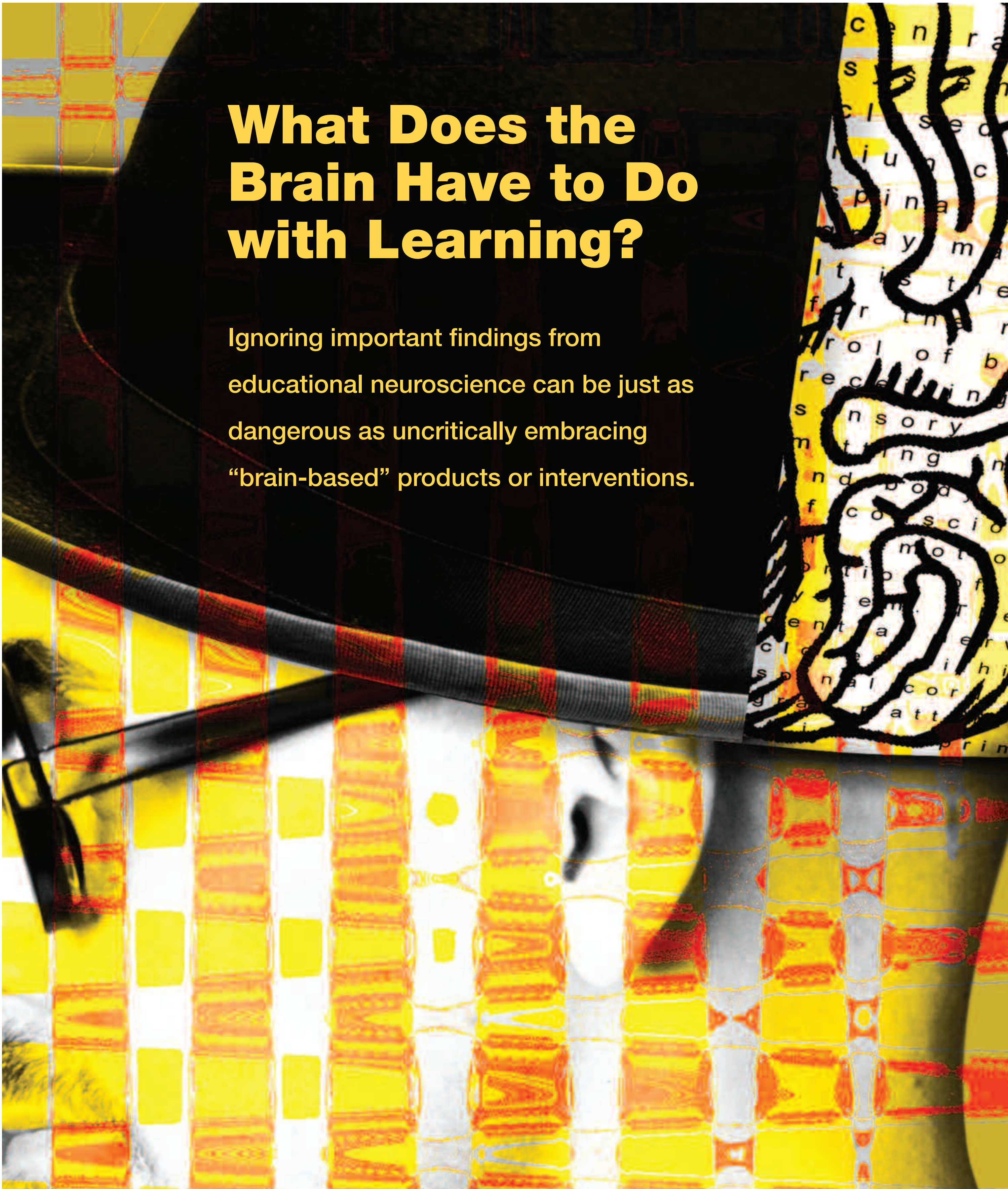

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What Does the Brain Have to Do with Learning?

Ignoring important findings from educational neuroscience can be just as dangerous as uncritically embracing "brain-based" products or interventions.

