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Math anxiety and math achievement: The effects of emotional and math strategy training

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Abstract

Math anxiety (MA) is a specific feeling of tension generated by the manipulation of numerical stimuli in daily life and academic situations (Richardson & Suinn, 1972). This condition has significant repercussions on the individual's life at personal, social, and economic level. Literature on the topic of MA alleviation, however, is still scarce. This study aims at contributing to this field by addressing MA prevention in school-age children. We have developed two different training methods administered to two groups of fourth graders: (a) MA training focusing on identifying and copying with MA-related feelings ($N = 76$); and (b) Math strategy training focusing on supplementary exercises to enhance calculation strategies ($N = 76$). We also carried out a Control training involving a range of activities, such as reading comic strips, describing characters in the story, and combining text and images to obtain an original narrative text ($N = 72$). We evaluated the differential effects of these training methods on MA, general anxiety, and math achievement before and after the training. Results indicate that MA training contributes to a decrease in MA level, although it does not appear to affect math achievement; Math strategy training, on the other hand, results in far transfer on a reduction of MA level as well as near transfer on the improvement of math achievement. Data are discussed in terms of specific mechanisms underlying each type of training method, and with specific focus on the evaluation of educational and developmental opportunities linked to MA prevention and improvement of math abilities in school-age children.

KEYWORDS

fourth-grade children, math abilities, math anxiety, math strategies and emotional factors, primary school, training

1 | INTRODUCTION

Given math's relevance at individual, educational, and social developmental level, improving math abilities, while also reducing cognitive and emotional risk factors of math difficulties, is of great importance in today's numerate society. Previous research has focused on cognitive factors that either support or impair math learning in individuals with math difficulties (Fuchs, Geary, et al., 2010; Passolunghi & Lanfranchi, 2012; Peng, Namkung, Barnes, & Sun,

2016; St Clair-Thompson & Gathercole, 2006). Studies seem to indicate that, among emotional factors, math anxiety (MA) is consistently related to poor math abilities (Namkung, Peng, & Lin, 2019).

Anxiety is defined as "an emotion characterized by feelings of tension, worried thoughts, and physical changes like increased blood pressure" (American Psychiatric Association, 2013). However, MA is a specific form of anxiety that may be generated by specific stimuli, such as exposition to numerical stimuli or calculations. This condition is "a feeling of tension and anxiety that interferes with

manipulation of numbers and the solving of mathematical problems in ordinary life and academic situations” (Richardson & Suinn, 1972). MA has specific repercussions on personal and social aspects of life, which may result in avoidance of math-related careers (Ashcraft & Ridley, 2005; Hembree, 1990; Maloney & Beilock, 2012), increased risk of mortgage default (Gerardi, Goette, & Meier, 2013), lower socioeconomic status (SES; Ritchie & Bates, 2013), and increased health costs (Reyna, Nelson, Han, & Dieckmann, 2009). As such, this condition affects not only individuals, but society as whole, as it generates higher public costs and decreases economic competitiveness (Dougherty, 2003; Reyna & Brainerd, 2007).

Various studies offer estimates of the prevalence of MA in terms of epidemiology percentage: when considering society as a whole, results range from 17% (Ashcraft & Moore, 2009) to 30% (Johnston-Wilder et al., 2014); in university students the prevalence is about 11% (Richardson & Suinn 1972); whereas incidence of extreme MA at secondary school level in the UK ranges between 2% and 6% (Chinn, 2009). There is no doubt, even when acknowledging the lowest estimate, that it is a very significant problem at individual and collective level.

Four meta-analysis studies examined the relation between MA and mathematics ability. The meta-analyses of Hembree (1990) and Ma (1999) included several studies with secondary students, but very few studies have involved primary school children so far. This initial lack of research involving young students could have resulted in the idea that MA typically develops only after years of persistent negative math experiences at school. However, recent studies point to the early onset of MA (Cargnelutti, Tomasetto, & Passolunghi, 2017; Ramirez, Gunderson, Levine, & Beilock, 2013; Vukovic, Kieffer, Bailey, & Harari, 2013; Wu, Amin, Barth, Malcarne, & Menon, 2012; Wu, Willcutt, Escovar, & Menon, 2014). The most recent meta-analytic investigations by Namkung et al. (2019) and Zhang, Zhao, and Kong (2019), which include a larger number of studies with primary school children, seem indeed to confirm a significant negative correlation between MA and mathematics performance ($r = -.34$ and $r = -.32$, respectively), in line with the two previous meta-analytic studies. Cognitive and emotional problems underlying math difficulties, however, could be largely dissociable. Devine, Hill, Carey, and Szűcs (2018) investigate the comorbidity of mathematical learning disability and MA in a large sample of primary school and secondary school children. They found that, while on the one hand children with mathematical learning disability display higher levels of MA than children with typical mathematics performance (see also Lai, Zhu, Chen, & Li, 2015; Passolunghi, 2011; Wu et al., 2014), on the other hand, the majority of children with high MA (about 77%) show average or even high mathematics performance. These findings suggest that high MA is not exclusive to children with math difficulties. In other words, children who are performing adequately in math may have math-related anxiety that could influence their mathematical well-being and may develop avoiding behaviors in the future.

