Brain Research, Learning, and Technology

By Laurence Wolff
Inter-American Development Bank

Advances in Brain Research

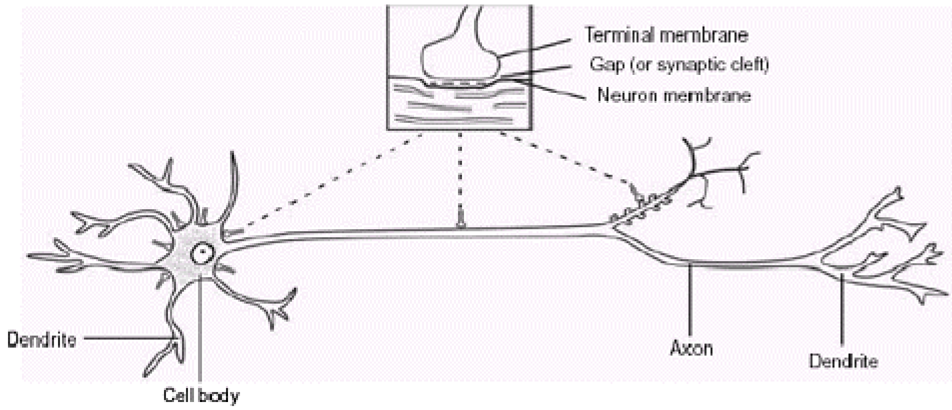
The human brain is perhaps the most complex entity in the universe. The basic unit of information processing in the brain is the neuron, a cell capable of accumulating and transmitting electrical activity. There are approximately 100 billion neurons in a human brain, each of which may be connected to thousands of others. If mental states are produced by patterns of neural activity, then "knowledge," defined as whatever drives cognitive flow from one mental state to another, must be coded in the neural connections, or synapses. **Figure 1** provides a schematic of the synapses on neuron.

The last decade has seen enormous strides in research on how the brain works. Especially through magnetic resonance imaging (MRI), positron emission tomography (PET), and other tools, researchers can now identify how different parts of the brain are involved in different mental processes. **Figure 2** shows the regions in the brain involved in language processing and other tasks.

Implications for Education and Learning

Brain research is beginning to shed light on fundamental, as well as, applied questions about human learning. While it is still too early, eventually neuroscientists, educators, and cognitive psychologists will develop a common language, and a new multidisciplinary science will be born. Aware of the importance of this process, the OECD recently commissioned a series of meetings and a monograph on the subject (OECD, *Understanding the Brain)*. The experts convened for these meetings predict that critical neuroscience concepts such as plasticity and periodicity will eventually find a place in education theory and practice. ***Plasticity*** confirms that brains continue to develop, learn and change until advanced senility or death intervenes. ***Periodicity*** refers to sensitive periods or windows of

Figure 1. **Different types of synapses on a neuron**



Note: The synapse includes the neuron membrane, the membrane of the terminal and the gap in between these two structures.
Source: Jean-Pierre Souteyrand for the OECD.

opportunity when the developing brain is particularly sensitive to certain stimuli and very ready to learn. Education systems can be taking advantage of these sensitivities.

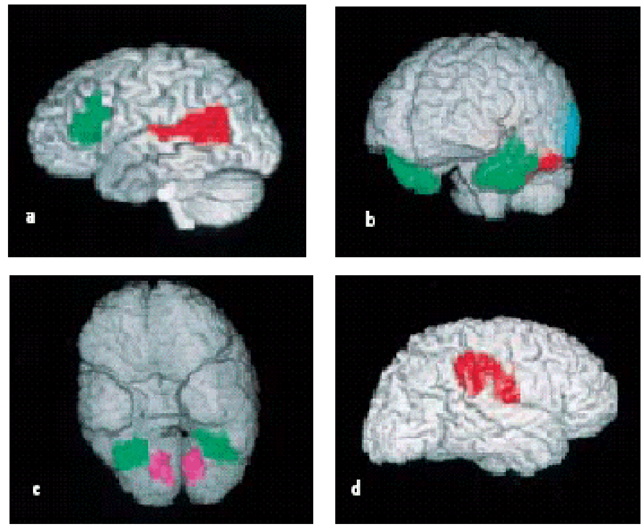
One approach to linking learning with neuroscience would be to identify the serious sensitive periods (periodicity) for the learning of a variety of subjects and to arrange educational experiences in accordance with these sensitive periods. This may be particularly appropriate for language learning. For example, it has been shown that the sensitive period in which the brain appears to be hard-wired for language acquisition appears to be up to age 13. It is far more difficult to master the grammar of a second language after that age. This result is at odds with education policies in numerous countries where second language learning starts at approximately 13 years of age. It suggests that the best way to learn a second language would be through immersion at a lower age.

Children with dyslexia cannot use the normal brain regions to decode letters, and have to rely on a different location of the brain for decoding. Research has recently shown that the rate of dyslexia in countries such as Italy is half that of the USA (Dana Foundation, *BrainWork*, March 2001). This is apparently a result of the fact that Italian has a "shallow orthography," meaning that more often than not the same letter groups in Italian represent the same sound in the written language. In contrast, English is considered one of the most difficult written languages to master because of its irregular orthography. The (revolutionary) implication would be to abandon current English orthography and to create a written English language with a regular orthography.

Brain research also confirms that life-long learning is not a dream since it is embedded in the capacity of the brain to respond throughout life to environmental demands. Previously it was thought that brain neurons were lost from birth onwards. Now it is clear that if one does not have a specific disease, then most, if not all, of the neurons remain healthy until death (USC). In fact, while the ability to master grammar appears to accrue best at a younger age, vocabulary learning continues throughout life.

