Memory, Hither Come

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Memory is a complicated thing, a relative to truth, but not its twin.
—BARBARA KINGSOVER, from Animal Dreams

Learning itself is not a monolithic enterprise, but a complex process that plays out within a triumvirate of attention, memory, and learning. Each of these three components possesses singular qualities, yet they are so deeply intertwined that when any one part of the learning triumvirate is compromised, the learning journey itself suffers.

In a previous column, I considered each of the members of this triumvirate, with a particular focus on attention itself as the prerequisite condition upon which the dynamic dance between memory and learning depends. The neural substrate of learning (how brain cells permanently form connections) depends upon the act of attention as new input is being received by the learner. Stated plainly, learning cannot happen until a person first “attends”; in cognitive terms, contrary to what Woody Allen famously said, success in the learning domain involves much more than just “showing up.” Recent studies, for example, revealed that a specific part of the brain (the parahippocampal cortex, or PHC) activates into a kind of “pre-attentional” state of mind, making test subjects more receptive to learning new things. Future studies on what researchers called “states of receptivity for learning, or preparedness for learning” will aim for ways to predict and encourage PHC activity.

The most critical issue for music performance 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 (e.g., how to read moveable clef) or of the body (e.g., how to maintain a lowered larynx). Either way, “recall,” whether a learned fact or a motor action, cannot happen without attention (and, perhaps, PHC activity), having husbanded the information input at the front end of the learning process. Hence the title of my previous column, “Choosing Attention,” alluded to both the necessity of attention and the relative freedom of the learner to opt for varying degrees of responsibility while attending.

Given that human attention is more beset than ever before by such twenty-first century phenomena as constant ambient noise levels in the environment, a 24/7 news cycle, and the general information overload made possible by digital technology, this freedom is at once more challenged than ever before, and more crucial. These issues were the subjects of two previous columns in
which I considered the effects of the aptly named “Screen Invasion” on attention and learning. This installment of “Mindful Voice” is focused on the second player in the attention/memory/learning triumvirate and what teachers and learners can do to aid this central component of the learning process. Since much of the background material for understanding memory was laid out in “Choosing Attention,” readers are urged to consult that article while reading this one.

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. This elegant explanation by research psychologist Gary Marcus belies the complex neurobiological process of learning, itself encoded in the maxim known as Hebb’s rule: “neurons (nerve cells) that fire together, wire together.” Simply explained, a new memory begins when the synapses (the gap between neurons) are excited by a thought or sensation. When this nascent memory is recalled, the same neural pathways are reactivated. Repeated firing of the same neurons is what creates a neural trace or neural pathway—a memory. And memory is so fundamental to learning that for anyone but the most rigorous cognitive expert, the term “memory” may be considered synonymous with the term “learned.”

Memory itself has lately enjoyed a starring role in current brain research, in large part due to the outright alarm over projections that by the mid-century mark, the number of Alzheimer’s disease patients in America could reach 16 million, costing an estimated $1 trillion in medical and nursing home expenditures alone. On January 4, 2011, President Obama signed into law the National Alzheimer’s Project Act, which required the Department of Health and Human Services to draft a national plan with the ultimate goal of overcoming Alzheimer’s disease. Later that year, the Obama Administration announced a $156 million dollar investment, and in May 2012, the national plan was officially launched.

The current study of memory is following a well worn pattern in scientific research by researching what goes awry in the damaged brain of AD sufferers. The study of “systems breakdowns” is essentially a reductionist viewpoint, where the brain is broken down into its component parts. According to this viewpoint, disease and loss in one part of a system can reveal how its parts must have interacted with the intact, healthy ones. Further insight is offered, it is believed, by studying how the remaining healthy components of the system compensate for the devastated ones.

Not all science conducts its research through a reductionist lens. Emergence theory holds that complex systems are more than the sum of their parts, and no one could dispute that the human mind is a paragon of complexity. Nevertheless, the birth of brain science owes its very origin to the systems breakdown of one Phineas Gage, a railroad worker whose accident with a tamping iron and some gunpowder in 1848 left him with a shattered left frontal brain lobe. Gage’s subsequent bizarre behavior ignited early theories on brain localization, and the connection between brain function and personality, ultimately giving rise to brain science.