Despite the increasing number of studies that demonstrate the effects of MA on math achievements and its well-acknowledged mediating role in math performance (see Mammarella, Caviola, &

Research Highlights

- One of the first attempts at developing and evaluating math strategies and emotional training methods aimed at reducing math anxiety and improving achievements in schoolchildren
- Evaluation of near and far transfer effects of an emotional training on math anxiety compared to a math strategy training on math abilities in schoolchildren

Dowker, 2019), research on training interventions on MA, especially with young children, is surprisingly lacking. In the following section we provide an overview of the existing literature devoted to this field, focusing on studies evaluating MA repercussions on math learning and putting forward MA coping strategies.

2 | STATE OF THE ART OF MATH ANXIETY TRAINING FOCUSED ON MATH ABILITY

Our overview of the relevant literature distinguishes between three main categories of MA treatments: (a) treatments specifically addressing cognitive strategies to cope with MA (e.g., changing mindset, using relaxation and/or systematic desensitization); (b) neuropsychological stimulation methods; (c) math exercises and enhancement of math strategies with a far transfer on MA to reduce MA itself. We describe the training methods in each category from an age-related perspective, that is, from older to younger students.

2.1 | Treatments specifically addressing cognitive strategies to cope with MA

In the first category we include the pioneering study of Suinn and Richardson (1971) testing the beneficial effects of relaxation and systematic desensitization in alleviating anxiety and improving results in math-related tasks in university students. Three groups were compared: the first group received a training to reduce anxiety reactions using relaxation and positive feeling; the second group received a training using the traditional desensitization paradigm; the third and largest group of non-anxious controls received no treatment. Results showed a significant decrease in MA level for both treatment groups with respect to the control group. However, when the pre- and post-test scores in math ability were examined, only the standard desensitization group showed a significant increase in their math performance. More recently, Zettle (2003) successfully used behavioral therapy and systematic desensitization to reduce MA in university students, although no improvement was observed with respect to their mathematical skills. Zettle's study, however, focused on a very small group of participants and did not include any control group.

The first category also takes into account treatments that allow for re-examination and assessment of the nature and consequences of anxiety (e.g., raising participants' awareness on the potential positive effect of anxiety-related mental arousal on their performance). Jamieson, Mendes, Blackstock, and Schmader (2010) found that informing undergraduate students that physiological arousal could improve their performance resulted in an actual improvement of their math-related achievements (see also Johns, Inzlicht, & Schmader, 2008). Their evidence was further corroborated by the fact that, within their overall examined population, only students that received the training improved their performance in a laboratory-simulated Graduate Record Examination on math (GRE-math), whereas no improvement was registered in the control group.

Reappraisal and control of tension and negative feelings may also be achieved through expressive writing. This technique is a simple exercise, whereby individuals write down their negative feelings and relate them to an important stressor they are facing. Park, Ramirez, and Beilock (2014) proved the positive correlation between expressive writing and improved performance in calculation tasks in university students with severe MA. The analyzed population included students with both severe and mild MA, who were randomly assigned to either the expressive writing group or the control group. Students in the expressive writing group were asked to write openly about their thoughts and feelings in relation to the upcoming math test. Students with severe MA showed a significant improvement in their math score already after their first session of expressive writing, effectively reducing the performance gap between them and the students with mild MA. A possible explanation is that writing reduces ruminating behavior, thereby liberating working memory resources, as they are no longer consumed by worries and negative thoughts. Ramirez and Beilock (2011) tested this assumption in ninth graders in both a laboratory setting and field experiments (i.e., before the first final exam of the children's high school career). Expressive writing proved beneficial in both settings, although only for students with severe MA. Such results are strongly dependent on single individuals' level of anxiety (which may be either mild or severe) in relation to tests and exams: individuals with severe test anxiety experience more tension and need to write down more negative thoughts with respect to their peers, which is why they benefit more from this exercise.

