Relation of State- and Trait-Math Anxiety to Intelligence, Math Achievement and Learning Motivation

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Orbach, L., Herzog, M., & Fritz, A. (in press). Relation of State- and Trait-Math Anxiety to Intelligence, Math Achievement and Learning Motivation. Journal of Numerical Cognition. 5(3), XXX-XXX.

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Paper accepted: 16/04/2019

Abstract

This study investigates math anxiety (MA) by comparing trait-components of MA with real-time assessments of situational anxiety responses (state-components) in children. The research to date on MA in children is somewhat disparate in regard to methodology, and firm conclusions regarding the relation of MA to intelligence, math achievement and learning motivation are not readily drawn. Typically, the measures used in the MA research have differed by operationalizing either trait-MA and/or state- (or statelike)-MA, but have failed to compare the implications of their respective assumptions and the significance of their findings. Trait-MA and state-MA, self-ratings of math skills, attitudes towards mathematics, math achievement, the social anxiety, test anxiety, learning motivation and intelligence of 1,179 students (48.1% girls) from grades 4 and 5, were assessed. The findings yield evidence of a pronounced state-trait discrepancy. A negative correlation between state-MA and math achievement was observed for all intelligence levels, even when controlling for test- and social-anxiety traits, while there was no negative relation between trait-MA and achievement. State-MA was associated with lower intelligence, lower self-ratings, more negative attitudes, higher performance avoidance and work avoidance goals. In contrast, trait-MA was slightly related to higher mastery approach goals. The failure to adequately differentiate between state- and trait-based research into MA appears to be one reason for key inconsistencies between research findings and warrants further investigations.

Keywords

math anxiety, state- and trait anxiety, math performance, learning motivation, educational psychology

Introduction

Motivational and affective factors have an impact on school learning; this appears to be especially true for mathematics (Hattie, 2009). Many children report anxiety prior to math exams or daily math lessons (OECD, 2013; Chinn, 2009; Sorvo et al., 2017; Devine, Carey, Hill, & Szűcs, 2018). Even for adults math triggers emotions and some adults who are confronted with a difficult math task feel as if they are being taken back to their experience of failure in math tests in school. Since the 1970s, math anxiety (MA) has been associated with lower achievement in mathematics. Many surveys conducted with young- and middle-aged adults report a negative correlation between MA and math test results (Hembree, 1990). However, for many years the research has focused on adults—that is to say, mostly college students. Only recently, in the last decade, has more research been carried with school children, and instruments developed for assessing MA in children (Thomas & Dowker, 2000; Wu, Barth, Amin, Malcarne, & Menon, 2012; Ramirez, Gunderson, Levine, & Beilock, 2013; Orbach, Herzog, & Fritz, 2019).

However, research findings concerning the MA-performance link in children, as opposed to prior findings from research on adults, are inconsistent. It is still unclear when the onset of relationship between MA and math performance occurs. Some surveys reported correlations in primary school grades (Punaro & Reeves, 2012; Vukovic, Kieffer, Bailey, & Harari, 2013; Harari, Vukovic, & Bailey, 2013; Ramirez et al., 2013; Ramirez, Chang, Maloney, Levine, & Beilock, 2016; Ganley & McGraw 2016; Cargnelutti, Tomasetto, & Passolunghi, 2017; Caviola, Primi, Chiesi, & Mammarella, 2017; Gunderson, Park, Maloney, Beilock, & Levine, 2018), whereas other studies did not find any stable relation in that age group (Thomas & Dowker, 2000; Krinzinger et al., 2007; Krinzinger, Kaufmann, & Willmes, 2009; Haase et al., 2012; Wood et al. 2012).

One current problem of MA research is that no universal diagnosis criteria are available, and thus different ways to operationalise MA in children have been implemented. This problem exists in research on adults also, but MA in adults is mainly assessed with one instrument, the Mathematics Anxiety Rating Scale (MARS) or shorter versions of this questionnaire (AMAS; sMARS; MARS-R). This leads to greater consistency in findings. Another point of criticism can be seen in the lack of instruments for real-time assessment of situational anxiety responses (state assessment). Research on MA is mostly realised through self-reports, including hypothetical/retrospective questions about anxiety in math situations or fear of failure in math (Sorvo et al., 2017). In the light of surveys indicating that self-report questionnaires yield clearly different results from instruments for real-time assessment (Buehler & McFarland, 2001; Wilson & Gilbert, 2005; Levine, Safer, & Lench, 2006; Goetz, Bieg, Lüdtke, Pekrun, & Hall, 2013; Bieg, Goetz, & Lipnevich, 2014; Bieg, Goetz, Wolter, & Hall, 2015; Roos, Bieg, Frenzel, Taxer, & Zeidner, 2015), it becomes apparent that surveys assessing both state- and trait-MA in children are necessary. By measuring state- and trait-MA in a large sample of primary and early secondary school children, the present survey aims to examine differences between both MA types and to contribute to clarifying the contradictory research to date.

