

Maths anxiety and poor performance: Targeted tuition to break the vicious cycle

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In this paper, part of a larger study investigating the efficacy of targeted tuition for 30 upper primary and middle school students with mathematical learning difficulties (MLD) is described. Mathematics anxiety (MA) was measured before and after 24 individual tuition sessions delivered to one group by personal videoconferencing (PVC) and to another group face-to-face (FtF). Comparisons of pre- and post-test anxiety ratings showed significantly decreased MA levels for the PVC tuition group but not the FtF group. Both groups showed significant improvements in standardised mathematics scores after the tuition. These results suggest that targeted tuition delivered by PVC may decrease MA in students with MLD.

It is now widely recognised that a substantial proportion of school students have difficulties with learning mathematics. Estimates from the United States and Australia suggest that approximately 7% of students will meet the criteria for mathematical learning disabilities, now termed *learning disorder with specific impairments in mathematics* (American Psychiatric Association, 2013) in at least one area of mathematics, and that an additional 10% of students will be identified as low achieving before graduating from high school (Geary, 2011; Graham & Bailey, 2007). An important factor contributing to the difficulties with school mathematics experienced by students with mathematical learning disorders and consistently low mathematical performances (hereafter referred to as *mathematical learning difficulties [MLD]*) is MA (Rubinsten & Tannock, 2010). MA is defined as the emotional reaction, involving feelings of anxiety, tension and fear, experienced by some individuals when faced with a situation which requires them to solve mathematics problems (Ashcraft, Krause, & Hopko, 2007).

MA may be particularly detrimental for students with MLD (Rubinsten & Tannock, 2010). Research findings suggest that there is a reciprocal relationship between poor mathematical performances and MA whereby both factors impact negatively on each other (Carey, Hill, Devine, & Szücs, 2016; Ma & Xu, 2004) establishing a vicious cycle that confounds efforts to assist students with MLD to acquire essential mathematical competencies. Therefore, remediation programs for these students should aim to increase mathematical performances and to reduce, or avoid, MA. In this paper, an investigation of the impact of a targeted, conceptual instruction-based, individual tuition program targeting number sense and fluency with basic number facts on the MA levels of students with MLD is described. The individual tuition programs were delivered both FtF and by PVC. The efficacy of PVC for the delivery of specialist support (such as Third-wave interventions) may be particularly important to students located in regional and remote Western Australia (WA) who have consistently shown poorer performances than students residing in metropolitan areas on state and national numeracy assessments (Australian Curriculum Assessment and Reporting Authority [ACARA], 2008-2018). The research question guiding the investigation was: Does targeted tuition delivered by PVC reduce the MA of students with MLD?

Previous Research

Few studies have investigated MA and achievement in middle and high school students. Correlations between MA and mathematics achievement were reported for students in grades 5 to 12 (-0.34) by Hembree (1990), and for high school students (-0.30) by Ashcraft and Kirk (2001) and these correlations were found to be consistent across school year levels, for Grades 4 to 12 (Ma, 1999). Wang and colleagues reported inconsistent findings. Wang, Shakeshaft, Schofield, and Malanchini (2018) found negative associations between MA and mathematics achievement for Italian high school students (mean age = 15.87 years). However, findings from an earlier study (Wang et al., 2015) involving US students (mean age = 12.25 years) indicated that both high and low levels of MA were associated with low mathematical achievement. Madjar, Zalsman, Weizman, Lev-Ran, and Shoval (2018) reported higher and more stable MA levels in lower achieving middle school students.

In terms of the types of mathematics tasks impacted by MA, Hembree (1990) reported similar correlations between MA and computation (-0.25), concepts (-0.27), and problem solving (-0.27). However, more recent studies have yielded mixed findings (Punaro & Reeve, 2012; Wang et al., 2015), with some authors suggesting a negative association between MA and only mathematics tasks that load working memory (WM) (Wu, Barth, Amin, Malcarne, & Menon, 2012). Dowker, Sarkar, and Looi (2016) posited that young elementary students are already using WM dependent mental strategies; hence, their progress is more significantly negatively impacted by MA. This may also be the case for students with MLD who cannot rely on fluent retrieval of numerical facts from long-term memory (Mazzocco, 2007), and often use inefficient, WM demanding strategies to derive even basic number combinations (Geary, 2004). Hence, the negative impact of MA on these processes may be particularly detrimental for this group of students also. Indeed, there is some evidence to suggest that MA may be particularly prevalent amongst students with MLD (Ma & Xu, 2004; Passolunghi, 2011).

