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THE MAGIC OF MEMORY - AN ILLUSTRATED SUPPLEMENTAL GUIDE

By

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A capstone project submitted for Graduation with University Honors

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University Honors
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ABSTRACT

Learning complex topics such as cognition, chemistry, or biology, can be difficult for students of all ages. Visualizations can help portray challenging material in a more clear and concise manner, while helping students make inferences and develop a deeper understanding (Bobek & Tversky, 2016). One of the major arguments for using visual aids in learning environments is that individuals are able to identify gaps in their knowledge and make inferences (Bobek & Tversky, 2016). The book consists of three main chapters, respectively titled *Short Term Memory*, *Working Memory*, and *Long Term Memory*, including a bonus chapter at the end titled *Studying with the Magic of Memory*. The bonus section is intended to be a "summary" of all three chapters that utilizes the science of memory to discuss effective study tips students can use to improve their knowledge retention, academic habits, and memorization skills. Each chapter is divided into mini sections that show the reader a short comic strip about the subtopic in a way that is easy to understand, followed by a more in-depth text explanation. The comic strips feature two main characters, Anjana and Ji-Hoon, who are middle schoolers learning about Memory. The two friends guide the reader through the book, picking apart subtopics that tend to be challenging when presented solely through text. The purposes of this high-school level illustrated supplemental guide are to allow students to learn about the basics of memory in a way that is palatable and to bridge the gap between academic texts and the general public.

ACKNOWLEDGMENTS

I would like to take this opportunity to thank everyone who has aided me in this long journey the past two years - the people that have made this book possible!

I thank my wonderful mentor Dr. Rebekah Richert for always being there and providing honest feedback and guidance throughout the process. During every meeting, I felt as though I could always depend on her to tell me what needed to be changed and what I had done very well - she never hesitates to tell me I should be proud of myself!

I also thank my loving family: Amma, Appa, and Vishal, who have been helping out in the process from the beginning. They have heard me ask, “Can you read this and tell me if it makes sense?”, “What is the most difficult thing to understand?”, and “Do you think I should make the drawing about this?” many, many times. They were my first “test audience!”

I thank my partner Ashwin and all my friends for supporting me along the way. They were always willing to proofread my work or offer me (much needed) suggestions!

Lastly, I would like to thank all the faculty who have helped me throughout the whole process, from before I even wrote a single word, to now, having written and drawn my whole book. A big thank you to Dr. Richard Cardullo and Dr. David Cocker for all their help during my time in HNPG 150 (my first honors class!), and Mayra Jones, my honors counselor, for always checking in on me and being there with me during my time in University Honors!

It feels so surreal to be writing all this because it makes me realize that the journey is almost coming to an end! I still remember when I was first starting this project and felt unsure if I could even take on something as big and intimidating as a book. I often doubted if this was even a good idea, or if anyone would even be interested in reading it. But, with the support of everyone around me, I was able to power through this journey and finally be able to see the fruits of my labor!

So, again, thank you to everyone who was a part of this endeavour - the Magic of Memory would not be possible without you all!

FOREWORD

“Oh wow, I swear I remember that happening,” you tell your friend. “That never happened, you must not be remembering it right,” she says. Has this ever happened to you before? It has definitely happened to me more than once. I tend to be so confident about a situation and even remember specific details, but someone else has a totally different account of what happened! How is this possible? How can two people who witnessed the same event remember two different stories? How can you remember your family trip to Hawaii when you were a child, but you can’t remember what you had for dinner last night? And what does sleep have to do with memory? Can you really learn more for your biology test by sleeping on your textbook? Good news, with this illustrated supplemental guide on memory, you now have all the answers in your hand! Well, maybe not *all* of the answers, but surely all the important ones.

Now, what might one gain from an illustrated supplemental guide about *anything*? Do pictures really help you learn difficult concepts? Studies have shown that visualizations can help portray challenging material in a more clear and concise manner while helping students make inferences and develop a deeper understanding (Bobek & Tversky, 2016). This means that pictures have the ability to make learning difficult concepts easier! Illustrations are more concrete than words and allow students to remember information better since most of our sensory cortex in the brain is actually dedicated to vision (Kouyoumdjian, 2012).

