4
   e 382-43-24
   f 947-342-45
   g 903-539-325
   h 78-342-578
   i 382-290-176-8

4 Count the number of correct responses, noting the last complete number-set your partner remembered correctly.

5 Compare this result with the earlier one. What differences do you note? How might you explain this?

CHECK YOUR UNDERSTANDING 3.1

1 Which of the following statements is correct?

   A Echoic memory lasts for approximately 3 or 4 seconds.
   B STM's capacity is limited but its duration is unlimited.
   C We cannot consciously increase the duration of STM because STM is beyond our voluntary control.
   D Iconic memory is an exact replica of auditory information.

Continued

short-term memory (STM)
The second and most active memory system in the multi-store model of memory; stores a limited amount of information entering from sensory memory or retrieved from LTM for a short period of time unless the information is rehearsed

magic number 7 (+ or – 2)
The number of single items of information that the average short-term memory can hold at any one time

chunking
Grouping separate items of information to form a larger single information unit (chunk) so our short-term memory can hold more than the usual seven single items of information at any given moment

2 Indicate whether the following statements are true (T) or false (F).
   a Sensory memory stores a limited amount of sensory information.
   b Forgetting is rapid in sensory memory.
   c Echoic memory stores information for approximately 1/3 to 1/2 of a second.
   d Chunking involves grouping separate bits of information to form a larger single information unit so our STM can hold more than the usual seven single pieces of information at any given moment.
3 Fill in the gaps with the correct terms.
   a The sensory register for sound-based information is ____________ memory.
   b The sensory register for visual information is ____________ memory.
   c Sensory memory has a(n) ____________ capacity but a ____________ duration.
   d The process of ____________ groups information into larger single units so more information can fit into STM.
4 Sensory memory stores information:
   A according to its meaning.
   B for an unlimited time.
   C as an exact replica of its original sensory form.
   D sent from both short-term and long-term memory.
5 The capacity of STM for most people is:
   A 6–11 single bits of information.
   B 4–10 single bits of information.
   C 5–9 single bits of information.
   D unlimited.

STM duration

STM has a limited duration, holding only small amounts of information for approximately 18–20 seconds before the information starts to disappear. If unimportant excess information remained for longer, we might miss out on new and vital information. For example, if a bank teller serves a customer who is withdrawing $552.89 from a savings account, the teller keeps the amount of money in his short-term memory for a short period of time, as he serves the customer. By the time the next customer steps up to the window, the amount has vanished from the teller's memory, and his STM is 'clear' so as to deal with the next transaction.

STM's duration, however, can be prolonged by rehearsal, which involves actively manipulating information to hold it in STM for longer than the usual 18–20 seconds. Rehearsal can take the form of either maintenance rehearsal or elaborative rehearsal.

INCREASING STM'S DURATION: MAINTENANCE REHEARSAL

Maintenance rehearsal involves repeating information (silently or verbally) a number of times so it can be held in STM for longer than the usual 18–20 seconds. Research suggests that the more times information is rehearsed, the longer it is held in STM, and the higher its chances are of being stored in LTM (Barsalou, 1992).

You have probably used this method to remember a new telephone number for a short period of time before dialling it. This mechanical repetition helps retain the number in STM long enough for you to make your call. Soon after, the number is lost from STM.

Maintenance rehearsal is very effective for storing meaningless information in STM for an extended period. However, it restricts the amount of new information entering from sensory memory and LTM. Additionally, maintenance rehearsal is very easily interrupted and, because it does not involve assigning meaning, it adds nothing to the understanding of information. Therefore, it is not a very effective way of transferring information to LTM for relatively permanent storage.

Table 3.2 outlines the advantages and limitations of maintenance rehearsal.

Table 3.2 Advantages and limitations of maintenance rehearsal

ADVANTAGES	LIMITATIONS
• Allows information to be stored in STM for longer than the usual 18–20 seconds • Good for remembering meaningless information	• Easily interrupted by information entering STM from sensory memory or LTM • Does not add to understanding • Restricts entry of new information into STM • Limited effectiveness in transferring information from STM to LTM

INCREASING STM'S DURATION: ELABORATIVE REHEARSAL

If you are introduced to someone and you are interrupted, the person's name may slip out of your STM. If you make the effort to pay careful attention to the name and repeat it several times, you may remember it. But if you use the name in your next sentence or two, you will increase the chance of storing it in your LTM (Neath, 1998). When you do this you are adding meaning to the name and you are practising elaborative rehearsal.

Elaborative rehearsal involves linking new information in some *meaningful* way with information already stored in LTM, or with other pieces of new information, to hold it in STM for longer than the usual 18–20 seconds. This increases its chances of transfer to and retrieval from LTM. Creating links between information items adds more detail to the new information. It also helps organise new information based on meaning, and this is very effective for achieving long-term retention (Howard, 1983).

The elaborative rehearsal technique of self-referencing – linking new information to the self or to personal experience – also increases your chances of LTM retention. Information deemed 'relevant to me' is more likely to be processed deeply because it assumes a personal significance (Symons & Johnson, 1997) and deep processing increases the likelihood of such information being accessible for later retrieval.

Elaborative rehearsal takes longer than maintenance rehearsal, and it requires more of a conscious effort to recall information previously stored in LTM. Because it involves accessing information already in LTM, its effectiveness depends on how deeply you initially encoded the previously stored information and on your ability to quickly access this specific information.

Table 3.3 outlines the advantages and limitations of elaborative rehearsal.

Table 3.3 Advantages and limitations of elaborative rehearsal

ADVANTAGES	LIMITATIONS
• Increases understanding because it requires deep processing • Adds more detail, which increases retrieval chances • Increases the possibility of long-term retention because it organises new information according to meaning • Makes information more accessible because it creates more potential retrieval cues	• Takes longer than maintenance rehearsal • Is difficult to practise in situations where information entering STM is rapidly changing • Relies on the ability to retrieve information previously stored in LTM • Requires more conscious effort than maintenance rehearsal

Serial-position effect

Rehearsal (particularly elaborative rehearsal) helps to move information from STM into LTM, and organisation helps with its retrieval. The *order* in which we process information also affects retrieval. This is referred to as the serial-position effect – a pattern of recall for list items, where recall is better for items at the beginning or end of a list, than for items in the middle.

Many psychologists believe the serial-position effect occurs because humans have both STM and LTM. They claim that its existence supports the theory that STM and LTM are indeed separate subsystems within the memory system.

RECENCY EFFECT

When experimenters show participants a list of unrelated items (such as words, names or dates) and *immediately* ask them to recall the items in any order, participants are typically best able to remember items at the end of the list. Items at the beginning of the list are next most easily remembered, and participants have greatest difficulty recalling the items in the middle of the list. This is the serial-position effect known as the recency effect: where recall is best for items at the *end* of a list, then for items at the beginning, then for items in the middle.

Try to memorise the following list, reading it only once. Then cover the list and immediately try to recall as many items as you can.

> bread, apples, milk, ham, biscuits, rice, sauce, butter, mustard, cheese, lettuce, carrots, onions, soup, jam

If you are like most people, you will best recall items at the *end* of the list, then items at the beginning of the list. It will be hardest for you to recall items from the middle.

Psychologists believe the recency effect occurs because when recall immediately follows learning, the last few items on a list are able to be accessed because they are still stored in STM.

PRIMACY EFFECT

If recall of a list of items is delayed, attention shifts from the last items to the first items, causing the recency effect to be lost and replaced by the serial-position effect known as the primacy effect. The

rehearsal
The active manipulation of information in short-term memory in order to hold it for longer than the usual 18–20 seconds

maintenance rehearsal
The rehearsal technique involving the repetition of information a number of times so it can be held in short-term memory for longer than the usual 18–20 seconds

elaborative rehearsal
The rehearsal technique involving linking new information in some meaningful way with information already stored in LTM, or with other pieces of new information, to hold it in short-term memory for longer than the usual 18–20 seconds

self-referencing
An elaborative rehearsal technique involving linking new information to the self or to personal experience to hold it in short-term memory for longer than the usual 18–20 seconds and to increase its chances of transfer to and retrieval from LTM

serial-position effect
A pattern of recall for list items, where recall is better for items at the beginning or end of a list than for items in the middle

recency effect
The serial-position effect where recall is best for items at the end of a list, then for items at the beginning, then for items in the middle of the list

primacy effect
The serial position effect where recall is best for the first items on the list, then for items at the end of the list, then for items in the middle of the list

primacy effect is the serial-position effect where recall is best for the *first* items on the list, then for items at the end, then for items in the middle.

Try to memorise the following list, reading it only once. Then cover the list and do something else for 30 seconds (do not rehearse list items during those 30 seconds). After 30 seconds, try to recall as many items as you can.

> dog, horse, bear, cow, sheep, deer, lion, elephant, giraffe, pig, cat, duck, donkey, tiger, chicken

If you are like most people, you will have better recall for items at the *beginning* of the list, then for items at the end of the list. It will be hardest for you to recall items from the middle.

The primacy effect is believed to occur because the first items on a list enter an 'empty' STM. Subsequent activities interfere with the items at the end of the list but not items at the beginning of the list; so, as there is no other information in STM to interfere

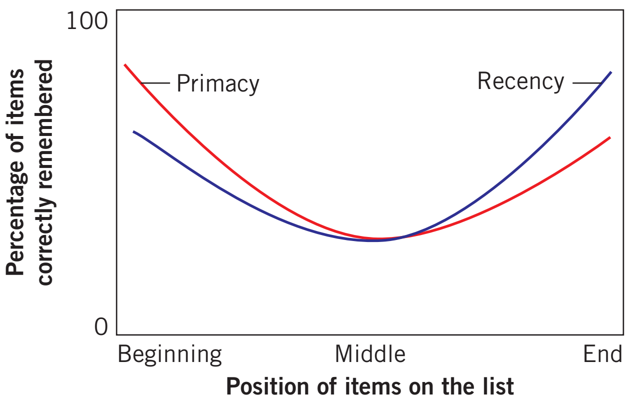


Figure 3.10 These curves show the general idea of the two types of serial-position effect. The blue line shows the recency effect, where recall is likely to be best for items at the *end* of a list, then for items at the beginning, then for items in the middle. The red line shows the primacy effect, where recall is likely to be best for items at the *beginning* of a list, then for items at the end, then for items in the middle.

Figure 3.11 The names Queen Elizabeth II is most likely to forget are those of the people in the middle of the line.

with them, they receive full attention and are able to begin transfer to LTM (Medin & Ross, 1992).

Why do we have most difficulty remembering the middle items? By the time we get to the middle of the list there is already too much information in STM to allow effective rehearsal of new items. Without rehearsal, the middle list-words drop out of STM (see Figure 3.11). Whenever you have to learn something in order, be aware of the serial-position effect. Give extra practice to the middle of a list, poem or speech.

LONG-TERM MEMORY (LTM)

According to the multi-store model of memory, once information in STM has been processed, it is transferred to a third memory store used for relatively permanent storage of an unlimited amount of information: long-term memory (LTM). When required at a later date, we retrieve information by locating it in LTM and returning it to conscious awareness. In this way, information not only flows from STM to LTM, but can also flow back from LTM to STM.

LTM is not merely a form of STM that holds information for a longer period. Information in LTM is stored in an organised manner based on its meaning and importance. If you make an error in LTM, it probably relates to meaning. For example, if you are trying to recall the word 'car' from a memorised list, you are more likely to mistakenly say 'truck' or 'automobile' than you are to say 'star'.

Most psychologists believe that although eternal memories are a myth, long-term memories are relatively permanent (Barsalou, 1992; Loftus & Loftus, 1980). That is, once a LTM has been formed, it can be stored for up to a lifetime. The reasons we cannot remember every long-term memory we have formed relate to an inability to retrieve information (discussed in the next chapter), not to the fact that those memories have dropped out of or been lost from LTM.

'Try it yourself 3.2' explores the effect of LTM on understanding new information.

Later in this chapter we will examine LTM in detail, including the types of memories that make up LTM and how information is organised in this component of memory.

TRY IT YOURSELF 3.2
Effect of LTM on understanding new information

Read the following paragraph.

> The procedure is actually quite simple. First you arrange things into different groups. Of course, one pile may be sufficient depending on how much there is to do. If you have to go somewhere else due to lack of facilities, that is the next step;

otherwise you are pretty well set. It is important not to overdo any particular endeavour. That is, it is better to do too few things at once than too many. In the short run this may not seem important, but complications from doing too many can easily arise. A mistake can be expensive as well. The manipulation of the appropriate mechanisms should be self-explanatory, and we need not dwell on it here. At first the whole procedure will seem complicated. Soon, however, it will become just another facet of life. It is difficult to foresee any end to the necessity for this task in the immediate future, but then, one never can tell.

Source: Bransford, J. D., & Johnson, M. K. (1972). Contextual prerequisites for understanding: Some investigations of comprehension and recall. *Journal of Verbal Learning and Verbal Behaviour, 11*, p. 722.

What do you think the paragraph is about? The paragraph is about how to wash clothes! Had the title 'How to wash clothes' been present, the paragraph should have made sense to you and been much easier to remember. If you read it again with the title in mind, your prior knowledge will allow you to encode the information at a deeper level and to process the paragraph more efficiently. The title acts as a clue that allows you to access information about the topic that you have stored in your LTM. In general, the more you know about a topic, the easier it becomes to remember new things about it.

CHECK YOUR UNDERSTANDING 3.2

1 Match each term with its correct definition.

a	Maintenance rehearsal	**i**	A form of rehearsal that involves linking new information to the self or personal experience
b	Elaborative rehearsal	**ii**	A pattern of recall for list items, where recall is better for the first or last items in a list, than for items in the middle of the list
c	Self-referencing	**iii**	The serial-position effect where recall is best for the first items on the list, then for items at the end of the list, then for items in the middle of the list
d	Serial-position effect	**iv**	The serial-position effect where recall is superior for items at the end of a list, then for items at the beginning, then for items in the middle of the list
e	Primacy effect	**v**	Involves repeating information a number of times to store it in STM for longer than the usual 18–20 seconds
f	Recency effect	**vi**	Involves linking new information in some meaningful way with information already stored in LTM, or with other bits of new information, to hold it in STM for longer than the usual 18–20 seconds

2 Which of the following is the most effective way of moving information from STM to LTM storage?

A Maintenance rehearsal
B Elaborative rehearsal
C Primacy rehearsal
D Repetition a number of times

3 Fill in the gaps below with the correct terms.

a Short-term memories are very sensitive to ________________, but they can be prolonged by ___________rehearsal (silent repetition).

b The tendency to remember the first and last items in a list better than the items in the middle is called the ______________________.

c Elaborative rehearsal takes ___________ time than maintenance rehearsal and involves accessing information already in __________.

d According to the multi-store model of memory, information is initially encoded in ____________ memory and finally stored in _______________ memory.

