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Choosing Attention

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The previous installment of this column, "Digital Natives and Digital Immigrants: Teaching and Learning in the Digital Age," was an overview of the cognitive effects of digital technology, in particular, the Internet. Digital technology has altered both the way we access information and the way we cognitively process it.[1] The Internet has not just changed the way we read; it has changed the way we think by literally changing our brains.

These changes are due to a complex process that plays out within a triumvirate of attention, memory, and learning. Like the gifts of the three wise men, each of these abilities possesses singular qualities, while at the same time, they are deeply intertwined. And just as the Magi might never have made it to that stable in Bethlehem had they not banded together and combined their singular attributes, when one part of the learning triumvirate is compromised, the learning journey itself suffers.

As considered through this attention/memory/learning axis, questions concerning the interplay between singing practice and learned habits arise. For example, are there different attentional needs for purely mental versus motor tasks—or does music require attention to both? What happens cognitively between practice sessions? And in light of the aptly-named "Screen Invasion,"[2] is the practice room still the scene of focused attention? Or is it now one more space that is vulnerable to shattering by the ubiquitous reach of a Smartphone? In order to consider these questions, a closer look at each of the members of the triumvirate of attention, memory, and learning is in order.

THE SEARCH FOR MEMORY

> The ability to learn starts with the ability to remember. An organism can learn from experience only if it can rewire its nervous system in a lasting way; there can be no learning without memory.[3]

This beautifully simple explanation by research psychologist Gary Marcus belies the complex neurochemical process of learning, itself encoded in the memorable maxim known as Hebb's rule: "*neurons* (nerve cells) that fire together, wire together." Simply explained, any task or sensation, whether mental or muscular, creates a response in the spaces (synapses) between neurons. If the task is repeated often enough, the repetitions eventually create synaptic links in a "neuronal pathway." Repeated firing of the same neurons in the same pathway is what creates a memory, or "neural trace;" and memory is so fundamental to learning that, in a sense, memory and learning are one.

The neurobiological process that allows humans to progress from the transitive phase of "learning" to "have learned," as a *fait accompli*, is still not entirely understood, nor is the question of how the brain creates memories. These questions have occupied scientists for well over the past four decades, but breakthroughs have occurred, notably in the work of the eminent neuroscientist Eric Kandel, who was awarded a Nobel Prize in 2000 for his work on the biological basis of memory. Like most significant scientific discoveries, Kandel's was a team effort built upon important preexisting ones.

It has long been known, for example, that learning itself is highly dependent upon memory, and that there are at least two distinct types of each: *short-term memory* and *long-term memory.* Within long-term memory, yet two more distinct types of learning exist: *declarative* (also called *explicit*) and *procedural* (also called *implicit*).

The latter type, *procedural learning*, is associated largely with physical skills and habits, much of which occurs outside our awareness. Procedural learning belongs to the realm of motor learning, where musicians, dancers, athletes, and others who depend upon a high level of motor skill practice their art. In this realm, once certain aspects of technique are learned, their recall does not depend upon conscious application; we judge growth in the motor learning realm by the automaticity with which we can retrieve technique. In other words, by the time our star soprano is giving her senior recital, we expect that she will not be issuing herself physical commands such as, "Remember to breathe down-and-out!" Indeed, it is believed that the psychological phenomenon known as "choking" (a technical mistake made by a well trained performer, in front of an audience) occurs when a performer in the physical realm, like a professional golfer, consciously tries to retrieve technical information instead of swinging on "automatic pilot." The catch is, the technique has to be so well learned as to have been transferred, or "consolidated," from short-term into long-term memory. This underscores that choking is not the province of beginners, but "the special hell of choking—messing up in front on an audience—is reserved for accomplished performers who have pursued (and paid for) hours and hours of training."[4]

The former type of long-term memory listed above, *declarative learning,* may be easily thought of as the kind of learning for which we attend school (also called *explicit learning*). Within *declarative/explicit learning* is yet another bifurcation, the division between *semantic memory,* or stored information about words, and *episodic memory,* which stores specific personal experiences that can be pinpointed in time, such as one's wedding day or, less joyfully, where we were on 9/11.