Why did I decide to create this supplemental guide? I always knew that illustrations and visual guides allowed me to have a better understanding of concepts I learned in school, and my peers and friends usually felt the same way. After all, who wants to read a textbook full of just words? Personally, I tend to get lost in the information and am unable to visualize conceptual ideas or relate them to the real world. Especially when studying subjects such as chemistry, biology, or cognitive psychology, I have found through personal experience that drawing out concepts and having a visual aid works wonders.

Why memory? Memory is one of the most vital superpowers humans possess. Yes, it is a superpower. Without memory, we wouldn’t be able to ride a bike, cook our favorite meal, remember our loved ones, or be able to learn new things about the world. To help you harness your superpower, this book is purposefully written in user-friendly language instead of the research language that is typically used in many textbooks and research papers. With that said, I hope you enjoy this illustrated guide and learn a thing or two about the amazing superpower that is memory!

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What is Memory?

Memory. What comes to mind when you hear the word? You may be thinking about events that have happened to you in the past, or when you have recalled information during an exam at school. In the modern world, memory is typically a tangible item that is only stored in your brain (Zlotnik & Vansintjan, 2019). It is something that humans can retrieve at will and it can be unique to each person, due to individual life differences. So yes, you can remember things that have occurred in your life or recall pieces of information that you have stored because of your memory. However, more recently, scientists are beginning to define memory in a new way - it is now being used to describe storing information in a more general way. Rather than memory just referring to the brain or remembering information, it can also refer to the retrieval of information in the body, such as in DNA, neurochemical processes, or even digital information storage in phones, computers, and other forms of technology (Zlotnik & Vansintjan, 2019). In other words, a memory is no longer just an item in the brain - it can be a chemical process between neurons or stored on a hard drive.

BREAKING NEWS!

Introducing our helpful friends Anjana and Ji-Hoon! From here on out, they will be helping us understand the content in a more simplified way. You will be able to see Anjana and Ji-Hoon discussing the topic before you read about it in more detail. With both of their wise words alongside the text, you will be on your way to becoming a near-expert on the magic of memory!


anjana
ji-hoon
Hey Ji-hoon, do you know what memory is?
Duh, it's when your brain recalls information you've learned or things that have happened before!
sure! But it's actually more simple than that. Anything that stores infor-mation has memory!
Woah! Does my phone have memory?
absolutely! so does your TV, laptop, xbox, and even other parts of your body like the immune system!
what about this camera?
well, not the camera itself, but the SD card inside has memory like the brain!
speaking of memory, my teacher was talking about short-term memory in class and I was confused.
I'm glad you asked because that's what we'll be learning about later!

Interestingly, there are a few early research findings that support this new definition of memory. In the 19th century, scientists discovered that memories are stored through the connections between neurons growing stronger, rather than by new neurons being created; they came to this conclusion after finding that the number of neurons in the brain does not increase by very much after reaching adulthood (Ramón y Cajal, 1894). Now, if you have ever opened a psychology textbook, you may be able to recall the most famous example of classical conditioning involving Pavlov's dog. It was a psychology experiment in which the researcher, Pavlov, had trained his dog to produce a salivating response whenever he heard him ring a bell. Pavlov would repeatedly ring a bell and serve the dog food immediately. Over time, the dog had been conditioned to associate the bell with mealtime, and would salivate just by hearing it! Studies by Eric Kandel (Aplysia Californica) have shown us that even classical conditioning can be a form of memory storage and can be observed in simple organisms (Kandel et al., 2012).

Zlotnik and Vansintjan (2019) explain that memory is actually a relationship where one biological or chemical process is blended with another, and both processes are changed in some way. If we can wrap our heads around the strange idea that storage of information can exist outside the mind, we open a door of so many possibilities. Memory is also a dynamic process, meaning that it is a work in progress. Just like how our bodies, brains, and technology are always changing, so is memory!

Speaking of technology, we have seen so many innovations in recent years. Devices like smartphones, mind-controlled prosthetic limbs, laptops, and Google Glasses are able to store information like the brain and allow us to interact with and perceive our surroundings using this retrieved information (Zlotnik & Vansintjan, 2019). Scientists are now proposing a new word to describe how human cognition goes far beyond the brain - 4E cognition. 4E cognition is an ever-changing interaction between an organism and its surroundings; cognition, or the mind, is, therefore, a product of our brain, body, and environment all interacting with one another.