4 Indicate whether the following statements are true (T) or false (F).

a Generally, a short-term memory lasts for about 18–20 seconds unless rehearsed.

b Maintenance rehearsal helps to store information longer in sensory memory.

c Elaborative rehearsal helps us organise single items of information into larger, meaningful single units so that greater STM storage is possible.

d Recency effect occurs when you are more likely to remember items at the beginning of a list than those at the end or in the middle.

5 The technique for extending STM's duration by creating links between new information and information already stored in LTM is:

A maintenance rehearsal.
B elaborative rehearsal.
C chunking.
D serial-position effect.

long-term memory (LTM)
The third memory system in the multi-store model of memory; used for relatively permanent storage of an unlimited amount of information

Alternatives to the multi-store model

BADDELEY AND HITCH: A MODEL OF WORKING MEMORY

Although most psychologists agree with Atkinson and Shiffrin's proposition that memory consists of three separate stores through which information passes, in recent years their view of STM has been challenged. The multi-store model of memory suggests that STM is a single memory store and that merely holding information there is sufficient for it to be transferred to LTM – that is, the longer the information is held, the higher the probability of transfer. Yet it does not account for evidence that demonstrates that information is not just passively held in STM; it is also actively manipulated (or 'worked on').

Alan Baddeley and Graham Hitch (1974) suggest that STM is not a single memory store that passively holds information. They suggest it is an active, multi-component memory system that performs a variety of tasks. Baddeley and Hitch propose that working memory is the subsystem of STM that temporarily stores *and* manipulates a limited amount of information needed to perform cognitive tasks. In doing this, working memory encodes the information into LTM and also retrieves it from LTM. (The rest of STM is used to temporarily hold information until it is taken up by working memory or ignored.)

The term 'working' is used because it indicates that we are actively doing something with the information (Baddeley, 1981). For example, when we perform mental arithmetic, working memory holds the numbers while we manipulate them and it holds words while we compose a meaningful sentence. Working memory holds all the information needed for cognitive activities, such as thinking, planning and analysis. In this way, working memory provides the focus of consciousness, in that it holds the information you are consciously thinking about now (Cohen, 1990).

Originally, Baddeley and Hitch suggested that working memory consisted of three separate but interrelated components. The first and second components – a *phonological loop* and a *visuospatial sketchpad* – each have independent capacity limits. These independent 'slave' systems briefly store information needed by the third component, the *central executive*, which integrates information, and plans and controls behaviour as we perform cognitive tasks. In 2000, Baddeley added a third slave system: the *episodic buffer*. (See Figure 3.12.) We will now explore these components.

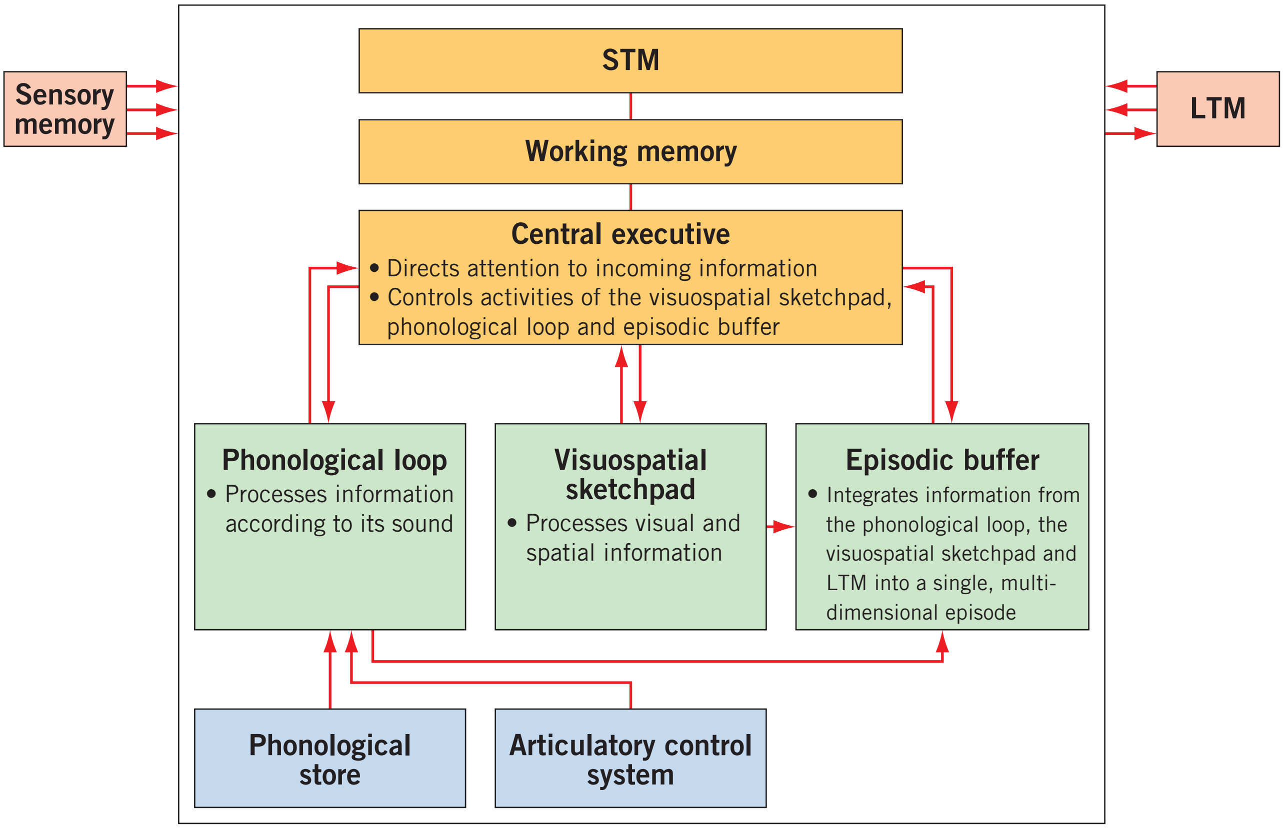


Figure 3.12 According to Baddeley and Hitch, working memory consists of a central executive and three slave systems: the phonological loop, the visuospatial sketchpad and the episodic buffer.

The phonological loop: Our 'inner voice and ear'

The phonological loop (sometimes referred to as the *articulatory loop*) is an area of working memory that stores a limited number of sounds (speech-based and acoustic) received from the echoic memory and/or LTM for up to two seconds unless the information is rehearsed.

The phonological loop holds verbal information in the order in which words are presented and rehearsed, to prevent its rapid decay when we are speaking. It is at work when you recite a telephone number to temporarily retain it, or when you prepare words to speak aloud.

The phonological loop has two subsystems – one for storage and one for processing. The phonological store (the 'inner ear') holds the representations of sounds for approximately 1.5–2 seconds. These representations then fade unless they are taken up by the articulatory control system (the 'inner voice'). This system holds the sounds we want to keep or are preparing to speak, in their order, for up to two seconds, by *subvocalising* (rehearsing by silently repeating) them on a loop to prevent decay. When we silently read, the articulatory control system converts written material to sounds (speech-based) so they can enter the phonological loop.

Phonological loop activity is limited to the amount that can be said in two seconds (Baddeley, 1996). Therefore, storage is limited by the time it takes for pronunciation, not by the amount of information. For example, if you were listening to the radio while I was talking to you, how much would you remember of what I said? It would be hard to remember both because of the phonological loop's limited capacity, which stores about 1.5–2 seconds' worth of words.

The visuospatial sketchpad: Our 'inner eye'

The visuospatial sketchpad (or the 'inner eye') briefly stores a limited amount of visual and spatial information received from sensory memory or LTM. It deals with what information looks like (visual) and how it is laid out in space (spatial) by representing information in the form of visual features such as size, shape and colour, or the location or speed of objects in space.

The visuospatial sketchpad also has storage and processing components. It stores information only briefly, but long enough for us to rehearse it and to manipulate and process it. If you closed your eyes and tried to visualise the objects presently in the room, you would be relying on the visuospatial sketchpad's storage component. The processing part of the visuospatial sketchpad operates when, for example, you are travelling along a familiar road and visualise what is around the next corner. It is also involved in spatial thinking, such as planning your route through a complex building or forming mental images and rotating them.

Episodic buffer

As mentioned previously, Baddeley added a third working memory slave system in the year 2000: the episodic buffer. The episodic buffer briefly stores a limited amount of information from the phonological loop and the visuospatial sketchpad with information retrieved from LTM, and integrates it into a single multi-dimensional representation or 'episode'. In doing so, it acts as an intermediary, or 'buffer', between the phonological loop, visuospatial sketchpad and LTM so that we can make sense of information entering different parts of working memory (Sternberg, 2003).

Central executive: Controlling activity

The central executive monitors, coordinates and integrates information from the phonological loop, visuospatial sketchpad and episodic buffer, as well as

working memory
According to Baddeley and Hitch, an active subsystem of STM that temporarily stores and manipulates a limited amount of information needed to perform cognitive tasks

phonological loop
An area of working memory that stores a limited number of sounds (speech-based and acoustic) received from the echoic memory and/or LTM for up to two seconds unless the information is rehearsed

phonological store
A subsystem of working memory's phonological loop that holds representations of sounds for up to two seconds; known as the 'inner ear'

articulatory control system
A subsystem of working memory's phonological loop that holds the sounds we want to keep or are preparing to speak, in their order, for up to two seconds, by subvocalising them; known as the 'inner voice'

visuospatial sketchpad
The area of working memory that briefly stores the visual and spatial information that is received from sensory memory or LTM

episodic buffer
An area of working memory that briefly stores a limited amount of sound-based information from the phonological loop and visual and spatial information from the visuospatial sketchpad with information retrieved from LTM, and integrates it into a single multi-dimensional representation or 'episode'

central executive
An area of working memory that monitors, coordinates and integrates information received from the phonological loop, visuospatial sketchpad, episodic buffer and LTM

information retrieved from LTM needed to complete cognitively demanding tasks (see Figure 3.13). It has a limited capacity, and it can store information for approximately 18–20 seconds without rehearsal.

Figure 3.13 Working memory's central executive controls and integrates information from its three 'slave' systems so we can decide what action to take; for example, what to eat from the fridge.

Because the central executive controls and integrates the flow of information from its slave systems, it plays a major role in attention. It controls which items move in and out of STM by deciding which information arriving from sensory memory will be attended to, and by controlling the retrieval process from LTM. Therefore, the central executive plays a major role in planning and controlling behaviour as it switches attention between tasks and selects strategies to tackle the problem being worked on (Baddeley, 1988; Morris, 1987; Morris & Jones, 1990). The central executive also coordinates the activities needed to carry out more than one processing task at a time, so it is in control when we multi-task. It is at work when, for example, you mentally weigh up pros and cons before deciding which sound system or mobile phone to buy.

We might imagine working memory as a multimedia production house, which continuously generates and manipulates images and sounds, coordinating the integration of sight and sound into meaningful arrangements. Once images, sounds and other information are stored, they are still available for reformatting and reintegration in new ways, as new demands and new information become available (Sternberg, 2003).

The two key characteristics of Atkinson and Shiffrin's multi-store model that originally defined STM – limited capacity and limited duration – are still present in the working memory model. However, the Baddeley and Hitch model accounts for evidence that STM handles a greater variety of functions and depends on more complicated processes than previously thought.

'Focus on Research: Evidence in support of working memory' outlines one of Baddeley and Hitch's experiments into working memory.

FOCUS ON RESEARCH

Evidence in support of working memory

Baddeley and Hitch (1974) asked participants to perform tasks involving STM function.

In the control condition, participants completed a reasoning task. The task involved judging whether certain statements about the order of letters presented to them were correct, by answering 'yes' or 'no'. For example, the two letters 'BA' might be presented along with a statement such as 'A follows B'. Participants would have to decide whether this was true, and respond by pressing a 'yes' or 'no' button.

In the experimental condition, participants were asked to complete the reasoning task and also complete a rehearsal task *at the same time*. The rehearsal task involved rehearsing a list of up to eight random numbers.

The time it took to complete the reasoning task in each condition was recorded.

It was found that the time taken to complete the reasoning task was basically the same for each condition. When participants completed the reasoning task on its own, the average times recorded were less than one second faster than when they completed the reasoning and rehearsal task simultaneously. In addition, the error rate remained at about 5 per cent, no matter how many numbers the participants rehearsed.

Baddeley and Hitch concluded that STM (or the subsystem of working memory) can deal with more than the average seven pieces of information and that two tasks can be successfully carried out simultaneously provided that they are being dealt with by different parts of the memory system.

Their results led to the conclusion that suggested that there are a number of components within working memory (the phonological loop, the visuospatial sketchpad and the central executive) that operate partially independently of one another (Baddeley, 1986, 1988; Baddeley & Hitch, 1974). The experiment suggested that the phonological loop and the visuospatial sketchpad have limited capacity, but that the limits of these two components are independent. As Baddeley and Hitch discovered, you can rehearse numbers in the phonological loop while making decisions about the spatial arrangement of letters on the visuospatial sketchpad.

QUESTIONS

1. Write a hypothesis for this experiment.
2. Identify the independent variable.
3. Identify the dependent variable.
4. List the results.
5. What conclusion(s) did Baddeley and Hitch arrive at?

CHECK YOUR UNDERSTANDING 3.3

1 Which of the following statements is incorrect?
   A Working memory is an active subsystem of STM.
   B Working memory has unlimited capacity and duration.
   C Working memory has limited capacity and duration.
   D Working memory is the area of STM that momentarily holds and manipulates information.

