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Math self-efficacy or anxiety? The role of emotional and motivational contribution in math performance

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Abstract
Various studies have highlighted the important influence of math ability in a numerate society. In this study, we investigated the influence of emotional (math anxiety and math enjoyment) and cognitive-motivational (math self-efficacy) factors on math performance. Participants were 145 fifth-grade students (84 boys and 61 girls). The results showed that math performance was negatively correlated with math anxiety and positively correlated with math enjoyment and math self-efficacy. Moreover, math anxiety was negatively associated with enjoyment in math and math self-efficacy, whereas math enjoyment was positively correlated with math self-efficacy. Hierarchical regression analysis showed a significant influence of math anxiety and math self-efficacy on math performance in fifth-grade students. Results are discussed in terms of a new perspective in emotional and motivational factors to train in school contexts.

Keywords Anxiety · Enjoyment · Self-efficacy · Math performance · Primary school students

1 Introduction

In a numerate society, math achievement plays a fundamental role in educational, occupational, and financial success. In fact, literature shows the relevance of math abilities in a variety of aspects that go from employment opportunities (Bynner & Parsons, 1997; Rivera-Batiz, 1992), salary size (Dougherty, 2003), and socio-economic status (SES) (Gerardi et al., 2013; Gross et al., 2009) to longer-term physical and mental health outcomes (Furlong et al., 2015; Gross et al., 2009).

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Furthermore, mathematical proficiency is progressively recognized as essential for the economic success of a nation, thus showing relevant implications at a collective/societal level (Foley et al., 2017; Peterson et al., 2011).

Despite the central role of numeracy in different contexts and everyday situations, children's underachievement in mathematics remains a consistent and significant problem (Dowker, 2004). The Programme for International Student Assessment (PISA) showed that a growing number of students struggle with numbers and mathematical calculations. PISA 2018 report (Schleicher, 2019) indicated that 24% of the survey's participants did not reach the baseline of Level 2 (which refers to the ability to extract relevant information from a single source and to use basic algorithms, formulae, procedures, or conventions to solve problems involving whole numbers). Students performed poorly when asked to formulate mathematical situations, and they showed better results in applying and evaluating math outcomes. Furthermore, the report observed that 30% of students felt nervous or powerless when faced with mathematical problems and performed less well than expected in mathematics (OECD, 2013). Generally, around 20% of students show low numeracy skills and, depending on classification criteria, between 4% and 14% of children and adolescents have been identified with difficulties in at least one mathematical area (Barbaresi et al., 2005; Butterworth, 2010; Shalev, 2007).

Given the salient impact of numeracy on many aspects of personal and collective life, it is increasingly crucial to understand which factors underly the emergence of good mathematical performance in order to prevent different forms of underachievement or confirmed disabilities in mathematics. Besides cognitive skills (e.g., intelligence, attention, executive functions, working memory; Giofrè et al., 2014; Passolunghi & Lafranchi, 2012), recent literature has highlighted the essential role of emotional (e.g., math anxiety and math enjoyment; Mammarella et al., 2018; Pellizzoni et al., 2022; Putwain et al., 2021) and cognitive-motivational (e.g., self-efficacy; Di Giunta et al., 2013; Justicia-Galiano et al., 2017) aspects in children's math achievement.

Regarding emotional factors, the majority of studies involving primary school children have investigated the detrimental effect of negative emotions, such as math anxiety, on math proficiency (Barroso et al., 2021). However, less research has been done on positive emotions (Pekrun, 2000; Putwain, et al., 2021) such as enjoyment in math. Concerning motivational aspects in math educational settings, literature has recognized the prominent role of math self-efficacy (Bandura, 1977, 1982; see also Pajares & Kranzler, 1995; Pajares & Miller, 1994). Nevertheless, relatively few studies have analysed, guided by a more comprehensive approach, the influence of emotions (both negative and positive) and motivational aspects on math attainments in school aged children (e.g., Forsblom et al., 2022). To address this gap in literature, the present study aimed to:

(1) Deepen the research on the relation between negative and positive emotions, in an attempt to gain a more balanced view of learners' emotional experiences in school, acknowledging the crucial role of the motivational construct of self-efficacy on math attainments of fifth-graders;

(2) Observe the predictive role of the above-mentioned factors in their math performance.

