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How trait and state mathematics anxiety could affect performance: Evidence from children with and without Specific Learning Disorders

Rachele Lievore[a,*], Sara Caviola[a,b], Irene C. Mammarella[a,*]

[a] Department of Developmental and Social Psychology, University of Padova, Italy
[b] School of Psychology, Faculty of Medicine and Health, University of Leeds, UK

A R T I C L E I N F O

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A B S T R A C T

The aim of this study was to investigate trait and state mathematics anxiety (MA) in children with Specific Learning Disorders (SLD; N = 56), aged between 8 and 14 years old, compared to non-diagnosed (ND; N = 56) participants matched for age, gender, and IQ. In addition to a trait-like questionnaire on MA, participants were tested with a time-pressure math task, during which MA-state components and perceived competence were assessed. Lower levels of trait MA and a higher task-related perception of competence were found to positively predict math attainment in the entire sample, whereas specific MA-state patterns emerged distinctly in children with and without SLD. In children with SLD, a higher emotional arousal during the task was consistent with better performance, whereas greater worries were linked to worse math execution. Conversely, in ND children, greater task-related worries were associated with better performance. Educational institutions and practitioners should consider how emotional responses, self-evaluations, negative thoughts, and worries may impact the process of learning mathematics. These factors can significantly affect performance, especially when assessing the acquisition of specific mathematical skills.

Educational relevance and implications statement: The findings of the present study reveal that the math performance of children, both with and without SLD, may be negatively influenced by specific emotional responses, intrusive thoughts, and worries. Therefore, it is crucial to consider both protective and risk factors in educational practices. On a practical level, teachers and clinicians should be aware that proficiency might be affected by time pressure, potentially elevating the level of state mathematics anxiety. Interventions that focus on affective and cognitive factors related to performance could have positive implications for the learning process in students facing academic difficulties.

1. Introduction

It has been widely suggested that a complex combination of underlying cognitive, emotional, and contextual aspects supports mathematical learning and performance (Cipora et al., 2022; Mammarella et al., 2019). Within the multidimensional mathematical domain, mental calculation has been extensively studied (Caviola et al., 2018; Xu et al., 2021) since it is a crucial ability necessary in both academic and everyday contexts (e.g., paying for purchases, playing games). Moreover, mental calculation has been closely associated with specific affective components, such as math-related emotions (Forsblom et al., 2022; Lichtenfeld et al., 2023) and anxiety (Barroso et al., 2021; Caviola et al., 2022; Namkung et al., 2019).

1.1. The relationship between mathematics anxiety and mathematical performance

Emotional aspects may play an important role in mathematics performance, especially concerning anxiety mindsets (Putwain & Wood, 2023; Robson et al., 2023). Negative emotions, such as anxiety or those arising in stressful situations, can interfere with success in mathematical tasks (Ramirez et al., 2018). In this regard, a specific form of anxiety associated with mathematics has been named mathematics anxiety (MA). MA is used to describe a combination of negative feelings, including tension, discomfort, and fear, experienced when thinking about and performing mathematical tasks in both academic situations and everyday life (Ashcraft, 2002; Hembree, 1990; Ma et al., 2004). The negative correlation between MA and math performance has been

* Corresponding authors at: Department of Development and Social Psychology, University of Padova, Via Venezia 8, 35131 Padova, Italy.
E-mail addresses: rachele.lievore@studenti.unipd.it (R. Lievore), irene.mammarella@unipd.it (I.C. Mammarella).

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commonly observed (for a mini-review, see Carey et al., 2016). However, there is a paucity of longitudinal studies on the subject (Ma et al., 2004; Sorvo et al., 2019, 2022; Vukovic et al., 2013), which does not allow speculation on the association's direction over time. Overall, the difficulty in determining the direction of the association between MA and math skill acquisition has led to the hypothesis of a bidirectional relationship between them (Jansen et al., 2013).

It is worth noting that perceived competence and the expectancy of success or failure might also play an important role in defining the relationship between math performance and related negative (or positive) feelings (Pekrun, 2006; Weiner, 2005; Wigfield & Eccles, 2000). The correlation between MA and perceived competence, specifically individuals' perception of their own competency, seems to support the idea of self-perception and self-efficacy as key determinants of math achievement (Bandura et al., 1999; Jansen et al., 2013; Malanchini et al., 2020). Low perceived competence in math may be associated with insufficient math performance (Eccles & Jacobs, 1986; Ganley & Lubienski, 2016; Ganley & Vasilyeva, 2011). MA may also contribute to low perceived competence regarding math expertise, and repetitive failures might further diminish the perception of competence (Lee, 2009; Ma, 1999; Malanchini et al., 2020). Therefore, lower perceived competence might be both antecedent and consequent to poor math achievement, highlighting a reciprocal relationship between math achievement and confidence (Ganley & Lubienski, 2016; Justicia-Galiano et al., 2017).

1.2. The distinction between trait and state mathematics anxiety

It is worth noting that MA has frequently been evaluated using trait-like self-report questionnaires, implicitly legitimizing the idea that this form of academic anxiety is a permanent trait. However, less has been done to investigate state MA (Mammarella et al., 2023). It is necessary to differentiate between trait and state MA (Cipora et al., 2022; Mammarella et al., 2023): the former refers to the idea of an enduring, non-modifiable, generalized personality feature, usually assessed with self-report questionnaires; the latter refers to the emotional and cognitive responses individuals implement when facing a stressful math situation, which can only be appraised with state measures. A clear discrepancy between retrospective self-reports and real-time assessments (Sorvo et al., 2017) has advanced the idea that trait-like questionnaires, influenced by subjective beliefs and reappraisal thoughts related to past experiences (Goetz et al., 2013; Robinson & Clore, 2002; Roos et al., 2015), cannot be considered a comprehensive evaluation of the actual emotional states experienced during math situations. Instead, real-time assessments might be more suitable to study state MA, classified as a temporary and math-situation-related anxiety reaction linked to increased arousal of the autonomic nervous system (Orbach et al., 2020; Roos et al., 2015). State MA should be assessed using a more explicit/direct approach, bringing together experimental manipulations (e.g., time constraint paradigms), state-like questionnaires, and autonomic measures related to a specific task (Mammarella et al., 2023). Increasing time pressure during a mathematical task makes it more difficult to perform, thus prompting an anxiety state that allows a truthful analysis of how anxiety can interfere with task execution (Kellogg et al., 1999; Rieskamp & Hoffrage, 2008; Tsui & Mazzocco, 2006).