2 Fill in the gaps below with the correct terms.
   a The __________________ is the area of working memory that integrates information from the LTM with information from the visuospatial sketchpad and the phonological loop into a single multi-dimensional event.
   b The __________________ monitors, coordinates and integrates information from the three slave systems and LTM.
   c Attention in working memory is controlled by the _____________________.

3 According to Baddeley and Hitch, the role of the visuospatial sketchpad in working memory is to:
   A integrate information from the phonological loop, episodic buffer and central executive.
   B store visual and spatial information received from sensory memory and LTM.
   C store auditory information received from sensory memory and LTM.
   D integrate auditory and visual information into one event or episode.

4 Indicate whether the following statements are true (T) or false (F).
   a The words we are preparing to speak aloud are held in the central executive until needed.
   b The visuospatial sketchpad has an unlimited capacity.
   c The phonological loop has an unlimited duration.
   d The central executive has a limited capacity.

5 Match each term with its correct definition.

a Phonological loop	i The area of working memory that briefly stores visual and spatial information
b Visuospatial sketchpad	ii The area of working memory that briefly stores and integrates sound-based information, visual and spatial information and information from LTM into a single multi-dimensional representation
c Episodic buffer	iii The area of working memory that monitors, coordinates and integrates information received from the phonological loop, visuospatial sketchpad, episodic buffer and LTM
d Central executive	iv The area of working memory that stores speech-based and acoustic information

CRAIK AND LOCKHART: LEVELS OF PROCESSING MODEL

Craik and Lockhart (1972) are also critical of the multi-store model. They suggest that memory is not made up of three separate stores and that there is no clear distinction between STM and LTM (and Baddeley's working memory). Their levels of processing model focuses on the *processes* – different levels of operations – involved in memory rather than on the structures involved.

Craik and Lockhart suggest that the memory system consists of sensory memory and one other memory store, and that storage varies along a continuum of levels of processing ranging from shallow to deep processing. How long and how well information is stored does not depend on three distinctly different types of memory systems; it depends on the level of processing used during encoding. Information can be processed in many ways – structurally, phonemically or semantically – and each one requires a deeper level of encoding. The deeper the level, the more lasting the memory code and the more likely it is that information may be retrieved.

Shallow processing involves structural encoding because it focuses on basic (structural) perceptual information such as the physical structure of the stimulus information. For example, if words are flashed on a screen, structural encoding registers such things as what they looked like (capital or lower case) or how long they were (how many letters), but this

levels of processing model
The theory that after information leaves sensory memory, its storage varies along a continuum of levels of processing ranging from shallow to deep processing; the level of processing used during encoding determines how long and how well information is stored

shallow processing
Processing information using structural encoding

structural encoding
Encoding information according to its basic (structural) perceptual features

information is usually soon lost (Weiten, 1992). Because shallow processing encodes information at a basic level, it does not involve meaning, so it creates weak memory traces that may fade quickly or be harder to retrieve.

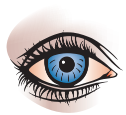
Intermediate processing involves phonemic encoding because it emphasises what words sound like when we are identifying or naming the information either silently or aloud.

Deep processing uses semantic encoding because it emphasises meaning by linking new information to previously learnt information with similar meaning that is already stored in LTM. This linking creates associations between the new memory and existing memories and creates deeper memory traces that are stored for longer, making retrieval more likely (Ellis, 1987; Ellis & Hunt, 1993).

According to Craik and Lockhart, the type of rehearsal involved is crucial to the depth of processing achieved. Maintenance rehearsal uses shallow processing to preserve information but it doesn't produce a lasting memory trace. Elaborative rehearsal uses semantic processing, therefore it increases the depth of analysis and produces longer-lasting traces. (Memory traces will be examined later in this chapter.)

Table 3.4 outlines the levels of processing and encoding in Craik and Lockhart's model.

Table 3.4 The levels of processing model

LEVELS OF PROCESSING	TYPE OF ENCODING	EFFECT
Shallow (maintenance rehearsal)	Structural (Looks like ...) 	Produces weak memory traces that fade rapidly
Intermediate	Phonemic (Sounds like ...) 	Produces memory traces stronger than those produced by structural encoding, but not as strong as memory traces produced by semantic encoding
Deep (elaborative rehearsal)	Semantic (Means ...)	Produces long-lasting memory traces

In 1975, to test the levels of processing theory, Craik and his colleague Tulving conducted a number of experiments in which they presented participants with a word list. Before each word was briefly presented, it was preceded by a question about a specific aspect of the word. The questions were asked in random order, and varied, to encourage the three different levels of processing in progressive order of depth. For example, the first question, 'Is the word in capital letters?', asked about the physical structure of the word, so it was expected to encourage structural encoding. The second question, 'Does the word rhyme with "weight"?', asked about pronunciation, so it encouraged phonemic encoding. The third question, 'Would the word fit in the sentence, "He met a ______ on the street"?', encouraged semantic encoding because participants had to consider its meaning. Participants were given two seconds to answer each question by pressing either a 'Yes' or 'No' key. Their answers and response times were recorded.

It was found that responses were slowest when semantic encoding was encouraged. This was followed by phonemic encoding. Responses were quickest for questions requiring structural encoding.

A surprise test was also given to participants after they had been shown 60 words and made 60 responses. In this test, participants were presented with a list of 180 words and asked to identify the 60 words used in the experiment. This test was conducted to see which type of encoding/processing produced the longest-lasting memory traces.

Of the three 'types' of words on the list, the percentage of words recalled was highest for those words associated with semantic encoding, followed by those words associated with phonemic encoding. The percentage of structurally-encoded words recalled was lowest.

Craik and Lockhart concluded that the differences in response times are consistent with the theory that phonemic and semantic encoding are deeper levels of processing, and that semantic codes support memory more than phonemic codes, which are better than structural codes. Finally, they concluded that deeper levels of processing produce more durable memory codes, which result in better retention.

CHECK YOUR UNDERSTANDING 3.4

1 Indicate whether the following statements are true (T) or false (F).

  a The levels of processing model emphasises the three structures involved in information processing.

  b Craik and Lockhart's (1972) model of memory suggests that STM and LTM are separate information stores.

  c Shallow processing relies on semantic encoding.

2 Fill in the gaps below with the correct terms.

  a ________________ encoding emphasises what words sound like when we are identifying information by naming it.

  b ____________ encoding results in longer-lasting memory codes.

  c Encoding information according to its visual features involves __________________ encoding.

3 Craik and Lockhart's levels of processing model of memory suggests that:

A better storage results from shallow processing.

B better storage results from intermediate processing.

C better storage results from deep processing.

D the level of processing used during encoding has minimal impact on storage.

4 Which of the following statements is incorrect for the levels of processing theory?

A Phonemic encoding is used during intermediate processing.

B Deep processing uses semantic encoding.

C Intermediate processing creates longer lasting memory traces than shallow processing.

D Deep processing emphasises what words sound like when we are identifying or naming information.

5 Match each term with its correct definition.

a	Semantic encoding	i	Processing that relies on phonemic encoding
b	Deep processing	ii	Encoding that focuses on what words sound like when we are identifying or naming information
c	Phonemic encoding	iii	Processing that relies on semantic encoding
d	Intermediate processing	iv	Encoding that focuses on the basic perceptual features of the stimulus information
e	Structural encoding	v	Encoding information according to its meaning
f	Shallow processing	vi	Processing that relies on structural encoding

Types of memories and organisation in LTM

Let us now return to the concept of LTM as a separate memory store and explore this component of memory. Studies of amnesia sufferers have found that while some may be unable to learn new information such as a telephone number, an address or a person's name, they can learn to solve complex puzzles in the same amount of time as normal subjects (Squire & Zola-Morgan, 1988). This finding supports the theory that not only is LTM a separate memory store, but it stores different types of memories. We must understand these types of memories before we can examine how information is organised in LTM.

TYPES OF MEMORIES IN LTM

There are two major memory types in LTM, which we will now explore. Figure 3.14 shows a model of the types of memory that make up LTM.

Procedural memory: Learnt actions and skills

The memory of learnt actions and skills – for example, memories of how to do things such as walk, talk, juggle or ride a bike – is known as procedural memory. Although we store these memories in our LTM, they often involve complicated sequences of movements that we are usually unaware of or that we are unable to articulate. Therefore, we can usually only fully express a procedural memory as an action. This may explain why even patients with amnesia are able to perform routine procedures and why a gymnast, for example, may be able to perform but not describe in words the exact movements required for a routine.

Procedural memories appear to register in low brain areas that are beyond conscious control, thus they represent the more basic, 'automatic' elements of learning and memory related to actions (Gabrieli, 1998). This is probably why they are the LTM type that is most resistant to forgetting (as the saying goes, we never forget how to ride a bike!).

Declarative memory: Facts and rules

The LTM store for factual information – such as names, faces, words, dates and ideas – is known as declarative memory. Declarative memories are expressed as words or symbols. For example, knowing that Melbourne is the capital of Victoria or that you received a blue bicycle for your 10th birthday are examples of declarative memory. Many psychologists believe that declarative memory can be further divided into *semantic memory* and *episodic memory* (Nyberg & Tulving, 1996).

intermediate processing
Processing information using phonemic encoding

phonemic encoding
Encoding information according to the sound of the word used to identify the information

deep processing
Processing information using semantic encoding

semantic encoding
Encoding information according to its meaning

procedural memory
A type of LTM for learnt actions and skills that can usually only be expressed as actions

declarative memory
A type of LTM for specific factual information that can be expressed in words; subgroups are semantic memory and episodic memory

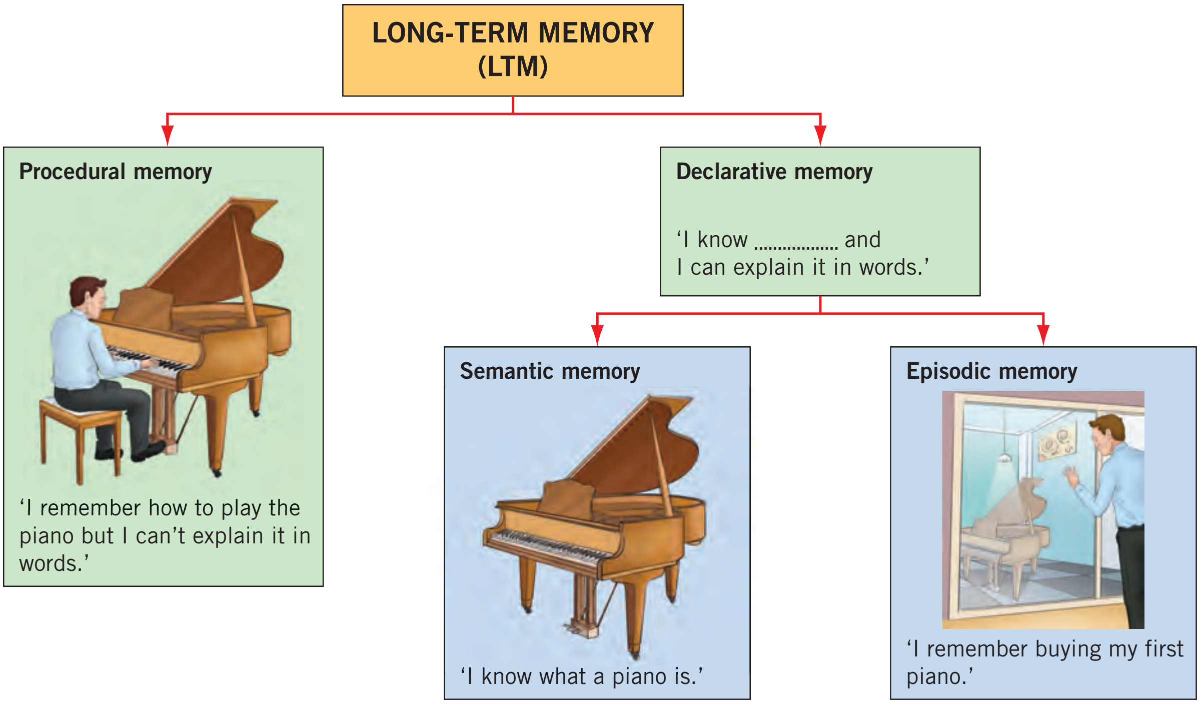


Figure 3.14 LTM is divided into procedural memory and declarative memory. Declarative memories can be either semantic or episodic.

SEMANTIC MEMORY: MEANING

The names of objects, the days of the week and months of the year, simple mathematics skills, words and language, and other general facts are quite resistant to forgetting. Such impersonal facts and rules make up the part of LTM called semantic memory (see Figure 3.15).

Semantic memory holds the factual information we use for making meaning so we understand the world around us. Semantic memory involves general factual information about the world that does not involve the memory of personally significant events or episodes that are tied to a specific time or place. It would be rare, for instance, to remember when and where you first learnt the names of the seasons, but do you know whether snow falls in winter or summer? Most people know the answer to this question without remembering a specific episode in which they learnt the information.

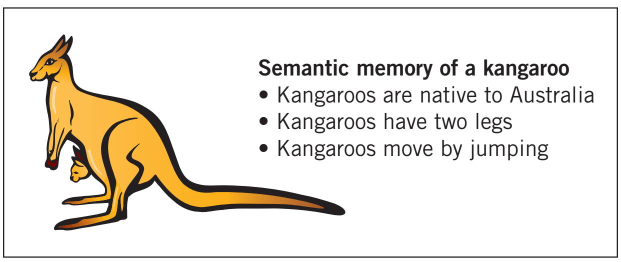


Figure 3.15 We store impersonal factual information and rules in semantic memory. These memories allow us to make meaning.

EPISODIC MEMORY: TIME AND PLACE

Episodic memory stores personally significant events or episodes that are related to a specific time or place, such as a special birthday celebration (Figure 3.16) or your first day at secondary school. As a general

Figure 3.16 Episodic memories, such as special birthdays, are connected to specific times and places.

rule, people convey episodic memories by stating, ‘I remember when …’, whereas they convey semantic memories by saying, ‘I know that …’ (Tulving, 1972).

