The brain and accelerative learning

James D. Hand

The relationship between various types of brain functions and learning has interested educators for the past 15-20 years. Memory appears to be a phenomenon widely spread among cortical regions. Both short-term and long-term memory storage are discussed. Attention is being paid to left and right hemispheric functions as well as to MacLean's concept of the triune brain. Educators have sought, in recent years, to apply brain research findings in schooling. Suggestions are offered both to students and teachers, based upon the research and theories discussed here.

Opvoedkundiges hou hulle die afgelope 15-20 jaar reeds besig met die verhouding tussen leer en die verskillende soorte breinfunksies. Geheue skyn 'n fenomeen te wees wat wyd versprei is in die kortikale areas. Kort- sowel as langtermyngeheue en die retensie daarvan word bespreek. Opvattings oor die linker en die regter hemisfere kry aandag, sowel as MacLean se konsep van die brein as drie-ledig. Opvoedkundiges poog veral in die laaste jare om die resultate van breinnavorsing toe te pas op die onderrig-situasie. Voorstelle wat gebaseer is op sodanige navorsing word hier gedoen aan studente sowel as onderwysers.

Perception, pattern recognition and the hypothesis of formative causation

The story of the brain and learning and, specifically, accelerative learning is tied inextricably to perception and pattern recognition.

Pribram (1979), Hart (1983), Hydén (1977) and others have indicated that the human brain functions on the basis of pattern recognition, both in terms of gross input recognition through the senses and in terms of internal neural transmission. We identify patterns in the environment and our nerve cells either pass on or block that message to other neurons based on a recognition factor which leads to secretion of excitory or inhibitory chemicals. Through this process, apparently, we learn and remember.

Pattern recognition

The classroom, very often, is a structured environment in which the teacher tries to help the students learn to identify and understand these patterns. In Microbiology, for instance, there is a pattern to the information which microbiologists have at their disposal which helps them remember the information in their field. To students new to the field, the information is like a maze or a scatterplot of thousands of seemingly unrelated facts and data. The same is true for those first learning a foreign language, reading skills, or any new and different subject. If the students succeed, most often it is because they recognize the pattern that ties all the information together.

Perception

Perception is an ACTIVE process of selection and matching of patterns from external stimuli and from within our highly organized brains, not just a passive reception of the external stimuli. Since learning is based upon perception, it must also be an active process, as described by Hydén. Recognizing what the pattern is *not* is equally as important as recognizing what the pattern is.

As an example of the complexity of perception we can look at the optic system. The optic nerve originates in the posterior portion of the retina of the eye. The nerve consists of about one million fibres, each originating in one tiny part of the retina. Some fibres relay information about edges, shapes, surfaces and textures, while others transmit colour information. Each of these fibres of the nerve connect to a specific site on the lateral geniculate nucleus, a plate-like structure about mid-way back in the neocortex. This means that the retina is mapped onto the lateral geniculate nucleus via the optic nerve. From there, nerves relay the visual information to appropriate sites in the visual cortex, located at the back of the neocortex in the occipital lobe of the brain.

No matter which of the five senses are considered, the brain transmits the information internally to various brain regions by an electrochemical process. A thorough description of this process is provided by Stevens (1979). Pribram (1979) speculated rather accurately that the information is coded by frequency and amplitude of the electrical portion of the message. It is known that highly complex messages can be encoded through waveform interactions which result in what is known as an interference pattern. This is the process by which holographs are produced and by which Hugo Zuccarelli recently produced "holophonic sound". Holophonics purportedly transmit more directly to brain sites than normal sound recordings, by including a referent tone (see *Brain/Mind Bulletin,* May 30, 1983).

While individual cells and small groups of cells resonate to their own frequencies and amplitudes, each major portion of the neocortex is generally internally synchronized. Consequently, a person may have an active beta rhythm (13-30+ cycles per second) generated over melodic interpretation centres when listening to an orchestral arrangement while the more relaxed alpha rhythm (8-12 c.p.s.) is generated within the verbal centres which are not currently in use. It is entirely possible that the effects of the passive concert phase of accelerative learning promotes faster learning by relaxing major portions of the brain so that those which are active encounter little interference from the other portions.

Sheldrake's hypothesis of formative causation

Sheldrake (1981) hypothesizes that information can be passed indirectly between members of a species, even between generations, by a phenomenon termed morphic resonance through morphogenic fields. *Morpho* means form, and *genic* refers to generated. Therefore, morpho-genic means generated form. Sheldrake posits that these fields are neither energy nor mass in nature, but have some as yet undetermined structure and wholeness.