1.3. The multidimensionality of mathematics anxiety

Although MA cannot be reduced to other forms of academic anxiety (i.e., test anxiety; Caviola et al., 2022), it is multidimensional, akin to the other types of anxiety (Morris et al., 1981), and it can be described as having cognitive, emotional, and psychophysiological components (Ashcraft, 2019; Cipora et al., 2019). There is wide-ranging consensus recognizing two main components of MA (Dowker et al., 2016; Ho et al., 2000; Wigfield & Meece, 1988): a cognitive component ("worries"), which includes concerns about performance and the perceived risk of failure resulting in disapproval by those evaluating the performance in comparison to a standard of achievement; and an affective component ("emotionality"), which refers to tension, frustration, and physiological arousal felt in evaluative settings.

According to well-established theories (e.g., Eysenck et al., 2007; Eysenck & Calvo, 1992; Eysenck & Derakshan, 2011), worries might cause distracting thoughts that interfere with cognitive resources at different levels, thus reducing the mental assets available and consequently impairing performance effectiveness. Within the MA research field, worrying thoughts are assumed to overload working memory capacity, leading to a decrease in math performance (Pellizzoni et al., 2022; Živković et al., 2022). However, at times, anxious individuals put more effort into task performance to overcome the consequences of anxiety (Eysenck & Calvo, 1992).

Emotionality refers to an individual's perception of the physiological-affective aspects of anxiety, that is, signs of autonomic arousal and unpleasant feeling states (Morris et al., 1981). Following this line of reasoning, enhanced arousal and high-perceived tension can act as a push and provide higher motivation towards the task, thus empowering performance, or, on the contrary, they can overwhelm individual resources (Seery, 2011).

The cognitive, emotional, and psychophysiological components of MA might produce adverse consequences on math performance, especially in children with academic difficulties.

1.4. Mathematics anxiety and Specific Learning Disorders

Indeed, though MA is known to have adverse outcomes on math achievement (and vice versa) in the general population, the effects might be exacerbated in a subgroup of neurodevelopmental disorders characterized by difficulties in academic settings, known as Specific Learning Disorders (SLD). This generic term refers to a broader diagnostic category that incorporates difficulties in learning academic skills, such as reading, writing, and mathematics, despite average (or above) intellectual abilities (DSM-5; American Psychiatric Association [APA], 2013).

The prevalence of neurodevelopmental learning disorders in reading (dyslexia) and mathematical processes (dyscalculia) clearly show high rates of co-occurrence (comorbidity) between these disorders (Mammarella, Bomba, et al., 2013; Moll et al., 2019; Willcutt et al., 2019) as well as with other neurodevelopmental disorders (Mammarella, Caviola, et al., 2013; Peterson et al., 2021), such as attention-deficit-hyperactivity disorder (ADHD; Crisci et al., 2021; Pennington, 2006). In their Opinion Paper, Peters and Ansari (2019) explained the necessity of overcoming the problems associated with a categorical approach by considering the overlap between learning disorders, rather than entirely distinct domains of learning. As a matter of fact, children with difficulties in one domain (e.g., reading) frequently experience challenges in at least another domain (e.g., arithmetic) (Landerl & Moll, 2010; Moll et al., 2015; Pennington et al., 2019). Moreover, Specific Learning Disorders seem to be characterized by different behavioral but similar neuropsychological (Willcutt et al., 2013) and brain activity profiles (Peters et al., 2018). For this reason, the concept of "specific" learning disorders, affecting one learning domain only, is seriously called into question (APA, 2013).

Besides heterogeneous cognitive profiles, children with SLD may exhibit high levels of academic anxiety, including MA and test anxiety (Cassady, 2022), combined with low self-concept as a secondary reaction to experienced academic difficulties or because of school challenges (Haft et al., 2019; Novita, 2016; Terras et al., 2009). Regarding MA, some discrepancies in the presence of the trait MA component in children with SLD have emerged in the literature, with some studies suggesting higher levels of trait MA in SLD (Lai et al., 2015; Passolunghi, 2011), while others indicate similar levels in children with and without math difficulties (Mutlu, 2019; Wigfield & Meece, 1988). Math performance and associated cognitive and emotional mechanisms have also been explored in both developmental dyscalculia and dyslexia, with results showing that individuals with these conditions are at a higher risk of failure in math. There is also evidence that other factors, such as anxious thoughts and feelings, can increase this risk (Kucian et al., 2018; Mammarella et al., 2015; Rubinsten & Tannock, 2010).

However, to the best of our knowledge, no studies have employed an experimental task to distinguish between state and trait MA in children with SLD. Therefore, further research is necessary to unravel which type of anxiety exerts a more significant influence on mathematical performance in this population.

1.5. The present study

To the best of our knowledge, a comprehensive study seeking to clarify the impact of *trait MA* on math performance in children with SLD compared to children with no-diagnosis, and also examining emotional and cognitive components during real-time math assessments (*MA-state measures*), has never been done. The novelty of the present study lies in two aspects. The first one is that a group of children with SLD, with major impairments in both reading and math abilities, has been selected to explore MA in a systematic way, by evaluating both trait and state MA measures, and their role in mathematics performance. The second aspect is related to the computerized timed math task implemented in this study, which is believed to elicit a stress response due to time constraints (similar to those usually faced by students at school), with the aim of examining state components of MA (valence, arousal, worries), and perceived competence.

We tested children aged between 8 and 14 years old with SLD and ND using a questionnaire on trait MA (AMAS; Hopko et al., 2003) and a time-pressure math task. We also evaluated the role of MA-state measures before (baseline) and after the math task (task-related), distinguishing between affective (valence, arousal) and cognitive (worries) components of MA, in addition to perception of competence.

As concerns trait MA, based on the literature, it seemed reasonable to hypothesize that higher levels of trait MA would be consistent with worse performance on the math task, both in children with (Kucian et al., 2018; Mutlu, 2019; Rubinsten & Tannock, 2010) and without SLD (Carey et al., 2016).

Regarding state measures (MA-state measures and perceived competence), we expected an intermediate level of arousal and worries to be associated with better math performance under pressure in ND children. This is because concerns might motivate students to try harder (Kellogg et al., 1999; Maloney et al., 2014; Wigfield & Meece, 1988), aligning with evidence suggesting that optimal efficiency is reached with an intermediate level of stress (Yerkes & Dodson, 1908). On the other hand, lower levels of valence and perceived competence may be linked to lower scores on the math test (Ganley & Lubienski, 2016; Ganley & Vasilyeva, 2011; Jansen et al., 2013). Although no previous studies have applied time constraints to a math task with children with SLD, we predicted that lower arousal, valence, and worries could be linked to decreased perceived competence and self-expectations. This, in turn, might be consistent with lower achievement in the math task, as compared to ND participants (Ho et al., 2000; Wigfield & Meece, 1988).

2. Method

2.1. Participants

The study involved 112 children and adolescents aged between 8 and 14 years old divided into two groups: 56 (33 M) with Specific Learning Disorders (SLD), and 56 (28 M) matched ND comparisons. The two groups did not differ statistically in chronological age [$F\ (1,\ 110) = 1.00$, $p = .32$, $Cohen's\ d = -0.19$], gender distribution [$X^2 = 0.90$, $df = 1$, $p = .34$], or total IQ [$F\ (1,\ 110) = 1.72$, $p = .20$, $Cohen's\ d = -0.25$]. The sample has been recruited from clinical centres (SLD) and schools (ND).

