Interventions to Address Mathematics Anxiety: An Overview and Recommendations

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Introduction

Mathematics anxiety (MA) can be described as tense and anxious feelings that impede the ability to manipulate numbers and solve mathematical problems in academic and ordinary life situations (Richardson & Suinn, 1972). Despite normal performance in most thinking and reasoning tasks, mathematics (maths) anxious individuals demonstrate poor attainment when solving maths problems (Ashcraft & Moore, 2009; Maloney & Beilock, 2012) as MA interferes with the cognitive processes required for successful mathematical problem solving. Recent work in this area has identified a neural threat response to maths stimuli when high maths anxious individuals are simply presented with a maths problem (Pizzie & Kraemer, 2017) or merely numbers (Batashvili et al., 2020). As an emotional rather than intellectual problem, MA places the individual in a cognitively passive state in which they experience panic, depression, helplessness, nervousness and fearfulness (Luo et al., 2009) and is a particular issue for those whose ability is already poor (Witt, 2012).

Carey et al. (2016) provides a useful discussion of the relationship between MA and performance, comparing a deficit theory and the debilitating anxiety model. The deficit theory argues that maths performance deficits, for example on maths tests, generate mild to extreme anxiety, which may be generalised in other situations. In contrast the debilitating anxiety model suggests that anxiety, particularly maths anxiety, reduces maths performance by affecting cognitive and emotional processes. In support of the deficit theory, there is longitudinal evidence to suggest that early poor maths performance can lead to the development of MA (Ma & Xu, 2004). There is also evidence of immediate effects of MA on performance, supporting the debilitating anxiety model. For example, time pressure detrimentally impacts performance among high maths anxious adults (Hunt & Sandhu, 2017) and the removal of time pressure lessens the impact of MA on performance (Faust et al., 1996). Furthermore, self-reported MA appears to be directly related to children's physiological reactivity to maths problems that increase in difficulty (Hunt et al., 2017). Moreover, there is evidence to suggest that physiological reactivity to mathematical problem solving is greater when individuals appraise the task as threatening (Maier et al., 2003). These findings indicate that MA may lead to an affective drop in performance (Ashcraft & Moore, 2009) based on the argument that MA consumes essential working memory resources required for effective mathematical problem solving (Ashcraft & Krause, 2007). According to Carey and colleagues (2016) mixed evidence for the deficit and debilitating anxiety models might point towards a reciprocal relationship between MA and performance. That is, early poor performance may trigger the onset of MA, which in turn leads to poor performance, resulting in a vicious cycle.

Here we draw together empirical evidence from attempts to reduce MA, synthesising the literature and capturing a wide range of studies. Whilst a fully systematic approach has not been taken, the review considers work reported in peer-reviewed papers. In addition, only studies published since 1990 have been included as this provides a useful comparison against the findings reported in Hembree's (1990) seminal meta-analysis. Furthermore, the review focuses on MA and, accordingly, includes studies that have explicitly measured MA after the intervention; studies that aimed to reduce MA but only measured, for example, maths performance, were excluded. Studies that clearly represent interventions to address MA are reported in Table 1. Finally, we suggest directions for further interventions, considering recent theoretical developments in the field.

Table 1. Mathematics Anxiety (MA) Intervention Studies.

Study	Sample size	Population	Type of intervention	Measures of maths anxiety	Additional outcomes	Main findings
Lavasani & Khandan (2011).	40	Secondary school students (aged 13-14 years), Iran.	Co-operative learning vs. traditional method.	"18-item mathematics anxiety scale".	Help-seeking behaviour.	Co-operative learning resulted in significantly lower MA, decreased help avoidance behaviour and increased help seeking behaviour.
Segumpan & Tan (2018).	90	Secondary school students (aged 12-13 years), Philippines.	Flipped classroom vs. traditional method.	Mathematics Self-Efficacy and Anxiety Questionnaire. (MSEAQ; May, 2009).	Maths performance.	Significantly lower MA and greater maths performance in the flipped classroom condition compared to the control condition post-intervention.

