WE ARE WHAT WE REMEMBER:

UNRAVELLING MEMORIES

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The human brain never stops recording. It stores large amounts of information effortlessly. How does it achieve this? And, why are memories so important? This article provides insights to what encompasses memory and the role memories play in our lives.

Do you remember your first day at school? Try to visualize what your classroom looked like. What colour was your uniform? Who accompanied you to school? Were you crying? What did your teacher look like? Some of us have such a vivid memory of our first day at school that it can make us nostalgic even much later in life. If you cannot remember your first day of school, just relax! There is a biological reason behind this lapse in memory that I will explain a little later.

Try another example. Think of the best birthday you've ever had. How old did you turn that year? Did you cut a cake? What flavour was it? Do you remember the people who were part of your birthday celebrations? What were you wearing?

Reminiscences of the first day at school or a fun birthday are memories of events or specific episodes in one's life, and are thus called episodic memories. While significant episodes from our lives are remembered long after, like the ones highlighted in the examples above; insignificant ones, like what you ate for breakfast a month ago, are soon forgotten. Episodic memories are one kind of memory.

Are there other types of memory?

Different types of memory

Long-term memories are of two kinds – explicit and implicit memories (Fig.1).

Declarative (Explicit) Memories

Any memory that requires conscious or deliberate effort to remember information is called a declarative memory. These memories can be explicitly recalled and verbalized, and make us aware of what we know and what we do not know. Explicit memories are of two types -

1. **Episodic memory** refers to our ability to remember details of time, place, the people involved, and specific activities that occur during an event. We absorb information from our surroundings by

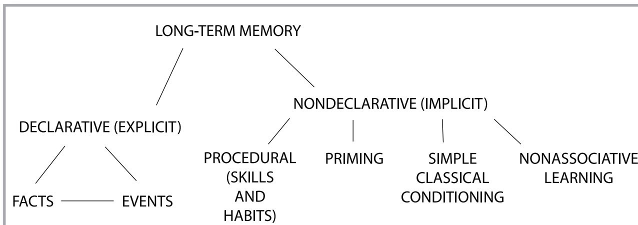

Figure 1. Classification of long-term memories.

continuously forming a series of episodic memories. Our memories of episodes from the past act as our references when we make decisions or solve problems.

2. **Semantic memories** refer to our ability to remember general knowledge and facts, such as, Tokyo being the capital of Japan, or plants making their food through photosynthesis. This type of memory contains schemas or rules of behaviour. For example, after going to the airport several times, we develop a schema for the actions that have to be taken at the airport – check in your baggage, collect boarding tickets, pass a security check and then board the flight. We develop several such mental schemas over a lifetime, which guide our behaviour and reduce the effort taken to complete a task or activity.

Non-Declarative (Implicit) Memory

Implicit memories do not require conscious thought. They are elicited from experience, without reaching our awareness. They are of four types:

1. **Procedural memory** is responsible for our motor skills and habits, such as riding a bike, swimming or typing. The motor cortex (Fig. 2) in our brain coordinates directly with the muscles needed to execute these actions.

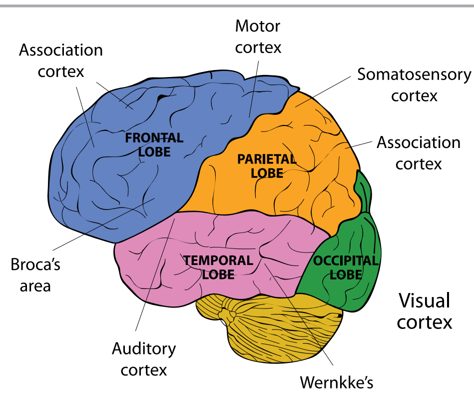

Figure 2. Cortices of the human brain.

2. **Priming:** Before you read ahead, try completing the words in the box below (Fig. 3).

RED	PLUM
BLUE	NECTARINE
ORANGE	PEAR
YELLOW	APPLE
GR_____	GR_____

Figure 3. Why do you fill different words in the two columns?

Here is a video with another example of priming: https://www.youtube.com/watch?v=5g4_v4JStOU.

