The process and reliability of human memory

Key dot points from study design

Process of memory

* the multi-store model of memory (Atkinson-Shriffin) with reference to the function, capacity and duration of sensory short-term and long-term memory
* interactions between specific regions of the brain (cerebral cortex, hippocampus, amygdala and cerebellum) in the storage of long-term memories, including implicit and explicit memories.

Reliability of memory

* methods to retrieve information from memory or demonstrate the existence of information in memory, including recall, recognition, relearning and reconstruction
* the effects of brain trauma on areas of the brain associated with memory and neurodegenerative diseases, including brain surgery, anterograde amnesia and Alzheimer’s disease
* the factors influencing a person’s ability and inability to remember information, including context and state dependent cues, maintenance and elaborative rehearsal and serial position effect
* the reconstruction of memories as evidence for the fallibility of memory, with reference to Loftus’ research into the effect of leading questions on eye-witness testimonies.

The process of memory

Human memory is often compared to a computer in the way that we input, save and later retrieve information. In order for a memory to be formed and information to be retained, several processes have to take place, otherwise the information may be lost.

Encoding – Storage – Retrieval

These are three basic processes that must take place in order for a memory to be formed on a relatively permanent basis.

**Encoding** is the process of translating raw sensory information into a form that your brain understands. If we think about visual information, which travels into our eyes in the form of light waves, our brain is unable to read this information in its raw sensory form. So, the photoreceptors in the retina change (or transduce) the light energy into electrochemical energy (which is how neurons communicate and transmit information) so that the brain can interpret the stimulus. This process of encoding happens for all the senses in the different receptor sites in the body.

It’s like how you choose the letters and numbers that you input into a computer when you type in a Word document – you have to hit the right keys so that the computer understands the information in your head.

**Storage** is the process of keeping the information in memory for a period of time so that we can use it. If information is encoded properly, then it will be stored. This works like a hard drive on your computer. Information is stored in your memory systems by meaning, this means that information that is linked is kept close together.

This is like when you choose which folder you want to save a document in. All of your Psychology might be saved in a folder, then you might have sub folders for all documents linked to Learning and Memory.

**Retrieval** is the process of accessing previously stored information when you need it. Retrieval is aided by effective storage, as well as using cues or hints from the environment to access the information that you want.

This is like searching for a particular file in your computer using a spotlight search (using a hint or a cue) or when you look in a particular folder for a document in your storage. Finding a document that you saved earlier is made easier by saving it in the right folder and naming the file something that is linked to the content of the document.

The Atkinson-Shiffrin Multi-Store Model of Memory (1968)

The three processes of encoding, storage and retrieval operate on three different levels of memory, all of which interact with one another in order for memories to be formed. These three levels form a theory developed called the multi-store model of memory, and are sensory memory, short-term memory (STM) and long-term memory (LTM).

Sensory Memory

This is the first level of memory, and it involves all incoming information from the outside world, as in through your five senses. Each sense is received by a different sensory register, processed using a different type of sensory memory in a different part of your brain.

Sensory registers have a large capacity for unprocessed information, but they are only able to capture really clear images (traces) for a short amount of time – just long enough for anything relevant to be paid attention to and transferred into STM.

The function of sensory memory is to hold sensory information for a brief period of time so the information overlaps slightly – this allows us to view our world in an uninterrupted way rather than a series of still images or disjointed sounds.

The two different types of sensory memory that have been explored in the most amount of detail are iconic (visual) memory and echoic (auditory) memory.

Iconic memory

This store receives visual sensory information from the eyes and holds a really short visual image of what you have just seen. The capacity of iconic memory is very large, and is only limited by the vision of the individual. The duration (as in how long it is stored for) is very short though, around 0.3 seconds. This allows ‘smooth’ perception rather than blurred moving objects or static images.

Examples of iconic memory are writing your name with a sparkler and being able to see it for a short time afterward, and shaking a pencil up and down so it appears to be ‘bendy’.

Echoic memory

This is the sensory memory store for sound information (hearing). As with iconic memory, the capacity is very large and is only limited by how well you can hear. The duration of echoic memory is about 3 – 4 seconds; any shorter and you would not have enough time to understand someone speaking to you. You need to be able to remember what was said at the start of their sentence to understand the end.

An example of echoic memory is when someone asks you something, and you ask them to repeat it, but then you answer the question before they can.

