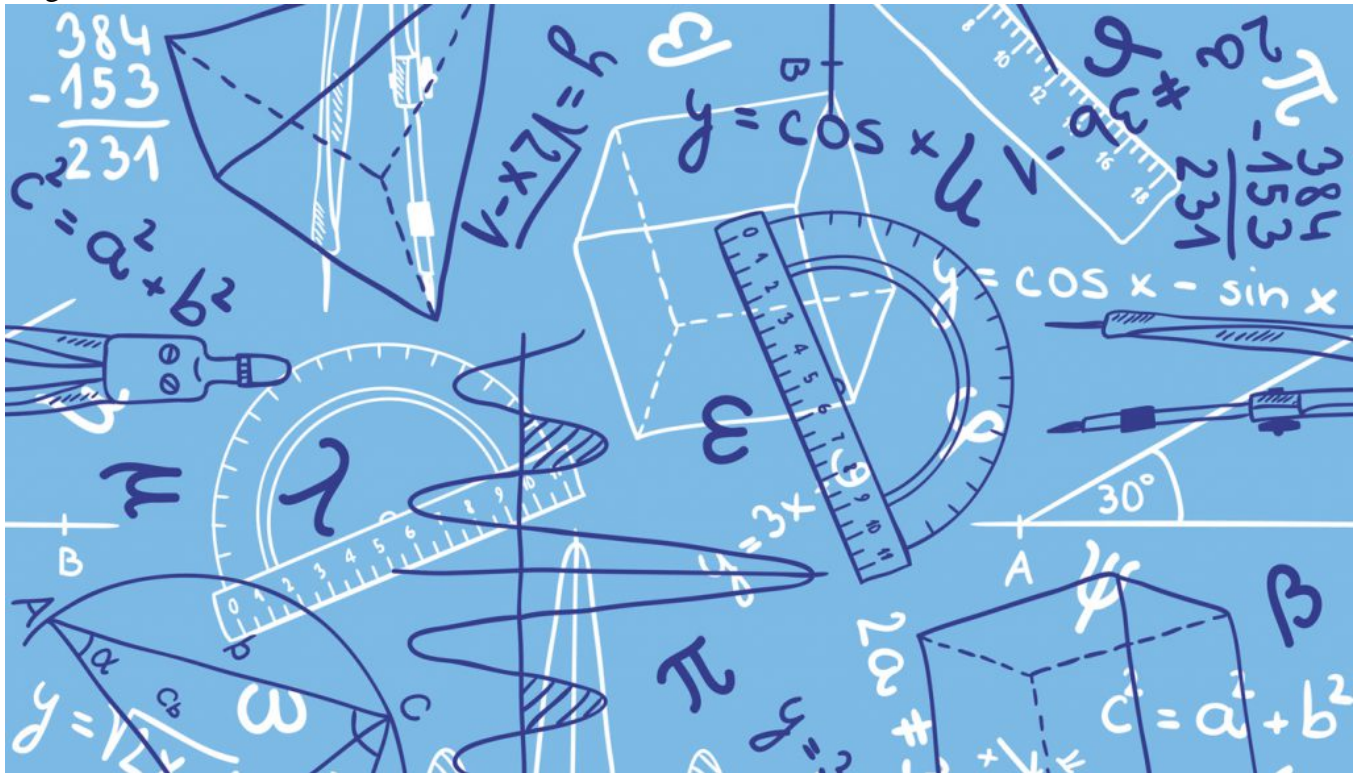


Nervous About Numbers

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Having trouble with math, whether because of anxious avoidance or cognitive deficits, is considered at least as limiting as having difficulty reading — yet is far less understood.

Math anxiety is a negative emotional reaction to math and can foster tension and dread into adulthood, perpetuating a vicious cycle of avoidance and ignorance.

And it's fairly prevalent, with moderate to high math anxiety reported by an estimated 25% of 4-year US college students and up to 80% of community college students. Nearly half of first and second graders surveyed reported math anxiety as well; their anxiety was linked to lower achievement.

New insights into the neurological activity that occurs when people experience math anxiety may help students, parents, educators, and psychologists find ways to get the numerically nervous to approach equations with equanimity and enjoy broader, better paying career opportunities and greater competence in everyday life.