Memory is the process of encoding, storing, and retrieving information (Squire, 2009). It includes three main parts: sensory memory, short-term memory, and long-term memory (the last two are what we will be discussing in this chapter!). Following this new definition of memory, an experience is also a form of stored information, but not in the traditional sense (Zlotnik & Vansintjan, 2019). Here, experience is referring to the kind of knowledge you retain after learning a skill or knowing how to do something, like riding a bike or making your favorite dish without a recipe, not events in your life. These things that you become experienced in require consolidation and retrieval of information; you are only able to remember how to make your mom's famous pasta by heart because you have done it so many times - it is encoded in your brain. Even things like immunity and allergic reactions can be considered memory since your body remembers the virus or bacteria that has entered your body and is equipped with the information necessary to expel it from your body (Zlotnik & Vansintjan, 2019). Although it may sound like it, not everything is considered memory. Zlotnik and Vansintjan (2019) make it clear that memory requires a body or vessel - even with technology, the body is the electronic device itself that allows for information to be stored. Memory is the big umbrella term for processes of the mind like learning and conditioning, which allows us to perceive memory as a fluid, interactive, and ever-changing process.

Chapter 1: Short Term Memory

What is Short-Term Memory?

Your biology teacher starts talking about how tropical forests are near the equator and are home to 6% of the planet's land along with 50% of animal life. As you start writing down notes, you start trying to remember all these bits of information even though this is the first time you are hearing about them. Simply put, this is essentially what STM, or short-term memory, is. You store new information temporarily in your short-term memory. But what does that *really* mean?

Researchers Kolb and Wishaw (2009) have defined STM as a cognitive system we use to store sensory information, actions, and other types of information such as numbers, words, and names for a short period of time. The average person can hold up to about 7 pieces of information (plus or minus 2) at a time in their STM stores (Miller, 1956, as cited by Aben et al., 2021). Miller believed that there were a limited number of spaces in your STM in which you could store new information. Interestingly, Jacobs (1887) used a digit span test with every letter and number besides "w" and "7" (since they had two syllables) and found that people have an easier time recalling numbers than letters (McLeod, S.A., 2009). Although Atkinson and Shiffrin (1971) found that information is typically only kept in your STM for 15-30 seconds, you can keep information there longer by repeating it out loud (rehearsal)! This is why many students (including myself) swear by verbal study methods - explaining concepts to other people or even repeating them out loud to yourself! *If you're dying to learn more study methods feel free to skip ahead to the end of the book (but only if you come back here and keep reading about STM).* As you might expect, the longer you wait, the less information you can recall from STM (Peterson and Peterson, 1959, as cited by McLeod, S.A., 2009).

Now, when we talk about STM, there are some other terms we need to consider. Working memory, or WM, is defined as one of the executive functions that lets us work with information without losing track of what we are doing (Rosen, 2021). Think of it kind of like a sticky note. Another term you have probably heard of is long-term memory or LTM. These three terms, along with a couple of other ones, are extremely important in knowing how memory works, and we will revisit them later in the book. For now, we will be focusing on just STM!

Attention comes into play when talking about STM specifically. Attention refers to the way you prioritize information according to what you are doing in the current moment and what that task requires of you (Nobre & Stokes, 2011). For example, if you are making some macaroni and cheese for Thanksgiving dinner with your family, you are focusing all (or most) of your attention on cooking the pasta, mixing in the cheese, and baking the dish in the oven with some breadcrumbs. Or if you are in class, you will likely be focusing your attention on what the teacher is saying and writing down notes. Your attention allows you to ignore distractions and continue the steps of the task at hand.