Definitions of State- and Trait-Math Anxiety

One basic model for classifying anxiety reactions is the state-trait-anxiety model (Spielberger, 1972), in which a distinction is made between anxiety as a state and as a personality trait (Figure 1). According to this model, state-math anxiety (state-MA) is a temporary and situation-related anxiety reaction that is associated with an increased arousal of the autonomic nervous system. Trait-math anxiety (trait-MA), as a personality trait, entails an acquired and relatively enduring individual disposition. Due to this disposition the individual perceives a variety of math situations as ‘potentially dangerous’ (Spielberger, 1972). A fundamental aspect of anxiety core beliefs (trait-component) is the fear of failure.

Fear of failure is part and parcel of anxiety traits, as it poses a threat to any individual's self-esteem (Spielberger, 1972; Atkinson, 1964; Heckhausen & Heckhausen, 2010). Individuals with trait-MA are inclined towards anxiety, which should lead to more state-MA in various math-related situations. Spielberger assumed that the frequency and intensity of state-anxieties influences the development of personality traits.

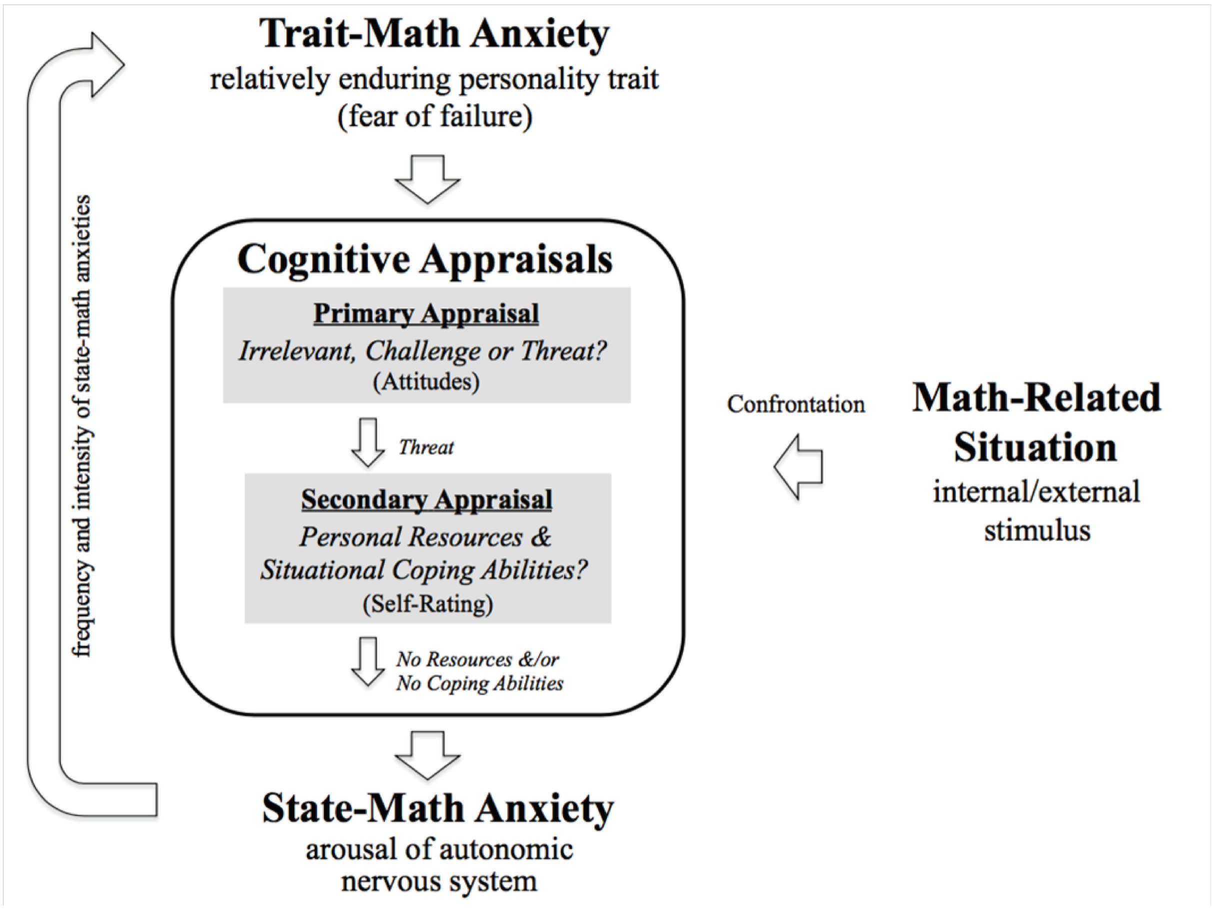

Figure 1. State-trait model of math anxiety

Cognitive appraisal theories provide a useful approach to refining the understanding of state-emotions. In line with Lazarus' transactional model (2001), two appraisals (subjective evaluation processes) are carried out when the individual evaluates the situation and his own coping abilities. The first appraisal consists in assessing how significant the situation is for the individual (Is the situation threatening, challenging or irrelevant?). The second appraisal evaluates the individual’s own personal resources and situational coping abilities (Does the individual believe that he can handle the situation and is in control of it?). If there is an imbalance between these appraisals, the individual experiences state-anxiety. In this case, the individual perceives the situation as threatening and does not believe that he is able to cope with it.

Operationalisation of Math Anxiety

The measures currently used in research differ in relation to their conceptions of MA according to whether they operationalise trait-MA and/or statelike-MA measures. Through operationalising fear of failure in math, the relatively enduring personality disposition of MA (trait) is assessed, while the question of anxiety experience in math-related situations focuses on a statelike component of MA (Orbach et al., 2019). To our knowledge, seven instruments are available to assess MA in young children. The SEMA (Wu et al., 2012), CMAQ-R (Ramirez et al., 2016), mAMAS (Carey et al., 2017), MASYC (Harari et al., 2013) and MASYC-R (Ganley & McGraw, 2016) instruments are based on the basic model of MARS (Richardson & Suinn, 1972), and assess the anxiety level in math-related situations (statelike) by asking hypothetical/retrospective questions, e.g. 'How nervous does this make you feel? You have to sit down to start your math homework'. Moreover, the MASYC and MASYC-R include worry, negative reaction and math confidence factors, which also allows for the measuring of trait aspects. The CAMS (Jameson, 2013) assesses general MA (statelike), math performance anxiety (statelike) and math error anxiety (trait), while the MAQ (Thomas & Dowker, 2000) assesses fear of failure in mathematics (trait), self-rating of math skills, and attitudes towards mathematics.

General issues with the assessing of state-emotions need to be raised. The available instruments (using online reports) do not measure state-anxieties in acute situations.

