The effect of math anxiety on the numerical brain

Mathematical skills are increasingly valuable in our technology-focused society. However, interventions and policies aiming to enhance those skills often overlook the negative emotional context that can surround math, with its potentially dramatic consequences for acquiring numerical skills.

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Executive summary

- Although it is clear that math skills are increasingly needed in our technology-driven society, interventions and policies aiming to enhance those skills often overlook the negative emotional context that often surrounds math, which can have dramatic consequences for the acquisition of numerical skills.
- Indeed, many people are anxious about math and this anxiety might not only impair learning but also drive them away from career opportunities in STEM fields. Studies indicate that anxiety about math may affect the normal functioning of the brain mechanisms that support math learning and may induce math struggles. This may lead to a vicious circle in which more struggles lead to more anxiety, etc.
- Ways to break this circle include enhancing the math home learning environment and ensuring that teachers are not anxious about math themselves.

Introduction

Mathematical skills are increasingly valuable in our technology-focused society. Yet, studies consistently show that many educated adults lack the basic numerical abilities needed in the workplace, particularly for jobs in the science, technology, engineering, and math (STEM) fields. Although this has prompted governments worldwide to focus on improving the content of math education, an important factor that is often overlooked when talking about improving numeracy is the emotional aspect of math learning. Of course, students vastly differ in the disciplines they may like or dislike in school. But math is unique in the strength and prevalence of the emotional response that it can trigger. Many students and adults report disliking math, often saying that they are not "math persons" or that math makes them nervous[1]. Such math anxiety, which can be defined as "a feeling of tension and anxiety that interferes with the manipulation of numbers and the solving of mathematical problems"[2], may not only affect individuals in school settings (e.g., during math tests). It may also interfere with numerical skills in everyday life. In fact, math-anxious people are likely to avoid situations in which they have to manipulate numbers. This may, of course, affect their career choices. Because the prevalence of math anxiety is typically estimated between 10% to 30%[3], this may explain to a large extent students' disaffection for STEM jobs. Therefore, any serious attempt to improve numeracy and access to STEM fields in the general population should tackle math anxiety.

Math anxiety starts early

Relatively few studies have investigated math anxiety in young children. However, the available evidence indicates that math anxiety often starts early. For example, in a recent study conducted on 2[nd] and 3[rd] graders, researchers asked children to tell them how nervous they are in certain situations that involve doing math, such as when they are about to take a math test or when someone asks them to cut up an apple pie into four equal parts[4]. Not only did the researchers find that many children were anxious in these situations, but they also discovered that the level of math anxiety was inversely related to math achievement. In other words, the more anxious a child was, the worse s/he feared a math test. Recently, a study even found noticeable levels of math anxiety among children as early as in 1[st] grade[5], suggesting that this fear of math may start at the very beginning of math education!

Math anxiety affects the numerical brain by depleting working memory resources

Neuroscience studies indicate that math anxiety is driven by brain activity in areas that are largely dissociated from the main regions known to support math learning. However, such activity eventually interferes with the normal functioning of brain regions that support numerical processing during math tasks. For example, in a recent experiment, a group of researchers measured the degree of math anxiety of several adult participants using a specific questionnaire[6]. They then asked these adults to solve math problems while measuring their brain activity in a magnetic resonance imaging scanner (MRI). For instance, participants had to verify whether arithmetic problems such as (4 * 2) – 6 = 3 are correct. The results showed that the most math-anxious participants activated several brain regions usually involved in experiencing physical pain. This was actually observed before participants even had to solve the problems (when they were simply expecting them) (see Figure 1). Interestingly, no such activity was present when participants actually solved the problems, leading the researchers to posit that "it is not that math itself hurts; rather, the anticipation of math is painful"[6].

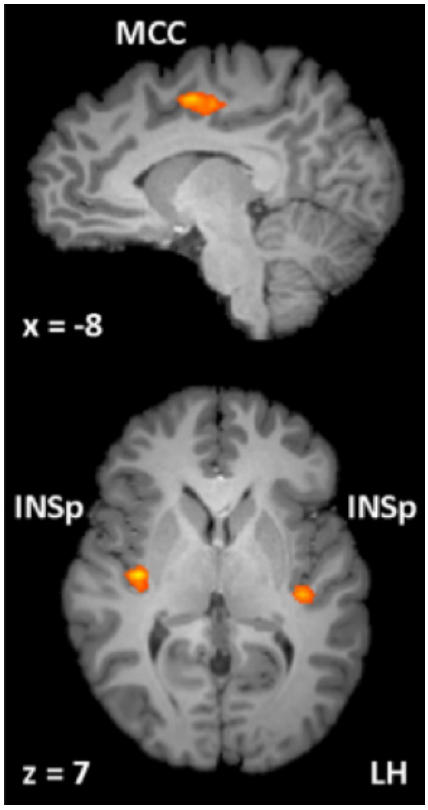

Figure 1. Expecting to solve math problems is associated with brain activity in regions typically related to physical pain in math-anxious adults. Regions are depicted in orange on two pictures of the brain taken using a magnetic resonance imaging scanner. (Reproduced from Ref. [6])