The mixture of terminology about learning is confusing, due to several factors. Historically, memory studies now span well over a century, so that numerous researchers have played successive parts in the expansion of the field. Often, with each new theory came a new lexicon; rather than supplanting the previous vocabulary, new terms were simply grafted onto older ones. And such research (and its resulting vocabulary) reflected not only its investigators' interests and biases, but also the era in which it was conducted. This is generally true of any scientific study, which will tend to reflect the ethos of its field until an idea so far out of the mainstream resonates with the *Zeitgeist* as to engender what science historian Thomas Kuhn dubbed a "paradigm shift."[5]

At psychology's inception as a field in the latter part of the nineteenth century, the focus was on consciousness *per se*. This was gradually supplanted by behaviorist psychology that held sway through much of the first half of the twentieth century until the cognitive revolution, sparked in the 1950s, had all but supplanted behaviorism by the 1970s. At that time, cognitive psychology began to merge with neuroscience. This marriage was consummated in 1980s with the advent of brain imaging techniques like positron-emission tomography (PET) and functional magnetic resonance imaging (fMRI), and together begat cognitive neuroscience, the new science of the mind.

The lexicon for attention, learning, and memory reflects each of these historical junctures in the field of psychology—but the field itself is hardly settled. It is not a stretch to say that new discoveries in the science of the mind are being made practically daily. And as our understanding of the biological bases of attention, learning, and memory continues to expand, so too will the terminology. To aid understanding of these concepts as they exist at present, please see Tables 1 and 2.

Kandel's breakthrough was the discovery that short-term memory is not a diminutive version of long-term memory, as previously thought; rather, short-term memory is altogether biologically distinct from long-term memory. Short-term memories cause biochemical changes

TABLE 1. **Short-Term Memory: 2 Types.**

Short-Term Memory	Working Memory
Refers to **storage** of information.	Refers to the **structures and processes** used for temporarily storing and manipulating information.
Immediate impressions. NO manipulation or organization of material held in memory.	YES: Storing, manipulating, and organizing information.
Two short-term storage mechanisms: 1) the phonological loop (how language sounds); 2) visuospatial "sketchpad."	Plays role in transfer of information to long-term memory.
Also called *primary* or *active memory.*	Also called *working attention*.
Duration: 20–30 seconds.	"One of the major building blocks of IQ" (Beilock).
Capacity: Plus or minus seven items; or 4 "chunks."	Involves the ability to hold information in mind (and protect that information from disappearing) while doing something else at the same time (Beilock).

TABLE 2. **Long-Term Memory: 2 Types.**

Declarative Memory	Procedural Memory (Physical Skills)
Also called *explicit memory.*	Also called *implicit memory.*
Also called *long term*—or *complex memory.*	Also called *nondeclarative memory.*
Also known as *propositional knowledge;* "know that" (Gardner).	Also known as *tacit knowledge;* "know-how" (Gardner).
Requires *selective attention* for both *encoding* and *recall* (Kandel).	Largely unconscious (Beilock).
Two types: 1. *Semantic* (words); 2. *Episodic* (events).	Associated with *motor skill memory, or* physical "habits."

in the brain, indeed—but long-term memories cause anatomic ones, by literally increasing the number of synaptic connections in the brain. So unless our short-term impressions are fixed, or "consolidated," once they wash through our neurons, these impressions aren't remembered. Conversely, if short-term impressions become long-term ones, either through voluntary effort ("I must memorize that in German, *ie* is pronounced /i/ not an /aI/"), or involuntarily, through an attachment to strong emotion ("I will never forget my shame and embarrassment when I mispronounced "liebe" for a German audience!"), our brain structure changes, harboring the memory deep in our brain tissue. Learning and memory unite.

