TOK

1. To what extent are models useful as a tool of acquiring knowledge?
2. Name examples of models that are used in other disciplines, for example, geography, natural sciences, mathematics.
3. What are the common limitations of models? Think about the inevitable simplification.
4. If models simplify reality, why use them in the production of knowledge?

After you familiarize yourself with the computer metaphor in psychology, answer this question: why does the computer metaphor qualify as a model?

In the computer metaphor, the brain is the hardware and the mind is the software. The mind consists of some functional blocks, and these blocks work together to receive, encode, store, process and exchange information. Just as computers have different kinds of memory, for example, human memory in one of the models is postulated to have distinctly different "stores": sensory store, short-term memory store, long-term memory store. Models in cognitive psychology describe how information flows from one store to another and the nature of the interaction between different subsystems of this complex cognitive architecture. (We will come back to the computer metaphor in this unit and look at more specific examples of models in cognitive psychology.)

To sum up step 4, psychology turned attention back to the black box, but on a new level. Instead of introspection, which had been criticized heavily on the grounds of subjectivity, psychology now made use of models. A scientist suggests a model of a cognitive process and, based on this model, formulates a number of predictions. These predictions are experimentally tested; the model is fit to the observed data. If the model does not fit well enough, it is revised and the cycle repeats. It is similar to the process used in physics to study subatomic particles, which are also directly unobservable: we build models and predict how the particles will behave when they collide with each other; then we accelerate and collide the particles and compare the observed behaviour to the predictions.

Step 5: behavioural economics

The computer metaphor seems to fit so well with our understanding of how mind works. What could be wrong with it?

One thing that the computer metaphor does not account for is human irrationality. Think back to step 2. This is exactly what Freud did not accept about psychology of the mind. The computer metaphor operates on the assumption of rationality in information processing. No one would deny that people have biases and make mistakes, but under the computer metaphor in step 4 these were considered to be "bugs in the system", occasional deviations from the general rule.

The first major attack on this assumption was from the notion of **cognitive biases**. This notion was introduced in 1972 by **Amos Tversky** and **Daniel Kahneman**, the only psychologists so far to have won the Nobel Prize (there's no Nobel Prize for psychology, so they were awarded for economics). Essentially, cognitive biases are systematic deviations from rationality in judgment. What makes their discovery game-changing is the fact that they are **systematic**: as it turns out, many mistakes in judgments are not random, they are recurrent, predictable and very common for human decision-making. So, irrationality is not some occasional deviation from the norm; it is the norm in itself.

This area of research is rapidly gaining popularity. A lot of cognitive biases have been systematically studied and documented. For example, people have a tendency to overestimate small probabilities and underestimate large probabilities (as you might guess, this has been extensively used by insurance companies).

Behavioural economics emerged on the basis of cognitive biases as a whole new knowledge area. Behavioural economics studies economic decision-making and tries to include irrational variables into traditional economic models to better explain (and predict) people's choices, especially under uncertainty. The monetary gains from a thoughtful evidence-based application of psychological variables in economic models have been attractive. We will return to the discussion of cognitive biases in decision-making later in this unit.

See video

Dan Ariely (from Duke University) extensively popularizes research in the field of cognitive biases and behavioural economics. A good way to get a feel for this area of research is through his insightful TED Talks:

"Are we in control of our own decisions" (2008). www.ted.com/talks/dan_ariely_asks_are_we_in_control_of_our_own_decisions

"Our buggy moral code" (2009). www.ted.com/talks/dan_ariely_on_our_buggy_moral_code

He is also famous for his book *Predictably Irrational*, and his courses have been made available on the website *Coursera*. Check these out to get a glimpse of behavioural economics.

Overview

If you look back at the five steps in the development of the cognitive approach in psychology, you will see that they make a spiral pattern with each next step identifying an issue in the previous stage and suggesting an improvement. Note that the stages do not replace each other. For example, behavioural economics has not "replaced" cognitive psychology but rather formed its own independent areas of research.

In this unit, we will look more closely at steps 4 and 5. The cognitive approach in psychology deals with studying mental representations and cognitive processes. Some cognitive processes are: perception, memory, thinking, problem-solving, decision-making, imagination, language. For the purposes of this unit, we will mostly focus on memory, thinking and decision-making.

