Brain-Based Learning

The wave of the brain

By Ruth Palombo Weiss

It's a jungle out there! We have all heard and probably uttered that phrase. Well, the Nobel Prize winning neurobiologist Gerald Edelman postulates that it's a jungle inside there as well. Edelman, director of the Neuroscience Institute at the Scripps Research Institute, compares our brains to a dense web of interconnecting synapses. His metaphor gives us insight into current, sometimes confusing, research on how the brain works and its connection to learning theory.

Many of us use the Internet daily and are astounded by the vast and seemingly endless connections we can make. The brain's interconnections exceed the Internet's by an astronomical number. The typical brain has approximately 100 billion neurons, and each neuron has one to 10,000 synaptic connections to other neurons. Says Edelman, "The intricacy and numerosity of brain connections are extraordinary."

Our brains are suffused with a vast number of interdependent networks. We process all incoming information through those networks, and any information already stored influences how and what we learn.

"The human brain is the best-organized, most functional three pounds of matter in the known universe," says educator Robert Sylwester in his book, *A Celebration of Neurons: An Educator's Guide to the Human Brain*. "It's responsible for Beethoven's Ninth Symphony, computers, the Sistine Chapel, automobiles, the Second World War, *Hamlet*, apple pie, and a whole lot more."

Increasingly, educators such as Sylwester are relying on brain-based learning theory to take advantage of the growing body of evidence that neurologists are uncovering about how humans learn. He says, "To learn more about the brain, scientists had to discover how to perform intricate studies that would provide solid information on its most basic operations—the normal and abnormal actions of a single neuron, the synchronized actions of networks of neurons, and the factors that trigger neuronal activity."

It's clear that no two human brains are alike. Every nerve cell (neuron) serves as a relay station. Neurons not only receive signals from other cells, but they also process the signals and send them on to other cells across tiny gaps called synapses. Chemicals called neurotransmitters (there may be as many as 100) cause the signals to flow from one neuron to another. That electrochemical process is the basis of all human behavior. Every time we speak, move, or think, electrical and chemical communication are taking place between tens of thousands of neurons.

"As a nerve cell is stimulated by new experiences and exposure to incoming information from the senses, it grows branches called dendrites. Dendrites are the major receptive surface of the nerve cell. One nerve cell can receive input from as many as 20,000 other nerve cells. If you have 100 billion cells in your brain, think of the complexity! With use, you grow branches; with impoverishment, you lose them.

"The ability to change the structure and chemistry of the brain in response to the environment is what we call plasticity," says Marian Diamond, a neuroscientist and professor of neuroanatomy at the University of California at Berkeley.

The Gist

- ❑ The human brain's interconnections exceed the Internet's by an astronomical number.
- ❑ Educators are increasingly relying on brain-based learning theory.
- ❑ Imaging technologies such as MRIs are helping scientists understand memory, recall, and how the brain manages information and information overload.

As we might imagine, for a subject as vast and complicated as brain research and learning theory there are a variety of views. Some scientists feel that there are fundamental differences between learning and education. They insist that brain-based research on learning isn't the same as research done on education theory. They also note that many of the initial neurological inquiries into learning have been done on animals and that it's an iffy proposition to extrapolate from animals to humans.

But during the past 10 years, known as the Decade of the Brain, a number of scientists have been using new technologies such as Magnetic Resonance Imaging (MRI), Functional MRI (fMRI), and Positron Emission Topography (PET) scans. Those tests help scientists explore how human brains process memory, emotion, attention, patterning, and context—

A Few Brain Facts

- Weight: 3 pounds
- Shape: walnut
- Color: uncooked liver

The brain is divided into two hemispheres called the *cerebral cortex* (commonly known as the conscious thinking center), covered in a thin skin of deeply wrinkled gray tissue, and separated by the *corpus callosum*. That curved band of white tissue acts as a bridge between the two halves, shuttling information back and forth at such a rate of speed that for all practical purposes the two hemispheres act as one. With the exception of the *pineal gland*, every brain module is duplicated in each hemisphere—another of nature's creative duplication systems.

The areas lying beneath the corpus callosum make up the *limbic system*, the area that relates to the unconscious and yet profoundly affects our experience. Its job is to feed information upward to the conscious cortex. Emotions are generated in the limbic system along with many urges that direct our behavior and usually help in survival. Within this limbic system, are the

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- *hypothalamus*. and *pituitary glands*. Adapt the body to environment by constantly adjusting hormones.
- *amygdala*. Registers and generates fear.

Last, the *brainstem* carries information from the body into the brain and establishes general levels of alertness and such automatic tasks as breathing, blood pressure, and heartbeat.

A few additional terms are needed to understand the brain's physiology:

- *neuron*. The primary building block of the brain. Neurons carry electrical charges and make chemical connections to other neurons.
- *axons*. Long fibers (extending from the cell body) that receive messages.
- *dendrites*. Short fibers (surrounding the cell body) that receive messages.
- *synapses*. Tiny gaps between axons and dendrites (with chemical bridges) that transmit messages.
- *myelin* A sheath that serves as insulation and allows electricity to flow between the axons and dendrites.