Exposure to a particular stimulus influences our sensitivity and response to a later stimulus. Priming brings certain associations or thinking patterns to the forefront that influence our subsequent decisions, actions, or behaviours. In Fig. 3, the colour list primes 'green' while the fruit list primes 'grape' from their respective categories.

3. **In classical conditioning**, a new response is learned by making new associations. When two stimuli that were not related to each other are linked together, they can produce a learned response.

The most famous experiment of classical conditioning was demonstrated by Ian Pavlov, a Russian scientist. Pavlov's dog would salivate every time it saw food. One day Pavlov observed that the dog began salivating when he heard Pavlov's footsteps, much before seeing the food he'd brought. Pavlov decided to test this experimentally. He struck a bell before giving the dog his food every time. Over the next several meals, the dog learned to associate the ringing of the bell with arrival of food. So the dog began salivating when the bell was struck, much before the food was brought into sight. Thus a neutral stimulus, such as the ringing of a bell, was associated to the involuntary response of salivating. Other such involuntary responses include crying, laughing and freezing.

Watch two more videos of classical conditioning in humans: https://www.youtube.com/watch?v=Eo7jcI8fAuI https://www.youtube.com/watch?v=OwBQIhg6CvE .

4. **In non-associative memory**, repeated exposure to a stimulus increases or decreases the response to that stimulus. When the response to a stimulus decreases, it is called habituation. For example, while sitting in a library to read, you are startled by the sudden sound of a loud bang. You figure out that some construction has begun on the floor above, and when the banging continues, you are less distracted by it. Gradually, you are able to ignore the noise, and continue reading. What happens in this case is that you become habituated to the noise. On the other hand, when a response to a stimulus increases, it is called sensitization. For example, while trying to sleep, you hear a water faucet leaking. Every drop that

falls makes a sound which increasingly draws your attention to it, and stops you from falling asleep.

Both these examples are over short time scales, but habituation and sensitization can also occur over larger time scales and result in long lasting changes in behaviour. One example of long term habituation can be seen when we travel across time zones. Our body is jetlagged for the first few days, but after that we gradually settle into the day and night routine of the new time zone. An example of long-term sensitization would be a war veteran dropping to the ground on hearing a sudden sound, like the bursting of a car tyre, and responding as if a gun had been fired.

How does our brain form a memory?

Our identities are formed based on our recollections of the many different episodes/events that we experience in our lives. It is through our ability to form episodic memories that we are able to recollect both the good and bad events from our past. Keeping in mind the role of episodic memories in defining us, let's take a look at how these memories are formed.

Imagine that you witness a road accident while travelling in a bus. The sensory information that you see and hear is processed first. The visual information entering the eye travels to the back of your brain to the visual cortex in the occipital lobe (Fig. 2). The brain cells or neurons of this area are specialized to process information such as shape, size, colour and movement. Similarly, the neurons in the auditory cortex located at the crossover area between medial, frontal and parietal lobes (Fig. 2) analyse different sounds. The processed visual and auditory information travels to the temporal cortex where objects, people and sounds are identified. Simultaneously, the parietal cortex assesses the relative location of the objects and people around you. All identified information is then bound together by the 'hippocampus', named after the sea-horse or sea monster in Greek mythology that it resembles in shape (Fig. 4), to form an episodic memory. Each of us has two hippocampi, situated deep inside the temporal lobes on either sides of the brain, behind both ears (Fig. 5). While the hippocampi do not store any information within themselves, they play an important role in forming, storing and retrieving details of events. Each hippocampus functions like a library catalogue - it maintains the location for every memory it has helped form. So where is the memory of an event stored?

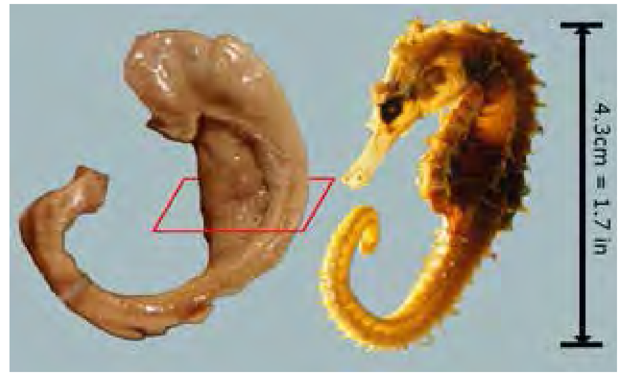

Figure 4. The human Hippocampus (left) and the seahorse (right) look very similar.

