IN connection

Science of Memories

Research and Framework

Contents

This report identifies the factors that increase the likelihood of a person forming and subsequently recalling a memory in Western society today. We explain how our memory works and whether technology is having an impact, and outline Inconnection's Science of Memories Framework. The Science of Memories Framework establishes the most important factors for strengthening memory formation and the factors that trigger memory recall. The report concludes by determining the impact that technology is having on these factors and whether we are still able to form strong memories under certain emotional conditions.

Section 1: How are memories formed and recalled?

In simple terms, memory can be described as the ability to encode, store and retrieve information. It allows us to draw on our past experiences and use this information in the present (Sternberg, 1999) so we can learn and adapt over time. If we could not remember past events, we could not learn or develop language, relationships or personal identity (Eysenck, 2012).

Often memory is described as an information processing system with a sensory processor that feeds into the short term and long-term memory (Baddley, 2007).

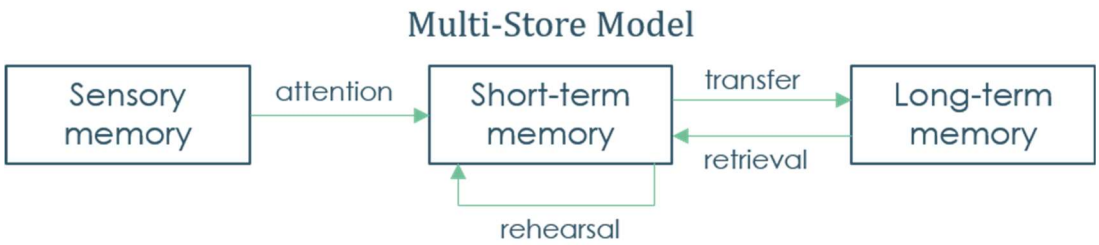
Sensory Memory

The sensory memory is where any information is first registered in the form of chemical and physical stimuli. In order to cope with the huge amounts of incoming information, the sensory memory has a large capacity, but it only stores information for 200-500 milliseconds before a new stimulus replaces it.

Short Term Memory

The short-term memory is often referred to as the 'working memory' because it describes what the brain is currently working on. That could be processing stimuli from the present moment whilst also recalling something from the long-term memory to provide context and meaning. The short-term memory has a finite capacity which means it can only retain so much information at any one time. This has been widely accepted as approximately 7 pieces of information since Miller's (1956) famous paper on the brain's capacity for processing information.

The basic memory model by Atkinson and Shiffrin (1968) shows how the short-term memory can be 'refreshed' through rehearsal and then some information can be transferred to the long-term memory.



Although the model has been criticised for being too simple, as it suggests that the only way for a long-term memory to be formed is through rehearsal, it does highlight the importance of attention which we cover in more detail later on in the paper.

Long Term Memory

The long-term memory is slightly more complicated, as it is split into the explicit memory and the implicit memory. The explicit memory refers to the *conscious* storage and recollection of information (Graf and Schacter, 1985) and the implicit memory is the *unconscious* storage and recollection of information (Foerde and Poldrack, 2009), such as how to ride a bike.

The explicit memory includes semantic memory and episodic memory. *Semantic memory* refers to information that is encoded with specific meaning (Eysenck, 2012), for example general knowledge such as the names of colours or the fact that the grass is green. The *episodic memory* is memory for specific events (Eysenck, 2012), such as the sensations, emotions and personal associations of a particular place or time.

The types of memories that we are interested in exploring further in this paper are the consciously formed explicit memories which are stored in the long-term memory.

How are memories recalled?

Memory recall refers to the subsequent re-accessing of information from the past which has been encoded and stored in the brain. This process is known as 'remembering' and is one of the three main processes of memory.

To recall a memory, you are required to re-visit the nerve pathways the brain formed when encoding the memory in the first place. It effectively brings a memory from long-term storage into the short-term or working memory. The strength of the nerve pathways determines how quickly the memory can be recalled and re-remembering can strengthen these pathways.

