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ABSTRACT

Theories of neuroscience are presented to demonstrate the significance of storytelling and narrative to education by relating brain function to learning. A few key concepts are reviewed to establish a common working vocabulary with regard to neural networks. The tensor network theory and the neurognosis theory are described to provide understanding of brain functions during learning. It is apparent that learning is based on previous learning, and that unless new information is related to preexisting student interest and knowledge, there will be no previously established neural network to which students can connect new extensions. Educators must work with the functioning of student brains, and not against it. They must recognize that the brain is structured, or "wired," to detect patterns and that there is an underlying impulse to take in information in symbolic form. Storytelling and narratives are a good way to encourage new connections and the recognition of new patterns and relationships among objects and ideas. An example is given in a description of students who learn the geography of West Africa through story-telling rather than through memorizing lists of facts and geographic details. (Contains 6 references.) (SLD)

STORY-TELLING AND NARRATIVE: A NEUROPHILOSOPHICAL PERSPECTIVE

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As Leslie Hart states, "The brain is the organ of learning." (Hart, 1983, p. 10) For this reason, we as educators have the responsibility to understand brain function. Theories of neuroscience presented here demonstrate the significance of storytelling and narrative to education by relating brain function to learning.

Overview of Brain Organization and Structure

In order to reveal the relevance of neuroscience to education, we must first establish a basic level understanding of the brain's organization and structure. Both the complexities and sheer volume of material available from neuroscience regarding brain function cannot be addressed in this cursory summary. Instead, I will present and review a few key concepts in order to clarify a common working vocabulary that will be useful for this meeting.

At the organ level, our brains are composed of three basic parts. The first is the brain stem, also known as the reptilian brain, because it resembles the entire brain of a reptile. The brain stem regulates basic bodily functions such as heart rate and breathing, and determines the general level of alertness of a person. (Ornstein, 1984) For example, when danger is sensed, the brain stem places the human response system on alert, preparing for fight or flight responses. The second major part of the brain is the 'old mammalian' brain which is composed of the cerebellum, or little brain and limbic system. The major function of the cerebellum is the coordination of muscle movement, while the limbic system coordinates emotional functioning. Blood sugar levels, body temperature, heartbeat rate and other bodily functions are effected in emotional reactions. The limbic system adjusts these bodily functions in response to our emotional states. (Ornstein,

1984) By far the most significant part of the brain for eoucators is the "new mammalian brain" or cerebrum. Virtually all learning occurs in this part which is responsible for organizing information, remembering and sorting data, communicating our responses to incoming stimulus, and understanding and creating our worlds. (Hart, 1983) The attributes which we often claim make us uniquely human (language skills, decision making, the exercise and expression of free will or self) all find their source in the cerebrum.

Neurons and Neural Networks

At the cellular level, we find that the basic cell of the brain is the neuron. Neurons serve as variable switches which are triggered via electrochemical reactions. These electrochemical reactions cause the neuron to "fire" or "not fire" at different levels depending on impulses received. These firings are, in turn, parts of the chain reactions through which the brain operates, and interprets the world. The results of these chain reactions of neural firings constitute brain functioning: the physiological aspects of the activities we name as conscious and non-conscious, subconscious or unconscious, are all controlled in this manner.

A neuron is composed of a nucleus which resides within the cell body, dendrites which receive input in the form of electrochemical stimulation from other neurons, and axons which relay information from one neuron to another. Although the roles of axon and dendrite are not exclusive, generally, axons relay the output, while dendrites receive input. (Churchland, 1988) The point where dendrite meets axon and electrochemical impulses are transmitted is called a synapse. Synapses therefore represent the crucial points of communication between neurons. (Churchland, 1988)

There are three classes of neurons grouped according to function: Sensory neurons, motor neurons, and interneurons. Sensory neurons translate sensations or stimuli entering the body as electrochemical impulses while motor neurons cause muscle contractions resulting in movement. Interneurons are an eclectic group which encompasses the remainder of neurons. These neurons take on a variety of functions by relaying information from neuron to neuron, thereby producing the recognizable patterns of brain function and activity. (Churchland, 1988)