There is little evidence to indicate the best way to ameliorate MA in school students with MLD. Given the negative relationship between MA and mathematic performances, it has been suggested that interventions designed to improve mathematics achievement may be an effective way to reduce MA by disrupting the poor performance – MA reciprocal cycle (Rubinsten & Tannock, 2010). Findings from a study investigating the impact of one-to-one tuition on MA and associated brain activation patterns in Grade 3 students showed significantly reduced MA and amygdala activity during mathematics tasks (Supekar, Iuculano, Chen, & Menon, 2015); hyperactivity of the amygdala was previously shown to be associated with childhood MA (Young, Wu, & Menon, 2012). In the Supekar et al. (2015) study, tuition was conducted for 8-weeks (total number of sessions = 24) for 40-50 minutes duration. Post-tuition mathematics aptitude scores were not reported, so the impact of the tuition on the mathematics performances of these students could not be established. Nevertheless, these results showing the effectiveness of short-term tuition for reducing MA are encouraging. No data were found to indicate whether similar reductions in MA can be achieved by implementing remotely delivered targeted tuition for students with MLD.

Research Purpose

In this paper the focus is on one of the aims of a larger study in which the effectiveness of a targeted, conceptual instruction-based, individual tuition program, aimed at improving number sense and fluency with basic skills in mathematics for upper primary and middle school students with MLDs was investigated.

The Study

The study utilised a two-phase sequential, mixed method design in which numerical data were collected to determine any changes in MA levels following targeted tuition delivered to one group of students by PVC (see below), and to another group FtF, and to compare the results for the two groups. Numerical data pertaining to mathematical performances were also collected; these results have been reported elsewhere (Kestel & Forgasz, 2018).

Participants

Thirty students from school years 4 - 9 were selected for participation in the study from an initial cohort identified as requiring specialist intervention by educational psychologists or teachers. The participants were not deemed to be intellectually impaired but had achieved below average numeracy scores in the most recent national testing program, had shown persistent poor performance in school mathematics over a period of one year, and scored below the 35th percentile rank in pre-intervention standardised testing.

Students were assigned to one of two intervention (tuition) conditions: (1) participants receiving tuition by PVC delivery, (2) participants receiving tuition by FtF delivery. Assignment of participants to experimental groups was based on pragmatic considerations similar to those normally influencing the choice of delivery modality, for example, distance between locality of tutor and student. Participants from both metropolitan and regional locations were included in the PVC group to control for the lower mathematics performances of students in regional and remote schools in WA (e.g., ACARA, 2016).

Pre-test and Post-test Assessment Measures

To measure the degree of MA they experienced prior to, and following, the tuition program, all participants completed a nine-item MA assessment tool, the Abbreviated Maths Anxiety Scale [AMAS] (Hopko, Mahadevan, Bare, & Hunt, 2003). The two-week test-retest reliability of the AMAS was shown to be 0.85 (Hopko, 2003). The psychometric properties of the AMAS has frequently been assessed and found to be highly reliable (Dowker et al., 2016). The AMAS uses a 5-point Likert-type response format, ranging from 1 (low anxiety) to 5 (high anxiety). Typically, the total score is calculated from a summation of the scores on each of the nine items (Hopko et al., 2003). A mean AMAS score for each participant was derived from the average of the scores across the nine items of the assessment tool to better reflect the meaning of the Likert-type scale. The wording of the test items was highly reflective of the American vernacular and there was concern that the language may confuse some Australian participants in the current study. Hence, minor modifications to the wording of the test items were made to reflect Australian language norms (Table 1). The researcher explained the use of the Likert-type scale to each of the participants. To determine any changes in mathematical performances following the tuition program, all participants completed pre- and post-test standardised mathematics tests (PATMaths (Australian Council for Educational Research [ACER], 2016) and tests of basic number fact fluency (Royer & Tronsky, 1998). Although the sample size was small, statistical procedures were performed to ascertain the significance of any changes in scores, following other studies involving small numbers of participants (Bellert, 2009; Kaufmann, Handl & Thony, 2003). Effect sizes were calculated for each assessment measure and rated from small to large according to Cohen's (1988) criteria, as an indicator of the contribution of the results (Durlak, 2009).