Rather, individuals are requested to rate how anxious they would feel in a described situation. That is a significant difference, because these instruments are not directly assessing an emotional experience. As research has shown, humans answering retrospective and hypothetical questions about emotions do not use information from their episodic memory. They are led by semantic knowledge about emotions and subjective beliefs. Therefore, individuals are using their semantic emotional knowledge to answer, so that their answers are influenced by core beliefs (Robinson & Clore, 2002). Integral parts of core beliefs are self-rating and attitudes. Consequently, instruments assessing anxiety in math-related situations are not really state-anxiety instruments, but rather are a mixture of state- and trait-MA components (Orbach et al., 2019). In the academic literature to date, such a distinction is not applied; this could be one reason for the disparate findings on MA in children.

The Math Anxiety-Performance Link

For several years, the effect of MA on math performance in young adults has been proven by assessing MA with instruments such as MARS, using hypothetical/retrospective items (Hembree, 1990; Ma, 1999). This mixed type MA shows a negative short- and long-term effect on acquiring and applying math skills. Meta-studies examined a moderate correlation (r = -.27 to r = -.34) between standardised math tests and MA (mixed type). This relation is in accordance with the correlation (r = -.30) between test anxiety and school performance (Hembree, 1988, 1990; Ma, 1999). In contrast, the research on the MA-performance link in children is highly contradictory. Some research has been unable identify any relation at all between MA and performance in primary school, even though fear about failure in mathematics has been assessed as a trait-component of MA (Thomas & Dowker, 2000; Krinzinger et al., 2007; Krinzinger et al., 2009; Haase et al., 2012; Wood et al. 2012). This finding led to the assumption that the performance-inhibiting effects of MA do not occur until secondary school (Dowker, 2005). Other studies however, seem to disprove this assumption by demonstrating a negative influence of MA in primary school grades, assessed through a mixture of state- and trait-MA[i] components. The discovered correlations ranged from low (-.19) to moderate (-.35) coefficients and have been similarly observed in first grade students (Punaro & Reeves, 2012; Vukovic et al., 2013; Harari et al., 2013; Ramirez et al., 2013; Ramirez et al., 2016; Ganley & McGraw, 2016; Cargnelutti et al., 2017; Caviola et al., 2017; Gunderson et al., 2018). However, not all children reporting MA showed low math achievement. In studies by Ramirez et al. (2013, 2016) the effects varied, depending on the dimension of working memory capacity. Only primary school students who could rely on a high working memory capacity exhibited a negative impact on their math performance. One explanation for this could be that these children prefer advanced problem-solving strategies, which require more memory capacity, whereas children with lower working memory capacity use more rudimentary strategies. On the other hand, no systematic relation to intelligence has been assumed since the first publication concerning MA (Dreger & Aiken, 1957; Ashcraft & Ridley, 2005). Nonetheless, if quantitative items of intelligence measures are not considered, no correlation between MA and intelligence can be observed (Hembree, 1990; Young, Wu, & Menon, 2012).

