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The Neuroscience of Learning: A New Paradigm for Corporate Education

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"Learning is not compulsory, but neither is survival."—W. Edwards Deming

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Introduction

Learning is a critical organizational competency—so much so that Arie De Geus' statement has become almost a truism today. Yet, most organizations do not effectively build this competency at an organizational or individual level. A study of the effectiveness of organizational training conducted by Cross (2002) concluded that only 10 to 20 percent of formal organizational training transfers to the job. On the other hand, informal learning—which accounts for at least 80 percent of organizational learning—and is the very essence of the learning that de Geus is referring to—happens in an ad hoc manner, without design or strategy.

Our current work environment only increases the barriers to effective learning. Information overload, a term coined by Alvin Toffler in the 1970s, today yields 3 million results on Google. An article in Harvard Business Review titled "Death by Information Overload" captures the zeitgeist. At any moment, multiple stimuli are fighting for our limited attention.

Rapidly changing technologies—especially social and digital media—coupled with this data explosion and the generally heightened pace of change have a particularly strong impact on the "Millenials" or "Netgeners." These younger learners are now entering the workforce with dramatically shifted requirements for interacting with new information. They have expectations of flawless, highly interactive media and demand control over how they spend their time. As a result, their learning style requires active rather than passive learning and the construction of meaning rather than instruction. And, while the youngest members of the workforce embody these changes most fully—the forces that affect their learning style impact all of us to at least some degree (Elliot, 2009).

Building learning as a core competency requires that we take a new look at how we approach organizational learning. The past 15 years of research in the cognitive sciences—especially neuroscience—have produced some profound insights into the ways that learning occurs. These insights are particularly relevant in today's climate, and can help us to design learning interventions that tap into how the brain naturally learns so people can sort through the clutter and noise in the environment. We believe that the application of these insights to workplace learning—both formal and informal—can help organizations achieve sustainable competitive advantage.

Learning and Neuroscience

"Learning is one of the defining aspects of being human. Truly profound learning experiences change who we are—we change through learning. All learning involves thinking and doing, action and reflection. Learning changes what we can do—it is always active—you haven't learned to walk until you walk." — Peter Senge

Up until the 1980's, scientists thought the structure of the brain developed during childhood and that once developed, there was very little room for change. Scientists now know that the brain possesses enormous capacity to change: People's ability to process widely varied information and complex new experiences with relative ease can often be surprising. The brain's ability to act and react in ever-changing ways is known as neuroplasticity ("Understanding What Makes People Tick," 2009, p. 6).

"The ability to learn faster than your competitors may be the only sustainable competitive advantage."

— Arie De Geus

At the core, learning is change. Learning changes the physical structure of the brain and results in its organization and reorganization. Learning is always happening—consciously and unconsciously. Yet, when developing training for business environments, we spend most of our time focused on the content we want people to know rather than how they will learn. As a result, we fail to engage them, fail to keep them engaged, and fail to help them transfer their knowledge into action. Deep, lasting learning that results in changed performance does not happen.

Certainly, good instructional design can go a long way toward getting it right. Even at its best, however, it misses out on some powerful new insights into the workings of the brain—insights that can help us create learning experiences that are both more effective and more efficient. And, more often than not, learning professionals struggle to stand up to the pressure to get quantities of information to learners quickly.

Training buyers often feel they get more for their money if they can include more content in a training session. Neuroscience offers a new way to think about the design of learning activities and programs. A biological approach cuts through the clutter of potentially conflicting learning theories. By moving beyond theory to empirically-based statements, "proven" takes on a new meaning.

Overview
This paper brings together some of the available knowledge about learning and the brain and how that knowledge can be directly applied to learning in an organizational setting. We begin by presenting a model that provides a neuroscientific description of a foundational learning cycle, developed by James Zull, an educator, biologist and student of neuroscience. After that we explore several key topics—specifically, neural networks and connections, the social brain, attention and multisensory learning—looking at the science and the initial implications for organizational learning.

We then synthesize our findings into six broad design principles. We conclude with some initial thoughts on how we can rapidly and powerfully apply these principles.
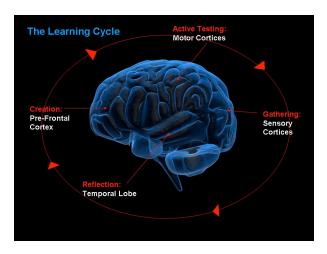
Our Methodology
This paper is a result of a collaborative design effort—and the process employed to create it embodies many of the principles that we describe. A Maritz Learning cross-functional team divided an extensive reading list among its members. The team then gathered to co-create a way of understanding neuroscience and learning and its application to organizational training and learning. The team drew out from its research the six principles presented here. The goal is for these six principles to be incorporated into learning design and tested through the application of neuro-informed learning interventions and programs.

The Learning Cycle
Educator and biologist Zull (2002) proposes a learning cycle that links the breakthrough work of Kolb (1981) on experiential learning with neuroscientific research. The cycle begins with gathering information followed by reflection, creating and active testing. Each step of the cycle is associated with a different region of the brain—those areas associated with sensory, associative and motor functions (Zull, 2002). While this alignment with parts of the brain is oversimplified, as these functions are more networked and less hierarchal than this picture would suggest, it provides a useful way to understand the overall workings of the brain as related to learning.

