fMRI Research on Dyslexic Children's Brains Pre and Post-Fast ForWord
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http://www.stanford.edu/dept/news/pr/03/dyslexia226.html
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Dyslexic children's brains operate more like those of normal readers following training designed to help them hear sounds in words, new study finds

For the first time, researchers have shown that the brains of dyslexic children can be rewired -- after undergoing intensive remediation training -- to function more like those found in normal readers.

The training program, which is designed to help dyslexics understand rapidly changing sounds that are the building blocks of language, helped the participants become better readers after just eight weeks.

The findings were released Monday in "Neural deficits in children with dyslexia ameliorated by behavioral remediation: Evidence from functional MRI," published by the *Proceedings of the National Academy of Sciences Early Edition*.

"It was very dramatic to see the huge differences that occurred in the brains of these children," said Stanford psychology Professor John Gabrieli, one of the study's authors. "The intervention, although substantial, only covered eight weeks. One note of optimism about the study is that such a limited intervention can have a substantial effect on reading scores."

Brain imaging scans of the children who participated in the training showed that critical areas of the brain used for reading were activated for the first time, and that they began to function more normally. Furthermore, additional regions of the brain were activated in what the researchers believe the dyslexics may have used as a compensatory process as they learned to read more fluently.

Gabrieli said the study's findings may help demonstrate how different kinds of reading programs can tackle various problems faced by poor readers. "This is showing us for the first time the specific changes in the brains of children receiving this sort of treatment, and how that is coupled with the improvement they have in reading and language ability," he said. "We're hoping that this becomes an additional tool to understand how educational remediation programs alter children's abilities, as they must do, by changing the way their brains process information."

Study co-author Paula Tallal, professor of neuroscience at Rutgers University and a founder of Scientific Learning Corporation, the Oakland-based company that designed the program, said the findings are also important because it is the first time a commercial product has been proven scientifically to work using standardized educational testing and brain imaging. Scientific Learning's computer program, *Fast ForWord Language*, focuses on helping children become more fluent at processing the rapidly changing sounds, she said.

"In light of President [George W.] Bush's legislation, No Child Left Behind, which mandates that only scientifically validated applications be used for intervening with children, this program has the potential to address the crisis we are facing in the number of children failing to meet [educational] standards," she said. The No Child Left Behind Act of 2001 places an emphasis on teaching methods that have been proven scientifically to work.

Dyslexia, sometimes called "word blindness," is a common disorder, affecting 5 to 10 percent of Americans, Gabrieli said. It is defined as a specific difficulty in reading that is severe enough to interfere with academic functioning and cannot be accounted for by lack of educational opportunities, personal motivation or problems in sight or sound. Tallal said that studies estimate that about 40 percent of people with dyslexia inherit it genetically. Other factors believed to trigger the disorder include prematurity at birth, developmental language impairment and attention deficits, she said.

Dyslexics have trouble distinguishing between letters that rhyme, such as 'B' and 'D.' "If you hear the sound 'ba' in butter and 'da' in Doug, the only way we know the difference is in the first 40 milliseconds of the onset of those sounds," Tallal explained. "The ability to extract the sounds out of words is what is called phonological awareness. We have to be aware that words can be broken into sounds, called phonemes, and that these sounds have to be identified with letters." This process might appear intuitive, but it is a learned skill, Tallal said.

The training program the children took part in was targeted at helping them learn to process and interpret the very rapid sequence of sounds within words and sentences by exaggerating and slowing them down. "These are the building blocks you have to have in place before you can learn to read," Tallal said. "I think *Fast ForWord* is building the scaffold for reading, and doing it based on scientific knowledge of the most efficient and effective way of helping the brain learn."

The study

The study included 20 dyslexic children aged 8 to 12 years. Their brains were scanned using functional magnetic resonance imaging (fMRI) at Stanford's Lucas Center for Magnetic Resonance Spectroscopy before and after participating in the eight-week training program. A control group of 12 children with normal reading abilities also had their brains scanned but did not participate in the training.

