

When and How Neuroscience Applies To Education

While he agrees with Eric Jensen that the findings of neuroscience are relevant to education, careful speculation about how they actually apply leads Mr. Willingham to offer a more sober estimate of their value.

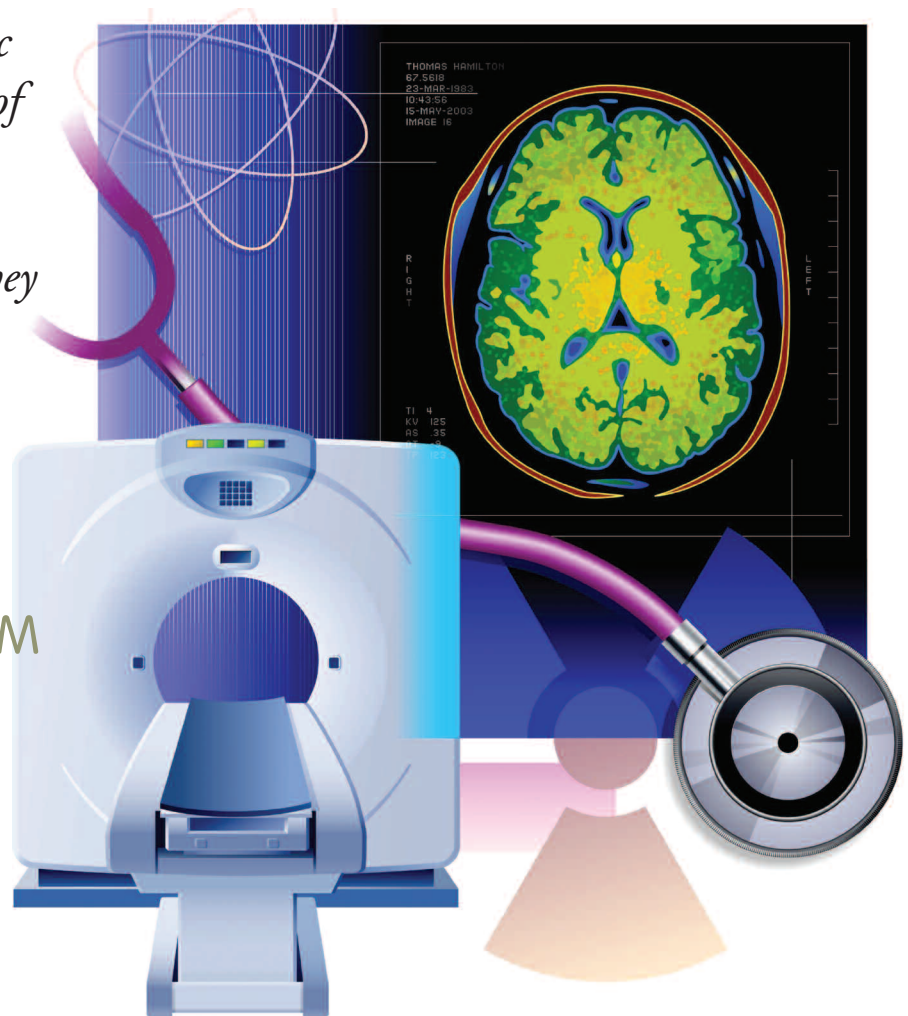
BY DAN WILLINGHAM

I AGREE WITH Eric Jensen on several important points, among them: that neuroscientific data are relevant to educational research, that these data have already proved useful, and that neuroscience alone should not be expected to generate classroom-ready prescriptions.

I sharply disagree with him, however, on the prospects for neuroscience to make frequent and important contributions to education.

I set two criteria for a “contribution” to education: the data must tell us something that we did not already know, and that something must hold the promise of helping teachers or students. For example, I ex-

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pect that most teachers know that students do not learn well if they are hungry or uncomfortably warm. What then does an understanding of the neurobiology of hunger and its effect on cognition add to a teacher’s practice?

One might argue that teachers should understand *why* they do what they do, for example, why they ensure that the room is comfortable. I disagree. All of us make use of technologies that we do not understand, and we do so without concern because understanding

or ignorance wouldn't change practice. I don't understand what my computer hardware is doing as I type this reply, but if I did, that knowledge would not change how I typed or what I wrote. Thus, while it might be rewarding for a teacher to understand some neurobiology, I argue that education has not moved forward unless that knowledge improves his or her teaching.

