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ABSTRACT

This paper describes three models of brain function, each of which contributes to an integrated understanding of human learning. The first model, the up-and-down model, emphasizes the interconnection between brain structures and functions, and argues that since physiological, emotional, and cognitive responses are inseparable, the learning context is important to learning outcomes. The second model, the side-by-side model, is based on the differences between the two cerebral hemispheres. Central to this model is the idea that the way the two hemispheres work together to produce a unitary understanding of experiences, or the way they fail to cooperate, may account for individual differences in learning. Since balanced instructional practices have a greater potential of reaching a variety of individuals in any classroom, it is recommended that learning experiences include both visuo-spatial (concrete) and verbal (abstract) components. Finally, the connections model of the brain function suggests that neurochemical connections within the brain encode experiences and that those patterns of connections are responsible for understanding. The process of making such connections is seen as a generative action by which people make decisions regarding their learning and behavior. (Author/MP)

Brain Functioning Models for Learning

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Brain Functioning Models for Learning

Brain Models

The idea of using models to explain what the brain is, how it functions, and what processes it controls is not new. In the past, the brain has been described as a bellows for air or a pump for blood. The phrenology fad of the late 1800's attempted to locate personality traits supposedly localized in the brain by careful analysis of bumps on the skull. Improved technology has changed the metaphor we use for the brain. We now have the telephone, television, automobile, and computer as metaphors or models. In fact, each of the models reflects partial explanation of complex neural operation. The brain is central to respiratory and cardio-vascular functioning. Some specific areas of the brain are highly implicated in certain abilities. The brain's rapid processing and responding does make the computer an easy analogy.

Oversimplification, then overelaboration, of such models renders each of them untenable. Recent research in many of the fields of neuroscience has resulted in a new set of models which are based on brain functioning. Three complementary models from neurological research and theory appear to have particular relevance for learning and teaching. (Languis, Sanders, and Tipps, 1980). Each of the three models helps increase comprehension of the complex interrelated systems that affect learning:

1. Up and Down or Evolutionary and Reticular Activating System Models
2. Side-by-Side or Hemispheric Brain Models
3. Making Connections or Program of the Brain Models

Some brain anatomy and physiology will be discussed as part of the three models; however, description of the neural structure goes beyond the scope of this presentation.

Up and Down Models

In the 1950's Stellar presented one of the first up-and-down models of the brain. He viewed the cortex as possessing a steering function for behavior and the midbrain having a starting/stopping function. An automobile steering wheel might represent the cortex and brain stem while the accelerator and brake pedal would be the limbic system. Though simplistic, the model broke with prevailing notions of the cortex as the sole executive of the neurological system.

Stellar pointed to the important ascending and descending communications between brain structures and pivotal role of the limbic system in deciding the actions of the brain and the body. MacLean (1978) called his more complete up-and-down model the triune, or three-part brain. In relating the old brain stem, middle limbic system, and new cortex, he found that the developing complexity of the human nervous system parallels that of animal brains on the lower to higher phylyogenetic scale.

The brain stem of the human brain, which MacLean called Reptilian complex (R-complex), resembles reptilian brains in structure and function. The R-complex handles primary survival instincts: obtaining food, finding and guarding territories or homesites, ritual courting and mating, and social routines such as greeting and migration. MacLean suggests that humans often also respond unconsciously to the calls of the R-complex. Regular seats at the dinner table serve to remind us that humans also have social routines. Lower brain structures control automatic life support function and may dictate specific social behaviors which preserve the species. While lower animals may live their whole life under the influence of their instincts, animals higher on the phylyogenetic scale have higher structures which allow a greater diversity of behavior. Humans are strongly influenced by higher brain functions of the limbic system and cortex.

The limbic system includes a number of complex neural structures--thalamus, hypothalamus, hippocampus, etc. The limbic system regulates internal body state through hormones released into the blood stream and through nerve connections both higher and lower in the nervous system. With hormones, the brain automatically adjusts body function to respond to different situations and activities. When a person runs, the heart speeds up, respiration increases, and body temperature is controlled through perspiration. Hunger and thirst activate drives to satisfy needs. Danger or threat floods the body with hormones that temporarily increase alertness and strength. Physiological reactions to exertion, thirst, and fear differ only slightly from the physiological reactions that accompany emotional responses to a wide variety of situations. Homeostasis is a major responsibility of the structures in the midbrain.