Part of the hypothesis suggests that if a group of individuals in a species learns something, it will be easier for others of the same species to learn it. Sheldrake asked persons interested in researching this to submit proposals to the British journal *New Scientist* in a 1983 competition. The Tiger Trust (Netherlands) added a European prize of 5 000 Guilders, and the Tarrytown Group of New York offered $10 000 for the best proof or disproof of formative causation. Two experiments were chosen for 1983, one with foreign language poems and one with visual images.

In the first study, a leading Japanese poet provided three poems with similar metre and rhyme, one meaningless, one newly composed and meaningful, and one traditional rhyme learned by generations of Japanese children (see *Brain/Mind Bulletin,* May 30, 1983). Persons in several other countries, including the United States and Canada were asked to memorize the three poems without knowing which rhyme was which, and report which poems were easiest and most difficult to memorize. Considerably more than half (about 60%) of the participants found the traditional poem easier to learn. About 30% rated the nonsense poem easiest, while only about 10% found the new, meaningful poem easiest to learn *(Brain/Mind Bulletin,* September 12, 1983).

The second study (reported in *New Scientist,* vol. 100) used two pictures abstracted in such a way as to "hide" the image. Sheldrake hypothesized that there would be "a tendency for a hidden image to become easier to see if many other people had already seen it". The two pictures were sent to several cohorts in Europe, Africa, and North and South America. Each cohort showed both pictures to a group and gathered base-line data regarding how many people could identify each image during a one-minute viewing. The next week one of the pictures was selected at random and shown to two million viewers of a British television programme. The identity of the picture selected was withheld from Sheldrake and the other researchers. The picture was shown in original form then the hidden image was revealed to the viewers, and finally the image was returned to its original form. Once seen, the hidden image is quite obvious to the viewer. After the British showing, the experimenters tested another group at each site. The televised picture served as the experimental condition and the other picture as the control. The proportion of persons able to identify the test picture around the world after the British had experienced the hidden image increased 76%. The proportion of those identifying the control picture increased only 9%.

FIG. 1

Evidence continues to build in support of Sheldrake's hypothesis. If he is correct, it may have an unusual implication for educators. We may find that, when students are learning something new, it makes sense to focus on the more capable learners first; for if they master the new idea it may be easier for the less capable to master it later.

A microscopic look at the brain

The normal human brain weighs about three pounds. Within this marvellous structure we have approximately *100 billion nerve cells*. Each of these neurons receives inputs from 100 to 1 000 other neurons across 1 000 to 10 000 relay points called synapses. This means that there are, at a conservative estimate, some *100 trillion connections* between neurons in the brain. This complex interconnection of message-bearing relays makes the human brain by far the most intricate "machinery" known at this time. Humans are born with virtually all the brain nerve cells we will ever have. We begin producing them in large numbers at about 25 days gestation. Neurons are generated at the astonishing rate of 250 000-280 000 per minute as the foetus develops over the next eight months (Cowan 1979).

To communicate with the rest of the body, the 100 billion neurons of the brain are connected with 10 billion neurons in the brainstem and spinal cord, and a "mere" one million neurons stretching across the remainder of the body (Hubel 1979). All these are immature nerve cells in that, at birth, they are almost naked and have made few connections with the other neurons with which they will ultimately communicate. There is some evidence that learning occurs *in utero;* consequently we can confidently state that many neuronal synapses have formed. These are, however, proportionately few of the 100 trillion which will be formed later in life.

At maturity, brain cells are coated with a myelin sheath, a coating of insulation around the axon (or output end). The input centres (dendrites and the cell body) remain naked. The coating process takes from about 37 weeks gestation (7 ½ months *in utero*) until age 20 to complete. This is an important process. Brain cells are packed tightly together, separated by a thin film of fluid. Signals coming into the cell through the dendrites or cell body must be passed along the axon to the next cells in the network. While the axons are partially naked, the message travels primarily along the axon itself. When insulated, or myelinated, small gaps remain in the sheath, spaced approximately one millimeter apart. The message passing along the axon travels by jumping from gap to gap where the extra-cellular fluid makes direct contact with the axon. Insulated nerve cells, then, conduct impulses faster than unmyelinated ones (Stevens 1979).

At the junction, or synapse between neurons, chemical release is triggered by the electrical charge travelling down the axon of the first cell. If the chemical passes on the message, or excites the next cell, it is called an excitory chemical. If it blocks the message, it is termed inhibitory. Since there may be multiple or no connections with a nearby cell, there are four possibilities resulting:

- all connections excite the next cell;
- all connections inhibit the message to the next cell;
- some excite and some inhibit, reducing the strength of message passed to the next cell;
- the two cells have no direct connection.

