

# Learning & Memory

## HOW DO WE REMEMBER AND WHY DO WE OFTEN FORGET?

by Kenneth Wesson, PhD

*The advantage of a bad memory is that one enjoys several times the same good things for the very first time.* —*Friedrich Nietzsche*

MEMORY SITUATION #1: Immediately after your assistant has given you the number of an important client, you hang up, but before you can dial, someone asks you for the time. After announcing the time, you ready your index finger to dial the client's phone number, which has escaped from memory. After asking for the number a second time, you scowl at all oncoming strangers to ward off any mental interlopers prior to dialing.

MEMORY SITUATION #2: After returning from a 15th wedding anniversary cruise with 12 Mediterranean ports of call, you effusively describe your vacation to a neighbor. However, when asked about your exact itinerary, you stare blankly. (If it's any consolation, you could recognize the cities if you heard them.)

MEMORY SITUATION #3: After studying all night for an important college exam, you purchase a jumbo cup of double-caffeinated Kenyan coffee. After getting stuck in traffic, you finally arrive at the campus, find a parking spot and sprint into the exam room with only seconds to spare. With the test now sitting directly in front of you, the first question is unbelievably easy, but suddenly you cannot retrieve the answer. The harder you try, the more elusive it becomes, playing a game of mental hide-and-seek with you.

WHAT STUDENTS ENCODE DEPENDS ON WHAT THEY ARE PAYING ATTENTION TO AT THE TIME.

Are you losing your memory? Are these the first signs of dementia? Chances are, neither.

When our memory is strained, these can be the unsurprising, as well as embarrassing, results. Stress and multitasking are among the chief causes of memory lapses. In the first memory situation, interference prevents recall. In the second situation, a lack of memory maintenance hampers retrieval along with exceeding the "7 items +/- 2" memory rule. Our third case of memory failure most likely reflects the consequences of stress, poor nutrition and exhaustion more than it involves academic difficulty or memory loss. Nearly every aspect of our daily lives are influence in a significant way by memory.

Are memory and recall really so complicated? The bigger question is, "How do we remember and why do we often forget?" Like health, everyone's memory is impacted by an infinite number of variables that can lead to a wide range of outcomes depending upon the circumstances. Familiarity with those conditions and the accompanying terms used to describe them is helpful to parents and teachers. (See sidebar: "Useful Memory Terminology for Parents and Educators.")

In a contemporary world where exchanges of massive amounts of information have become the norm, students are inundated by far more information than learners from just one generation earlier. Dr. James Appleberry, president of the American Association of State Colleges and Universities, predicted that by the year 2020, human knowledge or information will double

CONTINUED ON PAGE 38

every 73 days. For decades, Jupiter was described in science textbooks as a planet with 13 moons. With improved celestial observation technology, the figure for Jupiter was recently revised to 63 moons, giving it the largest retinue of moons with "reasonably secure" orbits of any planet in our solar system. While the facts continue to change, the best techniques for remembering, fortunately, do not.

WHAT IS LEARNING AND MEMORY?

Memories are the internal mental records that we maintain, which give us instant access to our personal past, complete with all of the facts that we know and the skills that we have cultivated. Encoding, storage and retrieval are the three primary stages of the human memory process. (Forgetting may constitute the fourth stage of memory, although forgetting is technically a *setback* in memory retrieval).

During the encoding stage, information is sent to the brain, where it is dissected into its most significant composing elements. An ensemble of brain cells processes incoming stimuli and translates that information into a specialized neural code. In the storage phase of memory formation, the brain must retain encoded data over extended periods of time. Retrieval constitutes the right of entry into the infinite world of stored information, where we bring old information out of permanent memory back into working memory, which can be mentally manipulated for usage.

Theoretically, learning is the capability of modifying information already stored in memory based on new input or experiences. Since memory is contingent upon prior learning, the first step in memory is learning, which occurs when our sensory systems send information to the brain. Our sensory system can hold numerous items simultaneously, but only momentarily. Learning is an active process that involves sensory input to the brain, which occurs automatically, and an ability to extract meaning from sensory input by paying attention to it long enough to reach working (short-term) memory, where consideration for transfer into permanent (long-term) memory takes place.

Sensory information enters consciousness naturally in two subtypes, both of which are somewhat fleeting. Iconic memories of visual information have a duration of 0.3 seconds, while echoic memories of auditory information will last about four to five seconds. The brain shows more partiality to iconic information. (See "Visualization and Memory Lists"). Vision has a much longer history in the human experience than does the printed word. By exploiting this competency, students learn quickly when they can visualize the concept while studying, by directed use of the mind's eye, where mental pictures can be developed.