The clinical group was assessed at the child and adolescent psychiatric service centers to which they had been referred. After explaining the research project to the directors of the clinical center, they contacted the families of children with SLD, inquiring about their potential interest and willingness to participate. If affirmative, permission is sought to share the contact information with the experimenter. All participants in the clinical group had been previously diagnosed with SLD, according to the DSM-IV-TR, the DSM-5 (APA, 2000, 2013) or ICD-10 (WHO, 1992) criteria, with major impairments in both reading and math abilities. Diagnoses of SLD were also confirmed by implementing some age-appropriate subtests that evaluated reading and math competencies, such as reading lists of words and pseudo-words (MT-Avanzate-3, Cornoldi et al., 2017; DDE-2, Sartori et al., 2007) and mental calculation (AC-MT-3, Cornoldi et al., 2020; MT-Avanzate-3, Cornoldi et al., 2017).

The control group comprised healthy children without any diagnosis (ND) of psychiatric, neurological, or neurodevelopmental disorders. They were engaged and examined individually at their respective schools during regular school hours, outside the classroom, so as not to disturb the continuation of the lesson. ND children came from different classes of different schools situated in a middle socioeconomic area. A first contact with school principals was planned for the initial acceptance of the research, during which the study was presented in detail (objectives, method, materials, and experimental procedure). Informed consent forms were distributed to teachers, who then handed them to parents through the students and signed them before the start of the project.

Participants taking medication, having other known genetic conditions, a history of neurological diseases, comorbid psychopathologies, or certified physical and intellectual disabilities were excluded. All children and adolescents were native Italian speakers, and none had any visual or hearing impairments. Participants of both groups were included in this study only if they achieved a standard score of 80 or more for the abbreviated version of IQ on the Wechsler Intelligence Scales (WISC IV; Wechsler, 2003).

The two groups differed statistically in both reading (errors and speed – measured in syllables per second (syll/s) - in words and pseudo-words) and math (mental calculation accuracy and response times) subtests, with the SLD group showing greater impairment than the ND group. A summary of the participants' characteristics is shown in Table 1.

2.2. Questionnaires

2.2.1. General trait anxiety

The parents' version of the Multidimensional Anxiety Scale for Children (MASC-2; March, 2012) was administered. It is a 50-item questionnaire that evaluates the presence of anxiety, including a total score and six subscales: Separation Anxiety, Generalized Anxiety Disorder, Social Anxiety (composed by Humiliation/Rejection, and Performance Fears), Obsessions and Compulsions, Physical Symptoms (composed by Panic, and Tense/Restless), and Harm Avoidance. The rating scale ranges from 0 ("never") to 3 ("often"). Raw scores are converted into T scores using normative data that considers the child's age and gender. This tool also features an Inconsistency Index that identifies possible unreliable ratings by comparing scores on eight item-pairs with the highest bivariate inter-item correlations from the development sample. In this study, the total T score has been considered. Moreover, additional analyses reported in the supplementary materials (see Table S2) include the child (self-report) version of the MASC-2, which is structured identically to the parents' version. For our sample, Cronbach's α (parents' version) = 0.89 [C.I. = 0.88–0.91]; Cronbach's α (children's version) = 0.90 [C.I. = 0.89–0.91].

2.2.2. Trait mathematics anxiety

Children were asked to complete the Abbreviated Math Anxiety Scale (AMAS; Hopko et al., 2003), which includes nine Likert-type items

Table 1
Descriptive statistics and statistical analyses for individuals with Specific Learning Disorders (SLD) and those with no diagnosis (ND).

Measures	SLD (n = 56)		ND (n = 56)		*F* *(1, 110)*	*p*	*Cohen's d*
Gender M:F	33:23		28:28				
	M	*SD*	*M*	*SD*			
Age	12.38	1.55	12.67	1.60	1.00	0.32	−0.19
IQ	105.96	9.14	108.14	8.41	1.72	0.20	−0.25
Reading (z-score)							
Words (errors)	2.45	1.04	0.26	0.87	144.40	**<0.001**	2.27
Words (syll/s)	−1.95	1.05	−0.47	0.90	64.34	**<0.001**	−1.52
Pseudo-words (errors)	1.51	1.39	−0.11	0.82	57.37	**<0.001**	1.43
Pseudo-words (syll/s)	−1.55	0.86	−0.48	0.88	42.53	**<0.001**	−1.23
Math (z-score)							
Mental calculation (accuracy)	−1.07	1.09	0.12	0.96	37.12	**<0.001**	−1.15
Mental calculation (response times)	1.42	1.25	0.36	1.02	24.05	**<0.001**	0.92

Note: All reading, and math subtests are expressed in standardized z scores. SD: standard deviation; IQ: intelligence quotient. On words and pseudo-words tasks, the time was measured based on the number of syllables read aloud per second (syll/s) based on normative data (z-scores). Statistically significant values are in bold.

ranging from 1 ("strongly disagree") to 5 ("strongly agree") related to feelings towards mathematics, specifically regarding worries, negative thoughts, and affective dispositions. Higher scores on the scale indicate higher levels of MA. We administered the Italian version of the AMAS (Caviola et al., 2017). Based on the current sample, Cronbach's α = 0.83 [C.I. = 0.80–0.84].

2.3. Experimental materials

2.3.1. Math task

This task, adapted from Caviola and colleagues (Caviola et al., 2016, 2018), was a computerized mental calculation task whose purpose was to induce a consistent stress response due to the presence of time constraints. The task consisted of 60 multiple-choices trials (plus three practice trials with feedback) presented in two blocks of 30 trials each: the first block involved simple two-digit additions (without carrying), and the second involved simple two-digit subtractions (without borrowing). The operations to be solved appeared at the top of the display with three answer options arranged horizontally underneath. Participants had to choose the correct answer among the three alternative choices (the correct answer, the correct answer plus or minus 1, and the correct answer plus or minus 10). The order of the three possible answers was counterbalanced to control for potential order effects or sequence effects that may confound the results. Participants had to press a keyboard key based on the position on the screen of the answer they wanted to select ("z" for the left choice, "v" for the one in the middle, and "m" for the right one). Time pressure was induced by the presence of a countdown clock that marked the time on the left-bottom side of the screen: participants had to solve the operations within the time limit of 10 seconds. If the time ran out, the program automatically moved on to the next operation. Accuracy and response times (RTs) were recorded for each operation. RTs were defined as the time lapsing between the appearance of the operation on the screen and the moment an answer was selected. However, only accuracy was taken into account in the statistical analyses since the time constraint procedure prevented us from obtaining reliable reaction times. Cronbach's α (computed using the polychoric correlation matrix for binary data) = 0.91 [C.I. = 0.88–0.94].