2.2 | Neuropsychological stimulation methods

The second potential form of treatment is noninvasive brain stimulation used by researchers to modulate neural activities (Lyons & Beilock, 2012; Sarkar, Dowker, & Cohen Kadosh, 2014; Young, Wu, & Menon, 2012). Transcranial electrical stimulation is used to modulate cortical activity in regions that may facilitate emotional control of negative feelings related to math tasks, in order to enhance math performance. Sarkar et al. (2014) tested this technique on adults with mild and severe MA, by administering stimulation to both left and right dorsolateral prefrontal cortices. The authors

found that this specific kind of brain stimulation resulted in shorter reaction times in arithmetic decision tasks in adults with severe MA. In adults with mild MA, however, the opposite pattern was observed, namely worse performance and longer reaction time after stimulation. Albeit promising, this technique still requires further testing, particularly in real-life educational contexts. Furthermore, mathematical tasks used in Sarkar et al.'s (2014) study were limited to verification tasks of simple arithmetic operations (e.g., " $6 \times 2 = 12$. True or false?"). A broader spectrum of math-related tasks, including more complex and challenging calculations, could further corroborate these results.

2.3 | Math exercises and enhancement of math strategies

The third type of training focuses on the training of math abilities with a beneficial transfer on MA. The only study investigating the effect of math training on MA and arithmetic skills in primary school children was carried out by Supekar, Iuculano, Chen, and Menon (2015). In this study, 7- to 9-year-old children received an intensive eight-week one-on-one math tutoring training consisting of three sessions per week, each with a duration of 40–50 min (Supekar et al., 2015). Training activities were based on the MathWise training method developed by Fuchs, Fuchs, Schumacher, and Seethaler (2013), which was specifically devised to improve number knowledge and increase speed in efficient counting and the application of calculation strategies. Functional magnetic resonance imaging (fMRI) was performed before and after the training, and children were also administered a MA Questionnaire using the Scale for Early Mathematics Anxiety (SEMA; Wu & Menon, 2012). During the fMRI sessions children performed simple addition tasks (e.g., $3 + 4 = 7$) and control tasks (e.g., $7 = 7$) to verify the validity of number identity expressions. Participants were labeled as either severely or mildly math-anxious using a median split of pre-test SEMA scores. Before the training, fMRI scan results revealed that severely math-anxious children had aberrant neural responses and connectivity in emotion-related circuits at amygdala level. After the training, however, no aberrant amygdala activity was detected in the follow-up fMRI results, which now matched fMRI scan results of mildly math-anxious children. Supekar et al.'s (2015) study also indicates that severely math-anxious children display a significant decrease in MA level after the training. Finally, and with regard to behavioral performance in arithmetic tasks, their training seemed to equally benefit both severely and mildly anxious children. These findings provide promising evidence of the positive correlation between math training, desensitization, and exposure to mathematical stimuli, on the one hand, and a decrease in MA level and math ability improvement, on the other (see also Abramowitz, Deacon, & Whiteside, 2011 for exposure therapy for anxiety). Admittedly, Supekar et al.'s study (2015) has various limitations: first of all, their sample size of 28 children was too small to be considered representative, and lacked comparison with a control group (either passive or active). Moreover, severe MA and mild

MA were identified using a median split of MA scores, which may have resulted in the inclusion of participants with nearly average MA scores in the severe MA group. A generalization of these results to clinically severe MA is therefore of questionable validity. Finally, the post-training evaluation of math ability was based on mere verification addition tasks (e.g., $2 + 4 = 6$) and not on a more comprehensive math assessment.

In a recent study on this issue, Berkowitz et al. (2015) were able to show a positive effect of structured parent-child home math activities on math performance in first graders, especially when their parents suffer from severe MA. Children and parents received an iPad with an app, called Bedtime Learning Together, which offers math tasks requiring structured parent-child interaction. Such tasks typically focus on counting fluency, simple geometry, arithmetic, and probability calculation. Children's improvement in math performance by the end of the year was directly proportional to the frequency of structured interactions on the app they had carried out with their parents throughout the year. The control group was offered a reading app, which, however, did not yield significant results. Interestingly, the math app also seemed to alleviate the negative relation between parents' MA and children's math achievement. When parents with severe MA used the math app at least once per week, their children's math achievements by the end of the school year did not significantly differ from those of children whose parents had mild MA and used the same app.

3 | THE PRESENT STUDY

In our overview, we argue that previous studies do demonstrate the detrimental effects of MA on math abilities, but at the same time provide only limited insight on MA training methods, often with contradictory results. Furthermore, even when such results on mathematical abilities are positive, they are tested only through the observation of simple calculation skills (see Park et al., 2014; Sarkar et al., 2014). We also point out that the majority of these studies focus on university students or adults, and only rarely on primary school children, despite well-documented evidence of MA's tendency to early onset and its multi-componential developmental roots (Rubinsten, Marciano, Levy, & Cohen, 2018). Targeted training aimed at reducing MA impact on achievement while also improving mathematical performance is crucial in ensuring early prevention of mathematical difficulties, improving education and employment opportunities, and promoting personal and economic wellbeing. Such training should be administered to a sample of representative size, since, as mentioned in the previous section, so far the only study (Supekar et al., 2015) on the effect of MA on math ability in school-age children does not provide sufficient evidence for the generalization of its results. Finally, to the best of our knowledge, so far, no study has compared the effects of MA training based on cognitive strategies with those of training focused on improving mathematical skills to assess their specific impact on MA and math performance, respectively.

