Educators' Notebook
Reviews of Research of Interest to Educators

Can Brain Research Help Teachers?

Kelvin Seifert

Can brain science help us teach more effectively? It is tempting for teachers to hope so, and a variety of books and articles have appeared in the past decade based on that hope. Many of these publications are indeed helpful to educators, but not because they are based on brain science. Their helpfulness derives almost entirely from their borrowing and revising ideas for teaching found elsewhere in the literature and wisdom of educators and psychologists.

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Introduction

As Mary Shelley showed in *Frankenstein* (1818/1984), the brain can be as fascinating as it is mysterious. So it is probably inevitable that educators should ask the obvious: Can brain science help us teach more effectively? The claims that neuroscience is relevant to education rest on three well-established findings about physiological development. First, from infancy through late childhood, there is a dramatic increase in the number of synapses that connect neurons in the brain, followed by a period of synaptic elimination or "pruning". Second, there are experience-dependent critical periods in the development of neurons of the sensory and motor systems. Third, in rats (though not necessarily in humans), complex environments cause new synapses to form. From these ideas some educators have argued that early childhood is a crucial time (a "critical period") to provide deliberate educational enrichment, and that children's development will be more limited if the same interventions are offered at later ages. The ages for the critical period vary depending on the author, from birth to three years, or birth to six, or birth to ten, or three years to ten. The enrichment is not the sort that occurs naturally to every child, such as hearing the voices and watching the sights that continually surround every individual. It is the sort that must be provided on purpose, such as exposure to classical music or print materials earlier than happens in conventional school curricula.

Do Changes in Synaptic Density Really Matter?

A detailed look at these three claims, however, does not support any particular educational conclusions. Take the finding about synaptic growth. Educators who cite a scientific reference for this idea usually cite work done on rhesus monkeys during the 1980s and 1990s by Goldman-Rakic (1987) and Rakic (1995). These researchers found that synaptic density (i.e. the number of neurons per volume of brain tissue) increases in these monkeys during the first four months of their lives, and does so uniformly in all areas of the cerebral cortex. Synaptic pruning occurs from four months until about three years, at which time the monkeys are fully adult. In assessing the relevance of this research, however, educators should realize that synaptic <u>density</u> provides a poor measure of the formation of individual brain synapses, especially in humans, because of overall growth in the size of the brain during infancy. From birth to age four, the human brain normally quadruples in volume; if the actual number of synapses remains constant, then synaptic <u>density</u> will obviously decrease-to nearly adult levels. This is in fact the trend which occurs in humans, at least in the part of the human brain that has been studied most carefully, the visual cortex. In the one other area of the human brain where synaptic density has also been studied, the cerebral cortex, density actually increases for much longer, and pruning is not complete until adolescence (Bruer, 1997).

How Critical are Critical Periods?

The existence and timing of critical periods has been studied heavily since the 1960s, using animals at first and later using humans. In the classic study cited most often (Wiesel & Hubel, 1965), kittens were prevented from seeing in one eye for one year following birth. When they were finally allowed to use the visually deprived eye, the kittens were unable to use the eye to guide their behavior (e.g. they could not use it to jump up on a chair). From this finding, educators and others have sometimes concluded that early experience is not only important, but crucial for survival. What they have generally overlooked, however, has been the follow-up research, which tempered the critical period idea significantly. The kittens in the Hubel and Wiesel experiment, for example, could (and did) regain visual function in their deprived eyes if they were given a sort of feline physiotherapy or training forcing them to use the eyes for a year following the initial deprivation (Chow and Steward, 1972; LeVay, Wiesel, & Hubel, 1980). Slight differences in the timing of initial deprivation, furthermore, greatly reduced the impact of the deprivation and increased the kittens' abilities to recover. The critical period still mattered, but not as much as was first thought.

In humans, there is indeed evidence for critical periods, but it is much less certain or clear than in kittens. Language acquisition research on humans, for example, suggests that the best time to acquire phonology of your native language is between birth and about age 12, and the best time to acquire its syntax is between birth and age 16 (Kuhl, 1994). When it comes to vocabulary, however, there simply is no critical period: we continue learning new words throughout life (Neville, 1995). These periods are obviously much more stretched out over time than the "critical" periods found in the visual deprivation research on kittens. But they are much more relevant to teaching and school curriculum issues.