PVC Tuition

Tuition delivered by PVC utilised the iVocalize Web Conference tool, a Voice over Internet Protocol (VoIP) software application, allowing real-time, online interactive

communication and featuring audio and webcam video, whiteboard, live screencasting, synchronised web browsing, text chat, and PowerPoint (iVocalize LLC, 2009). Participants required a Mac or Windows computer with audio capabilities (built in speaker and microphone or headset with microphone) and a reliable internet connection. At the time of the study, the researcher had been using the iVocalize Web Conference tool to tutor students with learning difficulties in both metropolitan and regional locations for three years, experiencing few internet connection problems. The whiteboard feature allowed upload of worksheets and provided a laser pointer and various annotation tools, as well as a ‘save’ function so that participant work could be recorded. The live screencasting function enabled the demonstration of computer software and the broadcast of a live video of a moderator’s (the tutor’s; see below) desktop. The live screencasting and/or the synchronised web browsing functions enabled the use of virtual manipulatives (controlled by the tutor) during PVC tuition sessions. The researcher made deliberate attempts to replicate instructions and demonstrations used in FtF tuition during the PVC tuition sessions (see below).

Table 1
AMAS test items

Modified AMAS Test Items
1. Having to use times tables charts in maths books
2. Thinking about having to do a maths test the day before the test
3. Watching a teacher do an algebraic equation (division sum for primary school) on the board
4. Doing a maths exam (like NAPLAN)
5. Being given maths homework with lots of difficult problems that is due the next day
6. Listening to the teacher explain a topic in maths
7. Listening to another student explain a maths formula
8. Being given a ‘pop’ (unexpected mental test) quiz in maths
9. Starting a new topic in maths

NOTE: The language of the test items was modified to reflect the Australian vernacular. Students were required to rate their anxiety on a Likert-type scale: 1 = not really nervous (low anxiety), 2 = a bit nervous, 3 = quite nervous, 4 = very nervous, 5 = extremely nervous (high anxiety)

Experimental Intervention

Individual tuition programs, featuring explicit, conceptual instruction and differential practice targeting number sense, efficiency of numerical strategy use, and basic number fact fluency across the four mathematical operations (addition, subtraction, multiplication and division) were implemented with participants in the two experimental (tuition) groups. Instructional materials for the FtF and PVC groups were similar and included: Integer rods and Base-10 blocks, 100-square, number lines, dot-array and digit dice, PC-based visual representations of counter and block arrays, and diagrams drawn on whiteboards; timed practice was undertaken using PC-based computer games. The difference in instructional materials between the groups was the use of concrete manipulatives in the FtF group. Wherever possible, interactive whiteboard visual representations of concrete manipulatives were used in place of concrete manipulatives for the PVC group. Also, participants in the FtF group had control of PC-based games, whereas the tutor assumed control of the games in response to verbal instructions given by the participants in the PVC group.

The individual tuition programs delivered by PVC and FtF modalities followed the same format. Tuition was delivered to 39 of the participants by the researcher, a specialist teacher

with 7 years' experience working with students with learning difficulties and disabilities. Tuition was delivered to one participant in the FtF group by a graduate teacher where each tuition session was conducted under the direct supervision of the researcher to ensure fidelity of the intervention (Graham & Bailey, 2007). All participants received a maximum of 24 individual tuition sessions at a frequency of one tuition session per week for the first 12 sessions. The final 12 sessions were conducted at a frequency of two sessions per week. The maximum duration of each session was 45 minutes.

Results

Pre- and post-test AMAS data was available for all 30 of the study participants. Results of preliminary data analyses revealed a normal distribution of scores, so parametric statistical techniques were applied. Paired sample t-tests were conducted to compare pre- and post-test mean AMAS scores for both tuition groups (Table 2), to determine the significance of any changes in MA after the tuition. According to the Likert-type scale employed, higher scores indicated greater anxiety levels.

Mean AMAS scores across the nine test items for students in the PVC group showed a significant decrease from pre-test ($M = 2.64, SD = 0.58$) to post-test ($M = 2.37, SD = 0.67$); $t(19) = 2.27, p < .05$, (two-tailed). The mean decrease in average AMAS scores was 0.27 with a 95% confidence interval ranging from 0.02 to 0.52. The d value (.42) indicated a medium effect size. By comparison, there was no significant decrease in average AMAS scores from pre-test to post-test for students in the FtF tuition group (see below). These results suggested that for these students with MLD, participation in a tuition program targeting number sense and fluency with basic number facts and delivered by PVC resulted in reduced MA.