Step	Description	Key words
1. Introspectionism	Psychology should study the mind. The mind is rational and can therefore be studied by means of introspection.	Conscious, rational, introspection
2. Psychoanalysis	Rationality is but a small part of human life. The mind is mostly irrational and should therefore be studied by methods such as dream interpretation.	Unconscious, irrational, psychoanalysis
3. Behaviourism	Such methods are highly subjective and the mind is not directly observable. The mind is a black box, and psychology should study observable behaviour (inputs and outputs).	Observable, objective, trial and error, black box
4. Cognitive psychology	Doing so, however, does not allow us to understand a number of complex behaviours. The black box is an important component and should be returned to the realm of psychology. However, it should be studied objectively. This can be done by using models. We make predictions based on models, fit the predictions with observed data and choose the best-fitting model. The overarching model for cognitive psychology is the computer metaphor.	Latent, mental representation, model, computer metaphor, conscious, rational
5. Behavioural economics	People make mistakes in their judgments, and these mistakes are not just random deviations from the norm. Sometimes the biases are systematic and predictable. Irrational decisions are an important part of human behaviour, and irrationality in judgment and decision-making should be accounted for in the models of cognitive functioning.	Latent, mental representation, model, computer metaphor, unconscious, irrational

▲ Table 3.1

Principles of the cognitive approach to behaviour

From the history of the development of cognitive psychology we can formulate the basic principles that define the cognitive approach.

- Principle 1—mental processes can be studied scientifically (remember our discussion about testing predictions based on models, and how this is exactly what modern physics uses when studying unobservable particles).
- Principle 2—mental representations guide behaviour (remember Tolman's research and our discussion on the black box being an important moderator between stimuli and reactions).
- Principle 3—cognitive processes do not function in isolation.
- Principle 4—biases in cognitive processes can be systematic and predictable (remember step 5 and the ideas of behavioural economics).

These principles underlie research in the cognitive approach, and it is a good idea for you to keep them in mind at all times when considering the cognitive approach.

ATL skills: Self-management

The principles of the cognitive approach to behaviour are important assumptions made by cognitive psychologists. You need to clearly understand these principles and refer to them when relevant in answering examination questions.

Create a mind map or another visualization of the principles of the cognitive approach to behaviour. Include references to supporting research studies. Use mind map-building software so that you can add supporting studies to each principle later as you go through the material in this unit.

Exam tip

Please keep in mind that the section "Concepts and principles of the cognitive approach to behaviour" does not directly correspond to any topic from the IB psychology subject guide. This means that you will not be directly assessed on this section and there will be no examination questions related to the principles or the history of the cognitive approach.

However, it is important to understand the concepts presented here (such as mental representations or models) because these concepts will be used in other topics throughout the unit.

While you are not required to use this material in examination answers, you can use it, to the extent that it is relevant and you stay focused on the question.

Models of memory

Inquiry questions

- Does memory consist of separate stores?
- How many separate stores are there?
- What is the duration and capacity of human memory?
- Is rehearsal the best way to memorize information?
- How can we test hypotheses about the existence of separate stores in human memory?

What you will learn in this section

- Atkinson and Shiffrin (1968): the multi-store memory model
  - Sensory memory, short-term memory (STM), long-term memory (LTM)
  - Duration, capacity and transfer conditions
- Support for the model
  - Support for sensory memory: partial report technique (Sperling, 1960)
  - Support for STM and LTM being separate memory stores: serial position effect (Glanzer and Cunitz, 1966)
- Criticism of the model
  - Emphasis on structure over function
  - Rote rehearsal is the only mechanism of transfer; alternative model: levels of processing (Craik and Lockhart, 1972)
  - Only explains the flow of information in one direction, but bidirectional flow is necessary to explain the findings of the levels-of-processing model (Craik and Tulving, 1975)
  - LTM might not be a unitary store: procedural, episodic and semantic memory
  - There might be more components in short-term memory (working memory model)
- Baddeley and Hitch (1974): the working memory model
  - The dual task technique
  - The central executive, the visuospatial sketchpad and the phonological loop
- Support for the model
  - Memory for speech material uses a sound-based storage system (the phonological loop): phonological similarity effect discovered by Conrad and Hull (1964)
  - Effects of articulatory suppression on phonological similarity effect: Baddeley, Lewis and Vallar (1984); this supports separate stores for visual and auditory information
  - Support for the central executive: Baddeley (1996)
- Evaluation of the model
  - Good explanatory power
  - Hard to test empirically in all its entirety

This section also links to:

- principles of the cognitive approach to behaviour
- localization of function (biological approach to behaviour)
- models of thinking and decision-making.

Psychology in real life

Anterograde amnesia is a type of memory loss that affects the ability to form new memories but does not affect memories of the past. There are many well-documented cases of anterograde amnesia that can shed light on the nature of human memory.