STM and New Information

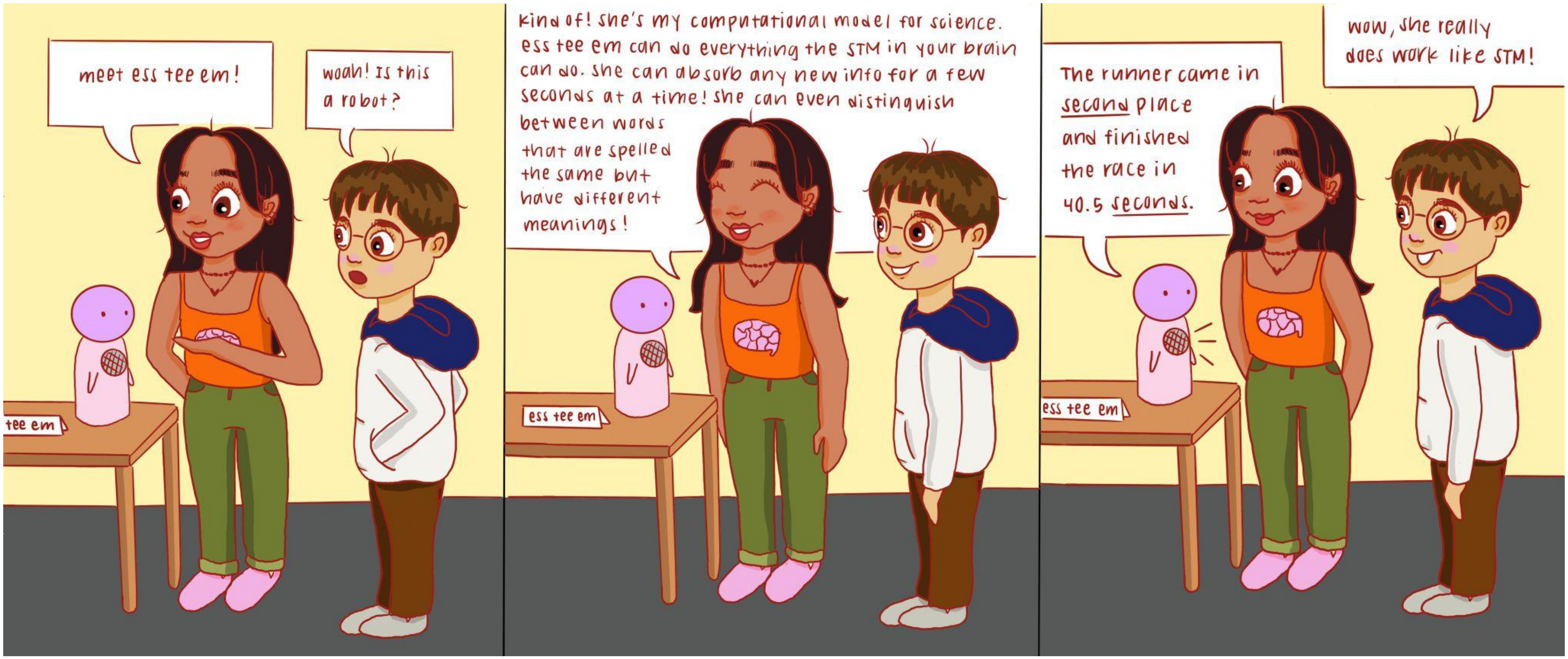
STM, in modern scientific research, is seen as a representation - it is the stimuli in your surroundings that go into your conscious awareness and cause you to act a certain way. In other words, STM is not an exact recreation of what is happening in the world around us - it represents what is happening through words, images, and sounds. Remembering these new bits of stimuli or information is independent of other sensory information you may be taking in; STM does not interfere with information already stored in your brain (Nobre A. C., & Stokes M. G., 2011).

Some experts argue that STM is nothing more than just activated LTM. However, Norris (2017), like many other researchers, argues that STM needs to be able to support memory for newly learned information, storage of multiple similar pieces of information, among other things, and that these things cannot be achieved by just activating your long-term memory. He suggests that LTM cannot allow you to perform tasks like remembering a sequence of numbers by itself - it needs an additional mechanism. Researchers who believe this argue that STM has a buffer or many buffers that hold information in your memory before it goes to LTM.

How are these theories being tested? There have been many studies focusing on patients who suffer from impaired STM - instead of being able to remember about 7 new pieces of information, they can only remember about 2 to 4 (Norris, 2017). Interestingly, these patients still have perfectly unaffected LTM! One main piece of evidence of this is that these individuals have almost no trouble learning new information related to things they may already know. However, they do struggle with learning new words. So a patient with decreased STM capacity may be able to learn about new advances in organic chemistry if they were already a chemist but might struggle with learning a new recipe for banana bread. Because they already knew the principles of chemistry (more than the average person), new advances in the field might make more sense to them, and thus be easier to learn. Memorizing a recipe for banana bread, however, might be something totally different for them if they were not previously familiar with baking or cooking. Not surprisingly, the patients also have issues with learning new sequences of numbers, since you must run this information through STM before it reaches your LTM.