By Jennifer M. Worden, Christina Hinton, and Kurt W. Fischer

The amount of information on learning and the brain circulating in the education community can be dizzying, and, unfortunately, much of this information is inaccurate. Laboratories are often disconnected from the challenges of real classrooms. And teachers and parents often don't know how to ensure that scientists are exploring the questions that they most want answered.

But the emerging field known as Mind, Brain, and Education (MBE) is committed to connecting diverse disciplines — including cognitive psychology, biology, and education — and using this collected knowledge to inform education policy, practice, and research. We believe that MBE can help increase understanding and separate sound science from myths.

Several "myths" impede knowledge sharing among groups that want to understand and improve teaching and learning. Some of those myths are about the field itself: the role of neuroscience in informing education and the false division between researchers and educators. Other myths, what we call neuromyths, have become widespread and influence how we educate children: left brain/right brain, critical periods, and gender differences in the brain.

We should approach findings in educational neuroscience and so-called brain-based programs with cautious optimism. Ignoring important findings from this field can be just as dangerous as uncritically embracing products or interventions that claim to be based on these findings.

MYTH #1

The brain is irrelevant in learning.

After Bruno della Chiesa, a leader in educational neuroscience, proposed launching a project on neuroscience and learning to an international audi-

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ence of policy makers, he was confronted with a surprising question from a French colleague: “Qu’est-ce que le cerveau a à voir avec l’apprentissage?” or “What does the brain have to do with learning?” Bruer (1997) presented a more refined and nuanced version of this question when he argued that brain science isn’t directly relevant to learning. Cognitive psychology, he said, must mediate between neuroscience and education to develop useful applications. While there are some limitations in translating neuroscientific findings directly into classroom applications, these limitations are typically due more to insufficient collaboration among researchers and educators than to intrinsic limitations.

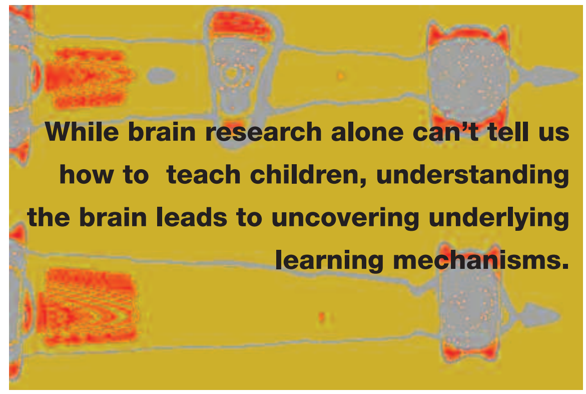
In fact, neuroscience and education have successfully worked together to build knowledge that’s applicable to the classroom. For example, consider dyslexia. Education researchers have established that most dyslexic students have difficulty analyzing the sounds of words. Many of these students can learn to read through different learning pathways that use distinctive processes, but they still have difficulties analyzing sounds at lower levels (Fink 2006). Biological and cognitive research helped explain how this pattern of strengths and weaknesses emerges through differences in genetics and corresponding brain processes (Haworth et al. 2007). By understanding both the manifestations of dyslexia across many students and some of the causes for different profiles of dyslexia, researchers have been able to quickly identify students at risk for dyslexia and design differentiated interventions. As Denis Mareschal and his colleagues (2007) have pointed out, education research often studies the “what,” focusing on the outcomes of learning. By using different methods, including those from cognitive psychology and neuroscience, we can also study the “why” and the “how” of learning. While brain research alone can’t tell us how to teach children, understanding the brain leads to uncovering underlying learning mechanisms.

There is no inherent correlation between brain size and intelligence or academic achievement.

MYTH #2

Neuroscientists know it all, and teachers don’t understand research.

A second myth is the false divide between scientists and educators. While there are some barriers to communication between researchers and educators, these barriers are far from insurmountable. Science is often seen as a collection of inviolate truths when, in fact, science is about iteratively seeking information that allows us to refine ideas and hypotheses. There are rarely quick fixes, and in our experience, educators are sometimes frustrated by the seemingly never-ending rotation of “research-based” interventions that they’re expected to implement. Simultaneously, educators sometimes feel, often rightfully so, that neuroscience research has little or no bearing on their classroom work. Of course, there is research that directly addresses the needs and questions of students and teachers, and some of it is wildly successful at improving educational outcomes. However, there could be much more such research if educators and researchers had more opportunities to communicate and collaborate.