Of all the LTM types, episodic memories are the least resistant to forgetting. Very vivid episodic memories are termed *flashbulb memories* (Brown & Kulik, 1977). Flashbulb memories involve recalling exactly what you were doing and where you were when a particularly important, exciting or emotional event happened. See Figure 3.17 for a humorous take on flashbulb memories.

More facts of nature: All forest animals, to this very day, remember exactly where they were and what they were doing when they heard that Bambi’s mother had been shot.

Figure 3.17 Flashbulb memories involve remembering where you were and what you were doing when a particular event happened.

‘A closer look: Does scent enhance consumer product memories?’ examines the potential effect of scent on memory retention.

A CLOSER LOOK

Does scent enhance consumer product memories?

It may seem odd to add scent to products like sewing thread, automobile tyres and tennis balls, as some companies have done. But a new study in the *Journal of Consumer Research* by Aradhna Krishna (University of Michigan), May Lwin (Nanyang Technological University, Singapore) and Maureen Morrin (Rutgers University) says scent helps consumers remember product information because it enhances the product’s distinctiveness within its surrounding context. However while ambient (atmospheric) scents seem to boost memory for all the objects encountered in the scented environment (product, signs, lighting, salespeople), it doesn’t much help people remember particular products.

In one study, the authors had 151 participants evaluate pencils that were unscented, scented with pine scent (common), or scented with tea tree scent (uncommon).

‘We found that the memory for the scented pencils was much greater than memory for the unscented pencils, and that this effect was especially pronounced after a time delay,’ the authors write. They also found that participants’ memory of the uncommonly (tea tree) scented pencils was more resistant to decay.

In a second study, the authors compared the effectiveness of product scent to ambient scent. The researchers manipulated whether or not the target product (facial tissues) was scented and whether or not the room was scented.

‘We find again that when a product is scented, long-term memory for that product’s attributes increases and further, that product scent is more effective than ambient scent at enhancing memory for product-related information,’ the authors write.

Source: Adapted from *Science Daily* online (2009) Does Scent Enhance Consumer Product Memories? 15 December.

SEMANTIC NETWORK THEORY

We will now examine how information is stored and organised in LTM. There are a number of different theories about this subject, but the prevailing belief is that information in LTM is stored and organised semantically (according to meaning). This theory is known as semantic network theory (see Figure 3.18).

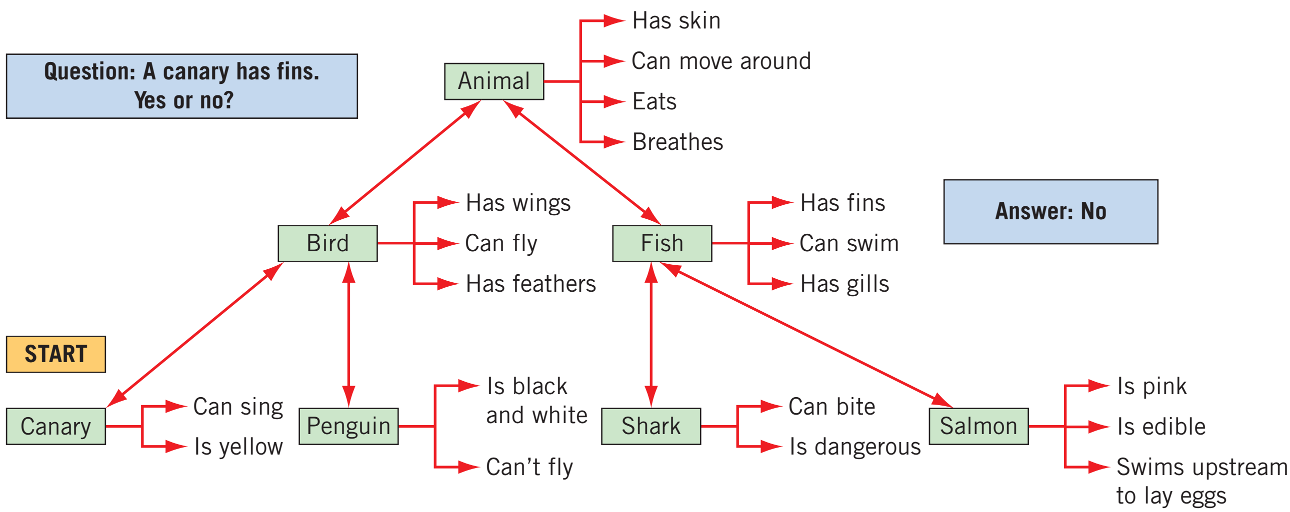
Semantic network theory suggests that long-term memories are stored and organised in concepts (nodes) based on shared meaning and connected by meaningful links. That is, new information that has a similar meaning to information already stored in LTM is stored close to that similar information already in LTM. The grouping may be based on similarity of rules, images, categories, symbols, formal meaning or personal meaning (Baddeley, 1990; 1996). In terms of information links, ‘canary’ is probably closer to ‘bird’ in your semantic network than ‘animal’ is to ‘canary’.

Concepts sharing a similar meaning are stored close together; therefore, they have short, strong links. When you attempt to retrieve a specific memory you begin by conducting a memory search in one of the LTM areas using various memory cues as a trigger for the targeted memory. This involves tracing the associations along the links in this area until you ‘hit’ your targeted memory. Once you do

semantic memory
A type of declarative memory for impersonal factual knowledge about the world

episodic memory
A type of declarative memory for personally significant events associated with specific times and places

semantic network theory
The theory of how information in LTM is stored and organised in a hierarchical network of linked meanings



Source: Adapted from Collins & Quillian, 1969

Figure 3.18 This hypothetical network of animal facts illustrates the basic principle behind semantic network theory.

this, those memories that have a short, strong link to the targeted memory are also activated, and they in turn activate other memories, and so on (Collins & Loftus, 1975). Concepts that are not similar in meaning are stored further apart, and the links between them are longer and weaker. Therefore, it takes longer to retrieve them.

Semantic network theory also suggests that these concepts are organised systematically in the form of overlapping networks of concepts. In addition, semantic networks have a hierarchical structure, with different levels representing concepts ranging from the most abstract (broad) to the most concrete (specific) (Collins & Quillian, 1969).

VIDEO
Short- and long-term memory

View 'Videolink: Short- and long-term memory' for an overview on what you have learnt about these components of memory.

TRY IT YOURSELF 3.3
Organisation and retrieval

1 To illustrate how semantic networks operate, learn the following list of words. Allow yourself only 30 seconds.

car	bus	truck	pear	mattress
orange	school	pillow	blanket	doona
bed	apple	taxi	cherry	house

2 Now, count backwards by threes for 30 seconds, starting at 389.

3 Now try to recall the words from the memorised list, in any order.

You probably find that you recall *groups* of words that relate to certain categories; for example, the fruits, and the bedroom items. This would demonstrate that you grouped the items according to meaning.

CHECK YOUR UNDERSTANDING 3.5

1 Fill in the gaps with the correct terms.
   a ________________ memories are linked to personally significant times and places.
   b Declarative memory can be divided into ____________ memory and _____________ memory.
   c Non-personal information that assists you in assigning meaning is stored in _____________ memory.
   d ____________ memories are the most resistant to forgetting.

2 Information in LTM is believed to be stored in or as:
   A a sequential way, similar to a recording on a videotape.
   B an alphabetical way, similar to words in a dictionary.
   C a series of fragments, each tagged to a specific rule that allows the fragments to be recombined into an accurate memory.
   D a series of fragments linked together in an interrelated manner.

3 Indicate whether the following statements are true (T) or false (F).
   a The memory of how to ride a bicycle is a semantic memory.
   b It is difficult to express a procedural memory in words.
   c Procedural memories are the LTM type that is most resistant to forgetting.
   d Knowing that the word 'cat' refers to an animal and not a colour is based on semantic memory.

4 Which of the following statements about semantic network theory is correct?

A Information in LTM is stored as an exact replica of its original form.

B Information in LTM is organised according to the type of encoding used to process it.

C Information in LTM that is similar in meaning is organised closer together than information further apart in meaning.

D Information in LTM is organised on the basis of similar structural features.

5 Match each term with its correct definition.

a	Procedural memory	i	The LTM for specific factual information that can be expressed in words
b	Episodic memory	ii	The declarative memory type for impersonal knowledge of factual information about the world
c	Declarative memory	iii	The LTM for learned actions and skills that can usually only be expressed as actions
d	Semantic memory	iv	The declarative memory type for personally significant events associated with specific times and places

The physiology of memory

NEURONS, SYNAPSES AND TRACES

How does our brain form memories? Researchers interested in memory formation and storage focus on what occurs in the brain during memory formation. Specifically, they are interested in changes within the brain's neurons and at the synapse between neurons. (To refresh your memory of the structure and role of neurons and synapses, read 'A closer look: The neuron' on page 41 of chapter 2. We will also learn more about neurons in chapter 5.)

Research suggests that neuronal activity is the basis of memory formation and storage, and that each memory has a unique pattern, or memory trace. A memory trace is a physical or chemical change that is believed to occur in brain cells as they store information during memory formation. One neuron stimulates another neuron to fire by releasing its neurotransmitters (chemicals released at the synapse that transmit messages between neurons) into the synapse (see Figure 5.9, page 164). Studies of lower-order animals indicate that when this stimulation occurs, a lasting change in the efficiency of the synapse is produced (Kandel & Schwartz, 1982). The receiving neuron becomes more likely to fire again in the future, thus making it easier for nervous impulses to travel the same pathway again.

'A closer look: First image of memories being made' explores a study that has discovered and captured an image of a mechanism involved in the formation of memory.

A CLOSER LOOK

First image of memories being made

A new study by the Montreal Neurological Institute and Hospital (The Neuro), McGill University and University of California, Los Angeles has captured an image for the first time of a mechanism, specifically protein translation, which underlies long-term memory (LTM) formation.

This is the first visual evidence that when a new memory is formed, new proteins are made locally at the synapse, increasing the strength of the synaptic connection and reinforcing the memory. The study is important for understanding how memory traces are created.

The research focused on synapses, which are the main site of exchange and storage in the brain. They form a vast but also constantly fluctuating network of connections whose ability to change and adapt (known as synaptic plasticity) may be the fundamental basis of learning and memory.

'If this network is constantly changing, how are memories formed? It has been known for some time that an important step in LTM formation is the "translation" (or production) of new proteins locally at the synapse, which strengthen the synaptic connection,' says Dr Wayne Sossin, neuroscientist at The Neuro and co-investigator in the study. 'Using a translational reporter, a fluorescent protein

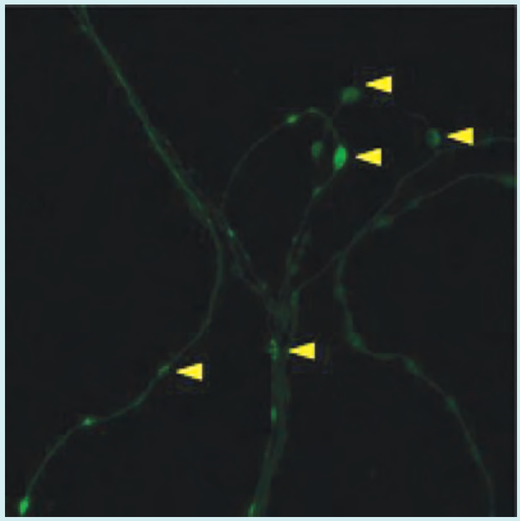


Figure 3.19 The increase in green fluorescence represents the imaging of local translation at synapses during long-term synaptic plasticity. This is a low-resolution image of the protein translation discovered in the study.

Continued

memory trace
A physical or chemical change that is believed to occur in brain cells as they store information during memory formation

neurotransmitters
Brain chemicals released at the synapse that transmit messages between neurons

can be easily detected and tracked and the increased local translation, or protein synthesis, during memory formation can be visualised. Importantly, this translation is synapse-specific and requires activation of the post-synaptic cell, showing that this step required cooperation between the pre- and post-synaptic compartments – the parts of the two neurons that meet at the synapse.'

LTM and synaptic plasticity require changes in gene expression and yet can occur in a synapse-specific manner. This study provides evidence that a mechanism that mediates this gene expression during neuronal plasticity involves regulated translation of localised mRNA (a specific biologically-important type of molecule) at stimulated synapses. These findings are instrumental in establishing the molecular processes involved in LTM formation and provide insight into diseases involving memory impairment.

Source: Adapted from *Science Daily* online (2009) 'First image of memories being made.' 19 June.

Kandel: In search of the memory trace

In 2000, Columbia University's Professor Eric Richard Kandel won the Nobel Prize for his previous work on the physiological basis of memory formation in neurons. In order to discover the molecular mechanisms involved, Kandel had studied learnt reflexes in a simple organism, the aplysia – or sea slug (see Figure 3.20). Aplysia were chosen because they have a very simple nervous system with a small number of extraordinarily large and distinctively pigmented nerve cells. This made it easy to observe any physiological changes, particularly synaptic changes, occurring during learning. Kandel observed the aplysia's neural connections before and after learning, noting any anatomical or chemical changes, particularly those relating to changes in the level of neurotransmitters released at the synapse.

Figure 3.20 An aplysia: The aplysia's simple nervous system allows psychologists to observe synaptic changes that occur during memory formation.

In one study, Kandel taught aplysia to withdraw its gill and water siphon in response to touch. Kandel began by repeatedly gently touching the aplysia's siphon. Ordinarily, sea slugs withdraw their gill and siphon at the slightest stimulation, but Kandel found that they soon habituate to being gently touched. Once habituation is established, withdrawal in response to touch stops. After the aplysia habituated to touch, Kandel followed the touch with a mild electric shock. Although the shock was harmless, it was strong enough to cause the reflex withdrawal of the gill and siphon. After several trials, the touch alone caused the gill and siphon to be withdrawn (Castelluci & Kandel, 1976). (This is an example of classical conditioning, which we will investigate in chapter 6.)

Kandel concluded that reflex learning had occurred because the aplysia had formed a memory of the association between touch and pain, causing the aplysia to release more of its neurotransmitters into its synapses. Based on these findings, Kandel theorised that memory formation depends on neuronal activity, specifically related to the release of neurotransmitters at specific synapses. Increases in the level of neurotransmitters strengthen the synaptic connections between neurons, resulting in more efficient synaptic transmission and more efficient neural circuits. Therefore, durable changes in synaptic transmission may be the neural building blocks of memory (Kandel & Schwartz, 1982).