Passolunghi et al (2020).	224 (3 studies; n = 76, n = 76, n = 72)	Fourth grade children, (aged 9-10 years; mean age = 9.60 years; SD = 0.27). Italy	MA training; maths strategy training.	Abbreviated Math Anxiety Scale (AMAS; Hopko et al., 2003; Caviola et al., 2017).	General anxiety; Primary mental abilities.	Repetition and exposure to maths, including focused training on basic emotions can increase maths ability and decrease MA.
Supekar et al (2015).	28	Third grade children (aged 8-9 years; low & high MA), USA.	Intensive 8-week one-to-one cognitive tutoring program to improve mathematical skills and reduce MA (3 weekly sessions).	Scale for Early Mathematics Anxiety (SEMA; Wu et al., 2012).	Intelligence; Achievement; Working memory; Brain activity.	Sustained exposure to mathematical stimuli can reduce MA.
Alanazi (2020).	60	First grade primary school children (aged 6-7 years), Saudi Arabia.	Active recreational maths games (24 sessions over 2 months; 3 weekly sessions).	Mathematics Anxiety Scale for Children (Chiu & Henry, 1990); Arabic translated (Adnan & Ibrahim, 1990).	Maths performance.	MA was significantly lower in the intervention group post intervention.
Jansen et al (2013).	207	Grades 3-6 primary school children (aged 6-10 years), Netherlands.	Math Garden ("a web-based computer adaptive application for practicing mathematical skills").	The Math Anxiety Scale for Children (Chiu & Henry, 1990); Dutch translated (MASC-NL; Jansen et al., 2013).	Cognitive competence; social competence; general self-worth; maths task performance.	Computer based activity resulted in a small performance improvement, but there was an absence of effect on MA.
Karimi & Kenkatesan (2009).	25	High school students (aged 13-16 years), Iran.	Cognitive Behavioural Group Therapy (CBGT) (15 sessions for 1.5 hours).	Mathematics Anxiety Rating Scale (Alexander & Martray, 1989).	None.	MA reduced following CBGT and suggests that reappraisal may be an effective strategy.
Sheffield & Hunt (2006).	154	Children (aged 10-11 years), UK.	Modified systematic desensitization.	Mathematics Anxiety Scale for Children (MASC; Chiu & Henry, 1990).	Maths performance.	The use of a physiological strategy resulted in decreased MA and improved performance.
Brunyé et al (2013).	36	University students (low & high MA), mean age = 20.80 years, SD = 2.60. USA.	Breathing exercises.	30-item Mathematics Anxiety Rating Scale (MARS; Suinn & Winston, 2003)-but only to define different groups.	Mood; Arithmetic performance.	Focused breathing improved calmness ratings and mitigated maths anxiety effects on arithmetic performance.

Salazar (2019).	106	UG students (aged 18-45 years; mean age = 21.03 years; SD = 0.49. USA.	Colouring Mandalas vs. Free form vs. Doodle before maths problems.	Abbreviated Math Anxiety Scale (AMAS; Hopko et al., 2003).	None.	Colouring (both groups) was associated with reduced MA (control was not).
Davis & Kahn (2018).	59	Undergraduate students (aged 18-23 years; mean age = 21 years) USA.	Virtual reality relaxation vs. Passive control.	Math Anxiety Rating Scale -Revised (MARS-R; Plake & Parker, 1982).	Maths performance.	Significantly lower MA and higher maths performance between groups post-intervention.
Gan et al (2016).	105	Undergraduate students (aged 19-31 years; mean age = 22.23 years; SD = 2.08). Singapore.	Stimulating vs. Sedative music vs. No music before maths problems.	Abbreviated MARS (Alexander & Martray, 1989).	State anxiety, blood pressure and heart rate.	Sedative music associated with reduced MA and STAI.
Jamieson et al (2016).	93	Community college students (aged 18-58 years; mean age = 29.40 years). USA.	Re-appraisal vs. Suppression Control (Ignore negative cognitions).	Abbreviated Math Anxiety Scale (Hopko et al., 2003).	Stress appraisals; Maths performance.	MA decreased, coping resources increased and performance improved in reappraisal group compared to suppression control. Resource appraisals mediated performance.
Dorothea (2016).	5	Secondary school students (aged 17-19 years). Italy.	Dramatherapy.	"Personal questionnaire" involving a range of items pertaining to MA/stress; Interview.	Maths self-efficacy.	Some descriptive evidence to support a decrease in stress associated with maths, along with increased maths self-efficacy.
Samuel & Warner (2021); Experiment 1.	40	Community college students (mean age 17.92 years). USA.	Combined mindfulness and growth mindset intervention embedded into curriculum vs. Passive Control.	Revised Math Anxiety Rating Scale (RMARS; Alexander & Martray, 1989).	Maths self-efficacy.	MA decreased and self-efficacy decreased in the intervention group but not control group.

According to a Hembree's 1990 meta-analysis, whole-class curricular based changes were shown to be ineffective in reducing MA. Such changes included, for instance, the use of specialist equipment and technology, different instructions and variations in the presentation of material. With the notable increase in availability and power of technology, particularly the rapid gains in internet provision in schools, it may be necessary to further explore the utility of these resources in the context of reducing MA. Recent research has also demonstrated how pedagogical changes may support the reduction of MA in the classroom. Pedagogical approaches facilitate maths learning, and thus arguably support a deficit argument, whereby improving mathematical knowledge and encouraging more effective learning behaviours may contribute to lower MA and improved maths self-efficacy. For instance, Lavasani and Khandan (2011) used a co-operative learning intervention to address MA in Iranian eighth graders by encouraging interactions among peers and the teacher. The intervention resulted in a significant reduction in MA and an observed increase in help-seeking behaviour, suggesting classroom activities that encourage working together and seeking support reduce avoidance.

