The Causes and Remedies for Mathematics Anxiety

What is Mathematics Anxiety?

Among the many obstacles that students can face in the mathematics classroom, the affective component is often overlooked.  The construct of mathematics anxiety typically refers to the emotional and mental distress that occurs in some students while attempting to understand mathematics.  Though in practice it is somewhat ill defined.  Beginning in 1972, the Mathematics Anxiety Rating Scale (MARS) was developed by Dr. Suinn Richard. (Wu, Amin, Malcarne, Menon, 2012)  While an improvement in understanding anxiety in practice, it is unclear how Dr. Richards conceptualized mathematics anxiety and the intended use of the test.  The content specific aspects are geared toward arithmetic and algebra, whereas other subjects are poorly represented.  It is also unclear how the MARS scale would differentiate between or be influenced by factors such as dislike of mathematics, clinical anxiety, social anxiety, and mathematics competency (McMorris, 1988).   Since that time, a variety of other methods of measurement have been developed, including Revised Mathematics Anxiety Survey (R-Manx), the Fennema-Sherman Mathematics Attitudes Scales, and surveys designed to measure attributes the relate to anxiety.

These scales primarily measure the cognitive component of mathematics anxiety. Related to this are the emotional and physiological components. More research into their interrelatedness must be done. One of the more interesting findings is that increased cortisol, a physiological result of stress, can actually boost performance in a test when physiological stress responses are viewed positively. (Maloney, 2012) This seems to indicate that the experience of anxiety is part of a useful phenomenon, but that something about thought patterns may cause it to become maladaptive.

 Though the construct of mathematics anxiety is vague within mathematics education, it is apparent that the construct being measured has a considerable correlation with student success in mathematics.  Helping to determine the causes, and means to reduce anxiety would be a great boon to current and future students of mathematics.  This paper explores the research community’s exploration into these topics.

Causes of Mathematics Anxiety

There have been a large variety of hypothesized reasons for why students develop anxiety in mathematics.  One of the early mathematics anxiety researchers, Tobias, has been a significant proponent of the view that gender plays a large role in mathematics anxiety.  She has withdrawn from her belief that females are the only ones who must cope with mathematics anxiety in a significant way, but still recognizes obstacles that women can face.  Though Hembree’s (1990) does support her findings that girls exhibit more mathematics anxiety. Though, it would appear that most, if not all students are sometimes subject to enough anxiety to alter their performance ability. (Mitt, 2012)  In her book, Overcoming Mathematics Anxiety, submits a set of environmental factors that many girls are exposed to that may influence their heightened anxiety.  Tobias (1993) views cultural belief as a primary cause for girls’ mathematics troubles. This describes the conviction that girls are less proficient at mathematics, creating a feedback loop in the zeitgeist.  For girls who fail, they are likely to attribute that to their natural disposition.  For some, this belief also brings with it the stigma about being a mathematics whiz and these potential mathematicsematicians sabotage themselves.  Tobias postulates that, “Ironically, fear of being too smart may lead to such passivity in the mathematics class that eventually these girls develop a conviction that they are dumb.” (Tobias, 1993, p.63)  Even those that persevere may find that they are isolated from peers who share an interest in mathematics, lacking a person they can learn mathematics fluency with, outside of a possible parent.  In fact, Geist (2010) hypothesizes that the increased stimulation from a more mathematicsematically inclined home environment is a primary reason that parent education is so highly correlated with success in mathematics, implying that many children may be left almost entirely without someone to converse with mathematicsematically.  In addition to limiting beliefs of various sorts, Tobias states that society handicaps women by making an assertive personality undesirable, suggesting that if girls were more encouraged to be less passive and have a greater locus of control, that they would find more success in mathematics.  For Tobias, the cause of mathematics anxiety is primarily a society that artificially hampers girls’ abilities, causing them to be anxious about performance.

Geist (2010), a proponent of new teaching methods that taking student thinking into account, also recognizes that gender issues and parental education can play a part in mathematics anxiety.  However, he more emphasizes the prominent role that teachers play in creating atmosphere and lesson plans.   For example, by citing both anecdotal evidence and a study by Williams (2000), he implies that high risk tests that value rote learning and recitation cause higher anxiety.  Although Geist made some good arguments for his points.  I found that his sources left something to be desired. Williams’ paper did not appear to be published, and it directly addressed performance rather than anxiety.  He also references a book by Marilyn Burns that did not seem to have research backing, but instead focused on the advice of Burns. Though some of his references are suspect and seems to be unsubstantiated by solid evidence, Geist does point to sensible places for future research to study causes of mathematics anxiety.  In addition, more research must be done to determine how a student’s past experiences and history play a role in how learning programs affect their mathematics anxiety level.