Another function of the limbic system, relay of sensory information, is related to the cognitive functioning of the hemispheres. Information from the sense organs are relayed through the spinal cord and brain stem and dispatched by the limbic system to general and specific areas of the neo-cortex. MacLean's so-called "new brain" enables humans to decide how to respond to situations, use language, plan for the future, and look consciously at those thought processes. Whether sensory information reaches the neo-cortex for such processing seems to be determined by the reticular activating system (RAS).

The reticular activating system is another up-and-down brain model which emphasizes the interconnectedness of MacLean's triune brain. Within the brain are groups of cell clusters (nuclei) which form the RAS. The RAS plays a crucial role in determining which environmental stimuli arouse an individual, focus attention, and result in experience and action. Some incoming sensory signals pass through the RAS to higher brain centers but other are stopped. This is called a gating function. Recent research suggests reciprocal connections, perhaps a kind of feedback loop, between the planning function of the frontal lobes of the brain and the RAS. General arousal appears to be an underlying process which involves virtually all brain structures in the ascending and descending RAS network. (Young, 1978)

If the selective gating of the RAS did not occur, humans might drown in a deluge of sensory stimulation. A response such as removing a finger from a hot stove may need only the reflexive motor control low in the nervous system. Adjusting to heat or cold requires the higher level activity of the midbrain homeostatic mechanism. Confrontation with new information calls on the associative capacity of the cortex. Rowe (1978) suggest that the importance of discrepance or surprise in classroom settings is due to its ability to open the RAS gates.

The up-and-down models of the brain agree that the function of higher and lower structures are interrelated. Maslow's hierarchy of needs is a familiar schema that parallels the hierarchy of brain-behavior relationships. The lower brain is concerned with physiological and safety needs to survive. The middle brain and limbic system is concerned with emotional and social well-being and equilibrium. The highest structures are concerned with knowing, being, and consciousness.

The up-and-down models suggest that brain function is integrated. Arousal, sensory relay, emotional reactions, and thinking are intimately interrelated. The whole-brain concept supports the whole-person concept. Physical, emotional, social, and cognitive are convenient labels for aspects of human development but are inseparable when dealing with individual human beings. The limbic systems central location and its emotional function may be a particularly crucial idea from the up-and-down brain models. How the limbic system performs its co-ordinating function may be very subject to the emotional climate. Play has a highly posistive affaective quality and may enable humans to experience more, learn more, and create more then learning modes with neutral or negative affect. Tipps (1981) compated several developmental play theories to neurological development to posit a reciprocal relationship between play and brain development.

Side-by-Side Models

The bilateral symmetry of the brain suggests another view of brain functioning. The hemispheric model began with Broca's work in the mid-1800's with stroke and brain damage patients. He found that language deficits were associated with damage to the left hemisphere.

Work by Sperry and his associates in the early 1960's provided dramatic evidence that two separate thinking systems characterize cortical functioning (Sperry, Gazzaniga, and Bogen 1969). The hemispheres are joined by a communication network of neural fibers; the corpus callosum is a major connecting structure. The corpus callosum of each of several epileptic patients was surgically cut to prevent transmission of electrical disturbance, which characterizes epilepsy, from one side of the brain to the other. Since the hemispheres of the brain are connected to the opposite sides of the body for sensory input and motor control, most information presented to the left ear, left hand, and left visual field of each eye goes to the right hemisphere and vice versa. For the split-brain patients, the information sent to one hemisphere could not travel across the corpus callosum to inform the other side of the brain. One side of the brain and its half of the body did not know what the other half was doing.

Ingenious experiments were used by the brain investigators to examine the special abilities of the two hemispheres. For example, in one such experiment, the subject was given objects to feel separately with either the right or left hand. The subject's own hands and the objects to be felt were shielded from the subject's eyesight. When the subject's left hand (right hemisphere) was presented a cut-out numeral to feel, the person could indicate the value of the numeral with fingers, but only with the left hand. When the subject was to name the object or show the value with his right hand (left hemisphere) the person could only guess. Even though the right hemisphere could not verbally describe a cup presented to the left hand, it could find the cup, again tactually.