Kandel's theory is supported by findings in people who suffer from Alzheimer's disease. Alzheimer's disease is characterised by severe memory impairment, which appears to be due to inadequate production of the neurotransmitter acetylcholine (Allen, Dawbarn, & Wilcock, 1988). Thus, an adequate supply of acetylcholine may be essential to memory formation. (Alzheimer's disease is discussed in more detail later in this chapter.) In addition, drugs that block neurotransmitters have also been shown to disrupt information storage (Squire, 1987). For example, alcohol impairs memory formation by disrupting the activity of the neurotransmitter serotonin (Weingartner et al., 1983). This is why, after a night of heavy drinking, the next morning a person may have trouble remembering events of the previous evening.

BRAIN AREAS INVOLVED IN MEMORY

Psychologists believe that no single brain structure or area is responsible for memory. Research results, such as those provided by Karl Lashley (1950), suggest that memory is the result of the interaction of a number of brain areas. In one experiment, Lashley trained rats to solve a maze and then removed various parts of their brain. When he retested their memory of the maze, the rats demonstrated some memory deficit, but retained partial memory of how to solve the maze. The amount of memory remaining seemed to depend on the *total* amount of brain tissue removed, not on the particular portion of the brain removed. Lashley concluded that a single memory can be stored in various parts of the brain; therefore, memory depends on the integration of activity in several areas of the brain. These areas include the temporal lobes and the hippocampus.

The temporal lobes

The fact that individuals who experience damage to their temporal lobes often suffer from amnesia – a temporary or permanent, partial or complete loss of memory – suggests that the temporal lobes play a major role in memory formation and storage.

Modern brain imaging techniques, such as PET and MRI scans, show that individuals who experience severe memory loss typically have damage in the temporal lobes. For example, MRI scans of sufferers of Alzheimer's disease show severe temporal lobe shrinkage, particularly towards the middle of the lobe. Because Alzheimer's sufferers experience a progressive inability to access old memories as well as form new memories (particularly autobiographical and fact-based memories), psychologists suggest that temporal lobe function is critical to memory function.

Research findings indicate that severe damage to the left temporal lobe results in difficulty remembering and understanding language, causing an inability to name familiar objects, places or faces (Kolb & Whishaw, 1990). As a result, psychologists believe that the names of familiar people, animals and tools are stored in the left temporal lobe, as well as factual information and information relating to personally significant events that can be expressed in words. As we discovered in chapter 2, when Wernicke's area is damaged, people cannot remember the meaning of words or the rules of language. Research has also shown that damage to the right temporal lobe can result in impaired memory for non-verbal information such as recognising familiar faces, music and pictures.

The hippocampus

Located below the cortex and buried deep within the brain, the hippocampus extends into the temporal lobes (see Figure 3.21). Psychologists believe that the hippocampus is heavily involved in forming, sorting and storing memories.

The hippocampus is located close to Wernicke's area (see chapter 2). PET scans show the hippocampus 'lighting up' when people recall words, suggesting that it plays a major role in the memory of language. The fact that people who experience severe hippocampal damage also experience memory loss for language also supports this view (Squire, 1987).

Organising spatial information and the ability to navigate through space is also believed to be linked to hippocampal activity. For example, brain imaging technologies show that your right hippocampus becomes more active if you mentally plan a drive across town. Damage to this area can make it difficult to navigate through space and many amnesia sufferers who experience hippocampal damage often get lost in 'familiar' surroundings such as their own neighbourhood (Maguire, Frackowiak & Frith, 1997).

Research suggests that if the hippocampus is damaged, specific types of new information may not be able to enter the memory system and old information in LTM may not be able to be accessed. Individuals with hippocampal damage have difficulty forming new memories, particularly memories involving information or events related to the self. They behave as though they were stuck in the past and they may have difficulty forming new LTMs of facts and events (Bigler et al., 1996). They find it difficult to concentrate and to learn new factual information; however, their ability to learn new skills or procedures appears unaffected. For example, they may not be able to remember who visited them yesterday but they can learn to solve a new puzzle, even if they later cannot actually remember learning how to do it. If the damage is severe, they may lose the ability to carry out an extended sequence of actions – such as making a cup of tea or dressing themselves – because they forget what they had planned to do.

These memory deficits have led to the belief that the hippocampus also plays a crucial role in the transfer of information, acting as a sort of 'switching station' where new information is passed from STM into LTM for lasting storage (Gabrieli, 1998). Scans

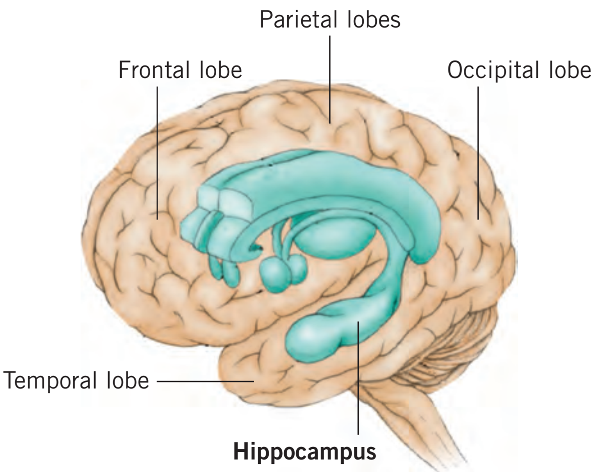


Figure 3.21 The hippocampus is buried deep within the brain, and extends into the temporal lobes. Damage to the hippocampus can result in amnesia.

Alzheimer's disease
An irreversible and progressive neurodegenerative disease that gradually kills brain cells, causing severe cognitive and behavioural decline that eventually results in death

acetylcholine
A neurotransmitter that carries information between the synapses of cells believed to be involved in learning, memory and mood

amnesia
A temporary or permanent, partial or complete loss of memory

hippocampus
A brain structure buried deep within the brain and extending into the temporal lobes; associated with memory formation and storage

and images of brains in action support this, as they show that the hippocampus receives input from all association areas and sends signals back to them as well as other areas.

View 'Videolink: Life without memory: The case of Clive Wearing' to explore the real-life case of Clive Wearing, a man incapable of making new memories. This is part 1a of the video. If you have time, you may wish to view parts 1b, 2a and 2b. 'Focus on research: Study shows busy minds good for the what's-its-name' investigates a study into hippocampal activity as age progresses. 'A closer look: H. M.' explores the role of the hippocampus in the famous case study of a patient known as 'H. M.'.

VIDEO
Life without memory: The case of Clive Wearing

FOCUS ON RESEARCH

Study shows busy minds good for the what's-its-name

That part of the brain responsible for memory shrinks twice as much in elderly people who had little education, limited social life or have not kept mentally active since their teens, a study has found.

Researchers at the University of NSW followed a group of 60-year-olds over three years. It found that those who had been mentally and physically active continually since the age of 13 had a larger hippocampus, the part of the brain governing short-term memory and navigation skills.

A small or atrophied hippocampus is a major factor in developing Alzheimer's disease, and mental activity has been found to delay the onset of some other degenerative brain diseases, such as Huntington's and Parkinson's. The author of the report, Michael Valenzuela, of the university's school of psychiatry, said researchers had for the first time compared brains, using magnetic resonance imaging, over many years in relation to mental activity patterns.

This added weight to previous work that showed that complex mental activity helped block dementia. 'It also helps throw some light on why there has been this consistent link between mental activity and lower dementia risk,' Dr Valenzuela said. But he said the study, published in the Public Library of Science's *ONE* journal, indicated that the size of the hippocampus was not directly related to intelligence. 'Among the people who had the bigger hippocampi, it came down to them having a real diversity of interests,' he said. Some had gone back to university in the 60s and 70s, and others had a variety of interests and socialised 'quite a lot'.

He said that while many drug companies were searching for ways to stop the hippocampus shrinking, people could help themselves. 'Our prior research shows the risk for dementia is quite malleable, even into late life,' he said. 'It is vital that everyone is involved in cognitive, social and physical activities in late life such as dancing, tai chi, sailing, travelling and learning a new language, for example.'

Source: Benson, K. (2008) 'Study shows busy minds good for the what's-its-name.' *The Age*. 15 July.

QUESTIONS

1 Write a hypothesis for this study.
2 Identify the independent variable and the dependent variable.
3 Identify the results of this study.
4 Identify the conclusions drawn from the results.

A CLOSER LOOK

H. M.

The hippocampus' role in memory is clearly illustrated by a famous case study of a patient, known as 'H. M.', by Canadian psychologist Brenda Milner. Two years after an operation to minimise epileptic seizures damaged his hippocampus, 29-year-old H. M. continued to give his age as 27. He also reported that it seemed as if the operation had just taken place (Milner, 1965). His memory of events before the operation remained clear, but he found forming new LTMs almost impossible. When his parents moved to a new house a few blocks away on the same street, he could not remember the new address. Month after month, he read the same magazines over and over without finding them familiar.

H. M. still had a short-term memory, but if you met him and then left the room to return 15 minutes later, he would not recognise you (Hilts, 1995). Yet, he vividly remembered his early past, and he could retain small bits of new information for short periods. At one point Milner asked H. M. to remember three numbers. By making elaborate associations, he managed to retain the numbers for 15 minutes. But moments later, he could not recall the digits or the train of associations that had helped in recalling them. He could not even remember being assigned the task.

CONSOLIDATION THEORY: MEMORIES ON THE MOVE

The process by which a relatively permanent LTM is formed is called consolidation. During consolidation, a memory is made 'solid' or 'stable'. According to consolidation theory, it takes approximately 30 minutes for a new memory to be transferred from STM to LTM for relatively permanent storage (Squire, Knowlton & Musen, 1993). As we learn the information, and during the time it takes to transfer it from STM to LTM, physical and chemical changes occur in brain cells as we lay down a chemical memory trace of what has been learnt. During this time, providing there is no interruption to the process, a new and lasting LTM is gradually formed. However, if consolidation is interrupted, the memory may be either damaged or lost (see Figure 3.22).

In one experiment to demonstrate consolidation, a rat was placed on a small platform overhanging a floor. When the rat stepped off the platform onto the floor, it received a *painful* electric shock through the floor. After only one shock, each time the rat was placed on the platform it would not step down onto the floor. The rat obviously remembered the shock and was avoiding the floor.

The rat was then given a harmless electric shock to the brain, interrupting the memory trace and preventing consolidation of the memory of pain when stepping off the platform. The rat was then placed on the platform again, and it proceeded to step down onto the shock-floor as if it didn't remember that the floor would give it a shock. It again received a shock through the floor.

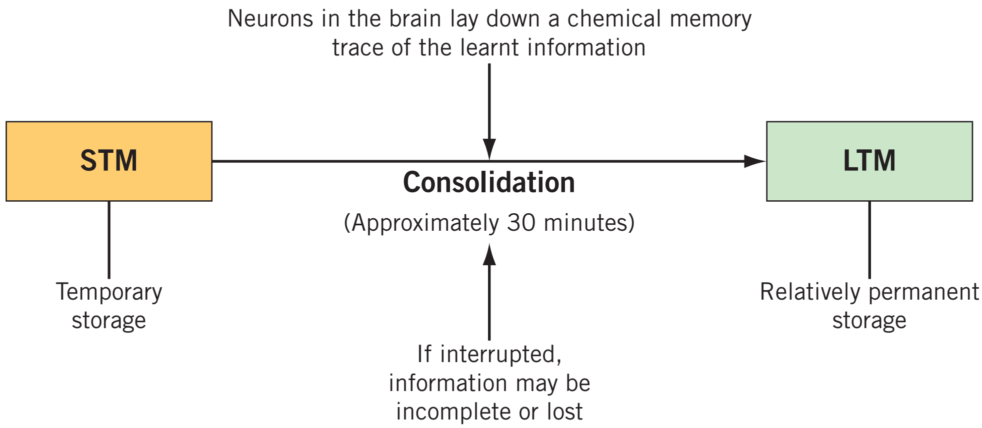


Figure 3.22 The consolidation theory

This process was repeated several times – after the rat stepped onto the floor and received the shock through its body, the researchers *immediately* administered a harmless shock to its brain. Each time the rat was placed on the platform after receiving the shock to its brain, it would continue to step down onto the floor. The experimenters concluded that each delivery of the shock to the brain erased the prior memory of the painful shock to the body – in other words, it disrupted consolidation of the memory of pain.

What would happen if shocks were given *several hours after* the learning? If enough time (more than 30 minutes) is allowed to pass between learning and the delivery of the shock to the brain, the memory passing from STM to LTM will be unaffected because consolidation will already be complete. That is why people with mild head injuries caused by an accident often lose memories from just before the accident, while older memories remain intact (Baddeley, 1990).

CHECK YOUR UNDERSTANDING 3.6

1 Indicate whether the following statements are true (T) or false (F).

- a Encoding refers to the amount of information that is held in the memory system.
- b Neurotransmitters are chemicals released at the synapse between neurons.
- c All memories are stored in the hippocampus.
- d Damage to the temporal lobe can cause memory loss.
- e Consolidation of a short-term memory into a long-term memory takes approximately 60 minutes.

2 Fill in the gaps with the correct terms.

- a The space between neurons is called a ________________.
- b Memory loss that can be temporary or permanent, partial or complete is known as ________________ .
- c ________________ results in the formation of a relatively permanent LTM.
- d ________________ are chemicals that make synapses more efficient.

3 One of the major roles of the hippocampus is to:

- A transfer information from STM to LTM.
- B transfer information from LTM to STM.
- C transmit signals across the synapse.