Michelle Philpots suffered a head injury twice: once in a motorcycle accident in 1985 and again in a car accident five years later. These injuries triggered the development of epileptic seizures and loss of the ability to form new memories completely by 1994. Since that time Michelle's memory is wiped clean every time she goes to sleep. When she wakes up she believes it is still 1994. Her husband has to show her their wedding pictures every morning to remind her that they are married (they got married in 1997). She discovers every morning that she is much older than she thinks. Also she has no idea that she is suffering from memory loss—this is another discovery she makes on a daily basis. You could say that her memory span is 24 hours, but forgetting can occur in shorter time intervals, too. At some point she got fired from her office job after she photocopied the same single document over and over again multiple times. Her husband is grateful that she remembers him. He keeps a collection of photos handy and tells his wife the history of their life together every single time she wakes up. On the plus side, she never gets bored with good old jokes and TV programmes, and she gets to fall in love with her husband over and over again. This story became the basis of a popular Hollywood comedy, *50 First Dates*. https://tinyurl.com/m7mbg98

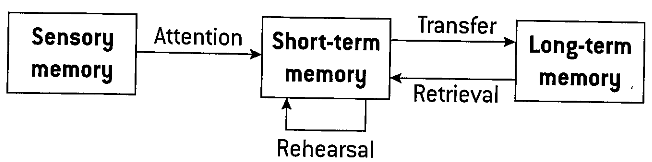
Clive Wearing's window of awareness is even shorter than that, somewhere between 7 and 30 seconds. He can forget the beginning of a sentence before you get to its end. In 1985 he was an acknowledged expert in music, at the height of his career. He suffered from encephalitis which resulted in extensive damage to the hippocampus. He has both retrograde amnesia (inability to recall the past) and anterograde amnesia. He remembers little of his life before 1985. Remarkably, however, he recalls how to play the piano and conduct the choir. Every 20–30 seconds he keeps waking up from the coma. He was encouraged to keep a journal of his thoughts, and he keeps writing, in sudden joyful insight, that he is finally awake and fully conscious… only to notice a couple of seconds later that the whole journal is filled with identical entries. He gets frustrated, he crosses out the previous entries and circles the new one, and it starts all over again. He is always glad to see his wife and he greets her every time he sees her as if it's the first time after a really long break, even if she just went to the bathroom for a couple of minutes. There is a documentary about Clive Wearing that is worth watching if you want to know more: https://tinyurl.com/kqxqdcu

The multi-store memory model

Memory is a cognitive process used to encode, store and retrieve information. The multi-store memory model was proposed by **Atkinson and Shiffrin** in 1968. In this model, human memory is said to consist of three separate components:

1. sensory memory
2. short-term memory store
3. long-term memory store.

Each of these components is characterized by a specific **duration** (for how long the store is able to hold information) and **capacity** (how many units of information it can hold). In order for information to move to the next memory store, certain **conditions** have to be met.



▲ Figure 3.6 Multi-store memory model

The **sensory memory store** (or the sensory register) does not process information. Its function is to detect information and hold it until it is either transferred further into the short-term memory store or lost. Sensory memory actually consists of several sub-components, one for each modality: visual information, auditory, olfactory, and so on. Most of the research, however, has focused on **iconic memory** (for visual inputs) and **echoic memory** (for auditory inputs).

The capacity of sensory memory is only limited by our perception, for example, iconic memory can keep everything that enters our visual field and echoic memory can hold everything that we acoustically perceive at any moment.

However, the duration of sensory memory is short. Traces in iconic memory decay after 1 second of inattention, while traces in echoic memory can decay after 2–5 seconds.

The condition that has to be met for information to transfer from sensory memory to short-term memory is **attention**. If a unit of information is attended to, it does not decay, but moves to the next memory store. Conversely, if it does not catch our attention, it fades away. So potentially sensory memory has unlimited capacity, but it is only transient, and we can only attend to a small subset of information stored in sensory memory.

TOK

The fact that we can only attend to a limited amount of information in our sensory memory at a given time links to the TOK concept of "selectivity of perception". Recall examples from various areas of knowledge that show how selectivity of perception affects our knowledge in a discipline. How does it work in history, for example?

As information enters the **short-term memory (STM)** store, it can undergo some primitive transformations. For example, if you see a word (visually), you can subvocally pronounce it and it will enter the short-term memory store acoustically. So the differences between modalities in short-term memory, to some extent, are erased.