The right hemisphere was mute but not ignorant, as had sometimes been thought.

In another study Levy, Trevarthen, and Sperry (1972) had split-brain subjects memorize the pictures and names of eight persons. The subjects then were asked to identify pictures which were actually combined halves (chimera) of two of the faces already associated with names. Subjects watched a dot in the center of a screen. Then a chimera picture was flashed for a fraction of a second--too short a time for the eyes to scan across the picture. When asked to identify the person's face by pointing, subjects found the face which had occupied the left visual space (right hemisphere). However, when subjects were asked to name the face they had seen, they named the person seen in the right visual field, information that had been received by the left hemisphere.

Investigation in dozens of studies discovered a pattern of strengths demonstrated by the two halves of the brain. They found in a majority of people the left hemisphere tends to operate as an analytic specialist, a detailed and sequential builder of ideas, and is best able to store or retrieve information in a part-by-part coded form such as words. The right hemisphere in most people tends to work as a specialist in understanding an entire idea, filling in the necessary missing gaps, and is prone to store or retrieve information in a spatial manner such as pictures or images.

The importance of split-brain discoveries might have been limited if work had not also been continued with people having an intact corpus callosum. To assess hemispheric processing in normal adults and children, experiments were devised in which individuals were asked to respond to stimuli presented simultaneously to the two hemispheres via contralateral connections from the right and left hand, right and left ear, or right and left visual half-field. These research techniques imply that simultaneous presentation to the two brain hemispheres will cause competition between them and that the hemisphere which has a thinking style best suited to the task will perform better. (Note: For a comprehensive review of this data see Wittrock (1978), Chall and Mirsky (1978), and Rectak (1980).)

Kimura (1966) employed a dichotic listening technique in which competing signals were directed simultaneously to each ear. When numbers were used as stimuli, the left hemisphere/right ear was more accurate. However, when environmental sounds were used, the right hemisphere/left ear was more accurate (Knox and Kimura 1970). These findings point to the verbal speciality of the left hemisphere while suggesting auditory input of less verbally coded information is handled best by the right hemisphere. Witelson (1977) used the sense of touch in dichaptic tests. When right-handed children reached into a curtained box and explored irregular shapes with fingers of each hand, the left hand was more accurate at identifying shapes; again supporting the spatial strength of the right hemisphere consistent with the split-brain findings. The electroencephalogram (EEG), another research technique, records and analyzes brain waves while individuals perform tasks. EEG studies show that while a subject is doing a verbal task such as writing a letter or taking notes, alpha waves (which indicate brain idling) are more prevalent in the right hemisphere and beta waves (which indicate higher level cognitive processing) are more prevalent in the left hemisphere. During a spatial task, such as constructing a block design, the pattern of brain waves is reversed (Galin and Ornstein, 1975).

All these studies could be and sometimes have been misinterpreted to mean language is a completely left-brain activity or art is an entirely right-brain one. This dichotomous interpretation misses the point of hemispheric brain functioning--differences in processing. The two hemispheres extract different aspects of meaning from the same experience. In appreciating a painting, both overall color and contour and specific features are assessed. Music has a recognizable melody even when details such as key and tempo are changed. Mathematics uses specific symbols and linear operations to express relationships between abstract ideas.

The two hemispheres generate unitary inner experiences by providing two points of view on external experiences. The corpus callosum and other connections allow interhemispheric communication for comparing and evaluating the knowledge of each side. People engage the analytic and emotional, verbal and visuo-spatial, sequential and simultaneous modes. The mode actually used depends on many variables. Personal preference or intention, salient features of experience, instructions, habitual reliance on one type--all may determine which processing style takes the lead. One side may dominate the reception and the response without the check and balance of complementary processing. Integrated experience for meaningful learning is one clear educational implication of the hemispheric model.