Recent brain research has also served to disprove a number of popular assumptions, or "neuro-myths," about the brain and learning (OECD, *Understanding the Brain*, pp. 69-73). For example, it had been argued that the brain was plastic only or mainly during ages 1-3. This misconception is a result of the fact that the number of synapses grows enormously during this period, continuing and finally ending around the time of adulthood. It has now been shown that learning is a combination not only of increased neural connections but also "selective pruning," which is known to be a normal and necessary process of growth and development, explicitly designed to reduce the brain's energy requirements (R. Wolff). The "neuro-myth" was that

Figure 2. **Regions of the Brain Involved in Different Tasks**



Neuroscience continues to associate specific brain structrues with specific tasks. Some language regions are highlighted in *a* and *b*. Color-processing (*red*) and face-processing (*green*) regions are shown in *c*. One's own body sense dependes on the regions shown in *d*.

Source: "The Hidden Mind," Scientific American.Spring 2002.

educational interventions, including enriched environments, had to be timed with "synaptogenesis," since the more synapses available, and the least pruning, the higher the potential for learning. It has now been shown that even in cases of extreme deprivation, such as Romanian orphans, rehabilitation is possible. The point of the critique is not to condemn early educational interventions but rather to challenge the claim that the value of early educational intervention is based on a neuro-scientific consensus or brain imperative.

Other recent research with implications for learning includes, for example, the identification of a gene in mice that assembles a particular molecule in the brain that affects learning, and manipulation of this molecule to produce "brainier mice" (Tsien). Research has also shown that men and women display patterns of behavior and cognition that reflect hormonal influences on brain development (Kimura). Another area of critical importance is that of emotional intelligence. When some areas of the brain critical for emotional and social judgments are compromised, individuals can lose their social judgment even while keeping their IQ. The implications for schooling as well as for society at a whole are potentially revolutionary.

Can "technology fixes" eventually improve learning? The simple answer is yes, since it is already happening. Within the next century there could well be a pill or a tiny implant that could be inserted into the brain and suddenly enable someone to speak fluent French or do advanced calculus (Dana Foundation, *Brain Work*, May-June 2002). There will certainly be interventions to improve memory and there already are many drugs that improve emotional functioning. Based on the above-mentioned research on mice, genetic manipulation could create "brilliant" children. While these possibilities seem revolutionary, they are no different in principle from wearing glasses, which enables one to read and therefore learn more effectively, or sitting under electric lights, which enables one to study more hours in the course of the day.

Consciousness and Neuro-ethics

The ethical issue underlying the approaches outlined above lies in the fact that they will be available only to those who can afford them and may further exacerbate social and economic inequalities. But neuroscience faces a broader ethical issue: it could eventually rob mankind of the sense of what makes us uniquely human, including the concept of free will. A conference on neuro-ethics (Dana Foundation, *Brain Work*, May-June 2002) has examined these issues. Conference participants argued that it would eventually be possible to understand how people make decisions in ambiguous situations. It will also eventually be possible to develop a simple test that could identify lesions in the brain, which lead towards criminal inclinations. The result will be that the range of deviant behavior based on neurotic impulses that could be considered as exculpatory will expand, which could require rethinking the criminal justice system. Nevertheless, most experts believe that the complexity of the brain is so great that the notion of free will or personal responsibility will surely remain. Reductionist research will have to be linked with other disciplines, transcending the natural sciences, social science, and humanities, and including even insights from quantum theory, in order to understand better consciousness and the nature of ethical behavior. It may be that "conscious experience" will eventually be considered a "fundamental feature, irreducible to nothing more basic." Perhaps "Psychophysical" laws will be identified to show how physical systems are translated into consciousness (Chalmers). In any event, the possibility of challenging free will must not preclude continuing basic brain research.

Additional Information

The Dana Foundation (www.dana.org) provides an on-line monthly magazine (*Brain Work*) on new findings in brain research written for the lay reader. The International Brain Research Organization (www.ibro.org) is an association dedicated to communication among brain researchers around the world. It provides a variety of programs, workshops and publications. The National Institute for Mental Health (NIMH) (www.nimh.nih.gov) provides information from the Federal agency that conducts and supports research on mental illnesses. The National Institute of Neurological Disorders and Stroke (www.ninds.nih.gov) conducts research on disorders of the brain and nervous system. BrainNet (www.brainnet.org) is an alliance of associations that also seeks to distribute information on brain disorders. A special issue of Scientific American (*The Hidden Mind*, Spring 2002), provides both an overview of recent research and speculation on where the research will lead, and a recent publication by the OECD (*Understanding the Brain*) summarizes the results of a conference on the brain and learning.

Bibliography

Chalmers, David, "The Puzzle of Conscious Experience," *The Hidden Mind*, Scientific *American*, Spring 2002.

Dana Foundation, *Brain Work*, May-June 2002, www.dana.org.

Gazzaniga, Michael, "The Split Brain Revisited," *The Hidden Mind*, *Scientific American*, Spring 2002.

Hickock, Gregory, et. al., "Sign Language in the Brain," *The Hidden Mind*, *Scientific American*, Spring 2002.

Kimura, Doreen, "Sex Differences in the Brain," *The Hidden Mind, Scientific American*, Spring 2002.

OECD, *Understanding the Brain*, *Towards a New Learning Science*, OECD, 2002, Paris.

Tsien, Joe, "Building a Brainier Mouse," *Scientific American*, April 2000.

University of Southern California (USC), *USC Health Magazine*, November 2002.

Wolff, Rebecca, "Synaptic Pruning," unpublished paper, Washington, DC., March 2002.