Moreover, a study of secondary school students in the Philippines used a flipped classroom approach to successfully reduce MA, possibly due to the greater interactivity and dynamic nature of learning afforded by the approach (Segumpan & Tan, 2018). Group-based formative feedback has been successfully used for students studying statistics (Núñez-Peña et al., 2015), whereby perceived usefulness of feedback predicted exam grades. The authors suggest the feedback approach may have increased students' confidence, which acted as a buffer against MA and/or its effects.More extensive work (Passolunghi et al., 2020) focused on MA prevention in fourth-grade (aged 9-10 years) primary school children in Italy and tested the efficacy of three divergent training methods: (1) MA training (knowledge and recognition of basic emotions); (2) maths strategy training (practising calculation skills); and (3) control training (playful activities on reading/drawing comic strips). MA was measured using the 9-item Abbreviated Math Anxiety Scale (AMAS; Hopko et al., 2003; Caviola et al., 2017) and maths abilities were measured-in contrast to more traditional simple calculation tasks-using the MAT-M3 (pre-test) and MAT-M4 (post-test) (Amoretti et al., 2007) that consist of a range of tasks, e.g., ranking numbers, solving word problems of various concepts and decomposing numbers, to more validly measure maths performance. The findings showed that maths strategy training both improved maths ability and decreased MA, while MA training was only associated with reducing MA level; no performance improvements were observed. The importance of these findings relates to the efficacy of MA training in supporting the reappraisal of maths, even in younger children. Passolunghi and colleagues (2020) posit that repetition and exposure to maths-as well as focused training on basic emotions-can promote a sense of self-control, which may explain the observed reduction in MA and associated improvement in attainment. This relates to both the deficit theory and debilitating anxiety model, whereby exposure leads to lower anxiety, and thus provides more maths dedicated cognitive capacity.

However, the practical application of targeted strategies is dependent on available resources, including time (curriculum demands) and funding. Aligning with increased attention on functional strategies and child-centred research, Fuchs et al. (2013) investigated the impact of divergent practice types on number knowledge in first-grade children (UK age 6-7 years) at risk of MA. Over a 16-week period, 30-minute tutor-led practice sessions took place thrice weekly for the assigned groups to improve simple addition and subtraction: (1) Number knowledge with speeded practice (cardinality, subtraction as the inverse of addition, quick responding & efficient counting procedures), and (2) Number knowledge with non-speeded practice (careful execution of strategies and understanding relations & principles that are the basis of reasoning to support retrieval). They found that number knowledge training with speeded practice supports at-risk children's arithmetic competence, as well as complex calculations due to compensating for weak reasoning ability. Extending this work, Supekar and colleagues (2015) state that MA during early childhood has adverse long-term consequences; accordingly, early identification and alleviation is important. Their own research centred on maths training (3 sessions per week) and desensitisation through an intensive 8-week one-to-one cognitive tutoring program, that aimed to improve maths skill and determine whether this could reduce MA. Twenty-eight children in grade three (UK aged 8-9 years) participated, as this was considered a critical early-onset period for MA, although groups were formed using a median split of a normal sample (Sokolowski & Necka, 2016). Pre and post training Functional Magnetic Resonance Imaging (fMRI) was conducted whilst children simultaneously completed simple addition tasks. The post fMRI scans revealed a decrease in local amygdala circuits for those initially identified as high MA-reflecting fMRI data of mildly-anxious children and supporting the debilitating anxiety model of MA. The findings demonstrate the effectiveness of intensive maths tuition. However, this approach requires suitable resources, which may not be available for many given time and curriculum demands. It is also uncertain whether similar effects would be observed in older children or adults.

Recent comparisons between traditional teaching approaches and active recreational maths games (ARMG) have been trialled (Alanazi, 2020). In this research, a sample of 60 first-grade Saudi Arabian primary school children (UK age 6-7 years) were randomly allocated to the control group (n = 32) or experimental group that would participate in three weekly, 45-minute sessions (including counting, subtraction, additions, shapes) over a two-month period, and MA scores were determined using a translated 23-item iteration of the Mathematics Anxiety Scale for Children (Chiu & Henry, 1990; Adnan & Ibrahim, 1990). Performance was measured by a test created that aligned with the curriculum and was validated by six maths education experts. The findings showed a significant decline in self-reported MA at post test for the experimental group, whereas an increase was observed for the control group, indicating that traditional approaches may not be effective and supportive for emotions and deeper processing. The findings also showed a significant performance improvement for the experimental group, supporting ARMG as a potentially effective MA strategy and general approach to teaching maths. However, this strategy requires further testing with a larger and more demographically diverse population. Nonetheless, studies that have implemented and reported targeted strategies appears to show a trend of reducing MA, and-to an extent-promoting maths attainment. Alanazi (2020) suggests that this may be associated with supporting self-concept, self-esteem (Hughes, 2003), self-confidence and, crucially, self-efficacy (Pajares & Graham, 1999). Jansen and colleagues (2003) manipulated perceived success rates on a computer-based maths task completed by primary school children (aged 6-10 years). Whilst they found higher perceived success was associated with more future attempts and ultimately greater real success, interestingly there was an absence of effect on MA. These findings suggest that whilst such interventions are beneficial in certain ways, e.g., enhancing maths self-efficacy and/or maths attainment, they fail to consistently reduce MA.