Writing words in the air on an imaginary blackboard forces students not only to visualize the order of letters in a word, but to maintain visually what they have already written in working memory as they continue to write. From first grade to medical school, this technique is equally effective. When young learners are taught to construct diagrams that show relationships (graphic organizers), their memory of content improves substantially. Robert Marzano found that these "nonlinguistic representations" can increase achievement scores by 27 percentile points.

We constantly perceive vast amounts of information each minute, but we make no attempt to recall very much of it. Equally important, we cannot remember information that we failed to encode for memory storage in the first place.

Once the elements that make up an experience are classified according to their special traits, each part is shunted to a different brain region for further detailed analysis, where a comparative search for recognizable similarities to previously encountered information begins. The various pieces of new information get stored in neural circuits distributed throughout the cerebral cortex. Because the elements making up a memory reside in multiple cortical areas, the stronger the network linking the associated pieces together, the more resistant to it will be to forgetting.

As the brain transacts learning events, physical changes occur both within brain circuitry and in its structure-function correlations. Here the brain parts company with the popular comparisons to a digital video recorder. Memory is quite fluid, and, over time, the brain continues to revisit and reorganize stored information with each subsequent experience in a cyclical fashion, reprogramming its contents through a repetitive updating procedure known as brain plasticity. This is advantageous, since improvements are made repeatedly to existing data. Prior knowledge is revised based on new input, resulting in a more accurate representation of the current world, increasing one's probability of thriving. The flip side of these constant memory revisions is that eyewitness accounts often become less reliable with the passage of time.

With new experiences, we amend, rather than maintain and protect, our past memories—occasionally changing them beyond recognition. The newly stored information has been altered, forming new and modified representations of events and our malleable knowledge, which serve as our guides to the environment.

When first exposed to a new song, we establish new neural connections—of the sounds, the emotional pleasure, where we heard this new song, the lyrics, the title, the artist, similar songs, etc.—to represent this novel sensory experience. However, upon hearing the same song on a second occasion, it is processed as a neurologically different experience, where established connections are re-activated as *recognition*. We now *recall* the song, which did not occur upon first exposure, sing along with now recognizable lyrics (also impossible during the initial exposure) and later reproduce the lyrics in the absence of any song being played. All new learning pathways are built from existing circuits and are accompanied by changes in brain physiology as a result of experience.

Although academic language describes learning as the "acquisition of knowledge," new information instead gets *integrated* into the complex web of existing data, rather than *acquired* and stored in isolation. Thus, integrating the curriculum enhances content retention when subject matter enjoys the benefit of multiple integrated connections.

THE RELATIONSHIP BETWEEN LEARNING AND MEMORY

While memory cannot occur without learning, once information has been learned, our memory may allow the learning to decay. Occasionally, memory will unintentionally play a bit loose with the truth regarding what was previously learned.

Emotions can be a catalyst or an impediment to learning. It has been estimated that 95% of our reactions are unconsciously driven by the amygdala and only modestly impacted by the executive centers of the cerebral cortex. Although ours is generally considered a rational brain, it is an *emotional* brain, where feelings receive first priority. A student who is upset is one who cannot learn and will not remember content information well during assessment.

In school, mere exposure to content information (lecture, text, etc.) is no guarantee that it will reach the personal/emotional threshold of "personal importance" to the learner, where encoding the information for permanent memory storage is deemed warranted. What students encode depends on what they are paying attention to at the time. Although we often wonder why our students forget important lesson content, the bigger problem is, *Was it ever encoded for memory?*

An important distinction has to be made between listening and remembering. Teachers often feel obligated to clarify what indeed is important, at least for testing purposes, because students cannot "essentialize" (a term coined by Dr. Robert Grant), separating the crucial from the tangential.

Several connected brain regions play key roles in memory formation, including the thalamus, amygdala, hippocampus and cerebral cortex. It is the interaction of nearly all parts of the brain that allows for the construction of our memories.

The amygdala and the hippocampus are vital to learning in the classroom:

1. The stronger the emotions connected to an experience, the stronger the subsequent memory.
2. The neural networks most important *emotionally* to a student are bathed with neuronutrients, enhancing memory formation and retention.
3. Learning experiences become more memorable when social-emotional memories are part of the learning event, which is why cooperative learning is such a powerful memory-enhancer in schools.

