

Maths Anxiety: Theory to Practice

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February 7, 2019

Abstract

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1 Literature Review (/1100 words)

Prevalence

Maths anxiety is hugely prevalent, and consequently the literature describing research around it is extensive. The Organisation for Economic Co-operation and Development (OECD) (2013) 2012 Programme for International Student Assessment (PISA) report states that across OECD countries, over 30% of 15 year old students “get very nervous doing mathematics problems”, and over 60% of students “worry about getting poor grades in mathematics”.

Why is Maths Anxiety Important?

It is my view that as teachers our foremost concern should be for the wellbeing of our students. Lyons and Beilock (2012b) used functional magnetic resonance imaging (fMRI) to demonstrate that students categorised as having a high level of maths anxiety will often experience the anticipation of a maths task as visceral pain. Moral imperative (and ethical duty of care) requires us to take every step possible to protect our students from such an experience.

Beyond the clear and overwhelming wellbeing concerns, it is also important to recognise the connection between maths anxiety and performance, and the complex web of stakeholders surrounding a students academic success in maths. Foley et al. (2017) discuss the negative correlation between maths anxiety and performance shown in the 2012 PISA (OECD, 2013) report, and also note the rising demand for Science, Technology, Engineering and Mathematics (STEM) professionals worldwide. It has been shown that when a student has low self-concept (correlated with high maths anxiety), they will tend not to enroll in maths beyond the minimum requirements for graduation (Ashcraft, Krause, & Hopko, 2007). Beyond highschool graduation, it has been shown that students affect towards maths can predict their university major (LeFevre, Kulak, & Heymans, 1992). So although many governments and industries around the world are recognising their

need for more mathematics-qualified graduates, addressing maths anxiety may be a key piece to the puzzle of filling this demand.

History of Maths Anxiety as a Distinct Phenomena to General Anxiety

The existence of maths anxiety as “emotional disturbances in the presence of mathematics” has been noted as early as the 1950’s, Dreger and Aiken Jr (1957) even postulated that what he tentatively designated “Number Anxiety” and later became to be known as Maths Anxiety could be a distinct syndrome from general anxiety. Later the landmark meta-study of Hembree (1990) supported this hypothesis, showing a correlation of only 0.38 between maths anxiety and general anxiety. In more recent times, this hypothesis has also been confirmed by Young, Wu, and Menon (2012) using fMRI to show that the brain activity in a person experiencing maths anxiety is measurably distinct from that in a person suffering general anxiety. These later studies including the meta-analysis of Hembree (1990) but also later the work of Kazelskis et al. (2000) and others further delineated maths anxiety from test anxiety, and this work continued until today it is quite well accepted that these anxieties although they share some overlap, are meaningfully distinct constructs. For more on the history of maths anxiety, Suárez-Pellicioni, Núñez-Peña, and Colomé (2016) offers a more detailed review.

History of Instruments for Measuring Maths Anxiety

Significant work has been done over the years to develop psychometrics to measure maths anxiety, almost exclusively consisting of self-reporting surveys (with the exception of some more modern fMRI work, such as that of Lyons and Beilock (2012a)). One of the earliest instruments for measuring maths anxiety was the Maths Anxiety Rating Scale (MARS) 98-item 5-point Likert scale of Richardson and Suinn (1972). Since then, many different groups have split off and created

various revised versions of a number of offshoots of this original idea, but all rely on a self-reporting survey. An example of one of the more recently developed scales is the Maths Anxiety Scale — Revised (MAS-R) of Bai, Wang, Pan, and Frey (2009), which they later did some work to demonstrate was very reproducible (Bai, 2011).

Current Theories on the Maths Anxiety-Performance Link

It is difficult to separate the study of maths anxiety itself from research about the maths anxiety-performance link, and so most maths anxiety research, with the possible exception of some of the recent fMRI work such as Young et al. (2012) and Lyons and Beilock (2012b), is actually research on the maths anxiety-performance link. As summarised by Ramirez, Shaw, and Maloney (2018), there are two broad modes of thought in terms of explaining the maths anxiety-performance link. I will adopt the terminology of Ramirez et al. (2018) for these: the “Disruption Account” and the “Reduced Competency Account”. Ramirez et al. (2018) make a convincing argument that although these two modes of thought might seem to compete at first glance, they are in fact not mutually exclusive and are actually compatible with each other. Ramirez et al. (2018) suggests a third “Interpretation Account” which encapsulates observations made by both lines of research, see Figure 1.

