
Which Brain Research Can Educators Trust?

Neurological research has discovered much about how the brain works, Dr. Willis writes. But educators need to be cautious when applying this research to teaching.

BY JUDY WILLIS, M.D.

IN 1681 Thomas Willis coined the term “neurology.” And 300 years later I began my practice of child and adult neurology. When I subsequently moved into teaching, I found that the tools of neuroimaging, which show the brain actively processing information, helped me make connections between classroom strategies and neuroscience.

Let me begin with a brief explanation of the three most important technological advances in brain research: Positron Emission Tomography (PET), Functional Magnetic Resonance Imaging (fMRI), and Quantitative Encephalography (qEEG). PET relies on the fact that the brain is extremely hungry for glucose and oxygen. PET scans measure the burning of glucose in the brain. In this technique, positron-emitting isotopes, which function as radioactive tracers, are injected into the arteries in combination with glucose. The rate at which specific regions of the brain metabolize the glucose is recorded while the subject is engaged in various sorts of

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cognitive activities. These recordings are then used to produce maps of areas of high brain activity during particular cognitive functions.

A similar technology is employed in fMRI. However, fMRI takes advantage of a special property of hemoglobin, a blood protein that brings oxygen to body tissues. Hemoglobin that is carrying oxygen differs from hemoglobin that is not carrying oxygen. Active regions of the brain receive more blood and thus more oxygen than less-active

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regions. By detecting oxygen-containing hemoglobin, scientists use fMRI to assess changes in blood flow, and thereby metabolic activity, in specific areas of the brain while subjects are engaged in various activities.

Finally, qEEG or brainwave monitoring provides brain-mapping data that are based on the very precise localization of brainwave patterns coming from the parts of the brain that are actively engaged in the processing of information. Through digital technology, qEEG records electrical patterns at the surface of the scalp that represent cortical electrical activity or brainwaves; qEEG recording as it is used in learning research measures the brain's responses to reading, listening, math, or other learning and thinking activities and provides visual summaries in topographic maps.

Only in the past 20 years, with the ability to track the neural circuits that enable us to think and learn, have cognitive neuroscientists been able to study how our brain structures support our mental functions. Today, research in learning, thinking, and remembering is being conducted more and more at the level of neural circuits, synapses, and neurotransmitters, and the time for mind-blowing advances in classroom teaching strategies is at hand.

Brain-based research in learning has given educational researchers the means to translate neuroimaging data into classroom strategies that are designed to stimulate parts of the brain seen to be metabolically activated during the stages of information processing, memory, and recall. And what has emerged from the neuroscience of learning over the past two decades is a body of highly suggestive evidence that suc-

cessful strategies teach for meaning and understanding, that learning-conducive classrooms are low in threat and high in reasonable challenge, and that students who are actively engaged and motivated devote more brain activity (as measured by metabolic processes) to learning.

BRAIN-BASED RESEARCH — A WARNING LABEL

Good-quality, peer-reviewed brain research can provide solid biological data and explanations, but educators need to be cautious about the claims that are said to be based on brain research. Not all of them are valid. Subsequent reevaluation of some early research interpreting PET scans has given us reason to be careful about which research we judge to be valid enough to connect with actual learning.

During my chief residency at UCLA, one of my senior residents, John Mazziotta, now chairman of the UCLA Department of Neurology, was working with the new PET scanner and doing research along with Doctors Michael Phelps and Harry Chugani to evaluate the brain metabolism of patients with seizures and other neurological disorders that affect brain activity. In 1987, this UCLA group published the first research that used the new imaging technology to track brain development in children.