The hippocampus plays a crucial role in forming and storing our memories of facts and events. Initially, short-term memories are briefly stored in the hippocampus, prior to being transferred to other brain regions where they are consolidated with prior knowledge into long-term memories. While persistent stress can damage hippocampal brain cells, patterns, emotions, relevance, context, content and sense-making boost attention, memory formation and recall. Collectively, they can determine what information reaches permanent memory storage. As Stanford Ericksen summarized the requisite emotional element in learning, "Students learn what they care about and remember what they understand."

When information is determined to have potential long-term value, the hippocampus links the significant elements of that event or experience together, forming a permanent memory. Creating, storing, retrieving and using our spatial memories and episodic memories are characteristic brain capacities made possible by the hippocampus. When we daydream, the hippocampus is strikingly active. Brain-imaging studies have shown heightened activations in

CONTINUED ON PAGE 40



## Useful Memory Terminology for Parents and Educators

**TIP-OF-THE-TONGUE PHENOMENON:** When a person cannot recall the exact memory item but shows a slight degree of recall for one or more of its characteristics ("I think the name begins with the letter…").

**RETRIEVAL CUES:** A clue or prompt that activates the retrieval of a particular piece of stored information from long-term memory. There are two types of retrieval cues: recognition (when a specific cue matches information already in permanent memory); and recall (the active process of searching one's memory in order reproduce information).

**RELEARNING:** The situation where learning material a second time will typically will take less time and effort than initial learning.

**PRIMACY EFFECT:** Remembering information that appeared at the beginning of a lecture, an experience or a list.

**RECENCY EFFECT:** Remembering facts or information at the end of an experience or list. Thus, talent contestants prefer to be the first or last performer on stage.

**PROACTIVE INTERFERENCE:** Old information interferes with recall of new information.
"The President of the United States is Bill _____."
"I love you, _____" (and mistakenly insert a *former* lover's name).

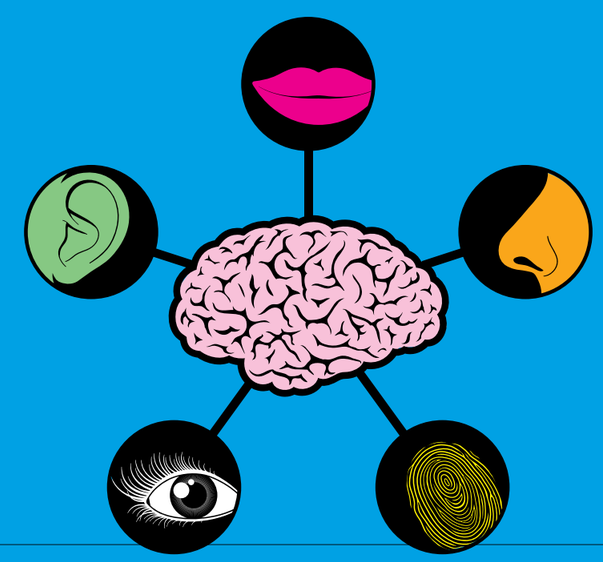
**RETROACTIVE INTERFERENCE:** When new information interferes with the retrieval of stored memory.
"I live at _____ ." (Your former address comes to mind, but not the current one).

**DECAY THEORY:** specific memories and details fade with time.

**MOTIVATED FORGETTING** (repression) involves the deliberate loss of painful memories (protective memory loss).

**RETRIEVAL FAILURES** occur when information known to be stored in long-term memory cannot be brought to consciousness.

WE CONSTANTLY PERCEIVE VAST AMOUNTS OF INFORMATION EACH MINUTE, BUT WE MAKE NO ATTEMPT TO RECALL VERY MUCH OF IT.



the hippocampus not only when we are recalling memories but also when we put the mind on "wander and wonder." This has important implications concerning creativity and innovation, which are based on our ability to manipulate and expand on stored factual information.

Upon hearing a new girlfriend's birthday, that information enters her companion's short-term memory. As the relationship progresses, this short-term memory is converted into permanent memory through the process of consolidation. Emotional memories are among our strongest and easiest to recall—an A on a final exam, our high school and college graduation ceremonies, our senior prom date, etc. As a result, neurodegenerative diseases including Alzheimer's are extremely terrifying, since the disease causes us to forget critical information identifying who we are, who we love and who loves us most—our emotional connections.

When a noteworthy personal date is shared with a loved one—e.g., an anniversary—that random day is tagged in the vast chronological time scale and is emotionally coded, making it a prime candidate for permanent memory storage. Those dates of significance require regular attention, mental rehearsals and reinforcement to maintain our ability to recall them effortlessly. Classical conditioning would suggest that a secondary motivation exists—punishment associated with any tendency to forget those dates—which increases the probability that they will enjoy flawless recollection.