Looking at the individual neuron as it meets another provides a deceptively simple diagram from which we can begin to understand brain function. Feeling a sense of familiarity with this process, we may be tempted to imagine brain function as a single train of electrochemical impulses moving from neuron to neuron. However, the complexity of the human brain cannot be grasped so easily. The same process of synaptic firing takes place in neurons from the earthworm to the human being, and yet ... At some point, brain functioning makes a quantum leap wherein a change in number constitutes a change in kind. The brain functions at a speed which cannot be accounted for within a linear model of neuron relationships, and simple multiplication of single firings of neurons will not account for the complexity of our thinking processes. This difference may be accounted for through understanding of neural networks, the patterns formed by the firing of neurons. Stated simply, a neural network is a collection of neural cells. These networks are constantly coming in and going out of formation in the brain in a never ending symphony of sounding and resounding.

A metaphor from computer technology is useful here. The speed at which the brain functions indicates that the processing of information is similar to 'parallel' processing rather than the more traditional linear processing. Traditional digital processing in computers requires linear movement through a system of check points. Each point must be accounted for during processing until a pattern is recognized. The computer begins at a starting point and moves through a software program, interpreting flag posts such as "If x, goto end/ if not x, goto next." This type of processing is slow in comparison to parallel processing. Parallel processing makes use of vectors: input and programs are coded so that multiple switches are read simultaneously allowing a pattern as a whole to be recognized more quickly. Neural networks can be understood as organic parallel-type processors which allow the brain to handle massive input at a phenomenal rate. Thus, the parallel processing metaphor allows us to come closer in our imaginations to perceiving the magnitude and structure of brain functioning using neural networks.

There are two theories which I find most helpful in understanding the patterns and linkages formed in neural networks: the Tensor Network theory and the Neurognosis theory.

Tensor Network Theory

Patricia Churchland presents the Tensor Network theory in her book **Neurophilosophy: Toward a Unified Science of the Mind Brain**. This mathematical description of neural networking illustrates the firing of neurons in time and space. She explains: "A tensor is a generalized mathematical function for transforming vectors [generally conceived of as arrows of specific length and direction within a Cartesian coordinate system] into other vectors, irrespective of the differences in metric and dimension of the coordinate systems... The hypothesis is that the connectivity relations between a given input ensemble and its output ensemble are the physical embodiment of a tensor." (Churchland, 1986, p. 418) Thus, according to this theory, networks are viewed as paths or connections through which a particular stimulus (or vector as defined within one grid of coordinates) is translated, or reinterpreted, into the terms of another grid of understanding. For example, there are four distinct kinds of receptor cells on the tongue which limit the variety of taste responses available. Taste will therefore fall somewhere within the "grid" or coordinate system formed by the potential response of these four types of receptors. (Churchland, 1988) A more complicated example is the everyday occurrence of recognizing a friend. The stimuli of seeing and hearing a friend registers a particular pattern in the neural networks of the brain. This pattern is recognized by the brain and translated as my friend, "Opal" because of its appearance as the vector which corresponds to "Opal." According to the Tensor Model, the neural networks respond "as if" the stimuli recorded as "Opal" occurred as the particular vector.

The tensor network theory runs the risk of being taken too "literally." The brain is not set up in a grid-like fashion, but the use of vectors and grids makes it a little easier for the mathematically fluent among us to imagine how patterns are recognized in the brain. It is important to remind ourselves that while there is not a literal grid in which vectors are recorded, there is a range of possible stimuli to which the brain can respond. Nonetheless, the organization of the brain is much more fluid and flexible than this metaphor may lead us to imagine.

Neurognosis

The second theory of neural networking is that of Neurognosis. Laughlin, McManus and d'Aquili present this theory in their book, **Brain, Symbol and Experience**. This theory is based in a "biogenetic structuralism" which understands the mind and brain to be two levels of the same reality. "Mind is how brain experiences its own functioning, and brain provides the structure of the mind." (Laughlin, McManus, & d'Aquili, 1990, p. 11)

The term neurognosis refers to both the initial and subsequent organization of a neural network. The initial organization of a neural network is largely a product of genetic coding, while "subsequent organization is influenced by factors external to the neurons' boundaries including [their] interactions with one or more neural networks." (Laughlin, McManus, & d'Aquili, 1990, p. 35) In fact, as Laughlin points out "the development of nerve cells appears to be motivated by an imperative to be active, and to reach out and communicate with other cells." (Laughlin, McManus, & d'Aquili, 1990, p. 52) Thus, our neurons have a genetic imperative to form and move in and out of networks. In this way, most neurons do not function independently and randomly, but instead, form connections with other neurons, and thereby form and connect with neural networks.