The definitions come from Mapping the Mind *by Rita Carter.*

among other areas in this vast area of inquiry.

Renate Numella Caine and Geoffrey Caine, in their book *Unleashing the Power of Perceptual Change: The Potential of Brain-Based Teaching*, confirm the idea that our brains are whole and interconnected. "Even though there are a multitude of specific modules with specific functions, thought, emotion, physical health, the nature of our interactions with others, even the time and environment in which we learn, are not separated in the brain. They are not dealt with one thing at a time."

Says Edelman: "The nervous system behavior is to some extent self-generated in loops: Brain activity leads to movement, which leads to further sensation and perception and still further movement. The layers and loops between them are the most intricate of any object we know, and they are dynamic. They continually change. Parts of the brain (indeed, the major portion of its tissues) receive input only from other parts of the brain, and they give outputs to other parts without intervention from the outside world. The brain might be said to be in touch more with itself than with anything else."

There are several areas/topics that brain-based learning theories are examining. As we will see, they are interconnected in much the same way as our own complex neuronal groups.

Attention

It appears that the thalamus, in the center of the brain, plays an especially important role in attention. According to Sylwester, the thalamus is the "relay center between our sense organs and the cortex.... This process holds the important information within our attentional and short-term memory systems by ignoring the less important information, and thus seems to create the visual awareness we experience." Eric Jensen, author of *Teaching With the Brain in Mind*, points out that our bodies have high-low cycles of about 90 to 110 minutes. When students are at the top of those cycles, they're more attentive. At the bottom of the cycle, people's energy drops along with their level of attention. Jensen suggests that if educators and trainers "learn to ride with the cycles," they'll have fewer problems.

Renate Caine talks about the different types of motivators and what happens in our brains depending on the source of motivation. "When we encounter high stress in learning, there is a psychophysiological response to the threat, accompanied by a feeling of helplessness or fatigue. This type of response keeps people from using their higher order, more complex thinking, and creativity."

During high-stress situations, physiologically the information takes the primary pathway through the thalamus and amygdala and then moves into the cerebellum. Memorization of isolated facts can be accomplished under high-stress conditions, but higher order and creative thinking may be lost. We tend to respond with either a primitive mode of behaving or to rely solely on early programmed behavior.

In situations that may involve stress but in which we have a sense of control or choice, the physiology shifts. The primary path is no longer directly through the amygdala but through other paths of the cortex, the parts that are involved in higher-order functioning. Thus, we avoid a "knee jerk response."

Learning situations that are low stress favor reflection and analytic thinking. Says Renate Caine, "The thalamus, hippocampus, and cortex (where stored memories are housed and higher-level thinking takes place) are involved. With this system, you can translate factual elements and make connections. Furthermore, you can make inferences based on other things you know. That higher-order thinking includes synthesizing information and integrating it to come up with new ideas."

Context and patterns

"Without context, emotions, or patterns, information is considered meaningless. There's a tendency to try to form some kind of meaningful pattern out of our learning—this process seems innate," says Jensen.

He adds, "While the brain is a consummate pattern maker, intellectual maturity often enriches the process. PET scans indicate that a novice chess player burns more glucose (has to work harder) and uses the step-by-step sequential left side of the brain. A master chess player uses less glucose and engages larger patterns from the right side of the brain."

A lot of recent memory research involves pattern-making abilities. One study that has been replicated several times involves reading a long list of words to a subject. When the subject is asked to remember certain words on the list, an interesting thing happens. Let's say the list has 25 words strung together, including cake, cookie, sugar, train, candy, tree, car, dog. If asked whether the word *sweet* is on the list (it wasn't), most subjects say *yes* because of the words *cake, cookies,* and *sugar*. Interestingly, the same area of the brain that registered other words on the list lights up on an MRI.

That clearly illustrates the economy of brain-processing mechanisms. The brain makes a connection and generalizes even though the generalization might be wrong. One conclusion is that detail isn't efficient and generalization is, though not always correct. The brain doesn't have values; it's an information organ. It isn't an arbiter of values, of right and wrong. What we do have is a system that puts related events together in hierarchies and categories.

Geoffrey Caine states: "The brain-mind naturally organizes information into categories. We can generically call that 'patterning.' These patterns always involve interpreting information in context. There's a great deal of research to show that we learn from focused attention as well as from peripheral perception. When people are forming patterns, a lot of the information that brings the pattern together is peripheral or contextual information."

Emotion

The amygdala, an almond-shaped structure in the brain's center, seems most involved with emotions. According to Jensen, it has 12 to 15 distinct emotive regions and often exerts a tremendous influence on the cortex. "Information flows both ways between the amygdala and the cortex, but many other areas are involved in subtle emotions," he says.

"Making daily decisions based on emotions is not an exception; it's the rule," says professor Antonio Damasio, a neurologist at the University of Iowa, in his book *Descartes's Error: Emotion, Reason, and the Human Brain.* "While extremes of emotion are usually harmful to our best thinking, a middle ground makes sense. Appropriate emotions speed up decision making enormously."