Memory recall is often triggered by sensory stimuli, such as a smell, sound or even an emotion that was present when the memory formed. In terms of episodic memories, this can often take you back to a particular place or time that you have stored in your long-term memory.

In section 3 of this paper, we define the factors that impact how we form and recall memories.

Section 2: Memories and Technology

It has been estimated that humans today are exposed to five times as much information as they were in 1986 (Fastcompany, 2019).

100 years ago, people were lucky to have read the equivalent of 50 books in their lifetime but in today's technological society, it's likely that most children have watched 100-200 films by the age of 12 (Telegraph, 2007). In 2007 it was estimated that people were consuming the equivalent of 174 newspapers per day through a combination of television, radio and the internet (Telegraph, 2007) but with the rise of social media and the increasingly digital world, we predict that the figure today is much higher.

But how do we process so much information? We know that our brain has a way of filtering information through our sensory, short term and long term memory but is that changing with the introduction of technology?

Is technology affecting how we form memories?

According to the Office for National Statistics, 87% of adults used the Internet daily or almost every day in the UK in 2019 (Ons.gov.uk, 2019).

The internet acts as a fantastic source of information but is this impacting how we form memories? With so much information so easily accessible, there's an argument to suggest that people don't feel the need to remember as much themselves. The internet is like an 'external hard drive' (Wegner and Ward, 2013) that we know we can access whenever we need. Some argue that as a result, our brain has a lower capacity for remembering (Gregorie, 2017) whereas others say that this 'offloading' of information frees up cognitive resources for other activities or more important information (Storm and Stone, 2014).

One study that supports both of these viewpoints to an extent suggests that technology hasn't changed how much we can remember but the way we organise information (The Conversation, 2018). Participants were asked to type a series of statements that would be saved in specific folders. They were then asked to recall the statements and the folders where the files were located. The results showed that they were better at recalling the file locations than the statements. This suggests that we prioritise the information that we know will no longer be available – in this case, the participants knew that if they remembered the file locations they would be able to find the statements.

A similar idea can be applied to the types of memories that we store in our long-term memory – semantic and episodic. Research suggests that we are relying on our brain's 'external hard drive' (the internet and technology) for our semantic memories but our episodic memories are unaffected (stlmag, 2019).

Semantic memories are facts, figures and general knowledge which can be found on the Internet. Episodic memories are our personal memories of a particular place

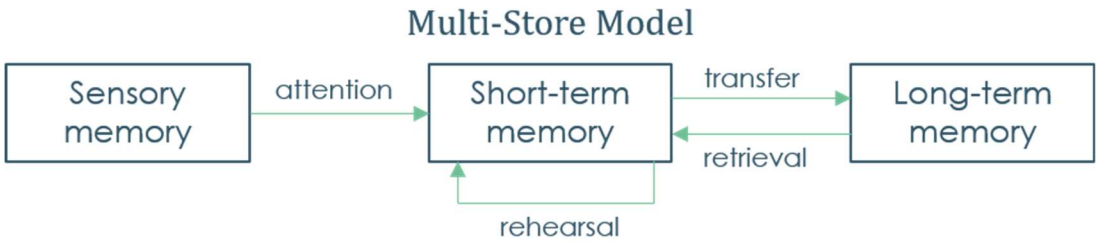
or time that we rely on ourselves to remember. It could be argued that by 'offloading' our semantic memories, our memories can become richer and stronger.

Is technology affecting how we recall memories?

As technology changes the way we form memories, it also changes the way we recall them.

Repeated interruptions are known to significantly affect concentration levels and with people checking their mobile phone on average every 12 minutes (The Guardian, 2018) there's an argument to suggest that technology is having an impact on concentration. Zaldy, S. Tan, director of the Memory Disorders Clinic at Beth Israel Deaconess Medical Centre, says that lower levels of concentration and higher levels of distraction make our memories 'messy', so they are harder to recall (The Age, 2016).