What educational practices encourage the learner to create two-sided meanings of experience? A balanced curriculum and instructional program ask the learner to derive both relational understanding and verbal labels. When children manipulate puzzles, they discover how the shapes fit together. Describing the parts may help children recognize and relate different parts. The labels and the shapes work together to create a meaningful product. Likewise, manipulation of beads and pegs contribute to understanding of number concepts. "Five" is a paltry label without understanding of "fiveness." Science offers the teachers and child many opportunities to explore materials, patterns, and relationships in the world. Balancing visual and auditory input with tactile stimulation appears to be one way to encourage two-sided knowledge. Exploratory, hands-on play has been advocated by early childhood philosophers, psychologists, and practitioners, but may also be important for adolescent and adult learners. Understanding how the two halves of the brain integrate experience provides additional support for play as an important contributor to learning.

In addition, the side-by-side model provides a foundation for a new appreciation and assessment of individual differences. Differences may arise from: (1) predominant processing styles of individuals and their ability to adapt processing appropriately, (2) experiences that enhance or inhibit integration of processing, (3) dynamic interaction of processing styles and experience. Recognition of individual and group differences based on hemispheric processing should lead to broader definition of intelligence and learning. Verbal measures may not tap the broad range of knowledge which children and adults have. Just one example is preliminary research which suggests imagery as an important factor in learning and memory.

Making Connections: Programs of the Brain

The inner workings of the brain that result in behavior provide another set of questions, research directions, and models of brain functioning. Hebb (1949) suggested that pathways connecting certain cells are strengthened by experience resulting in cell assemblies. In the thirty years since Hebb's work, the idea of connection in the brain has been pursued in two ways. Neurochemistry deals with actual neuronal linkages and describes the function of neurotransmitters in facilitating or inhibiting brain connections. The other approach suggests programs of behavior resulting from neuronal operation. The two approaches provide a microcosmic and a macrocosmic view of how functional connections and patterns are established in the brain.

The micro-structure of the brain hints at the intricate and complex nature of neurochemical connection. In addition to cells found in all tissue, two distinctive types of cells are found in the brain: neuron or nerve cells and glial cells. Neurons act on one another electrically and chemically and interact with glial cells, possibly exchanging nutrients as well as ions.

A synapse, the point of interaction between neurons, is actually a gap between the sending mechanism of one cell and the receiving mechanism of another. What is exchanged at synaptic sites are neurochemical transmitter substances including hormones, enzymes, and peptides. Advanced technology in magnification, photography, and computer analysis allows investigation of the powerful effects of transmitter substances on behavior. Such studies yield: (1) knowledge about specific substances and their function in the nervous system, (2) understanding of the ways in which drugs work to mimic or interrupt natural neural processes, (3) insight into the complexity of actions and interactions of structures and substances in the brain.

Complexity of neural connections points not only to intricate neurochemical interactions but also to the immense number of cells. Each of the approximately twelve billion neurons in the human brain has up to five thousand synapses. The number of possible interconnections in the brain is larger than the number of atomic particles in the universe (Thompson 1975). All growth, structural development, and functional activity involves either transmission or change in the myraid chemical connections. Clearly meaningful brain activity in the usual sense does not occur when one neuron fires: neither does brain functioning characteristically involve activity in all the billions of neurons. Instead, neurons seem to be activitated in groups and sequances in some probabilistic or statistical manner.

The processes associating neurochemical connections with behaviors have been compared to computer programs or telephone switchboards. Such hard-wired programs might be appropriate for describing instinctual responses of the lower brain, but they are limited for describing individuality in learning and thinking. Hebb's cell assemblies link experiences, neurochemical function, and behavior in an early model of brain programs. Thus, Hebb's model marks movement from an inert to a dynamic model of brain function.

In Hebb's model, varied and associated experiences result in networks of related cell assemblies. These cell assemblies make generalized responses possible; for example, people learn many forms of triangles, chairs, and friendship by recognizing defining characteristics. A closed figure with three sides and three angles can be equilateral, right, or obtuse; however, each is a triangle. A chair has physical properties and functional characteristics and is part of an elaborate classification system--furniture. Friendship is even more abstract and is learned after varied experience. People learn to recognize, differentiate, and respond appropriately to thousands of events and "ideas" which are neurochemically formed programs.