It is worth noting that Lazarides and Ittel (2012) observed a range of individual differences in children's judgements of instructional quality in maths classes. This serves to demonstrate the complexity of factors that are involved in the formation of children's maths attitudes, especially as they found such judgements to be associated with self-concept and interest in maths. However, targeted strategies such as MA training, maths strategy training and ARMG may be associated with explanatory styles in response to difficulties, thus impacting MA levels. According to previous work (Yates, 2002), pessimism in maths is associated with a decrease in persistence and assertiveness, and early optimism links with constructive work habits in later education. Optimism has also been shown to relate to confidence in decision making, mental rigidity and emotional intelligence. In contrast, pessimism relates to worry, despair, guilt and depression (Al-Ansari, 2003). This places emphasis on early strategies and for educators to have a greater understanding of emotional and empirically supported responses associated with maths, with emphasis on promoting a positive outlook. We consider corresponding research and strategies within this paper. Indeed, such strategies may have a positive impact on the negative relationship observed between MA and attainment. Ramirez et al. (2016) explored this association with an emphasis on problem-solving strategies which, in young children, are rudimentary (e.g., finger counting) but eventually develop problem-answer associations such as understanding that 3 + 3 = 6. Building on this, children begin to use strategies such as retrieval, decomposition and reconstruction, although this is a more working memory intensive strategy (Ramirez et al., 2016). In their work, it was found that MA in UK children (aged 6-8 years) disrupted working memory capacity, preventing those with high MA from utilising more advanced problem-solving methods. Therefore, targeted strategies that reduce MA-lessening the demand on working memory (debilitating anxiety model)-should be trialled and more widely adopted in classrooms as standard practice. Concerning emotions and MA, Karimi and colleagues (2009) conducted research with 25 high school students aged 13-16 years who were measured for MA through the RMARS (Alexander & Martray, 1989). The 5-point Likert scale included 12-items relating to maths test anxiety and 13-items gauging anxiety in relation to completing mathematical tasks. Following completion of the RMARS, students were either assigned to a control or experimental group. The experimental group engaged with Cognitive Behavioural Group Therapy (CBGT) that was conducted over 15 sessions, in which participants identified their negative thoughts and learnt how to cope with these. The RMARS was completed again, following the conclusion of consistent and intensive CBGT. The results indicated that MA scores had significantly decreased at post intervention. This supports the notion that MA is a negative emotional response affecting cognitions, rather than an intellectual deficit (Luo et al., 2009) and reappraisal may be an effective strategy to addressing the implications of the debilitating anxiety model. Similarly, Lyons and Beilock (2012) demonstrated that those with high levels of MA have increased activity in the frontoparietal network that is involved in the regulation of emotion, through simply anticipating a maths task. Yet, when those high in MA are taught strategies to regulate negative emotions, they perform at an equivalent level to those with low MA. This demonstrates that an emotional element is influential in the maintenance of MA and can be alleviated to reveal genuine ability.

Given the consistent finding that MA is negatively related to willingness to pursue future study or work involving maths (Chipman et al., 2002; Ahmed, 2018) it may be that interventions are required to support initial engagement. This may be necessary, for example, for students who are afraid of entering a maths class, let alone engage with maths learning or problem solving. Sheffield and Hunt (2006) used a modified systematic desensitisation approach with older children aged between 10-11 years. MA scores were determined through the Mathematics Anxiety Scale for Children (MASC; Chiu & Henry, 1990) and performance was assessed on several addition problems. Children practiced relaxing diaphragmatic breathing whilst imagining a maths situation to reduce anxiety. They were further exposed to progressively more difficult maths problems whilst performing relaxing breathing. At one and five weeks later, children again completed the MASC. Analysis of results revealed that those in the intervention group had decreased anxiety and improved performance at post 1 week and 5 weeks. This indicated the value of physiological type strategies to address MA, although further work is required given the existence of baseline differences between the groups. It may be that a systematic approach involving physical relaxation is required for those individuals with a particularly high level of MA, especially as recent work has highlighted a brain response associated with the processing of even basic numerical information (Batashvili et al., 2019).