Significantly though, neurons tend to form clusters or linkages with other neurons in networks in a set order. It is as if neurons establish relationships with other neurons and prefer association with these familiar neurons over unfamiliar neurons. These connections are called entrainments. Although the term entrainment may imply linearity in neural relationships, it is crucial to note this is misleading. Emphasis must be placed upon the dynamic, parallel and multiply-associative nature of neural networks.

Over time, the patterns formed by these entrainments may eventually become 'canalized' in the brain. For example, the network formed by neurons B, F, J and D may become habituated in the brain as a result of repeated firings, as if these neurons seek one another out in order to continue their relationships. This process of habituation has been termed canalization, representing a tendency of neurons to fall into particular formations or non-linear canals.

Eventually canalized linkages of neurons may experience automatization, and recede from conscious control. At this point, the canalization becomes somewhat more rigid, and occurs "automatically." Laughlin and co-authors state, "When a network has developed sufficiently to provide for an activity without conscious control of information, that function is relegated to the [non-conscious] network and will be disentrained from conscious network." (Laughlin, McManus, & d'Aquili, 1990, p. 99) A common example which begins well within conscious control is driving a car. At first, the motions and coordination of this complex task requires constant attention and concentration. Later, however, such careful attention may actually inhibit the performance of the task. Race car drivers, for example, must learn to respond automatically to the demands of operating their car. The conscious network is much too slow to respond to the changing conditions of the race track.

Thus, learning, according to this model, is the activity of forming novel multiply-associative neural entrainments and habituating or canalizing these new relationships. The flexibility of neurognosis in forming new entrainments allows the incredible variety of human mental experience. Yet there are limits. "Neurognosis determines to a large extent what can be learned, in what form it can be learned, and how fast and how much of it can be learned" (Laughlin, McManus, & d'Aquili, 1990, p. 61) It is important to note that this biogenetic structuralist account places structural organization over function. As learning occurs, the structure mediating behavior is changed or altered allowing for the subsequent change in behavior. (Laughlin, McManus, & d'Aquili, 1990) Stated as a principle, "for every event in consciousness, there is a corresponding and causally interrelated physiological event." (Laughlin, McManus, & d'Aquili, 1990, p. 94) Until the neural entrainment structure exists to support any particular set of conclusions and reaction to stimuli, those conclusions and reactions will not be produced. Although seemingly tautological, the importance of this statement lies in establishing the primacy of the structure. Without the structure, the function will not be realized. The process of neurognosis leading to canalization and eventual automatization is metaphorical of the learning process itself. The role of neurognosis in brain functioning is to produce learning. Forging new connections and generating new entrainments is at the heart of the learning process, but this cannot occur without linkages to previous entrainments which form the basis of the pre-existing structure.

This is an important lesson for educators, because it reminds us that all learning is based on previous learning. Nonetheless, this does not mean that students must take colonial history before contemporary history, or geometry before algebra II. It means that unless and until we relate new information to pre-existing student interest and knowledge, there will be no point of entry; no previously established neural network onto which students can connect or "hang" new extensions. We may cause previously unconnected neurons to meet for an instant, but if we do not link these new connections with more established neural networks, these connections will be very short-lived.

Laughlin, and co-authors cite the existence of a "cognitive imperative," or epistemic hunger as the motivation for the brain/mind's building of entrainments and neural networks. This "fundamental drive in the functioning of neurocognition to complete the cycle from stimulus input to evocation of models and appropriate attribution or action related to the stimulus" is the magnification to larger scale the genetic propensity of neurons to seek out relationships. (Laughlin, McManus, & d'Aquili, 1990, p. 166)

We are "wired" to receive stimulus and to process the stimulus into out[illegible], to recognize patterns, and generate responses to our world. Through a process Laughlin and co-authors call homeomorphogenesis, human "experience is [at base] symbolic because the system that generates the experience processes only symbolic material" (Laughlin, McManus, & d'Aquili, 1990, p. 245)