4 Match each term with its correct definition.

a	Consolidation	i	A brain structure associated with the consolidation of memories
b	Temporal lobe	ii	The gap between neurons over which messages are transmitted
c	Hippocampus	iii	Brain chemicals released at the synapse that transmit messages between neurons
d	Synapse	iv	The process by which relatively permanent memories are formed
e	Neurotransmitter	v	Brain area located on the sides of the brain that plays a crucial role in learning and memory

5 According to consolidation theory:

- A brain cells change during memory formation.
- B biochemical memory traces are the result of consolidation.
- C interruption to consolidation can result in the partial or total loss of information.
- D All of the above

consolidation
The process by which a relatively permanent LTM is formed

consolidation theory
The theory that during learning and in the approximately 30 minutes after learning, changes in brain cells occur as information is transferred from STM to LTM for relatively permanent storage

Memory decline and the healthy ageing brain

Like other physiological structures, the brain also changes with age; however, there is no conclusive evidence to suggest that memory will automatically malfunction as a result of normal ageing.

Older individuals *may* experience some decline in memory ability because a general slowing of the nervous system occurs as part of normal ageing. This results in an increased 'lag' time between neurons transmitting information, which causes our brain to be slower at processing, manipulating and retrieving information (Schaie, 1989). Slower processing means that more information entering the system will fade before it can receive further processing. So, the healthy ageing brain does not forget more rapidly, but it may take longer to learn and store information (Figure 3.23).

Figure 3.23 While a healthy ageing brain does not necessarily forget rapidly, it may take an older or elderly person longer to learn new information.

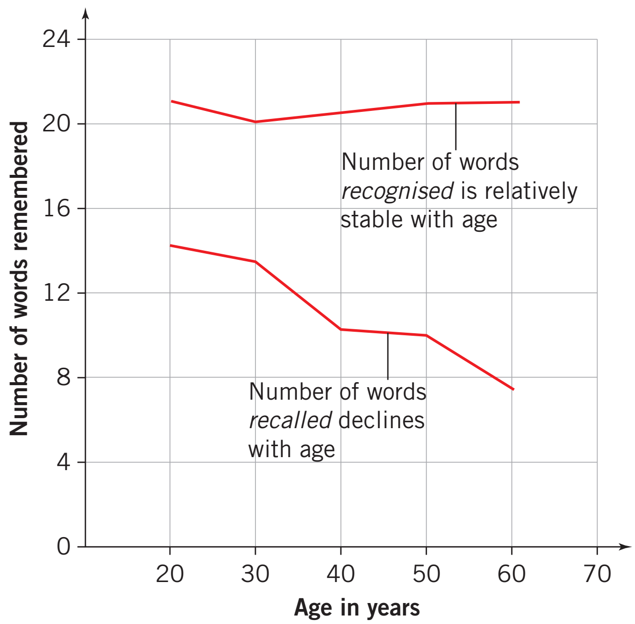
Normal ageing is also accompanied by a slow and steady loss of brain tissue, beginning in early adulthood and continuing over the lifespan. This tissue loss results in subtle, mild cognitive changes and small memory deficits. However, because these changes do not impair overall daily functioning, significant memory loss is *not* a normal age-related memory change (Jernigan et al., 2001). Additionally, if older, healthy individuals learn new things well, forgetting will not be any more rapid for them than for other age groups.

FACTORS INFLUENCING MEMORY PERFORMANCE AS WE AGE

Recall versus recognition

The measure of retention chosen to indicate memory loss can affect conclusions about the relationship between age and memory. Results may vary depending on whether the older person is asked to *recall* information (such as, 'Name the Prime Minister of Australia') or *recognise* information that they should know when it is presented to them among several alternatives (such as in a multiple-choice question). (These different measures of retention will be explored further in chapter 4.)

Schonfield and Robertson (1966) demonstrated that older individuals will remember more information if they are asked to recognise it, rather than recall it. Schonfield and Robertson asked adults of various ages to learn a list of 24 words. Without giving any clues, the researchers asked some participants to recall as many words as they could, and others simply to recognise words, using multiple-choice questions. As Figure 3.24 shows, younger adults had better recall, but researchers found no similar memory decline with age on the recognition tests.



Source: Myers, 2001

Figure 3.24 Graph of results on tests of recall and recognition in adulthood. The ability to recall new information generally declines in early and middle adulthood, while the ability to recognise new information does not.

Memory type

When we speak of memory types, we refer to the contents of LTM. Findings from studies of people who experience significant memory loss suggest that LTM is a separate memory store that holds different types of memories. As we learnt earlier, procedural memory stores memories of learnt actions and skills that can usually only be expressed as actions, while declarative memory stores memories of specific factual information that can be expressed in words. Declarative memories can be further divided into semantic memories (impersonal factual knowledge about the world) or episodic memories (personally significant experiences associated with specific times and places).

Studies indicate that episodic memories may be affected by normal ageing more than other memory types. As adults age, they remember fewer episodic memories related to their early childhood, although they vividly recall recent personally significant events as well as those that occurred in the second two decades of their lives (Holmes & Conway, 1999; Rubin, Rahhal & Poon, 1998).

Swedish psychologist Lars-Goran Nilsson and his colleagues (1996) tested the episodic memory of 1000 adults aged from 35 to 80 and found that older participants scored lower on 26 different measures of episodic memory than did younger participants. However, there was little decline in procedural memory of older participants (see Figure 3.25).

Research such a Nilsson's indicates that although a decline in episodic memory can begin as early as the age of 30, procedural memories seem to remain intact over time. Semantic memories also appear to be very resistant to the ageing process. Therefore, if conclusions drawn about age and memory are based on retrieving episodic memories, results may differ from tests involving procedural or semantic memories.

Meaningfulness and complexity

The effect that the meaningfulness of information has on memory ability also varies with age. Research involving participants memorising simple lists of words, nonsense syllables or paired associations indicates that older participants often find these artificial laboratory tasks meaningless and uninteresting. When asked to recall information that is meaningless to them, the older the people are, the more errors they are likely to make. In other words, older people's capacity to learn and remember meaningful material shows less decline than their capacity to learn and remember meaningless information (Graf, 1990).

Age may, however, have a negative impact on our STM's ability to simultaneously store *and* manipulate information. If you ask an older person to perform a complex task requiring divided attention, usually they do not perform as well as younger individuals. If you ask them to focus their attention on a simple, single task, such as memorising and recalling a short list of words, the accuracy of their recall is similar to that of younger individuals.

Figure 3.25 Procedural memories, such as how to ride a bicycle, are particularly durable into old age.

Attitude, effort and memory use

Psychologist Jane Berry and her colleagues (1989) measured elderly participants' beliefs about their own memory skills. Berry found that 60–80-year-old adults were less confident in their memory ability than were 18–30-year-olds. Berry concluded that although there may be some natural decline in memory for specific types of information as people age, a lack of self-confidence may worsen the problem. 'A closer look: Think memory worsens with age? Then yours probably will' provides support for Berry's conclusions.

A CLOSER LOOK

Think memory worsens with age? Then yours probably will

Thinking your memory will get worse as you get older may actually be a self-fulfilling prophecy. Researchers at North Carolina State University have found that senior citizens who think older people should perform poorly on tests of memory actually score much worse than seniors who do not buy in to negative stereotypes about ageing and memory loss.

Researcher Dr Tomm Hess and his colleagues from NC State show that older adults' ability to remember suffers when negative stereotypes are 'activated' in a given situation. Older adults will perform more poorly on a memory test if they are told that older people do poorly on that particular type of memory test. Memory also suffers if senior citizens believe they are being 'stigmatised,' meaning that others are looking down on them because of their age.

'Such situations may be a part of older adults' everyday experience,' Hess says, 'Such as being concerned about what others think of them at work having a negative effect on their performance – and thus potentially reinforcing the negative stereotypes.' However, Hess adds, 'The positive flip-side of this is that those who do not feel stigmatised, or those in situations where more positive views of ageing are activated, exhibit significantly higher levels of memory performance.' In other words, if you are confident that ageing will not ravage your memory, you are more likely to perform well on memory-related tasks.

Negative effects were also strongest for older adults with the highest levels of education. 'We interpret this as being consistent with the idea that those who value their ability to remember things most are the most likely to be sensitive to the negative implications of stereotypes and thus are most likely to exhibit the problems associated with the stereotype,' says Hess.

'The take-home message is that social factors may have a negative effect on older adults' memory performance.'

Source: Adapted from *Science Daily* online (2009) 'Think Memory Worsens With Age? Then Yours Probably Will.' 23 April.

Although ageing is a natural developmental process that begins at birth and ends with death, it is highly individualised and it is not the only cause of brain changes. An individual's lifestyle, environmental factors and genetic makeup can accelerate the normal ageing process. Neuroscientists now believe that the normal ageing brain can remain healthy and fully functioning and that disease, not ageing, is the cause of the most severe decline in memory as we age.

Amnesia: Where have the memories gone?

EFFECTS OF BRAIN INJURY

Amnesia, as we have learnt, refers to a temporary or permanent, partial or complete loss of memory. If brain damage results in amnesia, then the amnesia is said to have an *organic cause*. Brain damage can result from a severe blow to the head, stroke, chronic alcoholism, electroconvulsive therapy, malnutrition, infection, tumour, brain surgery or disease.

Although different forms of brain injury or trauma can result in different amnesia symptoms, general symptoms include memory loss, confusion and the inability to recognise familiar faces, objects or places. For example, one type of brain injury may cause a 'gap' in memories *preceding* the amnesia-causing event while another injury may result in memory loss for events that *follow* the amnesia-causing event.

Amnesia can also occur in the absence of physical injury; for example, because we are either consciously or unconsciously motivated to forget traumatic memories. When this occurs, the amnesia is said to have a *psychological* cause. (The concept of motivated forgetting is explored in chapter 4, on page 128.)

Retrograde and anterograde amnesia

Retrograde amnesia refers to memory-loss for events occurring *before* the amnesia-causing event. The prefix *retro* means 'moving backwards', and sufferers of complete retrograde amnesia are unable to remember events prior to experiencing their amnesia-causing event. However, those who suffer from partial retrograde amnesia are able to access some long-term memories. The extent to which they are able to do so depends on the degree of their brain injury.

Retrograde amnesia can be better understood if we remember the role of consolidation in memory formation. As you know, consolidation theory suggests that forming a long-term memory requires approximately 30 minutes. Individuals who suffer traumatic head injuries (such as those received in traffic accidents or by any severe blow to the head) often experience partial retrograde amnesia and they are unable to recall events just prior to the injury. Because they often have good memory for old events and can form new memories, this amnesia form is generally attributed to an interruption to consolidation.

Retrograde amnesia is often temporary, and memories of events leading up to the amnesia-causing event return gradually. The most distant memories are usually recalled first; however, recovery is usually incomplete. The person may never remember the last few seconds before the amnesia-causing event.

The prefix 'antero' means 'forwards', so the memory loss experienced from anterograde amnesia occurs for events that happen *after* the amnesia-causing event (or forward in time). Sufferers of complete anterograde amnesia can retrieve memories from their LTM but they are unable to form *new* long-term memories, even though their STM still functions. However, those who suffer from partial

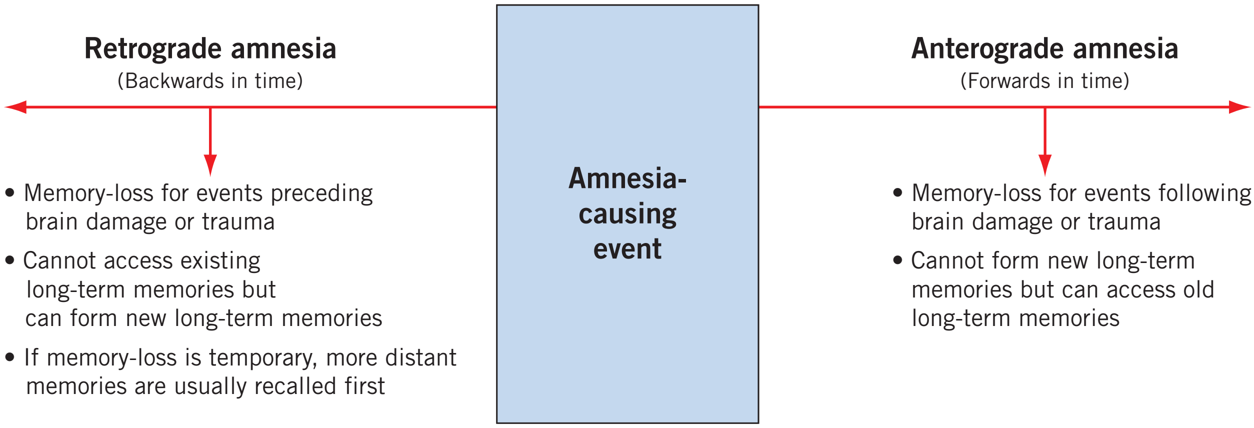


Figure 3.26 Retrograde and anterograde amnesia

anterograde amnesia do succeed in forming some new long-term memories. When recovering from anterograde amnesia, the most recent memories are often recalled before distant ones.

'A closer look: The experience of an extreme amnesiac' presents a famous case of a sufferer of extreme anterograde amnesia.

VIDEO
Amnesia and brain Injury

View 'Videolink: Amnesia and brain injury' to learn more about the types of amnesia.

A CLOSER LOOK

The experience of an extreme amnesiac

In 1985, neurologist Oliver Sacks wrote *The Man Who Mistook His Wife for a Hat,* a book of clinical case studies taken from his experience. One case study describes Sacks' patient Jimmie, a 49-year-old man who had brain damage. Jimmie had no memory for events occurring after he received a brain injury in 1945. In 1975 when Sacks asked his age, Jimmie replied, 'Nineteen'. Sacks gave Jimmie a mirror and asked him if he saw a 19-year-old looking out from it. When Jimmie looked in the mirror he turned pale, gripped the chair, swore, and frantically asked, 'What's going on? What's happened to me?' However, when Jimmie's attention was diverted to some children playing outside, he forgot about the mirror and his panic ended.

Although his intellectual and perceptual powers were preserved, in many ways time had stopped for Jimmie. Jimmie's form of anterograde amnesia still allowed him to register memory; however, distracting environmental stimuli made it difficult for him to consolidate memory traces and form new, lasting long-term memories.

CHECK YOUR UNDERSTANDING 3.7

1 Research on memory decline over the lifespan generally indicates that:

A a significant decline in memory is inevitable once a person reaches the age of 65.

B retention of early episodic memories is most vulnerable to advancing age.

C young adults tend to do better on tests of recognition when compared with much older adults.