There is certainly a relationship between mathematics anxiety and performance.  However, Hembree (1990) suggests there is little evidence that poor performance causes mathematics anxiety or even that IQ is a determining factor. To back up this idea, Jansen (2013) actually implemented a program that became more or less difficult based to match the student’s ability in order to ensure that students got an approximate portion of them correct. The program gave one group of students problems that they would answer with high accuracy, and another group were given questions which would be answered with much lower accuracy. There was not a significant difference in the groups’ anxiety levels at the end of the study. It is possible that the aversion and anxious thought patterns could be built up over time. However, it does not appear that levels of success have a significant effect on anxiety according to Jensen’s study.

Hembree (1990) did find evidence that mathematics anxiety does relate to general anxiety.  This implies that rather than attempting to get rid of mathematics phobias, it may be more fruitful to use generalized anxiety approaches with students.  If this is the case, techniques such as cognitive therapy could become primary in treating student with mathematics anxiety.  Note that Hembree’s study does indicate that reducing mathematics anxiety also improves mathematics performance, implying a causal relationship.

Effects on Learning and Behavior

Anxiety appears to be a fairly insubstantial obstacle, particularly when it does not involve any immediate threat to a person’s survival.  Therefore, it makes one question why it appears to have a crippling effect on some students’ ability to do mathematics.  Many students report feeling tension and fear that seems similar to experiencing a significant threat. Lyons and Beilock (2012) observed what was actually going on inside the mind during these phenomena related to mathematics anxiety by using a combination of fMRI, Short Mathematics Anxiety Rating Scale (SMARS), and several mathematics problem sets. The fMRI is used to observe levels of brain activities in in different parts of the brain.  While anticipating the work of doing mathematics, the fMRI scans detected an increased activity in parts of the brain related to visceral threat and pain, which had a direct correlation with SMARS results.  So, despite no danger of significant harm from doing mathematics, some students seem mentally impacted as though they are.

Through cue-based mechanisms, Lyons and Beilock (2012) determined that anticipation, but not the actual performance of mathematics, caused these responses.  This gives a neural explanation of why some students avoid mathematics subjects despite the career advantages for taking them. In addition to this visceral consequences, Malone y (2012) points out that worrisome thought takes up mental resources that should be directed toward mathematics. It is unclear how connected the emotion and thoughts related to anxiety are and to what extent they appear in tandem with one another. Witt (2012) claims, “The anxious reaction causes a fall in central executive working memory functioning, something that has been shown in many studies to underpin successful mathematicsematical processing.” (p.272)  These studies open the door for further research, including the investigation of a possible Pavlovian mechanism that high anxiety students are exposed to, similar to what Geist posits.  Perhaps most significantly, this provides a new perspective on the problem, how to help students cope with the anticipation of doing mathematics in the, future, rather than anxiety generated while performing the mathematics.

It is commonly known that anxiety will influence a student’s decisions about what classes to take, often leading to avoidance of mathematics (Maloney & Beiolcok, 2012). This can drastically alter a person’s career path. As Tobias (1990) observed, when a student eliminates mathematics from the curriculum, it automatically shuts the student off from being successful in most university majors, significantly narrowing a student’s options.

Pedagogical Interventions

Discourse, although it does not consistently increase mathematics performance, has been found to have a strong, positive impact on students’ anxiety toward mathematics.  In Dogan (2012) two groups were studied, one with a lecture-based structure, and another that was discourse-based.  The discourse-based class made a great many all around improvements to anxiety, fear, and enjoyment of mathematics, and several other factors relating to anxiety.  It is unclear what it is about the discourse focus encouraging these changes.  It has been hypothesized that it could be due to the confidence from reasoning out mathematical discoveries or from students feeling more at ease in the socially infused discourse environment.  Geist (2010) implies that many of the rote ways of learning and teaching mathematics over time are the partial cause of the stress students experience.  The absence of those factors may also contribute to decreased mathematics anxiety.

