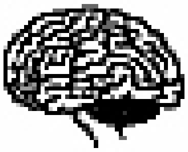
INSIDE INTELLIGENCE

Brain imagery shows that human abilities come in many combinations. **By Grace Rubenstein**



Every perceptive teacher sees a diversity of strengths and weaknesses in each of her students: There is the child who loves math but has trouble playing well with classmates, the one who makes friends easily but struggles to stay focused on written tasks, and another who creates beautiful paintings but can't seem to retain much of what she's read.

Recent brain research shows that the complex abilities apparent in individual kids are reflected on the inside, as well as the outside. Parts of the brain involved in reading, math, music, and personal relationships are different—larger or smaller, more or less active—in every child. These circuits are independent, so even if a child struggles in one domain, like reading, he may have a neurological advantage in others. And perhaps most surprising, scientists have established that learning and practicing certain skills can cause the corresponding brain areas to morph and grow. In other words, by helping a child hone her abilities, you can actually change her brain.

One camp of psychologists has long touted a single kind of smart, called fluid intelligence, which involves the ability to reason and solve problems. Some studies have shown a link between this trait and activity in certain parts of the brain. The new research doesn't disprove this, nor does it prove Howard Gardner's theory that we in fact have multiple intelligences. (The idea of "intelligence" is too subjective to be proven.) But it shows that a kaleidoscope of ability is mapped in our brains, and that, with the help of brain-imaging technology, these are variations of "intelligences" we can actually see.

"A lot of people have this intuition that if you're bad at one thing, then you're going to be bad at other things," says Bruce McCandliss, a psychology professor at Vanderbilt University, who has published multiple studies on the subject. "But here's a really strong case that shows these things are dissociated from each other, and we should think of all children as a mosaic of things that they're exceptional at and things they might struggle with."

Imaging studies have shown differences in brain architecture and activity that correspond to a host of capabilities: reading, math, music, athletics, and interpersonal relations. If we see all these abilities as aspects of intelligence, then intelligence has no single address in the brain. Each skill involves multiple gears that are spread out across the brain and that work together through intricate networks. For a child to successfully perform a skill, such as reading, all the areas involved in reading must work in concert, linked by well-built, lightning-fast neural connections. And the brains of individual children will respond to challenges in different ways, even when presented with the same problem.

In a 2005 study published in *Cognitive Brain Research*, researchers gave a difficult problem to boys who were gifted in math and to others with average math skills. The task involved mental rotation—the ability to create and manipulate an image in your head. Using functional magnetic resonance imaging (fMRI), the scientists saw several areas of the brain become active in the average-ability boys while they did the task. In the math-gifted boys, those areas and additional ones lit up like a Christmas tree, showing significantly more activity.

A year later, a study by McCandliss and another researcher that focused on brain structure found a connection between reading skills and white matter, the bundles of electricity-conducting tissues that link parts of the brain together, like the fiber-optic cable network to the Internet.

McCandliss and Sumit Niogi showed

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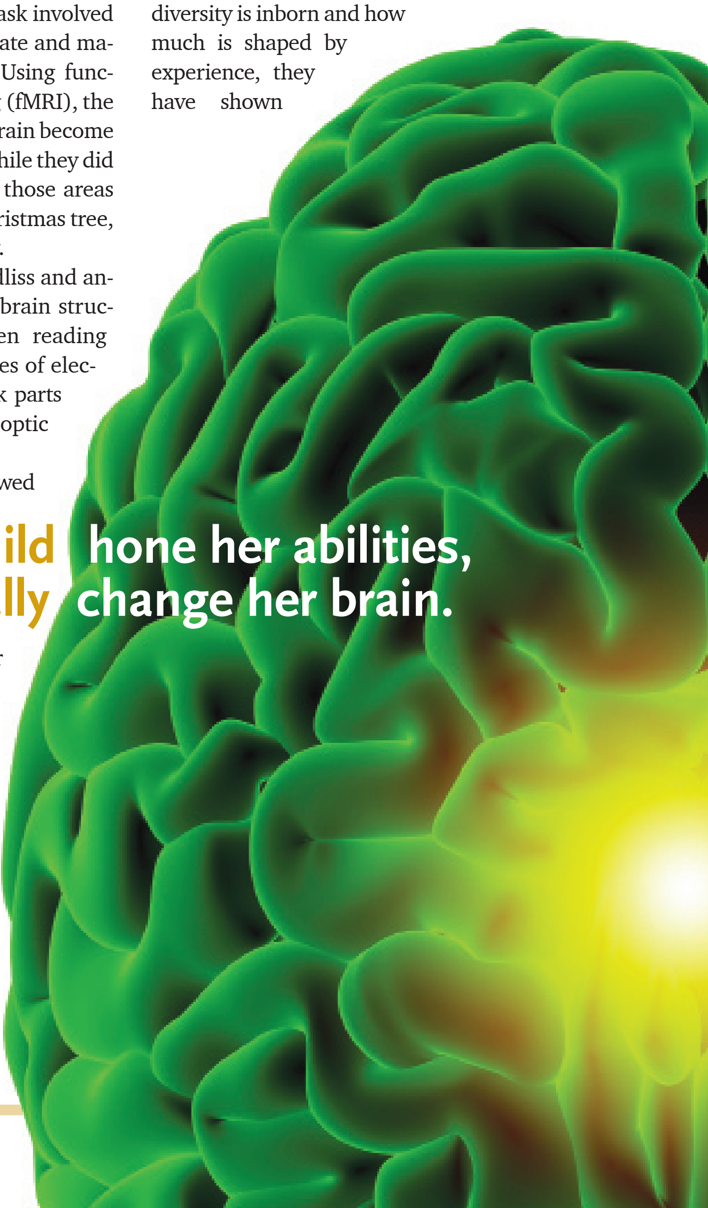
that the stronger the white matter tract in a particular mid-left area of the brain—the thicker its electrical insulation and the more well organized its fibers—the higher the reading scores of children they tested. The white matter variations accounted not only for the range of scores among typical readers but also for the differences in performance between these children and others with a likely reading disability. In the same study, the researchers found that the strength of kids' reading circuits was unrelated to that of their circuits for another skill critical in school: short-term memory.