"I never teach my pupils; I only attempt to provide the conditions in which they can learn."

— Albert Einstein

The learning cycle consists of four stages: gather sensory experiences through the sensory cortices; engage in reflective observation, drawing on the temporal lobe; create new concepts in the prefrontal cortex; and actively test through our motor cortices. The complete cycle of learning arises from the very structure of the brain and results in new and lasting physical connections. Zull suggests that the power and duration of learning is proportionate to how many regions of the brain are engaged. The completion of the entire cycle is required for true change in behavior and performance.

Gathering

The first part of the cycle involves gathering information. This step engages the sensory cortices, which receive input from the outside world in the form of vision, hearing, touch, position, smell and taste. These cortices are where concrete experience is first recorded in the brain—where the raw materials are gathered for the remaining elements of the learning cycle. In a typical organization learning program, this part of the cycle receives the most focus and energy— most explanations, presentations and large portions of courses focus heavily on gathering information.

Reflection

Reflection, the second part of the cycle, engages the temporal lobe. During reflection, the brain integrates the sensory information received during the gathering stage. Reflection is inherently private—it happens within the learner and requires time and space for learners to pause and digest. Even the quickest learner needs reflection time. Without reflection, learning will be disconnected and shallow—sufficient to pass a test after a night of cramming—but otherwise transitory. And, in business settings, transitory is rarely, if ever, sufficient. Reflection is ultimately a search for connections—conscious and subconscious—and it works better when sensory inputs are shut out. Eliminating distractions allows the brain to focus attention on integrating information already received.

Reflection is necessary for insight formulation—the somewhat mysterious process that occurs when a solution comes to mind suddenly, often after an impasse, and seems obviously correct. Insights fuel the creativity and innovation that are prerequisites for success in today's competitive marketplace. ("Understanding What Makes People Tick," 2009).

The implication is that we need to build reflection into the learning solutions we design, and give careful thought to the quantity of information that can be covered and to the pacing of the delivery of information. Reflection can happen both within and between learning activities—and a little bit of reflection time goes a long way. Research clearly demonstrates the benefits of spacing vs. massing practice and training (Zull, 2002)—it would seem that one benefit of spaced practice is the opportunity it gives for in-between reflection—both conscious and unconscious. Time out between learning events for relaxing, disconnecting and sleeping is critical. Giving learners reflection questions or integrative assignments can further increase opportunities for reflection.

Creation

Creation is the point in the learning cycle at which the learner shifts from receiving and absorbing information to creating knowledge in the form of abstractions such as ideas, plans, concepts and symbolic representations. The prefrontal cortex is fully engaged in this executive brain process.

Creation involves the manipulation of information in working memory to create new relationships and new meaning. Data is organized into new arrangements and that data is attached to the networks that represent prior knowledge. (In the next section, we explore this concept in greater depth.) Through this process, learners create their own understandings.

> Creation often involves language: I believe learners take a huge step when they assemble their images into specific language. With some exceptions, I think we should insist that they do it. If language is a plan for action, then our insistence that a learner explain something "in your own words" takes on a new meaning. It means "tell me your plan for action." And it means more than just words. It means "in your own sentences, in your own paragraphs!" It means that you want to see planning and you want it to lead somewhere (Zull, 2002, p. 200).

Zull also notes that people create based on the unique ways that their individual brains operate. What works for one person is not necessarily what works for another. To that end, learners need to have the opportunity to make meaning in their own ways. Attempts to save time by explaining things more often than not result in the loss of meaning creation. Until learners actively create their own ideas, learning has little chance of enduring. By definition, creation requires giving control to the learner. According to Zull (2002, p. 202), "we must trust the brain to think."

Robert Bjork, a cognitive psychologist at UCLA, has spent decades researching the learning process and the conditions necessary for learning to stick in both the short and long term. His work aligns with and strengthens Zull's model. He finds that long-term learning is deepened through a method that he calls "generating." In multiple studies, Bjork and his colleagues found that even minor shifts in the learning process that promoted creation of knowledge rather than passive studying of content result in longer lasting learning (Richland, Bjork, Finley & Linn, 2005).

Active Testing

Active testing differs from most people's typical understanding of testing. Active testing is actually a physical process that engages the motor cortex. It allows the brain to make the abstract concrete by converting mental ideas into physical events—into action. According to Zull (2002), any action inspired by ideas qualifies as active testing: reading another book on the topic; talking to someone about the book; explaining and talking about what was learned; hearing what someone else thinks; searching the topic on the web; seeking out people who live the topic and talking to them; setting up experiments to test.

One of the most interesting of Bjork's findings, which aligns with and expands the concept of active testing, is that retrieving memory is a learning event. He shows that the very act of recalling information reinforces and embeds learning and suggests that activities that ask learners to retrieve learning within the learning process can be very powerful (Bjork & Linn, 2001).

"I am always ready to learn although I do not always like being taught."