One way to support such interaction is through research schools, where educators and researchers work alongside one another to conduct research (Hinton and Fischer 2008, 2010). In research schools, educators and researchers work together 1) to formulate a research question that’s both feasible and relevant to practice, 2) to design a study to answer this question, 3) to collect ecologically valid data, 4) to interpret the results, and 5) to design interventions or policies that are implied by those results. This is the most certain way to ensure that researchers are asking the questions that matter to teachers and that teachers are engaged in both the inputs and outputs of research. Both scientists and educators have important knowledge to contribute to solving educational problems, and supporting this type of collaborative work leads to improved educational outcomes.

One result of the difficulties in translating neuroscientific findings for the education community has been the perpetuation of neuromyths, misinformation about the brain and the way we learn that has led to common popular beliefs. While there are unfortunately many of these neuromyths floating about, we’ve chosen to highlight three that have particularly important implications for education: right brain/left brain, critical periods, and gender differences in the brain.

MYTH #3

Johnny is right brained and that is why. . . .

This myth can be traced back to the days of phrenology in the 19th century, when some believed that particular characteristics resided in certain sections of the brain, which could be detected by mapping individuals' skulls. We still see ridiculous permutations of this kind of myth in the popular press from time to time (i.e., there have been accounts of the "love area" of the brain and similar ideas, such as a "warrior gene").

Most of us recognize that feeling the ridges on one's head isn't likely to tell us whether someone is particularly empathetic or likely to be good in math. However, a modern version of these beliefs is common: People believe that each hemisphere of the brain controls separate cognitive skills. For example, if you Google "right brain left brain," you'll learn within the first few hits that the left hemisphere is much more logical and analytical while the right hemisphere is creative and holistic. You can even take a short quiz to find out which hemisphere dominates in your case, and you'll learn that schooling tends to emphasize left-brained skills.

But all of this is simply not true.

First, all of us use all of our brains, so the idea that we use mainly one hemisphere just doesn't make much sense. Certain hemispheres of the brain do play a larger role in particular functions, such as the left hemisphere in many speech functions in most people. However, all complex learning tasks involve a widely distributed network of brain areas. In fact, functional imaging technology, which allows us to view brain activity while people are performing cognitive tasks, shows that reading even a relatively simple word such as "dog" activates networks widely distributed across the brain, including both the right and left hemispheres (Poldrack, Halchenko, and Hanson 2009). Moreover, some functions involve different brain areas in different people (Fischer, Immordino-Yang, and Waber 2007). We now know that the brain is remarkably adaptive, with the capacity to adapt to new demands and new environments across an individual's life, even late in life (OECD 2007; Shonkoff and Phillips 2000).

What are the implications of the pervasiveness of this myth for education? One of the most dangerous implications centers on teacher and parent expectations for students, which often lead to stereotyping students' capabilities and limitations according to adult perceptions of their strengths or weaknesses. Research on motivation indicates that students and teachers alike often falsely believe that intelligence is a fixed, intrinsic characteristic (Dweck 1988). Coupled with the right brain/left brain neuromyth, this can result in Johnny thinking he's simply not good at math and, importantly, that he can't change this characteristic of his brain. Of course, individuals do indeed have relative strengths and weaknesses, but it's important not to stereotype them or treat them as fixed and immutable. The right brain/left brain split is indeed a myth, not a fact. It's wrong to imply that strengths and weaknesses come from the dominance of one hemisphere and are resistant to good teaching and learning. Profiles of strengths and weaknesses are much more complex than simple hemispheric dominance, and they're malleable because the brain is remarkably flexible and adaptive (OECD 2007; Shonkoff and Phillips 2000).

MYTH #4

Everyone knows you can't learn a language after age __ .