Causes of Math Anxiety

The causes of math anxiety can be environmental (bad experiences, bad teachers), personal (lack of confidence, low self-esteem), or cognitive (innate qualities, e.g., low intelligence or maybe just the obvious — not being naturally adept at math, which fuels a sense of inadequacy).

Stanford University's Vinod Menon, a professor of psychiatry and behavioral sciences, speculates that math, because it requires precise answers, may provoke more anxiety over making mistakes than reading does. What's more, math anxiety might decrease the performance of otherwise capable students.

For children with an actual math learning disability, called developmental dyscalculia, things can snowball.

To understand what's going on with these youngsters, psychological scientists turned to an affective priming test that can reveal latent feelings. In such tests, people who view priming words that match how they feel about a stimulus have been found to respond to those target stimuli faster. The feeling-matching words are thought to "prime the pump," activating feelings and enabling faster responses. Thus, faster responses to math problems after negative primes could reveal math anxiety, providing insight into when people are either unaware of their anxiety or too embarrassed to admit it.

Indeed, Rosemary Tannock of the University of Toronto, Canada, and Orly Rubinsten of the University of Haifa, Israel, in 2010 reported that children age 7 to 13 with developmental dyscalculia showed implicit signs of math anxiety. First, on a computer screen, the children were shown an emotional priming word and then a simple addition, subtraction, multiplication, or division equation, such as $2 + 4 = 6$ or $3 \times 4 = 12$. The children with dyscalculia responded "true" or "false" significantly faster after they saw negative or math-related words than after they saw positive or neutral words. Such responses were taken as a sign of math anxiety, especially because the control group of students without dyscalculia did the opposite, responding more quickly to math problems after they saw positive or neutral words.

These results revealed how, in childhood, arithmetic, emotions, and low achievement can get all tangled up. The challenge is then to disentangle them before anxiety makes it even harder to move forward.

Addressing math anxiety may be particularly important for girls, who take fewer advanced math courses and tend to pursue professions that don't require as much quantitative skill. Girls don't avoid math because of aptitude; instead, cultural factors and educators' own biases may be involved.

APS Fellow Sian Beilock of the University of Chicago and her fellow researchers recently found that as early as first and second grade, higher math anxiety on the part of the teacher was associated with lower math achievement, but for girls more than for boys.

By adulthood, more women than men report math anxiety. Is that because women report more anxiety generally? To get past this potential confound, Rubinsten, Noam Bialik, and Yael Solar of the University of Haifa, Israel, used the same emotional-priming test used by Tannock and Rubinsten with children and reported in 2012 that women and men responded differently when solving math problems.

The 23 young men studied were faster to say simple math equations presented on a computer screen were true or false after viewing *positive* emotional primes such as "achievement" and "appreciation." However, the 30 young women studied were faster to judge the same equations after viewing *negative* primes such as "failure" and "rejection."

The researchers believed that the reason women made these judgments more quickly after being primed

with negative emotional words was that they were experiencing math anxiety. They speculated that women receive negative environmental messages early in their education, and as a result carry forward basic deficits that make it harder for them to learn higher math.

Pain in the Brain

Whatever the cause, psychological scientists are eager to reduce the damaging impact of math anxiety on people and professions. Their work has moved rapidly from blackboard to brain.

In a seminal 2007 paper, APS Charter Member Mark Ashcraft and Jeremy Krause, both of the University of Nevada, Las Vegas, reported that working memory is the “missing link” between anxious feelings and impaired cognition. They showed that math anxiety can curtail working memory, reducing the critical ability to mentally juggle more than one item at a time.

Imaging research has confirmed the biological reality of math anxiety, in part by explaining how working memory gets choked off. It also explains why Beilock likens math anxiety to a phobia: It is specific, ranges in severity, and has precise neural roots.

First to identify the neural correlates of math anxiety were Menon, Christina Young, and Sarah Wu, who reported in the May 2012 issue of *Psychological Science* that math anxiety in children as young as age 7 to 9 years was associated with specific patterns of brain hyperactivity and connectivity.

Of the 46 second and third graders (28 boys and 18 girls) studied, children whose high math anxiety was validated using the Scale for Early Mathematics Anxiety showed different brain-activation patterns than children with low or no anxiety about math.

When in the scanners, students were presented with simple and complex math equations (e.g., $5 + 2 = 7$) and asked to press a button to say whether the answer shown was right or wrong.