— Winston Churchill

Initial Implications

To increase learning effectiveness, learning solutions should allow for gathering, reflection, creation and practice of retrieval within the learning process itself. While employing this approach may seem to require greater time and effort in actuality it is more efficient: the result is that what is learned is more deeply embedded and the likelihood of the learner being able to apply learning on the job dramatically increases.

While ensuring the inclusion of all the elements of the cycle may require an initial slowing down and a reduction in the quantity of content that can be covered in a learning experience, the result will be a profound shift in the quality of learning—and ultimately the difference between time and money well spent or time and money wasted. Slowing down is counterintuitive in the information environment in which we operate—but it becomes absolutely imperative when one weaves in a deep understanding of how the brain functions. Deciding what is really most important becomes a critical design step.

Together, Zull and Bjork provide powerful arguments for changing the typical ways that learning events are conducted—and reinforced. The insights we have gleaned from the human sciences give us the ability to construct more effective reinforcement strategies that align with how the brain learns. They also provide a stronger basis for suggesting that reinforcement is a critical component of a learning offering—and that the lines between formal and informal learning must becomes less rigid—with reinforcement being embedded into on-the-job, informal learning.

When designing, developing and delivering learning, we need to keep all of the elements of the cycle in mind, and continuously return to the cycle as a framework. We also need to remember that learners must ultimately create their own meaning and their own learning—that giving learners maximum control of the learning experience is more than a "nice-to-have," it is necessary for deep learning to occur.

Another powerful way to help people engage in the learning cycle is to increase their awareness of the very nature of the learning process. Teaching metacognitive strategies—how to learn more effectively based on the way that brains learn—could optimize learning by creating more conscious learners. To be metacognitive is to be constantly "thinking about one's own thinking"—and, in the process, deepening learning. By helping learners consciously adopt more effective learning strategies and giving them insight into the power of those strategies we can affect the quality of day-to-day informal workplace learning

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Neural Networks and Connections

Neuroplasticity is perhaps the single most important concept in terms of learning and the brain. The knowledge that our brain is constantly changing and growing—that cortical plasticity extends throughout the human lifespan—shifts our understanding of what is possible for adult learners. Learning is not just changing external behavior, but changing the very wiring of the brain as it relates to those behaviors. Deep, lasting change is possible at all ages.

Hebbian Synapses

In 1949, Canadian psychologist Donald Hebb proposed a way that learning might exist at the level of synapses. His proposition lead to the well-known phrase "neurons that fire together wire together" and, today, two cells that are strengthened in this way are called a "Hebbian synapse" (Hebb, 1949). In the early 1970s, Hebb's hypothesis began to be confirmed through neuroscientific research—and has gained further support as new methods and tools have emerged.

"When we try to pick out anything by itself, we find it hitched to everything else in the universe."

— John Muir

What Hebb hypothesized and what has since been proven is that neurons that are repeatedly used grow stronger synapses and more effective neuronal networks. And the more they fire, the more they send out new branches looking for more new and useful connections. From this emerges the idea of "attention density" proposed by Jeffrey Schwartz. Focused attention and repetition helps neurons fire solidly together, creating new learning (Schwartz & Begley, 2003).

Learning affects the brain in two different ways—either by altering existing connections or by creating brand new connections. New connections lead to an increase in overall synaptic density, while altering connections makes existing pathways more efficient or suitable. In both cases, the brain is remolded to take in new data and, if useful, retain it.

Prior Knowledge

Learning begins with connecting with what we already know. There is a neuronal network in the brain for everything we know. Every fact we know, every idea we understand, and every action we take assumes the form of a network of neurons in our brain.

Brain structure dictates that learning design should begin with what the learner knows. The challenge is that one person's network does not resemble another person's network and that these networks are both complicated and tangled. Using the learner's networks as the starting point requires a significant shift from the view of learning as imparting knowledge.

Developing Expertise

Experts and novices learning differently–a distinction that can help us design more effective and higher impact learning. Experts have more connections and interconnections, stronger ties between connections, and a better organized knowledge structure. This makes it easier for them to acquire and assimilate new information and retrieve prior knowledge.

Working memory, which we will explore further in our discussion of attention, has limited capacity. Though reference is often made to the "magical number seven" (Miller, 1956), recent research has demonstrated that the capacity is far more limited. Cowan (2005) recently proposed that working memory has a capacity of about four chunks in young adults (and fewer in children and older adults)—a number that is becoming widely accepted.
Despite these limitations, some adults have been able to vastly increase their ability to memorize digits—up to eighty. Studies demonstrate that this is accomplished through extensive training and the use of a strategy that involves organizing the digits into groups and then memorizing these groups of digits as single chunks so that the total number of chunks is still small (Chase, Ericcson & Faloon, 1980).

Expertise is not about increasing working memory capacity—it is about organizing information in the brain and increasing the size of chunks. The novice and expert organize information into chunks of different sizes. An expert with well-formed connections can attach things to old networks and quickly move them to long-term memory. A novice with far fewer prior connections cannot hold new information in isolation. Working memory is more actively engaged, more energy is expended in learning, and there is a greater challenge in moving knowledge through the learning cycle and into long-term memory. Breaking learning into chunks that are manageable for novices is critical (Zull, 2002). Another difference between novices and experts is that experts are able to quickly sort through sensory data and identify which are important and which aren't. Novices see the details but cannot identify which are important. For novices, part of the learning process must include helping them sort through

the fine details and guide them in determining what is important. When training novices, it is important to look at the world through their eyes (sometimes not such an easy task for experts). When training experts, it is important to respect the depth and richness of their networks.