Another moderating variable in the relationship between MA and math achievement could be learning motivation. Various definitions of learning motivation are used in the academic literature, making it difficult to compare findings. Fundamental is the differentiation between learning and performance goals: While learning goal motivations focus on acquiring new knowledge and skills, performance-orientation learning motivation is associated with a tendency to display one’s superior abilities to others and to hide one’s inferior abilities (Dweck, 1986; Murayama, Elliot, & Friedman, 2012). In general, a positive correlation between math achievement and learning motivation is assumed (Garon-Carrier et al., 2015). In the context of research on MA, learning motivation could have an essential impact on the learning behaviour of math anxious children (Hembree, 1990; Gottfried, 1990). It is possible that children with MA are less motivated to learn math, and that higher learning motivation reduces their avoidance behaviour (Lyons & Beilock, 2012; Chang & Beilock, 2016). Furthermore, learning motivation could have a direct influence on performance in an exam. Some children with low MA might experience performing-enhancing effects (Wang et al., 2015). One new finding indicates that entity motivational frameworks – in contrast to incremental frameworks – predict higher MA levels six months later in primary school children. Children with performance goals are especially vulnerable to this effect (Gunderson et al., 2018). At this point, it is not possible to verify these hypotheses sufficiently, because only few surveys have investigated the effect of learning motivation on the relation between MA and math achievement.

Performance-inhibiting effects of MA can be explained by avoidance behaviour (behavioural anxiety reaction) and deficits in the attention control system of anxious individuals (the effects of anxiety on working memory processes). When individuals are experiencing MA, working memory resources are blocked and deprived of actual task processing capacity, because their attention shifts from task-oriented processing to threat-related stimuli (Ashcraft & Kirk, 2001; Suárez-Pellicioni, Nunez-Pena, & Colomé, 2016). Additionally, individuals with MA will avoid being confronted with mathematical situations such as math classes or homework, leading to a decrease in opportunities to learn math (Ashcraft & Moore, 2009). These patterns of avoidance can also be observed in individuals working on math problems. Math anxious individuals show a faster processing speed and a higher error rate, lack attentiveness, show lower participation in class and fleeting learning behaviour (Ashcraft & Faust, 1994, Ashcraft & Moore, 2009). Today, such avoidance behaviours can be explained by neuroscientific findings, which indicate that the experience of MA is associated with brain areas that are involved in pain processing and less so in executive functioning (Young et al., 2012; Lyons & Beilock, 2012; Suárez-Pellicioni, Núnez-

Peña, & Colomé, 2013; Klados, Pandria, Micheloyannis, Margulies, Bamidis, 2017, Hartwright et al., 2018).

Recent Research on State-Math Anxieties

Previously, research on MA was mainly conducted using self-reports rather than instruments for real-time assessment of situational anxiety arousal. Considering the fact that a number of surveys have examined a significant discrepancy between self-reports and state assessments of emotions, this is to be seen as an important consideration. In general, higher trait-emotion scores were found compared to state-emotion scores: this suggests that actual state-emotions are overestimated in self-reports. This phenomenon is called intensity or impact bias (Buehler & McFarland, 2001; Wilson & Gilbert, 2005; Levine, Safer, & Lench, 2006). The few studies assessing both state- and trait-MA have also identified a state-trait-discrepancy (Goetz et al., 2013; Bieg et al., 2014, 2015).