The capacity of short-term memory has been extensively studied, and it has been established to be **7±2 chunks** of information. This number was empirically justified in GA Miller's article "The Magical Number Seven" in 1956. The trick is that a chunk is not only an individual unit, it can be a meaningful combination of individual units. For example, the sequence of symbols PCBMXBMWXBOXPS4 makes 15 units of information, which falls outside the capacity of short-term memory. If, however, you perform some grouping: PC – BMX – BMW – XBOX – PS4, it now becomes five chunks!

The duration of short-term memory is somewhat dependent on the modality, but is generally no longer than 30 seconds. If the information is left unattended, the trace fades away in this period of time.

The condition for increasing the duration of short-term memory and transferring information into the third store (long-term memory) is **rehearsal**. If we rehearse information (for example, repeat words over and over again or keep coming back to a mental image), it stays in the STM longer, and eventually the trace gets consolidated and the information enters the long-term memory store.

Long-term memory (LTM) is described as a place for storing large amounts of information for indefinite periods of time (Galotti, 2008, p 147).

The current estimate of the capacity of LTM is that it is potentially virtually unlimited. Psychologists have failed to quantify the capacity of LTM or at least provide an approximate estimate. You can probably remember times when you saw or heard something and never thought of it again, but then suddenly one day some contextual cue triggers those distant memories, and you suddenly remember something that you thought had been long forgotten. There are also well-known case studies of "memory champions". In some cases memory champions can recollect long strings of digits that they had memorized many years before, although they never rehearsed the digits since that time.

Exercise

Do some research and suggest your explanation for phenomenal memory (extraordinary memory powers). How is phenomenal memory possible? Can it be learned?

You may start exploring the issue with this story of Laurence Kim Peek (1951–2009), an American savant who became the inspiration for the movie *Rain Man*. He read countless books and instantly memorized them. Reportedly he could accurately recall the contents of at least 12,000 books. He could also carry out complex calculations in his mind without a need for a calculator.

https://tinyurl.com/kn3u27d

Although the capacity of LTM is potentially unlimited, not all information that is stored in LTM is easily retrievable. It is not storing but retrieving information from memory that may be problematic.

Similarly, the limit for the duration of long-term memory has not been established, and potentially it is longer than a lifetime.

As mentioned above, the condition for information to enter LTM is rehearsal. According to the classical multi-store memory model, rehearsal gradually consolidates the memory trace and so increases the probability of information permanently entering the LTM store.

ATL skills: Thinking

1. Why is Atkinson and Shiffrin's multi-store memory model a model?
2. List all the essential properties of models (irrespective of the area of knowledge) and discuss how these properties are manifested in the multi-store memory model.

Remember that Atkinson and Shiffrin's multi-store memory model is a model. It has a lot of components that require testing. It raises these questions.

1. Are the memory stores really distinct and separate? For example, is sensory memory really separate from STM?
2. Are there really three memory stores, not more, not less?
3. Are sensory modalities within sensory memory just modalities? Why not separate memory stores?
4. Is there a physiological basis for the memory stores or are they just constructs? In other words, do the separate stores exist objectively in the form of separate brain structures?
5. Is rehearsal necessary and sufficient for the transfer of information from STM to LTM? Can this transfer occur without rehearsal? Can the transfer fail to occur in the presence of rehearsal?
6. Does information really only flow in one direction (from sensory memory to LTM)? Can information flow backwards, for example, can LTM influence which pieces of data are selected from sensory memory and transferred into STM?

Exercise

1. Split into six groups.
2. Each group will take one of the six questions listed above and design an experiment to empirically answer the question.
3. When presenting your experiment to the larger group, demonstrate how exactly your experimental procedure will support (or refute) the hypothesis that is relevant to the question.

Think "out of the box". Don't worry if the suggestions seem absurd. Psychologists spend years carefully designing studies like that. The purpose of the exercise is just to try, (probably) fail and then laugh about it!

All these questions and predictions require a series of carefully controlled experiments. One reason for us studying this model in IB psychology is that it was one of the most successful and popular models of the time, in the sense that it stood up to trial by empirical data.

Support for the multi-store memory model

We will consider two research studies that aimed to test different aspects of the multi-store memory model.

In 1960 **Sperling** tested the existence of iconic memory (part of sensory memory). He used the so-called "partial-report technique". In the experiment participants were presented with a tachistoscopic image of a grid of alphanumeric characters, as shown in Figure 3.7.