The “Disruption Account” is currently considered as the dominant theory, seemingly spearheaded by the work of Ashcraft et al. and is based on a body of work centered around the concept of working memory (Ashcraft & Kirk, 2001; Ashcraft & Krause, 2007). Specifically, the thought is that maths anxiety takes up students working memory, which prevents them from using that working memory to complete maths tasks and hence impacts performance. The “Reduced Competency Account”, which seems to be less popular in recent times, claims that lower ability

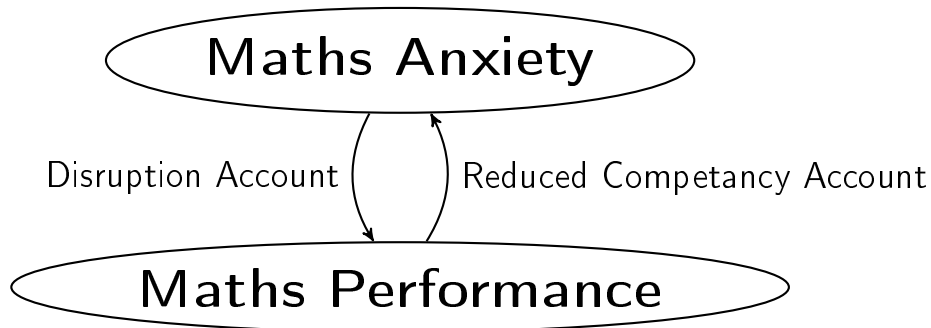


Figure 1: The Interpretation Account of Ramirez et al. (2018) for the maths anxiety-performance link showing how the Disruption Account and the Reduced Competancy Account can be compatible.

in maths leads to negative experiences associated to maths, and that these negative experiences cause maths anxiety to develop. There is also a significant body of work to support this hypothesis, including the meta-analysis of Hembree (1990) discussed above and more recent follow-up work such as the large longitudinal study of Ma and Xu (2004) which found that although past maths anxiety was correlated with future maths performance it was a small effect, while past maths performance had a strong effect on future maths anxiety.

Complexities in Designing and Implementing Interventions

These large theoretical views are of course oversimplifications of what is an incredibly complex and interconnected topic. They also imply very different approaches for intervention. The “Reduced Competancy Account” would imply interventions to boost maths performance and hence allow students to experience success in math should also help to reduce maths anxiety. The results of Supekar, luculano, Chen, and Menon (2015) seem to support this hypothesis as when students are given an intensive 8-week tutoring program to boost their maths skills, this is asso-

ciated to a reduction in maths anxiety. However Jansen et al. (2013) showed that although students attempt more problems and perform better when they are experience more success in maths, their improved performance is almost completely predicted by the number of problems they attempted, not their experience of success. To confuse things further, in the work of Jansen et al. (2013) the improved performance did not appear to have any effect on maths anxiety, although this may be limited by the fact that it was a single time-point study. Faust (1996) demonstrated an anxiety-complexity effect which further supports the implication that scaffolding is an important component in maths anxiety interventions. Faust (1996) showed that low and high maths anxiety groups perform similarly on low complexity problems, but in high complexity problems the high anxiety groups performance is impacted.

On the other side of the intervention spectrum are “Disruption Account” motivated approaches motivated by the understanding that if students maths anxiety can be reduced, they will have increased working memory available, and their performance will improve. One fairly direct and successful attempt at this is that of Park, Ramirez, and Beilock (2014), in which they used expressive writing exercises to help guide students self-perceived narratives about their maths experiences and thereby reduce their maths anxiety. Notably the approach of Park et al. (2014) is in line with some successful exposure based treatments for clinical anxiety disorders including Post-Traumatic Stress Disorder (PTSD) (see Becker, Darius, and Schaumberg (2007) and Foa et al. (2005)). Another approach that has shown success in this vein doesn't attempt to directly reduce the anxiety experienced, but rather reappraise it's symptoms (Jamieson, Peters, Greenwood, & Altose, 2016). In this approach stress is reconceptualised as a coping tool, an evolutionary method for heightening performance in response to a challenge to be overcome, instead of a symptom of exposure to something to be feared and avoided. The work of (Wang et al., 2015) shows the role of intrinsic motivation in mediating the relationship between maths anxiety and performance — specifically that although in students with low intrinsic motivation a direct negative correlation was observed between math anxiety and performance, in high intrinsic motivation students this

2. *PROPOSED RESEARCH DESIGN/ METHODOLOGY/ BUDGET OUTLINE* (/700 WORDS) 7

was not the case, instead a inverted U-shape association was observed, implying that a moderate amount of anxiety was correlated to improved performance for these students. The proposed interpretation for this more or less lies in the area of 'productive struggle'. Lin-Siegler, Ahn, Chen, Fang, and Luna-Lucero (2016) expose students in a classroom to struggles experienced by famous scientists in order to help normalise the concept of productive struggle, a concept that has also been discussed as important in the maths classroom (? , ?).