THE ROCK STAR OF NEUROSCIENCE

Kandel's revelations throughout the last decades of the twentieth century occurred practically simultaneously with the work of other neuroscientists who were making exciting discoveries of their own involving *neurogenesis* (the birth of brain cells) and *neural plasticity* (physiological changes in the brain due to experience). Only a little over a decade ago, it was believed that brain cells could not change; that, in essence, "We emerge from the womb with the only brain we will ever have."[6] But thanks to several intrepid neuroscientists who, despite ridicule and suppression by the gatekeepers of their profession, plowed ahead with their research, neurogenesis and neuroplasticity are now accepted wisdom. These two doctrines have conjoined with the biological bases of memory, resulting in what Kandel himself dubbed a connected "family of processes"[7] Kandel's position as a leading pioneer in the new science of the mind recently earned him the nickname "the rock star of neuroscience."[8] Such a moniker certainly reflects Kandel's well earned position of eminence, but it also says something about the wider culture of this new science. Like the many fields it encompasses, the new science of mind can be seen from multiple perspectives: the foil to behaviorism, the new horizon in psychology—or what columnist and pundit David Brooks has taken to grandly calling "the new humanism."[9]

As for musicians who have never heard of Dr. Kandel, they may be amused to learn that Kandel himself had never heard of a certain *bona fide* rock star until he found himself sitting next to her on a television talk show discussing the subject of "consciousness." Apparently, his explanation was so inspiring that it earned the eighty-one year-old neuroscientist "a big hug and a kiss" from the legendary Tina Turner.[10]

PAYING ATTENTION

The neural substrate of learning, that is, forming ("firing") and keeping ("wiring") new connections between brain cells, depends upon the act of attention as new input is being received by the learner. Learning cannot happen until a person first "attends"—and in the neuroscience of attention, to "attend" means more than just showing up. Within the triumvirate of attention/learning/memory, the attribute of attention must get priority, for attention is the prerequisite condition upon which the dynamic dance between memory and learning depends.

But perhaps even more critical for musicians is attention's product: recall. The evidence that a thing is truly learned is shown by its repeatability, which is a feat of memory, whether of the intellect (like a math formula) or the body (like a dance step). And recall, whether a fact or an action, absolutely cannot happen without attention that attended information input at the front end of the learning process.

Recent research into the neural substrates of attention has spawned several new theories. Fundamentally, it is now widely accepted that attention is not centered in one specific brain location (the "modular model"), but rather, attention is distributed throughout a connected neural network in the brain.[11] This "network connectivity" theory is part of a larger (and increasingly accepted) working hypothesis within cognitive neuroscience which holds that complex cognitive processes cannot be explained by the modular model alone.

> Although the modular model may accurately describe many cognitive functions, it is insufficient to explain complex cognitive processes that cannot be localized to isolated brain regions. It is unlikely that our ability to get the gist of a conversation, for instance, is the work of a single specialized brain module. Such complex behavior more likely arises from interactions between brain regions through network connectivity.[12]

Utilizing the "network connectivity" theory, researchers have broken down the component parts of attention. So far, three distinct yet interconnected attention networks have emerged.

The "alerting network" is like a first response team; it sounds the alarm and warns the brain to pay attention to sensory stimuli. For example, the attention paid to a startlingly loud noise is automatic, borne from the so-called "bottom-up response" of our autonomic nervous system.

An entrained "orienting network" enables the brain to spring into action, largely outside our conscious awareness. In other words, we do not need to stop and consider that loud noises may spell danger; most of us will have leaped out of the way long seconds ahead of the third network's reaction, the "top-down" brain processing known as "executive attention," which comes on line to explain that the source of the loud noise is simply a car backfiring.

"Executive attention" is mostly located in the brain's prefrontal cortex, and acts as a kind of control tower that allows some incoming stimuli to be heeded, while suppressing others. The executive attention system governs conscious control of attention (called "selective attention"), which is what allows us to filter out the most important bits from the wealth of stimuli that assaults our senses minute to minute while simply existing. Executive attention is also what guides the socially lauded virtue of self-control. Perhaps not surprisingly, research on what goes awry in the brains of people diagnosed with Attention Deficit/Hyperactivity Disorder (ADHD) has focused on the executive attention system. To continue the control tower metaphor, the leading theory holds that ADHD brains possess a control tower in which almost everything is allowed to land, while little is deflected. Thus is ADHD a misnamed malady. Its hallmark is hardly a *deficit* of attention, but its opposite: an attentional overload. And this sensory overload, it is thought, creates another hallmark of ADHD, namely, impulsivity, or a failure of "response inhibition,"[13] that is, failure to read social cues and alter one's behavior accordingly.