7	I	V	F
X	L	5	3
B	4	W	7

▲ Figure 3.7 An example of a grid used in the study

The image was flashed up for only 50 milliseconds (ms: 1/20 of a second).

There were two conditions.

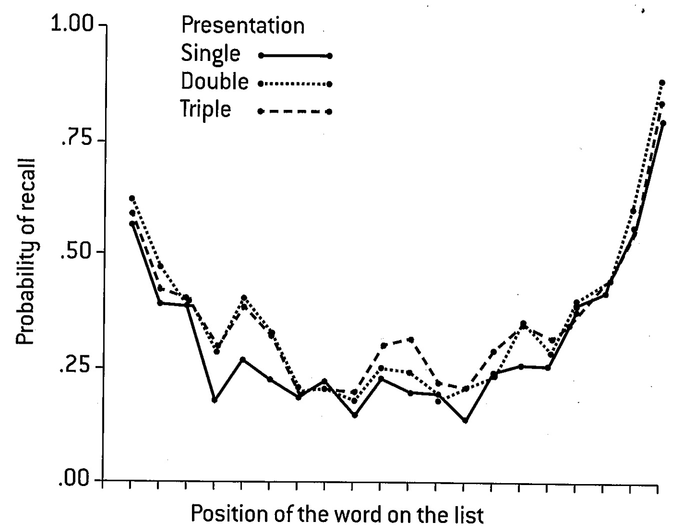
- In the **whole-report** condition, participants were given an empty grid and required to fill it out with all the alphanumeric characters in the appropriate positions. They were asked to guess when they were not certain. Participants were able to recall an average of 4 out of 12 characters (35%).
- In the **partial-report** condition, participants were presented with the stimulus as before, but were only required to recall one of the rows from the grid. The instruction indicating which row to recall was given in the form of a sound. The tone sounded approximately 50 ms *after* the visual presentation, so participants did not know until they heard the tone which of the rows was called for. Participants were instructed to recall the top row on hearing a high tone, the middle row on hearing a middle tone, and the bottom row on hearing a low tone. Participants were usually able to recall three or four characters from the row. As the row was selected at random, and after the presentation of the stimulus, we can conclude that 75–100% of the entire grid was accessible to the participant for a brief amount of time after the presentation of stimulus.

The interpretation of the findings, in line with the multi-store memory model, is that after we have been exposed to a visual stimulus, its trace stays in our memory for a short period of time. If attended to, some parts of this trace can be further consolidated and transferred into the STM. If not attended to, the information decays.

Glanzer and Cunitz (1966) are famous for their research on **serial position effect**, which serves as support for STM and LTM being separate memory stores. Serial position effect is the tendency to recall the first and the last items on a list better than items in the middle. Participants were required to memorize lists of words followed by a free-recall task (a free-recall task is when you are permitted to recall the words in any order).

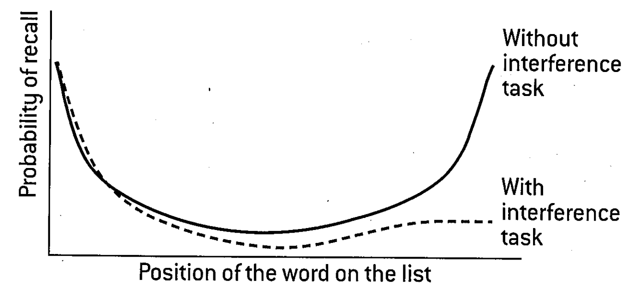
There were two conditions.

- In the first condition, participants (240 army-enlisted men) were presented with recordings of 20-word lists consisting of common one-syllable nouns. Immediately after hearing the words they were required to do a free-recall task for two minutes. Results of these trials clearly demonstrated serial position effect in both its aspects: participants were better at remembering words at the start of the list (**primacy effect**) and at the end of the list (**recency effect**). This did not depend on the number of repetitions of each word (see Figure 3.8).



▲ Figure 3.8 Serial position effect

- In the second condition, researchers introduced a delay between the end of the list and the start of recall. During the delay, participants engaged in a filler task: counting backwards from a given number for 30 seconds. The filler task was meant to prevent rehearsal. The resulting data indicated that participants were still successful at recalling the words from the start of the list (primacy effect preserved), but were no longer able to recall the words from the end of the list (recency effect disappeared).



▲ Figure 3.9 Disappearance of recency effect after a filler task

Why does the recency effect disappear while the primacy effect stays? Glanzer and Cunitz explained that when people are hearing a list of words with the intention to memorize them, they tend to repeat the words to themselves. The first words on the list get repeated (rehearsed) more often and enter the long-term memory, which is unaffected by the delay and the filler task. However, the last words on the list are not rehearsed enough.