This is supported further by Atkinson and Shiffrin's (1968) memory model which highlights the importance of 'attention' in the first stages of forming a memory. It suggests that for someone to form and subsequently easily recall a memory, it's highly important that the subject is engaged.



The way that we store memories also has an impact on how they are recalled. If some of our memories are stored externally, as suggested by Wegner and Ward (2013), it means they aren't available for recall. Ward (The Age, 2016) argues that this has a knock-on effect, impacting the formation of new ideas. She says that the internal memory is where the dots are joined and new ideas are formed, therefore if some of our memories aren't available for recall we cannot form new ideas using these memories.

Section 3: Inconnection's Science of Memories Framework

We have identified the fact that people in Western society are exposed to an enormous volume of information – approximately 34gb per day (Tech 21 Century, 2016) - and it's predicted that we forget over 40% of that information after 24 hours (Psychestudy, 2017). This means that only a fraction of what we are exposed to is retained through the formation of memories.

Working with psychologist Dr Hamilton, we have identified a number of factors, including emotional states, that contribute to memory formation as well as factors which stimulate memory recall. We have also highlighted the factors that we believe may or may not be affected by technology.

Factors that strengthen memory formation

Attention and Motivation

As identified in Atkinson and Shiffrin's (1968) memory model, attention is vital for memory formation.

It would be impossible to process every piece of information our sensory memory receives, so only the things that capture our attention are taken into our short term and long term memories.

Depending on the context, what we pay attention to and ultimately encode will depend on our motivation to form a memory. This can work both ways: if we are motivated, we are more likely to be paying attention or, alternatively, if something gets our attention, we are more likely to be motivated.

Certain situations can affect our levels of attention and motivation. For example, in a fearful or surprising situation, our senses are heightened and our motivation to remember is driven by a survival instinct. The next few paragraphs outline the emotional states which have been closely linked with strengthened memory formation.

Fear

Studies have shown that fear can have a huge effect on memory, which is perhaps why it's one of the most studied areas of cognitive psychology. Although there is some conflicting evidence, the general consensus is that people's recollection of traumatic events is heightened, and people are able to remember vivid details with ease.

This is because fear activates a different part of the brain – the amygdala. The amygdala is involved in highly emotional memories which include pleasurable memories as well as fear. A release of adrenaline causes a series of biochemical reactions that is thought to enhance memory storage of the immediately preceding events (Phelps and Anderson, 1997).

A study by McKinnon supports the idea that fear enhances memory (BBC, 2015).

McKinnon interviewed 15 passengers who were on board a plane that had to make an emergency landing after a fuel leak. She wanted to compare their recollection of three events: the flight itself, an emotionally neutral event from the same year and their experience during 9/11 the following month. 6 of the 15 people interviewed exhibited PTSD symptoms following the flight's emergency landing.

McKinnon found that all of the passengers had vivid recollections of the event and those who went on to develop PTSD also had a vivid recollection of both 9/11 and the neutral memory from the same time period. This supports the idea that fear changes how the brain stores memories and those with PTSD have difficulty editing what they recollect, or the fading the contents of memory.

But a fearful memory doesn't have to be life threatening to be remembered. For example, you might vividly remember the first time you ever rode a rollercoaster or held a spider.

Belonging

The human need to belong has been widely studied in psychology, with some of the most notable findings being the 'own group bias' or 'in-group favouritism' (Van Bavel et al 2012, Bernstein 2007) which is a pattern of favouring members of one's in-group over out-group members.

As found by Van Bavel et al (2012), this 'favouritism' can provide a motivation for remembering and as a result, they found that people showed superior facial recognition for own-group members compared to non-group members.

The feeling of belonging has also been proven to positively affect student's academic performance (Allen and Bowles, 2012), perhaps due to the increased motivation to learn.

Both of these studies support the idea that memory formation and recall is more likely to occur if the individual is motivated by a sense of belonging.