These gradations of message networking increase the complexity of the 100 trillion synaptic connections by at least threefold. With at least 100-1 000 neurons passing and inhibiting messages to the receiving neuron, it is easy to see how intricate the process is which will determine not only whether the receiving cell will pass the message onward, but if it does, just how strong that message will be to the next neuron. As the learner interacts with the environment (teacher, peers, texts, etc.) proteins present in nerve cell membranes apparently enable the activation of very large numbers of neurons simultaneously. The more sensory channels used to input the information, the greater the number of storage sites activated (Hydén 1977). When learning starts, there is an increased synthesis of messenger RNA in nerve cells, which induces production of certain proteins and molecular pattern changes in brain cells. As Hydén points out:

> The working hypothesis is that protein differentiation, caused by experience and learning, will secure the concomitant activation of all the neurons which have undergone a similar differentiation and on the same stimulus. It does not matter in what part of the brain the neurons are located ... at learning, neurons become highly active. The learning mechanism of the brain in the first hand is *active,* not *reactive* as in a conditioned system. (Hydén 1977:215).

When a person learns his/her native language and no other, there is an identifiable section of the brain in which it is housed. When a second language is learned after puberty, it must be stored in another place. This appears to be because the neuronal connections in the first site are already taken up by the native language. Neurobiologically, B.F. Skinner was accurate when he pointed out that it is more difficult to unlearn something (reworking the established neuronal connections) than to learn it. If we take a child whose brain has many undedicated synaptic possibilities, and teach the child two or more languages during the formative years, we find that all those languages can be found in the same general area. While this is an indication of the plasticity of the youthful brain, it is not an indictment of the mature brain. There is ample evidence that adults can learn, and that the mature brain can disconnect and reconnect neurons to accomplish this, although it takes longer than the initial connection. The most striking evidence of this comes from research with stroke victims who are relearning how to walk, talk, write and perform other functions by miming patterns from normal brains shown on oscilloscopes.

Short-term memory and its pitfalls

For the purposes of this discussion, short-term memory refers to storage of information lasting from one-quarter of a second to one hour without rehearsal. With rehearsal, short-term memory can be maintained almost indefinitely, but usually does not last beyond eight hours due to lack of practice. When a person actively thinks or contemplates events (i.e., is consciously aware), even if this incorporates long-term storage, the short-term memory is being employed.

Unless short-term memories are committed to long-term storage, they are quickly lost. The short-term proteins triggered by the hippocampus are broken down and flushed from the system so that the short-term memory is cleared to receive new input. Because of this, there are several pitfalls involved with short-term storage: masking, capacity limitation, short duration, item and order information loss, and recency effects (O'Keefe and Nadel 1978). Masking occurs when facts, concepts or principles being learned are similar in some respect. The first learned item is generally stronger, having been rehearsed. The teacher must take care to separate these concepts in the learner's mind.

Duration involves the times indicated at the beginning of this section. Short-term memory is just that: short-term. If the instructor expects the learner to maintain the information long-term, the structure for long-term storage must be instituted (see Long-Term Memory).

Recency refers to the effect which can be stated as "that which was rehearsed more recently will be stronger than that rehearsed less recently". This is due to a lower synaptic threshold (easier transmission) for the most recently practised information.

This effect is most easily seen in students who cram for relatively short, non-comprehensive examinations. What they have just rehearsed blocks what they crammed an hour ago. Capacity limitation is severe with short-term memory, generally limited to seven discrete items. The pitfall here is that students can juggle enough information in short-term memory to pass most weekly or bi-weekly tests on individual chapters, units or modules; and this can be done without committing the information to long-term memory.

Item and order information frequently are lost rapidly from short term memory. An example of item loss is forgetting an appointment before it is written down or forgetting the name of the third planet from the Sun. An example of order loss is confusing the sequence of recent American presidents (Nixon, Carter, Ford, Reagan).

Long-term memory: taxon and locale

Information processed into long-term storage is encoded in multiple areas of the brain, because experiences have multiple sensory aspects (Gazzaniga and LeDoux 1978). Much of the human brain has been mapped for functions controlled and type of information processed at given sites. Pribram (1979) and others have found a positive correlation between areas activated during both intake and recall, in terms of latency (delay of neuronal activity) and amplitude (voltage of the encephalogram). Those areas stimulated during intake match those activated during recall. And the more types of stimuli, the more sites used to store the information.