Intricately linked to these twin hallmarks of attentional overload and impulsivity is the neurotransmitter dopamine. Dopamine is widely understood as the chemical link in the response and reward circuit fundamental to human behavior—we seek to repeat acts that bring us pleasure, like eating and sex—and so it is often caricatured in the popular media as the "feel-good" hormone. Additionally, dopamine is being heavily scrutinized for its role as a link in the chain of addictive behaviors. However, recent research into the role that dopamine plays in the attention/memory/learning triumvirate indicates that its roles are not limited to the pleasure-reward cycle. It seems that dopamine generally helps govern motivation, and thus mediates attention. It appears that ADHD people possess lower than normal levels of two key proteins involved in the transport and reception of dopamine.[14] Indeed, the currently preferred pharmacological treatments for ADHD (such as the amphetamine-derivatives Ritalin and Adderall) work by increasing dopamine levels in the brain. At present, it is unclear exactly how this occurs, though it is theorized that the effect comes from the medications' ability to block transporters that remove dopamine from the synapse once it has been released, allowing it to remain there longer and thus boost attention.

Further research into the nature of ADHD involves testing the hypotheses that ADHD afflicted people have a deficit in their short-term memory's ability to hold onto information at this initial stage of the learning process, and that the timing of their information processing is awry.[15] Yet another theory considers that the normal brain periods of activity and rest may be out of sync in people with ADHD, whereby their brains are in the "rest" phase when they ought to be attending.[16]

While these working theories hold promise for the management of ADHD, what is clear at present is this:

> Our present state of knowledge is that there is no one core psychological deficit that we've been able to identify as yet that is at the heart of ADHD . . . As with other psychological disorders, there is no brain, blood, or psychological test that definitively identifies ADHD. We just don't know what the core deficit is.[17]

ATTENTIONAL AIDS: EMOTION AND DESIRE

We may well wonder what works to boost attention, both in the ADHD and the non-ADHD brain. Thus far in brain science, only a few simple answers emerge. For starters, "emotion—some." That is, strong emotion can help encode memory. At its most benign and transcendent, happy episodes, like the joy at the birth of a child, can become fixed (consolidated) in our memory. It is perhaps for this reason that technical breakthroughs in a voice lesson, or superlative achievements reached in performance, are deeply remembered (the assumption here being that such milestones are attended with positive emotion). It also explains why the attributes of motivation and desire are such important components for learning. Unless a person cares enough to expend some effort, he will not learn because he will not have "attended." When I have noted a certain complacency in a lesson (for example, among high school students who are taking lessons because of their parents' wishes), I will jokingly charge them with being "AWOL—absent without leave." Seen through the biological basis of the attention/learning/memory triumvirate, this description is quite accurate.

On the other end of the emotion spectrum, frightening events can become so encoded in memory that certain stimuli, especially smells and sounds, can activate the "alerting network" of the autonomic nervous system. This network is triggered far ahead of our rational thought processes, which, while rational (and highly dependent upon declarative learning) is also slow and cumbersome. Harmless sounds like fireworks can recall a returning war veteran's memories of enemy fire with devastating consequences for mental health, as seen in Post Traumatic Stress Disorder (PTSD). Even the scent of a certain aftershave or a personal ringtone on a cell phone, if they are entangled and encoded in the memory of an emotionally brutal coaching or a particularly humiliating audition, can engender symptoms of PTSD.

Indeed, Kandel's own research path that led him to study memory was a deeply personal and traumatic one. As a boy living in Nazi-occupied Vienna, his family was evicted, his father arrested without charge, and his home ransacked during the infamous *Kristallnacht,* the "night of the broken glass," in which Jewish homes, shops, and synagogues were ransacked throughout Germany and

Austria. The memories of that night in 1938 still haunt him today, and the exhortation to "never forget" is what led him to "investigate the biological basis of that motto: the processes in the brain that enable us to remember."[18]

Two further parameters critical to the attention/memory/learning journey are sleep and restorative exercise.