1.1 Theoretical framework

The present study is driven by the theoretical model of control-value theory (CVT. Pekrun, 2006; Pekrun et al., 2007). CVT provides an attempt to link emotional and motivational aspects and academic achievement. The model considers different types of achievement emotions organized in a three-dimensional taxonomy: (a) focus (i.e., outcome-related emotions vs. activity-related emotions); (b) valence (i.e., positive vs. negative emotions); and (c) activation (activating vs. deactivating). Furthermore, CVT proposes that two types of cognitive evaluations function as core determinants of achievement emotions: (1) control appraisals and (2) value appraisals. Control appraisals evaluate the individuals' perceptions of their competence and control over achievement-related activities and outcomes (e.g., self-efficacy expectations), and causal attributions. Value appraisals assess the values of these activities and outcomes. Previous studies evaluating this model have confirmed that students' emotions are related to personal perceptions and value of achievement-related performances (Goetz et al., 2010; Putwain et al., 2018a) and emotions are linked to achievement (Putwain et al., 2018b). However, there is a lack of studies investigating the role of both emotional and motivational aspects on achievement of math-related outcomes (e.g., Forsblom et al., 2022; Putwain et al., 2021).

1.2 The influence of negative and positive emotions on math performance

During math learning, children can experience a wide range of emotions, including negative and positive ones. In the present study, we focused in particular on math anxiety and enjoyment in math since they: (a) are frequently experienced emotions in math classes (García et al., 2016; Luttenberger et al., 2018); (b) are well investigated in the literature on math learning (García et al., 2016; Ma, 1999) and (c) have been widely recognized to influence the learner's math achievement (Forsblom et al., 2022; Zhang et al., 2019). Math anxiety and enjoyment in math have opposite valence: the former is considered a negative or unpleasant emotional response, whereas the latter represents a positive or pleasant emotion. Nevertheless, both are able to produce an activation on students (Pekrun, 2006) and impact their learning process as well as their performance. In the following paragraphs, we briefly describe some studies on math anxiety and enjoyment in math.

1.3 Math anxiety

Math anxiety (MA) is a specific dispositional and dysfunctional emotional response aroused by situations involving mathematics (Ashcraft & Ridley, 2005). It has been estimated that 17% of the population has high levels of MA (Ashcraft & Moore, 2009). Numerous studies investigating the role of MA in middle and high school students (e.g., Ma & Xu, 2004) as well as in undergraduate students (e.g., Faust, 1996) highlighted the detrimental effect of this negative emotion on math performance: high levels of MA seem to hinder math achievement disregarding true math ability (see also Barroso et al., 2021; Namkung et al., 2019; Zhang et al., 2019). More recently, researchers have been interested in the effects of MA on primary school students and some studies revealed that MA could negatively influence math performance already in primary education (Cargnelutti et al., 2017; Passolunghi et al., 2019; Ramirez et al., 2016; Sorvo et al., 2017). Notably, the development of MA does not only lead to lower math performance but also to significant negative middle- and long-term consequences. For instance, considering middle-term effects, students with high levels of MA tend to avoid the enrolment in math-intensive courses (Ashcraft & Ridley, 2005; Maloney & Beilock, 2012), experience negative attitudes towards math (Dowker et al., 2016; Gierl & Bisanz, 1995) and maintain a negative perception of their mathematical skills (Ashcraft, 2002). Long-term consequences concern the decrease in employment opportunities and lower life quality (Barroso et al., 2021; Dowker et al., 2016; Namkung et al., 2019). Considering the significant detrimental impact of MA, it is essential to further investigate this emotion already in primary education.

It must be noted that MA differs from other forms of anxiety, such as test anxiety (TA) or general anxiety (GA, Donolato et al., 2020). TA is a specific type of anxiety triggered by test or assessment situations (Caviola et al., 2022), whereas GA is an individual's tendency to worry in general about life events, their behaviours and their own abilities (Eysenck & Calvo, 1992). Some studies showed that math performance is negatively impacted also by TA and GA (Donolato et al., 2020; Hembree, 1990). For instance, the meta-analytic findings from Caviola and colleagues (2022) showed that both MA and TA could influence math performance. Therefore, it is important to evaluate the unique role of MA on children's math proficiency by considering within the same study also other forms of anxiety.

1.4 Enjoyment in math

On the other hand, enjoyment in math represents a positive and physiologically activating emotion toward mathematics (Pekrun, 2011) and it is generally experienced if the learning process is perceived as interesting and intrinsically rewarding (Camacho-Morles et al., 2021). Several studies showed a moderate positive correlation between math-related enjoyment and math achievement (García et al., 2016; Herges et al., 2017; Pekrun et al., 2017; Pinxten et al., 2014). This pleasant emotional factor seems to impact academic achievement indirectly since it can positively contribute to self-regulation, intrinsic motivation, and it can facilitate the activation of cognitive processes and on-task attention (Aspinwall, 1998; Pekrun et al., 2002).

