Maths Anxiety: Theory to Practice

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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

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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

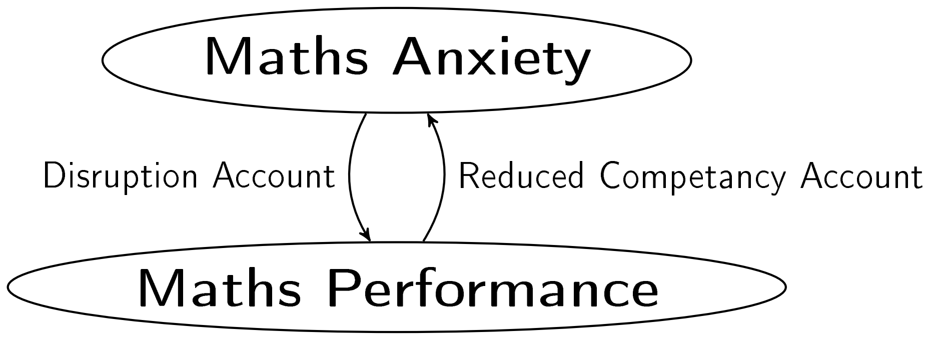

Figure 1: The Interpretation Account of Ramirez et al. (2018) for the maths anxiety-performance link showing how the Disruption Account and the Reduced Competency Account can be compatible.

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 Competency 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, Iuculano, 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 associated 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 does not 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 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 int he 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 (Hiebert & Grouws, 2007).

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

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

Because of how the broad view of the research on the maths anxiety-performance link seems to give the two directional cyclic relationship described by the "Interpretation Account" shown in Figure 1, I hypothesise that part of the reason for the lack of long-term effectiveness of the interventions trialled is that any given intervention focuses on breaking one particular link in the cycle, leaving the others in place to re-engage once the intervention is over. I propose a multi-pronged intervention in which multiple links in the cycle are attacked simultaneously to disrupt the maths anxiety-performance link, and I hypothesise that this approach will result in a longer term sustained effect on both students wellbeing, reducing their negative affect towards maths and their maths anxiety, but also an improvement in maths performance.

- 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 heart rate, 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".

Methodology

This research is predicated on collaborating with a school and the maths faculty therein. There will be two key components to the study: an intensive tutoring program in which the students will have private tutors hired to help boost their maths skills, and a professional development program for the teachers. This professionsal development program for teachers will help the teachers, with the occasional help of guest speakers, will modify their teaching in a number of key ways:

- Incorporate examples of productive struggle into the classrooms.

- Coach students on how to reappraise physiological signs of stress as a response to a challenge to be overcome.

- Expressive writing takss to help guide students naratives about their math abilities.

Throughout there will be 5 primary forms of data collection:

- During school holidays there will be social teacher debrefiing sessions in which the teachers will be asked to provide feedback on their perspectives on the effects of the interventions.

- Assessment results for students academic performance will be collated for an entire three year period including a year prior to the interventions and a year afterwards.
- Students will complete self-surveys on both maths anxiety, and maths self-concept/ efficacy the year prior, during, and the year after the interventions.
- The expressive writing tasks will yield written work from each student describing their narative view of their journey learning maths, which can also be used to assess their self-concept/ efficacy in a deeper way.