One framework for reviewing long-term memory systems is that proposed by O'Keefe and Nadel (1978), involving the taxon (rote) and locale (contextual) systems. The taxon system is categorical, lacks a spatio-temporal context, and decays greatly over time if the information goes unrehearsed.

The locale system, on the other hand, is based on context. It employs time and space coordinates, multiple channels for storage and retrieval of any or all of the relationships involved in the specific memory. Items stored in the locale long-term system are relatively permanent. Single occurrences, if they are greatly important or unusual to the person, are also stored here because they are contextual. The time-space coordinates attached to these memories allow for minimal interference between different representations of the same item. Memories which rely primarily on verbal communication will be nearly context-free and will be consigned to the taxon memory system, subject to considerable decay if not used often. By adding pictures, sounds, aromas and so on, a context is built around the verbal, causing the memory to be placed within the locale system.

When something learned is practised many times, in exactly the same way each time, the axonal and dendritic connections enlarge. This allows for more chemical transmission to be emitted into the synapse, which in turns makes it easier for the message to be passed on. When a learned item is practised many times in many different ways, the neurons make new connections with different cells, branching the message to several sites of the brain and networking the information. The first instance occurs most often with the taxon system, and the latter with the locale. When information is not practised or recalled for a considerable period of time, and the synapse is not activated, the connection atrophies, making recall more difficult. This we term "forgetting".

Left-right hemispheric brain functions

Research on left and right hemispheric differences began in the last century with the work of Broca, who discovered the speech centre, and Wernicke, who discovered the area which interprets speech. Among the myriad of scientists investigating the capacities and dominance of each hemisphere, Kimura (1973) seems to have made one of the more important discoveries: that, in the normally functioning brain, both hemispheres *share* in mental activities. Scientists have yet to discover any one higher intellectual function controlled entirely by one hemisphere. Some scientists still refer to "the dominant hemisphere", meaning the side of the brain primarily responsible for language processing. This seems to be changing rapidly, however.

In a recent interview, Levy (1985), a prodigy of the Nobel laureate Roger Sperry, stated:

> One of the ideas I had when I was still working with Roger Sperry was that the right hemisphere of the human brain attends to and represents the holistic, configurational aspects of its experiences and that the left hemisphere is more analytic. The

> right hemisphere synthesizes things into a global form, whereas the left seems to pay attention to specific and detailed features. This is now a popular notion, *but I think it may be wrong*. Reality, in that instance, may have been playing a game with us. (emphasis added by James D. Hand)

Levy states that she now believes that both hemispheres hold the capability to synthesize information separately within the specific domain of each:

> It seems possible that when a task is within the specialized domain of a hemisphere, then information is synthesized into some higher order configuration, and that feature-by-feature processing is compelled for the unspecialized hemisphere that lacks the capacity for deriving the emergent synthesis. The way each hemisphere deals with incoming information—how it encodes it—depends on what sort of information it is and what the hemisphere can do with it.

When Levy speaks of the "specialized domain" of a hemisphere, she is referring to major capabilities it has that are only minor capacities of the opposite hemisphere. From the popular listing of these domains we should now delete analysis of detail and sequence information from the list of left brain specialities, and synthesis and holism from the list of right brain specialities.

Left Hemisphere	*Right Hemisphere*
– verbal, linguistic	– intonation, inflection
– ideation (abstractions)	– pictorial and pattern sense
– conceptual similarities	– visual similarities
	– location in space
– sense of time	– controls left side of body
– controls right side of body	– melodic perception
– numerics, quantities	– poetic processing
– logic	– insight
– outlook	
– geometric configurations	

This listing holds for over 90% of the tested right-handed males from Western cultures. There is considerable variation when investigations involve females, left-handed persons, youngsters and those from non-Western cultures.

The triune brain

The concept of triune (three-part) brain is one of the more exciting developments in recent brain research. MacLean (1973; Holden 1979) refers to three separate and distinct functional portions of the brain: the reticular formation (sometimes called the reptilian complex or R-complex) including the midbrain, pons, medulla oblongata and reticular activating system; the limbic system, which includes the amygdala, hippocampus, hypothalamus and pituitary bodies; and the neocortex or outer mantle of the brain. Each of these three portions, according to research by McLean, has its own special abilities, mentality, view of the world, sense of time and space, memories and its own motor functions. The three portions are interconnected by neuronal pathways, yet are neurochemically, and functionally distinct from one another. The behaviour displayed by a person may be determined by any one of these regions at any given time.

The R-complex plays an important role in aggressive behaviour, ritualistic behaviour, territoriality and the establishment of social hierarchies. Basic needs and sexual drive are also programmed into this portion of the brain.