Miss Wood: Hey Fanufu, what time is it?

Fanufu: What did you say?.... oh, it’s 2 o’clock.

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|  | ICONIC (VISUAL) MEMORY | ECHOIC (AUDITORY) MEMORY |
| CAPACITY | Virtually unlimited, restricted only by the individual’s ability to see/hear |
| DURATION | Approximately 0.3 seconds | Approximately 3 – 4 seconds |
| PROCESSING | No additional processing, beyond raw perceptual processing |

Loss of information from sensory memory occurs when we do not pay attention to the stimulus coming in through our sensory receptor sites. If we did pay attention to everything, you would not have the capacity to think about anything else! Sensory memory acts like a sieve to sift out only the information that our brain thinks is relevant or important.

Short-term memory (STM)

Also referred to as ‘working memory’, STM allows us to manipulate information that has come in through sensory memory, as well as information that is stored in long-term memory. Anything that you are thinking about at a given moment is happening and being worked on in your STM.

STM has a limited capacity as well as a limited duration. Because of this, information that is in your STM is very susceptible to interruption and interference.

Capacity of STM

Your short-term memory can hold an average of 7 + or – 2 pieces of information at any one time. This means that you can’t hold more than 9 pieces of information (on average) in your STM.

Increasing the capacity of STM

You can increase the amount you can hold in your STM by using a method called **chunking**. This is when you group individual bits of information into groups, or chunks. For example, you could try and remember the digits 0, 4, 2, 9, 3, 6, 0, 6, 4, 2 as individual units and probably struggle, or you could ‘chunk’ them as 0429 360 642. Instead of 10 units you now have 3.

Chunking can also involve organizing items into familiar, manageable units, such as the use of acronyms; BOLTSS = Border, Orientation, Legend, Title, Scale and Source, or FRO MO BRO = Frontal Lobe, Motor Cortex and Broca’s Area

Duration of STM

The length of time that you can hold information in STM for is between 18 and 30 seconds. If you do not transfer this information into long-term memory in this time, it will be lost from memory.

Increasing the duration of STM

**Rehearsing** information in STM prevents it from being lost or displaced from STM. The longer information is in STM, the greater the probability that it will be transferred into storage in LTM.

**Maintenance rehearsal** relies on the constant recitation of information in a rote way (over and over again). Maintenance rehearsal is easily affected by distraction, which can displace information from STM.

In contrast, **elaborative rehearsal** involves expanding (or elaborating) the new information by adding to it or linking it to what you already know, thereby making it more meaningful. This may involve considering the meaning of the new material (semantics) or its physical properties, associating it with previously learned information – the deeper the information is processed, the more likely it is that you will remember it.

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|  | SHORT TERM MEMORY |
| CAPACITY | Limited to approximately 7+-2 bits of information; this can be expanded by ‘chunking’ information into larger units |
| DURATION | Approximately 18 – 20 seconds |
| PROCESSING | To hold information in STM, it often encoded verbally, however other strategies such as visualization may be used, making it possible to ‘rehearse’ the information |

Long-term memory (LTM)

LTM is a potentially permanent memory store that has an infinite capacity for storing information for an extensive period of time.

LTM stores all the information that we don’t need right now. Because this information is not immediately active, it needs to be retrieved back into STM when we need to use it.

Procedural memory

This is a type of LTM that involves thought processes and skills about how to perform certain tasks, and it allows you to complete a course of action (like typing your shoelaces or writing your name). Essentially, procedural memory is *knowing how*.

Declarative memory

This is a type of LTM of specific facts or events that you know about the world and yourself and can draw on in order to communicate to others (things that you can *declare*). Essentially, declarative memory is *knowing that*.

Episodic memory

This is a type of declarative memory for autobiographical information – personal events and experiences from your own life and the context in which they occurred. This is something like recalling the day and place of an event like your 16th birthday.

Semantic memory

This is a type of declarative memory that involved specialized knowledge of factual information about the world. This could be general knowledge, things learned in school or the meaning of words. This is something like knowing that Athens is the capital of Greece, and that there are 5 Olympic rings.

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|  | LONG-TERM MEMORY |
| CAPACITY | Virtually unlimited |
| DURATION | Up to a lifetime; potentially permanent |
| PROCESSING | Information is organized according to meaning and is associatively linked |

Implicit and explicit memory

Explicit memories are not rudie memories; they are things that you are aware of – information that can be consciously remembered (including episodic and semantic) and involves an intentional, deliberate attempt to retrieve previously stored information. These are also known as declarative memories because you can ‘declare’ them. When you do your exams, you are drawing on explicit memories.