Should write a wrap-up of the lit. review.

2 Proposed research design/ methodology/ budget outline (/700 words)

I propose a four-fold approach for addressing maths anxiety:

- An intensive tutoring program to boost students math abilities, along the same lines as that of Supekar et al. (2015).
- Coaching around reappraisal of physiological signs of stress (increased heartrate, sweaty palms, etc.) such as that of Jamieson et al. (2016) to interpret these signs as an evolutionary trait that increases fitness and performance in response to a challenge, instead of interpreting them as signs of danger to run from and avoid.
- Guided expressive writing, such as the approach of Park et al. (2014), based on and similar to clinical psychological therapy approaches to treating other anxieties that have been shown to be effective.
- Teacher coaching and visiting expert demonstrations on how to engage in "productive struggle".

My hypothesis is that there will be an interaction effect between these different approaches, that where one approach may fail for a particular student, a combined approach could succeed.

To test this hypothesis we will do an initial trial, and then follow the participants longitudinally to identify potential longterm effects caused by changed mindset towards mathematics by trajectory analysis.

3 Ethics Issues (/100 words)

4 Executive Summary (/100-150 words)

Glossary

fMRI functional magnetic resonance imaging. 2–4

MARS Maths Anxiety Rating Scale. 4

MAS-R Maths Anxiety Scale — Revised. 4

NAPLAN National Assessment Program — Literacy and Numeracy. 3

OECD Organisation for Economic Co-operation and Development. 2, 9

PISA Programme for International Student Assessment. 2, 9

STEM Science, Technology, Engineering and Mathematics. 2

References

Ashcraft, M. H., & Kirk, E. P. (2001). The relationships among working memory, math anxiety, and performance. *Journal of experimental psychology: General*, 130(2), 224.

Ashcraft, M. H., & Krause, J. A. (2007, Apr 01). Working memory, math performance, and math anxiety. *Psychonomic Bulletin & Review*, 14(2), 243–248. Retrieved from <https://doi.org/10.3758/BF03194059> doi: 10.3758/BF03194059

- Ashcraft, M. H., Krause, J. A., & Hopko, D. R. (2007). Is math anxiety a mathematical learning disability? In D. B. Berch & M. M. M. Mazzocco (Eds.), *Why is math so hard for some children? The nature and origins of mathematical learning difficulties and disabilities* (p. 329-348). Baltimore, MD, US: Paul H Brookes Publishing.
- Bai, H. (2011). Cross-validating a bidimensional mathematics anxiety scale. *Assessment*, 18(1), 115-122. Retrieved from <https://doi.org/10.1177/1073191110364312> (PMID: 20212074) doi: 10.1177/1073191110364312
- Bai, H., Wang, L., Pan, W., & Frey, M. (2009). Measuring mathematics anxiety: Psychometric analysis of a bidimensional affective scale. *Journal of Instructional Psychology*, 36(3).
- Becker, C. B., Darius, E., & Schaumberg, K. (2007). An analog study of patient preferences for exposure versus alternative treatments for posttraumatic stress disorder. *Behaviour Research and Therapy*, 45(12), 2861 - 2873. Retrieved from <http://www.sciencedirect.com/science/article/pii/S0005796707001118> doi: <https://doi.org/10.1016/j.brat.2007.05.006>
- Dreger, R. M., & Aiken Jr, L. R. (1957). The identification of number anxiety in a college population. *Journal of Educational Psychology*, 48(6), 344.
- Faust, M. W. (1996). Mathematics anxiety effects in simple and complex addition. *Mathematical Cognition*, 2(1), 25-62.
- Foa, E. B., Hembree, E. A., Cahill, S. P., Rauch, S. A. M., Riggs, D. S., Feeny, N. C., & Yadin, E. (2005). Randomized trial of prolonged exposure for posttraumatic stress disorder with and without cognitive restructuring: outcome at academic and community clinics. *Journal of consulting and clinical psychology*, 73(5).
- Foley, A. E., Herts, J. B., Borgonovi, F., Guerriero, S., Levine, S. C., & Beilock, S. L. (2017). The math anxiety-performance link: A global phenomenon. *Current Directions in Psychological Science*, 26(1), 52-58. Retrieved from <https://doi.org/10.1177/0963721416672463> doi: 10.1177/0963721416672463
- Hembree, R. (1990). The nature, effects, and relief of mathematics anxiety.