Besides significant correlations, some studies revealed that enjoyment in math could predict subsequent math achievement. For instance, Putwain et al. (2018b) investigated longitudinally the reciprocal relationship between enjoyment in math, boredom, and math performance in primary school children (5^{th} and 6^{th} grade). Data on math achievement were collected at two times (T1 and T3), enjoyment in math and boredom were collected at the second (T2) and at the fourth time (T4).

Regarding enjoyment, results confirmed that higher enjoyment in math at T2 positively influenced math achievement at T3, and that higher math achievement at T3 predicted higher enjoyment at T4. Similarly, in a longitudinal study involving fifth- and seventh graders conducted by Forsblom et al. (2022) appraisals of perceived competence in math, perceived value of math, math emotions (enjoyment, anger and boredom), and math achievement were evaluated in three consecutive annual assessments. The results showed, again, a positive influence of enjoyment and negative influence of anger and boredom on students' achievement in mathematics and highlighted the importance of control-value appraisals and achievement as antecedents of these emotions. The role of enjoyment in math learning was corroborated also by a cross-cultural study (Raccanello et al., 2018) conducted in Italy, Germany, and the USA with second- and fourth-grade students. Findings showed a positive relation between enjoyment in math and math achievement and confirmed the importance of positive emotions on math achievement among different cultures.

In synthesis, existing literature underlines the relevance of negative and positive emotions for math performance. In particular, MA seems to reduce motivation and interfere with information processing resources, thus often leading to lower achievement (Dowker et al., 2016). In contrast, enjoyment in math is motivating and broadens thought–action activities producing a greater level of achievement (Pekrun et al., 2011). Moreover, available studies indicate a significant relation between negative and positive emotions toward maths: MA is negatively associated with enjoyment in math (Ashcraft & Ridley, 2005; Tapia & Marsh, 2004). Despite numerous studies that have examined the role of emotions on math performance, it is also important to consider the motivational construct of self-efficacy. A deeper understanding of the role that the latter plays in mathematics will help with comprehending individual differences in math learning.

1.5 The influence of math self-efficacy on math performance

Generally, self-efficacy is defined in Bandura's theory (1977) as an individual's belief in his or her capacity to execute behaviours necessary to achieve desired performance attainments. Similarly, math self-efficacy represents individuals' assessments of their ability to solve specific math problems, perform math tasks, and succeed in mathematics-related courses (Lane & Lane, 2001; Luttenberger et al., 2018; Pajares, 2005; Pastorelli et al., 2001). It must be noted that the construct of math self-efficacy differs from other expectancy beliefs, such as math self-concept (Lee, 2009). According to Pajares (1996), math self-efficacy is more context-specific and involves judgments of one's ability to execute a particular math task, whereas math self-concept is a more global construct of self-competence in the math domain. For instance, math self-efficacy could be assessed as an individual's confidence in solving specific math problems (e.g., "I can do this mathematics problem"), while math self-concept could be evaluated as one's judgment of self-worth as a math student (e.g., "I am good at mathematics") (Pajares & Miller, 1994; Pintrich & Schunk, 1995). In the present study, we focused on math self-efficacy, since (1) we were interested in evaluating how individuals' beliefs of their capability to handle the specific task request (in contrast to a more generic sense of self-worth in the math domain) could influence their math performance, and because (2) some studies revealed that math performance is more strongly related to math self-efficacy compared to math self-concept (e.g., Pajares & Miller, 1994; Pietsch et al., 2003).

The construct of math self-efficacy plays a central role in the context of math learning. It has been shown that students who approach school with strong internal resources (such as self-efficacy) manage to engage more in mathematical learning and are better "equipped" to meet the challenges of the discipline (Martin & Rimm-Kaufman, 2015). Research converges in agreement that holding positive beliefs about the ability to succeed in math tasks is related to higher math achievement among children and adolescents (e.g., Ma & Kishor, 1997; OECD, 2013; Recber et al., 2018; Singh et al., 2002) and improved learning and problem-solving among adults (e.g., Cooper et al., 2018; Hattikudur et al., 2016). It is hypothesized that students who believe they are capable in a domain are more interested, motivated and effortful in new learning (Ainley & Ainley, 2011; Hoffman, 2010), take better advantage of cognitive supports and self-regulatory strategies during learning and problem-solving (Cooper et al., 2018; Hattikudur et al., 2016), and persist in the face of difficulty (Ainley et al., 2002; Pajares & Graham, 1999), which leads to higher achievement (Berger & Karabenick, 2011; Rosário et al., 2013). Various studies showed that math self-efficacy acts as a very powerful motivational resource that supports individuals to engage, persevere, and accomplish goals in mathematics (Kalaycıoğlu, 2015; Lee et al., 2022). Self-efficacy beliefs are also an important factor influencing educational and career choices (Zimmerman, 2000): students who perceive themselves as good mathematics learners are more likely to attain advanced math courses and enter STEM careers (Bong & Skaalvik, 2003; Wang et al., 2013).