The limbic system controls strong and vivid emotions, attitudes, prejudices, and motivations not necessarily tied to basic biological needs. The hypothalamus and hippocampus control the formation of long-term and short-term memory. The hippocampus also controls certain emotional states. The pituitary controls the endocrine system. Imbalance in endocrine production alters moods, which provides an important clue to the relationship between learning/memory, attitudes and mental states. MacLean (1973) states that malfunctions of the limbic organs can lead to rage, fear, or sentimentality that have no readily apparent external cause.

The relatively massive neocortex surrounds the limbic system, which in turn sits atop the reticular formation (R-complex). This region controls human intellectual functions such as logic, the quest for knowledge, anticipation of the future, anxiety, language processing and other indicators of intellect. Fully 70% of the 100 billion neurons in the brain are located in the neocortex.

The lower two regions of the Triune Brain control pulse, heart rate, blood pressure, respiratory rate and body temperature through the hypothalamus (the ultimate controller) and the reticular activating system within the R-complex. These same regions control the following:

- submission/aggression
- sexual courtship and display
- follow-my-leader rituals
- hunting/gathering
- bonding/protecting/caring
- flocking
- mass migration
- ganging up on the weak and the new
- defending territory
- ritualistic greeting
- playing
- rejoicing/sorrowing

These regions are unable to directly verbalize meaning beyond emotive expressions. If one considers this list while recalling the behaviours of students, teachers, administrators and staff in our schools, one can see how many of the daily activities of people come from the two lower regions of the brain. All these behaviours, so pervasive in daily life, interfere and often conflict with the intellectual activities of the neocortex.

The story becomes even more intricate when one considers the following. Sensory inputs from seeing, hearing, touch and taste go through the thalamus, which apparently translates the message and sends it on to appropriate sections of the neocortex. Each primary receiving area of the neocortex (totalling about one-fourth of this region) connects to associative areas, which integrate sensory inputs from two or more primary areas. These, in turn, eventually connect with the hippocampus or amygdala, or both. The hippocampus and amygdala are the primary influences on the hypothalamus from the cerebrum. The hypothalamus controls the involuntary muscles surrounding the intestines, airways, arteries and veins, urinary tract, and the glands. It also, as stated previously, controls blood pressure, heart rate and respiratory rate. As we look at the loop leading from the initial stimulation of the limbic system from sensory inputs, to the neocortical areas and back to the limbic system, consider this:

- Amygdala controls rage and fear

- Hippocampus gauges expectation and reality; stimulates and controls short-term memory; and inhibits the reticular activating system, thereby influencing tension/relaxation

- Hypothalamus controls the fight/flight response and aspects of both short-term and long-term memory.

Intellectual activity is obviously hampered by rage, fear, disparities between expectations and reality, tension and feelings triggered by fight-or-flight situations. To overcome these negative influences, as promoted by SALT techniques, the following would seem to be in order:

- pleasant surroundings

- recall of best performance

- relaxation/peacefulness

- emphasis on positives

- recall for times when learning was easy and enjoyable.

Beta endorphins and enkephalins

The endorphins and enkephalins are the brain's natural opiates. They are generated when we feel good about something or someone, or when we are extremely relaxed, as found in isolation tank experiments (see *Brain/Mind Bulletin* 9(4), January 23, 1984). As shown by the previous discussion, emotions and learning are tied inextricably within the limbic system. When endorphins and enkephalins are produced, the person feels good—a natural "high". This process, relaxing the limbic system's negative potential, allows intellectual pursuit to progress more readily than when negative feelings prevail. To be positive, perhaps we should guide our students toward comfort management rather than stress management.

Handedness

Because of the relatively few left-handed people in America, they have often been intentionally excluded from hemispheric lateralization studies because it has long been recognized that left-handed people are different. A few researchers, such as Geschwind, have focused attention specifically on the left-handed and ambidextrous, to determine how their brains are organized. Kocel (1977) found that 65% of left-handed people tested displayed the left hemisphere as the dominant verbal hemisphere. This leaves 35% for whom verbal abilities are right hemispheric predominant or shared relatively equally between the two halves of the brain.

Geschwind, intrigued by the apparent link between left-handedness, certain immune diseases and learning disabilities, surveyed nearly 3 000 people in Scotland, and found that the rates of learning disabilities and immunological diseases were, indeed, higher for left-handed people than for the right-handed (Garmon 1985). Geschwind and Galaburda (1985) believe that foetal exposure to high levels of the male hormone testosterone also accounts for the following:

- Left-handedness is found more often among males than females

- Developmental disorders related to reading and speech are more common in males

- Females are better at verbal talents while males test out better at spatial skills (thought to be right hemispheric dominant)

- Certain immunological diseases are more common among males.