The critical period myth is another neuromyth that has a significant influence on how we educate. This neuromyth is related to the previous one in that it rests on a static conception of the brain, which we now know to be false. A critical period is a period of time when some stimuli must be presented in order for a biological function to be activated. While there's evidence for limited critical periods in brain development in limited domains (such as the strength of vision in the two eyes), no evidence supports a critical period for academic skills.

People show large individual differences in learning a new language, and some individuals can still acquire close to a native accent in adulthood.

We most often hear the critical period myth applied to language acquisition, with the prevalent belief being that it's impossible or at least extremely difficult to achieve competency in a language after a certain age. The age that people cite often varies from 3 or 4 to a high of about 13 or 14. This myth is so attractive, in part, because it seems to hold true to the experience of many people who struggled through a second language requirement in school only to promptly forget almost everything after graduation.

In fact, however, extensive research shows that there are *sensitive periods* for certain aspects of language, but not a *critical period* for language learning. Sensitive periods are "windows of opportunity" in which an individual can acquire a certain ability most easily and efficiently. For example, there appears to be a sensitive period for learning phonology, with

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evidence that infants are initially able to recognize and distinguish phonemes across multiple languages, but after three to six months of age (and exposure to the sounds of the languages spoken at home), children become more skilled at producing the sounds that appear in languages that they have heard (Neville and Bruer 2001). This effect appears to be the result of neural pruning (removing less efficient neural connections), probably to increase the efficiency of sound processing by the brain. One result may be increased difficulty with age in acquiring a native-like accent in a non-native language. However, people show large individual differences in learning a new language, and some individuals can still acquire close to a native accent in adulthood.

Other studies have shown that adult non-native language learners are actually quicker at acquiring new vocabulary in a second language and that they may draw on a sophisticated understanding of meanings that gives them advantages over young children (Snow and Hoefnagel-Hohle 1978). In short, there is no evidence that there are biological critical periods for acquiring non-native languages. Recent studies have even begun exploring the cognitive benefits of acquiring a non-native language in adulthood for mitigating or delaying the symptoms of some age-related disorders such as Alzheimer's.

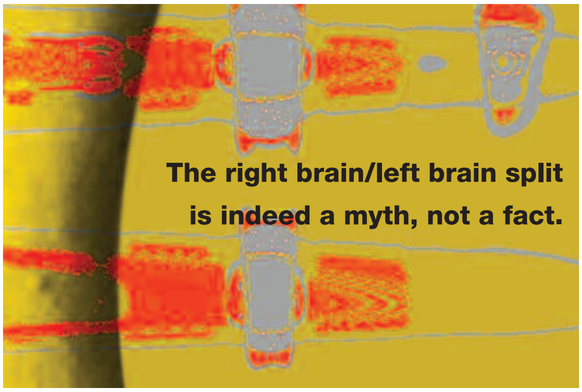
In the United States, as elsewhere, globalization and migration patterns have meant a dramatic increase in the number of non-native language learners who enter school each year. Understanding how these students learn has important implications for all students, particularly in a world where multilingualism is becoming the expectation instead of the exception. Some estimates suggest that outside of the United States, two-thirds of the world population speak more than one language competently. If American students are to be successful, educators and parents must have clear expectations regarding students' language acquisition based on evidence, not neuromyths.

MYTH #5

Girls are better at reading, but boys dominate math and science.

Like the other neuromyths, popular conceptions about ability differences between boys and girls come from misinterpretations of legitimate neuroscientific findings. Brain size does correlate with overall body size, and men are larger on average than women. Therefore, many men will have larger brains on average than many women simply because they tend, on average, to be physically larger. At the same time, women who are larger will typically have larger brains than men who are smaller.

Also, contrary to common belief, there is no inherent correlation between brain size and intelligence or academic achievement. Yes, men and women show important differences — most clearly in sexual anatomy and also in cultural roles, which lead to differences for men and women in every culture. However, neither boys nor girls have any inherent advantage in general. Girls show a small advantage in language on average, but many boys are better at language than most girls. Boys show a small advantage in spatial reasoning on average, but many girls are better at spatial reasoning than most boys.