Prosters, Hart's (1975) version of programs, serve as templates that the brain uses as it quickly scans its repertoire. Main features of a current experience are compared with existing prosters. When the two match, response is practically automatic and unconscious. Expectations that are met do not require adjustments; however, events that have no pre-existing proster events cannot be matched. Hart stated that the brain's ability to deal with newness is impaired under threat or extreme emotion. The reticular activating system downshifts to older, lower pre-programs that prevent new connections and learning.

Memory becomes important in the concept of brain programs. What is memory and where is it? Pribram (1971) speculated that memory works like a photographic hologram in which experience is stored throughout the brain. As early as 1935, Lashley suggested that no evidence exists for localized engram storage in either of the menispheres. Meyer and Meyer (in press) pursued this notion of 20 years of comparative experimental animal studies. They stated that efforts to "bake, burn, freeze, and cut" memories from the cortex have failed and that no injury through which the individual can survive destroys memory completely. They proposed the hypothalamus in the limbic system as a likely site of storage and stressed that damage to the cortex results in loss of ability to retrieve the memory, not in loss of the memory itself.

Despite the difficulty of locating the site of the memory, Young (1978) suggested that the effects of coded and stored memory are evident in all human behavior. He proposed four levels of brain programs which "are a most intricate set of plans and arrangements . . .which have been constructed from influences, some recent, some from long, long ago (p. 11)." DNA genetic preprogramming determines individual characteristics such as hair color and body shape. Evolutionary characteristics of the species, including brain structure, represent another preprogrammed level.

The ability to learn from experience is a dynamic program which allows planning based upon goal-directed, selective, and intentional programs. Finally, while other animals have capacity to learn, only people have developed access to cultural and historical programs or memory outside the body. Recorded thought from cave drawings to computer storage capacity provides resources for choosing action with a prespective beyond the present.

Young stated that his model is hypothetical, but he was certain of four elements of brain programs:

1. The brain responds to uniquely human characteristics such as the human voice and facial configuration.
2. The brain establishes and uses elaborate abstract coding systems such as language, mathematics, and the arts to represent experience.
3. The brain deals with the world systematically.
4. The brain works as an integrated whole.

Infancy research in the past two decades has done much to support Young's first premise. Human infants come equipped with rudimentary skills which distinguish them as active learners able to recognize patterns and use them to achieve their ends.

The strongest message to educators from the connections or programs model of the brain is that learning is a generative process (Wittrock, 1981). Individuals construct meaning through patterns in their environment. Development and memory of patterned ideas are enhanced through multiple experiences in a variety of contexts rather than simple repetition. Wittrock believes that what we learn depends on the "intentions, dispositions, sets, and memories we bring to a situation" (p. 12). Learning in the connections sense is not random response to the world but the desire and ability to create meanings and use them.

Conclusions

Three models of brain functioning have been described because each contributes to an integrted understanding of the brain and how humans learn. The up-and-down model emphasized how brain structures and functions are interconnected. Physiological, emotional, and cognitive responses are inseparable because that all areas of the brain are engaged in sensing, feeling, and thinking. Therefore learning context is very important to learning outcomes. The side-by-side model is based on the differences in processing styles of the two cerebral hemispheres. How the two processing models work together to produce a unitary understanding of experiences, or how they fail to co-operate, may provide important clues to individual differences in learning. The recommendation from the hemispheric model is that learning experiences include visuo-spatial (concrete) and verbal (abstract) components. Balanced instructional practices have a greater potential of reaching the variety of individuals in any class. Finally the connections model of brain functioning suggests that neurochemical connections encode experiences and that those patterns of connections are responsible for understanding. The process of making connections is seen as a generative process by which people make decisions regarding their learning and actions.

The brain is believed to be both a source and an instrument of humanity. Many questions which have been asked about human nature have not been answered by neuroscience thus far. Neurophychological research can never answer questions apart from a broader context of human behavior. But educators who deal with learners everyday have much to gain by being brain-wise; by remembering that the primary program of the brain is becoming human. Only other humans can provide the examples of communication, cooperation, and caring which are essential to being human.

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