D elderly people can remember most things when they are motivated to do so.

2 Indicate whether the following statements are true (T) or false (F).

a Older people perform better on memory tests that require them to recall information than on tests that require them to recognise information.

b Procedural memories are a type of declarative memory.

c Significant memory malfunction is not an automatic result of normal ageing.

3 Which of the following is true of the effect of normal ageing on long-term memory types?

A Semantic memories usually last longer than procedural memories.

B Procedural memories usually last longer than semantic memories.

C Remembering the day you learnt how to knit is an example of a procedural memory.

Continued

retrograde amnesia
A form of memory loss for events occurring *before* an amnesia-causing event

anterograde amnesia
A form of memory loss for events that happen *after* an amnesia-causing event

4 Fill in the gaps with the correct terms.

a _______________ amnesia involves an inability to store and/or retrieve new information in LTM.

b _______________ amnesia involves an inability to retrieve old long-term memories.

c Seventy-two-year-old Clarence was involved in a car accident that damaged his hippocampus. Now, Clarence cannot remember what he watched on TV last night; however, he can remember his age, his name and the names of his life-long friends. Clarence is most probably suffering from __________________ amnesia.

5 Which of the following statements is true of retrograde amnesia?

A Memories from the distant past usually return before memories from the recent past.

B Memories from the recent past usually return before memories from the distant past.

C Sufferers have difficulty forming new long-term memories.

EFFECTS OF NEURODEGENERATIVE DISEASE

What happens when a person experiences brain disease? Like any brain injury, brain disease disrupts brain functioning, including memory processes. A range of neurodegenerative diseases can gradually and progressively kill nerve cells, causing nervous system dysfunction and permanent loss of ability. Neurodegenerative diseases can have a genetic cause but they can also be caused by chronic alcoholism, tumour, stroke, toxins, chemicals and viruses. They can affect balance, movement, talking, breathing, heart function and cognition. When the brain experiences neurodegenerative disease that affects cognition, the result may be *dementia*.

Dementia

Dementia, in itself, is not a disease – it is a general term describing the symptoms of a variety of illnesses that cause changes in the brain that lead to severe, progressive and permanent loss of intellectual capacity that severely interferes with a person's daily functioning (Alzheimer's Australia, 2010).

Dementia affects a number of brain areas, and symptoms vary depending on the particular area of the brain affected. However, all forms of disease that result in dementia kill brain cells (neurons) and cause brain dysfunction that leads to progressive, irreversible cognitive decline – usually accompanied by personality and behaviour changes – that severely impairs daily functioning. Characteristic dementia-related cognitive loss includes disrupted thinking, reasoning, communication, personality, cognitive speed and memory.

One of the main dementia symptoms is a persistent and progressive short-term and long-term memory loss that interferes with normal functioning (see Figure 3.27). Because dementia typically appears in later life, its symptoms have been mistakenly assumed to be indicators of old age. As noted previously, people who age normally usually experience some changes in attention and memory but this does not generally interfere with their everyday lives. An example of occasional memory loss is forgetting where we put the car keys. The person with dementia, however, may not only forget where they put the car keys but also forget what the keys are used for.

Figure 3.27 Dementia causes people to slip into a slow mental decline that severely interferes with their daily functioning.

Other dementia symptoms include repeatedly asking the same question, confusion, increased anxiety or paranoia, personality changes, lack of initiative, difficulty learning new information or retrieving old memories, and loss of ability to perform everyday tasks. Common forms of dementia include Vascular dementia, Lewy Body dementia, Frontotemporal dementia, and Alzheimer's disease.

Table 3.5 shows the differences between normal memory loss and dementia-related memory loss.

Table 3.5 Ageing: Dementia-related memory loss vs normal memory loss

DESCRIPTION	DEMENTIA-RELATED MEMORY LOSS	NORMAL MEMORY LOSS
Events	Forgets part or all of an event	Memory of events may sometimes be vague
Words or names for things or objects	Progressively forgets	Sometimes forgets; words or names are on the tip of the tongue
Attention	Increasingly unable to concentrate on TV programs, films, books or conversations	Able to follow
Written and verbal instructions	Increasingly unable to follow	Able to follow
Stored knowledge	Progressively loses information such as that relating to historical or political events	Recall may be slower but information is essentially retained
Everyday skills such as dressing and cooking	Progressively loses capacity to perform routine tasks	Retains ability, unless physically impaired

Source: Adapted from Alzheimer's Australia, 2010.

ALZHEIMER'S DISEASE

The most common form of dementia among older people is Alzheimer's disease – an irreversible, progressive and fatal neurodegenerative disease that attacks the brain and kills brain cells, causing severe cognitive and behavioural decline. Alzheimer's disease accounts for between 50 per cent and 70 per cent of all Australian dementia cases (Alzheimer's Australia, 2009). Most people who age normally do not develop Alzheimer's disease, but the risk of developing it increases with age. Usually symptoms appear after the age of 65; however, early onset can occur in one's 30s. Currently, Alzheimer's disease is the fourth largest cause of death in Australia and it affects one in four people over 85 years of age (Mental Health Research Institute of Victoria, 2004).

Alzheimer's disease is named after the German neurologist Dr Alois Alzheimer. In 1906,

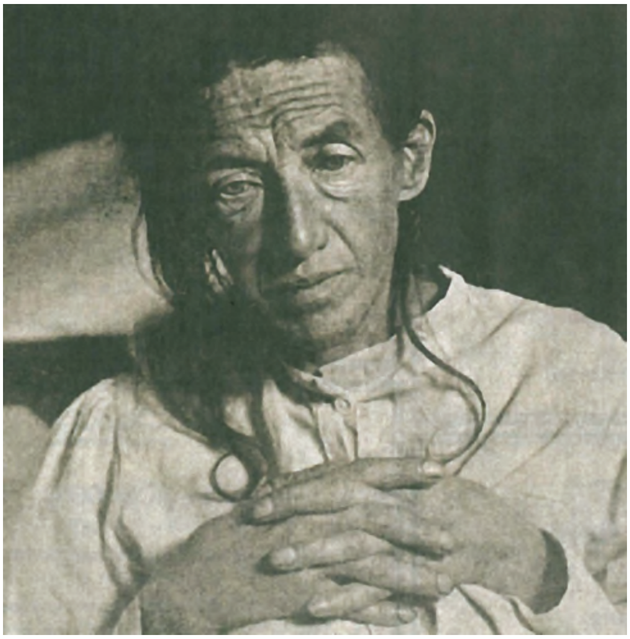


Figure 3.28 Auguste D., a patient of Dr Alois Alzheimer

Dr Alzheimer performed an autopsy on the brain of a 51-year-old woman, Auguste D., who had died of unusual mental illness (see Figure 3.28). Her symptoms included memory loss, language problems and unpredictable behaviour. Upon autopsy, Dr Alzheimer noticed that Auguste D.'s brain was very different to a normal brain. He found dramatic shrinkage, especially of the cortex. He also found dead and dying brain cells and recorded that Auguste D.'s brain tissue consisted of many abnormal clumps and tangled bundles of fibres around these cells. Today, these anatomical features are considered clear indicators of Alzheimer's disease.

Brain scans of Alzheimer sufferers indicate that the earliest damage occurs in the hippocampus. This is slowly followed by a loss of neurons and synapses in the cerebral cortex and certain subcortical regions, particularly in the temporal lobe, parietal lobe and frontal lobe. When the brain begins to atrophy (shrink), the neural systems critical for attention, memory, learning and higher cognitive abilities do not function effectively because they have far fewer nerve cells and synapses. Autopsies also reveal that the amount of folds (gyri) of the Alzheimer's brain decrease and the fluid-filled spaces (ventricles) in

neurodegenerative disease
A disease that gradually and progressively kills nerve cells and results in nervous system dysfunction and permanent loss of ability

dementia
A general term that describes the symptoms of a variety of brain illnesses that progressively kill brain cells and result in irreversible structural and chemical changes in the brain that lead to permanent and severe cognitive loss

a

b

Figure 3.29 (a)The Alzheimer's brain at the right is much smaller and the gaps between the folds of brain tissue are much wider than the non-Alzheimer's brain at the left; (b) A cross-section of a normal brain (left) and an Alzheimer's brain (right)

the folds are grossly enlarged compared to a healthy brain (Figure 3.29).

There is no single known cause of Alzheimer's disease but scans and autopsies reveal unusual webs and tangles in brain cells leading to and from the hippocampus (Nagy et al., 1996). Clustered deposits of abnormal beta-amyloid protein form outside of and between nerve cells. Beta-amyloid exists in normal brains but when this normally harmless protein accumulates it forms amyloid plaques. Amyloid plaques are sticky, abnormal clusters of protein fragments that collect on the outside of nerve cells, destroying the synapses and the conduction of nerve impulses. Nerve cells are damaged when amyloid reacts with the metals copper and iron, which are naturally abundant in the brain. This chemical reaction is similar to rusting and the affected neurons no longer transmit information properly (Mental Health Research Institute of Victoria, 2004).

The Alzheimer's brain also contains neurofibrillary tangles, which consist of twisted strands of highly soluble tau protein found in the centre of dead and dying nerve cells. Tau proteins are involved in the structure of nerve cells and they are found throughout healthy nervous systems. When they are working properly, tau proteins help to stabilise nerve cells. However, if they become overexcited – as is believed to happen with Alzheimer's disease – they begin to assemble nerves in a chaotic and tangled form.

Scientists suggest that plaques and tangles gradually disrupt the normal organisation of and communication between brain cells, causing them to eventually die. As a result, there is interference in the way information travels within the brain's neurons and the activity of neurotransmitters that carry messages across the synaptic gap between neurons.

Although many older people who age normally develop some brain plaques and tangles and they also suffer occasional memory loss, Alzheimer's sufferers have many more plaques and tangles than average (see Figure 3.30). They also have them in different brain locations and their memory-loss is significant.

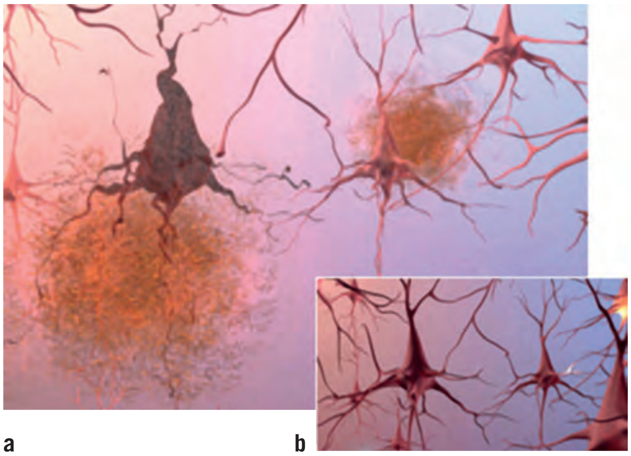


Figure 3.30 Tissue in an Alzheimer's-affected brain (a) contains fewer nerve cells and synapses than a healthy brain (b). Alzheimer's tissue is characterised by amyloid plaques and neurofibrillary tangles.

Tests show that the Alzheimer's brain also produces reduced levels of several neurotransmitters. In particular, there is a low level of acetylcholine, a neurotransmitter that carries information between the synapses of cells, because Alzheimer's disease systematically destroys the neurons that produce acetylcholine. The belief that acetylcholine plays a vital role in memory is supported by evidence that drugs that block the action of acetylcholine have been found to disrupt the formation of memory in healthy subjects.

View 'Videolink: What is Alzheimer's disease?' to see a presentation on Alzheimer's disease. 'A closer look: Old drug may have new use in Alzheimer's fight' explains how the testing of an established drug shows promise for further trials in fighting Alzheimer's disease.

VIDEO
What is Alzheimer's disease?

A CLOSER LOOK

Old drug may have new use in Alzheimer's fight

A recent study found that clioquinol, which was developed 100 years ago, is able to absorb the zinc and copper compounds that concentrate in the brains of Alzheimer's sufferers before dementia sets in. The research was conducted by institutions in Australia, Britain, the US, Sweden and Germany, and Melbourne and Monash universities and the Royal Melbourne Hospital were involved.

Zinc and copper attached to a common brain protein called beta-amyloid can turn oxygen into hydrogen peroxide, a toxin that destroys brain cells, which may be responsible for the holes found in the brains of Alzheimer's patients. Doctors believe that by absorbing the zinc and copper, clioquinol can halt, and possibly reduce, the brain damage that causes Alzheimer's victims to lose their memory.

To test this theory, 36 Alzheimer's patients were divided into two groups. Over 36 weeks some were given clioquinol, others a placebo. The patients taking clioquinol experienced a decline in their mental faculties of just 1.4 per cent, far better than those taking the placebo. After 24 weeks, however, the trend became less pronounced. Dr Colin Masters, a co-author of the study from Melbourne University, said the biochemical efficacy of clioquinol in this population was 'sufficiently encouraging to allow for future trials'.

One fear over the long-term use of clioquinol was that it might damage peripheral nerves and the nerves in the eye.

Source: Cauchi, S. (2004) 'Old drug may have new use in Alzheimer's fight.' *The Age.* 1 December.

amyloid plaques
Sticky, abnormal clusters of beta-amyloid fragments that collect on the outside of nerve cells, destroying the synapses and the conduction of nerve impulses

neurofibrillary tangles
Twisted strands of tau protein found in the centre of dead and dying nerve cells

CHECK YOUR UNDERSTANDING 3.8

1 Match each term with its correct definition.

a Dementia	**i** A neurotransmitter that carries information across the synapse and is believed to be involved in learning and memory
b Neurodegenerative disease	**ii** The symptoms of a variety of brain illnesses that progressively kill brain cells, causing permanent and severe cognitive loss
c Alzheimer's disease	**iii** Twisted strands of tau protein found in the centre of dead and dying nerve cells
d Amyloid plaques	**iv** A disease that progressively kills nerve cells and results in nervous system dysfunction and permanent loss of ability
e Neurofibrillary tangles	**v** Sticky, abnormal clusters of beta-amyloid fragments that collect on the outside of nerve cells, destroying the synapses
f Acetylcholine	**vi** An irreversible, fatal neurodegenerative disease that causes severe cognitive and behavioural decline

2 Indicate whether the following statements are true (T) or false (F).

a Dementia is another term for Alzheimer's disease.

b Alzheimer's disease usually begins when nerve cells in the hippocampus die.

c Alzheimer's disease is fatal.