Research examining the state-trait-discrepancy in MA has focused on gender differences and the effect of academic self-concepts on the state-trait-discrepancy. The self-concept of students has an influence on the extent of discrepancy. Higher self-concepts are associated with lower discrepancy, leading to the assumption that these students evaluate their anxieties more realistically (Goetz et al., 2013; Bieg et al., 2014). Nevertheless, higher levels of self-concepts in high achievers can also lead to an underestimation of trait-MA (Roos et al., 2015). The differentiation between state- and trait-MA provides further information on gender differences in secondary school children. In three studies girls reported higher trait-MA than boys, while no significant differences in state-MA scores were found (Goetz et al., 2013). Girls expected higher anxiety levels than they experienced in an actual math-related situation. Interestingly, the state-trait-discrepancies were greater in girls, who consider math as a male domain (Bieg et al., 2015). Therefore, it is apparent that trait-

MA is more influenced by gender stereotypes. These findings are in line with observations by Sorvo et al. (2017). In their survey, gender differences were identified in trait self-reports about anxiety in math-related situations.

Another research project used real-time assessments of MA: Trezise and Reeve (2018) investigated the relationship between state-MA, state working memory capacities (WMC) and arithmetic or algebraic problem solving in 13 to 15-year-old students. Their key finding was that different state-MA levels and WMC interacted in a significant way over time. Students with lower state-MA and higher WMC had stable profiles, with good math performances, whereas students with initially higher state-MA and/or lower WMC often displayed an increase in state-MA during task processing. The unstable group with higher state-MA and lower WMC exhibited the lowest performance levels (Trezise & Reeve, 2014, 2016). State-MA varied in response to the complexity of the math problem and/or to time pressure (Trezise & Reeve, 2018; Punaro & Reeve, 2012). It became apparent that state-MA changes as a function of the specific math situation and is associated with lower WMC and poorer performances.

Until now, only two surveys have assessed salivary cortisol as a measure of physiological anxiety response. In both studies MA was assessed with self-report questions about anxiety concerning math-related situations. Mattarella-Micke et al. (2011) were able to find a negative relationship between cortisol concentration and math performance in highly math-anxious college students with high WMC, whereas less math-anxious students with high WMC showed a positive relationship. No connection was found in college students with low WMC. Following the approach of Schachter and Singer (1962) the researchers discussed that the interpretation of the math situation deceived whether a physiological arousal has a disruptive or beneficial effect on performance. Pletzer et al. (2010) found a negative relation between MA and the results of a statistics examination in only those college students, who showed an increase in cortisol levels before the examination.

Research Questions in the Present Study

The findings of research on the correlation between MA and math performance in children are inconsistent. Thus, there is not sufficient evidence to support the claim that the math anxiety-performance link already exists in primary school students. The present research aims at examining state- and trait-components of MA and their connections to math achievement and other predictors of academic achievement in fourth and fifth graders. This age group was chosen because it represents the transition time between primary and secondary school in Germany. The first research question deals with distributions of state- and trait-MA: Do both MA distributions differ in children (research question 1, RQ1)? In this context the aspect of gender ratio is examined. The second aim was to investigate the relationship between state- and trait-MA and math achievement: To what extent do both MA types relate to math achievement (while controlling for test and social anxiety) (RQ2)? Based on the findings by Ramirez et al. (2013) on working memory capacities, the third aim was to analyse whether intelligence moderates the relationship between MA and math achievement also (RQ3). Additionally, the survey explores the possible effect size of MA: What magnitud0es of influence do both MA types have in relation to other predictors of math achievement (RQ4)? Finally, the relation between both MA types and other non-cognitive predictors of academic achievement, like learning motivation and attitudes, is analysed (RQ5).

Material and Methods

Participants

The sample consisted of 1,179 fourth and fifth grade students (48.1% girls) from nineteen schools in the state of North Rhine-Westphalia, Germany (Table 1). In 13 of the schools, the entire grade participated. All children attended regular schools. Students with special educational needs could not be included in the study. Trained graduate students collected the data during regular school lessons. For all children, opt-out parental consent was given.

Table 1. Descriptive Data of Observed Participants

	N	Mean age in months (SD)	Age range in months	School type description
Primary	343 (48.7% girls)	123.25 (4.96)	102-144	
Secondary	836 (46.9% girls)	137.72 (6.90)	121-170	
Gesamtschule	329 (44.4% girls)	139.59 (7.51)		*Comprehensive secondary school for mixed abilities*
Realschule	251 (45.4% girls)	137.29 (6.95)		*Secondary school with the focus on preparing for vocational training*
Gymnasium	256 (51.6% girls)	135.87 (5.37)		*Secondary school leading to the exam required for studies at university*

Procedure

In spring 2017, the grad students were trained for the in-class assessment, which was conducted on three consecutive days at the end of the school year in summer 2017. On the first day, the state-MA was assessed immediately prior to and after a math test by measuring the situation-related anxiety reaction. Afterwards the students filled out a questionnaire, which assessed learning motivation. On the second day, trait-MA was measured before a math test. Afterwards, social- and test-anxiety questionnaires were completed. On the last day, the intelligence test was conducted (Figure 2).

