Memory Processes

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Abstract

This paper is intended to be a brief discussion on memory. It describes how memories are formed, stored, and retrieved. It also covers the implications and the process of memory loss (amnesia). Examples of conflicting witness testimony and distorted recollections are used. There is also a discussion on the brain's response to drugs and stress as they pertain to the formation and loss of memories. The Human Factors: Error & Threat Management Course covers memory in depth. Please refer to the course text for additional information.

Introduction:

In order to understand how the loss of memory works, it's good to know how we store memories in the first place. The human brain is a truly amazing organ. It gives us the power to think, plan, speak and imagine. It also gives us the ability to make and store memories. Just 1.5 kilograms of tissue inside your head contains *you*. It learns from its mistakes and it invents new strategies for your survival. As the supreme co-coordinator of your body's complex workings, it knows things you don't realize you know. It runs your life, and if it dies, you die.

The brain is a system of mind-boggling complexity. The basic brain cell, the neuron, is a nerve cell with cable-like and thread-like outgrowths connecting it to other neurons. There are a staggering 100 billion neurons in the brain, and a typical neuron makes between 1,000 and 10,000 connections to other neurons. The brain's activity is carried out through message-bearing electrical impulses, which travel along complex routes through the brain's web of connections.

So much activity requires energy, and the brain has an insatiable appetite for sugar and oxygen. It consumes 20% of all the oxygen available to your body, and it requires 120 grams of glucose a day. It can only store two grams of glucose itself, so when you're asleep and glucose isn't being provided by food intake, it removes glucose from storage in the muscles and liver to feed itself, and if you fast (for example, by dieting), it will find glucose by breaking down your muscle proteins.

Both sugar and oxygen are carried to the brain by the blood. The brain receives 15%-20% of the blood flowing from your heart.

The vital and complex nature of this organ means that if it is damaged, the consequences are at once extremely grave and very difficult to treat. It is also highly susceptible to drugs which can pass through the blood-brain barrier and interfere with electro-chemical transmissions. Although scientists have mapped out certain areas of the brain, their map is by no means comprehensive. Nor do they fully understand the connections between different parts of the brain.

Physiologically speaking, a memory is the result of chemical or even structural changes in synaptic transmissions between neurons. The three main stages in the formation and retrieval of memory, from an information processing perspective are:

- Encoding: The registration and consolidation of received information
- Storage: The creation of a permanent record of the encoded information.
- Retrieval: The calling back of the stored information in response to some cue for use in some process or activity.

During these three stages changes occur, and a pathway is created. This pathway is called a memory trace. Signals can travel along these memory traces through the brain. Making and storing memories is a complex process involving many regions of the brain, including the frontal, temporal and parietal lobes. Drugs, damage or disease in these areas can result in varying degrees of memory loss (amnesia).

There are several different types of amnesia, and they can be caused by such things as disease or head trauma. Sometimes the memory loss associated with amnesia includes everything from a person's past, and other times just bits and pieces are missing. In most cases, amnesia is a temporary condition and is very brief, lasting from a few seconds to a few hours. However, the duration can be longer depending on the severity of the disease or trauma, possibly lasting for a few weeks or even months.

As the amnesiac recovers, he or she usually recalls older memories first, and then more recent memories, until almost all memory is recovered. Memories of events that occurred around the time of the accident or onset of amnesia are sometimes never recovered. The two most commonly discussed forms of amnesia are retrograde amnesia and anterograde amnesia. If someone is suffering from retrograde amnesia, he or she cannot recall memories that occurred before the onset of amnesia. If someone has anterograde amnesia, he or she cannot remember incidents that happen after the onset of amnesia.

Example:

The bedrock of the American judicial process is the honesty of witnesses in trial. Eyewitness testimony can make a deep impression on a jury, which is often exclusively assigned the role of sorting out credibility issues and making judgments about the truth of witness statements. Arriving at a just result and a correct determination of truth is difficult enough without the added possibility that witnesses themselves may not be aware of inaccuracies in their testimony. Several studies have been conducted on human memory and on subjects' propensity to remember erroneously events and details that did not occur. An experiment in the mid-seventies demonstrating the effect of a third party's introducing false facts into memory. Subjects were shown a slide of a car at an intersection with either a yield sign or a stop sign. Experimenters asked participants questions, falsely introducing the term "stop sign" into the question instead of referring to the yield sign participants had actually seen. Similarly, experimenters falsely substituted the term "yield sign" in questions directed to participants who had actually seen the stop sign slide. The results indicated that subjects remembered seeing the false image. In the initial part of the experiment, subjects also viewed a slide showing a car accident. Some subjects were later asked how fast the cars were traveling when they "hit" each other. Others were asked how fast the cars were traveling when they "smashed" into each other. Those subjects questioned using the word "smashed" were more likely to report having seen broken glass in the original slide. The introduction of false cues altered participants' memories. Courts, lawyers and police officers are now aware of the ability of third parties to introduce false memories to witnesses. However, psychologists have long recognized that gap filling and reliance on assumptions are necessary to function in our society. For example, if we did not assume that mail will be delivered or that the supermarkets will continue to stock bread, we would behave quite differently than we do. We are constantly filling in the gaps in our recollection and interpreting things we hear.