One of the most significant pieces of evidence for the existence of STM comes from the work of Baddeley and colleagues (Baddeley, 1966a, 1966b; Baddeley & Ecob, 1970, as cited by Norris, 2017). They believed that STM holds spoken information for only about a few seconds and that rehearsing/studying this information can allow you to remember it for longer (Baddeley, Lewis, & Vallar, 1984, as cited by Norris 2017). *We will be learning more about studying using the powers of memory towards the end of the book!* The main piece of evidence they came up with for this idea was that confusion in memory in STM usually happens when you are trying to remember phonological information, AKA speech-based memory. On the other hand, in LTM, confusion tends to happen when one tries to remember semantic information - “general” factual knowledge like algebra and the alphabet (Norris, 2017). For example, if your English teacher was telling you to write down a sentence that they were saying out loud, you may have some trouble remembering the exact words they were saying while you try to write them down. Conversely, when trying to remember what you studied during a history test (likely from your LTM), you are more likely to have trouble remembering facts and concepts.

Computational Modeling



Now that we know the basics of STM, let's briefly touch on something a bit more challenging. Much of modern STM research uses something called *computational modeling*. These models use algorithms programmed into specific computer software to provide accurate representations of what our STM is like; we can learn about mistakes we might make when trying to recall information, how we learn sequences, what happens when phonological information (words and speech) is too similar, and more (Norris, 2017). However, as great as these models are, they are likely not perfect and can be debated. The main issue at hand when considering computer models is that they must be able to represent "multiple tokens." What does this mean? Consider the sentence "Buffalo buffalo buffalo Buffalo buffalo." *Yes, this is a sentence.* It has 5 tokens, or variations, of the same word. You can think of tokens as being like the term 'representation' that we covered earlier. Buffalo can refer to bison in North America, can mean "to confuse," or can be the name of a town (Norris, 2017). Although it may be easy to repeat this sentence back to someone (you may just say the word buffalo 5 times), it is very hard to understand the meaning of all 5 tokens. If STM was nothing more than activated LTM, as some researchers argue, you would not be able to recall a sentence with 5 different tokens of the same word; you would only have one representation of "buffalo" that all sounds the same. In contrast, this sentence would be stored in LTM with both the word and its associated meaning. Since most computational STM models can represent multiple tokens, it is safe to assume that they accurately represent real STM.

STM models must also contain structured representations and variable binding. Let's take a step back and consider what these two terms really mean. Once a model is able to represent multiple tokens, it needs to meet a few other prerequisites. It also needs to account for *working memory*, which we briefly discussed at the beginning of this section. Since we store vast amounts of new and often unpredictable information in our working memory, the STM model must be able to account for this. So, in addition to activating pre-existing knowledge or representations in our memory, STM models must be able to store completely new information (Norris, 2017).

Additionally, *variable binding* is representing multiple tokens along with each of their relationships and other parts of the sentence or piece of information (Norris, 2017). For example, in the sentence, “The girl loved how the girl would always read on the bus to school,” it must be recognized that there are different girls - one girl who reads on the bus and one who observes her. Essentially, variable binding involves assigning variables (A,B,C, etc.) to represent different pieces of information.

All in all, the debate regarding STM being its own separate system vs. being the same thing as activated LTM is still ongoing today. However, we do have quite a bit of evidence supporting the idea that STM is separate from activated LTM that stems from accurate computational models. Assuming that STM is just activated LTM would not be completely accurate, since simply activating LTM would not allow you to store completely new information or represent multiple tokens (Norris, 2017). Now that you’re familiar with short-term memory, let’s move on to long-term!

Chapter 2: Working Memory

What is Working Memory?

Your calculus teacher starts talking about a new chapter in your textbook - Integrals. It's a topic you've never learned before, so you start writing down notes from the slides. The information your teacher gives you enters your *working memory.* But, since you just learned about derivatives, you are able to connect that information to the new information that is being taught. In a sense, working memory is like a sticky note in the brain. Rosen (2014) adds that working memory can also help the brain organize new information to be stored in Long-Term Memory. Now, what is the difference between working memory and short-term memory (STM)? This hot question is still being debated by many psychology and neurology researchers, as some believe that they are the same, while others believe they are different. The general consensus is that while they are quite similar, working memory lasts longer than STM and is involved in changing information so it can be stored long-term (Saline, 2022). STM can be thought of as a tool that lets you remember something for a few seconds - it is part of a bigger system (working memory). Working memory is what allows you to *store* information as well as process/change it.