The theory regarding the connection between testoterone levels, disease and learning disabilities is most controversial, as indicated in the editorial immediately preceding the first part of the series by Geschwind and Galaburda (Joynt 1985). As Joynt states:

> It is a bold look at a new area of neurobiology. It is provocative. Members of the editorial board who reviewed this were not in total agreement but they were excited about the insights and implications for research.

Whether or not the theory is considered controversial, the Geschwind-Galaburda work is eminently thorough and detailed, citing over 650 sources of brain lateralization studies.

Witelson (1985) found that, in men and women, left-handed and ambidextrous people have a corpus callosum eleven percent larger than right-handed persons. It is not yet known whether this is because of a larger number of neuron fibres, thicker fibres, or more sparsely distributed nerve cells. It is known that the brain of an eight month old foetus has two to three times the number of brain neurons than does an adult (McAuliffe 1985). Nerve cells die off and nerve axons are eliminated as the developing brain "fine-tunes" its connections. This continues through early childhood as learning compounds rapidly. One scientist, Blakemore of Oxford University, estimates "that as many as ninety percent of the connections you see in the adult brain are nonfunctional" (McAuliffe 1985), an interesting thought in light of the often stated guess that mankind uses less than ten percent of his brain capacity. Witelson believes that fewer nerve fibres are eliminated in left-handers' brains, accounting for the larger corpus callosum. This would account for the lesser hemispheric specialization for language and spatial tasks in the left-handed and, possibly, the increased frequency of certain learning disabilities in this group.

Male-female differences and similarities

A number of researchers (mostly female) have undertaken the task of identifying anatomical and functional differences between brains of males and females (Kimura 1985; McGlone 1978; Levy 1985). They have found that "women's brains are more diffusely organized than men's" and one major study found that the corpus callosum is slightly larger in women (Kimura 1985). With this in mind, it is somewhat puzzling that right-handedness is more predominant in women (a sign of hemispheric specialization); and that right hemispheric damage results in no more speech disorders than in men, as one would expect if women depend on both hemispheres for speech.

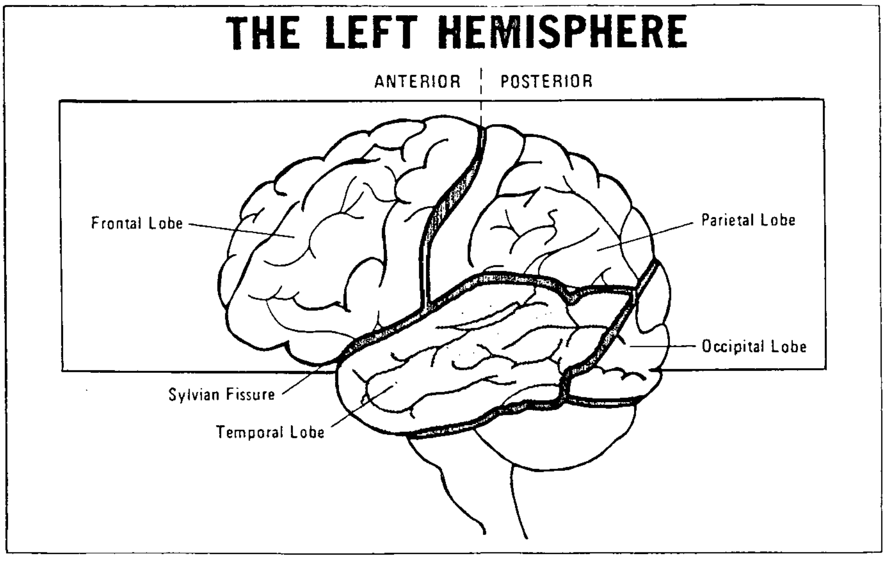
As Kimura put it, "It took me ten years to gather enough data on brain-damaged patients to make meaningful comparisons. But an important and surprising sex difference emerged." (Kimura 1985:54). While left hemisphere damage could cause speech disorders in both men and women, "different sites within that hemisphere were involved in the two sexes". The disorder could occur with either anterior (frontal) or posterior damage in men. For women it is much less likely to occur from restricted posterior damage:

> No woman has lost her capacity for speech because of damage to the left parietal lobe, but several men have. This seemed to suggest that the brain area involved in women's speech is, if anything, more localized than in men, at least in the left hemisphere. (Kimura 1985:54)

It seems, then, that speech-related abilities are found in a more compact area of the female left hemisphere, and there are no sex-related differences in speech disorders detectable at this point from right hemisphere damage. In women, "speech favors anterior systems and avoids the parietal region", unlike men (Kimura 1985:56).