There are some recent studies that demonstrate the value of interventions that combine relaxation with a focus on attention. For instance, Brunyé and colleagues (2013) adopted a focused breathing technique. Using mindful, diaphragmatic breathing and training individuals to refocus their attention, they found performance of high maths anxious students approached that of those low in MA. Salazar (2019) observed a positive effect of colouring mandalas on MA. A group of undergraduate students were instructed to colour in mandalas (either structured or unstructured drawings), whereas a control group was instructed to simply doodle. Salazar found that MA significantly reduced in the colouring condition and no significant reduction was seen in those who doodled. The author emphasises the benefits of such colouring as a therapeutic technique that induces both cognitive and physical calm. In another study, Davis and Kahn (2018) report on the use of virtual reality in the classroom as a moderator of the relationship between MA and performance. They demonstrated that calming scenarios presented via virtual reality reduced MA and improved performance compared to a control group. Furthermore, Gan and colleagues (2016) demonstrated how attending to sedative music during a maths task can be beneficial for students. They measured state anxiety, MA, and a range of physiological measures before, during, and after a maths task. Participants were assigned to one of three groups: sedative music, stimulative music, or no music. Results showed that state anxiety and systolic blood pressure were significantly reduced when participants listened to sedative music, leading Gan et al. to explain the findings using a perception-to-physiology model, whereby the sedative music first reduced perceived anxiety and this, in turn, reduced physical relaxation over time.

The longevity of treatment effects should also be considered. For instance, an early intervention to address MA (Bander et al., 1982) observed a positive effect of a cue-controlled relaxation technique at a three-week follow-up, compared to a range of other approaches, including study skills training and combined treatments. The varied studies and findings show the value of considering strategies that target physical relaxation but also those that facilitate focusing of one's attention. Arguably, this aids the directing of attention away from unhelpful, worrisome thoughts and enables those with high anxiety to gain attentional control (Eysenck et al., 2007). An alternative approach to training people to manage maths anxious feelings and sensations has been put forward by Jamieson and colleagues (2016). They examined the effects of reinterpreted reappraisal on performance. Participants were faced with an anxiety evoking task, some were told anxious feelings were beneficial to their performance, others were instructed to ignore negative thoughts associated with stress during exams. Individuals who had been reappraised to see anxiety as beneficial i) performed better, as indexed by exam grade, than controls and ii) had lower maths evaluation anxiety. Rather than aiming for physical relaxation, this approach emphasises one's mindset. It normalises anxious feelings and encourages a challenge and approach response to maths, rather than a threat and avoidant response (Jones et al., 2009).

Some studies have tested the impact of expressive writing on maths performance, based on previous findings that writing down worries and fears can help control worry (Klein & Boals, 2001). Ramirez and Beilock (2011) examined whether expressive writing with ninth grade students (UK aged 14-15 years) supports mathematical performance. Compared to control conditions, students that wrote expressively-and specifically about their test-related worries-before a high-pressure maths test demonstrated a significant increase in accuracy at post-test. Similar findings were observed in an additional study

(Ramirez and Beilock, 2011) that focused on test-anxious students (low and high), again demonstrating the effectiveness of expressive writing under high-pressure, as opposed to low-pressure conditions. Further to this work Park and colleagues (2014) investigated expressive writing in the context of MA by asking University students to write down (to express) their thoughts and feelings prior to a maths test. Compared to a control condition, they found the difference in performance of low and high maths anxious individuals was significantly reduced following expressive writing. Moreover, they observed a positive relationship between the number of anxiety-related words that were written and students' performance. Expressive writing is thought to increase the availability of working memory resources (Klein & Boals, 2001; Yogo & Fujihara, 2008). As such, the effectiveness of an expressive writing strategy may provide support for a debilitating anxiety model of MA. However, these studies have not explicitly measured changes in self-reported MA, so conclusions should be viewed with caution. As an alternative strategy Dorothea (2016) reports on the use of psychodrama group therapy for the treatment of high maths anxious pupils in a secondary school. Like expressive writing, this therapy encourages the expression of thoughts and feelings. It also provides a safe place for individuals to re-enact previous experiences, e.g., receiving a low maths grade. Whilst Dorothea provides some promising findings, limited conclusions can be drawn given the small sample size (five) and reliance on descriptive analyses.

Future Directions

The role of parents has become increasingly acknowledged as an important factor associated with children's MA. Maloney et al. (2015) explored the effects of parents' MA on their children's maths achievement and anxiety over the course of a school year. Findings showed that children's achievement and anxiety were higher at the end of the school year if their parents were highly maths anxious. However, this was only the case when those parents reported frequently helping their children with homework. Maloney and colleagues suggest this provides evidence of an intergenerational effect. Importantly, parents' MA did not predict children's reading achievement, suggesting that children's maths achievement is specifically affected by parental MA. Relatedly, Berkowitz et al. (2015) considered the role that home life has on maths achievement. They suggest that many parents consider maths education to be the responsibility of schools, overlooking the importance of the home learning environment on children's success in maths. They also consider that in cases when parents experience high MA, they will typically avoid talking about maths with their child. Yet, in cases when they do, the quality of their input is low, which may support the findings of Maloney and colleagues (2015). Berkowitz et al. (2015) conducted research with 587 first-grade children (UK aged 6-7 years) and focused on testing an educational intervention to promote interactions between children and parents relating to maths. The intervention took the form of an iPad application that included maths passages, with associated questions and covered topics including counting fluency, geometry and arithmetic, which children and parents could complete together. A control group was also incorporated, and children and parents completed tasks that related to reading comprehension, vocabulary, phonics and spellings. The results showed that the more frequently parents and their children used the app each week, the higher children's maths achievement was at the end of the school year. This was a finding that was only evident for the maths group and demonstrated that maths achievement in school is related to the home learning environment. Moreover, children of high anxious parents who used the application more frequently had higher maths achievement at the end of the year than children of high anxious parents who did not use the application frequently. Whilst these findings may appear at odds with those of Maloney et al. (2015) they could point towards the quality of parent-child interactions, particularly in relation to supporting parents with current maths learning practices. As such, future work should focus on strategies that support parents' understanding of modern approaches in maths education and scaffold the maths support they provide to their children.