The imaging confirms that there are differences in the brain between people who learn one way and those who learn another way, says Sally Shaywitz, Yale University's Audrey G. Ratner Professor of Learning Development, who studies dyslexia. "It explains what seems unexplainable," she says. "Why should a very bright child not be able to read? But it also tells us that other areas of the brain aren't affected."

Yet neurological profiles are not, as McCandliss puts it, "manifest destiny." Even though scientists don't know yet how much of our brain diversity is inborn and how much is shaped by experience, they have shown

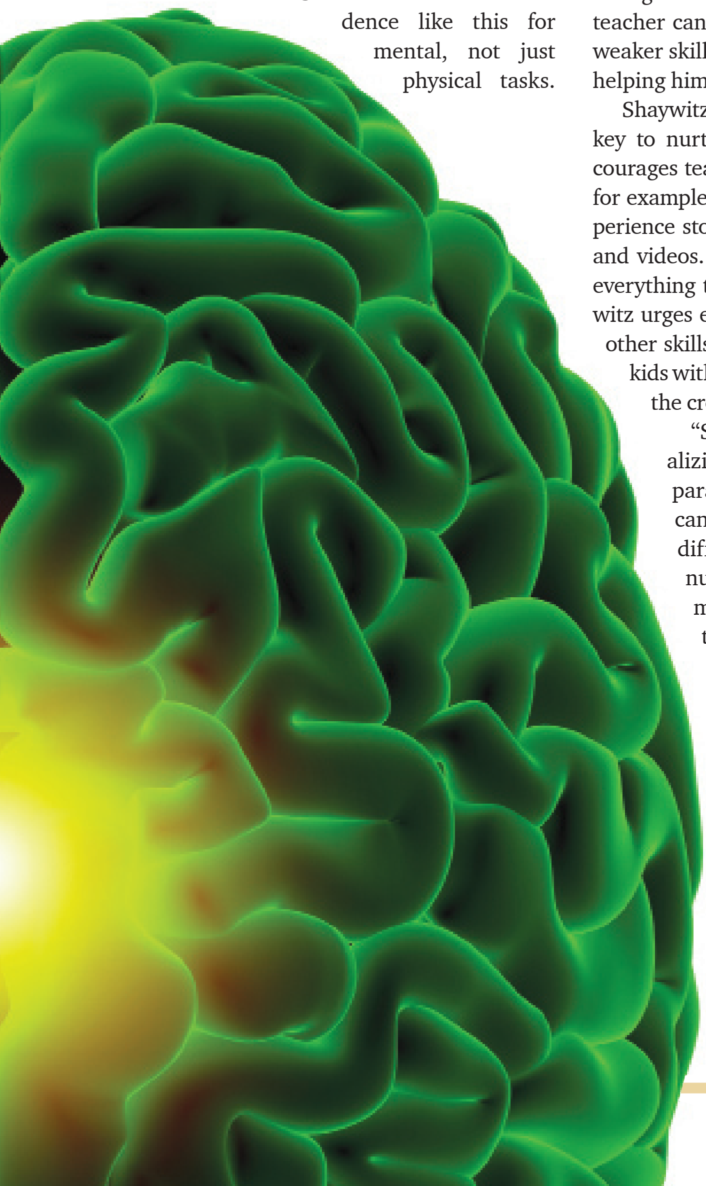


that the act of learning can change the brain.