A memory is represented in our brain by groups of neurons. Neurons group together if they process information at the same time. In the example of a road accident, the visual information (e.g. an injured person), auditory information (e.g. people running, ambulance arriving, etc.) and location of the accident, are all processed simultaneously by neurons in different regions of the brain. Those neurons became active at the same time and, therefore, together form a memory.

The connections between groups of neurons forming an episodic memory are controlled by the hippocampus. When we recollect such an episode in the future – say a few days or weeks later, the hippocampus makes the particular group of neurons active again and we remember events as though we are reliving them.

Typically, the hippocampi are not very well developed at birth. At around age 2, the hippocampi begin to mature and connect with other brain regions. That is why infants and toddlers are unable to remember many events or episodes from their lives. By the age of 4,

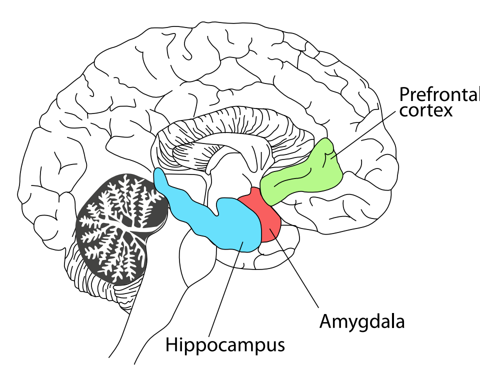

Figure 5. The hippocampus and amygdala are situated bilaterally, deep inside the medial temporal lobes of the brain.

The Case of HM

Henry Gustav Molaison (February 26, 1926 – December 2, 2008), called as H.M., by researchers, was the most studied patient in the history of neuroscience. For more than 50 years, his unique case helped scientists to study memory. At age 7, HM was knocked down by a bicycle that resulted in seizures or epileptic attacks, which worsened after he turned 16. He could not lead a normal life. Dr. William Scoville, a neurosurgeon at Hartford Hospital, Connecticut, USA recommended a surgical treatment for his epilepsy. Removing brain tissue within HM's bilateral medial temporal lobes would control his seizures. That surgery left HM, then 27 years old, with severe memory problems. He could remember his name, family and childhood but he could not remember his day-to-day activities. Neither could he remember his doctor who visited him daily. That left Dr. Scoville baffled because he had never come across such a patient. Dr. Scoville then invited Dr. Brenda Milner, a clinical neuropsychologist, to study HM. Dr. Milner had worked with similar patients but none of them showed symptoms that were as severe as those in HM. Over many years of testing HM, her team found that HM's intellectual abilities were intact. He could remember facts and general knowledge. He could also learn motor skills (like tracing a star by looking at its mirror reflection) over many practice trials, but was never conscious of these learning sessions. Her efforts over years of tests on HM revealed that HM found it difficult to remember events from the past few years (retrograde amnesia) leading up to his surgery. Neither could HM form new memories (antero-grade amnesia), which is why he could not remember his doctor. He lived only in the present. Dr. Scoville and Dr. Milner pieced together this puzzle to conclude that in an effort to curb HM's seizures, Dr. Scoville had removed the 'hippocampus', a specific region within the medial temporal lobe that is important for forming, maintaining, and retrieving long-term memories.

Source: Squire, L. (2009). The legacy of patient HM for neuroscience. Neuron, 61(1): 6–9. Big Picture: Inside the Brain (2013). Published by the Wellcome Trust, a charity registered in England and Wales, no. 210183. bigpictureeducation.com.

children begin to slowly recollect events and verbalize what they remember, but not as well as adults. This is probably the reason why many of us cannot remember events from when we were kids, such as our first day at school. Our hippocampi were still developing at that age, and the memories that were formed then did not last very long.