There is also evidence that parents' maths attitudes influence the development of children's maths attitudes (Dowker et al., 2012; Vukovic et al., 2013). Through focus groups with young children (aged 4-7 years) in the UK, Petronzi and colleagues (2017) found that positive attitudes were associated with children being assured that their parents would assist them with their maths work. Mazzocco et al. (2012) stated that it is crucial for parents to promote the value of maths, although this assumes that parents are able to extinguish negative attitudes that they may have. Indeed, Fraser and Honeyford (2013) considered that some parents may not value achievement in maths, and children are susceptible to learning and adopting this same belief through transference of attitudes (Rossnan, 2006; Gunderson et al., 2012) particularly if they are expressive of their personal difficulties with maths to their children (Erden & Akgül, 2010). Exposure to such attitudes may affect the extent to which children engage with maths. The work of Else-Quest and colleagues (2008) provides some insight. In assessing behavioural expression of emotions among 165 mother-child dyads, the researchers observed significant positive correlations in the emotions expressed between mothers and their children during mathematical problem solving at home. Emotions included positive ones, such as joy, pride and humour, whereas negative emotions included frustration, sadness and contempt. The authors discuss these findings in relation to emotional contagion: the way in which one person may mimic another's emotional expressions automatically and without conscious thought (Hatfield et al., 1993). As Else-Quest et al. (2008) point out, such correlations in expressed emotion may highlight the way in which parents can shape their child's emotions during homework interactions. It may also emphasise the need for parents to carefully monitor and regulate their own emotions; detailed analysis showed that mothers were more likely to display contempt during maths-learning interactions following their child's earlier poor performance. Future interventions should target parents' understanding of their own attitudes and behaviours and enable them to manage their interactions with their children effectively.

Pessimism and negative attitudes in maths are associated with low self-efficacy (Zimmerman, 2000) and motivational and cognitive deficits (Kolacinski , 2003). Ramirez and colleagues (2018) discuss MA in relation to negative appraisals of previous maths experiences. A key tenet of this proposition is that "dysfunctional self-schemas" can develop, which negatively affect a person's appraisal of their own ability to do well in maths (Ahmed et al., 2012). That is, MA is related to a greater propensity to view one's past maths performance as worse than it really was. According to Ramirez and colleagues (2018), this may explain why maths self-concept is such a strong predictor of maths performance. Further to this, the authors refer to finding that motivation moderates the relationship between MA and performance (Wang et al., 2015). These findings have suggested that people with low intrinsic motivation may be less likely to use positive appraisal processes. Instead, they may focus on negative thoughts and worries, thus disrupting working memory. Recent support for this argument is provided by O'Leary and colleagues (2017). They found significantly higher MA among participants who reported specific negative past experiences involving others (e.g., a teacher), including people who participants perceived as having increased their MA or lowered their confidence. Appraisals of previous experiences could involve a disproportionate and unhelpful focus on negative events. It is also feasible that neutral maths experiences are appraised negatively, but further work is needed to assess this. Nevertheless, such findings provide a new direction for strategies designed to alleviate MA. In particular, work on instructional framing has shown that framing instructions in a positive way can facilitate a challenge appraisal of an upcoming maths task (Feinberg & Aiello, 2010). Future research should consider whether changes to instructional framing also reduce MA. It would also be worthwhile assessing the efficacy of strategies that address maladaptive appraisals of previous maths experiences.

According to Mazzocco (2007) teachers do children a disservice when demonstrating a dislike of maths due to the influence of their attitudes on children's maths performance. Rahim and Koeslag (2005) proposed anxiety reduction in junior and intermediate pre-service teachers as an early intervention. They suggest that teachers should study their feelings of discomfort with numeracy and maths as a logical step. By alleviating maths worries in teachers, they should be more suitably prepared for students they encounter with similar feelings, and not convey negativity to the children, or intensify any underlying numeracy worries. Hamlett (2008) designed and implemented a ultiliteracy unit to provide pre-service teachers with the opportunity to tackle their specific mathematical difficulties and anxiety, through a variety of methods, including group work; self-paced work, use of websites, pen and paperwork, practical tasks, and access to a skilled tutor. The unit aimed to encourage and build mathematical confidence and familiarise the students with concepts and strategies that they may have forgotten. Moreover, Hamlett (2008) discussed motivation, task completion, and seeking help as behaviours that lead to success, which the unit further attempted to promote. Results indicated that confidence ratings had improved, but pre-service students maintained low confidence about teaching a skill as opposed to performing the task themselves. This was despite a decrease in anxiety and stress as competence increased.