"One should not think of intelligence as a single thing that's fixed and that nothing can be done about," says Michael Posner, founding director of Cornell University's Sackler Institute for Developmental Psychology and now a professor emeritus of psychology at the University of Oregon. "Just as there are multiple individual differences in different areas, there are ways of training these different brain networks, and that might change the brain processes underlying them."

In musicians who play stringed instruments, for instance, the brain areas that affect the fingers of the left hand are larger than other people's. This effect, described in *Science* magazine in 1995, is strongest for the four fingers—which do the bulk of the work manipulating the strings of, say, a violin—and weakest for the thumb. The earlier in life each musician had started to play, the more distinct were the differences in those parts of the brain.

Scientists have seen evidence like this for mental, not just physical tasks.



In studies with strong implications for school, Shaywitz, codirector of the Yale Center for Dyslexia & Creativity, has shown that teaching can alter the brains of disabled readers. She and colleagues spent a year helping children with reading disabilities build their phonological skills. Afterward, the children's reading improved, and fMRI pictures showed that activity in parts of their brains crucial for reading had jumped.

What does all this mean for educators? First, a caution: Neuroscientists insist there is no concrete proof that certain teaching practices are best for the brain. But we can make some inferences based on brain research, and in time our understanding will grow.

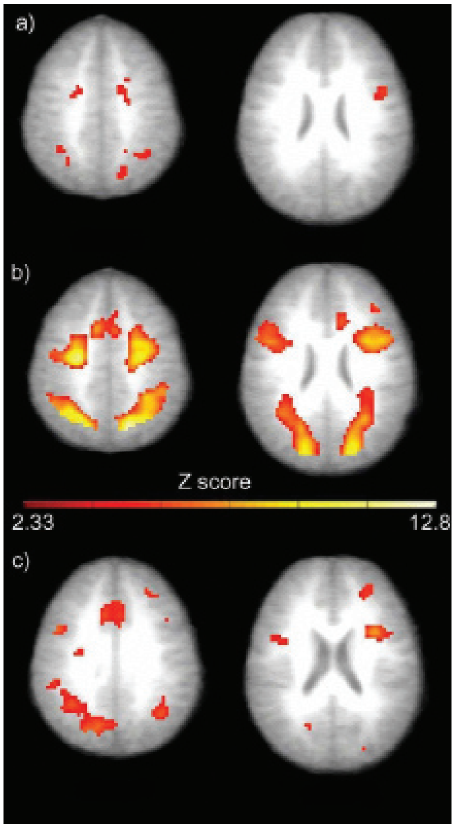
Judy Willis, a neurologist, middle school teacher, and author of several books on the subject, says educators can achieve a lot just by designing lessons that appeal to multiple senses. She suggests that teachers lead a child into a new subject through his particular strengths and interests. Once he's engaged, a teacher can challenge him to use a different, weaker skill set for another part of the lesson, helping him develop those parts of his brain.

Shaywitz advocates personalization as a key to nurturing children's growth. She encourages teachers to allow struggling readers, for example, to use dictation or to tell and experience stories through pictorial storyboards and videos. Reading is the bedrock of almost everything that happens in schools, but Shaywitz urges educators to recognize and reward other skills, too, as she has found that many kids with reading disabilities have a flair for the creative and the visual.

"Schools like to talk about individualizing, but it's within very narrow parameters," says Shaywitz. "So if we can show that children's brains are different—that they need different nutrients, if you will—that's a tremendous step to say, 'It's not trivial; they're built differently.'"

The next step for scientists is to directly link brain changes to the broad experience of school. McCandliss is reseraching the difference that a year of school makes in the brains of first graders compared with peers who just missed the birthday cutoff for enrollment.

Of course, educators don't usually have to look inside a child's brain to see that she has learned something. But a deeper understanding of how education shapes the brain could give us new insights into what and how children can most successfully learn. Who knows: Maybe in some far-off future, we could supplement the narrow results of standardized tests with images of changes in the brain. e



A BRIGHT BUNCH: These images, from a 2005 study in *Cognitive Brain Research,* show horizontal slices in the brains of adolescent boys, as measured while they were doing a spatial math problem. The pictures (shown with the front of the head toward the top of the page) are composites from multiple boys—those shown in a) having average math ability, and those in b) being gifted in math. The brighter the color in these fMRI pictures and the higher the Z score (a statistical measure), the stronger the brain activity. The c) images show the active areas unique to the math-gifted brain.

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