In another study, the brain activity of 2[nd] and 3[rd] graders was measured while children solved arithmetic problems, again in an MRI scanner[7]. Children were split into two groups depending on their level of math anxiety (high or low). The researchers found that children in the high anxiety group activated brain areas associated with negative emotions (e.g., the amygdala) to a much greater extent than children in the low anxiety group (see Figure 2). Critically, this increase of activity in the amygdala was accompanied by a reduction of activity in the intraparietal sulcus, a brain structure that is critical for numerical processing. This indicates that math anxiety might interfere with the brain mechanisms that support numerical processing in children. The study also found that children from the high anxiety group had less activity in the prefrontal cortex (a region located at the front of the brain) than children from the low anxiety group. This region is known to be involved in what is often termed *working memory*, that is, the ability to keep information in mind for a short period of time while engaging in a task. For example, working memory is involved when recalling the different steps of a recipe when cooking or remembering a list of groceries while at the supermarket. Working memory is, of course, also heavily involved in math tasks, when, for example, a child has to remember which digit to carry when adding or subtracting double-digit numbers or the order of steps involved in solving a linear equation. This finding of reduced activity in a brain region that supports working memory in highly math-anxious children might indicate that math anxiety depletes the limited working memory resources available in these children. That is, whereas children who do not fear math may simply have to deal with the numerical aspects of math problem-solving, math-anxious children might also have to deal with their apprehension at the same time (leaving less room available in working memory for the math task). This has been confirmed by another study investigating the relationship between math anxiety and working memory resources in children in middle school: math-anxious students tend to be those with the poorest performance in working memory tasks[8].

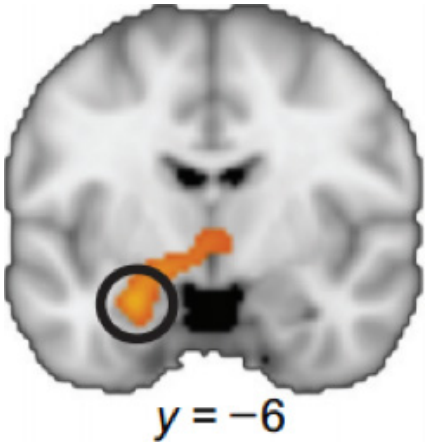

Figure 2. Math-anxious children (when compared to children who are not anxious) activate the amygdala, a brain region associated with negative emotions, when they solve math problems. Activation of the amygdala is shown in orange on a picture of the brain taken using a magnetic resonance imaging scanner. (Reproduced from Ref. [7])

Math anxiety is transmissible from teachers to children and from parents to children

A fundamental question is how children develop this fear of math. Of course, a first possibility is that math anxiety results from struggling with math in school. A significant number of children might indeed experience persistent difficulties with math learning, either because of a specific learning disability affecting numerical processing (i.e., dyscalculia) or because of more general cognitive deficits. This might progressively lead to an aversion towards anything related to math. However, the fact that math anxiety can be observed very early in children indicates that math anxiety may also predate math struggles and is not necessarily a consequence of it. In line with this claim, an increasing number of studies support the idea that children might develop a fear of math from environmental and social cues. A first indication of the transmissibility of math anxiety comes from a study in which several 1[st] and 2[nd] grade teachers were given a questionnaire assessing their anxiety towards math[9]. Similar to the questionnaire described above for children, teachers had to rate how anxious they were in situations such as reading a cash register receipt after buying something or studying for a math test. Math performance of children was also assessed at the beginning and the end of the school year. Not surprisingly, the researchers did not find any relationship between the level of teachers' math anxiety and the students' math performance at the beginning of the year. However, there was a clear relationship at the end of the year: the more anxious the teachers were about math, the lower their students' math achievement. It is also likely that math anxiety might be transmitted from parents to children. For instance, in another study of more than 400 American children in 1[st] and 2[nd] grades, children and their parents were given age-appropriate questionnaires assessing their respective levels of math anxiety[10]. The study showed a clear relationship between parents' math anxiety and their children's fear of math by the end of the school year. It also showed that the more math-anxious parents were, the less likely their children were to show large progress in math performance during the year. Interestingly, these relationships were only observed when math-anxious parents were involved in math homework, suggesting that subtle (or less subtle!) cues might be picked up by children when interacting with their parents around math.

How can we reduce math anxiety in children?