Expertise is specific. Every individual is a novice in some areas and an expert in others. Expertise in specific domains is not easily transferable to other domains, meaning that learning needs to be tailored to the expertise level of the audience. If the audience contains a mix of expertise levels, it needs to respond to individual needs to the extent possible.

Initial Implications
We need to actively help learners make meaningful connections and tap into prior knowledge and experience. Metaphors, analogies and stories are powerful vehicles for tapping into existing knowledge and experience—effective ways of making connections, seeing patterns and making meaning.

The critical differences between how novices and experts learn has important implications for how we organize learning. We need to tailor our solutions to align with the level of expertise of the audience. If the audience contains a mix of expertise levels, our solutions should take into account the needs of those different levels.

Whether learning is informal or formal, the way people work with information and what they need for it to make an impact stays constant. Helping people create connections—between new information and what they already know, between the big picture and the details that comprise it—is a key to lasting learning.

The Social Brain
The brain is social—it requires and thrives on interactions with other brains. In fact, the brain develops in concert with other brains—and requires those other brains to develop:

> Like every living system, from single neurons to complex ecosystems, the brain depends on interactions with others for its survival. Each brain is dependent on the scaffolding of caretakers and loved ones for its survival, growth and well-being . . . The brain is an organ of adaptation that builds its structure through interactions with others (Cozolino, 2006, p. 15).

Maslow Revisited
The evolving view of the brain as inherently social has major relevance to learning. UCLA social cognitive neuroscientist Matthew Lieberman (2008) goes so far as to challenge Maslow's pyramid, suggesting that social needs are at the bottom of the pyramid, more basic than food and water. He argues that for human beings to have their physical needs met, first they must establish a relationship with a parent, and their basic needs are only met through that social relationship. Lieberman's work demonstrates that the brain interacts with social needs using the very same brain networks used for physical survival. Being hungry or in pain and being socially ostracized activate similar threat and pain responses.

Studies have also demonstrated that infants are more likely to learn from a person than from an inanimate device. In these studies, as a robot's behaviors became more social, the infant's willingness to connect to and learn from it increased (Meltzoff, Kuhl, Movellan & Sejnowski, 2009.)

Mirror Neurons

In the 1980s, Giacomo Rizzolatti and several colleagues at the University of Parma, Italy, were doing neuroscientific research with monkeys, studying how different neurons were specifically associated with particular actions. During the course of their work they accidentally discovered that some of the neurons they recorded would respond when the monkey saw a researcher pick up a piece of food as well as when the monkey picked up the food. Later, in the 1990s, Rizzolatti and his colleagues published a seminal paper coining the mirror neuron system, describing its role in action recognition, and suggesting that humans, too, have a mirror neuron system. Much work has been done since on this topic, including fMRI studies demonstrating a human mirror neuron system. This is truly one of the most exciting areas of neuroscientific research with profound implications:

> Some scientists speculate that a mirror system in people forms the basis for social behavior, for our ability to imitate, acquire language, and show empathy and understanding. It also may have played a role in the evolution of speech (Society for Neuroscience, 2007).

Research shows that newborns as young as 42 minutes old match gestures shown to them. Before infants can see their own faces, before newborns see a reflection in the mirror, they are already mirroring the behavior of other humans (Meltzoff & Prinz, 2002). These findings— which have been validated cross-culturally—came as a shock to developmental theorists who had always believed that infants gradually progressed from non-imitation to imitation. These findings show us that mirror neurons kick in early and powerfully.

While this is a vast and complex topic whose full implications are as yet unclear, it shows the power of the brain as a social organ. Learning from others happens more directly, more automatically and more powerfully than was ever imagined.

Initial Implications

People learn from one another, sometimes without even realizing that they are doing so. With the increasing shift from face-to-face meetings and events to virtual and digital formats, careful thought must be given to how we build human interaction into learning solutions.

While there are excellent reasons and effective ways to deploy virtual and digital learning solutions, we also need to recognize that virtual and digital solutions aren't always the answer. We are wired to need social interactions and to make real connections with others. There is great power in the interactions among learners and between instructors and learners. We need to continue to find ways to nurture these connections—even in an increasingly digital workplace.

Emotion and Learning

More and more literature in psychology, neuroscience and economics is revealing the very critical role that emotion plays in our lives. Neuroscientific research has revealed that emotion and cognition are not neatly divided in the brain. Virtually all mental activities involve both emotion and cognition (LeDoux, 2000). When it comes to shaping our decisions and our actions, feeling counts every bit as much—and often more than—thought (Goleman, 1995). Richard Cytowic (1996), a memory researcher, puts it this way, "It is an emotional calculus, more than a logical one, that animates us."

"There can be no knowledge without emotion. To the cognition of the brain must be added the experience of the soul."