At the same time, some studies indicated that the relation between math achievement and math self-efficacy is bidirectional, as past students' experience with math can strongly influence their current math self-efficacy beliefs (Usher & Pajares, 2009). Persistent low achievement in math can result in lower self-efficacy and higher negative affect towards math and school in general (Du et al., 2021; Lee et al., 2022).

Moreover, according to CVT, students' judgments of self-efficacy would influence the emotions experienced in relation to math. For instance, the less students feel competent in solving math tasks, the more anxiety and the less enjoyment they will experience towards math, which, in turn, will negatively influence math learning. In contrast,, the more they consider themselves as capable of solving math tasks, the more they will enjoy working on them and the less anxious they will feel (Du et al., 2021; Forsblom et al., 2022). Supporting this theory, studies showed that higher math self-efficacy is correlated with lower MA (Ahmed et al., 2012; Donolato et al., 2019; Seaton et al., 2014; Wang et al., 2020), and some recent studies suggest that improving students' math self-efficacy could also be beneficial in reducing feelings of worry in relation to math (Rozgonjuk et al., 2020). This association has been also supported by recent meta-analytical findings, which revealed a moderately negative correlation (r = -.40) between the two constructs (Li et al., 2021). On the other hand, students' perceived competence in math was shown to be positively linked to enjoyment in math (Forsblom et al., 2022). Taken together, it seems that self-efficacy has a relevant role in math learning and the investigation of both emotional and motivational factors could provide a more comprehensive view of the difficulties children encounter in math.

2 The present study

Overall, the literature has shown an exhaustive evaluation of different emotional and motivational components on students' math achievement. However, few studies investigated the predictive role of both positive and negative emotions and math self-efficacy on math attainments (Forsblom et al., 2022; Kim et al., 2014; Putwain et al., 2021).

Moreover, it must be noted that studies examining these factors in primary-aged students are considerably rare (Cargnelutti et al., 2017; Putwain et al., 2021). Thus, further research is needed with younger samples in order to extend the available line of research. In this sense, a developmental period that warrants particular consideration is the last year of primary school. This is a relevant stage for children, as it represents the transition from primary to middle school, a time when students tend to describe mathematics as less interesting or enjoyable and report higher negative attitudes towards math (Adelson & McCoach, 2011; Sakiz et al., 2012; Waters et al., 2009). Therefore, examining emotional and motivational components and their relationship with math achievement in this educational stage, could provide some important considerations on how to prevent the development of future negative emotions and lower effort in mathematics.

Taken together, the main objectives of the current study were to:

(1) Evaluate the correlations between positive (i.e., enjoyment in math) and negative (i.e., MA) emotions, math self-efficacy and math achievement in primary school children. In doing this, we aimed to advance previous literature by a) evaluating, as mentioned previously, how these variables correlate during a psychological and educational transitioning year such as fifth grade, and b) examining students' emotions (MA and enjoyment in math) using self-report questionnaires which are not retrieved from the same achievement emotion scale. We considered using different tools fundamental to test the consistency of the findings observed in literature.
(2) Observe how MA, enjoyment in math, and math self-efficacy predict math performance in fifth-grade students, after taking into account children's GA. We judged this investigation essential considering that these factors are rarely studied simultaneously. In particular, we were interested in testing two different regression models to evaluate whether different emotions (enjoyment in math and MA) inserted in different block sequences predict math performance. To the best of our knowledge no study has explored this aspect.

Concerning the first aim, we hypothesized that MA would positively correlate with GA (Donolato et al., 2020; Passolunghi et al., 2019) and negatively with math self-efficacy (Wang et al., 2020), enjoyment in math (Ashcraft & Ridley, 2005), and math achievement (Zhang et al., 2019). We also expected that enjoyment in math would be positively correlated with math self-efficacy and math achievement (Goetz et al., 2007; Skaalvik et al., 2015). Regarding the second aim, we hypothesized the predictive role of MA (Cargnelutti et al., 2017), math self-efficacy, and enjoyment on math performance (Forsblom et al., 2022; Goetz et al., 2007) but not of GA.