Surprise

We know that unexpected events are more likely to be remembered than predictable, everyday occurrences but it is only recently that the underlying neural mechanisms for this are being explored.

The hippocampus has long been identified as a key part of the brain for memory formation and the nucleus accumbens is responsible for processing awards and novel information. It had previously been thought that a transfer between these two structures that occurs when someone is surprised is associated with enhanced memory of unexpected events (Science Daily 2010).

But more recent research by Dr. Axmacher et al (2010) into the electrical activity of these structures found that an unexpected stimulus triggered an early and a late electrical potential in the hippocampus, with the later signal also being recognised by the nucleus accumbens.

When the stimulus was predictable, the later signal in the nucleus accumbes was much smaller. This suggests that the nucleus accumbus may influence subsequent processing which serves to promote memory encoding for unexpected events.

Factors affected by Technology

As previously discussed in the paper, our ability to form memories is arguably being affected by the presence of technology, particularly in Western society.

Whilst we agree that technology can lesson our motivation to remember or provide more distractions, we would argue that it does not have an impact on memory formation in the context of the emotional states outlined above.

That's because the types of memories that are being formed under these highly emotional conditions are episodic memories, so the memories of a time and place. We previously identified that episodic memories remain relatively untouched by the impact of technology, arguably because they are unique to each individual and cannot be 'offloaded' onto a machine.

It could also be said that emotions such as fear and belonging are intrinsic to human nature and technology cannot interfere with the cognitive processes driving us to form stronger memories under these conditions.

Factors that trigger memory recall

Memory recall, or remembering, is the third and final process of memory after encoding and storage. There are a number of factors that can trigger memory recall, with the most widely studied being mood state dependent memory and the senses.

Mood-state dependent memory

Mood-state dependent memory has been widely studied, with Bower's (1981) famous paper still forming the backbone of a lot of today's research. He found that people were more likely to recall a memory if they were in the same mood during recall as formation. Similarly, if the mood during recall was greatly different from the mood when the memory was formed, people had difficulty remembering events. For example, if a person was in a negative mood when forming a memory, they were more likely to recall that memory when in a negative mood rather than a positive mood.

In the context of the emotional states outlined above, it could be suggested that if a person feels fearful, they are likely to recall previous situations where they also felt in fear. This is likely to have developed from a basic survival instinct, but it can be extended to more emotions and situations than just fear. For example, if you felt a sense of belonging with work colleagues after a day of team building activities, you might remember that day when working together on future projects.

Studies have also found that compared to a neutral mood, a positive mood encourages more relational elaboration (Lee and Sternthal, 1999). Relational

elaboration is where we encounter an item, a person or a product and immediately relate it to other similar things that we have categorised in our brain. For example, when we see a bottle of Fanta, we may also think of Coca-Cola, Sprite, Tango, etc. It has been found that we are more likely to recall these other connected items when we are in a positive mood rather than a negative mood.

This is perhaps due to dopamine having a memory boosting effect (Science News, 2010) but it could also be suggested that when we are in a positive mood, we feel more motivated and that strengthens both memory formation and recall. Marketers are very interested in relational elaboration because it means that the individual brands and their wider category can act as cues for retrieval of the target brand or product.

Senses and our memory

Our senses, in particularly smell, are well known cues for memory recall. The distinct smell of fresh cut grass or hearing a snippet of a song you loved in your teenage years can instantly conjure a very vivid and emotionally charged memory. The strong connection between our senses and memory has been widely studied with research pointing towards brain anatomy.

A recent study on rats found that the sensory brain regions which are responsible for processing sensory stimuli are also responsible, at least in part, for storing emotional memories. They trained rats to associate a certain sound with fear and then a month later, created a lesion in the part of the brain that processed the sound stimuli (the secondary sensory cortex). When the rats heard the sound again, they no longer froze suggesting that they 'forgot' the fear the previously associated with it as the memory was stored in the now-lesioned sensory cortex.