No neuroscientific data suggest that boy's brains are better suited to any given domain or subject or vice versa. The research pendulum is shifting from how to improve the performance of girls in math and science to how to improve academic outcomes for boys across domains. Individual differences in talents certainly exist, and every student has a profile of strengths and weaknesses, but no evidence suggests that these profiles are biologically limited by gender.

CONCLUSION

As so-called brain-based programs and interventions continue to be marketed to educators and parents, educators and parents must become ever more knowledgeable about how to distinguish legitimate scientific findings from misinterpretations and neuromyths. However, not all of the burden should fall on educators and parents. Researchers also have a responsibility to communicate their findings in ways that minimize misunderstanding. One responsible activity for researchers and educators alike is transdisciplinary discussion: Teachers and scientists can cooperate to use research to answer practical questions about the problems facing schools and families. Whether through research schools or with the help of neuroeducational engineers trained to join research with practice, our ultimate goal is to increase shared knowledge. By working together, we can shift our focus from debunking neuromyths to building understanding of teaching and learning. K

REFERENCES

Bruer, John T. "Education and the Brain: A Bridge Too Far." *Educational Researcher* 26, no. 8 (1997): 4-16.

Dweck, Carol S. "A Social-Cognitive Approach to Learning." *Psychological Review* 95, no. 2 (1988): 256-273.

Fink, Rosalie P. *Why Jane and Johnny Couldn't Read — And How They Learned*. Newark, Del.: International Reading Association, 2006.

Fischer, Kurt W., Mary H. Immordino-Yang, and Deborah P. Waber. "Toward a Grounded Synthesis of Mind, Brain, and Education for Reading Disorders: An Introduction to the Field and This Book." In *Mind, Brain, and Education in Reading Disorders,* ed. Kurt W. Fischer, Jane H. Bernstein, and Mary H. Immordino-Yang. Cambridge, U.K.: Cambridge University Press, 2007.

Haworth, Claire M.A., Emma L. Meaburn, Nicole Harlaar, and Robert Plomin. "Reading and Generalist Genes." *Mind, Brain, and Education* 4, no. 1 (December 2007): 173-180.

Hinton, Christina, and Kurt W. Fischer. "Research Schools: Grounding Research in Educational Practice." *Mind, Brain, and Education* 2, no. 4 (December 2008): 157-160.

Hinton, Christina, and Kurt W. Fischer. "Research Schools: Connecting Research and Practice at the Ross School." In *Educating the Whole Child for the Whole World: The Ross Schools and the Promise of Education for the Global Era,* ed. Marcelo Suárez-Orozco and Carolyn Sattin-Bajaj. New York: New York University Press, 2010.

Mareschal, Denis, Mark H. Johnson, Sylvain Sirois, Michael Spratling, Michael S.C. Thomas, and Gert Westermann. *Neuroconstructivism: How the Brain Constructs Cognition*, vols. 1 & 2. Oxford, U.K.: Oxford University Press, 2007.

Neville, Helen J., and John T. Bruer. "Language Processing: How Experience Affects Brain Organization." In *Critical Thinking About Critical Periods,* ed. Donald B. Bailey Jr., John T. Bruer, Frank J. Symons, and Jeff W. Lichtman. Baltimore, Md.: Paul H. Brookes, 2001: 151-172.

Organisation for Economic Co-operation and Development (OECD). *Understanding the Brain: The Birth of a Learning Science.* Paris, France: OECD, 2007.

Poldrack, Russell A., Yaroslav O. Halchenko, and Steven José Hanson. "Decoding the Large-Scale Structure of Brain Function by Classifying Mental States Across Individuals." *Psychological Science* 20, no. 11 (2009): 1364-1372.

Shonkoff, Jack P., and Deborah A. Phillips, eds. *From Neurons to Neighborhoods: The Science of Early Childhood Development.* Washington, D.C.: National Academy Press, 2000.

Snow, Catherine E., and Marian Hoefnagel-Hohle. "The Critical Period for Language Acquisition: Evidence from Second Language Learning." *Child Development* 49 (1978): 1114-1128.