3 Method

3.1 Participants

The participants were 150 fifth graders from five different primary schools located in North-Eastern Italy. Five participants ($n = 5$) produced outlier scores on math performance and were handled with listwise deletion. The final sample consisted of 145 students (84 male and 61 female) with $M_{age} = 10.36$, $SD = 0.47$. A priori power analysis for linear multiple regression was conducted in G*Power (Faul et al., 2007) to determine a sufficient sample size using an alpha of .05, a power of 0.95, a medium effect size ($f^2 = 0.15$) and four predictors. Based on the above-mentioned assumptions, the minimum sample size needed is 129. All participants were Caucasian and typically developing children. The SES of the sample was primarily middle class and established on the bases of school records. The research was approved by the Ethical Committee of the University of Trieste (n.119), and parents gave a written consent for their children to participate in the study. Students were informed that their participation was voluntary, and that they could withdraw from the study at any time.

3.2 Materials

3.2.1 Math anxiety

The *Abbreviated Math Anxiety Scale* (AMAS; Hopko et al., 2003, Italian version adapted by Caviola et al., 2017) is a self-report questionnaire with 9 items adapted to primary school students. Participants were asked to indicate how much anxiety they would feel in different situations that involve math on a 5-point Likert scale ranging from 1 (*low anxiety*) to 5 (*high anxiety*). The total score was calculated as the sum of the scores for each item and could range between a minimum of 9 and a maximum of 45. A higher total score corresponded to a higher level of MA. Cronbach alpha in the present sample was 0.80.

3.3 General anxiety

The *Revised Children's Manifest Anxiety Scale-Second Edition* (RCMAS-2), Short Form (Reynolds & Richmond, 2012) consists of 10 items that measure the level of general anxiety in children, with a YES–NO response modality. An example of an item is "I feel nervous”. The raw score was transformed into a standardized score with a conversion table. The minimum score was 36, the maximum score was 77. Cronbach alpha in the present sample is 0.70.

3.3.1 Enjoyment in mathematics

The *Achievement Emotions Questionnaire-Mathematics* (AEQ-M; Pekrun et al., 2007) presents a multidimensional self-report questionnaire created to assess the emotions experienced by students in mathematics. The questionnaire contains 60 items that measure seven discrete emotions related to math (pride, anger, enjoyment, anxiety, shame, hopelessness, and boredom) that can be experienced in class, when studying, when doing homework, and during tests or examinations. In the current study we used the Enjoyment scale, consisting of 10 items scored on a five-point Likert scale from 1 (*strongly disagree*) to 5 (*strongly agree*). An example of an item is "When I do my math homework, I am in a good mood". The total score was the sum of all scores for each item, with a higher score corresponding to more enjoyment in math. The total score could range between 10 and 50. Cronbach alpha in the present sample was 0.81.

3.3.2 Math self-efficacy

The *Mathematical Self-Efficacy Scale* (adapted by Caprara et al., 2011) is a self-report questionnaire that measures the perception of math self-efficacy. The scale is composed of 10 items scored on a Likert scale from 1 ((*not at all good/capable*) to 5 (*completely good/capable*). The questionnaire investigates two math self-efficacy domains: the perceived capacity in different mathematics tasks (e.g., "How good are you in the calculation?") and the perceived capacity in the ability to self-regulate activities (e.g., "Can you concentrate on the study in math without getting distracted?"). The total score was the sum of all scores for each item, with higher scores corresponding to higher math self-efficacy. The total score could range between 10 and 50. Cronbach alpha in the present sample was 0.82.

3.3.3 Math performance

As a measure of mathematics performance, we used a standardized test that evaluates calculation skills and math reasoning in children (AC-MT 3 6–14, Cornoldi et al., 2020). In particular, we used three paper-and-pencil subtests: Fluency, Inference, and Written Calculation. The Fluency task consisted of 15 arithmetic operations (7 additions, 5 subtractions, 3 multiplications) and participants were asked to solve as many operations as possible in one minute. The Inference task comprised 12 items divided into three different types of tasks that had to be completed in 2 min: in the first task, participants had to solve 4 arithmetic operations involving images, in the second task, they were asked to complete 4 operations by inserting the corresponding missing sign ($+, -, \times,,$:) and in the third task, they had to solve 4 operations by using the result of another similar operation as a cue. The Written

Calculation test consisted of 8 operations (2 additions, 2 subtractions, 2 multiplications, 2 divisions) to be carried out in five minutes. The sum of all correct answers presented the final score. Cronbach alpha in the present sample was 0.80.

3.3.4 Procedure

Measures were administered collectively at school in two sessions: in the first session, MA (AMAS), GA (RCMAS 2), math self-efficacy (Mathematical Self-Efficacy Scale), and enjoyment in math (AEQ-M) were assessed, whereas in the second session, children's math performance (Fluency, Inference, and Written Calculation) was evaluated. Both sessions lasted about 20 min. A fixed order of presentation of the tasks was used and only students who completed all measures were subsequently analysed.