So under what conditions do neuroscientific findings improve education? How do we integrate neuroscientific data with educational theory and practice? It's not enough to say that "the brain is intimately involved in and connected with everything educators and students do at school," which is Jensen's premise. That statement is true, but trivially so, because the brain is intimately involved in *anything* related to human affairs. The question is how we leverage what we know about the brain to help us better understand the processes of education. Jensen relies too heavily on his intuition that, because education relies on the brain, knowledge of the brain is *bound* to help.

But knowledge of the brain is not bound to help. This is where the problem of levels of analysis proves vital. Let's set neuroscience aside for a moment and consider how the levels problem plays out in cognitive psychology, using a simple example.

We know that memory is more enduring if you "overlearn" material — that is, continue studying it after you've mastered it.¹ So why not apply that knowledge to the classroom? Why not have students rehearse important facts (for example, multiplication tables) and not quit even when they have mastered them? Any classroom teacher knows that it's not that simple, because continuous practice will be purchased at considerable cost to motivation. So here's the rub: for the sake of simplicity, cognitive psychologists intentionally isolate one component of the mind (e.g., memory or attention) when they study it. But in the classroom, all of the components operate simultaneously. So a principle from the cognitive lab might backfire when it's put into the more complex classroom environment. That's the problem of levels of analysis. Cognitive psychologists study one level — individual components of the mind — but educators operate on a different level — the entire mind of the child. (Or, better put, the mind of the child in the context of a classroom, which complicates things still further.)

Now, how can we add neuroscientific data to this picture? Parts of the brain don't map onto the cognitive system, one for one. There is not a single part of the brain for "learning" and one for "attention." Each of those cognitive functions is served by a network of brain structures. "Memory" relies on the hippocampus,

entorhinal cortex, thalamus, and frontal cortex, at the least. Suppose I take an observation about the hippocampus — which I know contributes to memory — and try to draw a classroom application from that. In so doing, I'm assuming that whatever happens in the hippocampus is a reliable guide to what is happening in the memory system as a whole, even though the hippocampus is just one part of that system. And on top of that, I'm still making the other assumption — that if I do something known to benefit memory when the memory system is isolated (as in the laboratory), it will still benefit memory when applied to the mind taken as a whole in the classroom.

But, of course, Jensen never advocated going straight from hippocampus to classroom! He explicitly emphasized that brain-based learning must be multidisciplinary. He's simply arguing that neuroscience should have a place at the table, so to speak. What I argue, in turn, is that the levels-of-analysis problem greatly reduces the likelihood that neuroscience will offer educators much of a payoff. Educators should use these data, by all means, but they should also expect that they won't find occasion to do so very often. As one gets more distant from the desired level of analysis (the child in the classroom), the probability of learning anything useful diminishes. That's true because the interactions between components at one level of analysis make it difficult to predict what's going to happen at the next level of analysis. That is, if you care about whether a child is learning, knowing conditions that make the memory system in isolation operate more efficiently (which is what a cognitive psychologist might contribute) is no guarantee that you will know whether the child in the classroom will learn more quickly. And knowing whether conditions are right for neurogenesis (which is what a neuroscientist might contribute) is no guarantee that you know that the child's memory system will operate more efficiently.

Let's further consider Jensen's example — that exercise is correlated with neurogenesis. It is perfectly plausible that a daily exercise period would benefit learning. But it's just as plausible that exercise would, at the same time, have a negative effect on attention or on motivation. We wouldn't know until we examined the effect of exercise in a real-life school setting. Jensen agrees. And presumably if we couldn't detect a positive effect of exercise on educational outcomes, we would conclude that, neurogenesis notwithstanding, the cognitive system as a whole does not benefit from exercise. Likewise, if careful behavioral research indicated that exercise *did* help in a school setting and neuroscientists protested that it ought not to, we would consider

the data from the classroom to be decisive.

So what has neuroscience done for us? In this case, not much, because it's the classroom data that really matter. In principle, neuroscientists might suggest something that we could try in the classroom, and then we would decide — by behavioral (not neuroscientific) measures — whether it works or doesn't work. That would be a valuable contribution, but I don't believe that there will be many such situations — that is, one in which neuroscientists say, "Hey, maybe you should try this at school," and educational researchers say, "Never thought of that!" The notion that exercise helps cognition, for example, is hardly new.