Suggestive of its role in learning and memory, the hippocampus is also the only region of the human brain that undergoes 'neurogenesis' (the ability to generate new cells over one's lifetime). This is in contrast to the rest of the brain, which has the same number of cells from birth until death. We owe our ability to continuously learn and remember large and diverse amounts of information to hippocampal neurogenesis.

What affects our memories?

With time and regular overnight sleep, newly formed memories are consolidated and stored as long-term memories. With poor or no sleep, our memory-making mental processes are badly affected because the rhythms of brain activity during sleep provide an environment for neurons to make new connections within the brain. It is these new connections that give us the ability to make inferences, be creative, and generate knowledge and ideas.

Memories do not last in the same form forever, they change with time. Some fade slowly and eventually we forget them. Some are updated with new information, like in our understanding of concepts of math and science, which continuously evolve.

Emotions and stress can affect our ability to learn and remember. Emotions are regulated by the 'amygdala', a brain structure located adjacent to the hippocampus (Fig. 5). The amygdala processes all kinds of emotions, and also sends signals to the hippocampus about how positive or negative the individual felt at the time of learning or recall. Neurotransmitters or neuro-chemicals released in the brain during negative emotional states can impair our ability to learn and recall. That is why when you are stressed about writing an exam you sometimes struggle to remember even things that you otherwise remember well. In contrast, a traumatic experience can evoke such a powerful emotional response that it protects that particular memory of a trauma for life. An example of a traumatic experience could be of an accident in which you barely escaped with your life, but lost a family member. The difficulty in forgetting traumatic experiences can sometimes cause emotional or stress disorders in people.

What if we had no memories?

As discussed before, implicit memories do not require conscious or deliberate thought while explicit memories do. With conscious thought, we can relive our past, experience the present, and imagine the future. In other words, we can mentally travel in time. This ability depends critically on episodic memories, which are controlled by the hippocampus.

What if we had no hippocampi? This is answered by the case of a patient with missing hippocampi, known to researchers as HM (see Box 1: The Case of HM). Without hippocampi, HM struggled to recollect his past, and was unable to form new memories, or think about his future. This ability to mentally travel in time makes us conscious beings, a uniquely human trait.

Conclusion

While memories arise from our experiences in life, decades of research show us that our memories are not permanent; they change in form and/or accuracy. Current research is focussed on exploring all possible factors that can cause a memory to be altered. Knowing these factors can help provide therapy to people who suffer from memory disorders.

What we do understand, however, is that our memories are essential to us. We use them to draw references from the past to plan and predict our future. Both good and bad memories help shape our thinking, decision-making and problem-solving abilities. While negative experiences remind us of what can be detrimental and needs to be avoided; positive experiences encourage us to show certain other behaviours.

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Feathers and Warm Blood: Dino facts that you didn't know

– Vignesh Narayan

The different kinds of birds found today trace their ancestry back to dinosaurs. About 66 million years ago, a mass extinction event (probably an asteroid hitting the earth) decimated most of the dinosaur population.

The few that were left evolved into the birds that we see today. What few people know is that over the past two decades, archaeologists have unearthed thousands of fossils of dinosaurs that had feathers!

'Proto-feathers' or primitive feathers have been found on the fossils of a variety of dinosaurs, from meat-eating bird ancestors to plant-eating dinosaurs that were wiped out in the extinction event.

Using information from fossilized pigment cells, even the colour of the feathers of some dinosaur species have been worked out! According to researchers at the Yale university, Anchiornis huxleyi, a feathered dinosaur that lived during the late Jurassic period in China, sported grey plumage, a reddish Mohawk and white feathers on its wings and legs, which ended in black tips.

If feathers were not enough, researchers have used different types of measurements on the fossils of dinosaurs to conclude that the body temperatures of these gigantic creatures were between 36°C and 38°C, making them warm-blooded animals like birds, and not cold-blooded like the reptiles that we have today.

We are moving away from an image of dinosaurs as large cold-blooded reptiles. Instead we are beginning to see them as warm-blooded and brightly coloured animals that used feathers to fly and attract mates, much like birds do today.

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