During the imaging procedures, compared with the brains of nonanxious students, the brains of the students who fretted about figures revealed some significant differences, including:

- heightened activity in the right amygdala, the same area that responds with fear to trigger stimuli, such as seeing spiders or snakes;
- heightened activity in the hippocampus, which helps form new memories;
- reduced activity in parts of the prefrontal cortex involved with working memory, attention, and number reasoning; and
- greater connective strength between the amygdala and the part of the prefrontal cortex that regulates negative emotions.

These patterns help reveal how aberrant emotional activation hijacks mental resources required for math.

The right amygdala in particular plays a key role in learned fear and has multiple connections to other areas involved with cognition and emotion. Plus, Menon says its high plasticity means that it takes less and less exposure to math (the feared stimulus) to trigger the anxiety.

The fact that high-math-anxiety students were only marginally less accurate in their choices confirmed that anxiety and ability are separate issues. In addition, students with math anxiety were not found to be generally anxious. Nor did any students in the study group have a history of learning disabilities.

Both math anxiety and concomitant brain changes are found in children who have yet to learn their multiplication tables. These patterns threaten the acquisition of additional foundation skills such as long division, fractions, and percentages.

Equally dismaying, another study found that the mere expectation of doing math triggered the brain's pain network. Dividing 28 young adults evenly into high and low scorers on the Short Mathematics Anxiety Rating Scale, Ian Lyons and Beilock examined the brain activity of participants who expected to solve either a math or a word problem.

While in an MRI scanner, participants with high math anxiety showed significantly greater activation of brain areas that detect visceral threats when cued to expect math problems instead of word problems.

Some participants with high math anxiety showed significantly increased activity in the region linked to the experience of pain.

The findings, wrote Lyons and Beilock, suggest that the mere expectation of doing math is enough to activate brain regions associated with threat detection and pain. Even when it does not stem from a physiological insult, a sense of hurt or pain is still deeply unpleasant. What's more, the authors noted that the regions that went into overdrive when cued for math are very close to those activated during experiences of severe social rejection. No wonder some people avoid doing math: It makes them feel awful.

"There is a growing recognition that our neural hardware does not always distinguish clearly between the mental and the physical," says Beilock. "The fact that math-anxious folks activate some of the same areas of the brain that are activated when people feel physical pain tells us something important."

Sum Total

Given what brain research is teaching us about math anxiety, what can be done?

"We can tell parents and educators that math anxiety is real and it cannot be wished away. Early identification and treatment are essential," says Menon.

"Now that we know that math anxiety has a neurobiological profile like that of other anxieties," he says, "we can use techniques such as progressive exposure and cognitive-behavioral therapy, which have worked with other anxiety-provoking stimuli and phobias, to reduce math anxiety and its negative consequences on problem-solving skills."

Even something as simple as taking a few minutes to write out one's worries before taking a math test can help, perhaps by getting the feelings safely on paper and freeing up working memory, according to a recent psychological study.

In this study, Beilock and graduate student Annie Daeun Park, along with psychological scientist Gerardo Ramirez of the University of California, Los Angeles, assigned college students to either high-math-anxiety (44 students) or low-math-anxiety (36 students) groups, using a common self-report measure. Within those groups, students were asked to either sit quietly (control group) or to write before taking tests with math and word problems about their thoughts and feelings related to the coming exam. For students high in math anxiety, expressive writing was associated with significantly better work on the math problems — especially when their writing used words related to anxiety and showed insight into how it could affect their work.

Given findings such as these, Beilock says that educating teachers about the roots of math anxiety may help them adjust their methods to avoid embarrassing students who need more time. They also need to work through their own anxieties, if they harbor any, to avoid influencing their students — especially the girls.

School psychologists can tap these findings to understand the behavior and performance of math-phobic students and offer appropriate interventions, says Beilock, whose book *Choke: What the Secrets of the Brain Reveal About Getting It Right When You Have To* reveals more about strategies for optimal performance in the classroom and beyond.

Menon adds that “parents can ensure that learning math is as pleasant an experience as possible, and encourage their children to be emotionally resilient in the face of normal setbacks.

“Above all,” he concludes, “students can be reassured that qualms about math have no bearing on their innate ability. Treatment that attends to the emotional aspects of learning can bolster confidence and improve performance.”

“Being successful is not just about content knowledge,” says Beilock. “If we don’t consider attitudes, we are missing a big part of what it takes to create optimal learning conditions.”

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