Size, wiring of brain structures in kids predict benefit from math tutoring, study says

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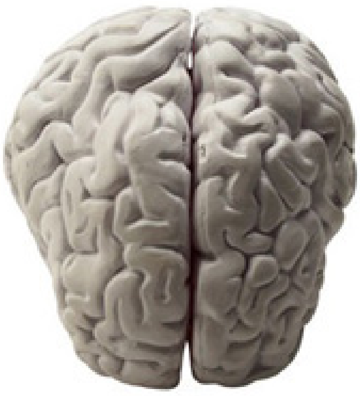

(Medical Xpress)—Why do some children learn math more easily than others? Research from the Stanford University School of Medicine has yielded an unexpected new answer.

In a study of third-graders' responses to math tutoring, Stanford scientists found that the size and wiring of specific brain structures predicted how much an individual child would benefit from math tutoring. However, traditional intelligence measures, such as children's IQs and their scores on tests of mathematical ability, did not predict improvements from tutoring.

The research is the first to use brain scans to look for a link between math-learning abilities and brain structure or function, and also the first to compare neural and cognitive predictors of kids' responses to tutoring. In addition, it provides information on the differences between how children and adults learn math, and could help researchers understand the origins of math-learning disabilities.

The study was published online April 29 in *Proceedings of the National Academy of Sciences*.

"What was really surprising was that intrinsic brain measures can predict change - we can actually predict how much a child is going to learn during eight weeks of math tutoring based on measures of brain structure and connectivity," said Vinod Menon, PhD, the study's senior author and a professor of psychiatry and behavioral sciences. Menon is also a member of the Child Health Research Institute at Lucile Packard Children's Hospital.

"The results are a significant step toward the development of targeted learning programs based on a child's current as well as predicted learning trajectory," said the study's lead author, Kaustubh Supekar, PhD, postdoctoral scholar in psychiatry and behavioral sciences.

Menon's team focused on third-grade students ages 8 and 9 because these children are at a critical stage for acquiring basic arithmetic skills. The study included 24 third-graders who participated in a well-validated program of 15 to 20 hours of individualized math tutoring over eight weeks. The tutors explained new concepts to children and also got them to practice math skills with an emphasis on speed, and the sessions were tailored to each child's level of understanding.

Before tutoring began, the children were given several standard neuropsychological assessments, including tests of IQ, working memory, reading and math-problem-solving abilities. Both before and after the eight-week tutoring period, children's arithmetic performance was tested, and all children had structural and functional magnetic resonance imaging scans performed on their brains. To control for the effects of math instruction the children received at school (rather than during tutoring), a comparison group of 16 third-grade children who did not receive tutoring, but who had the same testing and brain scans before and after an eight-week interval, was also included in the study.

All 24 children receiving tutoring improved their arithmetic performance. Their performance efficiency, a composite measure of accuracy and speed of problem solving, improved an average of 67 percent after tutoring. But individual gains varied widely, ranging from 8 percent to 198 percent improvement. The children who did not receive tutoring did not show any change in arithmetic performance during the study.

When the researchers analyzed the children's structural brain scans, they found that larger gray matter volume in three brain structures predicted greater ability to benefit from math tutoring. (The predictions were generated with a machine learning algorithm, the same type of data-analysis tool used to create movie recommendations for users of websites like Netflix, for example.) Of the three structures, the best predictor of improvement with tutoring was a larger hippocampus, a structure traditionally considered one of the brain's most important memory centers. Functional connections between the hippocampus and several other brain regions, especially the prefrontal cortex and basal ganglia, also predicted ability to benefit from tutoring. These regions are important for forming long-term memories.

"The part of the brain that is recruited in memories for places and events also plays a pivotal role in determining how much and how well a child learns math," Supekar said.

None of the neuropsychological assessment scores, such as IQ or tests of working memory, could predict how much an individual child would benefit from tutoring.

The brain systems highlighted by this study - including the hippocampus, basal ganglia and prefrontal cortex - are different from those previously implicated for math learning in adults, the researchers noted. When solving math problems, adults rely on brain regions that are specialized for representing complex visual objects and processing spatial information.

And the findings suggest that the tutoring approach used, which was tailored to each child's level of understanding and included lots of repetitive, high-speed arithmetic practice to help cement facts in children's heads, works because it is compatible with the way their brains encode facts. "Memory resources provided by the hippocampal system create a scaffold for learning math in the developing brain," Menon said. "Our findings suggest that, while conceptual knowledge about numbers is necessary for math learning, repeated, speeded practice and testing of simple number combinations is also needed to encode facts and encourage children's reliance on retrieval - the most efficient strategy for answering simple arithmetic problems." Once kids are able to pull up answers to basic arithmetic problems automatically from memory, their brains can tackle more complex problems.

The researchers' next steps will include comparing brain structure and wiring in children with and without math learning disabilities, analyzing how the wiring of the brain changes in response to tutoring and examining whether lower-performing children's brains can be exercised to help them learn math. "We're pushing a very ecologically relevant model of learning," Menon said. "Academic instruction should rely on validated instructional principles while incorporating individualized training to provide feedback on whether students are right or wrong, how they're wrong and how they can improve their math skills."

More information: Neural predictors of individual differences in response to math tutoring in primary-grade school children , www.pnas.org/cgi/doi/10.1073/pnas.1222154110

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