3 Fill in the gaps with the correct terms.

a Sufferers of Alzheimer's disease have many ________________________ in the centre of brain cells that are dead or dying.

b When protein fragments accumulate outside and between nerve cells in the brain they form ________________.

c The brain of people with Alzheimer's disease produces less of the neurotransmitter called ______________________.

4 Which of the following changes in memory performance is characteristic of the late stage of Alzheimer's disease?

A Severe disruption to short-term memory but retaining ability to consolidate new long-term memories

B No disruption to short-term memory but severe disruption in laying down new long-term memories

C Difficulty creating new long-term memories but no difficulty accessing old long-term memories

D Forgetting how to do everyday things and inability to form new long-term memories

5 Which of the following statements is *not* true of Alzheimer's disease?

A Alzheimer's disease cannot be cured.

B Alzheimer's disease affects both short-term and long-term memory function.

C Alzheimer's disease only affects people over 65 years of age.

D Alzheimer's disease is a form of dementia.

Chapter summary

WORDCHECK TEST YOURSELF

Memory:

- Memory is an active information-processing system that receives, stores, organises and recovers information
- Memory involves the major processes of encoding, storage and retrieval of information.

Atkinson and Shiffrin's multi-store model of memory, including influence of rehearsal, serial position effect and chunking:

- The memory model that visualises memory as a system consisting of multiple memory stores (sensory memory, STM and LTM) through which a stream of data flows for processing.
- *Rehearsal*: *Maintenance rehearsal* holds information in STM for longer than the usual 18–20 seconds but does not add meaning so it does not increase retrieval chances. *Elaborative rehearsal* adds meaning to information so it creates links and increases retrieval chances.
- *Serial-position effect*: When learning information, the position of information in an ordered list affects retrieval. When recall immediately follows learning, the items at the end of the list are remembered best (*recency effect*). When recall is delayed, the items at the beginning of the list are remembered best (*primacy effect*).
- *Chunking*: Grouping separate information items into larger single information units to effectively increase the amount of information (beyond the usual 7 + or – 2 single items) held in STM at any given time.

Organisation of information in LTM:

- Information in LTM is organised on the basis of meaning (semantically).
- LTMs are organised into memory types: procedural and declarative. Declarative memories can be divided into semantic or episodic memories.

Semantic network theory:

- Information in LTM is stored in an interrelated hierarchy of concepts linked by meaning.
- Concepts close in meaning have shorter links and are quicker and easier to retrieve.

The working memory model of memory:

- Baddeley and Hitch suggest that working memory is a form of STM that briefly stores *and* manipulates information while we complete a cognitive task.
- Working memory has the following components: the central executive and three slave systems (phonological loop, visuospatial sketchpad and episodic buffer).

The levels of processing model of memory:

- Craik and Lockhart suggest that after information leaves sensory memory its storage varies along a continuum of processing levels ranging from shallow to deep processing, and that the level of processing used during encoding determines how long and how well information is stored.

Role of physiological structures in memory formation:

- *Neurons*: Kandel's research using aplysia suggests that, during learning, neurons increase production of neurotransmitters ejected into the synapse, resulting in an increase in synaptic transmission and the formation of a chemical trace of the information.
- *Temporal lobe*: Assists in memory of language, specifically for naming familiar objects, places and faces, and for constructing fluent, articulate and coherent speech. Also involved in the memory of facts, personally significant events and familiar routines
- *Hippocampus*: Assists memory formation, sorting and storage and the transfer of information from STM to LTM. Damage can lead to permanent short-term and long-term memory dysfunction.

Consolidation theory:

- The theory that it takes approximately 30 minutes for information to be transferred from STM to LTM, during which time brain cells change as a chemical memory trace of the information is laid down. Interruptions to the consolidation process can result in information loss or damage.

Memory function as we age:

- Memory function does not automatically decline with age, but information is processed more slowly.
- Memory performance for older people can be influenced by the retention measure chosen, the memory type tested, the meaningfulness and complexity of learnt information, the person's attitude to their memory ability, the effort they put into memorising information and how they actively try to strengthen their memory.

Amnesia; neurodegenerative diseases:

- *Amnesia*: Involves permanent or temporary, partial or complete memory loss. Retrograde amnesia is memory loss for events prior to the amnesia-causing event; anterograde amnesia is memory loss following the amnesia-causing event. Amnesia can have organic or psychological causes.
- *Neurodegenerative disease*: A disease that gradually and progressively kills nerve cells and results in nervous system dysfunction and permanent loss of ability, such as Alzheimer's disease.
- *Dementia*: The symptoms of a variety of brain illnesses that progressively kill brain cells and result in irreversible structural and chemical brain changes that lead to permanent and severe cognitive loss.
- *Alzheimer's disease*: An irreversible, progressive and fatal neurodegenerative disease that attacks the brain and kills brain cells, causing severe cognitive and behavioural decline.

- Brain changes that interrupt transmission of information between neurons typically include the formation of amyloid plaques and neurofibrillary tangles, and a decrease in the production of acetylcholine.

Apply your knowledge and skills

SECTION A: MULTIPLE-CHOICE QUESTIONS

1 Sensory information must be converted into a form (code) that can be used in the memory system. This conversion process is known as:

- **A** storage.
- **B** duration.
- **C** encoding.
- **D** retrieval.

2 The three major memory processes that occur in order are:

- **A** retrieval, storage, encoding
- **B** encoding, storage, retrieval
- **C** storage, encoding, retrieval
- **D** storage, retrieval, encoding

3 Research into the physiological basis of memory suggests that:

- **A** the hippocampus is the brain structure responsible for all memory formation and storage.
- **B** memory formation begins at specific synapses in the brain.
- **C** the temporal lobes are the brain areas responsible for all memory formation and storage.
- **D** memory formation begins with the formation of plaques and tangles in the brain.

4 Which of the following statements concerning age-related memory decline is correct?

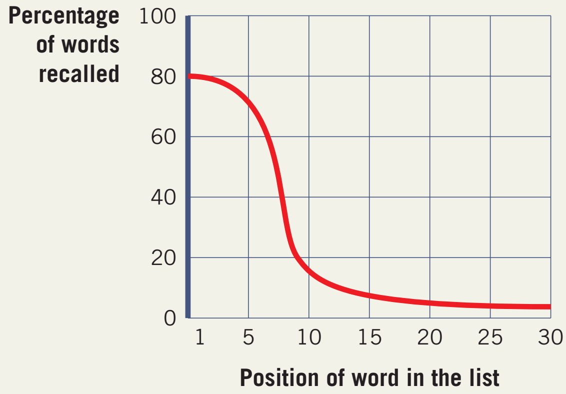
- **A** Age-related memory decline affects all types of information equally strongly.
- **B** All people over 85 years of age will experience significant memory decline.
- **C** The more recent the information, the better it is remembered.
- **D** Elderly people perform better on tasks involving recognition than on tasks involving recall.

5 If material is unrehearsed, it usually fades from STM after:

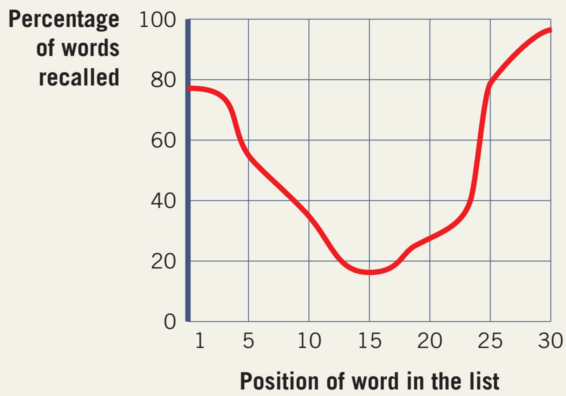
- **A** approximately 3–4 seconds.
- **B** approximately 7 seconds (+ or –2).
- **C** approximately 12–18 seconds.
- **D** approximately 18–20 seconds.

6 Which of the following graphs best represents serial-position effect?

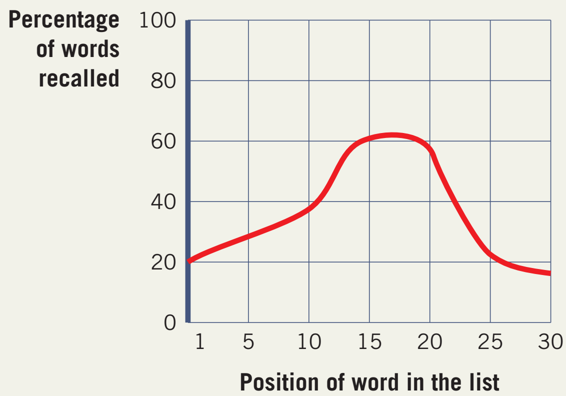
A



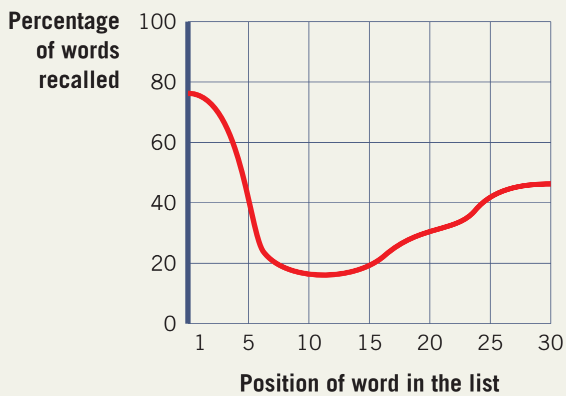
B



C



D



7 Which of the following is the most effective way to transfer information from STM to LTM?

A Chunking

B Serial position

C Elaborative rehearsal

D Maintenance rehearsal

8 On recovering consciousness, a footballer who has been knocked unconscious during a match is unable to recall events that occurred in the 15 minutes before being knocked out. According to consolidation theory, this occurs because of:

A insufficient time to consolidate sensory information in STM.

B insufficient attention being paid during the 15 minutes before being knocked out.

C insufficient time for his brain cells to lay down memory traces of the events occurring 15 minutes prior to being knocked out.

D insufficient rehearsal of information relating to the events in the 15 minutes prior to being knocked out.

9 Which of the following statements about storage in LTM is true?

A LTM's storage capacity is limited.

B LTM's storage capacity is unlimited.

C LTMs are stored according to the similarity of their structural features.

D LTMs are stored phonemically.

10 The component of working memory that is said to control attention is the:

A Phonological loop

B Visuospatial sketchpad

C Episodic buffer

D Central executive

11 Information in sensory memory is available for:

A approximately 1/3 to 1/2 of a second.

B up to a few seconds.

C approximately 18–20 seconds, unless rehearsed.

D up-to-a-lifetime

12 Paula memorised a list of words that included 'yacht', 'effort', 'instructor' and 'question'. Later, when she was attempting to recall them, she wrote 'ship', 'work', 'teacher' and 'enquiry'. This suggests that Paula encoded the original words:

A automatically.

B structurally.

C phonemically.

D semantically.

13 The semantic network theory of organisation in LTM suggests that:

A memories similar in sound are stored close together.

B LTM is organised into many overlapping networks based on shared meaning.

C LTM is organised into networks laid down in a sequential order like a tape recording.

D when long-term memories are being formed, a change in brain cells occurs.

14 In order to make it easier to remember her friend's new telephone number, Melanie organised the eight single digits into two single groups of four digits each. What memory technique was Melanie using?

A Maintenance rehearsal

B Elaborative rehearsal

C Chunking

D Repetition

15 Compared with younger people, older people:

A generally have poorer memory for most things.

B have better recall of recent events.

C have more problems recalling material without cues, but recognise items equally well.

D have more insight into and memory of material.

SECTION B: SHORT-ANSWER QUESTIONS

1 What is meant by the term *encoding*?

2 Explain the difference between *maintenance rehearsal* and *elaborative rehearsal*.

3 Explain the effect of *chunking* on STM.

4 Explain why an interruption to *consolidation* can result in memory damage or loss.

5 Identify two reasons why Alzheimer's disease is linked to memory loss.

6 On the first meeting of his scout group, Mr Smith asked the 20 group members to introduce themselves by calling out their names one at a time. As soon as the last member called out his name, Mr Smith attempted to recall as many of the names as he could. Which names would Mr Smith be most likely to recall, and why?

7 Explain the difference between episodic memory and semantic memory. Use an example to illustrate your answer.

8 Explain the differences in the roles the phonological loop, visuospatial sketchpad and episodic buffer play in working memory.

9 According to Craik and Lockhart's levels of processing theory of memory, why does semantic processing result in longer-term retention of information than structural processing?

10 Briefly describe how long-term memories are organised according to the semantic network model of LTM organisation.

SECTION C: EXTENDED-RESPONSE QUESTION

Use Atkinson and Shiffrin's multi-store model of memory to evaluate the effectiveness of rehearsal (maintenance and elaborative) on the retention of information for long periods.
This question is worth 10 marks.

SECTION D: ASSESSMENT TASK

Oral presentation

You may work independently or in groups. Choose one of the following tasks.

1 With the aid of a PowerPoint display, construct an oral presentation that compares the following models of memory: Aitkinson and Shiffrin's multi-store model, Baddeley and Hitch's working memory model and Craik and Lockhart's levels of processing model.

In your presentation you should:

- use two or more data types; for example, still or moving images, written text or sound
- feature between 10 and 15 slides
- summarise the key concepts in each theory
- refer to research that supports each theory
- provide an everyday application of each theory
- assess each theory in terms of its advantages and limitations
- speak for no longer than 10 minutes.

OR

2 With the aid of a PowerPoint display, construct an oral presentation that explains the difference between the effects of normal ageing on memory and the effects of neurodegenerative disease (such as dementia symptoms and Alzheimer's disease) on memory.

In your presentation you should:

- use two or more data types; for example, still or moving images, written text or sound
- feature between 10 and 15 slides
- refer to research that supports each theory
- clarify key terms and concepts
- speak for no longer than 10 minutes.