We also recommend consideration of cognitive growth theories and strategies in terms of MA and understanding why some children may encounter more difficulties than others. Mindset Theory differentiates between a fixed mind set and growth mind set (Dweck, 2006). A fixed mind set relates to children viewing their intelligence as stationary and effort as ineffective. Linking with an Entity Theory (Dweck et al., 1993), a person may feel that circumstances are outside their control in terms of having no power or ability to change the situation, which may lead to disengagement, frustration, and avoidance. In contrast, a growth mind set treats intelligence as fluid and changeable, and students gain satisfaction from the process of learning. For these, effort is valuable, and setbacks are met with feedback with which to build knowledge. This relates to an incremental view that considers students as aiming to master challenges and implement functional strategies when faced with difficulties. Samuel and Warner (2021) combined mindfulness and growth mindset intervention to reduce MA in college students enrolled on a statistics course. The intervention included: (1) explaining the principles of growth mindset theories, (2) a 1-minute deep breathing exercise before each statistics class (and being asked to think only about the present moment), (3) reciting five positive affirmations about maths (e.g. 'I am capable of understanding math'), (4) students being asked to be actively engaged in sessions, to use breathing techniques when feeling anxious, to reinforce effort and to offer verbal praise, (5) fixed mindset statements were reframed to represent growth mindset. Statistical data showed promising results for the strategy group, in that MA scores decreased at post intervention when compared to pre-intervention scores. In addition, qualitative findings indicated that the strategies supported students in calming down and thinking more clearly, providing support for the debilitating anxiety model. Furthermore, positive affirmations seemed to create a sense of belief in ability, as well as having control of emotions, particularly stress and feeling overwhelmed. Further research is required to extend this work with a particular focus on positive affirmation and self-regulation of anxiety. Such work aligns with findings that interventions based on cognitive restructuring are particularly effective at reducing MA (Hembree, 1990), as well as recent developments regarding mathematical resilience (Johnston-Wilder & Lee, 2010; Johnston-Wilder et al., 2016).

Metacognition is a key strategy in current education, which builds on the idea of incremental learning and counters the idea of fixed intelligence. Metacognition centres on how learners monitor and purposefully direct their learning; it relates to understanding and adapting cognitive strategies, e.g., memorization strategies or subject specific strategies to control cognition. Essentially, students are taught to plan, monitor and evaluative their learning, and is based on principles including modelling and promoting metacognitive discussions in the classroom Education Endowment Foundation, 2018). Morsanyi and et al. (2019) consider metacognition in the context of MA, whereby MA inhibits the efficiency of monitoring and control. Specifically, high maths anxious students may be less flexible in applying alternative strategies; they may set lower attainment goals, have lower confidence throughout the problem-solving process, and may discontinue the task (Jiang et al., 2021) However, Morsanyi and colleagues (2019) consider that high MA may increase cognitive effort to mitigate the adverse impact of anxiety and may therefore result in greater monitoring and control process e.g., more time devoted to a task and double-checking responses. Given the movement towards metacognitive strategies, this warrants further research and strategy implementation in the context of MA. This aligns with considerations that the focus should not be solely on reducing MA; there should be a focus on minimising the risk of developing MA through targeted exercises (to improve basic skills) and to support understanding and regulation of anxiety (Maloney & Beilock, 2012) to prevent a ‘snowball' effect (Ramirez et al., 2013).

Targeted strategies have applied principles of reflection, for example, bibliotherapy (Wilson, 2009). Previously used to support pre-service teachers with MA, bibliotherapy follows a 4-step process in which the reader: (1) identifies with a protagonist, (2) becomes emotionally involved and releases emotions, (3) becomes aware that their problem can be resolved, and (4) becomes aware that their issue is not unique to them. Wilson (2009) reported that the process elicited strong emotional responses in participants, which supported a perceived change in feelings towards the specific threat. In an ongoing study, Petronzi and colleagues (2021) designed a targeted storybook approach for addressing MA that can directly address issues of optimism and pessimism (Yates, 2002). As a strategy, the storybook approach can discuss feelings and issues about maths (as well as solutions) in a format that facilitates reflection for younger children who are perhaps unable to effectively apply this skill independently, or who may already be experiencing debilitating anxiety. This may specifically relate to self-regulation and metacognition.