Table 2

Pre- and post-test AMAS scores for PVC and FtF groups with paired samples t-test statistics

Group	Pre-test			Post-test		Statistics						
	n	Mean	SD	Mean	SD	df	t	p	MD ^a	95% CI	d ^b	
PVC	20	2.64	0.58	2.37	0.67	19	2.27	0.04*	0.27	0.02 - 0.52	0.42	
FtF	10	2.93	0.79	2.51	0.74	9	1.87	ns	0.42	-0.09 - 0.94	0.43	

NOTE: Mean units are average across nine AMAS items. Ranges: Pre-test (PVC = 2.00 – 3.88; FtF = 1.56 – 3.78) Post-test (PVC = 1.22 – 3.78; FtF = 1.56 – 3.78)

^aMD = mean difference.

*p < 0.05;

^bEffect size: small (d = 0.2), medium (d = 0.5), large (d = 0.8) (Cohen, 1988).

Discussion and Conclusion

The results of the current investigation suggested that a tuition program delivered by PVC may reduce MA in students with MLDs. After 24 tuition sessions, the PVC group showed lower average MA levels with an estimated effect size of 0.42 (Cohen, 1988). By comparison, students in the FtF tuition group also reported reduced MA levels, however, the decrease was not statistically significant. This lack of significance, however, may be attributable to a lack of statistical power (Field, 2013) due to the smaller number of participants in the FtF group, and the estimated medium effect size of 0.4 suggests that this may well have been the case. These results make it difficult to ascertain whether the PVC delivery modality influenced the decreased post-tuition MA levels reported by the PVC

group participants. Adding to this uncertainty is the lack of evidence from the literature, as no other research studies investigating the impact of PVC (or synchronous online) interventions on anxiety levels for students with MLD were found. What is clear, however, is that after the PVC tuition program, the participants in the present study reported significantly lower levels of MA. It has been suggested that interventions yielding effect sizes of more than 0.4 are worth implementing (Hattie, 2009). Hence, the results of the current study implied that the tuition program targeting number sense and conceptual understandings of basic number facts reduced the average MA levels of the participants (possibly in both tuition groups; see above) enough to be considered worthy of implementation. This finding of reduced MA following short-term, one-to-one tuition is consistent with that of Supekar et al. (2015) who employed a very similar intervention protocol to that used in the current study, albeit with younger (Grade 3) students.

The PVC tuition students also made significant gains in standardised test scores and in accuracy, but not speed, with basic number facts (except addition) (see Kestel & Forgasz, 2018) and these tangible improvements in mathematics competence may be linked to the reported reduction in anxiety towards mathematics. The relationship between MA and mathematics achievement has been established (e.g., Ashcraft & Kirk, 2001), however, the precise factors contributing to this relationship are not well understood. As suggested by other authors (Ashcraft et al., 2007), the reduced MA – improved mathematics achievement found in the current participants with MLD may be attributable to improved number sense, increased confidence towards mathematics, more efficient use of WM resources, or a combination of these and/or other factors.

Findings from previous studies suggested that MA disrupts performances on mathematical tasks with high WM demands (e.g., Cargnelutti, Tomasetto & Passolunghi, 2017). It has also been shown that students with MLD typically use inefficient, WM dependent numerical strategies (Geary, 2004). Hence, it is plausible that for the current study participants, gaining competency with the use of more efficient numerical strategies, evidenced by improved performances on basic number fact accuracy measures (see Kestel & Forgasz, 2018) may have decreased WM load and the impact of MA on their mathematical performances. Although some authors have reported no direct link between WM capacity and MA in students with MLDs (e.g., Passolunghi, 2011), it may be that more efficient use of WM resources positively impacts mathematical achievement that in turn, reduces MA and vice versa. However, more studies are required before such a theory can be substantiated.

Interventions which not only improve mathematics performances but also reduce MA levels are potentially of the greatest benefit to students with MLD. The possibility that such an intervention can be effectively delivered to these students remotely, as suggested by the results of the current study, is particularly encouraging given the vastness of countries like Australia, and the importance of acquiring mathematical competencies on the future career prospects (Stanley, 2008) for students in WA. It may also have implications for the ever increasing move towards online learning for students worldwide (Barbour, 2011). Before any definitive conclusions can be drawn, more research with larger samples of students with MLD is required to test whether these results can be replicated.

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