Without rehearsal, their trace in short-term memory decays in just 30 seconds, so the recency effect disappears after the filler task. Since one of the effects disappears and the other does not, it supports the idea that STM and LTM have **separate memory mechanisms** behind them.

Criticism of the multi-store memory model

There are some criticisms that are common for any model in cognitive psychology (for example, simplification, an inability to observe the components of the model, absence of a clear physiological basis), but the multi-store memory model has been criticized for a variety of more specific reasons.

First, a limitation of this model is that it focuses on structure rather than the process. Even the definition of memory as a cognitive process implies that to understand how information flows is more important than to see how many separate stores it goes through. This is not to say, of course, that structure is not important. However, structure in this model is emphasized.

Second, due to this lack of attention to memory as a process, the only mechanism that enables transfer of information from STM to LTM in the original multi-store memory model is rote rehearsal. This seems to be an oversimplification that ignores various strategies that may enhance memorization. To counter this, **Craik and Lockhart** (1972) proposed the **levels of processing (LOP)** model of memory. In this model recall is a function of depth of processing. According to Craik and Lockhart, information undergoes a series of levels of processing, shallow and deep, and the deeper information is processed, the stronger its trace in long-term memory. Shallow processing only takes into account superficial features of the stimulus, such as the physical properties (**structural processing**) or the acoustic properties (**phonetic processing**). This is exactly what happens in rote rehearsal: we either repeat something to ourselves (phonetic) or recreate the mental image of how something looks (structural). Deep processing, on the other hand, occurs in the form of **semantic processing** and involves building the stimulus into the structure of meaningful connections and associations, that is, linking it to prior knowledge.

One of the research studies that tested this model was conducted by Craik and Tulving.

Research in focus: Craik and Tulving (1975)

This experiment followed a repeated measures design. Using a tachistoscope, participants were shown words for 200 milliseconds. Before seeing each word, they were asked one of three types of yes-or-no questions, each relating to a different level of processing. These are examples of the questions.

- Is the word in capital letters? (structural processing)
- Does the word rhyme with "weight"? (phonetic processing)
- Is the word a type of fish? (semantic processing)
- Would the word fit the sentence "He met a ____ in the street"? (semantic processing)

After participants were asked the question, the word was revealed and they were required to press one of the buttons (yes or no) to indicate their response. After completing the whole list, they were given either a free-recall task ("recall all the words you can in any order") or a recognition task (where they were given a longer list of words and required to pick out the ones that they had seen earlier).

Both for recall and for recognition, memory performance was significantly better for those words that were preceded by a "semantic" question. For example, for a recognition task, the average percentage of words correctly recognized was:

- 16% for structural processing
- 57% for phonetic processing
- 83% for semantic processing. (Craik and Tulving, 1975, p 273).

The study supports the idea that consolidation of memory traces in LTM is not only due to rote rehearsal, and long-term memory is a function of *how* the information was processed at the stage of encoding.

Third, the multi-store memory model has been criticized for the fact that it only explains the flow of information in one direction, from sensory memory to the LTM. However, it can be argued that the opposite flow of information also takes place. For example, how can chunking (Miller, 1956) occur without using information that is already stored in the LTM? We perform chunking based on prior knowledge, and this has to require some access to the LTM. On the other hand, semantic processing at the stage of encoding (Craik and Tulving, 1975) also cannot occur without access to categories stored in the LTM. To know the answer to the question, "Is this word a type of fish?", I need to access my knowledge of different kinds of fish. If this influences the early stages of encoding (as was demonstrated in the levels of processing model), then we have to admit that there is **bidirectional flow of information** between memory stores.

Fourth, it has been argued that LTM is not a unitary store, and there are differences in the way different types of information are stored. At least three types of memory might be stored differently: **episodic** (memory of events), **procedural** (how-to memory, for example, memory of how to tie your laces or how to ride a bike) and **semantic** (general knowledge). One source of evidence for these claims is from case studies of amnesia where some memories were lost while others stayed intact.

Fifth, in a similar fashion, it has been argued that the unitary view of short-term memory is too simplistic, and there are more subcomponents in the STM. A much more sophisticated approach to STM was proposed by Baddeley and Hitch in 1974 (see below).