A few studies suggest ways to remediate math anxiety in children. First, because math anxiety is intertwined with math competence (i.e., children who are not good at math are likely to be anxious about it), much should be gained from focusing on building early math abilities in children. For example, a recent study demonstrated that an intensive 8-week math tutoring program not only improved math skills of math-anxious 3[rd] graders but also significantly reduced their fear of math[11]. Importantly, this reduction of math anxiety was accompanied by a decrease in activity in the amygdala, a region involved with fear processing (see Figure 3). Therefore, repeated exposure to what math-anxious children fear the most—math—can "make the child feel more in control of situations involving mathematical problem solving, thereby diminishing their math anxiety"[11]. In other words, more math may reduce the fear of math.

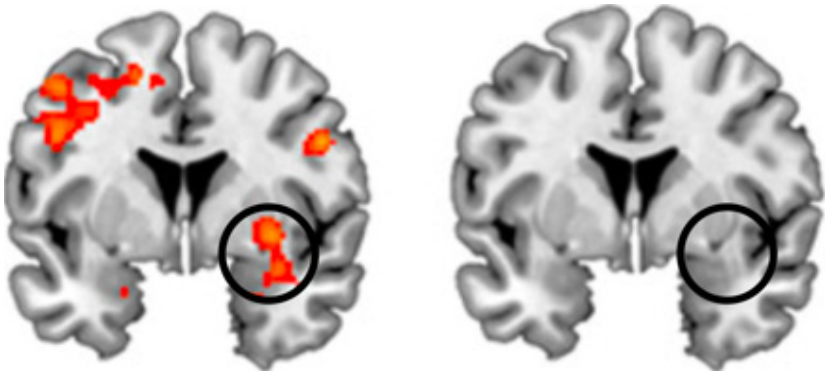

Figure 3. Reduction of activity in the amygdala during math problem-solving in math-anxious children (as compared to children who are not math-anxious) after intensive tutoring. Left: Brain activity in the amygdala (black circle) before tutoring. Right: Lack of brain activity in the amygdala (black circle) after tutoring. Activations are shown in orange on pictures of the brain taken using a magnetic resonance imaging scanner. (Reproduced from Ref. [11])

Second, given the transmissibility of math anxiety from adults to children, it may be critical to improve elementary school teachers' math training. It may also be beneficial to educate parents about ways to talk about math with their children at home. For example, parents need to be careful when talking negatively about math around their child (e.g., "I am not a math person") and should avoid emphasizing that it is okay for their child to struggle in math classes (it is likely more beneficial to adopt a more positive attitude and emphasize that s/he has the ability to solve even difficult math problems)[1]. Interestingly, a study recently suggested that providing opportunities for parents and children to engage in math together may help "cut the link between parents' high math anxiety and children's low math achievement"[12]. In that study, the researchers provided several families with a math problem every day during an entire school year. The idea was not for the child to solve the problem alone. Rather, the problems were designed so that they engaged both parents and children around them. The results showed that children from families who repeatedly engaged in solving these problems had a larger gain in math skills by the school year's end than children from families who did not engage in such an activity. Interestingly, the families who benefited the most from that intervention were families in which parents were the most anxious about math. This highlights how useful it might be to find ways to engage math-anxious parents in positive interactions around math with their children.

Third, it is likely that math anxiety may be at its peak during math assessments in school. It may thus be interesting to attempt to reduce such anxiety during testing periods. This might involve relying to a greater extent on untimed tests rather than timed tests[1]. An interesting method might also be to have students write about their feelings before starting the test. This was demonstrated in a study in which researchers asked college students to write about their feelings regarding the math test they were about to take[13]. Compared to a group of math-anxious students who did not have to do this writing exercise, the study found that math-anxious students who had the opportunity to express their feelings fared better on the test. In fact, there was no longer a difference between performances of highly math-anxious and less-anxious students (whereas there was a difference in the groups who did not have to write). Therefore, expressive writing might be a useful way to alleviate math anxiety before a test (perhaps because it helps students put the outcome of the test in perspective)[1].

Conclusion

In sum, it is clear that math learning has both a cognitive and an emotional component. There is no doubt that improving the content of what is taught and the strategies used to teach this content is important if one wants to improve students' numerical skills. However, the emotional aspect of math learning should not be forgotten, especially if one long-term goal is to promote more career choices in STEM fields. Many people have negative feelings about math and can develop real anxiety towards anything math-related. Studies indicate that such anxiety may affect the normal functioning of the brain mechanisms that support math learning and may induce math struggles. This may lead to a vicious circle in which more struggles lead to more anxiety, etc. However, we have shown here that there are ways to break this circle, notably by enhancing the math home learning environment and ensuring that teachers are not anxious about math themselves.

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