— Arnold Bennett

Not surprisingly, emotion plays a powerful and complex role in the learning process. The existence of neural wiring between the thinking and emotional centers of the brain suggest that emotions can either enhance or inhibit the brain's ability to learn. Understanding the right balance requires taking a closer look at the neuroscience around emotion and learning.

Getting the Right Balance

Emotion is the fuel and foundation of learning: emotion is required to engage the learning cycle as well as to move through it (Zull, 2002). However, the right amount of emotion is needed for learning—not too much and not too little. In the early twentieth century, psychologists discovered that learning is maximized in a moderate state of arousal—what we could call "relaxed alertness." If learners are not aroused at all, they will not engage—if they are too aroused, they will be unable to stay focused. More recently, neuroscience has provided a biological basis for these psychological findings, adding further support for Zull's understanding of the emotional chemicals of the brain as the fuel for learning:

It turns out that a moderate level of arousal triggers neural plasticity by increasing production of neurotransmitters and neural growth hormones, enhancing neural connections and cortical reorganization (Cozolino, 2006).

Cozolino calls the ideal emotional state for learning one of "safe emergency"—in other words, there is a high level of attention, without the negative impact of anxiety. Similarly, research has shown that stress in the learning environment, negative memories from prior learning, or stress in the broader environment can negatively impact the potential for learning. These stressors can operate at both conscious and subconscious levels. And, as findings in cognitive psychology and neuroscience indicate, the brain is geared to minimizing threat and maximizing reward (Gordon, 2000). Upon encountering a stimulus, the brain either tags it as good or bad: if good, the brain engages with or approaches it; if bad, the brain disengages, or avoids it. Some studies have found that it is easier to trigger an avoid response and harder to create an approach response because the avoid response creates far more arousal in the emotional networks of the brain (Baumeister, Bratslavsky & Vohs, 2001). The implications for learning are powerful. Learners are constantly and subconsciously monitoring their learning environments and are naturally wary of lurking threats. Openness to learn is greatly diminished when there is a perception of threat or when learners sense a potential for loss of control.

Emotion and Memory

The relationship between memory and emotion is also interdependent. Studies confirm that we remember emotionally charged events better than neutral events (Bechara, et al., 1995). And, we are less likely to remember information that follows an emotional event. In other words, strong emotion can impair memory for less emotional events and information experienced at the same time. And, while strong emotions can aid memory, stress at high levels, over time, limits the ability to learn and remember—sometimes permanently.

The impact of emotional events on our ability to learn further demonstrates the importance of our being aware of and sensitive to the emotional climates that we create during learning experiences as well as the emotional sensitivities of learners due to both personal and organizational factors.

How a person processes, encodes, and stores information in different emotional states may vary. The hippocampus, a region of the limbic system in the brain, is essential for declarative memory [memory of facts and events] and encoding episodic [memory of events] information for memory. Under high levels of stress, activation in the hippocampus decreases, affecting encoding of declarative and spatial memory. In contrast, the amygdale, another limbic structure, becomes more active under stress and enhances memory of emotionally relevant experiences and fear-conditioned memory. (Manning, 2007).

Emotions and Mirror Neurons

Mirror neurons play a role in the robust and reflexive transmission of emotions. A briefing published by the Society for Neuroscience ("Brain Briefs," 2008) notes that before the discovery of mirror neurons, scientists generally believed that the brain used logical thought processes to interpret and predict other people's actions. Now, many have come to believe that people understand others not by thinking, but by feeling. Mirror neurons appear to let people "simulate" not just others' actions, but the intentions and emotions behind those actions. When a person sees someone smile, for example, mirror neurons for smiling fire up, too, creating a sensation of the feeling associated with smiling. A person doesn't have to think about what the other person intends by smiling. A person experiences the meaning immediately and effortlessly. Daniel Goleman, author of Social Intelligence (2006), puts it this way: "When two people interact, their emotional centers influence each other, for better or for worse."

Initial Implications

Given what we have discovered about emotion, it is clear that attention must be paid to maintaining the kind of emotional state that supports learning:

• Create a strong enough emotional pull so that the learner chooses to engage with the learning content. (The all-important process of gaining learners' initial attention is further explored in the next section.) Visuals, stories, novelty and humor are all examples of stimuli that can create emotional engagement.

• Avoid creating an overly charged emotional environment that will negatively impact the learner and ultimately result in loss of focus and lack of engagement.

• Manage the learning environment—live, virtual or digital—to ensure that an approach state is created and maintained. Of particular importance is ensuring that the learner's status is retained, that the learner has an appropriate level of autonomy, and that the learning experience is perceived as fair (Rock, 2008).

• Evaluate learners' potential emotional triggers (for example, prior negative experiences with formal training or formal education) that might impact their ability to engage with new material.

• Recognize the power of the facilitator's mood (or that of other learners) in both live and virtual environments in establishing and maintaining appropriate levels of emotional engagement and in ensuring that an approach state is maintained.

• Consider the organizational environment—ongoing change initiatives and other external or internal pressures affecting people in the organization—and its potential for enhancing or impeding learning.