3 Ethics Issues (/100 words)

4 Executive Summary (/100-150 words)

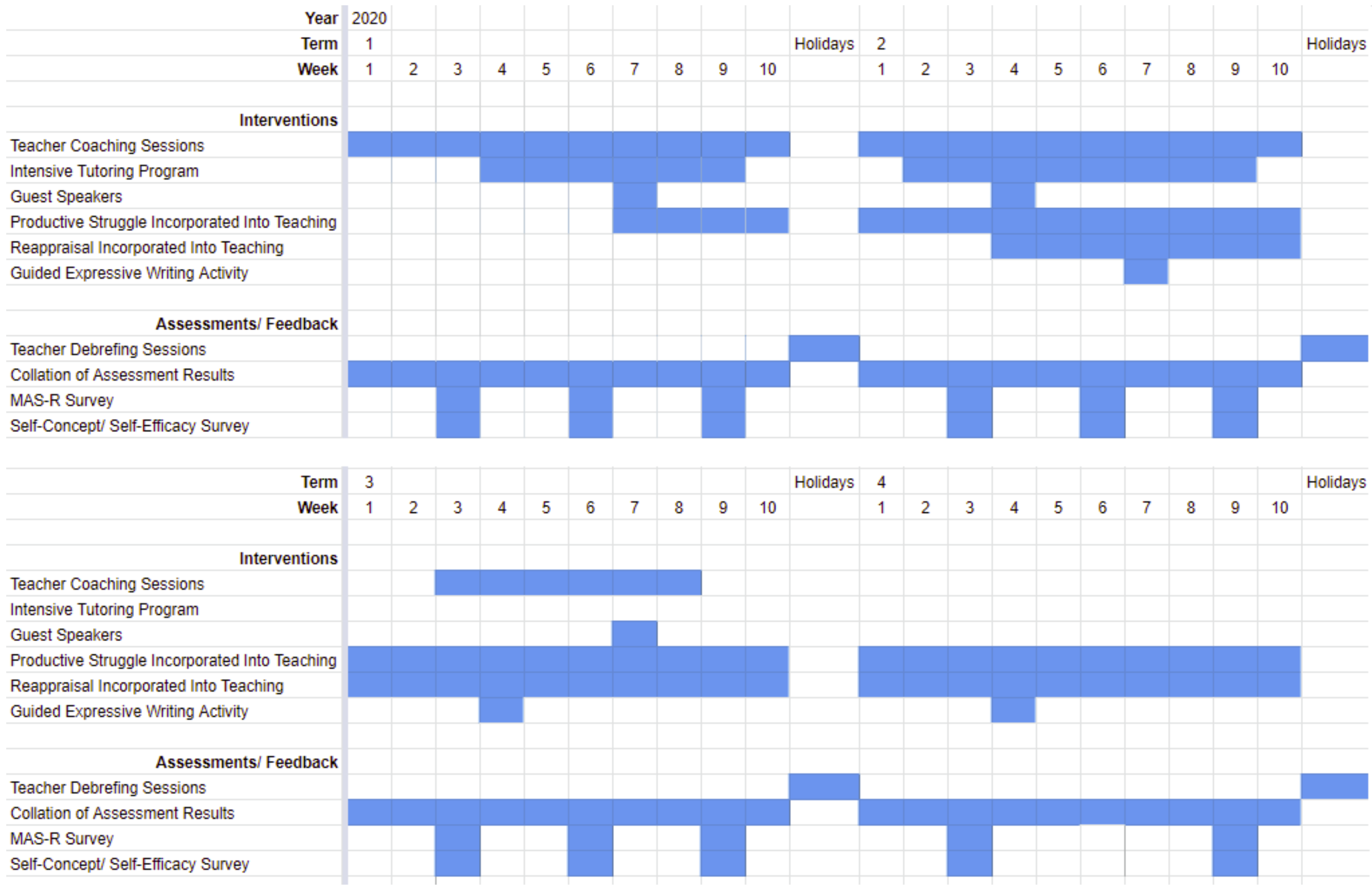

Figure 2: Gantt Chart

	Unit Cost	Units	Sub Total
Development Costs			
Teacher Coaching Sessions	$180.00	26	$4,680.00
Guided Expressive Writing Excercises	$300.00	3	$900.00
MAS-R Survey	$2,400.00	1	$2,400.00
Self-Concept/ Self-Efficacy Survey	$2,400.00	1	$2,400.00
Staff Wages for Interventions			
Teacher Coaching Sessions	$120.00	26	$3,120.00
Intensive Tutoring Program (per hour per student)	$60.00	600	$36,000.00
Guest Speakers (per session)	$300.00	5	$1,500.00
Running Costs/ Admin			
Printing and Stationary (per student)	$50.00	30	$1,500.00
Teacher Debrefing Sessions	$500.00	4	$2,000.00
Data Analysis and Project Management			
PI wages (per week)	$2,280.00	60	$136,800.00
Data Collation (per week)	$2,280.00	8	$18,240.00
Data Analysis (per week)	$2,280.00	10	$22,800.00
			Total
			$232,340.00

Table 1: Budget

Glossary

fMRI functional magnetic resonance imaging. 2–4

MARS Maths Anxiety Rating Scale. 3

MAS-R Maths Anxiety Scale — Revised. 4

OECD Organisation for Economic Co-operation and Development. 2, 16

PISA Programme for International Student Assessment. 2, 16

PTSD Post-Traumatic Stress Disorder. 6

STEM Science, Technology, Engineering and Mathematics. 2

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