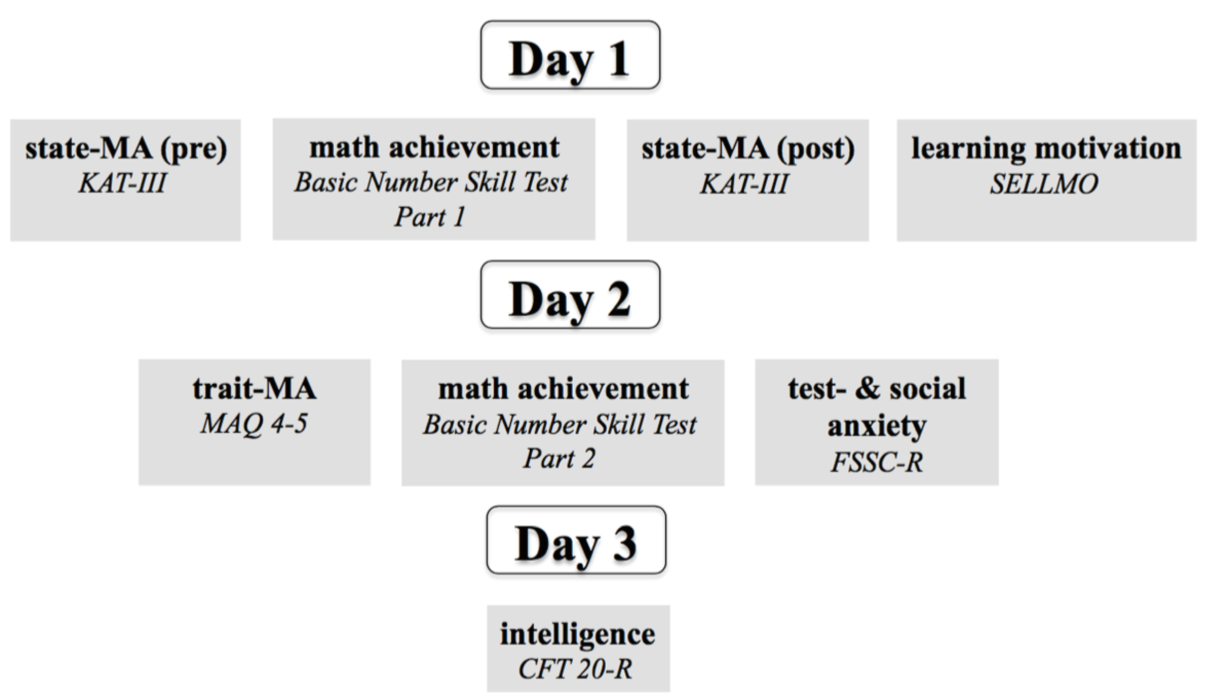

Figure 2. Procedure of the present research

Materials

Trait-MA

Trait-MA was assessed with the Mathematics Attitudes and Anxiety Questionnaire for grades 4 and 5 (MAQ 4-5) by measuring fear of failure in mathematics. The MAQ 4-5 (Orbach, Herzog, Fritz, 2019) can be used in a class setting and assesses trait math-anxiety (14 items), self-rating of math skills (7 items) and attitudes towards mathematics (7 items) using a 5-point Likert-type scale (0 to 4). In total, the questionnaire includes 28 items and 4 question types for 7 different mathematical situations (Table 2). The instrument is a version of the MAQ adapted by Thomas and Dowker (2000). In the framework of this study, the MAQ was modified to serve as a questionnaire for a group setting in grades 4 and 5. The reliability (internal consistency) is α = .83 to α = .92. Similar latent structures and degrees of criterion validity (Krinzinger et al., 2007; Wood et al., 2012) were found (Orbach et al., 2019) as in previous studies with the MAQ. The scale trait-MA is reported with reversed polarity, to ensure that the reports are generally comparable and to make them more readily intelligible. Higher values refer to greater intensity of trait-MA.