4 | RESEARCH QUESTIONS AND HYPOTHESIS

With the aim of contributing to fill these gaps in the literature, our study was designed to address the following issues:

1. Verifying and comparing the effects of different types of training on MA in primary school children. Of our three training methods, the first one is based on strategies to reduce MA (MA training); the second one focuses on the improvement of math abilities and strategies (Math strategy training); and the third one is based on reading and illustrating comic strips (Control training). All training methods were evaluated within a carefully controlled setting;
2. Verifying the effects of the different training methods on math abilities using a standardized math achievement test that assesses a comprehensive set of math abilities and is not limited to mere arithmetic verification.

With these goals in mind, we formulated the following research questions:

1. What are the specific beneficial effects of these three types of training on math abilities and MA?
2. Do Math strategy training and MA training have different near and far transfer effects?

We expected the three different training methods to have different effects. Math strategy training was expected to influence and improve math ability (near transfer), as well as reduce MA (far transfer) (e.g., Supekar et al., 2015, desensitization hypothesis). Recent research shows the beneficial effect of strategies training to enhance mental addition skills with 3rd- and 5th-grade schoolchildren, with an improvement in math competence, especially within the younger group (Caviola, Gerotto, & Mammarella, 2016). Similarly, Koponen et al. (2018) report on the beneficial effects of a strategic calculation training on math abilities in primary school children with poor calculation ability.

We expected the potential outcome of MA training to be two-fold: either near transfer on MA, or both near transfer on MA and far transfer on math performance, since the decrease in MA level may result in the enhancement of math abilities (for a review see Fuchs, Powell, et al., 2010).

5 | METHOD

5.1 | Participants

A total of 224 fourth graders ($M_{\text{age}} = 9.6$ years, $SD = 0.27$, 116 females, age range: 9.1–9.9 years) participated in the research. At the beginning of the study, 11 children were excluded because of their Specific Learning Disability diagnosis and one child was excluded

because of a general developmental delay. Throughout the study, eight children were absent at more than two sessions of the training and were subsequently excluded. Participating children were all Caucasian and with middle-class SES, according to their school records. All children, Italian native speakers, were attending five different schools located in the northern part of Italy. All parents signed an informed consent authorizing their children's participation in the study. Participants were randomly assigned to one of our three training methods, resulting in the following breakdown: 76 children were administered the MA training; 76 children were administered the Math strategy training; 72 children were assigned to an active control group.

5.2 | Training methods

The three training methods (see Figure 1) were designed to guide children from general issues (discovery and comprehension of the topics) to strategy application. Activities are presented first through a discovery methodology, and then with a more structured instructional guidance. Furthermore, we explored the possibility of organizing each training phase into two sessions, first to propose (meeting 1) and then to consolidate (meeting 2) the contents discussed. In fact, emotion description and emotion regulation are not topics usually proposed during school activities classes. Training sessions took place once per week for a total of eight 60-min sessions throughout the second part of the school year, namely from March to April. Pre-test evaluation was carried out between January and February, whereas post-test evaluation took place between May and June of the same year. The time lapse between the two evaluations was nearly 15 weeks.

5.2.1 | MA training

Sessions 1 and 2: knowledge and recognition of emotions. Type of activity: playful activities to exercise the recognition and evaluation

of different basic emotions and their valence in everyday life and in school life (task examples: draw your today inner weather forecast; think about how you feel today, what is causing positive or negative feelings), as well as high arousal emotions (task examples: when you feel angry, do you observe changes in your body? If so, where? What happens when you get too angry?; Stories of overwhelming emotions are read and discussed).

Sessions 3 and 4: Type of activity: playful activities on the importance of math in everyday life (task example: the story of the world without numbers) and effects of this school subject on emotions (task examples: read the short story “Math has trapped me” and discuss the character's feeling; explain why you like or dislike math).

Sessions 5, 6 and 7: Strategy-based techniques to enhance the use of strategies to decrease MA level: a) breathing exercises, b) safe place visualization, c) how to turn a negative thought into a positive one, based on cognitive behavioral therapy for children (Di Pietro, 2014; Ellis & Bernard, 2006). Participants engaged in various games and playful activities to practice these techniques.

Session 8: Synthesis of the previous meetings, identification of best strategies to reduce MA, and conclusive remarks.

5.2.2 | Math strategy training

Sessions 1 and 2: knowledge and recognition of math strategies. Type of activity: playful activities to exercise calculation skills both in spoken and written form, more specifically addition (task examples: tombola of addition, goose game of addition), and subtraction (task examples: goose game of subtraction; tombola of subtraction).

