New study sheds light on how children's brains memorize facts

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As children learn basic arithmetic, they gradually switch from solving problems by counting on their fingers to pulling facts from memory. The shift comes more easily for some kids than for others, but no one knows why.

Now, new brain-imaging research gives the first evidence drawn from a longitudinal study to explain how the brain reorganizes itself as children learn math facts. A precisely orchestrated group of brain changes, many involving the memory center known as the hippocampus, are essential to the transformation, according to a study from the Stanford University School of Medicine.

The results, which will be published online Aug. 17 in *Nature Neuroscience*, explain brain reorganization during normal development of cognitive skills and will serve as a point of comparison for future studies of what goes awry in the brains of children with learning disabilities.

"We wanted to understand how children acquire new knowledge, and determine why some children learn to retrieve facts from memory better than others," said Vinod Menon, PhD, professor of psychiatry and behavioral sciences and the senior author of the study. "This work provides insight into the dynamic changes that occur over the course of cognitive development in each child."

The study also adds to prior research into the differences between how children's and adults' brains solve math problems. Children use certain brain regions, including the hippocampus and the prefrontal cortex, very differently from adults when the two groups are solving the same types of math problems, the study showed.

"It was surprising to us that the hippocampal and prefrontal contributions to memory-based problem-solving during childhood don't look anything like what we would have expected for the adult brain," said postdoctoral scholar Shaozheng Qin, PhD, who is the paper's lead author.

Charting the Shifting Strategy

In the study, 28 children solved simple math problems while receiving two functional magnetic resonance imaging brain scans; the scans were done about 1.2 years apart. The researchers also scanned 20 adolescents and 20 adults at a single time point. At the start of the study, the children were ages 7-9. The adolescents were 14-17 and the adults were 19-22. The participants had normal IQs. Because the study examined normal math learning, potential participants with math-related learning disabilities and attention deficit hyperactivity disorder were excluded. The children and adolescents were studying math in school; the researchers did not provide any math instruction.

During the study, as the children aged from an average of 8.2 to 9.4 years, they became faster and more accurate at solving math problems, and relied more on retrieving math facts from memory and less on counting. As these shifts in strategy took place, the researchers saw several changes in the children's brains. The hippocampus, a region with many roles in shaping new memories, was activated more in children's brains after one year. Regions involved in counting, including parts of the prefrontal and parietal cortex, were activated less.

The scientists also saw changes in the degree to which the hippocampus was connected to other parts of children's brains, with several parts of the prefrontal, anterior temporal cortex and parietal cortex more strongly connected to the hippocampus after one year. Crucially, the stronger these connections, the greater was each individual child's ability to retrieve math facts from memory, a finding that suggests a starting point for future studies of math-learning disabilities.

Although children were using their hippocampus more after a year, adolescents and adults made minimal use of their hippocampus while solving math problems. Instead, they pulled math facts from well-developed information stores in the neocortex.

Memory Scaffold

"What this means is that the hippocampus is providing a scaffold for learning and consolidating facts into long-term memory in children," Menon said. Children's brains are building a schema for mathematical knowledge. The hippocampus helps support other parts of the brain as adultlike neural connections for solving math problems are being constructed. "In adults this scaffold is not needed because memory for math facts has most likely been consolidated into the neocortex," he said. Interestingly, the research also showed that, although the adult hippocampus is not as strongly engaged as in children, it seems to keep a backup copy of the math information that adults usually draw from the neocortex.

The researchers compared the level of variation in patterns of brain activity as children, adolescents and adults correctly solved math problems. The brain's activity patterns were more stable in adolescents and adults than in children, suggesting that as the brain gets better at solving math problems its activity becomes more consistent.

The next step, Menon said, is to compare the new findings about normal math learning to what happens in children with math-learning disabilities.

"In children with math-learning disabilities, we know that the ability to retrieve facts fluently is a basic problem, and remains a bottleneck for them in high school and college," he said. "Is it that the hippocampus can't provide a reliable scaffold to build good representations of math facts in other parts of the brain during the early stages of learning, and so the child continues to use inefficient strategies to solve math problems? We want to test this."

More information: Paper - dx.doi.org/10.1038/nn.3788

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