2.3.2. State measures

Children were also asked to report state aspects related to their subjective experience of the stressful math test. To do so, they were administered with self-report measures, before and after completing the task: emotional responses (arousal and valence) were measures using the Self-Assessment-Manikin scale (SAM; Bradley & Lang, 1994; Lang, 1980), whereas cognitive responses (worries) and perceived competence were assessed through an ad-hoc questionnaire (derived from Mammarella et al., 2023). Aspects reported before starting the task are consistent with participants' disposition in anticipation of the task (*baseline* measures), whereas those reported after finishing the task relate to emotions and thoughts experienced during execution of the same (*task-related* measures). In theory, the change from the baseline (i.e., the children are informed that they will perform a math test) to the task completion (i.e., the children concretely complete the task) represents the state MA. The two self-report measures administered before and after the task are described below. Materials are also available on OSF: https://osf.io/eqa8k/?view_only=93243d88160d4aeea3b2f9791f963440.

2.3.2.1. MA-state measures. Both emotional (arousal, valence) and cognitive (worries) components, were assessed to evaluate state responses to the stressful math task.

2.3.2.1.1. Emotional responses: arousal and valence. The Self-Assessment-Manikin scale (SAM; Bradley & Lang, 1994; Lang, 1980) is a culture-free assessment technique that assesses three aspects associated with a person's affective reaction to a wide variety of stimuli: *arousal* (from 1 = "calm/bored" to 9 = "arousing/nervous"), *valence* (from 1 = "unpleasant/negative" to 9 = "pleasant/positive") and *dominance* (from 1 = "out of control" to 9 = "under control"). Participants were asked to rate their emotional state after being asked, "How do you feel now? Please sign the point that better represents your emotional state", by choosing among non-verbal pictorial stimuli representing a 9-point dimensional scale. On the *arousal* scale, at one end is a sleeping manikin, while at the opposite end, an awakened jumping figure. On the *valence* scale, a manikin smiling at one extreme, contrasting with a frowning expression at the other. The *dominance* scale illustrates submission through a small manikin and dominance through a larger one (McManis et al., 2001). For the purpose of this study, only arousal and valence were administered and taken into account in the statistical analyses, since they are recognized as primary dimensions accounting for most of the variance in emotional judgments (Bradley & Lang, 1994). The SAM has been commonly used with Italian samples (Mammarella et al., 2023; Montefinese et al., 2014; Palomba et al., 2000), exhibiting good validity (Bynion & Feldner, 2020). In fact, correlations between SAM and a semantic differential method of affective rating were 0.94 for arousal and 0.97 for pleasure (Bradley & Lang, 1994); good reliability was also found in children's ability to make dimensional ratings of their emotional responses (McManis et al., 2001).

2.3.2.1.2. Cognitive responses: worries. In addition to participants' affective state, worries were also assessed through the administration of an ad-hoc questionnaire (derived from Mammarella et al., 2023) before and after finishing the math task. The questionnaire consisted of six questions about the participants' worries about the task. An example is: "During the math task, were you worried about your performance?". The child had to answer using a 4-point Likert scale from 1 ("not at all") to 4 ("a lot"), and the total score was considered. Higher scores were consistent with higher levels of worries. Cronbach's α based on the current sample was 0.81 [C.I. = 0.75–0.86] for baseline responses, and 0.89 [C.I. = 0.85–0.92] for task-related responses.

2.3.2.2. Perception of competence. Perceived competence was also assessed through the administration of a brief questionnaire composed by six questions (derived from Mammarella et al., 2023) before and after finishing the math task. An example of item is: "Do you think you were good at taking the math test?". Also in this case the child had to answer using a 4-point Likert scale from 1 ("not at all") to 4 ("a lot"), and the total score was considered. Higher scores were consistent with higher levels of perceived competence. Cronbach's α based on the current sample was 0.89 [C.I. = 0.86–0.92] for baseline responses, and 0.88 [C.I. = 0.84–0.91] for task-related responses.

2.4. Procedure

The study was approved by the research ethics board of the authors' institution and adheres to APA ethical standards. After obtaining written consent from the children's parents for their participation in the study, the participants were individually tested in a quiet room at specialized centers (SLD) or at school (ND) during two sessions, each lasting approximately 40 min. In the screening phase, the abbreviated IQ test was administered, and only participants who scored above 80 were included. Participants also completed specific subtests on reading and math competencies to confirm (or exclude in the case of ND) the diagnosis of SLD. The experimental phase included the questionnaire on general trait anxiety (MASC-2; children's version), trait MA (AMAS) and the math task, which also involved state measures of valence, arousal, worries, and perceived competence. The tasks in the experimental session (AMAS and the math task with state measures) were presented in a counterbalanced order. At the same time, parents completed the MASC-2 (parents' version) to assess the child's general trait anxiety. The experimenter provided instructions for each task, allowing the participant to practice before starting the experiment. The math task was created and administered using PsychoPy3 (Peirce et al., 2019) and a laptop computer with a 15-inch LCD screen.

Upon completion of the project, families and teachers could receive, upon request, a final report with scores presented individually (for parents) and aggregated (for schools), along with an interpretation that did not have any clinical-diagnostic purpose.

2.5. Statistical approach

Descriptive statistics of the measured variables and partial correlation analyses, divided by group (SLD and ND), are presented in Table S1 (Supplementary materials). Pearson's correlation analyses have been performed to analyze the association between the measured variables. Henceforth, the reference to state measures includes arousal, valence, worries and perceived competence, while when MA-state measures are mentioned, we refer to both emotional (arousal, valence) and cognitive (worries) components, excluding perceived competence.

Data were analyzed adopting a generalized linear mixed-effects approach fit by maximum likelihood, which incorporates both fixed-effects parameters and random effects in a linear predictor (McCulloch & Searle, 2004). Mixed models are an extension of regular regression models that allow response variables from different distributions, such as binary responses, and include random-effects parameters to account for dependencies among related data points (Singmann & Kellen, 2019). A logistic mixed-models approach was used to investigate the association between the dependent variable (math task) and the hypothesized predictors (Jaeger, 2008; Singmann & Kellen, 2019), with the function family as binomial, given that responses on the math task are correct (1) or incorrect (0). Estimate coefficients of mixed-models logistic regressions are unstandardized and on the logit scale. Participants and single operations were included as random effects to consider their variability in each mixed-effects model. The modes of the random effects are displayed in Fig. S1 (Supplementary materials).