4 Results

4.1 Analytic strategies

All statistical analyses were performed using SPSS IBM 21. To test our first hypothesis, we conducted a bivariate correlation analysis using Pearson *r* between MA, GA, math self-efficacy, enjoyment in math, and math performance. To examine our second hypothesis on the predictive role of MA, GA, math self-efficacy, and enjoyment in math, on math performance, a hierarchical regression analysis was conducted.

Descriptive statistics are presented in Table 1 and zero-ordered correlations in Table 2. From the inspection of the correlations, it can be noticed that math performance was negatively correlated with MA and positively correlated with enjoyment in math and math self-efficacy. Moreover, MA was negatively associated with enjoyment in math and math self-efficacy, whereas enjoyment in math was positively correlated with math self-efficacy.

To assess the unique contribution of the examined constructs on math performance, we conducted two hierarchical regression models. In the first model, math achievement was inserted as the dependent variable whereas the independent variables were: GA in the first block, MA in the second block, enjoyment in math in

Table 1 Descriptive statistics for all measures

	Mean (*SD*)	Skewness	Kurtosis	Minimum	Maximum
1. Math anxiety	21.64 (6.78)	0.43	-0.38	9	41
2. General anxiety	50.88 (8.40)	0.12	-0.54	36	77
3. Math self-efficacy	35.71 (6.48)	-0.38	0.04	16	50
4. Enjoyment	36.39 (7.91)	-0.63	0.52	17	50
5. Math performance	16.77 (5.96)	0	-0.89	4	30

Table 2 Zero-order correlations between all measures

	1	2	3	4	5
1. Math anxiety	–				
2. General anxiety	.367**	–			
3. Math self-efficacy	-.527**	-.216**	–		
4. Enjoyment	-.186*	-.056	.174*	–	
5. Math performance	-.429**	-.099	.430**	.259**	–

$^{*}p \leq .05$; $^{**}p \leq .01$

the third block, and math self-efficacy in the final block. In the second model, the dependent variable was, again, math achievement, but the blocks were different. In the first block, we inserted the measure of GA, in the second, block the measure of enjoyment in math, in the third, block MA, and in the fourth block math self-efficacy. With these two models, we wanted to verify the possibility for the different predictive roles of positive and negative emotions on math performance. Multiple regression assumptions (i.e., homoscedasticity, linearity and normality) have been controlled running a residual plot (Fig. 1) and a Q-Q plot (Fig. 2) (see Supplementary materials).

Results showed that GA (β= -0.146, p = .100) introduced in the first block did not predict math performance in the models (R^2 = 0.021, p = .100). The introduction of MA (β= .0.479, p = .000) in Block 2 of Model 1 (R^2 = 0.221, p = .000), and enjoyment (β = 0.319, p = .000) in Block 2 of Model 2 (R^2 = 0.117, p = .000) led both models to reach the significance, indicating that MA and enjoyment are significant predictors of math performance. Results also showed that MA (β= -0.414, p = .000) and enjoyment (β = 0.180, p = .037) significantly predicted math performance when introduced at the same time in models' Block 3 (R^2 = 0.248, p = .000), indicating that both MA and enjoyment concurrently explain children's math performance. The introduction of math self-efficacy (β = 0.259, p = .007) in both models (R^2 = 0.291, p = .000) was shown to be significant. Contextually, MA retained its significance, while enjoyment in math was no longer found to be a statistically significant predictor (Tables 3 and 4).

5 Discussion

Math ability is a crucial skill that must be acquired in a numerate society (Rivera-Batiz, 1992). Recent studies showed that MA (Namkung et al., 2019; Zhang, et al., 2019), enjoyment in math (Frenzel et al., 2009), and math self-efficacy (Pajares & Kranzel, 1995) play an important role in math achievement. However, there is a lack of studies investigating jointly the impact of these factors in a sample of primary school children (Forsblom et al., 2022). In line with these considerations, our study had two main objectives: (1) to advance the understanding of how positive (enjoyment in math) and negative (MA) emotions, math self-efficacy, and math achievement are correlated in a sample of fifth graders, and (2) to evaluate the predictive value of GA, MA, enjoyment in math, and math self-efficacy on math achievement.