In sum, our understanding of emotion and learning suggests that learning design must attend not only to the cognitive side of the learning equation but also to emotional elements that might once have been deemed out of scope or irrelevant.

Attention and Memory

Because of both how the brain is structured and the fast-paced, stimulus-rich environment that characterizes our lives, engaging and maintaining attention is a significant challenge. While we have touched on the topic of attention briefly throughout this paper, here we will take a deeper look at its direct implications for learning.

Engaging and Managing Attention

In order to engage a learner in the learning cycle—to even begin the process of gathering sensory data—attention must be harnessed. Pat Wolfe, an educator who focuses on the application of neuroscience to education, writes:

The brain is designed to immediately filter all incoming sensory stimuli and select only those that are relevant at that moment so as to encode them. There is actually no such thing as a learner who is not paying attention: the brain is always paying attention to something, although it may not focus on relevant information or on what the instructor intends (Wolfe, 1998). It drops information that doesn't fit easily into an existing network. It "forgets" information that it does not find useful and important. By necessity, the vast majority of sensory data is not encoded— the brain simply cannot pay attention to all the incoming stimuli—so it ignores information that, in terms of existing neural networks, is meaningless. In designing learning experiences, we must discover ways to quickly, effectively and powerfully grab the learner's attention.

Yet, engaging attention is only the beginning. Throughout the learning cycle attention must be managed, largely due to the severe constraints of working memory. The term working memory describes a "limited capacity system that is capable of storing and manipulating temporary information involved in the performance of complex cognitive tasks such as reasoning, comprehension and certain types of learning" (Baddely, 2009). In other words, working memory is where conscious thinking happens. Working memory has a smaller capacity than long-term memory and takes more energy. And, sustained use of working memory, even within its constraints, can deplete working memory effectiveness for short periods (Baumeister, Bratslavsky, Muraven & Tice, 1998; Vohs & Heatherton, 2000).

Designing learning experiences so as to minimize the load placed on working memory and enable effective processing is perhaps the key to attention management. Cognitive overload can result from the asking learners to do too much at once or from external distractions.

Multitasking and Its Impact on Learning

The brain can't attend to two or more attention-rich stimuli simultaneously—simply put, multitasking doesn't work ("Understanding What Makes People Tick," 2009). A 2000 study by Naveh-Benjamin and colleagues provides a deeper of understanding of what this means for learning. The authors discovered that there were significant differences between encoding and retrieval activities involved in processing information created through multitasking. The researchers demonstrated that encoding requires more attention than retrieval and that divided

"We live in an age of information overload, where attention has become the most valuable business currency."

— Thomas Davenport and John C. Beck, The Attention Economy

attention during the encoding phase of learning significantly reduced memory. Since encoding is the first of three memory stages (storage and retrieval are the other two), the implication is that the quantity and quality of memory is profoundly influenced by multitasking.

In another study, Poldrack and colleagues (2006) discovered that memories acquired when multitasking use the striatum, a region of the brain poorly suited to long-term memory and understanding. Learning that happens while multitasking cannot be generalized—and does not result in understanding or the ability to recall when needed. In his study, a group of 14 young adults were assigned an exercise that involved sorting shapes into different piles based on trial and error. The exercise was performed (by the same participants) under two different conditions—first without distractions and then, while listening to high and low beeps and counting the high ones. Participants were tested on what they learned in each condition. As fMRI results demonstrated, learning happened in both scenarios—but the way it happened and the brain systems involved were different. For the task performed while multitasking, the subjects' knowledge was less flexible—they could not extrapolate their knowledge to different contexts.

While performing the sorting task without multitasking, the hippocampus, a region of the brain involved in sorting, processing and recalling information, and critical for declarative memory (memory for facts and events) was active. The distractive beeps, however, shifted activity away from the hippocampus to the striatum, which is necessary for procedural memory (that is, habitual tasks, such as riding a bike).
Memories in the hippocampus are easier to recall in different situations, whereas those stored in the striatum are tied closely to the specific situation in which they were learned. The implication is that learning with the striatum leads to knowledge that cannot be generalized as well in new situations. (Foerde, Knowlton & Poldrack, 2006).

Continuous Partial Attention

Linda Stone, a former Microsoft vice president turned educator and speaker, coined the term "continuous partial attention" to describe how many people use attention today (Stone, 2008). The term goes beyond multitasking and refers to the desire to connect and be connected at all times and to the way that people scan the environment for the best place to be connected at any given moment.

> We pay continuous partial attention in an effort not to miss anything. It is an always-on, anywhere, anytime, anyplace behavior that involves an artificial sense of constant crisis. We are always in high alert when we pay continuous partial attention. This artificial sense of constant crisis is more typical of continuous partial attention than it is of multitasking (Stone, 2008).

Learning that happens while multitasking cannot be generalized—and does not result in understanding or the ability to recall when needed.

While Stone notes that this technique can be useful in small doses, it ultimately adds to stress and compromises a person's ability to reflect, to make decisions and to think creatively:

> In a 24/7, always-on world, continuous partial attention used as our dominant attention mode contributes to a feeling of overwhelm, over-stimulation and to a sense of being unfulfilled. We are so accessible, we're inaccessible. The latest, greatest powerful technologies have contributed to our feeling increasingly powerless . . . We have focused on managing our time. Our opportunity is to focus on how we manage our attention (Stone, 2008).

