

How One's 'Number Sense' Helps With Mathematics

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Scientists have for the first time established a link between a primitive, intuitive sense of numbers and performance in math classes, a finding that could lead to new ways to help children struggling in school.

A study involving 64 14-year-olds found that the teenagers who did well on a test that measured their "number sense" were much more likely to have gotten good grades in math classes.

"We discovered that a child's ability to quickly estimate how many things are in a group significantly predicts their performance in school mathematics all the way back to kindergarten," said Justin Halberda, an assistant professor of psychological and brain sciences at [Johns Hopkins University](#) who led the research, published online yesterday by the [journal Nature](#). "It was very surprising."

Other experts agreed.

"The link between math achievement and number sense is really stunning," said Peggy McCardle of the [National Institutes of Health](#), which funded the research. "The potential here could be very important."

Researchers have long known that people are born with the ability to quickly estimate relative numbers of objects, with studies finding the skill in children within months of being born and across cultures. It is what people use in day-to-day life to estimate everything from whether a stack of paper plates will suffice for a backyard barbecue to whether they have picked the best spot to squeeze onto a crowded train.

"It's what you and I use when we're getting on a bus and trying to figure out which door to go through," Halberda said. "We quickly scan the bus to see if there are more people on the front of the bus or the back of the bus."

Every animal tested has been found to have a number sense, including monkeys, pigeons and even rats, indicating that it is an ancient cognitive skill that evolved early. Such an ability would be crucial, for example, for rats assessing which trash can tends to yield the most scraps or for a chimp deciding whether to flee or attack an aggressor.

"Chimps have been seen apparently assessing the number of individuals in their group after hearing an aggressive vocalization," said Elizabeth M. Brannon, an associate professor of psychology and neuroscience at [Duke University](#). "If they are only with one individual or by themselves, they may not try to defend the territory, but if they have three or four, they might."

It has been unclear, however, whether this sense plays a role in the uniquely human ability to learn higher mathematics such as algebra, calculus and trigonometry.

"Humans actually have two separate senses of mathematics," Halberda said. "We have this intuitive sense of numbers that you and I use when we are looking at the bus, and we have a second system, which is what we use to learn in school. It relies on language, and only humans have that."

The first question Halberda and his colleagues wanted to answer was whether the number sense varies significantly among people. The researchers asked 14-year-old boys and girls to look at [videos](#) on a computer screen and estimate whether there were more flashing yellow dots or blue dots. When there was a big difference, most children easily got the right answer. But when the difference was smaller, some students clearly had more difficulty.

"That was very surprising to us," Halberda said. "The assumption was any variation wasn't going to be that large. This is very old cognitive machinery, so it was surprising there is such wide variation."

The researchers then examined whether there was any relationship to how well the students did in math class. They were surprised again.

"To me, it's mind-blowing," Halberda said. "While both abilities deal with numbers, they deal with numbers in two very different ways. Before this, all indications were they were separate systems."

The findings illustrate once again how many fundamental characteristics humans share with other species, Halberda said.

"We think of mathematics as the pinnacle achievement of humankind. It's something different and special that only humans have. We use mathematics to send a man to the moon. The idea that it relates in any way to what happens when a rat is looking for food is very surprising. It's moving to see a connection between ourselves and a human infant and another animal."

Moreover, the researchers found, the relationship between number sense and math ability appears to be independent of other factors that typically play a role in higher cognitive functions, including IQ, working memory, visual-spatial skills and verbal ability.

"Our data suggests there is a very specific relationship between the approximate number system and formal mathematics that is not dependent on any other ability," Halberda said.

Stanislas Dehaene, a French neuroscientist who has pioneered research in the field, praised the new work in an e-mail as a "beautiful demonstration" of the link to higher mathematical ability.

"We long suspected that symbolic mathematics was linked to the sense of numerosity or 'numerousness' of sets of concrete objects," wrote Dehaene, noting that while the cause-and-effect relationship between number sense and math remains to be proved, his team has

unpublished data suggesting that some children are born with a deficit in this ability. "Again, however, longitudinal studies would be needed to establish a genuine causality."

If it does, the work could lead to ways to identify students who may have trouble with math, Halberda and others said.

"We could pick up early on those kids who might be having difficulty and develop interventions that we think might work for them," McCardle said.

Halberda said he has already begun studying whether testing a child's number sense at age 3 predicts his performance in math class, whether there may be a way to boost a child's number sense, and whether doing so might help him learn math.