Regarding the first aim, math abilities were positively correlated with enjoyment and negatively with MA. This is in line with previous studies demonstrating that primary school students who experience higher math enjoyment are more successful in math (Frosblom et al., 2022; García et al., 2016), whereas children with higher levels of MA exhibit poorer math performance (Hill et al., 2016; Passolunghi et al., 2019). Furthermore, our data indicated a significant and negative correlation between MA and enjoyment in math. Not surprisingly, students with high MA experienced less enjoyment (Pajares & Graham, 1999; Pekrun, 2006; Skaalvik & Skaalvik, 2006; Wang et al., 2020; Zakariya, 2021). Results also revealed a positive correlation between enjoyment in math and math self-efficacy and a negative correlation between MA and math self-efficacy. In line with the CVT (Pekrun, 2006) and other empirical studies (e.g., Akin & Kurbanoglu, 2011), our findings suggested that achievement emotions and motivational aspects are related. Repeated failures or successes in a particular domain of academic performance could detract or enhance, respectively, the student's sense of subjective control and confidence, possibly contributing to the development of negative or positive emotions in the learning domain. Therefore, increased efficacy in math may act as a protective factor in math learning, providing students with resilience toward the development of MA and tempering the hindering effects of negative emotions (Du et al., 2021; Galla & Wood, 2012).

Related to the second aim of the study, we analysed the role of GA, MA, enjoyment in math, and math self-efficacy on math performance. We designed two different hierarchical regression models to evaluate whether different emotions (enjoyment in math and MA) inserted in different block sequences would differently predict math performance. It is important to notice that, in this study, we assessed GA in combination with MA, and the results distinguished the unique contribution of these two constructs and showed that GA was not a significant predictor of math

Table 3 Hierarchical regression analysis

Independent variables (blocks)	R^2	ΔR^2	Sig	β	*p*
1. GA	.021	.021	.100	-.146	.100
2. GA	.221	.200	.000	.026	.757
MA				-.479	.000
3. GA	.248	.027	.000	.046	.580
MA				-.414	.000
AEQ-M(E)				.180	.037
4. GA	.291	.043	.000	.042	.607
MA				-.286	.004
AEQ-M(E)				.130	.130
M—SE				.259	.007

GA-General anxiety; MA-Math anxiety; AEQ-M(E)-Enjoyment; M-SE-Math Self-efficacy

Table 4 Hierarchical regression analysis

Independent variables (blocks)	R^2	ΔR^2	Sig	β	*p*
1. GA	.021	.021	.100	-.146	.100
2. GA	.117	.096	.000	-.068	.431
AEQ-M(E)				.319	.000
3. GA	.248	.131	.000	.046	.580
AEQ-M(E)				.180	.037
MA				-.414	.000
4. GA	.291	.043	.000	.042	.607
AEQ-M(E)				.130	.130
MA				-.286	.004
M—SE				.259	.007

GA-General anxiety; AEQ-M(E)-Enjoyment; MA-Math anxiety; M-SE-Math Self-efficacy

performance. The findings are in line with previous studies that revealed that MA and GA have a small degree of shared components, but a large degree of unshared components (Malanchini et al., 2017; Wang et al., 2014).

In both hierarchical regression models, MA and math self-efficacy showed a significant concurrent quote of explained variance considering math performance, however enjoyment in math was not a significant predictor. In particular, both models revealed that MA could negatively predict math performance of fifth-grade students, whereas math self-efficacy could positively predict their math achievement. These findings confirm similar results of previous studies (Cargnelutti et al., 2017; Hacket & Betz, 1989; Pajares & Kranzler, 1995; Ramirez et al., 2016; Usher & Pajares, 2009).

Regarding MA, our study did replicate and confirm findings on the well acknowledged negative influence of MA on math performance in primary school children (Cargnelutti et al., 2017; Hill, et al., 2016; Passolunghi et al., 2019). Negative emotions can undermine successful performance by fostering avoidance motivations and a diminished sense of self-efficacy. Two recent studies (Gunderson et al., 2018; Pekrun et al., 2017) have provided evidence to support a reciprocal view of the relationship between MA and math performance and, in agreement with the present research, showed that lower mathematics achievement predicted higher MA with possible repercussions for the future. This proposal underscores the complex nature of mathematics achievement and recognizes that low achievement can elicit feelings of worry and uncertainty.