Implicit memories, in contrast, are memories without awareness, and includes things that you may not have even realized you have learned. Implicit memories can still effect our thoughts and behavior, especially things that are required to perform a particular task. Implicit memories include procedural memories, motor learning and classical conditioning. Recent research shows that the amygdala is the key brains structure involved in implicit memories. The emotional aspects of memory are also the responsibility of the amygdala, as well as the hippocampus.

Key brain structures involved in memory

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| BRAIN STRUCTURE | ROLE IT PLAYS IN MEMORY |
| Cerebral Cortex | * associated with the encoding, formation and storage of long-term declarative memories
* Pre-frontal cortex is thought to store short-term working memory tasks to enable encoding of information for long-term storage
* Occipital lobes (together with parts of the temporal lobes) store visual memories that allow you to recognize faces and images
* Medial temporal lobes (inside bit of the lobes) are linked with the activity of the hippocampus and amygdala
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| Cerebellum | * Encoding, processing and storing of automated procedural memories
* Classically conditioned responses (form of implicit memory)
* Motor skills tasks (works with frontal lobes – motor cortex)
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| Hippocampus | * Critical to the formation of memories, playing a role in deciding if information received by the senses is worth remembering
* Critical to the organization and consolidation of memory
* Associated with the recall of spatial relationships in the world around us
* Closely connected with our sense of smell
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| Amygdala | * Associated with memories for emotional events, especially fear conditioning
* Emotional memories that are implicit
* More emotionally-arousing information increases amygdala activity which links with retention (remembering)
* Memory for emotion shown on faces
* It activates the hippocampus which means it plays a part in the consolidation of declarative memory with emotional content (winning a spelling bee)
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Consolidation theory

This idea proposes that, in order for new information to be transferred effectively from STM to LTM there needs to be a time period during which these memories are able to be formed and stabilized without being disrupted. During this time, physical changes occur in the neurons (LTP) to enable permanent storage of the new information. Consolidation takes around 30 minutes on average, and once the memory is consolidated, it is relatively permanent.

I like to use the analogy of concrete setting, or becoming ‘solid’ (conSOLIDation… get it?). When you lay new concrete (new information) you want it to set and dry (form neural pathway) without anything touching it. If a massive windstorm comes and blows dirt and leaves and sticks into the wet concrete before it is set, it will not be in its original form. If there is interruption to the consolidation of a memory (like a blow to the head) before it ‘sets’, the memory may not be formed properly.

The effects of brain damage on memory (brain trauma & neurodegenerative disease)

Results from damage to the brain (eg stroke, disease, head injury, long term alcoholism, severe malnutrition, brain surgery or ageing.

Usually referred to as **organic amnesia. Amnesia** is used to refer to loss of memory, either partial or complete, temporary or permanent.

**Anterograde amnesia**

* Antero means forward – in this case, forward in time
* Occurs when memory loss for information or events occurs **after** the person sustains brain damage. (A for antero and A for after).
* People are able to remember events before the amnesia began, but cannot remember new information that is given to them once the amnesia has set in.
* Experienced frequently by people with **Karksakoff’s disease.** This is a disorder resulting in acute brain inflammation and damage to the hippocampus. Most sufferers are long term alcoholics.
* Experienced frequently also by people with **Alzheimer’s disease.** This is a degenerative brain disease linked to abnormal changes in brain tissue. Alzheimer’s has been specifically linked to a degeneration of the hippocampus. Alzheimer’s is irreversible.
* The hippocampus has been found to be vitally important for transferring information from STM to LTM.

**Retrograde amnesia**

* When brain damage affects memory for information or events experiences **before** the person sustains the damage.
* Usually temporary, and may be due to a blow to the head.
* The memory loss may be for moments before the blow to the head, weeks before or years before.
* People treated with electroconvulsive therapy (ECT) may experience it, which involves passing an electric current through the person’s skull, causing a seizure, to treat extreme depression and anxiety.
* Inability to remember past events is usually temporary
* Is explained by the information – processing model of memory in terms of an interruption to the consolidation of the memory trace.