TYPES OF MEMORY: SHORT-TERM AND LONG-TERM

The field of memory research began in earnest over fifty years ago at the start of the Cognitive Revolution. Most scholars agree that if this revolution can be said to have an official birthday, it surely was a symposium on information theory that occurred at the Massachusetts Institute of Technology in 1956. This “start of the modern scientific study of the mind” included the presentation of a landmark paper by psychologist George Miller. Miller’s talk, “The Magical Number Seven, Plus or Minus Two,” demonstrated the capacity of human working memory, and has come to be called “Miller’s Law.” The modern study of the mind grew rapidly; unfortunately, the new field’s lexicon surged out ahead of it.

In response to an array of evidence of various types that imply differing processes and types of memories, researchers have proposed a bewildering assortment of overlapping and non-overlapping distinctions: short-term versus long-term memory, semantic versus episodic knowledge, declarative versus procedural knowledge, stimulus-driven versus conceptually-driven knowledge, explicit versus implicit memories, controlled versus automatic processing, and memory as a tool, versus memory as an object, to name a few.
TABLE I. Short-Term Memory: 2 Types.

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

TABLE 2. Long-Term Memory: 2 Types.

<table>
<thead>
<tr>
<th>Declarative memory</th>
<th>Procedural memory (Physical Skills)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Also called explicit memory.</td>
<td>Also called implicit memory.</td>
</tr>
<tr>
<td>Also called long-term or complex memory</td>
<td>Also called nondeclarative memory.</td>
</tr>
<tr>
<td>Also known as Propositional Knowledge; “know that” (Gardner).</td>
<td>Also known as Tacit Knowledge; “know-how” (Gardner).</td>
</tr>
<tr>
<td>Requires selective attention for both encoding and recall (Kandel).</td>
<td>Largely unconscious (Beilock).</td>
</tr>
<tr>
<td>Two types: 1. Semantic (words); 2. Episodic (events).</td>
<td>Associated with motor skill memory, or physical “habits.”</td>
</tr>
<tr>
<td>Capacity: Plus or minus seven items; or 4 “chunks.”</td>
<td>Involves the ability to hold information in mind (and protect that information from disappearing) while doing something else at the same time (Beilock).</td>
</tr>
</tbody>
</table>

We shall leave “the current terminological turmoil” to the experts. For our purposes, we will consider two basic types, short-term memory and long-term memory (Tables 1 and 2).

Neuroscientist Eric Kandel was awarded a Nobel Prize in 2000 for his groundbreaking discovery that short-term memory is not a diminutive version of long-term memory, as was previously believed, but is altogether biologically distinct. Short-term memories cause biochemical changes in the brain, indeed, by the release of neurotransmitters; but long-term memories cause anatomic changes in brain tissue, by increasing the number of synaptic connections.8

Short-term memory has been compared to a scratch-pad, where impressions are jotted, but only momentarily. Unless short-term impressions are ushered into the antechamber of our working memory system, then finally cemented deep into long-term memory, once they wash through our neurons, they are just fleeting impressions, not the stuff of memory. The action of transferring short-term memories to long-term ones forms the core of the dynamic act of “learning.” The ultimate transformation of “learning” to “have learned,” as a fait accompli, is called “memory consolidation.”

THE ARTE DELLA MEMORIA

Once a notion makes the dynamic journey from a short-term impression to a fixed memory within brain tissue, it would seem that the story should end. After all, the postscript hardly seems interesting, being just a monoto-
nous cycle of memory’s retrieval, its use, and its return to the memory shelf. Indeed, from ancient times right through the mid-twentieth century, human memory was compared to a filing system comprised of millions of folders in which memories were stowed and organized. One had only to consult “V” for voice, or “B” for breathing, it was thought, to access all the accumulated information stored therein. And if memory operated like a filing system, unless an accident destroyed the file, or sloppy filing lost its contents, those memories should remain neatly stowed and intact, just like papers in a folder. This analogy surely has its roots in the ancient tradition of *ars memorativa* (the art of memory), a procedure practiced out of necessity (due to the scarcity of writing materials in the ancient world) for preserving and passing on knowledge. Specific mnemonic techniques were practiced at least through the end of the Renaissance. The most common one involved the use of an imagined place, such as a house with rooms, in which the thinker “placed” his thoughts for later retrieval by mentally “walking” back into the space.