Accuracy of recollection decreases at a geometric rather than arithmetic rate (so passage of time has a highly distorting effect on recollection); accuracy of recollection is not highly correlated with the recollector's confidence; and memory is highly suggestible – people are easily 'reminded' of events that never happened, and having been 'reminded' may thereafter hold the false recollection as tenaciously as they would a true one.

One of the things that we know about memory is that when you experience something extremely upsetting or traumatic, you don't just record the event like a video tape machine would work, the process is much more complex and what's happening is you're taking in bits and pieces of the experience, you're storing some information about the experience, but it's not some indelible image that you're going to be able to dig out and replay later on.

One of the things that happens when you have a victim of a serious crime and a police investigator is they both have the same goal. They want to see the crime solved and they're going to work together to do that. That is perfectly natural, but if you have somebody who is very, very motivated to see that crime solved, she may be especially sensitive to feedback that she might be getting from investigators who are assisting her in that process. If they have a suspect in mind, if they've an idea who the perpetrator is and they communicate that idea to the victim, even unwittingly, she may be more sensitive to picking up that communication.

If they explicitly give her feedback, "Well that's the guy we thought it was," then this can be a serious problem. This kind of feedback can artificially increase the confidence level of the victim, make the victim more certain if the police believe it, they must have a good reason, "I think that's the guy, in fact, I'm even more confident than I was before." Now, you have a victim who's going to be even more persuasive when she goes into the court room to testify than, perhaps, is warranted.

So in essence, what we may think of as being a memory cannot always be trusted. It can be manipulated or created entirely without us even being aware.

In order for short-term memory to become long-term memory, it must go through a process known as consolidation. During consolidation, short-term memory is repeatedly activated -- so much so that certain chemical and physical changes occur in the brain, permanently "embedding" the memory for long-term access. If, during this repeated activation, something interrupts the process -- let's say a concussion or other brain trauma - then short-term memory cannot be consolidated. Memories can't be "stored" for long-term access. This may be what's going on in anterograde amnesia.

It is believed that consolidation takes place in the Hippocampus, located in the temporal-lobe regions of the brain. Medical research indicates that it is the frontal and temporal lobes that are most often damaged during head injury. This is why many people who suffer severe head trauma or brain injury experience anterograde amnesia. If the Hippocampus is damaged, the amnesiac will be able to recall older memories, but won't be able to make any new ones.

Common Types of Amnesia:

- Anterograde Amnesia - Inability to remember ongoing events after the incidence of trauma or the onset of the disease that caused the amnesia
- Emotional/Hysterical Amnesia - Memory loss caused by psychological trauma; usually a temporary condition
- Lacunar Amnesia - Inability to remember a specific event

- Korsakoff Syndrome - Memory loss caused by chronic alcoholism
- Posthypnotic Amnesia - Memory loss sustained from a hypnotic state; can include inability to recall events that occurred during hypnosis or information stored in long-term memory
- Retrograde Amnesia - Inability to remember events that occurred before the incidence of trauma or the onset of the disease that caused the amnesia
- Transient Global Amnesia - Spontaneous memory loss that can last from minutes to several hours; usually seen in middle-aged to elderly people.
- Global Transitory Amnesia: Is short-lived and involves anterograde amnesia followed by retrograde amnesia.

Types of Memory

Exactly how the brain stores memories is not clearly understood. What we do know is that the brain stores different types of information in different places. Researchers have divided up our memories into three types:

Immediate Memory or Sensory Store: This consists of a mental snapshot of raw stimuli corresponding to sounds, sights, smells or tastes. Unless this snapshot is transferred to the short-term memory, it is lost forever. A significant amount of stimulus is received and filtered because it is of no importance to us.

Short-Term Memory or Working Memory: Is where sensory information is registered, organized, and consolidated. This refers to memories that last anywhere from a few seconds to a couple of minutes. Short-term memory has a limited capacity and additional information constantly replaces it.