O, Sleep

A host of recent research over the past decade has revealed the critical role that sleep plays in learning and memory, particularly procedural learning. More recent research has also shown the importance of sleep in declarative learning, further strengthening the two most prevalent theories regarding the brain processes that occur during sleep.

One theory concerns "synaptic pruning," the processes by which synapses that are weak wither away with no neuronal trace, leaving only the strongest synaptic connections behind. It is believed that sleep is the state most conducive to this process, because the brain is least subject to interference from incoming (daytime) stimuli.

A second theory is that the purpose of sleeping, in particular dreaming, is to replay the short-term memories gathered throughout the previous day and in so doing, strengthen the neural pathway of those memories and send them along their journey to consolidation and eventually, long-term memory.

> [B]oth theories are supported by the data . . . Both processes can take place simultaneously . . . one relieving the brain from the pressure of too much connectivity and the other maintaining and enhancing long-term memories.[19]

ART Walks

The benefits of exercise for the human body are both legion and well known. In neuroscience, new research is showing that even modest exercise holds specific brain benefits by increasing the volume of the *hippocampus*, a part of the brain that is central in the learning/memory cycle. The hippocampus is currently the subject of intense research, its importance evidenced by the appearance in 1991 of its own, separate journal. Its sudden stardom is due to a number of factors.

First, the hippocampus is critical to the creation of new memories; *à propos* Kandel's discoveries, the hippocampus is the place in which the chemical bath of short-term memory occurs. And new memories are the primary step in memory consolidation, the process by which immediate impressions can turn into long-term, hard-wired (and thus, learned) facts or skills. A second reason that the hippocampus is receiving so much attention (and grant support) is because it is the first area attacked in the onset of Alzheimer's disease. Damage to this site of short-term memory explains why people suffering in the early stages of dementia lose car keys and grocery lists, but not their most profound memories (both blissful and traumatic), nor skills belonging to the designation *procedural memory*, like riding a bicycle.

Therefore, the news that walking can benefit the brain by increasing the volume of the hippocampus, especially among people fifty-five and older, was greeted with much enthusiasm by the medical community. The best part of this news, according to the researchers, was the finding that some improvements were actually slightly higher among walkers than among a control group who did a variety of less aerobic exercise (including yoga and resistance training), proving that gym memberships and fancy equipment are not needed—just time and a good pair of walking shoes.[20]

But exactly where that walking takes place has also been revealed as an important parameter in the brain/exercise connection. According to proponents of "Attention Restoration Theory" (ART), attention is best refreshed by walking in nature.[21] While the bucolic aspects of nature (puffy cloud formations, birdsong, a beautiful sunset) will spark our attention involuntarily, it takes no conscious cognitive horsepower to process these impressions. Conversely, walking in a noisy urban environment, for example, creates a smorgasbord of stimuli competing for our attention. The result is a walk that could be anything from mentally exhausting to exhilarating—but it is probably not restorative to the attention/learning/memory circuit. And new research into the neuroscience of a talent specific to the brains of humans, that of insight, has shown that nature walks, sleep, and even warm showers—anything that induces relaxation—also engender creativity.[22] Hence familiar admonitions to "go for a walk" or "sleep on it" when wrestling with difficult decisions or searching for inspiration take on new authority. According to Michael Merzenich, a pioneer in the field of neural plasticity,

> In our future is brain aerobics. Get ready for it. It's going to be a part of every life, not too far in the future. Just like physical

exercise is a part of every well-organized life in the contemporary period.[23]

In the new age of the science of the mind, try taking your attention out for an evening stroll and then turning in for a good night's memory consolidation. You just might wake up with a whole new mind.

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2011 NATS Member Survey Factoid

Students regularly participate in

• Local Chapter NATS Auditions	52.4%
• Regional NATS Auditions	26.3%
• High School All-State Auditions	30.4%
• Metropolitan Opera Auditions	11.5%
• Classical Singer Auditions	15.6%
• Local Voice Competitions	44.0%
• Regional Voice Competitions	22.5%
• National Voice Competitions	12.0%