The *arte della memoria* was practiced in fifteenth century Florence by improvisatory singers and poets, who memorized long epic poems for public performance, even though methods of transcriptions existed. One of the most famous of the canterini, the blind Niccolò Cieco d’Arezzo, was in demand throughout Italy by priors, popes, and emperors.

All descriptions of Niccolò indicate that he was revered both for his skill and his character; like many canterini, his activities veered towards those of lay preacher, lecturing their urban audiences on matters of morality, religion, and civic virtue . . . The Neapolitan humanist Giovanni Pontano (1429–1503) later recorded his impression of Niccolo as a public singer in a passage from his *De fortitudo domestica* (Naples, 1490):

Good lord! What audiences have flocked to hear Niccolò Cieco; on feast days, he sang from the bench about numerous Etruscans, and sacred stories, and the histories of ancient things! Here there were learned men, here a great many Florentines, all running to hear him perform.

The strength of one’s memory has, for millennia, been linked with intellectual capacity, the arts of persuasion and storytelling, work ethic, and even morality itself, as revealed by such signifiers as “she has an encyclopedic memory,” or “her mind is like a steel trap,” and “he is as good as his word.”

Current neuroscientific understanding of memory is that it is not centered in one specific brain location (the “modular model”); rather, it is distributed throughout the brain via a connected neural network. This “network connectivity” theory is part of a larger, working hypothesis within cognitive neuroscience which holds that complex human behavior, like the attention/memory/learning triumvirate, arises from interactions between brain regions.

While understanding memory *per se* holds clinical implications for diseases like AD, nondisease related memory deficits (once thought to be the sole province of frauds and dunces) are receiving scrutiny in a less morally charged atmosphere through the objective lens of science. Theories such as “Adaptive Memory Theory” and “False Memory” have exposed human memory as highly labile, and thus surprisingly fallible, due to memory’s complex nature.

**ADAPTIVE MEMORY THEORY**

The act of creating new memories (in effect, learning) involves a process of first absorbing new information gathered by our scratch-pad/short-term memory, then combining this new information with long-term memories we already own. Unless we add *effort* into the mix (an essential component of learning to which we will return), chunks of the newly introduced experience that do not resonate with what we already possess then fade away. What remains is our own personally tailored version of events.

One memory researcher posits that the memories we create are those we hold most dear, precisely because we created them; our fabricated memories are more precious than facts. This explains one reason for the difficulty that politicians or community activists may experience when attempting to convince a skeptical audience of holes in their opponent’s budget plan, or the toxic effects of “fracking” (hydraulic fracturing) on the quality of the groundwater, even when presented with overwhelming evidence as proof. The problem isn’t that the audience members’ minds are “made up,” its that their memories are. Without effort, when new information attempts to infiltrate hardened beliefs, it simply bounces off, like a dull dart point against its target. Learning halts.
I posit that this cognitive firewall is doubly true in the realm of motor (muscle) learning. A singer with any amount of voice training possesses an accumulated fund of experiences (memories) on which to base her current vocal technique. When such a singer goes off to college and leaves behind her high school voice instructor, she may have difficulty making progress due to a strong tendency toward “adaptive memory processing”—defined as “using past experiences in service of the present.” In an attempt to blend novel verbal and motor information from the new teacher with previously learned motor skills and ideas, she may prune away a large chunk of new information (particularly if it was too demanding), and be left with only a slightly rearranged version of what she already practices. Worse, she may believe this version to be her brand-new college-level technique.