Information that cannot be successfully stored by the hippocampus cannot be remembered or subsequently retrieved. Due to the manner by which elements that compose a memory get distributed throughout the cortex, long-term memories are generally stored safely. Damage to the hippocampus renders the formation of new memories virtually impossible.

Emotional experiences (both positive and negative) enjoy the highest probability of reaching permanent memory storage. It is the amygdala-hippocampus connection that fosters the development of our most memorable moments in life. In the classroom, emotions determine what students pay attention to, which impacts what students will later remember.

MEMORY STRATEGIES

The complex human brain has an extensive repertoire of different types of memory strategies that are deployable for varying lengths of time on special occasions with distinctly different purposes and outcomes driven by multiple memory systems. (See "Types of Memory.")

If new connections are not strengthened by active usage, they soon disintegrate. The more frequently a given network of neurons fires together, the greater is the likelihood that they will hardwire together permanently, increasing the likelihood that they will fire in unison in the future, according to Donald Hebb, the father of cognitive neuroscience. But it can take as many as six exposures before new information enters into permanent memory.

LISTENING IS NOT NECESSARILY LEARNING

Reading does not necessarily lead to learning. Doing, engaging in two-way discourse and thinking will *aid* learning and memory; however, when students are doing, playing with objects, exploring, experimenting, talking, drawing, writing, listening, reading, speaking, applying and reflecting on *all* of these, neural pathways for learning develop inside the brain. The distinguished educator John Dewey said, "We don't learn from experience, we learn by *reflecting* on it."

Important distinctions must be made in memory formation between what one *understands* versus *remembers*; *recognizes* versus *recalls*; *remembers* versus can *reproduce*; *remembers* versus knows how to *apply*.

Although most adults can recall times in school when a greater emphasis was placed on whether we *remembered* the facts than on whether we understood how to use them intelligently, memorizing lists of facts and information is not an adequate approach to 21st-century learning. Rote learning for the Industrial Age differs significantly from dynamic memory, where learners examine *what* they know as they think about the quality of their own thinking and decision-making.

Perhaps the most useless of all academic exercises is memorizing terms from the dictionary. Instead, schools should use the *SCREAMS* approach to build a firm foundation for student vocabulary, by:

- **S**aying/pronouncing key vocabulary words
- **C**oncept mapping or word webs
- **R**eading words in context
- **E**xtracting personal meaning
- **A**ctive learning experiences where students use the new word frequently
- **M**emory formation (sense-making) based on utility
- **S**elf-monitoring for new opportunities to use the newly learned word

Our memories receive varying but focused treatment depending on the nature of the memory. A working memory is deliberately short-term, with limited recall capacity, because its "useful life" is brief by deliberate design. When we dial 411, all information reaching the auditory cortex and the hippocampus must be meticulously recalled with detailed precision. However, its utility is short-lived, with a correspondingly short-lived memory record (less than 30 seconds) established for the phone number. We are obligated to rehearse that number silently or aloud to retain it in working memory long enough to dial it.

Abbreviated memories of this genre typically have a capacity of seven items +/- two items. Thus, we can easily recite the seven days of the week, a seven-digit telephone number, Snow White's seven dwarves and the seven deadly sins. Yet, on average we can remember no more than seven of the biblical Ten Commandments, but seldom all 10. By grouping information into chunks, creating mentally bite-sized smaller groups of the larger units, recall improves impressively. A telephone number of 4082669497 is easier to remember as (408) 266-9497, by combining the random numbers into small groups. It is no surprise that math problems with a two-digit divisor and a three-digit dividend requiring 27 memorized steps are often met with failure and frustration.

Random numbers offer one level of memory challenge, while random information frequently exceeds its numerical cousins in difficulty. When attempting to memorize unrelated terms, mnemonics present the most practical solution. For students attempting to remember the most important neurotransmitters, the term "San Dope" works effectively.

### MNEMONICS: "SAN DOPE"

**S**erotonin 5-Hydroxytryptamine
**A**cetylcholine (ACh)*
**N**orepinephrine (NE)
**D**opamine (DA)
**O**xytocin
**P**henylethanolamine **
**E**pinephrine (adrenaline)

* Neurons that synthesize and release ACh are referred to as cholinergic neurons.

