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# **Gut Instinct's** Surprising Role in Math

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You are shopping in a busy supermarket and you're ready to pay up and go home. You perform a quick visual sweep of the checkout options and immediately start ramming your cart through traffic toward an appealingly unpeopled line halfway across the store. As you wait in line and start reading nutrition labels, you can't help but calculate that the 529 calories contained in a single slice of your Key lime cheesecake amounts to one-fourth of your recommended daily caloric allowance and will take you 90 minutes on the elliptical to burn off and you'd better just stick the thing behind this stack of Soap Opera Digests and hope a clerk finds it before it melts.

One shopping spree, two distinct number systems in play. Whenever we choose a shorter grocery line over a longer one, or a bustling restaurant over an unpopular one, we rally our approximate number system, an ancient and intuitive sense that we are born with and that we share with many other animals. Rats, pigeons, monkeys, babies -- all can tell more from fewer, abundant from stingy. An approximate number sense is essential to brute survival: how else can a bird find the best patch of berries, or two baboons know better than to pick a fight with a gang of six?

When it comes to genuine computation, however, to seeing a self-important number like 529 and panicking when you divide it into 2,200, or realizing that, hey, it's the square of 23! well, that calls for a very different number system, one that is specific, symbolic and highly abstract. By all evidence, scientists say, the capacity to do mathematics, to manipulate representations of numbers and explore the quantitative texture of our world is a uniquely human and very recent skill. People have been at it only for the last few millennia, it's not universal to all cultures, and it takes years of education to master. Math-making seems the opposite of automatic, which is why scientists long thought it had nothing to do with our ancient, pre-verbal size-em-up ways.

Yet a host of new studies suggests that the two number systems, the bestial and celestial, may be profoundly related, an insight with potentially broad implications for math education.

One research team has found that how readily people rally their approximate number sense is linked over time to success in even the most advanced and abstruse mathematics courses. Other scientists have shown that preschool children are remarkably good at approximating the impact of adding to or subtracting from large groups of items but are poor at translating the approximate into the specific. Taken together, the new research suggests that math teachers might do well to emphasize the power of the ballpark figure, to focus less on arithmetic precision and more on general reckoning.

"When mathematicians and physicists are left alone in a room, one of the games they'll play is called a Fermi problem, in which they try to figure out the approximate answer to an arbitrary problem," said Rebecca Saxe, a cognitive neuroscientist at the Massachusetts Institute of Technology who is married to a physicist. "They'll ask, how many piano tuners are there in Chicago, or what contribution to the ocean's temperature do fish make, and they'll try to come up with a plausible answer."

"What this suggests to me," she added, "is that the people whom we think of as being the most involved in the symbolic part of math intuitively know that they have to practice those other, nonsymbolic, approximating skills."

This month in the journal Nature, Justin Halberda and Lisa Feigenson of Johns Hopkins University and Michele Mazzocco of the Kennedy Krieger Institute in Baltimore described their study of 64 14-year-olds who were tested at length on the discriminating power of their approximate number sense. The teenagers sat at a computer as a series of slides with varying numbers of yellow and blue dots flashed on a screen for 200 milliseconds each -- barely as long as an eye blink. After each slide, the students pressed a button indicating whether they thought there had been more yellow dots or blue. (Take a version of the test.)

Given the antiquity and ubiquity of the nonverbal number sense, the researchers were impressed by how widely it varied in acuity. There were kids with fine powers of discrimination, able to distinguish ratios on the order of 9 blue dots for every 10 yellows, Dr. Feigenson said. "Others performed at a level comparable to a 9-month-old," barely able to tell if five yellows outgunned three blues. Comparing the acuity scores with other test results that Dr. Mazzocco had collected from the students over the past 10 years, the researchers found a robust correlation between dot-spotting prowess at age 14 and strong performance on a raft of standardized math tests from kindergarten onward. "We can't draw causal arrows one way or another," Dr. Feigenson said, "but your evolutionarily endowed sense of approximation is related to how good you are at formal math."

The researchers caution that they have no idea yet how the two number systems interact. Brain imaging studies have traced the approximate number sense to a specific neural structure called the intraparietal sulcus, which also helps assess features like an object's magnitude and distance. Symbolic math, by contrast, operates along a more widely distributed circuitry, activating many of the prefrontal regions of the brain that we associate with being human. Somewhere, local and global must be hooked up to a party line.

Other open questions include how malleable our inborn number sense may be, whether it can be improved with training, and whether those improvements would pay off in a greater appetite and aptitude for math. If children start training with the flashing dot game at age 4, will they be supernumerate by middle school?

Dr. Halberda, who happens to be Dr. Feigenson's spouse, relishes the work's philosophical implications. "What's interesting and surprising in our results is that the same system we spend years trying to acquire in school, and that we use to send a man to the moon, and that has inspired the likes of Plato, Einstein and Stephen Hawking, has something in common with what a rat is doing when it's out hunting for food," he said. "I find that deeply moving."

Behind every great leap of our computational mind lies the pitter-patter of rats' feet, the little squeak of rodent kind.

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