**Alzheimer’s Disease**

* A type of dementia that is categorised by the widespread degeneration of brain neurons causing memory loss, a decline in cognitive and social skills, and personality changes
* It involves both anterograde and retrograde amnesia because the disease affects both the hippocampus and the pre-frontal cortex.
* Earliest symptom is usually impaired declarative memory, where the patient has difficulty remembering events from the day before, forgets names and has difficulty finding the right word when speaking.
* They may repeat stories or questions, and eventually will fail to recognise familiar people and family members.
* Damage to the hippocampus causes cells to be lost, the brain to atrophy (shrink) and the damage to the temporal lobes means that the hippocampus is isolated.

**Brain Surgery**

People who have suffered extensive damage to both sides of their hippocampus

# Measures of retention

When psychologists refer the **sensitivity of retention** they are referring to the efficiency of a particular device for remembering information. The more sensitive the measure of retention, the more chance people have of being able to remember the information.

Relearning

The most sensitive measure of retention is **relearning**. This refers to learning information again, that has previously been learned or stored in LTM. If the information is learned more quickly the second time, it is assumed that the information has been retained somewhat in memory from the first time it was learned.

Relearning information is quicker than learning it for the first time.

When Ebbinghaus studied relearning, he used nonsense syllables (two consonants separated by a vowel) which would reduce the chance of certain words having more meaning for some individuals than others. He found that when individuals learned the nonsense syllables for the second time, they were learned more quickly than the first and that the third time they were learned was quicker than the second.

Relearning is also known as the **method of savings,** as it measures the amount of information that was saved in memory from the first time it was learned.

## The formula for this is as follows

Savings = (no of trials for original learning) – (no of trials for relearning) x 100

 (no of trials for original learning)

A savings score can be calculated on the amount of time taken to relearn new information. This formula is:

### (time for original learning) – (time for relearning) x 100

(time for original learning)

# Recognition

* The second most sensitive measure of retention
* Identifying the correct information from among alternatives, such as finding the words that have been learned from a list of possible alternatives.
* Recognition of words provides cues that assist in the location and retrieval of information from LTM.
* More sensitive than recall, as when participants were asked to recall a list of names, they could recall 69%, whereas participants who were asked to recognise a list of names were able to recognise 86%.
* Eg multiple choice tests

# Recall

* Least sensitive measure of retention
* Involves being asked to reproduce information with the fewest possible cues to assist retrieval.

## There are 3 categories of recall

**Free recall** is when participants are asked to remember as much information as they can, in no particular order.

**Serial recall** – when participants were asked to recall a list of words in the order they were presented.

**Cued recall** – makes use of more specific cues to aid retrieval. Eg, if you were asked to recall the elements in the periodic table, you would probably use the poem that uses the first letters of each element, to make retrieval easier.

Reconstruction

This is an explanation of memory which suggests that when you recall past experiences, you complete missing information by inventing some of the details, or they incorporate information received after the event in order to have a memory that ‘makes sense’. If the process of forming a memory in the first place is construction, then every time you recall it from LTM it is a reconstruction of the original memory and those original memory traces.

Serial Position Effect

* Suggests that recall is better for items at the beginning and end of a list than items in the middle
* **The primacy effect** describes the superior recall of items at the beginning of the list. (**Primary** is before **secondary)**
* **The recency effect** describes the superior recall of items at the end of the list. (**Recency** sounds like **recent** which are the items most **recently** heard.)
* If recall occurs immediately after the list is learned, the last few items are remembered best because they are still in STM.
* The first few items in a list are remembered well because they received more attention and rehearsal than other items and are therefore transferred into LTM.
* Items around the middle are presented too late to be adequately rehearsed and transferred into LTM and too early to still be in STM. Therefore items in the middle are more likely to be forgotten unless they are distinct or meaningful in some way.
* If recall is required 30seconds after the list has been learned, the recency effect does not occur, as the information has faded from STM.

Factors affecting memory retrieval

Context and state dependent cues

* **Encoding specificity principle** is the principle that involves a general rule that the more closely the retrieval cues match the original learning conditions, the more likely it is that the information will be recalled.
* **Context dependent cues** are environmental cues in the specific context (setting) where a memory was formed, which act as retrieval cues to help access the memories formed in that context. (eg leaving your bedroom to find your school shirt, and as soon as you leave the room, you have no idea why you have left the room, so go back to your bedroom to enable you to be in the same context as you were when the idea to find your shirt occurred to you.)
* This has been shown in an experiment by Godden and Baddeley, who found that participants could remember 20% more words when asked to replicate them in the same environment as they were learned (in this case, under the water). Therefore, if you were to have one of your exams in the room where you learned the information, you would be more likely to remember information than if tested in a neutral environment.
* **State dependent cues** are associated with an individual’s internal physiological and/ or psychological state at the time the memory was formed, which act as retrieval cues to help access these memories. (for example, you are likely to forget information learned when you are intoxicated, as you are in a difference state of consciousness than when the information was learned. You would be more likely to remember the information if you were in the same state).