** Phenylethanolamine N-methyltransferase converts norepinephrine to epinephrine.



## Visualization and Memory Lists

Review the following lists for 60 seconds each, then write down as many words as you can recall from each list.

| LIST A | LIST B |
|---|---|
| design | hat |
| credit | sunshine |
| such | boat |
| pleasure | school |
| cannot | daisy |
| within | teacher |
| blank | water |
| quick | stairs |
| task | duck |
| settle | fish |
| into | baseball |
| their | teacher |

Whether you are a teacher, student or parent, there are numerous means by which memory can be enhanced. Hands-on, active learning is concisely captured in the following Chinese proverb:

*I hear and I forget.*
*I read and I remember.*
*I do and I understand.*

For millennia, learning by doing served societies well as the fundamental basis of apprenticeship and mentorship. However, the list of best memory techniques goes well beyond just doing. (See "30 Ways to Improve Your Memory.")

When St. Anthony was pleadingly asked by a blind man, "What could be worse than losing your eyesight?" the Franciscan priest's response was, "Losing sight of your vision." Our vision for learning in our classrooms and homes should be crafted around the evolutionary history of the human brain. When we teach students to maximize their learning through multiple, related, firsthand active experiences, we teach them how to learn for a lifetime, rather than to memorize just for Friday's test.



# A Dictionary for Types of Memory

When someone tells you, "I think I'm losing my memory!" You might want to ask them, "Which memory?" We have several different memory types and pathways back to our memories.

**AUTOBIOGRAPHICAL MEMORIES** are the specific memories about our personal lives that make us the unique individuals who we are.

**CONDITIONAL MEMORIES** represent our knowledge of when and where to deploy a skill to solve a problem or to produce additional knowledge (a "cognitive toolbox").

**CONCEPTUAL MEMORY** is knowing what something is, how it works, *etc.*, which can be knowledge gained by learning (apprenticeship or mentorship) as well as through the analytical process sense-making.

**ECHOIC MEMORIES** are auditory memories (of songs, voices and sounds).

**EXPLICIT (declarative) MEMORIES** are working (short-term) memories which can be further divided into **semantic** (isolated words, facts, symbols, etc.) **memories** and **episodic memories**, which are memories of locations, events, circumstances and space. These particular memory episodes in life would include memorable moments (e.g., a 21st birthday celebration in Las Vegas), where the details of the memory are embedded in the broader experience.

**DECLARATIVE MEMORIES** are memories that can be articulated easily (dates, historical facts, telephone numbers, etc.), including what we can recall in our minds as imagery. They are easily established and the specific information easily forgotten, which leads to frustrations in the classroom.

**FLASHBULB MEMORIES** are recollections of where you were when a historically or personally significant event took place—the explosion of the Challenger Space Shuttle, the assassination of JFK, the tearing down of the Berlin wall, the attack on the World Trade Center or your wedding day.

**ICONIC MEMORIES** are visual memories (pictures). Since human vision preceded writing, visualization is a powerful learning aid.

**IMPLICIT (non-declarative) MEMORIES** include things we can *do* (typewriting, bicycle-riding, playin tennis, etc.) which comprise **procedural memories**—physical skills that require repetitive practice to learn, such as the ability to dance, drive a car, tie one's shoelaces or necktie. It constitutes the body's sensory-motor library of skills. **Motor memory** is the body of learned motoric habits (playing basketball) where "the mind is in the muscle." These are all described as non-declarative because we cannot say or "declare" how they are accomplished. How would you verbally *explain* riding a bicycle or dancing?

**PERMANENT (long-term) MEMORY** can be subdivided into **explicit** and **implicit memories.**

**REFLECTIVE MEMORIES**, or instinctive memories (e.g., knee-jerk response), are stored in the parietal lobes and the cerebellum. These memories can neither be trained for nor learned, since they occur naturally.

**SENSORY MEMORY** is the brief representation of a stimulus while it is being processed in one of the numerous sensory systems, most commonly tastes, smells, touch/textures, sights or sounds.

**SOURCE MEMORY** is knowing when and where a particular fact or aspect of knowledge was originally learned and how you came about knowing it. (When and where did you learn the significance of the date 1776?)

**WORKING (short-term) MEMORY** has a limited capacity of seven items and lasts approximately 30 seconds or less in duration.

### Words that can be visualized are easier to recall.

**Would the following events interfere with your recall?**

What would happen to your recall after:

1. Counting backwards by three beginning with the number 200?
2. Studying information from five other unrelated subjects?
3. Writing a 500-word essay?
4. A break of 10 minutes? One day? One week? One semester?