Some individuals with working memory problems may face some issues processing new information. For example, kids who struggle with their working memory may have trouble doing mental math, following instructions, or using feedback from a teacher to edit their essay. All these situations require one to take information from their short-term memory and "package" it into their working memory, in a way that allows them to retrieve the information after a short period of time. If your working memory didn't catch your teacher's exact instructions, you will have a hard time remembering what was asked of you.

Working Memory Decline

Working memory can be negatively affected by many factors, like age, mental illness, or injury. Nissim et al. (2017, as cited by Chai et. al, 2018) explain that older individuals typically perform worse on working memory tasks than younger individuals. They reported that decreases in cortical surface area in the frontal lobe of the brain's right hemisphere are linked with people who perform poorly on these tasks, which means that if your frontal lobe on the right side of your brain is smaller in size, you are likely to perform worse on working memory tasks than the average person.

As mentioned above, mental factors can affect working memory efficiency. Patients with MDD (major depressive disorder) perform poorly on working memory tasks where information manipulation was needed when completing a visual working memory task (Le et al., 2017, as cited by Chai et al., 2018). In other words, patients with MDD could not perform well on working memory tasks where they were required to manipulate new visual information. The visual working memory task in question was a "delayed recognition task" that needed the participants to remember and recognize faces after they were presented to them, while being observed through an fMRI machine.

Injury can also impact one's ability to have a normally-functioning working memory, especially ones affecting the frontal or parietal lobes (Chai et al., 2018). In a recent study, Dunning et al. (2016) found that patients with ranging levels of TBI (traumatic brain injuries) showed poor verbal short-term and verbal and visuospatial working memory when compared to individuals without TBIs. The study also found that the amount of time passed after the injury was a big factor in this decline in working memory, where, typically, the greater the time post-injury, the greater the level of cognitive decline in the individual.

Although there has been a lot of research so far about working memory decline, we still have so much more to learn about - working memory, just like all the other parts of our memory system, is very complex! Since working memory is intertwined with so many other parts of the brain, like STM and LTM, it is not easy to study. Chai et. al (2018) emphasize that working memory is the foundation of other parts of human cognition; this is the first step in understanding other parts of the brain like perception and emotional processing.

Chapter 3: Long Term Memory

What is Long-Term Memory?

Now, what is long-term memory? It is the final stage of the Atkinson-Shiffrin multi-store memory model that allows us to learn skills and remember information for a long period of time (McLeod, S.A., 2010). Essentially, long-term memory is a compilation of memories your brain has stored over a long period of time (Huizen, J., 2021). Information in LTM could remain there anywhere from a few minutes to your entire lifetime! When you study for your biology test, assuming you studied efficiently, you are likely to remember that information for maybe a couple of weeks, months, or even years (depending on how often you utilize that information). You've probably heard the saying "If you don't use it, you lose it." This applies with memory, as information in your LTM that you don't have use for anymore likely doesn't stay there forever. Your brain is always trying to save space for new information, and thus gets rid of things that it thinks you don't need. On the flip side, let's say you learned how to make pastries in culinary school. If you become a pastry chef for the rest of your career, you likely need to remember all the information and skills you learned in school. So, your LTM keeps that information safe. Although your LTM could technically store an unlimited amount of information, doing so wouldn't make information accessible when you need to remember something important (McLeod, S.A., 2010). If you remembered *everything* that you ever learned in your life, it would likely be harder for you to remember how to make pastries or ride a bike.

You likely have picked up on the notion that STM and LTM are very much intertwined, and that one can't work without the other. Researchers Cowan and Chen (2008) added that although the functions of STM and LTM are different, the two are closely related (cited by Norris, 2017). Learning new information that you will remember for a long time such as number sequences and new words requires the power of STM, and your ability to learn new information in the short term is influenced by the information you already know! As we mentioned before, even though your STM mainly deals with phonological information, or relating to words and speech, it is influenced by the semantics (general information and concepts) and other types of information in your LTM (Norris, 2017).

Norris adds that these two memory structures likely share the same features since they perform similar functions. They both have encoding, retention, and recall, and eventually lose information as a result of decay or something else interfering.