New insights and studies about multitasking and attention, combined with discoveries about the limitations of working memory, demonstrate just how critical attention management is in the learning process.

Novelty

A powerful strategy for harnessing attention with direct application to learning is related to novelty. Nico Bunzeck and Emrah Duzel (2006) conducted several experiments to study the effects of novelty on the brain. In the first, participants were shown images of different scenes and faces, both familiar and unfamiliar. Some of the images were unusual, appearing only rarely, while others contained negative emotional content, such as a car accident or an angry face. Participants showed increased production of dopamine, a neurotransmitter linked to pleasure and reward, when shown the new images, but not the unusual or emotional ones.

The experiment was repeated, with some of the images being less familiar and some more familiar. In this version of the study, only brand new information caused strong activity in the midbrain area, stimulated the production of dopamine.

The final experiment focused on testing the memory of the participants. The volunteers were tested on the new, familiar and very familiar images, both 20 minutes after viewing and a day later. Evidently, they performed best when new information had been combined with familiar information. Even the familiar information became easier to remember when it was learned alongside new facts.

> When we see something new, we see it has a potential for rewarding us in some way. This potential that lies in new things motivates us to explore our environment for rewards. The brain learns that the stimulus, once familiar, has no reward associated with it and so it loses its potential. For this reason, only completely new objects…increase our levels of dopamine (Duzel, 2006).

While novelty and tapping into prior knowledge may at first seem contradictory, they are separate dimensions of learning. Novelty helps the brain initially attend to a stimulus—then, once attended to, connections must be made for the information to take root. So, while the brain needs to make connections, it also likes things that are new. And, the brain relatively quickly ceases to recognize a stimulus as novel through a process known as habituation—in other words, once the brain has identified a familiar stimulus, it no longer holds that same potential for reward, so the brain continues to seek out new things.

│ 13

Guiding Attention

While tapping into prior knowledge and introducing novelty are two powerful strategies for engaging attention, additional approaches are required for maintaining and managing attention. While we generally think that focus is good—in fact, scanning is often better (Jonassen & Grabowski, 1993) It may seem counterintuitive, but the human brain is more proficient at noticing detail by scanning rather than by focusing intently. The brain evolved this way to enhance the chance of survival.

We exhaust our neurons if we make a constant demand on the same ones for too long. Instead of asking people to pay attention, we might ask them to look at things from many different angles. Instead of sitting still, we might ask them to move around so that they can see details. (Zull, 2002, p. 142).

Another strategy for managing attention involves awareness of what is involved in shifting attention from one topic to another. Shifting attention requires three discreet brain processes— disengaging, moving and re-engaging. Each process activates different parts of the brain and engages working memory—the process takes time and is energy depleting. Recognizing these shifts and allowing learners sufficient time to make them supports attention management (Wright and Ward, 2008).

Initial Implications

Information and stimulation overload are here to stay. Actively incorporating attention management strategies during learning design is of paramount importance:

• Eliminate multitasking to facilitate more efficient and effective encoding of knowledge

• Minimize the load placed on working memory by limiting distractions and avoiding asking learners to process vast amounts of information at one time

• Manage attention shifts, allowing learners sufficient time and space to make them

• Utilize novelty and surprise while allowing learners to make connections with existing knowledge

• Provide learners with awareness and skills training in attention management

We also need to help learners apply attention management strategies back on the job. These strategies include changing expectations that inadvertently encourage the productivity-sapping practices of multitasking and continuous partial attention. For example, we may need to allow more flexibility in employees' accessibility, allow them time for focusing on tasks without interruption, or give them permission to respond to email or voicemail in a manner that suits them.

Engaging the Senses

The final area that we explore in this paper is what is known as "multimodal" or "multisensory" learning. While there is a general belief that multisensory learning increases learning effectiveness, we wanted to know if neuroscientific research would validate this idea. At the same time, we wanted to understand more about the power of visual images in learning.

Several studies present initial evidence that multimodal learning does make a difference. In one study participants were trained over five days on a task that had either congruent audiovisual,

incongruent audiovisual stimuli, or only visual stimuli. The results definitively showed that training with congruent audiovisual stimuli produced significantly better results than training with incongruent audiovisual stimuli or with only visual stimuli (Kim, Seitz & Shams, 2008).

> The conclusion of this and other studies is that presenting material in two media—pictorial and verbal—is generally superior to presenting material in only a single medium—as long as the pictorial information is well designed and congruent (Mayer, 2001).

The Power of Visuals

Throughout our research we found many references to the power of visual images and the differences between the way the brain remembers words and remembers pictures. The brain has an extraordinary capacity to remember images. Memory experiments with pictures have shown that people can recall seeing hundreds, even thousands, of pictures (Standing, Conezio & Haber, 1970). Pictures seem to operate as "chunks" and while the brain can hold only a few chunks in working memory at a time, visual images allow the brain to hold and enlarge the scope of those chunks. This is because visual processes evolved over millions of years, so the brain machinery in highly efficient, especially in comparison to the circuitry involved in language (Medina, 2008).