Probably the most important implication of the sensory deprivation research on animals is a recommendation not to teachers but to parents: if your newborn or infant child shows any signs of sensory deprivation of any kind, it is important to seek medical help for it immediately, before the impact of deprivation

becomes significant. It may be possible to reverse or compensate for some or all of the impact, especially if parents (and medical personnel) deal with as soon as possible. By the time such a child comes to school, however, there will be much less that teachers can doñthough as special education teachers will confirm, there will still be ways to learn to work with the child's emerging disability.

Does Enrichment Lead To Synaptic Growth?

When educators have argued that enrichment promotes synaptic growth, they often cite a study by Greenough and his colleagues (Greenough, et al., 1987), in which laboratory rats were raised in various environments, and then later sacrificed so that their brain tissue could be examined. One of the environments was what Greenough called "complex" environment meant to mimic conditions in the wild-the rats were raised in groups in larger cages and were given various toys and obstacles to deal with. When these particular rats were sacrificed, the synaptic density for their visual cortex was 20% higher than the density for rats raised in much more austere conditions of standard laboratory cages. Synaptic density in other areas of their brains was also higher, but not by nearly as much. These findings suggested benefits for environmental complexity.

Note, however, that the complexity used in this experiment was not what educators usually mean by "enrichment": it was merely a simulation of naturally occurring conditions, rather than provision of unusually diverse stimuli. The analogue of "complexity" for human infants would be the social environment of an ordinary, non-abusive home or family - not an environment where the family (or teachers) went out of their ways to add challenges not usually encountered by human infants. If Greenough's experiment has any implications for human development, then, it is simply that "ordinary family life is better for infants than severely deprived social environments"- an idea for which most of us already know even without the help of neuroscience. Greenough also pointed out that the rats' increased synaptic density was <u>not</u> tied to any critical period of their lives. Density increased whether the rats were young or old, simply as a response to their more challenging (and normal) environments. Brain growth, in other words, was not necessarily tied to a experience-independent, developmental timetable - though as already mentioned, certain forms of it are to some extent. And brain growth definitely did not <u>cause</u> the rats to learn; it was the other way around.

How Greenough's study and the other critical period research can help educators plan a curriculum is far from clear. The learning that happens during the earliest, critical-period growth times (acute vision, clearly spoken phonology) is not under the control of educators. The learning that happens during the later, non-critical-period growth times (spatial navigation, vocabulary) may or may not be under our control. But as teachers, we already knew that.

Brain Research: The State of the Art

The actual current state of brain research involves a clumsy and frustrating trade-off between learning about the timing of neural events and learning about their location-a sort of Heisenberg-like uncertainty writ large. Either we can "see" exactly where brain cells are being active, or we can "hear" the overlapping sequences of their electrical activity, but we cannot do both at the same time (Bruer, 1997). The best-known scanning techniques (such as Positron Emission Tomography or PET) can pinpoint where activity occurs, but they require several seconds to "take a picture" of the location. This is far too slow to make PET scans educationally relevant: a child can read a couple of lines of print during that much time, and his brain cells will have undergone numerous transitions in the process. On the other hand, the best electrical recording techniques (such as electroencephalography or EEG) can pinpoint the timing of general activity of the brain to with a few milliseconds, but they are poor at showing its location. The two approaches can of course be combined to yield more information, but much hypothesizing and guesswork is still necessary to interpret the combined information well.

Given the clumsiness of current techniques for studying brain activity, it is indeed puzzling why it should hold such allure for some educators. Solving this particular puzzle is a challenge not for brain research, but for ethnographically minded educators. One possible explanation is that the alleged relevance of brain research helps to bolster or justify activities, such as teaching, which are not otherwise respected very well in society at large. Unfortunately, even if this explanation were true, it could backfire: relying on brain research to enhance the importance of early years education, for example, may also be an implicit admission that such education is not important in its own right. Even more ominously, relying on brain research to justify educational practices comes disturbingly close to giving up on students who do not learn the desired curriculum goals at the right time: it could be argued that children who have missed a particular critical period are therefore beyond help. The special educators among us may object to this conclusion. So would many high school teachers, since some of their students could be considered simply too old to educate in particular ways. These rather dark conclusions do not have to happen, however, if we can understand the true limits of brain research for education.

This is a brief review of a complex body of educational research. Since no brief review can capture the subtleties and qualifications reflected in the larger works, readers are urged to consult the references which have been cited. The views expressed in this notebook are those of the author. The sponsors welcome your comments on this issue and your suggestions for future issues of Educators' Notebook.

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