As educators, we need to keep this epistemic hunger in the foreground of our endeavors to educate our students. Too often, we present distillations of information and have the conclusions already drawn for our students. Instead of working with the operation and function of our students brains, we often work against this functioning. We present the pertinent facts already extracted from context in order to simplify the material for our students. Within this pedagogy, there is no need for students to engage in pattern detection, for the challenges have already been removed. There is no need for them to "complete the cycle" and respond to the stimulus we present. For example, repeating back "the seven causes of the Civil War" requires no personal engagement with curriculum content. Once we understand that the brain is "wired" to detect patterns and that there is an underlying impulse to take in information in symbolic form, we also see that our students are already prepared to do the difficult tasks of determining which are the pertinent pieces of data and which are not. Learners arrive in our classrooms fully capable of complex thinking. Our job as teachers is to present challenges which will continue to engage the interest and stimuli processing structures of our students. The desire and impulse to identify and classify connections between stimuli has been "wired" in. As Leslie Hart reminds us, "the learning process is incessant and individual." (Hart, 1983, p. 16).

In "real life" outside of the classroom, learners are continually extracting patterns from the confusion. Th ; brain operates on the basis of symbolic information. Stimuli is taken in by sensory neurons and translated as electrochemical impulses to be passed through the network, triggering a reaction. As we have seen, the brain's area of expertise is pattern detection and relating various kinds of stimuli to one another. We, as educators should take advantage of this operation in encouraging learning and not force the learner to "learn" or accept connections with very little stimuli. Often, in our classrooms, we eliminate distractions, terminate all talking between classmates, and focus attention on a single speaker. We then present distillations of course material in isolation from their significance. We attempt to make students memorize lists of information which may contain the kernels of pertinent information, such as a list of the capitals of major nations and their chief exports. We extract the "facts" from the plethora of information, in an effort to clarify the "important" information for our students. Conversely, it seems, that an understanding of brain function indicates we would better enable students to learn if we presented masses of information and allowed the learner to detect patterns.

Storytelling and Narratives

Storytelling and narratives are one excellent way of accomplishing this task. One of the brain's best tricks is to extract meaningful patterns from confusion. One of our chief concerns as educators ought to be encouraging new connections and the recognition of new patterns and relationships among objects and ideas.

A pertinent, personal and useful example to demonstrate the importance of story-telling to the learning process can be found in geography. As Americans, we are one of the least educated of the developed nations in regard to geography. I validate this every year by asking my students how much they know about world geography. Consistently, they know little to nothing about Asia, Africa, South America and the Middle East, slightly more about Europe, and a little more still about North America. In our schools, children are presented with lists of cities, rivers, and mountains to memorize and locate on maps. Taken out of context, these names and dots on maps are obviously trivialized and irrelevant to our students. Today, they, much as I did before them, 'cram' these bits of inconsequential data into short-term memory, just long enough for the exam, to be promptly forgotten.

Compare this scenario with which we are all familiar, with students who learn, for example, the geography of West Africa through story-telling. Rather than a dry and decontextualized list of nations and capitals, the students are shown a wide variety of materials from that region and are presented with tales from those who have lived or traveled in Western Africa. A student interested in clothing might be able to recall the geography of the region by 'hanging' the knowledge 'on the mental hook' of fabrics and couture, connecting to and extending previously established neural networks. The unique dress and colors of West Africa would provide an entry to understanding its peoples and geography. Within the brain, in some fashion, his entrainments regarding West African geography might very well begin with his previous knowledge of clothing in general, move to this particular region's costumes and then lead to other facts, including those deemed "important" to the official curriculum and testing. The student next to him though, while hearing the same stories and responding to the same stimuli regarding West Africa, would most likely use an entirely different set of 'mental hooks' or neural networks to capture both the "important" information along with more personally relevant facts about West African food, music religion, etc... what ever parts of the story appealed to her and could be linked to her previous knowledge.

In this way, through narrative, students come to know and understand West Africa as significant to their own lives, though West Africa remains thousands of miles away. These aspects will stay with the students much longer than any list of facts temporarily stored away for regurgitation on a near-future test. Appealing to each students unique hunger to learn by presenting a broad menu of possible "hooks" or connections with pre-existing neural networks, storytelling makes education fun and significant for students, and facilitates true and lasting brain-compatible learning.

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