Working memory model

Research revealed some phenomena that did not fit well with the view of STM as a unitary system. These "uncomfortable" results came from research studies that utilized the **dual-task technique**. In this technique, the participant is required to perform two memory operations simultaneously, for example, listen to a list of words (auditory stimulus) and memorize a series of geometrical shapes (visual stimulus). If STM really is a unitary store, the two sets of stimuli should interfere with each other, so memory will be limited by 7±2 units of whatever modality. However, it was discovered that in some cases performing a simultaneous task does *not* interfere with memory performance. For example, drawing something does not interfere with memorizing an auditory sequence of digits. To explain these conflicting findings, **Baddeley and Hitch** (1974) developed the working memory model. This model focuses on the structure of STM.

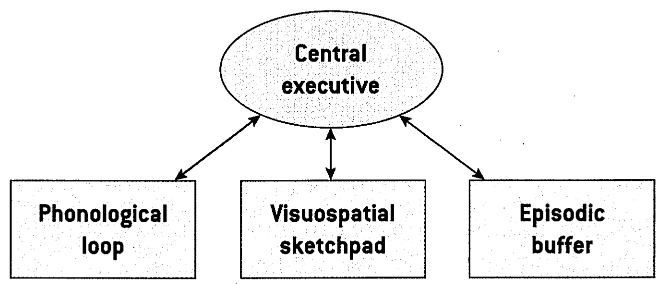
In the original model, working memory consists of a **central executive** that coordinates two subsystems: the **visuospatial sketchpad** and the **phonological loop**.

- The visuospatial sketchpad ("the inner eye") holds visual and spatial information.
- The phonological loop holds sound information and is further subdivided into the phonological store ("the inner ear") and the articulatory rehearsal component ("the inner voice"). The inner ear holds sound in a passive manner, for example, it holds someone's speech as we hear it. The inner voice, on the other hand, performs the following important functions.

  First, it turns visual stimuli into sounds. For example, if we are shown a list of written words, we may subvocally pronounce these words, changing the modality from visual to auditory, and the words will enter our STM through the auditory channel.

  Second, it allows the rehearsal of information held in the inner ear. By constantly repeating the words, we are increasing the duration of working memory and increasing the chances of transferring the information further into long-term memory storage.
- The central executive is a system that allocates resources between the visuospatial sketchpad and the phonological loop. In this sense, it is the "manager" for the other two systems.

In 2000 Baddeley and Hitch also added the fourth component, the **episodic buffer**, as a component that integrates information from the other components and also links this information to long-term memory structures.



▲ Figure 3.10 Working memory model

Support for the working memory model

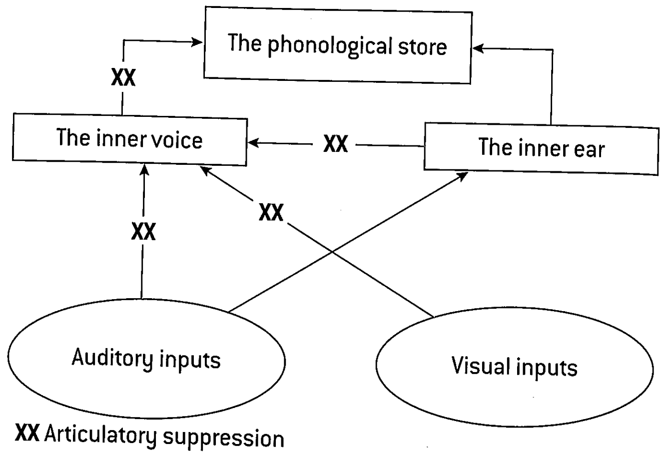
One of the starting principles of this model (that requires empirical testing) is the division of the unitary STM into three independent subcomponents: the central executive, the visuospatial sketchpad and the phonological loop. This has found support in a variety of studies using the dual-task technique. In some trials, both tasks used the same modality. The model predicts that in this case the two tasks will interfere with each other and the performance will be hindered. In other trials, the tasks used different modalities. The model predicts that the performance of the tasks will not be significantly hindered in this case.

Conrad and Hull (1964) demonstrated the **phonological similarity effect**. In their study participants were required to recall lists of letters. Some lists of letters were phonologically similar (for example, B, D, C, G, P) while others were not (for example, F, H, P, R, X). They found that rhyming lists were more difficult to remember. This is because the traces of similarly sounding letters (if they are encoded acoustically) are easier to confuse with each other. This supported the idea that memory for speech material uses a sound-based storage system, which we now know as the phonological store.