> ...Marian Diamond [found] that the right cortex is thicker in males at most ages, while the left cortex is thicker in females at some ages... (Kimura 1985:57)

FIGURE 2



There are other differences, as well. For hand movements involved in motor skills, men tend to use both the anterior and posterior regions of the left hemisphere; women use mostly the front (anterior) portion. For defining vocabulary words, women use both hemispheres, front and back, while men use the left hemisphere, front and back. And for other verbal skills, such as naming words beginning with a certain letter or describing appropriate social behaviour, both men and women use the front of the left hemisphere predominantly.

> Jerre Levy ... suggested some time ago that the two halves of the body, including the brain hemispheres, might grow at different rates in boys and girls, even before birth. The left hemisphere may develop more quickly in girls, and the right hemisphere in boys, thus favoring verbal skills in girls and spatial skills in boys.

At various stages in a person's life, then, structures are undergoing more- or less-rapid growth, and patterns of brain hemispheric functions will vary from time to time as a result. Spatial ability in women has been found to vary with natural levels of sex hormones on a monthly cycle. It seems to be best when oestrogen levels are lowest. When female sex hormones are at their highest levels, women perform best on motor skills tests. Despite these findings, Kimura reminds us:

> ...we can predict very little about an individual's mental capabilities based on his or her sex.
> ...biological sex itself has turned out to be much more variable and dynamic than we ever imagined. And brain organization patterns are even more variable from person to person, and probably even within the same person at different times. Further, on most tests of cognitive ability there is enormous overlap of men and women. We strain to look for differences and, of course, tend to emphasize the few we find. (Kimura 1985:58)

Mind modules

Michael Gazzaniga, of Cornell University Medical Center, has developed a new view of brain organization. Many researchers have gone on the assumption that thought processes proceed in serial order, with a unified, linear conscious experience. Gazzaniga argues, however:

> that the human brain has a modular organization; it is organized, that is, into relatively independent functioning units that work in parallel ways. Furthermore, these modules frequently operate apart from our conscious verbal selves.
>
> The realization that the mind has a modular organization suggests that some of our behavior should be accepted as capricous and that a particular act might have no organs in our conscious thought process. (Gazzaniga 1985a:30)

This concept follows closely from the work of MacLean on his theory of the triune brain.

Gazzaniga theorizes that the normal human brain has hundreds of modular processing systems; each capable of learning, actions, moods and responses; and that all but one work in nonverbal ways "such that their method of expression is solely through overt behavior or more covert emotional reactions" (Gazzaniga 1985a:32). These activities occur without verbal expression and "with abandon". Our verbal self must interpret and explain the actions, moods, and responses of the nonverbal mind modules. If there is no ready explanation, cognitive dissonance arises. Because people "cannot live in a state of conflict between a belief and something they have done, something has to give; what gives is usually the belief". The primary and associated verbal areas of the brain interpret our behaviours and emotional states, both for ourselves and those with whom we have contact, because of the brain's need to maintain a high degree of consistency in our behaviour. Through this we are capable of assessing the nature of our "self". The more disparate the actions of the nonverbal modules, the more the verbal self must explain or rationalize those actions, the closer grows the verbal self to the nonverbal in their views of the world and belief systems. It seems a fascinating puzzle, unravelling very slowly, that each human may have multiple personalities with multiple needs, goals and desires. At the very least, the views of MacLean and Gazzaniga should strike a note of truth in those of us who have acted "on impulse", done something even we could not readily explain later, and have had to modify our self perceptions as a result.

Suggestions for educators

The following suggestions are based upon what we know about the brain and how it functions. Some of the suggestions are common educational practices which can now be defended from an understanding of recent brain research. Some are espoused by those interested in accelerative teaching and learning. Other suggestions are new.

A great many students, perhaps the majority, mistakenly equate reading with studying. When reading silently, a relatively small portion of the neocortex is usually involved. By encouraging students to include other activities in their study, additional brain centres are activated.

- Read the words aloud — activates Broca's area, Wernicke's area, left hemisphere sensory and motor cortex, and the angular gyrus (primary auditory area).

- Read with emotion and inflection — activates right hemisphere areas for prosodic functions, right motor and sensory cortex, and limbic system.