Sessions 3 and 4: Type of activity: playful activities to exercise calculation skills both in spoken and written form, more specifically multiplication (task examples: crossword puzzle of multiplication; I am “the calculator”), and division (task examples: crossword puzzle of division; I am “the calculator”).

Sessions 5, 6 and 7: Strategy-based techniques to enhance math accuracy and speed: (a) number decomposition, (b) use of rhymes and

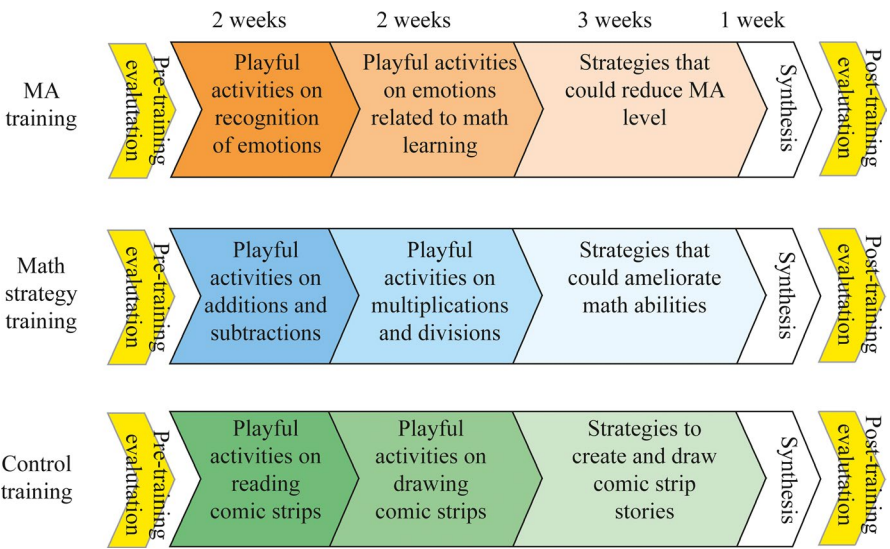


FIGURE 1 Study design: representation of the types of training methods

stories to reinforce memory for arithmetic facts, (c) retrieval of arithmetic facts in learning process. Participants engaged in activities to practice these strategies (Caviola et al., 2016; Koponen et al., 2018).

Session 8: Synthesis of the previous meetings, identification of best strategies to increase math abilities, and conclusive remarks.

5.2.3 | Control training

Sessions 1 and 2: knowledge and recognition of comic strips. Type of activity: playful activities to exercise basic knowledge of comic strips, with specific focus on their peculiar writing style, the way to read them, and how different characters are presented (task example: who am I? Guess which strip character I am thinking of; think of a joke and draw it as a comic strip).

Sessions 3 and 4: Type of activity: playful activities resulting in the ideation and realization of original characters for ideal comic strips, using different painting techniques (task example: draw your own character, give him/her a name and write your first balloon to introduce their story; interact with the classmates to create a story involving some of your characters).

Sessions 5, 6, and 7: Strategy-based techniques to improve the ability of integrating texts and pictures to create a comic strip: (a) text decomposition into sequences, (b) use of rhymes and jokes to create funny interactions between characters, (c) use of incongruity between what the characters say and their facial expressions to create an ironic effect. Participants engaged in various playful activities to practice these techniques.

Session 8: Synthesis of the previous meetings, identification of best strategies to create comic strips, and conclusive remarks.

5.3 | Tasks

5.3.1 | Verbal abilities

In order to evaluate their verbal IQ, children were administered the Primary Mental Abilities (PMA) Verbal Meaning subtest (Thurstone & Thurstone, 1981). The complete test consists of 60 items. Half of the items require children to identify the synonym of a target word. The other half requires children to indicate the picture that better corresponds to the target word. Raw scores were converted into standard ones (Mean 100 and *SD* 15). Test-retest reliability was 0.95.

5.3.2 | General anxiety

The Revised Children's Manifest Anxiety Scale—Second Edition (RCMAS-2; Reynolds, Richmond, Sella, Scozzari, & Di Pietro, 2012) is a self-report questionnaire used to identify the source and level of general anxiety in children and adolescents. In this specific study we used the RCMAS-2 in its short form, consisting of a selection of ten items.

Scores were calculated by assigning one point to every “yes” answer and zero points to every “no” answer. Test-retest reliability was 0.89.

5.3.3 | Math anxiety

The Abbreviated Math Anxiety Scale (AMAS; Caviola, Primi, Chiesi, & Mammarella, 2017; Hopko, Mahadevan, Bare, & Hunt, 2003) Questionnaire to evaluate MA in fourth graders was administered. This tool comprises nine items depicting situations involving number manipulations, and participants have to indicate how anxious they feel during each one of them, using a five-point Likert scale (e.g., 1 = a little anxious; 5 = extremely anxious). Test-retest reliability was 0.90.