Encoding


now, does anyone know what encoding means?
Isn't it how your brain changes sensory information so it can be stored?
WHAT IS E
exactly! encoding transforms events so they can be stored in STM or LTM. almost like how you need to code information through zeroes and ones to a computer!
get psyched about psychology!

Another form of interaction between LTM and STM happens during encoding, where new words you learn visually (like when an elementary school teacher writes vocabulary words on the board for students to learn) have to be changed into a "phonological form" so that your STM can take them in. This *recoding* process must interact with the information stored in your LTM for this to happen. This is part of the Baddeley and Hitch working memory concept, which, if you haven't realized by now, you won't stop hearing about! The process of encoding information into your LTM is physiologically different from STM, because the structure of your neurons changes (long-term potentiation), and new neural networks are created in your brain (The Human Memory, 2020).

When information from your STM becomes consolidated (encoded or processed), it goes to your LTM which is located in a part of your brain called the hippocampus (Huizen, J., 2021). A good way to remember this is the sentence "Hippocampus goes to campus to get some knowledge." At least that's how I remember it! There are two types of LTM: procedural and declarative. Huizen explains that procedural memory is information that is related to skills, like knowing how to ride a bike or making your favorite recipe. Declarative memory, on the other hand, is information related to facts, events, and experiences, like the time your parents bought you a puppy, or what you learned in history class.

Has there ever been a time when you were so sure that an event happened a certain way, but you later found out that it happened a different way? If so, you are definitely not alone. Research on human memory suggests that as information passes from sensory memory to STM to LTM, the amount of detail that you can remember decreases (Brady, T.F. et al., 2008). Think of it kind of like the game telephone - the word or phrase the first person comes up with likely isn't what the last person says. As the piece of information passes through all the people between the first and last person, it becomes so morphed that it is often completely different! Essentially, most people can only remember the gist of an event they experienced. Research has also shown that humans do not usually notice drastic changes in a scene - this is called *change blindness*. For example, while focusing on one aspect of the room, you may not notice if the color of the room changed or if large objects in the background have suddenly disappeared. This suggests that the amount of information about items we remember in the long-term is somewhat low (Brady, T.F. et al., 2008). Interestingly, your memory of an event can also be influenced by what you hear from other people. In cases of eyewitness testimony, details of visual memories individuals remember can be tampered with by other people if they are asked biased questions like "When did you see the perpetrator kill the victim?"

However, many recent studies have suggested that we might remember more details than we previously thought. Researcher Hollingworth has shown that when individuals were required to remember and recall 100 or more objects, they performed quite well, which suggests that we are capable of storing detailed (although not perfectly-detailed) visual information in LTM (Brady, T.F. et al., 2008).

LTM Loss

Long-term memory loss is what comes to mind when we think of memory loss in general. As you probably know, individuals with memory loss tend to forget dates, facts, skills, names, and pieces of information. Your LTM begins to "leak out" information as you age, which is usually a normal part of aging. However, there can be many conditions that cause significant memory loss that impacts your ability to lead a normal life, such as Alzheimer's or Dementia, for example. Some common causes of memory loss include aging, neurodegenerative conditions (slow death of nerve cells in your brain; dementia is one example of this), brain infections (HIV, meningitis, etc.), brain tumors, restrictions of blood flow (blood clots, hemorrhages, strokes), misusing alcohol (consuming large amounts over time), head injuries, some medications, sleep deprivation, and so much more (Scary, right? It seems as though every bad thing can affect memory - some serious causes and some that could happen to virtually anyone.

Let's take sleep deprivation, for example. Most if not all people have faced a lack of sleep at one point. It is known that lack of sleep over time can affect your performance, functioning, mental and physical health, and overall quality of life (Davis, K., 2020). Davis elaborates that sleep deprivation may make it harder for a person to form new memories and affects learning. Good sleep allows your neurons to communicate more efficiently with each other and slow-wave sleep (SWS) plays an important role in consolidating long-term memories (The Human Memory, 2020). This is why experts urge individuals to get more quality Zs in, whether that means changing up their schedule and going to bed earlier, or going to a doctor if they believe they have underlying issues that prevent them from getting sleep. Good quality sleep can impact so many areas of your life positively, including your memory. Maybe this is why everyone tells you to get a good night's rest before a big test or other important events that require you to perform well!