A hierarchical method was adopted to understand the contribution of each variable in predicting success in the timed math task. In the first model we included control variables as fixed effects (i.e., age, general trait anxiety, baseline arousal, valence, worries, and perceived competence). Baseline arousal, valence, worries, and perceived competence are intended to capture state measures in anticipation to the task, thus we are controlling for their contribution in the first step. In the second model we included all these plus the group. In the third model trait MA was added. In the fourth model we included self-reported evaluations of task-related arousal, valence, worries, and perceived competence, as state measures experienced during execution of the task. To test our initial hypotheses, the interactive effect of the group (i.e., SLD, ND) with *trait* MA and task-related arousal, valence, worries, and perceived competence (*state* measures) will be included in the fifth and last model. The hierarchical approach allows us to isolate the unique contribution of subsequent variables and understand the incremental contribution of each set of variables to the overall explanation of the dependent variable. This is done to determine whether the relationship between fixed effects and the mathematics performance differs when considering the groups separately (SLD, ND) rather than the total sample. By considering the baseline state measures as control variables, we will include their variance in our hierarchical regression model to ensure that we statistically (and theoretically) account for the contribution of baseline state measures in predicting mathematical performance. In this way, we are going to examine the relationship between task-related MA and the dependent variable while holding the baseline state measures constant, avoiding the potential confounder of the anticipation of the challenge. Indeed, in our view, the change from the baseline (i.e., when children are informed that they will perform a math test) to the task completion (i.e., when children concretely complete the task) essentially represents the state MA.

The same analyses with a generalized linear mixed-effects approach have been run by including the child (self-report) version of the MASC-2 as general trait anxiety and have been reported in the Supplementary materials (see Table S2). Moreover, the Supplementary materials section (see Table S3) includes the model with all predictors without controlling for baseline state measures (baseline arousal, valence, worries, and perceived competence).

The significance and goodness of fit of each regression model was examined by likelihood ratio tests based on the chi-square distribution (Pinheiro & Bates, 2000), which is useful to compare the fit of two nested models (Pavlov et al., 2020). Moreover, the best model was selected from the set of models used for testing by applying information-theoretic (I-T) approaches, considering the Akaike information criterion (AIC) of each model (Burnham et al., 2011). AIC is an estimator of prediction error and thereby the relative quality of statistical models for a given set of data. The values of AICs were computed for each model: given a set of candidate models, the preferred model is the one with the minimum AIC value, because it maximizes the estimated information loss. The log-likelihood value of each model was also reported as a measure of goodness of fit; the higher the value, the better the model (Dobson & Barnett, 2018). Finally, the conditional R^2 of the best-fitting model was reported as a proportion of total variance explained through both fixed and random effects (Nakagawa & Schielzeth, 2013).

Data were analyzed using R version 1.3.1093 (R Core Team, 2022). The "psych" (Revelle, 2021), "lavaan" (Rosseel, 2012), and "semTools"

(Jorgensen et al., 2018) packages were used to calculate the reliability of each measure. The “lme4” (Bates et al., 2015) and “glmmTMB” (Brooks et al., 2017) packages were used to run the generalized linear mixed regressions and compute the AIC indexes. We used the “lmtest” package to compute the likelihood ratio test for the significance and goodness of fit of regression models (Hothorn et al., 2015). The “ggplot2” package was used to obtain the graphical effects (Wickham, 2016). The “lattice” package (class ranef.lme) was used to plot the random effects from the mixed effects model (Sarkar, 2008). The dataset is available on OSF: https://osf.io/eqa8k/?view_only=93243d88160d4aeea3b2f9791f963440.

3. Results

3.1. Generalized linear mixed-effects models

To investigate the association between math performance and the measured variables, we followed the aforementioned model selection strategy. As shown in Table 2, the first step included the control variables (age, general trait anxiety, baseline arousal, valence, worries, and perceived competence), and had the highest AIC and the lowest log-likelihood value ($AIC = 6301.7$, $logLik = -3141.9$). The second model was statistically significant in comparison to the first one, $\chi 2(1) = 55.30$, $p < 0.001$, with a statistically significant effect of the group, $z = -8.44$, $p < 0.001$, while reducing the AIC and increasing the log-likelihood value of the model ($AIC = 6248.4$, $logLik = -3114.2$). In the third

Table 2
Generalized linear mixed-effects regression models with mathematics performance as dependent variable.

Fixed effects	*Estimate coefficient*	*95 % [C.I.]*	*SE*	*z value*	*p*
Model 1					
Age	**0.01**	**[0.005, 0.03]**	**0.005**	**3.01**	**0.002**
General trait anxiety	−0.008	[−0.02, 0.006]	0.007	−1.16	0.25
Baseline arousal	0.01	[−0.08, 0.10]	0.05	0.25	0.80
Baseline valence	0.04	[−0.06, 0.14]	0.05	0.84	0.40
Baseline worries	0.01	[−0.04, 0.07]	0.03	0.56	0.57
Baseline perceived competence	0.04	[−0.008, 0.08]	0.02	1.60	0.11
Model 2					
Age	**0.01**	**[0.004, 0.02]**	**0.004**	**2.87**	**0.004**
General trait anxiety	−0.001	[−0.01, 0.01]	0.006	−0.08	0.94
Baseline arousal	0.001	[−0.07, 0.07]	0.03	0.05	0.96
Baseline valence	0.04	[−0.03, 0.12]	0.04	1.13	0.26
Baseline worries	−0.01	[−0.05, 0.03]	0.02	−0.60	0.55
Baseline perceived competence	0.02	[−0.01, 0.06]	0.02	1.33	0.18
Group	**−1.22**	**[−1.49, 0.45]**	**0.14**	**−8.44**	**<0.001**
Model 3					
Age	**0.01**	**[0.003, 0.02]**	**0.004**	**2.86**	**0.004**
General trait anxiety	−0.001	[−0.01, 0.01]	0.005	−0.11	0.91
Baseline arousal	0.01	[−0.06, 0.08]	0.04	0.36	0.72
Baseline valence	0.05	[−0.03, 0.13]	0.04	1.26	0.20
Baseline worries	−0.005	[−0.05, 0.03]	0.02	−0.28	0.78
Baseline perceived competence	0.02	[−0.01, 0.06]	0.02	1.19	0.23
Group	**−1.18**	**[−1.46, −0.90]**	**0.14**	**−8.24**	**<0.001**
Trait MA	−0.02	[−0.04, 0.003]	0.01	−1.66	0.10
Model 4					
Age	**0.01**	**[0.005, 0.02]**	**0.004**	**3.25**	**0.001**
General trait anxiety	0.001	[−0.009, 0.01]	0.005	0.15	0.88
Baseline arousal	−0.005	[−0.07, 0.07]	0.04	−0.13	0.89
Baseline valence	0.009	[−0.07, 0.09]	0.04	0.23	0.82
Baseline worries	0.001	[−0.04, 0.04]	0.02	0.008	0.99
Baseline perceived competence	−0.009	[−0.05, 0.03]	0.02	−0.48	0.63
Group	**−1.05**	**[−1.33, −0.77]**	**0.14**	**−7.42**	**<0.001**
Trait MA	**−0.02**	**[−0.05, −0.003]**	**0.01**	**−2.23**	**0.02**
Task-related arousal	0.04	[−0.02, 0.11]	0.03	1.35	0.17
Task-related valence	0.03	[−0.05, 0.12]	0.04	0.74	0.46
Task-related worries	−0.004	[−0.04, 0.03]	0.02	−0.23	0.82
Task-related perceived competence	**0.07**	**[0.02, 0.11]**	**0.02**	**3.14**	**0.002**
Model 5					
Age	**0.01**	**[0.005, 0.02]**	**0.004**	**3.41**	**<0.001**
General trait anxiety	0.001	[−0.009, 0.01]	0.005	0.06	0.95
Baseline arousal	−0.001	[−0.07, 0.07]	0.03	0.002	0.99
Baseline valence	−0.02	[−0.09, 0.06]	0.04	−0.45	0.65
Baseline worries	−0.01	[−0.06, 0.03]	0.02	−0.59	0.55
Baseline perceived competence	−0.008	[−0.04, 0.03]	0.02	−0.47	0.63
Group	−0.77	[−2.64, 1.13]	0.96	−0.78	0.43
Trait MA	**−0.03**	**[−0.06, −0.002]**	**0.02**	**−2.07**	**0.04**
Task-related arousal	−0.06	[−0.17, 0.06]	0.06	−0.94	0.35
Task-related valence	−0.04	[−0.19, 0.10]	0.07	−0.59	0.55
Task-related worries	**0.07**	**[0.01, 0.12]**	**0.03**	**2.48**	**0.01**
Task-related perceived competence	**0.12**	**[0.05, 0.19]**	**0.04**	**3.34**	**<0.001**
Group * Trait MA	0.02	[−0.02, 0.06]	0.02	0.87	0.38
Group * Task-related arousal	**0.17**	**[0.03, 0.30]**	**0.07**	**2.47**	**0.01**
Group * Task-related valence	0.12	[−0.05, 0.29]	0.08	1.35	0.18
Group * Task-related worries	**−0.11**	**[−0.17, −0.04]**	**0.03**	**−3.39**	**<0.001**
Group * Task-related perceived competence	−0.07	[−0.15, 0.007]	0.04	−1.79	0.07