The scanning machines, which look like beds that slide into small tubes, normally are used to check for brain injuries or tumors, Gabrieli said. With slightly different software they can be used to measure which regions of the brain are active by looking for changes in blood oxygenation, a process that occurs in parts of the brain where the neurons are active.

Study lead author Elise Temple, assistant professor in human development at Cornell, headed the research as a graduate student at Stanford. Both the dyslexic children and the control group were asked to perform a simple rhyming task while having their brains scanned. Participants were shown two uppercase letters and told to push a button if the two letters rhymed with each other. For example, 'B' and 'D' would match, but not 'B' and 'K.' Twenty-minute sessions were broken into five-minute segments, during which the children had to stay completely still. Afterward, they were rewarded with Pokémon or baseball cards, and given a picture of their brain to take home. Before the sessions started, Temple allowed the children to play around the machines, which can be claustrophobic, to help them become comfortable with the testing process. "In this study, it was especially important not to have the experience be a bad one because we wanted them to come back," Temple said.

During the rhyming exercise, children with normal reading showed activity in both the language-critical left frontal and temporal regions of the brain, the latter of which is behind and above the left ear. Dyslexics, however, struggled with the task and failed to activate the temporal region, and showed some activity only in the frontal brain area.

Afterward, the dyslexic children used the *Fast ForWord Language* computer program for 100 minutes a day, five days a week, as part of their regular school day. "The computer games were fun, the kids liked them," Gabrieli said. The program consisted of seven exercises that rewarded players when they answered questions correctly. For example, when a picture of a boy and a toy was shown, a voice from the computer would ask the player to point to the boy, a step that required understanding the very brief difference in the sound of the first consonant in each word. Initially, the questions were asked in a slower, more exaggerated fashion than in normal speech to help the children understand the sounds inside the words. As the player progressed, the speed of the voice in the program slowly increased. "Each child worked at his or her own level," Tallal said. "The goal was to leave all children processing sounds correctly in words and sentences of increasing length and grammatical complexity."

The results

Following the training, the dyslexic children's scores went up in a number of language and reading tests, Gabrieli said. "The study supported the idea that for some children, getting training on just simply processing rapid sounds is a route to becoming much more fluent and capable readers," he said. In addition, activation of the children's brains fundamentally changed, becoming much more like that of good readers. "We see that the brains of these children are remarkably plastic and adaptive, and it makes us hopeful that the best language intervention programs in the future can alter the brains in fundamentally helpful ways," he said.

It is likely that the children will continue to need considerable help in reading, Gabrieli said. "This is not a one-shot vaccine," he said. "But it makes them much more prepared to take advantage of a regular curriculum to read successfully and do well."

The next step, Temple said, is to see if other commercial programs can alter the brain as well. "I don't know if these changes are unique to this program," she said. "Are there some training programs that are better for some kids than others?" A future goal would be to offer a series of tests to help select which programs best meet a child's needs, she said.

For many years, Gabrieli said, the nation has been concerned with the best methods to teach reading. "We're hoping that this becomes one piece of many pieces of research that will help us better understand ... what are effective ways to rescue children who have trouble reading," he said. In addition, the study brings the scientific use of brain imaging into the arena of education. "We'd like to use these cutting-edge tools of neuroscience to somehow directly assist thoughts about educational curricula, policies and ways to help children perform better in school and look forward to better futures," he said.

In addition to Temple, Tallal and Gabrieli, the paper was written by Gayle K. Deutsch, a senior clinical scientist at Stanford; Russell Poldrack, a former postdoctoral student at Stanford and currently assistant professor of psychology at the University of California-Los Angeles; Steven L. Miller of Scientific Learning Corporation; and Michael M. Merzenich, a founder of Scientific Learning and a professor at the University of California-San Francisco. *The Haan Foundation for Children helped fund the study.*