This provides evidence to support the idea that sensory information is coupled with emotional information and stored as a bundle. Each time the stimuli is encountered, the emotional information associated with it is triggered. Although the researchers note that whilst rats are good model for these types of experiments, more work is needed to determine whether the findings apply to humans too.

Other research suggests that memories relating to an event are scattered across the brain but marshalled by the hippocampus. If one of the senses evokes a memory, the hippocampus taps into other memories stored in the brain to build a detailed picture of the wider scenario. Just one sensory memory can quickly trigger this chain reaction to create a memory of the entire scenario.

The memory sense – smell

But perhaps the most interesting and conclusive research comes from studies on smell, which is often labelled 'the memory sense'. Smell is one of our strongest cues for memory recall and there are a number of theories why.

The first is biological, because of the direct route smell takes from detection to the limbic system (Whyy, 2014). The limbic system is a set of structures within the brain that are thought to play a huge part in controlling mood, memory, behaviour and emotion. This is unlike our other senses which are directed through the thalamus, which acts as a gatekeeper to our limbic system.

The limbic system is the oldest part of the brain, with very similar structurers found in the oldest mammals. This direct route that scent takes could have developed as a survival instinct as often smells such as smoke signal danger and require a quick reaction. Today, the direct route to our limbic system causes us to have almost instantaneous, emotionally charged memories.

The second reason lies within our ability to communicate. Unlike auditory or visual stimuli which can be easily described, scents cannot. Instead adjectives such as 'sweet' and 'summary' are used which don't accurately convey what the person is experiencing. So rather than labelling a smell, it instead becomes associated with the context of the time and we are reminded of that when we smell that particular scent (BBC, 2012).

As we are exposed to an almost unfathomable amount of sensory stimuli a day, it could be suggested that stimuli is only encoded with a memory when the factors that we have defined as strengthening memory formation are present. For example, hearing a snippet of a song played at your surprise birthday party takes you back to that moment because it was encoded when you were in the state of surprise.

Repetition

We know that repetition is one tool we can use to take a memory from our short term to our long-term memory but it can also trigger existing long term memories that were encoded years ago.

There are plenty of examples of how this might happen, for example, riding a double decker bus might remind you of the time you took an open top bus tour around New York City. Unlike sensory memory, these memories are triggered by being in a similar physical situation or doing a similar activity.

The types of memories that are triggered by repetition are usually novel or surprising events that stand out from the everyday.

Proximity

For the most part, our memory of an event or time in our life worsens as time goes on. It's easy for most people to remember what they did yesterday or last week, even if nothing significant happened, but what makes us remember some events from years ago and not others?

We know from emotional vs neutral word list experiments that emotional arousal can influence a person's ability to remember something (MacKay et al, 2004) and the same theory can be applied to our memories for larger events too. Memories that are encoded whilst we are in the emotional state of fear, surprise or belonging as

outlined earlier in the report are more likely to stay with us for longer than memories that are formed when we are in a neutral emotional state.

This shows how proximity from the event has less of an impact on emotionally charged memories than it does on neutral memories.

Conclusion

In conclusion, we have established that despite humans being exposed to an enormous volume of information, they are still able to form strong memories under certain emotional conditions and these memories can easily be recalled, even after a considerable amount of time has passed.

We have identified that the emotional states of fear, surprise and belonging improve the likelihood of someone forming a memory and the strength of those memories. That's because when our emotions are heightened, different areas of the brain such as the amygdala and the nucleus accumbens are recruited and subsequently affect how we encode and store emotional memories.

As a result, these emotional memories are some of the easiest for us to recall. They can be triggered by our mood, our senses and repetition of a similar situation. It appears that they are also more resistant to the passing of time than our other memories so they can be recalled years or even decades later.

We have used these emotional states to form our Science of Memories framework which is applied when designing events to provide clients with robust reasoning and rationale. As a result, there is no requirement for Inconnection clients to become memory specialists, instead they can draw on our know-how to create memories that matter through events and experiences – with the full knowledge that Inconnection understands the science to make it happen.

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