Baddeley, Lewis and Vallar (1984) explored the effects of **articulatory suppression** on the phonological similarity effect. Articulatory suppression is a method of blocking the "inner voice" (articulatory rehearsal component). In an experimental situation, articulatory suppression is simply asking your participants to repeat a sequence of sounds (for example, the-the-the or one-two-three-one-two-three) over and over again while at the same time performing the experimental task. In doing this, the capacity of the "inner voice" is filled up. What happens in this situation, according to the predictions of the working memory model? (Think back to the two functions of the "inner voice" discussed earlier.)

First, visual inputs cannot be recoded into sounds and hence cannot enter the phonological store.

Second, auditory inputs can enter the phonological store, but their rehearsal will be impossible.



▲ Figure 3.11 Effects of articulatory suppression

Baddeley, Lewis and Vallar used four conditions:

	Spoken mode of presentation	Written mode of presentation
Rhyming words	1	3
Non-rhyming words	2	4

▲ Table 3.2 Conditions in Baddeley, Lewis and Vallar (1984)

The results indicated that there was a phonological similarity effect between conditions 1 and 2 (that is, rhyming words were significantly harder to recall than non-rhyming words), but there was no phonological similarity effect between conditions 3 and 4 (for written material, rate of recall for both rhyming and non-rhyming words was the same).

When articulatory rehearsal is inhibited, spoken information can still enter the phonological store (the "inner ear") directly. Since rhyming words sound similar and create similar traces, these traces are easier to confuse so we observe the phonological similarity effect. Written information can also enter working memory, but it does not get recoded into sounds. Presumably it enters the visuospatial sketchpad. As the information is coded visually, the traces are not that easy to confuse, and the phonological similarity effect is not observed.

ATL skills: Thinking

1. Evaluate the extent to which this study supports the working memory model.
2. Are there alternative explanations that would fit equally well into the observed data?

For the central executive, one of the studies that provided supporting evidence was conducted by **Alan Baddeley** (1996). The starting point of his reasoning was that since the theoretical function of the central executive is to distribute and switch attention, it should be inhibited by tasks that require attentional switches, and at the same time it should not be inhibited by tasks that do not require attentional switches.

In the study, participants were required to produce random sequences of digits by pressing keyboard keys at the rate of one per second, determined by a metronome. To produce a random sequence of digits, you have to use your attentional resources because you need to take into account the previous digits that you have selected. So the dependent variable in this experiment was the **randomness** of the digit sequence (participants were required to produce sequences of 100 digits overall). The more random the sequence, the better the central executive performed at controlling this cognitive task.

Simultaneously, participants were required to engage in one of three tasks, at the same rate of one unit per second.

1. Recite the alphabet (A, B, C and so on).
2. Count (1, 2, 3 and so on).
3. Alternate between letters and numbers (A, 1, B, 2, C, 3 and so on).

The results showed that "whereas neither counting nor reciting the alphabet had a detectable effect on the randomness of keypressing, the concurrent alternation task markedly reduced randomness" (Baddeley, 1996, p 18). So it was concluded that this constant switching of retrieval plans is performed by a separate memory system (the central executive).

ATL skills: Research

Do you remember research methodology? Experiments are characterized by validity, and there are three broad types of validity: internal, external and construct.

Evaluate the construct validity of Baddeley's (1996) study. To what extent is randomness of a string of digits a good operationalization of the function of the central executive?

Evaluation of the working memory model

Overall, the strength of the working memory model is that it is more sophisticated than the multi-store memory model and allows us to explain a wider range of phenomena (for example, participants' performance in the dual-task technique or observable effects of articulatory suppression). The model can integrate a large number of findings from work on short-term memory. Subsequent research has also shown that there are physiological correlates to some of the separate components of the model. For example, distinctly different brain parts "light up" in brain scanning images when the task activates either the phonological loop or the visuospatial sketchpad. Finally, on the plus side, the working memory model does not overemphasize the role of rehearsal.

However, it should be noted that models of this degree of complexity are harder to test empirically. You must have noticed that all the experiments, however complicated, are only designed to test one specific aspect of the model (for example, the central executive). For complex models, it becomes increasingly difficult to design well-controlled studies that would test the model in its entirety. This means that the model is difficult to falsify. Maybe as a consequence of this, and due to the existence of multiple potential explanations of the same experimental result, the exact role of some of the components of the model (the central executive and especially the episodic buffer) remains unclear. Similarly, it has been argued that the visuospatial sketchpad should be further divided into two separate components, one for visual information and one for spatial information. Finally, working memory only involves STM and does not take into account other memory structures, such as LTM and sensory memory.