Ian Robertson, a Dublin-based neuroscientist, writes that "precisely because imagery tends to be underused, it tends to be less habitual, less automatic—and hence, potentially at least, more flexible" (Robertson, 2002). Visualization can be improved with practice at any age and can be tapped into more powerfully. Science also shows that visualization of an action or an activity engages the very same parts of the brain that actually doing that activity activates in the brain. This is why athletes often engage in mental practices—because they have physical benefit.

Initial Implications

Research in neuroscience strongly supports what is already considered a best practice in learning design—engaging multiple senses. It also demonstrates the unique power of visual images and suggests that using rich images and asking learners to engage visually—and through visualization—increases learning.

Brain-Based Design Principles

Throughout this paper, we have examined different ways in which neuroscientific and cognitive scientific research can inform the design of learning. We've looked at potential implications for these findings. As a way of summarizing our initial thinking on implications, we present six design principles that can serve as practical design tools.

Principle	Key Ideas
• Engage the entire learning cycle. Make time for reflection, creation and active testing.	• Ensure that all parts of the brain are engaged so that learning results in enduring biological and behavioral change. • In a fast-paced world with multiple stimuli, slowing down enough to engage the entire cycle has the potential to dramatically increase the power of learning interventions—less can truly become more. • Learners control what they do or do not learn. The learning cycle shifts power from the instructor and content to the learner and context.
• Make a connection with the learner's prior knowledge and experience.	• Drawing on what we know about neuroplasticity and the need to connect with prior knowledge, learning experiences must start with what the learner knows. • Stories, analogies and metaphors—especially those constructed by the learner—are examples of powerful ways to make connections. • Experts and novices have radically different understandings and connections. These differences must be understood and learning needs to be aligned to the needs of each. Paying attention to the unique attributes of novice and expert will significantly increase the impact of training.
• Create opportunities for social engagement and interaction as part of the learning process.	• The brain is social—and learning is social. Recognition of the importance of social connection in learning requires that we attend to the social dimensions of learning. This has particular impact on the design of digital learning that has not traditionally had a social dimension. Exploring ways to increase social engagement in eLearning is a major opportunity—especially as social media tools become more widely accessible and understood.
• Engage both feeling and thinking.	• Emotion is a necessary part of learning. Recognizing that getting the level of emotional engagement right—not too much, not too little—adds a new dimension to the design of learning experiences that has generally received too little attention.
• Actively attend to attention—gaining, holding and focusing the learner's attention.	• Attention, from initial engagement of attention through an entire learning experience, is a critical part of the design of learning. It is increasingly challenging to engage attention—yet increasingly clear that without it, learning does not occur. • Engaging emotion, creating connections to existing knowledge, incorporating novelty and utilizing storytelling are all ways to engage and manage attention. • Attention management requires that we be aware of the limitations of working memory and avoid cognitive overload throughout the learning experience.
• Engage a maximum number of senses—especially visual—when designing learning.	• Learning can be deeper, richer and more memorable when multiple senses are engaged. Integrating a greater degree of visual and multisensory elements into learning solutions can increase their impact and effectiveness.

Conclusions

Neuroscience can have many implications for the design of organizational learning. The chart below contrasts the current state of learning design with a vision of a potential future state.

Current	Future
• Present-Demo-Practice-Feedback	• Gather-Reflect-Create-Test
• Evaluative testing	• Active testing
• Cookie-cutter chunks	• Right-sized chunks
• Information	• Meaning
• What	• How
• Content-centric	• Learner-centric
• Training	• Learning
• Explanation	• Discovery
• Expert-driven	• Learner-driven
• Teachers	• Learning networks
• Set content	• Dynamic content
• Receiving meaning	• Creating meaning
• Information silos	• Connected information
• Start with what we know	• Start with what they know

When we began our work on neuroscience and learning, we were genuinely unsure about what we would find. We didn't know if we would simply be validating the instruction design principles we have abided by for decades —or if we would break new ground. In the end, we did both. In many cases, neuroscience does validate what good instructional design practice already suggests—and, in those instances, the contribution of neuroscience is to give those practices empirical validity. In other cases, neuroscience gives us new ways to think about learning that suggest genuinely different ways to approach workplace education.

We are excited to be exploring an area that elicits great interest yet remains largely untapped. Much of what is called brain-based education is geared at K–12 and is rife with "neuromyths" that still rely on outdated and simplistic assertions about the nature of the brain (Goswami, 2007). Taking a serious and thorough look at what neuroscience offers us and carefully applying that to our offerings holds out great potential for new ways of understanding and developing learning interventions.

And, at the same time as we are excited and see great potential, we need to remain cognizant of the nature of the field that we are exploring. While neuroscience research has produced more knowledge about the brain in the last decade than in all history prior, this is still a very new field. Consider that over 90 percent of neuroscientists who have ever lived are still alive and practicing today! To that end, we have attempted in this paper to be true to what is

known today—recognizing that this is a snapshot of knowledge at a particular moment in time and that we will need to revisit and evolve our thinking as the field grows and as more of the mysteries of the brain are revealed.

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