Enhancing memory

This is achieved through the quality of the encoding. If a fact or scene appeals to you or is very interesting, you won’t need to rehearse it in order to remember it. However, when information is not so interesting that it can be remembered without effort, the **quality of the encoding** is important**.**

Elaboration and organisation

* Elaboration is the way in which new information is linked to information already stored in LTM.
* The more extensively information is rehearsed, the deeper the encoding.
* **Self referencing** involves relating new information to personal experiences or your personal situation in some way.

Eyewitness testimony

This is a legal term referring to an account given by someone of an event that they have witnessed, such as the identification of perpetrators or details of a crime scene. These are generally used in criminal cases where individuals have to give a description of a crime to the police or the court.

To accurately remember the details about a crime, accident or other significant event, the witness must first encode the information. What is encoded depends on where an individual’s attention is directed at a particular time and what is taken in or perceived.

The longer the delay between the event and when they try to remember it, the less complete and accurate the account will be. According to the decay theory, it would be expected that some information would be lost, as a person’s memory of accidents or crimes would fade when there is a long delay between witnessing a crime and being asked to retrieve them memory of it.

If there are gaps do occur in a person’s memory, he or she may reconstruct it. This may involve filling in the missing information by making up some of the details in order to achieve a memory that ‘makes sense’ according to our attitudes and expectations about a particular event or person. This could include racial or gender bias.

Loftus has argued that, because of the reconstructive nature of memory, eyewitness memory is extremely unreliable because information from external sources received after the witnessed event can be incorporated into memory, thereby creating retroactive interference on the memory of that event.

The subtle use of language in questions can influence witnessed by suggesting a particular response. A number of research studies have shown that people’s memories of events can be affected by **leading questions**, which direct the witness towards the response desired by the questioner. “Objection! Leading the witness!”

Further to this, **misleading** **questions** which are intended to cause a witness to respond in a way that the questioner knows does not fit the the facts, can direct the witness to a particular re-interpretation of the event.

The phrasing of these questions not only decreases accuracy levels, but can also cause the information suggested or implied by such questions to be subsequently incorporated into memory.

For example, “Did you see the red car?” – the witness may not have been aware that the car was red, but may later come to ‘remember’ that the car was red.

In one experiment by Elizabeth Loftus, participants were shown a film of a car accident and then asked “About how fast were the cars going when they collided into each other?”. Alternative versions of the question used the words ‘smashed’, ‘bumped’, ‘hit’, or ‘contacted’. Although all the words refer to two objects coming together, they are different in the what they imply about the speed and force of impact.

Participants estimated higher speeds when they were asked about how the cars ‘smashed’ into each other in comparison to using the verb ‘hit’.

When they were asked whether they saw any broken glass at the accident, 14% of the ‘hit’ group recalled glass, whereas 32% of the ‘smashed’ group recalled glass (there was no glass).

Loftus and Palmer (1975) concluded that the wording of the question had biased the memory of the participants.

The also conducted a similar experiment in 1975 where participants were shown a film of a car accident and were able to get more participants to incorrectly recall seeing a broken headlight when asked “did you see the broken headlight?”, than asking “did you see a broken headlight?”

In an experiment into the **misinformation effect**, researchers got over a third of their participants to say they shook hands with Bugs Bunny at Disneyland by implanting the impossible suggestion – Bugs Bunny is not a Disney character (Loftus 2002). This study demonstrates the reconstructive nature of memory and that it is possible to convince people that they have witnessed something that has not actually happened.

Loftus believes that it is much easier to mislead and manipulate memory about minor details rather than about major details in an event.

Loftus also believes that memories are constantly being updated to fit ‘post-event information’, such as events, details and comments that are experienced later. We are often unable to distinguish the source of our memories, which can result in incorporating the misinformation into memory, along with accurate information that was encoded at the time of the event.