Table 2. Sample Items MAQ 4–5

Self-Rating		
How good are you at math homework?	4 3 2 1 0	very good (4) to very bad (0)
Attitudes		
How much do you like math homework?	0 1 2 3 4	dislike strongly (0) to like very much (4)
Trait-Math Anxiety		
How happy or unhappy are you if you have problems with math homework?	4 3 2 1 0	very happy (4) to very unhappy (0)
How worried are you if you have problems with math homework?	0 1 2 3 4	very worried (0) to very relaxed (4)

State-MA

The Kinder-Angst-Test-III (KAT-III) (Tewes & Naumann, 2017) was used to assess children's state-MA (Table 3). This instrument includes a self-evaluation questionnaire for current anxious expectation (10 items) and a questionnaire evaluating state-anxiety (10 items) retrospectively. Children indicate whether an emotional state applies to them currently (pre) or has done so recently (post). The reliability (internal consistency) is α = .77 to α = .78. Immediately before the assessment, the children were told that in front of them lay a book with a variety of math problems, and that they would now undertake a math test. Afterwards they were asked to indicate how they felt in the test situation. In order to control other influential factors, the participants were instructed verbally and in written form to rate the items only in the light of the math test. Other circumstances were not to be considered.

Table 3. Sample Items KAT-III (state)

Please indicate to what extent each of the following statements applies to you in this moment. *Please only give answers in accordance with your feelings and thoughts regarding the upcoming/completed math test.*		
Pre-Test		
I am nervous	Yes	No
Post-Test		
I was nervous	Yes	No

Test and Social-Anxiety Traits

Test- and social-anxiety traits were assessed as control variables using the German version of the Fear Survey Schedule for Children-Revised (FSSC-R) (Döpfner, Schnabel, Goletz, & Ollendick, 2006). This instrument includes 9 items to assess test-anxiety traits and 12 items to assess social-anxiety traits (Table 4). The reliability (internal consistency) is α = .76 to α = .78.

Table 4. Sample Items FSSC-R

Test anxiety traits			
I am anxious about failing the exam	0	1	2
Social anxiety traits			
I am anxious to meet someone for the first time	0	1	2

Intelligence

Intelligence was measured using the German adaption CFT 20-R (Weiß, 2006) of the Culture Fair Intelligence Test (Cattell & Cattell, 1960). The instrument is a nonverbal group test that evaluates fluid intelligence in four figural tasks (continuing logical progressions, classifications, matrices, topological conclusions). The reliability (internal consistency) is α = .92.

Learning Motivation

Learning motivation was assessed with the German instrument Skalen zur Erfassung der Lern- und Leistungsmotivation (SELLMO) [Scales for the measurement of learning motivation and achievement motivation] (Spinath, Stiensmeier-Pelster, Schöne, & Dickhäuser, 2012). This instrument assesses four scales (Table 5). The 'mastery approach goal' scale measures the goal of acquiring new knowledge and skills, the 'performance approach goal' scale measures the goal of performing in front of others, the 'performance avoidance goal' scale measures the tendency to avoid performing in front of others, and the 'work avoidance goal' scale assesses efforts to avoid work as much as possible in task processing. The reliability (internal consistency) is α = .76 to α = .89.

Table 5. Sample Items SELLMO

In school, my goal is, ...					
Mastery approach goal					
... to understand difficult subjects	1	2	3	4	5
Performance approach goal					
... to perform better than others	1	2	3	4	5
Performance avoidance goal					
... to avoid doing poorly	1	2	3	4	5
Work avoidance goal					
... to keep the amount of work low at all times	1	2	3	4	5

Math Achievement

To measure mathematical achievement, a basic number skill test (Ehlert, Herzog, & Fritz, in press) was used. The instrument consists of 96 items and assesses basic math competencies in the domains of the part-part-whole-concept, multiplication, division and understanding of the place value system. It was expected that all fourth and fifth graders could solve the tasks without time pressure. The test can be seen as a reliable and valid measure. The convergent validity was reviewed with the Deutscher Mathematiktest 4 and 5+ ((DEMAT 4 (r = .585)), DEMAT 5+ (r =. 565)). Also, the divergent validity was examined with the intelligent test CFT 20-R (r = .457). The reliability (internal consistency) is α = .86 to α = .89.

Grouping of children

In line with contemporary research (Ramirez et al., 2013; Dowker et al., 2016; Devine, Hill, Carey, Szűcs, 2018), the present survey considers state- and trait-MA as a continuum.

The statistical analyses were computed with the entire distribution of MA scores. In efforts to further analyse the relation between MA and other predictors of academic achievement, two groups were formed for each MA-type. Higher levels of state- and trait-MA were defined as scores above 1 *SD* above the mean, and lower levels were classified as scores equal to or above the mean.