Note: Trait MA, Trait mathematics anxiety. Statistically significant values are in bold.

Table 3
Model comparisons on goodness of fit.

Models	*χ2*	*df*	*p*	*AIC*	*logLik*
Model 1	–	–	–	6301.7	−3141.9
Model 2	55.30	1	**<0.001**	6248.4	−3114.2
Model 3	2.72	1	0.10	6247.7	−3112.8
Model 4	11.96	4	**0.02**	6243.7	−3106.9
Model 5	18.64	5	**0.002**	6235.1	−3097.6

Note: AIC, Akaike Information Criterion; logLik: log-likelihood. Statistically significant values are in bold.

step, we added trait MA, which had no statistically significant effect on the model, $\chi2(1) = 2.72$, $p = 0.10$; $AIC = 6247.7$, $logLik = -3112.8$. The fourth step, in which we included task-related arousal, valence, worries, and perceived competence, was statistically significant compared to the previous one, $\chi2(4) = 11.96$, $p = 0.02$; $AIC = 6243.7$, $logLik = -3106.9$, with a statistically significant main effect of group, $z = -7.42$, $p < 0.001$, trait MA, $z = -2.23$, $p = 0.02$, and task-related perceived competence, $z = 3.14$, $p = 0.002$.

Finally, our model fitting procedure revealed that the best-fitting model was Model 5 (see Tables 2 and 3), which included the following predictors: Age + General trait anxiety + Baseline arousal + Baseline valence + Baseline worries + Baseline perceived competence + Group + Trait MA + Task-related arousal + Task-related valence + Task-related worries + Task-related perceived competence + Group * Trait MA + Group * Task-related arousal + Group * Task-related valence + Group * Task-related worries + Group * Task-related perceived competence. This last step denoted the best-fitting model, $\chi2(5) = 18.64$, $p = 0.002$, while having the minimum AIC and the maximum log-likelihood value, $AIC = 6235.1$, $logLik = -3097.6$. Our variables together accounted for 24 % of the variance calculated using the conditional R-squared for both fixed and random effects.

As regards the main effects, age, $z = 3.41$, $p < 0.001$, trait MA, $z = -2.07$, $p = 0.04$, task-related worries, $z = 2.48$, $p = 0.01$, and task-related perceived competence, $z = 3.34$, $p < 0.001$, were significantly associated with math performance: higher age, task-related worries, and task-related perceived competence were related to a better math performance, whereas higher levels of trait MA were linked to a worse math performance in the total sample.

Moreover, two interaction effects were found to be statistically significant: the interaction between group and task-related arousal, $z = 2.47$, $p = 0.01$, and between group and task-related worries, $z = -3.39$, $p < 0.001$. More specifically, as Fig. 1 shows, higher levels of task-related arousal were consistent with a better math performance in the SLD group, but not in the ND group. Instead, higher levels of task-related worries were related to a better math performance in the ND group, but not in the SLD group, where higher levels of task-related worries were predictive of lower scores on the math task.

No other statistically significant main or interactive effects emerged.

4. Discussion

The aim of this study was to investigate trait MA, MA-state measures (cognitive and emotional responses), and perceived competence reported during real-time math assessment in children between 8 and 14 years old with Specific Learning Disorders (SLD) with major impairments in reading and math abilities, compared to matched non-diagnosed (ND) participants. Specifically, we planned to investigate whether trait MA and state measures could predict performance in a real-time math task in the two groups, after controlling for age, general trait anxiety, and baseline measures. In regard to MA-state measures, the focus was given to task-related affective (i.e., arousal, valence) and cognitive (i.e., worries) components, in addition to perceived competence. To the best of our knowledge, no previous studies have explored the construct of MA as a whole by considering both trait and state self-reports, and also examining the complex interplay between thoughts, worries and emotions related to an experimental stressful math task in children with and without SLD. The focal point of the discussion will be on protective and risk factors which may intervene while performing mental calculations in a real-time math task.