Brain research shows that emotions and thought are deeply interconnected. In *Molecules of Emotion*, Candace Pert wrote that on the surface of every cell in the body are receptors that respond to molecules such as various peptides and neurotransmitters. Scientists used to think that those neurotransmitters were found only in neurons in the brain, but it turns out they're in every part of the body. When we have a thought, many of the peptides and neurotransmitters interact with cells throughout the body, and those interactions trigger what we call "the experience of emotions."

"Good learning engages feelings. Rather than viewing them as an add-on, emotions are a form of learning. Emotions also engage meaning and predict future learning because they involve our goals, beliefs, biases, and expectancies. Emotions drive the threesome of attention, meaning, and memory," says Renate Caine.

According to Daniel Schacter of Harvard University, author of *Searching for Memory*, there are two possible explanations for the way emotionally charged events are emblazoned in our memories. One is that stress hormones and chemical messengers, or neurotransmitters, are released at such times, which "tag" the event with special significance and give it prominence in the memory pathways. The other explanation for what are commonly known as flashbulb memories is that even though they don't need to be rehearsed or reiterated, they usually are. "People tend to discuss and go over the things in their lives that are important to them, and that strengthens the memory," says Schacter.

Renate Caine points out that the climate of the workplace is critical to the kind of product you're going to get. If we feel supported in that environment, the physiological effect is a slight increase in dopamine, which releases the right amount of acetycholine (another neurotransmitter) that stimulates the hippocampus. People with increased dopamine show improved episodic memory, working memory, verbal functioning, flexibility in thinking, creative problem solving, decision making, and social interactions.

Memory and recall

One of the most spectacular uses of recently improved imaging technologies such as CAT scans, MRIs, and fMRIs is to show the brain at work—thereby helping scientists understand memory, recall, and how we manage information and information overload.

"Memory is the ability to repeat a performance. In the nervous system, it is a dynamic property of populations of neuronal groups. Unlike computer-based memory, brain-based memory is inexact. But it's also capable of great degrees of generalization. Memory would be useless if it couldn't in some way take into account the temporal succession of events—of sensory events as well as patterns of movement," says Edelman.

Rita Carter, who wrote *Mapping the Mind*, says that new neural connections are made with every incoming sensation and old ones disappear as memories fade.

"Each fleeting impression is recorded for a while in some new configuration, but if it's not laid down in memory, the pattern degenerates and the impression disappears like the buttocks-shaped hollow in a foam rubber cushion after you stand up. Patterns that linger may in turn connect with, and spark off, activity in other groups—forming associations (memories) or combining to create new concepts.

"Little explosions and waves of new activity, each with a characteristic pattern, are produced moment by moment as the brain reacts to outside stimuli. That activity creates a constantly changing internal environment, which the brain then reacts to as well. That creates a feedback loop that ensures constant change. The loop-back process, sometimes referred to as neural Darwinism, ensures that patterns that produce thoughts (and thus behavior) and that help the organism thrive are laid down permanently while those that are useless fade. It's not a rigid system."

According to Carter, it seems that incoming information is split into several parallel paths within the brain, each of which is given a slightly different treatment depending on the route it takes. Information that's of particular interest to one side of the brain will activate that side more strongly than the other. You can see that happen in a brain scan: The side that's in charge of a particular task will light up while the matching area on the other side will glow more dully.

For More About the Brain and Learning

- ascd.org
- brainconnection.com
- cainelearning.com
- dana.org
- 21learn.org
- lern.org
- newhorizons.org/blab.html
- thebrainstore.com

Geoffrey Caine reminds us that when we can connect rote memory with ordinary experience, we understand and make sense of things and remember more easily. To transfer information effectively, we need to see the relevance of what we're learning.

Motivation

Richard Restak, a neurobiologist, writes in his book *The Brain:* "Learning is not primarily dependent on a reward. In fact, rats—as well as humans—will consistently seek new experiences and behaviors with no perceivable reward or impetus. Experimental rats respond positively to simple novelty. Studies confirm that the mere pursuit of information can be valuable by itself and that humans are just as happy to seek novelty."

Robert Aitken at the Vancouver British Columbia Community College points out that we choose to stay motivated. "One of the things becoming clear is that our brains have been built for survival. That hasn't changed in 30,000 years. If something helps us survive, we're motivated to learn.

"Trainers have to find ways to convince learners that this is vital to their survival. If we get an emotional buy-in then learning takes place."

We can approach motivation from several different points of view, says Geoffrey Caine. "The distinction is between intrinsic and extrinsic motivation. Intrinsic motivation has to do with what we want, need, and desire. It's deeply grounded in our values and feelings. Extrinsic motivation is often an attempt by someone else trying to make us want to do something. In terms of learning and creativity, we know there's a positive correlation between creativity and intrinsic motivation. When we're organizing information in our minds, the way we form patterns is deeply motivated by what we're interested in."

We have all heard the phrase *Use it or lose it.* That's the ultimate truth of the healthy brain's capability to learn, change, and grow as long as we're alive.

"The most exciting discovery about all of this work is that education should continue for a lifetime. With enrichment, we grow dendrites; with impoverishment, we lose them at any age," concludes Diamond.

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