Long-Term Memory:

- Intermediate Long-Term Memory - Refers to memories that may last for days or even weeks, but eventually are lost forever (unless they are moved to long-term memory).
- Long-Term Memory - This refers to memories that can be recalled for many years (perhaps for an entire lifetime). Long-term memory forms a permanent database of memories. In order for short-term memories to be filed, permanent changes to brain cells have to take place.

It seems that the brain also has a number of different memory forms, including:

- Declarative: Conscious memories of information and events.
- Non-Declarative: Habit patterns that have been learned such as driving a car become ingrained and automatic.

Amnesia:

When the brain suffers an injury, not all memories are treated equally. Long-term memory is rarely affected, but short-term and intermediate long-term memories, which have not yet been permanently imprinted on our consciousness, are often lost.

The most common form of post-traumatic memory loss is anterograde amnesia. With this condition, a patient's memory of events before the accident is clear, but they find it difficult to hold short-term memories following the accident. For example, a doctor treating such a patient may be greeted as a new acquaintance at each consultation. This type of amnesia is rarely permanent.

The Brain's Response to Acute Stress

In response to severe threat, a part of the brain called the *hypothalamic-pituitary-adrenal* (HPA) system is activated.

Release of Steroid Hormones and the Stress Hormone Cortisol. The HPA systems trigger the production and release of steroid hormones (*glucocorticoids*), including the primary stress hormone *cortisol*. Cortisol is very important in marshaling systems throughout the body (including the heart, lungs, circulation, metabolism, immune systems, and skin) to deal quickly with the threat.

Release of Catecholamines. The HPA system also releases certain neurotransmitters (chemical messengers) called *catecholamines*, particularly those known as known as *dopamine*, *norepinephrine*, and *epinephrine* (also called adrenaline).

Catecholamines activate an area inside the brain called the *amygdala*, which apparently triggers an emotional response to a stressful event. This emotion is most likely fear.

Effects on Long- and Short Term Memory. During the stressful event, catecholamines suppress activity in areas at the front of the brain concerned with short-term memory, concentration, inhibition, and rational thought. This sequence of mental events allows a person to react quickly to the threat, either to fight or to flee from it. It also hinders the ability to handle complex social or intellectual tasks and behaviors during that time.

On the other hand, neurotransmitters at the same time signal the *hippocampus* (a nearby area in the brain) to store the emotionally loaded experience in long-term memory. In primitive times, this brain action would have been essential for survival, since long-lasting memories of dangerous stimuli (i.e., the specific) would be critical for avoiding such threats in the future.

The Brain's Response to Drugs:

A question came up in the Lake Tahoe class regarding how GHB and other "Date Rape" drugs affect the memory process.

Gammahydroxybutyric acid (GHB) is a new drug with abuse potential and is popularly known as "liquid ecstasy". Another similar class of drug is Rohypnol.

GHB is a naturally occurring compound of the mammalian brain. GHB is synthesized from GABA (a naturally occurring neurotransmitter in the brain). Since GHB can traverse the blood-brain barrier recent studies indicate that working memory may be significantly altered. Many studies indicate that the prefrontal medial cortex may be a crucial structure of working memory. These findings suggest that GHB could affect memory by altering the structure and/or function of specific brain regions such as prefrontal medial cortex.

Even though GHB is a naturally occurring compound found in the brain, excess GHB acts as a depressant on the central nervous system because it is rapidly metabolized by the body. The effects of the drug can be felt within fifteen minutes after ingestion.

GHB can cause dizziness, nausea, vomiting, confusion, seizures, respiratory depression, intense drowsiness, unconsciousness, and coma. In some cases, GHB also can cause "anterograde amnesia" (memory loss for the events following ingestion). This means that you may not be able to recall what happened to you while you were under the influence of the drug.

When GHB is ingested with alcohol or other drugs, the consequences may be life-threatening. Without immediate and appropriate medical care, the results may be fatal.

Remember in class we discussed how Cortisol produced in the Acute Stress Response also affects memory. Cortisol interferes with the transfer of information from short-term to long-term memory and interferes with the retrieval of information from long term memory. The mechanism with "Date Rape" drugs is very similar.

With regard to the human brain, it has been asserted that GABA signals interfere with the registration and consolidation stages of memory

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The “Date Rape” drugs can produce complete or partial amnesia (loss of memory) for the events that take place after it is ingested. This means that you may not be able to remember what you did - or what was done to you - while you are under the influence of the drug, which may be a significant period of time. This "amnesic" effect is especially likely when “Date Rape” drugs are ingested with alcohol.