However, if her preattentional state of mind was primed for the input of new information, and she adds effort to the mix, her memory creation (learning) could turn out quite differently. This is a case in which what science writer Jonah Lehrer calls “metacognition”—knowing about knowing—would be extremely valuable, both for the teacher and the learner.

**FALSE MEMORY**

Clearly, there is much to be lost in learning when we throw new information overboard in favor of our current mindset. And excessive false memory has a more sinister aspect when it spawns its pathologic progeny, deliberate lying. Research that aims to develop new lie detection technology has heated up in the post-9/11 years, with obvious implications for national security. Such technology also carries forebodings for assaults on such sacred concepts as human rights and fundamental notions of privacy.

It should be noted, however, that not all false memories are bad. Evolutionary psychologists point out that while an accurate memory was critical to human survival (remembering where the oasis is, or the direction a herd of animals migrates), the ability to construe memory was equally useful.

The animal that goes to a favorite food-foraging location and sees signs that a predator was there—but not the predator itself—may be on guard the next time. But the creature that falsely remembers the predator was actually there might be even more cautious.

Such habits of mind that developed for human survival have modern equivalents, say researchers who note that a slightly inflated sense of one’s abilities (what we might call “nerve” or “chutzpah”) might win a job or a competition, or remembering a childhood as happier than it actually was can have a positive effect on general well-being and productivity in adult life.

Exactly how memory consolidation occurs is a topic on the forefront of current memory research. What is most useful to us as singers and teachers of singing is what aids this process. The following discussion identifies two from a larger list of known aids to memory consolidation.

**TWO MEMORY AIDS**

Effort is a necessary companion to learning. Just how much effort one is willing to expend is a matter of choice on the part of the learner, and how much effort one is willing to mete out is a matter of judgment on the part of the teacher. According to cognitive psychologist Robert A. Bjork,

Instruction that makes performance improve rapidly often fails to support long-term retention and transfer, whereas teaching that appears to create difficulties for learners—slowing the rate of apparent learning—often optimizes long-term retention.

Bjork laid out this principle in his seminal 1994 paper, and later came to call these learning challenges “desirable difficulties,” which he has described as a set of manipulations that, while they create immediate difficulties for the learner, nevertheless have a positive effect on long-term learning. The way that desirable difficulties control the rate of information flow is a bit like the effect of placing a hurdle in front of a sprinter; by placing desirable difficulties in the path of the learner, he is forced to slow down the stage between short-term memory and memory consolidation. He must spend more time in the working memory realm, which appears to aid retention and later, recall.

Desirable difficulties in the motor learning realm (for example, the acquisition of vocal technique) may include new language challenges, range extension, and practice variations. It has long been known that distributed practice (spaced throughout the week) facilitates learning far better than massed practice does; likewise, introducing random and variable practice conditions, such as different practice spaces, are more effective for
learning than blocked practice (i.e., practicing the same gesture over and over).\textsuperscript{18}

There is also much research on the learning benefits of error, reflected in the general folk wisdom that solutions for which learners must struggle and eventually figure out themselves have more staying power than solutions that were simply presented to the learner, as in a lecture presentation. This observation has spawned such educational paradigms as “hands-on learning” and “workshop physics,” and is reflected in the common saying, “No pain, no gain.”

In summary, it is generally understood that the more challenging the task the teacher demands, the more the learner’s cognitive resources are brought forth. Further, the act of learning involves trial and error; this, combined with effort, may be very uncomfortable for the student. But psychological discomfort may be a bellwether that shows that learning is occurring. What can teachers do? Administer “desirable difficulties,” albeit with great compassion and goodwill. What can learners do? Don’t be dismayed by distress over difficulty. It might be a sign that you are getting what you paid for.