- Develop a pictorial image of the meaning of the words and sketch a visual summary — involves a major portion of the primary visual cortex, left and right motor and sensory cortices, central and peripheral nervous system from the brain stem through the arms, hands and fingers.

- Summarize in your own words and write down key words to recall lengthy descriptions — allows some storage of words in the right hemisphere to tie in with the pictorial memory.

- Colour-code the sketches — discrimination within the right visual cortex.

- Tie all of the above to laboratory or other experiential activities — activates left and right motor and sensory cortices, brain stem, central and peripheral nervous systems.

- For review of previously learned material, use relaxation techniques, remembrance of joyful and easy learning, and the playing of Baroque largo passages — lowers beta rhythms (13-30+ cycles per second) within the left hemisphere, allows increasing alpha rhythms (8-12 c.p.s.) in both hemispheres, impacts the limbic system components controlling emotion and memory, and works to lower blood pressure, heart rate, and respiratory rate.

- Test yourself after studying, emphasizing use of the key words and sketches in attempting to recall the details studied — reinforces neuronal connections established during initial learning, leading to hypertrophy and/or branching of neuron dendrites and making recall easier.

For the educator there are also several suggestions for planning instructional activities (Hand 1982; Hand 1984).

- Be careful not to detract from the clarity of the presentation, use as many types of sensory and theoretical inputs as possible. Multiple channels of input stimulate multiple brain sites and distribute neuronal connections across those sites. This improves recall capabilities because any of a number of stimuli can trigger the recall process.

- Teach and test to the same memory system. If you emphasize the rote taxon system in your instruction on a particular topic, use rote memory testing also. Do not assume that the information has also entered the contextual locale memory system. If you want the student to be able to apply what was rote memorized, provide appropriate practice to provide a context for its use. This employs the locale system, and then it is also appropriate to test from the locale memory.

- When the information or process being learned has direct applicability to some future learning or use (such as a job task), the learning should take place within a context as similar as possible to the context in which it will be used, in order to enhance later recall.

- When teaching for storage in locale memory, stress visual representations. Picture memory of humans is remarkably efficient.

- At the conclusion of the learning session, have the students relax for a few moments while they rehearse what they have just seen and heard. Memory practice and verbal associations between what was said and what was seen increase the students' ability to recall and uncover previously unremembered details. The "old saw" that a student should take a break and do something entirely different at the end of a study session was discovered to be a detriment to learning (Haber 1970).

- The more vivid and active the impression of what is being learned, the stronger the memory trace. The spike of electrical activity in the brain increases markedly with novel, surprising or vivid stimuli. This activity signals the hippocampus and hypothalamus to produce increased levels of neurochemicals related to memory formation.

- Ask the student to verbalize during perceptual experiences. When information of a perceptual nature, regardless of the sensory systems employed, is encoded while the information simultaneously is being verbalized, the internal language system is active, and the information is encoded verbally and nonverbally. A bond forms which allows the language system some access to memories laid down by the nonverbal systems.

- For individualized self-study materials, the setting in which they are used is at least equally important to learning as are the quality of content and the design used to present the information. Directions for use of the materials should include suggestions for appropriate settings in which study may be most effective. If the material can be used by pairs of students or by small groups for interactive study, directions should include suggestions for the most effective use of the materials in group discussion.

- Clarity reduces unwarranted anxiety. Explicit directions, unambiguous learning objectives, sample test items, practice and review items, clearly drawn diagrams with appropriate labels, worksheets, and well-outlined and clearly stated textual materials tend to let the student know exactly what is expected by the instructor. This frees the limbic system and neocortex from unwarranted anxiety about the requirements of the lesson or course.

- Examples used in instruction can affect the learner's attitude and mood. Effectiveness of examples is determined, internally, by the learner. Examples which are clearly pertinent to the subject, or to the life-goals of the student, provide a realistic backdrop for the information being learned. In many cases, the examples can draw upon aesthetic appeal, empathetic situations, or common positive personal experiences of the learners, all of which can have a positive influence on the student's limbic system. Developing a positive attitude toward learning, or at least avoiding alienation of the student, is important to hippocampal involvement in generating the proteins essential to long-term memory.

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THE REVOLUTION of intelligence will happen without fail in all countries of the world.
It will begin in the arms of all mothers.
The day mothers realize that they, and not nature, are the well-springs of their children's intelligence, that day and for that reason alone, the world will be changed forever.
The revolution of intelligence is not an act.
Not even a succession of acts.
It is a continuous, permanent course, an unending and dynamic series.
In truth, it started the day the first man appeared on the earth.
And it will only end with History.