As regards math self-efficacy, our study enriched previous research by finding that this construct is a significant predictor of math achievement already in primary education. Indeed, math self-efficacy has been widely examined in undergraduate students (Akin & Kurbanoglu, 2011; Pajares & Miller, 1994), high school (Pajares & Kranzler, 1995), and middle school students (Sağkal & Sönmez, 2022; Skaalvik et al., 2015), but more rarely in samples of primary school children (Arslan, 2012; Joët et al., 2011). Our data on fifth graders pointed out the important positive role of self-beliefs in math learning (Du et al., 2021; Griggs et al., 2013) confirming that feeling competent in math tasks can boost motivation, perseverance and the adoption of better cognitive or metacognitive strategies which support student's achievement and reduce the experience of negative emotions. To better understand the role of self-beliefs and math learning, future research should expand our findings investigating the effect of self-efficacy in early primary school children. Indeed, studies have shown that self-efficacy generally decreases as students grow up (Jacobs et al., 2002) and, therefore, the pattern of relationships between self-efficacy, emotions, and math achievement in early primary school may be different.

Concerning enjoyment in math, the results showed that despite a significant positive correlation with math performance, this emotion did not predict a significant quote of variance on math achievement in fifth grade students. It could be speculated that the construct of math self-efficacy is a stronger predictor for math performance compared to enjoyment in math (Pajares & Graham, 1999; Zakariya, 2021). This result seems to support, again, the CVT (Pekrun, 2006; Pekrun et al., 2007, 2017) which suggests the control appraisals (the individuals' perceptions of their competence and control over achievement-related activities) to be a core and predictive aspect of math learning process and a determinant of emotions achievement. Moreover, it must be noted that the literature in the field showed some contrasting results, with most studies indicating a positive correlation between enjoyment in math and math achievement (Frenzel et al., 2009; Putwain et al., 2018b), and others highlighting an absence of this relationship (Pekrun et al., 2006). Carver (2003) tried to explain the non-significant relationship between enjoyment and achievement arguing that when positive emotions arise, a signal that everything is going well is perceived and activity is no longer perceived as our priority. The "pre-ordering of priorities" situation shifts the attention, allocating the cognitive resources to other needs and compromising achievement and task performance. Another possible explanation of the absence of this effect could be found in the fact that younger students (e.g., second grade) typically have more positive attitudes towards math and enjoy math activities more than older students (e.g., fourth grade) (Raccanello et al., 2018). This is confirmed by various longitudinal studies which showed a reduction in motivation in the transition from elementary to secondary school (Paulick et al., 2013; Raccanello & Brondino, 2016). Therefore, considering our sample of fifth graders, it could be speculated that the relation between math enjoyment and math achievement does not emerge, since students have lower scores of enjoyment in math.

Overall, we can assume that, in fifth graders, MA and math self-efficacy could have a stronger and more relevant influence on students' math performance, while enjoyment in math showed a significant and positive correlation with math performance but did not emerge as a significant predictor.

6 Limitations and strengths of the study

There are some limitations to our research. First, we employed merely self-report questionnaires to assess GA, MA, self-efficacy, and enjoyment which can be challenging for some children and answers can be affected by the social desirability bias. Second, our sample involved only typically developing children, and we did not include students with learning disabilities although it could be very useful to investigate how positive and negative emotions influence their math performance. We also did not consider more complex models to explain the interplay between the above mentioned variables. Indeed, the aim of the present study was to evaluate the predictive role of affective and motivational aspects on math performance, and to untangle these complex relationships would have required a larger sample size and a longitudinal design.

Even with these limitations, the findings of the present study offer some important insights for mathematical education and the development of novel interventions in academic settings. Teachers and educational policies should place more attention on non-cognitive factors associated with math learning, strengthening positive attitudes, emotions, and beliefs towards math. Previous intervention programs targeting primary school students attempted to promote mathematical learning by reducing MA levels (see, Passolunghi et al., 2020). However, the results of our study highlight the crucial role of math self-efficacy and suggest that students with math difficulties could benefit more from an early intervention aimed at enhancing and cultivating positive beliefs and motivational attitude, through cognitive and metacognitive strategies, adaptive teaching, and gamification methodology, which could consequently reduce negative feelings related to math (Wang et al., 2020). In accordance with this idea, Passolunghi et al. (2020) found that interventions on emotional training and interventions on mathematical strategies contributed to decrease the level of MA in late primary school children, but only the training on mathematical strategies led to a significant improvement in math competence. The results suggest that math exercises enhance math competence and simultaneously strengthen learner's confidence and math self-efficacy, which consequently leads to a decrease in negative emotions.

In other words, future interventions aimed at promoting math skills and contrasting MA in primary school students should be targeted more on self-efficacy and perceived competence and not just on reducing negative emotions (Passolunghi et al., 2020). Interventions could, on one hand, enhance students' self-efficacy and enjoyment and, on the other, desensitize children to fear stimulus related to number manipulation. The resulting synergy is a virtuous cycle of competence gain and anxiety level reduction that could produce a salient repercussion at a personal, occupational and national level, empowering future generations in different societies (Pellizzoni et al., 2020).

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