Our findings confirm the first hypothesis regarding the relationship between trait MA and math performance. A statistically significant principal effect indicates that higher reported levels of trait MA were consistently associated with a lower probability of success on the mental calculation task in both children with and without SLD. This aligns with previous research emphasizing MA as a robust predictor of poor math performance (Barroso et al., 2021; Caviola et al., 2022; Namkung et al., 2019). While different profiles have been identified by considering the

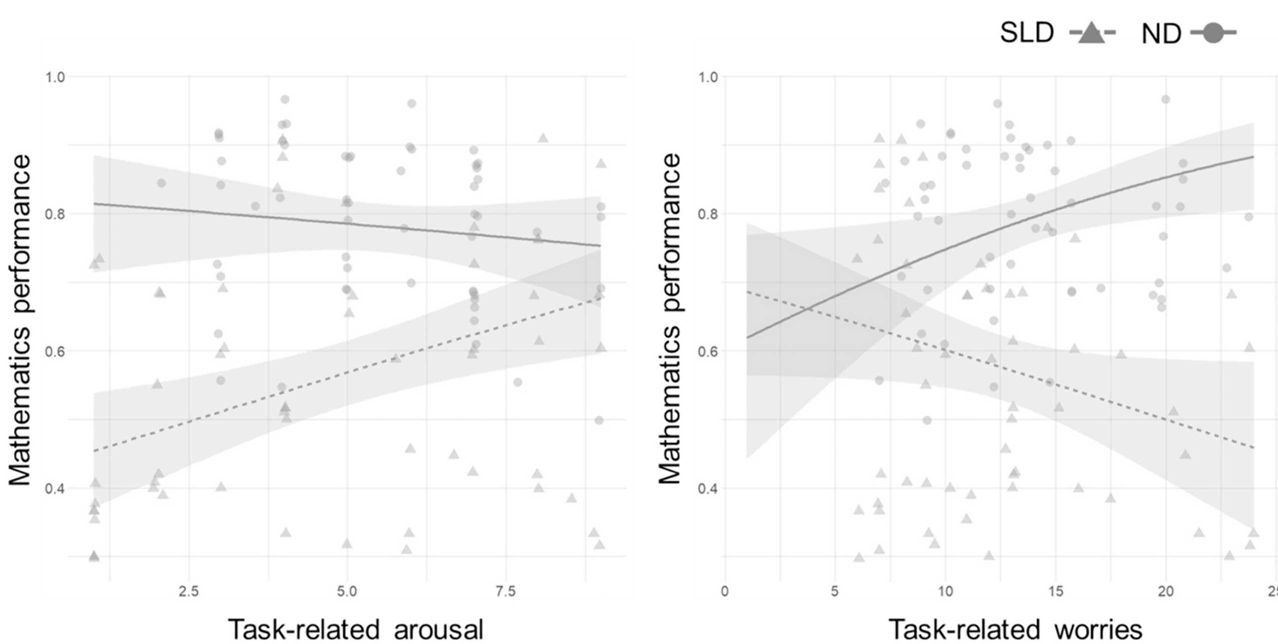

Fig. 1. Significant interaction effects of Group * Task-related arousal (left panel), and Group * Task-related worries (right panel) of the best-fitting model with mathematics performance as a dependent variable. Error bands represent 95 % confidence intervals.

presence of dyscalculia without MA, MA alone, or both dyscalculia and MA (Mammarella et al., 2015), our study underscores the importance of moving beyond the use of retrospective trait-like questionnaires. Authors have advocated for assessing emotions, thoughts, and worries that emerge during anxiety-inducing mathematics tasks (Cipora et al., 2022; Pizzie & Kraemer, 2021), particularly when evaluating the internal states of children with difficulties in math learning and testing. Their underlying cognitive and affective processing may differ from those who are not particularly challenged in this subject. In this sense, trait-like self-reports on MA might not fully capture the real emotional and cognitive load that could arise during the execution of mental calculations (Orbach et al., 2020). Indeed, while trait MA has been shown to predict math performance in the whole sample, differences (as well as similarities) between children with and without SLD emerged when addressing state mechanisms prompted by a real-time math assessment.

After controlling for age, general anxiety, and baseline state measures, a significant principal effect on math achievement emerged for the task-related perception of competence. Consideration of a bidirectional relationship is warranted. The positive association between math performance and perceived competence reveals a heightened awareness of one's own math abilities in school-aged children. This suggests a protective role of perceived competence on academic achievement, as feeling competent may lead to stronger efforts in math tasks, increased motivation, determination, and the implementation of better metacognitive strategies (Jansen et al., 2013; Marsh & Martin, 2011; Živković et al., 2022). Universally, the literature recognizes that perceived math competence positively correlates with math performance (Lee, 2009). This is also confirmed in our SLD and ND groups. However, when facing academic challenges, children are not only influenced by their abilities and perceptions but also by their emotional and cognitive reactions.

In terms of the differences between groups in the association between state MA components and performance, our findings indicate that children with SLD may specifically experience negative feelings related to math, which are then expressed through particular affective and cognitive responses (Dowker et al., 2016; Ho et al., 2000; Wigfield & Meece, 1988). Indeed, distinct patterns emerged in children with and without SLD: two statistically significant interaction effects occurred between group membership and the task-related arousal (affective) and worries (cognitive) components. It is essential to note that while the results are interesting and offer various points for reflection, they must be interpreted with caution given the small-to-moderate effect sizes of the differences between the groups.

For children with SLD, higher perceived arousal during the mental calculation task was consistent with better performance. This finding could be interpreted as confirmation that the physiological state represented by the reported arousal might be both protective and predictive of success in time-pressure math tasks. The link between physiological activity and motivational states, specifically threat and challenge, has been recognized in the literature (Seery, 2011). Contrary to threat, arousal associated with challenge does not denote a negative state, and it is traditionally linked to performance improvement, indicating that the body is allocating resources to meet the task demands. Emotional and motivational factors can indeed affect performance via the establishment of cognitive processes (Eysenck, 2012). In this sense, regulatory efforts expressed by a natural heightened excitement might help children with SLD to optimize stress responses to achieve positive benefits for their performance (Jamieson et al., 2010, 2022). On the contrary, reduced arousal during the execution of a math task in children with SLD could be interpreted as poor motivation, resignation, and awareness of one's own weaknesses (Cipora et al., 2022; Putwain et al., 2013; Tamir et al., 2015). Physiological activation could therefore represent a personal resource that helps in the execution of demanding tasks: those who feel activated perform better than those who are not motivated at all in succeeding. Interestingly, while the relationship does not appear for participants with ND, this group reported greater levels of physiological excitement than those with SLD (though not a statistically significant difference) and superior accuracy in the task, which might corroborate the idea of a positive relationship between arousal and math achievement. It is worth noting that we found no significant relationship between arousal and performance in the ND group probably because the task was not perceived as excessively difficult, but rather appropriate to their math abilities.