5.3.4 | Math abilities

In the pre-test phase, math abilities were evaluated using the MAT-M3 test (from Amoretti, Bazzini, Pesci, & Reggiani, 2007). We used the scale called *Number*, which includes a wide range of tasks. More specifically, it consists of 13 exercises (e.g., ranking numbers from lowest to highest, decomposing numbers, solving arithmetic word problems), each accounting for one point when solved correctly. In the post-test phase, the MAT-M4 test (from Amoretti et al., 2007) was used. Again, we used the scale called *Number*, which includes a wide spectrum of tasks. It consists of 15 tasks (e.g., writing down numbers in the rank of thousands, solving word problems involving the concepts of expenses and profits), each accounting for one point when solved correctly. Since the two tests differ in the number of items, raw scores were converted into Z-scores. Test-retest reliability values of MAT-M3 and MAT-M4 were 0.80 and 0.74, respectively.

6 | RESULTS

Means and standard deviations of pre-test and post-test scores of the three groups are presented in Table 1. Preliminary analysis yielded no statistically significant results between the three groups in terms of chronological age, $F(2, 221) = 1.85, p = .16, \eta_p^2 = 0.016$, gender, $F(2, 221) = 0.23, p = .80, \eta_p^2 = 0.002$, and amount of intervention sessions received, $F(2, 221) = 0.22, p = .81, \eta_p^2 = 0.002$. Therefore, these parameters were no longer included as covariates in the analysis.

6.1 | Pre-training evaluation

Differences at pre-test between the three groups were investigated through a multivariate analysis of variance (MANOVA) with the Group (either MA training, Math strategy training, or Control training) used as the fixed factor, and the measures of verbal IQ, MA, General Anxiety, and math abilities as the dependent variables. MANOVA

TABLE 1 Mean Pre- and Post-test scores in the different measures and Univariate Test results (from MANCOVA) for gain differences between the conditions

	MA training group				Math Strategy training group				Control training group			
	Pre-training		Post-training		Pre-training		Post-training		Pre-training		Post-training	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Verbal IQ (PMA)	74.11	8.07	–		73.42	11.01	–		76.58	5.84	–	
Math Anxiety (AMAS)	21.55	8.19	18.74	7.58	20.03	8.01	17.22	7.23	19.97	5.99	19.19	6.29
General Anxiety (RCMAS-2)	3.93	2.47	3.55	2.81	3.74	3.06	3.11	2.60	3.31	2.90	3.08	2.92
Math abilities (MAT-M3/ M4)	7.24 (–0.09)	1.99 (0.94)	8.13 (–0.34)	2.90 (0.98)	7.55 (0.06)	1.94 (0.92)	10.49 (0.46)	2.92 (0.99)	7.47 (0.02)	2.41 (1.14)	8.74 (–0.13)	2.55 (0.86)

Note: Since MAT–M3 and MAT–M4 consist of a different number of items, Z-scores in round brackets are reported. Z-scores were also used to carry out the MANCOVA.

 $p < .001$

results did not indicate any significant main effect for group factor (Wilks' Lambda = 0.96, $F(8, 436) = 1.17, p = .32, \eta_p^2 = 0.02$), since the three groups did not significantly differ from each other. More specifically, univariate test results established no significant difference at pre-test between the three groups in any measure: verbal IQ, $F(2, 221) = 2.74, p = .07, \eta_p^2 = 0.02$, MA, $F(2, 221) = 1.08, p = .34, \eta_p^2 = 0.01$, General Anxiety, $F(2, 221) = 0.96, p = .39, \eta_p^2 = 0.01$, math abilities, $F(2, 221) = 0.46, p = .64, \eta_p^2 = 0.004$.

6.2 | Post-training evaluation

After conducting a preliminary comparison between the three experimental conditions, performance gains between pre- and post-test sessions of all measures were examined. More specifically, we conducted a multivariate analysis of covariance (MANCOVA), with the Group (either MA training, Math strategy training, or Control training) used as the fixed factor, pre-test scores as the covariates, and gain scores (post-test scores minus pre-test scores) as the dependent variables. Bonferroni-adjusted post hoc pair-wise comparisons of gain scores were also carried out. For the comparison of gain difference between groups, η_p^2 was used as a measure of effect size. Cohen's (1988) criteria were used to classify effect sizes: small effect: $\eta_p^2 = 0.01$; medium effect: $\eta_p^2 = 0.06$; and large effect: $\eta_p^2 = 0.14$. Effect sizes (Cohen's d) for post hoc pair-wise comparisons were also reported: small effect $d = 0.20$; medium effect $d = 0.50$; large effect $d = 0.80$.