Still, there are other, more indirect, ways that neuroscience can illuminate educational theory. Although space limitations preclude a thorough treatment, I will mention three techniques.²

First, there are times when two well-developed behavioral theories make very similar predictions, making them difficult to separate with behavioral data. But at the neural level, it might be possible to make different predictions. For example, the nature of dyslexia was, for some time, controversial. Although some behavioral research indicated that it had a phonological basis,³ other researchers argued that phonology was not the fundamental problem in the disorder. Behavioral data were not conclusive.⁴ Brain-imaging data showed dyslexics to have decreased activation in brain regions known to support phonological coding,⁵ thus providing support to the phonological theory.

Second, neuroscientific data can show us that there is diversity where there appeared to be unity, or unity where one might suspect diversity. That is, we might discover that what seemed like a single type of behavior (e.g., "learning") is actually supported by two anatomically distinct brain systems. That indicates (but doesn't prove) that what we thought was a single function is in fact two different functions, operating in different ways. The study of learning and memory was

revolutionized in the 1980s by such observations.⁶ Neuroscientific data might also support the opposite conclusion. That is, we might suspect that two cognitive functions are separate but find that they rely on the same anatomical circuit. For example, although dyslexics show some diversity of behavioral symptoms across cultures and languages, the anatomical locus is quite consistent (at least in alphabetic languages), which indicates that the disorder is the same.⁷

Third, neuroscientific data might prove useful for the diagnosis of some learning disabilities. Researchers know that dyslexic readers show patterns of brain activity on electroencephalograms that differ from those of average readers.⁸ Several laboratories are attempting to discern whether abnormal brain activity is measurable *before* reading instruction begins, and there have been some promising results.⁹ Early diagnosis would allow early intervention, which could be an enormous advance.

In summary, I agree with Jensen that neuroscientific data can be of use to education. Indeed, they already have been. However, careful specification of how neuroscientific data and theory would actually apply to educational affairs leads to a more sober estimate of their value. The path to the improvement of education has proved steep and thorny. Neuroscience offers an occasional assist, not a significant shortcut.

1. Thomas F. Gilbert, "Overlearning and the Retention of Meaningful Prose," *Journal of General Psychology*, vol. 56, 1957, pp. 281-89.

2. For more details, see Daniel T. Willingham and Elizabeth Dunn, "What Neuroimaging and Brain Localization Can Do, Cannot Do, and Should Not Do for Social Psychology," *Journal of Personality and Social Psychology*, vol. 85, 2003, pp. 662-71; and Daniel T. Willingham and John W. Lloyd, "How Can Brain Imaging Research Help Education?," paper presented at the annual meeting of the American Educational Research Association, Chicago, 2007.

3. Richard K. Wagner and Joseph K. Torgesen, "The Nature of Phonological Processing and Its Causal Role in the Acquisition of Reading Skills," *Psychological Bulletin*, vol. 101, 1987, pp. 192-212.

4. For a review of theories, see Peggy McCardle, Hollis S. Scarborough, and Hugh W. Catts, "Predicting, Explaining, and Preventing Children's Reading Difficulties," *Learning Disabilities Research & Practice*, vol. 16, 2001, pp. 230-39.

5. Judith M. Rumsey et al., "Failure to Activate the Left Temporoparietal Cortex in Dyslexia: An Oxygen 15 Positron Emission Tomographic Study," *Archives of Neurology*, vol. 49, 1992, pp. 527-34.

6. For a review, see Daniel B. Willingham, "Memory Systems in the Human Brain," *Neuron*, January 1997, pp. 5-8.

7. Eraldo Paulesu et al., "Dyslexia: Cultural Diversity and Biological Unity," *Science*, vol. 291, 2001, pp. 2165-67.

8. Gal Ben-Yehudah, Karen Banai, and Merav Ahissar, "Patterns of Deficit in Auditory Temporal Processing Among Dyslexic Adults," *Neuroreport*, vol. 15, 2004, pp. 627-31.

9. Kimberly A. Espy, Dennis L. Molfese, and Victoria J. Molfese, "Development of Auditory Event-Related Potentials in Young Children and Relations to Word-Level Reading Abilities at Age 8 Years," *Annals of Dyslexia*, June 2004, pp. 9-38. **KK**

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