

2 Distinct Circuits in the Brain Believed Involved in Doing Math One for exact calculations, one for rough estimates

Sandra Blakeslee, New York Times
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The ability to do mathematics -- everything from simple arithmetic to thinking up equations that explain an expanding universe -- may stem from the interaction of two brain circuits that handle numbers differently, two scientists have found.

In a series of experiments involving bilingual college students, the researchers discovered that one circuit gives names to numbers and carries out exact calculations. A second circuit operates intuitively and is used for estimating quantities and other numerical relationships.

During human evolution, they suggest, these two brain areas combined forces and gave rise to the remarkable human capacity for manipulating numbers arithmetically. Their interaction may also underlie many kinds of advanced mathematics.

Dr. Stanislas Dehaene, a neuroscientist at the National Institute for Health and Medical Research (known as Inserm) in Orsay, France, and Dr. Elizabeth Spelke, a cognitive psychologist at the Massachusetts Institute of Technology in Cambridge, Mass., described the results of their study in last week's issue of Science magazine.

Dr. Brian Butterworth, a professor of cognitive neuroscience at University College London, hailed the new work as ``virtuoso stuff."

``Their experiments reveal the brain's numerical processes in unprecedented detail," said Butterworth, who is the author of ``What Counts: How Every Brain Is Hardwired for Math," to be published in August by the Free Press.

Until recently, little has been known about how the human brain actually does math. In the past, Dehaene said, ``the only source of information about the mental representations used in mathematics was the introspection of mathematicians."

Some mathematicians and scientists say language is crucial. But Albert Einstein, for example, once said, "words or language, as they are written or spoken, do not seem to play any role in my mechanism of thought."

More recent experiments have provided hints about where and how mathematical knowledge is embedded in the brain. Studies show that rhesus monkeys have a number sense and that chimps can use symbols for numbers. Birds and rats can count. Human infants can detect changes in the number of objects in an array, suggesting they have a number sense.

At the opposite end of the scale, stroke patients can lose aspects of their ability to do arithmetic, Dehaene said. For example, some cannot decide what number falls between 2 and 4 or whether 9 is closer to 10 or 5, yet they can easily rattle off multiplication tables.

Others cannot decide if $2 + 2$ equals 3 or 4 but if asked which number they prefer as an answer -- 3 or 9 -- they choose 3. From these clues, Dehaene postulated that within elementary arithmetic, there are at least two circuits for representing a number. One is language based. It stores tables of exact arithmetic knowledge, like the multiplication tables. The second is independent of language. It represents number magnitudes and has been called a mental "number line" used to approximate and manipulate quantities.

To test this idea, Dr. Spelke asked volunteers who were fluent in Russian and English to solve a series of arithmetic problems. One group was schooled in Russian, the other in English. One set of the math problems involved exact calculations: does 53 plus 68 equal 121 or 127? Another set of problems involved approximating answers: is 53 plus 68 closer to 120 or 150?

When approximating answers, both groups performed the same whether they were tested in English or Russian, Dehaene said. But a different pattern emerged for exact calculations. When those taught in Russian were tested in English or vice versa, he said, the volunteers needed up to a full second or more to solve the problem.

The researchers concluded that knowledge about exact problems is stored in a language area because subjects had to translate internally to solve the problem. But in

approximating answers, no translation time is required, suggesting that this ability is stored independently from language.

“I was amazed that the dissociation could be so sharp,” Dehaene said. “We presented our subjects with tasks that are superficially extremely similar. Our brains really solve these two tasks in quite different ways.”

Later, the researchers gave similar tests in exact and approximate arithmetic to French college students and used imaging techniques to see which areas of their brains were active. When approximating answers, their parietal lobes lit up.

These are regions on both sides of the brain that carry out visual and spatial tasks. It is where the mind makes analogies, guides hand and eye movements, rotates objects mentally and orients attention. When doing exact calculations, on the other hand, the left frontal lobe lit up the most. This is where the brain associates verbs and nouns and carries out other language tasks.

To rule out the possibility that people first use one area and switch to the other, the researchers took another set of brain images using a technique that captures the timing of events in hundredths of a second. They could see that the parietal and frontal circuits operate independently in doing the different kinds of arithmetic problems.

Dehaene said the new findings cannot determine which children are naturally better at math. Nor do they herald big changes in the way math is taught. The sole factor known to predict exceptional expertise in any field, Butterworth said, is hard work.

It looks like humans are “born with a start-up kit for numbers,” Butterworth said, and must practice, just as musicians do.

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