MANCOVA results revealed a significant main effect of group factor (Wilks' Lambda = 0.78, $F(6, 432) = 9.47, p = .000, \eta_p^2 = 0.12$), since the three groups (MA training, Math strategy training, and Control training) significantly differ from each other. More specifically, univariate test results showed a significant difference between groups in the AMAS, $F(2, 218) = 12.45, p = .000, \eta_p^2 = 0.10$, reflecting the differential effects of treatments. Bonferroni-adjusted post hoc pair-wise comparisons indicated that both training groups – MA training ($M_{diff} = -1.87, p = .000, d = 0.75$) and Math strategy training ($M_{diff} = -2.04, p = .000, d = 0.69$)—displayed a greater decrease in MA compared to the control group. Gain difference between the two training groups did not reach statistical significance ($M_{diff} = -0.18, p = 1, d = 0.004$). Furthermore, the univariate analysis conducted on RCMAS-2 did not show any significant difference between the three groups in the reduction of General Anxiety, $F(2, 218) = 0.40, p = .67, \eta_p^2 = 0.004$, indicating no differential effects of treatment.

The univariate analysis carried out on math abilities, evaluated through math achievement tests, also showed a significant difference between groups, $F(2, 218) = 16.91, p = .000, \eta_p^2 = 0.13$, reflecting the differential effects of trainings. Bonferroni-adjusted post hoc pair-wise comparisons showed that children in the Math strategy training group displayed a significantly greater improvement in math abilities compared to both MA training group ($M_{diff} = 0.70, p = .000, d = 0.67$) and Control training group ($M_{diff} = 0.58, p = .000, d = 0.56$). No significant difference was found between the MA training group

and the Control training group in terms of improvement of math performance ($M_{diff} = -0.12, p = 1, d = 0.11$).

To sum up, results highlighted a significant decrease in MA in both MA training group and Math strategy training groups, but not in the Control training group. Furthermore, a significant improvement in math abilities was observed only in the group trained specifically on math. Finally, no significant reduction in general anxiety emerged in either one of the three groups.

7 | DISCUSSION

The construct of MA has been studied for more than 60 years (for a review see Dowker, Sarkar, & Looi, 2016), since Dreger and Aiken (1957) formulated their description of “number anxiety.” In the past decades research pinpointed the highly detrimental effect of this emotional aspect on people's education, personal, and social life (Dowker et al., 2016), with a consistently widespread prevalence of this phenomenon regardless of criteria used to define it (Chinn, 2009). Regrettably, only a few studies have investigated possible strategies designed to alleviate this condition. In fact, to the best of our knowledge, this is the first study offering a comparison between near and far transfer effects of different types of training (i.e., MA training, Math strategy training, and Control training in reading abilities) on MA and math abilities. More specifically, our research provides new insight in the field in various respects: (a) evaluating the effects of a tailored training method administered to an under-researched age group (Ashcraft, 2002; Hembree, 1990; Maloney & Beilock, 2012); (b) providing methodological improvements to previously used experimental designs (larger sample, use of an active control group, specific control on verbal IQ, assessment of both general anxiety and specific MA); and (c) extending evaluation to a more comprehensive set of math abilities, especially challenging calculation and arithmetical word problems.

Our MA training focuses mainly on recognizing and managing anxiety feelings. Our Math strategy training involves specific math exercises and discussion of strategies to learn and solve calculation tasks. Activities proposed to the active control group revolved around comic strips, their reading methods, illustration of characters, and possible ways to combine text and images into an original narrative text. Based on our hypotheses, we expected more significant improvements in the two training groups with respect to the active control group. However, different effects were expected as a result of the specific nature of the two types of trainings. In line with our hypothesis, results showed that Math strategy training influenced and improved not only math ability (near transfer), but also contributed to a decrease in MA level in the form of far transfer (Supekar et al., 2015, desensitization hypothesis). MA training showed only near-transfer effects in reducing MA level, but no far transfer as there was no improvement of math abilities. As expected, neither MA training nor Math strategy training resulted in far transfer on general anxiety, which was used as a control variable since (a) neither one of the trainings targeted this specific aspect, and (b) general

anxiety could be considered a more stable aspect of personality than MA. Future studies could investigate the effect of MA trainings using a full range of different forms of anxiety (as test anxiety).