Their research studied 29 epileptic children, ranging in age from five days to 15 years. They first measured each child's resting metabolic brain state (metabolism of glucose when not being stimulated by sensory or cognitive data). The researchers determined that the highest rate of glucose metabolism in these children's brains in a resting state was at age 3 or 4, when the rate of glucose metabolism was twice that of adults. After age 4, the glucose metabolism remained relatively unchanged until age 9 or 10, when it began to drop toward the adult rate, which it reached at age 16 or 17, when it leveled off.¹

This UCLA research was not intended to be an educational research tool for identifying ages of high brain metabolism so they could be correlated with teaching interventions. Problems arose, however, when some readers assumed this information implied more than it actually did. For example, other research had counted the density of synaptic connections between brain cells in brain samples from autopsy material from people of all ages.² It turned out that there was a correlation between the age when synaptic density was greatest and the ages when glucose metabolism was greatest on the UCLA group's PET scans. However, neither of these findings proved that the reason for the higher glucose metabolism was to maintain the greater density of synapses. Nor did this research show that either greater synaptic density or greater brain metabolic activity was the direct cause of any potential for greater learning during those years.³

In fact, these neuroresearchers never claimed that periods of high metabolic activity were the optimal periods for learning to take place. That may well be the case, of course, but there still needs to be cognitive research tied to neuroimaging before we can make scientific claims about connections between brain synaptic density, metabolic activity, and potential for greatest learning.

There have also been problems with some brain research being used inappropriately to support education policies, such as the Reading First program, which most *Kappan* readers will recognize as a part of No Child Left Behind (NCLB). Claims that such research is based on a medical model, when examined closely, prove to be incorrect. In the medical model, independent research grants are not given by committees in which members have direct ties to the studies, so there is no pressure on scientists to skew their research to support any agenda. In addition, multiple centers do the same work independently, without political support or funding being tied to the outcome of the research. When data collection and interpretation are tied to political agendas or vested financial interests (e.g., the interests of publishing companies), there is a clear potential for bias. And in the cases where, for example, drug companies fund medical studies, scientists are now being required to disclose any such connections in their publications.

The findings of neuroimaging research for education and learning are still largely suggestive; they have not demonstrated a solid empirical link between how the brain learns and how it metabolizes oxygen or glucose. Teaching strategies derived from well-controlled neuroimaging studies are at best *compatible* with the research about how the brain seems to respond preferentially to the presentation of sensory stimuli.

There are no formal guidelines to which researchers, curriculum publishers, or private educational consultants must adhere when they make claims about brain-based educational strategies. And the conclusions of science in this area must remain speculative because there are very few confirmations of connections between neuroimaging, cognitive testing, educational strategies, and objective measurements of results. Even in the best of hands, with the most scrupulous of researchers and clinicians, the direct link from research to practical results remains at the level of guiding and of suggesting strategies that appear most consistent with the way the

brain seems to respond to stimuli.

Neuroimaging can demonstrate only that brain activity is *correlated* with a cognitive task or process. So far, it cannot demonstrate that activity in a region of the brain is necessary for the task or process. To do that conclusively would require a lesion that disrupts the neural input to the brain region to which a cognitive activity is attributed. These lesion studies are being done in animal models with techniques such as inducing electrical activity with magnetic stimulation that disrupts localized regions of brain activity. But we are not at the stage of safe lesion studies for human subjects.⁴

It would be premature and against my training as a medical doctor to state that *any* of the strategies that claim to be brain-based are as yet firmly validated by the complete meshing of simultaneous cognitive studies, neuroimaging, and educational classroom research. For now, a combination of the art of teaching and the science of how the brain responds metabolically to stimuli will be the best guide for educators in their efforts to find the best neuro-*logical* ways to present information in ways that potentiate learning.

1. Harry T. Chugani, Michael E. Phelps, and John C. Mazziotta, "Positron Emission Tomography Study of Human Brain Function Development," *Annals of Neurology*, vol. 22, 1987, pp. 487-97.

2. Peter R. Huttenlocher and A. S. Dabholkar, "Regional Differences in Synaptogenesis in Human Cerebral Cortex," *Journal of Comparative Neurology*, vol. 387, 1997, pp. 167-78.

3. Harry Chugani, "Neuroimaging of Developmental Nonlinearity and Developmental Pathologies," in R. W. Thatcher et al., eds., *Developmental Neuroimaging* (San Diego: Academic Press, 1996), pp. 187-95.

4. Russell A. Poldrack and Anthony D. Wagner, "What Can Neuroimaging Tell Us About the Mind? Insights from Prefrontal Cortex," *Current Directions in Psychological Science*, vol. 13, 2004, pp. 177-81. 

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