As shown in Table 1, existing intervention studies have relied on a range of self-report MA scales to measure MA. In order not to compromise validity, it is important that such self-report measures are selected based on the specific population under study. However, it is also worth noting differences in the underlying factor structure of the various self-report scales, which emphasises the multidimensional nature of MA. This is important in the context of interventions and the way their efficacy is evaluated. For instance, Jamieson et al. (2016) observed an effect of reappraisal on the maths evaluation subscale of the Abbreviated Mathematics Anxiety Scale (Hopko et al., 2003; Caviola et al., 2017) but no effect on the maths learning subscale. Many of the existing intervention studies have failed to consider the factors that comprise the scales used, which potentially limits understanding of the impact. Thus, future intervention studies need to consider assessment using sub-scales relevant to the nature of the intervention, i.e., those that are learning based and those that are evaluation based.

A further consideration is whether intervention studies are assessing the impact on short-lived reductions in anxiety or whether such reductions are maintained. State anxiety relates to the potential range of situations-or threats-that may cause temporary anxiety, leading to the experience of unpleasant emotional arousal and physiological responses that impact efficiency and performance. For those with high MA, this may be a maths lesson, examination or an everyday situation that requires the manipulation of numbers, particularly in situations perceived as high pressure. In contrast, trait anxiety refers to the general tendency to respond with anxiety to perceived threats, and, crucially, is a stable characteristic of the individual. Correspondingly, those with higher trait anxiety experience state anxiety more frequently and in higher magnitude (Spielberger, 1985). Trait anxiety is particularly triggered by perceived threats to performance (anticipated failure) (Horikawa & Yagi, 2012). In the context of MA, a reliance on trait-based MA scales to measure the impact of interventions may fail to capture the full extent of changes in state anxiety. Furthermore, the absence of follow-up testing in many studies creates uncertainty over the longevity of any positive effects that have been observed. Moreover, existing studies have tended to either measure MA explicitly using self-report measures or assume changes in behavioural outcomes (such as maths performance) are indirectly accounted for by changes in MA.

However, findings have demonstrated that maths achievement is better predicted by implicit and explicit MA combined (Westfall et al., 2020). Therefore, it may be necessary for future intervention work to include both implicit and explicit measures of MA in order to fully understand attempts to address MA. With regards to limited follow-up of the long-term effects of MA interventions, future work in this area could also examine the cumulative effects of MA, which are relatively unknown and could relate to the Allostatic Load Framework (McEwan, 1998). This theory considers the impact of stress/anxiety from a psychological/physiological perspective and the bodily reactions and psychosomatic outcomes (headaches, fatigue, sleep interruptions) that are amplified during periods of prolonged stress/anxiety, e.g., when somebody consistently experiences MA in a range of maths related situations.

Since Hembree's (1990) meta-analysis, several interventions have taken a whole-class approach, whether that is a new teaching/learning approach, or a psychological approach. In most cases this appears to have resulted in decreases in maths anxiety and, in many cases, improvements in maths performance. This marks a change from the conclusions drawn from Hembree's meta-analytic findings and suggests a whole-class approach can work, provided the intervention itself is suitable. There were a number of additional strengths and weaknesses of the reviewed studies. Most included the use of control groups and, in many cases, randomisation, which together allow causality to be determined. However, there was limited evidence of blinding of assessors. Moreover, most studies involved small samples and are likely to be underpowered to detect moderate effects. Some also reported participant withdrawal/attrition e.g., missing multiple intervention-based sessions, without providing details of the individual characteristics of those participants; intention to treat analyses were not reported (Fergusson et al., 2002).

Conclusion and Recommendations

The existence of MA across a range of countries, and therefore, educational systems, is evidenced through the studies considered in this review. Despite the suggestion that people experience intrinsically positive attitudes towards maths (Nicolaidou & Philippou, 2003), research has indicated that MA can develop in children as young as four years of age (Petronzi et al., 2017) with attitudes formed because of classroom-based negativity (Fraser et al., 2013). Therefore, it is important that suitable strategies are implemented in early schooling to minimise the development or exacerbation of MA. Changes in pedagogical practices may be beneficial in enhancing maths self-efficacy and helpful learning behaviours, sometimes effectively addressing MA. Those strategies that appear to be most effective in addressing MA are those that facilitate cognitive control, with an emphasis on attentional processes and emotion regulation. Thus, in the main, these studies provide support for the debilitating anxiety model. Whilst neurophysiological studies offer insight into our understanding of MA, we recommend a move away from potential strategies that are resource intensive. We propose the need for targeted strategies that are time and cost effective, especially those that lend themselves to a range of educational contexts, such as the home and virtual learning environment. Since MA is associated with avoidance (Chinn, 2012; Choe et al., 2019), as a starting point it is important that academic settings are inviting and encourage greater participation among maths learners (Hlalele, 2012). Pedagogical strategies that include a degree of co-construction may also encourage engagement and enjoyment, highlighting the relevance of maths. It is likely that a reciprocal relationship exists between MA and maths performance (Carey et al., 2016). As such, the designs of extant interventions make it difficult to determine the precise theoretical mechanisms that underpin the observed effects. Future work would benefit from testing a wider range of hypotheses pertaining to plausible targets associated with MA, including maths self-efficacy, social support, growth mindset and resilience.

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