Bonus: Studying with the Magic of Memory!

If you’ve ever found yourself struggling to find study habits that work for you, you are most definitely not alone. Many students struggle with developing good, active study habits that allow them to do well in school. Now, what do I mean by *active* studying? What are these *magic secrets* that get you good test scores and grades? I assure you all your questions will be answered! First, let me tell you about my study habit journey. It is a long journey with many roadblocks!

To be completely honest with you, in elementary and middle school, I did not study very much. In fact, all I knew about studying was that I needed to open my book and skim through a couple times. Nobody taught me how to study, and I figured I didn’t need to, since I was always near the top of my class and everything was easy. But once I entered high school, I was hit by a truck. Not a real truck! A truck of realization that all my friends and some of my peers were ahead of me. Somehow, they got A’s and I was getting B’s. In 9th grade, I had the same study “habits” I had in elementary and middle school. Not surprisingly, this no longer got me the grades and scores I wanted, since my classes were now more challenging. In 10th grade, I took my first AP class - AP World History. This class was no joke - I knew that I had to change something. In order to keep up with the fast pace, loads of homework, and test preparation, I often stayed up past my bedtime and woke up extra early on weekends. I was putting in way more time and effort than I had in my entire academic career. But, I only knew how to study *passively*. Passive studying is reading through your textbook or notes, and skimming through information. This method creates a false sense of familiarity - after skimming through your notes you may think you know all the information. However, when taking the test, you will probably not be able to recall any of it on your own. In 11th and 12th grade I continued to take many AP classes, in which I still used mainly passive study strategies. Occasionally, I tried using active study methods like flashcards and writing/drawing things from memory onto my whiteboard, but I had minimal results since I did not see the point of doing all this. I was working harder, not *smarter*. In other words, I was putting in so much time and effort but did not typically see the grades I wanted since I was not studying in a way that would allow me to actually retain and recall information. I didn’t know about the magic of memory!

As I entered college, I began taking difficult science classes for the first time in my life. In general chemistry, I studied passively. Obviously, my grades and test scores showed this. I realized why these were called *weeder* classes - the class average for chemistry tests was often 30-50%. After trying all year to improve my study habits through trial and error, something finally clicked. In my first college biology class, my professor once told me during his office hours that the reason many students do poorly on exams is because they are scared of making mistakes on practice exams and practice questions. Now what does this mean? Students are scared to even attempt practice questions because they don't want to keep getting things wrong. So, they would rather *passively* study and trick themselves into thinking they know all the material. You might be thinking this sounds crazy, but speaking from experience, this is so true! **This is the biggest mistake that was holding me back from academic success**. The reason I hesitated to do active recall was because I would make more mistakes and feel *dumb*. I realized that getting things wrong on the practice problems was the only way for me to learn the right answers so I can perform well on the *real* exam.

Once I understood this, I got to work. I started doing tons of practice problems on my big whiteboard - anything and everything I could find on youtube (shoutout Ochem Tutor!) and beyond. I dropped my old mindset that was dragging me down for the last few years. Instead of wondering why I had to do so much work, I challenged and pushed myself every day to come out of my comfort zone and do things I didn't want to do. I challenged my self to feel *dumb at first* so I could get a better score on my test. I used this technique as well as many others like teaching the material to a friend, using Quizlet, and making study guides. I used the *magic of memory* to aid my study sessions. I knew that information is more likely to end up in your long-term memory if you space out study sessions and learning. I knew that cramming was not going to work, and so I made it a rule to study at least a week in advance of every exam. **Finally, I saw the results that I wanted.** I ended up with an A in my Chemistry lab class and an A- in my Biology class over the summer, which I was more than happy with. I knew how hard I had worked every single day, and I was so proud of myself. I had done it! I had finally found study methods that worked for me!

As a closing note, I wanted to tell you all that different study methods work for different people. What works for me may not work for you. The process of developing study habits is really a journey of trial and errors. It's a journey that never ends! To this day, I am still learning better study habits and always trying to improve my academic performance. There is always room for improvement!

With that, I thank you all for reading this supplemental guide to memory and coming along on this journey with me. I hope you enjoyed the magic of memory and were able to implement some of these study tips into your own lives!

I wish you all a happy and successful journey on discovering the **magic of your own memory**!

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