Johnson and vander Sandt (2011) clearly indicate that learning programs can have markedly different effects on anxiety based on the type of student involved in them.  In their study, it appeared that additional content and pedagogy classes could have a positive effect on the anxiety and confidence levels of pre-service teachers.  However, this was highly contingent on the subgroup they started in.  In general, the subgroups of pre-service teachers with the most desirable initial traits, seemed to gain the most benefit.  This conclusion emphasizes that there should not be a ‘one size fits all’ mentality.  Future research could include how subgroups respond to a variety of other types of interventions.  It is likely that for a certain type of student traditional instruction is optimal, while other groups would be served better by a variety of alternative approaches.

Cognitive and Behavior Therapy Interventions

Most of the ways that mathematics education researchers have tried interventions involves a change of pedagogy.  There is a lot of research done on cognition and behavior change in psychology that could have application to mathematics anxiety issues, either as a separate supplement to pedagogy, or to influence the way lessons are given.  Unfortunately, most of the research done on this area is somewhat obscure and has not yet entered into the mainstream.  One of the most comprehensive examples of testing these approaches was Hembree’s (1990) study.  Interventions in the study fell into three categories, classroom accommodations, behavior therapy, and cognitive therapy.  Classroom interventions were not particularly effective at reducing mathematics anxiety or test anxiety. These involved offering a variety of amenities to students, such as small groups, self-paced work, and tutorials.  The behavioral therapy was also fairly unsuccessful.  However, the cognitive therapy showed some good results.  There was moderate success in using cognitive therapy to correct negative beliefs.  There was the most significant drop in anxiety when using systematic desensitization techniques.  This seems to confirm Lyon’s (2012) study indicating that mathematics anxiety is primarily caused by the anticipation of mathematics.  It is likely that by desensitizing a person to mathematics, the anticipatory response no longer has the same dramatic effect on them.

Karimi and Venkatesan (2009) introduced one of the more recent examples of a cognitive therapy study.  Their results were promising, as there was a significant improvement in the experimental group compared to the control group.  However, their results are hampered by not specifying what cognitive behavior therapy they introduced exactly, making the results somewhat vague.  In addition, it is clear that part of the project involved desensitization mathematics problems.    This part of the program seems like perfectly effective work, but makes it harder to determine if it was the cognitive therapy that contributed to the gains or merely more exposure to relevant material. This is an adequate start, but it is clear that more research must be done before determining the efficacy of behavioral therapy from modern psychology.

In addition to these larger scale therapy interventions discussed, there are some simple techniques from modern psychology that have shown promise for students with high mathematics anxiety. Simply having a student write down their worries and concerns about their mathematics class can alleviate some mathematics anxiety (Maloney, 2012). The symptoms of anxiety can actually thought of as an advantage for students! For example reframing symptoms of anxiety, such as sweaty palms or high heart rate, can be viewed as positive physiological responses to taking on ‘challenge’ such as a test. If a student is able to adopt these paradigms, then an increased physiological reaction from an examinations tends to improve the student’s results.

Conclusion

From the literature, it appears that there are three primary causes of mathematics anxiety.  These are beliefs, learning environment, and an anticipatory response. It is likely that these three variables are intertwined and strengthen one another.  Beliefs might include negative stereotypes about your own gender or race.  Cognitive restructuring of beliefs could be a partial solution to that malady.  Understanding based approaches, such as discourse, seem to have a positive effect on how a student’s learning environment affects his or her anxiety.  Lyons’ work (2012) indicates that the visceral physiological effect of anxiety happens while anticipating mathematics.  I would hypothesize that cognitive systematic desensitization as in Hombree’s (1990) study works to reduce that effect.  While certainly incomplete, these seem to be the most significant causes and remedies of anxiety in the literature.

Much more study needs to be done in mathematics anxiety.  It’s effect on students can be palpable.  The research done on cognitive and behavioral therapy is especially sparse and potentially fruitful.  If such therapy is proven to be successful, then a method of affordably and practically reproducing the effects must be sought.  In addition, although an intervention such as discourse has some results, it is not particularly effective.  I would like to see more innovations that could potentially bring more of the population to the realization that mathematics can be a fascinating and interesting subject.

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