- Journal for Research in Mathematics Education*, 21(1), 33–46. Retrieved from <http://www.jstor.org/stable/749455>
- Jamieson, J. P., Peters, B. J., Greenwood, E. J., & Altose, A. J. (2016). Reappraising stress arousal improves performance and reduces evaluation anxiety in classroom exam situations. *Social Psychological and Personality Science*, 7(6), 579-587. Retrieved from <https://doi.org/10.1177/1948550616644656> doi: 10.1177/1948550616644656
- Jansen, B. R., Louwerse, J., Straatemeier, M., der Ven, S. H. V., Klinkenberg, S., & der Maas, H. L. V. (2013). The influence of experiencing success in math on math anxiety, perceived math competence, and math performance. *Learning and Individual Differences*, 24, 190 - 197. Retrieved from <http://www.sciencedirect.com/science/article/pii/S1041608012001951> doi: <https://doi.org/10.1016/j.lindif.2012.12.014>
- Kazelskis, R., Reeves, C., Kersh, M. E., Bailey, G., Cole, K., Larmon, M., ... Holliday, D. C. (2000). Mathematics anxiety and test anxiety: Separate constructs? *The Journal of Experimental Education*, 68(2), 137-146. Retrieved from <https://doi.org/10.1080/00220970009598499> doi: 10.1080/00220970009598499
- LeFevre, J.-A., Kulak, A. G., & Heymans, S. L. (1992). Factors influencing the selection of university majors varying in mathematical content. *Canadian journal of behavioural science*, 24(3).
- Lin-Siegler, X., Ahn, J. N., Chen, J., Fang, F.-F. A., & Luna-Lucero, M. (2016). Even einstein struggled: Effects of learning about great scientists' struggles on high school students' motivation to learn science. *Journal of Educational Psychology*, 108(3), 314.
- Lyons, I. M., & Beilock, S. L. (2012a). Mathematics anxiety: Separating the math from the anxiety. *Cerebral Cortex*, 22(9), 2102-2110. Retrieved from <http://dx.doi.org/10.1093/cercor/bhr289> doi: 10.1093/cercor/bhr289
- Lyons, I. M., & Beilock, S. L. (2012b). When math hurts: math anxiety predicts pain network activation in anticipation of doing math. *PloS one*, 7(10),

e48076.

- Ma, X., & Xu, J. (2004). The causal ordering of mathematics anxiety and mathematics achievement: a longitudinal panel analysis. *Journal of Adolescence*, 27(2), 165 - 179. Retrieved from <http://www.sciencedirect.com/science/article/pii/S0140197103001064> doi: <https://doi.org/10.1016/j.adolescence.2003.11.003>
- Organisation for Economic Co-operation and Development (OECD). (2013). *Programme for International Student Assessment (PISA) 2012 results: ready to learn: students' engagement, drive and self-beliefs (volume iii): preliminary version*. PISA, OECD, Paris, France. Retrieved from <http://www.oecd.org/pisa/keyfindings/pisa-2012-results-volume-iii.htm> (viewed 4 Feb 2019)
- Park, D., Ramirez, G., & Beilock, S. L. (2014). The role of expressive writing in math anxiety. *Journal of experimental psychology. Applied*, 20 2, 103-11.
- Ramirez, G., Shaw, S. T., & Maloney, E. A. (2018). Math anxiety: Past research, promising interventions, and a new interpretation framework. *Educational Psychologist*, 1-20.
- Richardson, F. C., & Suinn, R. M. (1972). The mathematics anxiety rating scale: psychometric data. *Journal of counseling Psychology*, 19(6), 551.
- Suárez-Pellicioni, M., Núñez-Peña, M. I., & Colomé, À. (2016, Feb 01). Math anxiety: A review of its cognitive consequences, psychophysiological correlates, and brain bases. *Cognitive, Affective, & Behavioral Neuroscience*, 16(1), 3-22. Retrieved from <https://doi.org/10.3758/s13415-015-0370-7> doi: 10.3758/s13415-015-0370-7
- Supekar, K., Iuculano, T., Chen, L., & Menon, V. (2015). Remediation of childhood math anxiety and associated neural circuits through cognitive tutoring. *Journal of Neuroscience*, 35(36), 12574-12583. Retrieved from <http://www.jneurosci.org/content/35/36/12574> doi: 10.1523/JNEUROSCI.0786-15.2015
- Wang, Z., Lukowski, S. L., Hart, S. A., Lyons, I. M., Thompson, L. A., Kovas, Y., ... Petrill, S. A. (2015). Is math anxiety always bad for math learning?

- the role of math motivation. *Psychological Science*, 26(12), 1863-1876. Retrieved from <https://doi.org/10.1177/0956797615602471> (PMID: 26518438) doi: 10.1177/0956797615602471
- Young, C. B., Wu, S. S., & Menon, V. (2012). The neurodevelopmental basis of math anxiety. *Psychological Science*, 23(5), 492-501. Retrieved from <https://doi.org/10.1177/0956797611429134> (PMID: 22434239) doi: 10.1177/0956797611429134