Interestingly, reappraisal techniques promoted through MA training reduced MA even in younger children (thus confirming Hembree, 1990). The absence of far-transfer effect on math achievement could depend on a variety of factors. First, reappraisal is specifically linked to executive functioning (Johns et al., 2008), while children have notably limited cognitive and affective control abilities (Zelazo, Craik, & Booth, 2004), so this technique is more complex to train in primary school children than in older individuals. It would be useful to verify the effects of a longer training on math achievement, especially considering the importance of time in reappraising processes. Second, we believe that an online MA training (e.g., a training promoted during real math lessons and math testing) could facilitate children's acquisition of emotional techniques and their application to real-life situations. Finally, math evaluation proved to be quite challenging. Indeed, increased self-efficacy could be a determinant factor in enhancing one's math performance and reducing the level of anxiety during tasks. We believe that, in future studies, an evaluation of self-efficacy would prove useful in this type of investigation, considering its role in building self-esteem and contrasting MA in education settings. Moreover, the relation between math motivation and MA (see Wang et al., 2015) could also be included in future training studies. Finally, an assessment of participants' math motivation may provide useful insight, since math competence could change not only as a function of MA, but also as a function of motivation and individuals' approach to math tasks (Lyons & Beilock, 2012).

We found the results of Math strategy training particularly interesting, because of the far- and near-transfer effect that was obtained. Indeed, Math strategy training resulted not only in improved math abilities, but also in reduced MA. This training method focuses on both calculation and the use of strategies to solve simple math operations, which seems to influence different kinds of math abilities, such as numerical knowledge and word problem-solving abilities. In this sense, it is possible that, by helping to master math tasks promoting greater math self-efficacy, this training method has a direct effect on the decrease in MA level (for more on self-efficacy see Fast et al., 2010). Furthermore, Math strategy training means children's repeated exposure to the object of their fear, namely mathematical stimuli and education situations involving math, which could contribute to a systematic desensitization to numerical stimuli. Through repetition, children may develop a feeling of self-control in situations involving mathematical tasks, thereby reducing their MA. This view is supported by previous work showing that systematic desensitization is one of the most effective treatments for anxiety disorders (Van Etten & Taylor, 1998; Wolitzky-Taylor, Horowitz, Powers, & Telch, 2008). Finally, our outcomes provide corroboration to Supekar et al.'s (2015) results, as both studies aimed at decreasing the negative effect of MA through math training in school-age children (see also Abramowitz et al., 2011).

We are aware of our study's limitations, first of all in terms of duration and intensity of training, namely 60-min sessions administered weekly over a period of 8 weeks. Despite offering a sufficient

time frame to observe post-test improvements in MA and Math strategy training groups, such duration is too limited to provide solid evidence, particularly as regards the transfer effect of MA training. Furthermore, the absence of a follow-up session, together with the lack of math-related self-efficacy and self-esteem evaluations, limits any assessment on the duration and the magnitude of training effects.

We acknowledged that a matching procedure would have been useful to guarantee a stronger similarity between the three groups, especially in terms of IQ, considering its relevant role in academic achievements (Giofrè, Borella, & Mammarella, 2017). A further limitation is the fact that activities in our study engaged children only during classroom hours, without taking into account external factors, such as the influence of teachers or parents on MA and its onset and/or development, and therefore focusing exclusively on one component of the complex systemic model at the basis of MA risk factors (Rubinsten et al., 2018). Finally, the effects of the training are overall moderated in terms of the effect size, even if it is in line with other reports in the relevant literature (see, e.g., Supekar et al., 2015).

However, we believe that our study provides novel evidence on the use of specific and short-term math-tutoring programs, their effect on calculation abilities, and their positive correlation with general math ability improvements and a decrease in MA level in primary school children. Unfortunately, observed effects of MA training, albeit remarkable with regard to decreasing MA level, do not allow for a generalization of results in terms of improvement of math competence. This study may serve as a starting point for the design of targeted intervention programs to improve math abilities and reduce the derailing effects of MA as well as the incidence of risk of mathematical difficulties. In particular, our findings reinforce the conviction that training methods may have a beneficial effect on domain-specific math achievements (e.g., calculation). Such improvement may have positive effects on more general math abilities (e.g., word problem solving), which, in turn, could contribute to reducing MA. Progressive exposure to numerical stimuli using a game-like approach (e.g., based on daily math concepts that children have to deal with) could desensitize children to fears related to number manipulation, while also enhancing self-efficacy and control in MA. The resulting synergy is a virtuous cycle of competence gain and anxiety level reduction. A specific training focusing only on anxiety, regardless of its positive effects, did not prove sufficient to improve math abilities at a higher level. MA has significant repercussions on multiple levels of an individual's life, ranging from personal (Ashcraft & Ridley, 2005; Hembree, 1990; Maloney & Beilock, 2012) to social aspects (Reyna et al., 2009; Ritchie & Bates, 2013), which is why teachers, parents, researchers, and institutions in general may play a crucial role in promoting effective ways to ensure useful, long-term programs to enhance mathematical skills in future generations.

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CONFLICT OF INTEREST

We have no conflict of interest to disclose.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. Data are not publicly available due to privacy or ethical restrictions.

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