Rapid progress in the form of improved performance is reassuring to the learner, even though little learning may be taking place, whereas struggling and making errors are distressing, even though substantial learning may be taking place. Such a misreading of one’s progress... can lead trainees to prefer less effective training over more effective training.\textsuperscript{19}

Several important studies have provided further proof to support reigning theories regarding the starring role that sleep plays in learning. Sleep aids memory consolidation, to such an extent that it can now be said, we literally learn while we sleep.\textsuperscript{20} It seems that sleep is the state most conducive to the process of “synaptic pruning,” whereby the weakest connections between brain cells simply wither away, leaving only the strongest synaptic connections behind.

A second theory is that the purpose of sleeping, especially 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 memory consolidation.\textsuperscript{21}

In one study, scientist Matt Wilson discovered that the content of his lab rats’ dreams were the maze tasks he had set up for them earlier in the day. The animals were replaying their exact movements in their dreams and “practicing” them by replaying them through their mirror neuron systems—and thus fast-forwarding their memory consolidation.\textsuperscript{22}

The value of mirror neurons to the technique of silent practice is of keen interest to athletes, dancers, singers, and others who must perform at the highest levels of motor skill. The value of sleep to learning has only recently been recognized, but it seems safe to say that one way to prepare for an upcoming opera role or solo recital is to work at memorizing the staging and lyrics before retiring to bed, then just “sleep on it.”

\textbf{LEST WE FORGET: EMOTION}

By now, it should be apparent that this article was written from the perspective that the acquisition and maintenance of memory is, overall, a desired objective. Given that a healthy human brain contains approximately 200 billion neurons that are linked by hundreds of trillions of synapses, it would seem that these “action potentials” would give us limitless memory storage.\textsuperscript{23} Why, then, do most of us only remember a fraction of what we experience throughout a lifetime?

For clues, scientists are studying highly unusual people (assigned the name \textit{hyperthymestics}, from the Greek word “thymesis,” to remember) whose memories are so robust as to be “non-stop, uncontrollable and totally exhausting.”\textsuperscript{24} By studying these rare individuals, a new field of inquiry has opened up on the importance of forgetting. Indeed, it is not difficult to comprehend the chaos in our brains that would result if our synaptic pruning mechanism failed to “sift the wheat from the chaff.” And it is no wonder that the sufferer who first brought her symptoms to light described them in such emotionally charged terms.

Aside from a relative handful of atypical hyperthymestic humans, the third known memory aide is emotion. When strong emotion accompanies experience, the resultant episodic memory is impressed deep within our brain. This explains why the memory losses that accompany early stage AD are relatively inconsequential, while the connected emotion is not forgotten; joy is retained at the remembrance of one’s wedding day, for example, while the exact date or year is forgotten. And, of course, not every strong emotion is a happy one.
Such disorders as depression and posttraumatic stress disorder (PTSD) are characterized by the inability of the sufferer to let go of dark emotions or banish the memory of traumatic events. In these cases, the ability to forget is more important than the ability to remember.

Researchers at the University of St. Andrews in Scotland have been studying “intentional forgetting,” that is, preventing a negative memory that already exists from coming to mind. Early returns on their findings are fascinating. They found that after repeated blocking of the memory, while the mundane details of the event remained intact, the strong negative emotion that was attached to it faded. In this case, the basic characteristic of human memory that allows us to create and remix our own narrative can work in our favor. This is a central tenet of cognitive behavior therapy which, combined with the newly discovered principles of “neural plasticity,” hold much promise for certain types of psychological disorders, from performance anxiety to depression and PTSD.

Performers that suffer from performance anxiety find that its hallmark is a negative thought loop, rooted in one significant traumatic performance gaffe, such as a memory lapse, an embarrassing fall, or a missed cue. Such gaffes are known in the scientific literature as “choking,” and much is already known about why and how this particular affliction occurs. There has been far less research conducted on how to cure it. One obstacle will be sorting out how “intentional forgetting” differs from the so-called “ironic effect,” whereby the effort to block the unwanted thought causes it to actually increase in magnitude. Further research on “intentional forgetting” might lead to a positive mindset technique that can be practiced just as assiduously as voice technique.

NOTES
14. APS, “Illusory Memories.”
15. Ibid.
17. Bjork, 185–205.
21. Ibid.
27. Ibid.