In regard to the cognitive MA component, our findings revealed that higher levels of task-related worries are associated with worse math performance in children with SLD but with better math achievement in those without SLD. As for children with SLD, it might be that worries interfere with attentional resources, leading to impaired functioning, and thus cognitive resources (e.g., working memory) cannot be optimally used when performing stressful real-time math tasks (Ashcraft & Kirk, 2001; Eysenck & Calvo, 1992; Mammarella et al., 2015). Moreover, self-deprecating thoughts and concerns may distract from thinking about important math-related features, focusing instead on irrelevant information (Beilock, 2008; Beilock & DeCaro, 2007), especially in children with learning difficulties. Contrary to the affective component of MA (i.e., arousal), the cognitive one (i.e., worries) might represent a risk factor for math achievement in children with SLD, surpassing the beneficial effects of emotional arousal that are thus overshadowed by the prevailing association between cognitive anxiety and performance (Ho et al., 2000; Wang et al., 2015). Contrariwise, worries might be a protective aspect for children with typical development, encouraging them to give the best of themselves and achieve their goal, especially when tasks are not difficult to solve (Evans, 2000; Wang et al., 2015). Moreover, it is worth hypothesising that average working memory skills in non-diagnosed children may not have been impacted by worrying thoughts as occurred in participants with SLD (Beilock, 2008; Eysenck & Calvo, 1992; Mammarella et al., 2015). In the ND group, both preserved mathematical competences and working memory, combined with worries interpreted as motivational thoughts, might have facilitated, but also motivated, their success (Lyons & Beilock, 2012; Tsui & Mazzocco, 2006). In other words, the concerns, elicited by the timed condition and acting as the cognitive component of MA, may stimulate a better performance, given the age-appropriate mathematical competence and the presumed average cognitive skills.

4.1. Limitations and future directions

The present study, despite its novelty, is not without limitations, which should be considered in the formulation of future lines of research.

First, the sample size is relatively small, given the very restrictive inclusion and exclusion criteria applied and the delicate balance required between the availability of clinicians and families for data collection. Second, the clinical sample consisted of children with SLD with major impairments in both reading and math abilities, rather than children with math-specific difficulties. Combining participants with dyslexia and dyscalculia may introduce a confound, as their different academic profiles could have distinct influences on the performance in the math task (Moll et al., 2015).

As regards the math task, in the present study a computerized mental calculation task with time constraint and multiple-choice responses was employed. However, future research should implement a production task without response options, to reduce limitations of the verification task, such as the possibility to guess the correct response, or to realize the way in which multiple choices were chosen. In addition, the study did not include a control condition with a math task without time constraints, making it challenging to conclude that emotional and cognitive state measures are strictly related to the time-pressure condition. However, we controlled for age, general anxiety, and baseline measures, so we could have a valuable "real-time" measure of state emotions and thoughts associated with the task. Moreover, based on literature research, time pressure places constraints on the capacity for thought and action and elicits a well-established anxious state (Moore & Tenney, 2012).

Regarding the assessment of trait MA, a limitation is that the study considered it as a unitary construct, not investigating its multidimensionality (e.g., worries, emotionality), as was done for MA-state measures. Future studies should aim to develop a trait MA-questionnaire that investigates the emotional and cognitive components of MA, or at least assesses the same components across both trait and state MA. Concerning state measures, it is worth noting that the self-reports used may not comprehensively capture all the variables that can influence MA as a holistic concept. Future research should focus on additional aspects that could contribute to either heightening or diminishing levels of MA, such as students' attitudes towards mathematics, motivation, enjoyment, and self-efficacy. In this way, researchers can gain a comprehensive understanding of the multifaceted nature of MA and its impact on individuals' cognitive and affective responses in mathematical contexts.

In addition, the study did not include measures of working memory, so the interpretation that working memory skills in non-diagnosed children may have prevented worries from having a negative impact on their performance should be examined further in future research.

Additionally, the study did not measure psychophysiological indexes (e.g., electrodermal and cardiac activity), which might be registered while performing math tasks and serve as objective real-time measures of MA emotional components. Psychophysiological indexes may aid in better understanding how vagal activity and physiological arousal might intervene in the relationship between levels of MA and behavioral outcomes (Hunt et al., 2017; Levy & Rubinsten, 2021; Mammarella et al., 2023; Pizzie & Kraemer, 2021). Future research focusing specifically on the arousal-performance relationship will also need to consider the nonlinear dynamics, based on the optimal arousal hypothesis (Yerkes & Dodson, 1908), through alternative analytic approaches. Moreover, children might find difficulties in reporting emotions closely associated with bodily signals, such as somatic arousal under pressure, indicating the need for more objective measures. All these considerations highlight the need to consider behavioral responses in future studies, as well as state emotional, cognitive, and psychophysiological effects, when studying MA in children with and without SLD.

Finally, as already stated above, although the results offer several points for reflection, they must be taken with caution considering the small to moderate effect sizes; interpreting effect sizes in a too optimistic way may result in overestimating the practical significance and the real-world influence of an observed effect (Szücs & Ioannidis, 2017).

4.2. Educational and clinical implications

Our findings could have both educational and clinical implications. First, educators must be aware of the specific characteristics of children with SLD while performing school subject-related tasks; these include diminished self-efficacy, greater worries, and specific affective responses to challenges. Math performance of children with SLD might be worsened by altered emotional reactions and worries, thus it may be crucial to consider affective and cognitive factors in educational practices. In contrast, for children with SLD, exercises that are challenging but within their reach could be recommended to increase their level of physiological activation (protective factor) which in turn could help limit the negative impact of intrusive thoughts (risk factors), thereby empowering performance and learning. Second, teachers and clinicians should consider that time pressure could be considered a negative factor in terms of proficiency and MA. Third, interventions aimed at enhancing academic competences in children with SLD should address anxiety, negative thoughts and worries by fostering positive emotional activations. Indeed, clinical and educational interventions designed explicitly to relieve anxiety and enhance emotion regulation have also been found to have a positive effect on successful learning (Durlak et al., 2011). Overall, improving social and emotional skills, both in students and teachers, might contribute to more supportive learning environments, more positive attitudes about school, self, and others, which, in turn, would lead to enriching social behaviors, perceived competence, and academic performance (for a meta-analysis see Corcoran et al., 2018).

4.3. Conclusions

The present study offers insights into specific emotional and cognitive responses to a time-pressured math task in children with SLD compared to children without the diagnosis. In general, lower levels of trait MA and higher levels of perceived competence seem to serve as predictive factors for superior math performance in the overall sample. More specifically, certain state components of MA, such as task-related worries, may enhance math performance in children without SLD. Conversely, arousal and worries could be considered protective and risk factors, respectively, for math achievement in children with SLD.

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Ethics approval statement

The study was approved by the Ethics Committee on Psychology Research at the University of Padova.

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CRediT authorship contribution statement

Rachele Lievore: Writing – review & editing, Writing – original draft, Visualization, Methodology, Formal analysis, Data curation, Conceptualization. **Sara Caviola:** Writing – review & editing, Writing – original draft, Visualization, Supervision, Methodology, Conceptualization. **Irene C. Mammarella:** Writing – review & editing, Visualization, Supervision, Project administration, Methodology, Conceptualization.

Declaration of competing interest

The authors declare no competing interests.

Data availability statement

Data and materials are available on the following Open Science Framework repository: https://osf.io/eqa8k/?view_only=93243d88160d4aeea3b2f9791f963440.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.lindif.2024.102459.

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