Data Analysis

All statistical analyses were performed using IBM SPSS Statistics (Version 24). An alpha level of .05 was applied in this research, in accordance with the guidelines of Cohen (1994). Pearson's correlation analysis was utilized to evaluate correlation hypotheses. In line with Cohen (1988) correlation values of $r \geq .1$ were considered small, $r \geq .3$ medium and $r \geq .5$ large. Z-values were calculated to compare two correlation coefficients. One-way analysis of variance (ANOVA) was used to examine whether there is any difference between groups. An evaluation of group differences was conducted by means of Cohen's d or using the effect size η^2. According to Cohen (1988), values of $d \geq .2$ represent small, $d \geq .5$ medium and $d \geq .8$ large effect sizes respectively, whereas $\eta^2 \geq .01$ is interpreted as a small, $\eta^2 \geq .06$ a medium and $\eta^2 \geq .14$ a large effect size. Principal Component Analyses (PCA) were calculated to examine the relationship between state- and trait-MA. To investigate the possible moderating role of intelligence, conditional process modelling was applied by means of the PROCESS macro (Hayes, 2013). It was tested whether the separate variable intelligence moderates the relationship between state- or trait-MA and math achievement (model 1). Potential predictors of math achievement were explored using a multiple linear regression model. To examine which factors optimised prediction of math achievement, a sequential regression analysis was conducted. Variable blocks were formed on the basis of theoretical models to investigate which predictors improved R^2 significantly.

Results

Table 6 shows the descriptive statistics (means and standard deviation) for raw values on MAQ 4-5 scales, the Kinder-Angst-Test 3 (state-MA), a basic number skill test, FSSC-R (test-, social anxiety) and SELLMO (learning motivation) with regard to gender and type of school.

Table 6. Descriptive Statistics of Observed Variables

Variable	Group	M (SD)		
		male	female	total
Self-Rating	Primary	20.96 (5.5)	20.33 (4.3)	20.63 (5.0)
range of scale: 0-28	Secondary	21.08 (4.6)	19.23 (4.5)	20.21 (4.7)
Attitudes	Primary	19.84 (6.0)	19.42 (5.0)	19.62 (5.5)
range of scale: 0-28	Secondary	19.07 (6.2)	18.04 (5.1)	18.58 (5.7)
trait-MA	Primary	29.71 (10.7)	32.58 (11.1)	31.20 (11.0)
range of scale: 0-56	Secondary	30.55 (11.1)	33.86 (9.9)	32.12 (10.6)
state-MA (pre + post)	Primary	4.19 (3.8)	5.10 (4.1)	4.66 (3.9)
range of scale: 0-20	Secondary	3.29 (3.4)	4.60 (4.0)	3.91 (3.8)
state-MA (pre)	Primary	2.28 (2.0)	2.72 (2.2)	2.50 (2.1)
range of scale: 0-10	Secondary	1.94 (2.0)	2.48 (2.2)	2,20 (2,1)
state-MA (post)	Primary	1.90 (2.0)	2.41 (2.3)	2,17 (2.2)
range of scale: 0-10	Secondary	1.39 (1.8)	2.12 (2.3)	1,74 (2.1)
Test Anxiety	Primary	6.26 (4.1)	6.34 (3.7)	6.30 (3.9)
range of scale: 0-18	Secondary	6.36 (4.0)	7.15 (3.9)	6.74 (4.0)
Social Anxiety	Primary	5.87 (4.2)	6.40 (3.7)	6.14 (4.0)
range of scale: 0-24	Secondary	5.11 (4.0)	6.30 (4.0)	5.68 (4.0)
Learning	Primary	32.86 (5.7)	33.28 (5.1)	33.08 (5.4)
Motivation	Secondary	32.47 (6.1)	32.40 (5.4)	32.44 (5.8)
range of scale: 0-40				
Math Achiev.	Primary	72.95 (17.7)	76.14 (14.4)	74.57 (16.2)
range of scale: 0-96	Secondary	77.33 (16.7)	74.54 (15.8)	76.00 (16.3)

Research Question 1: Distribution of State- and Trait-MA in Children

The distributions of state (pre + post)- and trait-MA scores are presented in Figure 3; the descriptive statistics are reported in Table 6. Trait-MA scores can be seen as approximately normally distributed with a mean of 31.85 (*SD* = 10.75), whereas state-MA (pre + post) distribution was skewed to the right (skewness = 1.072.; kurtosis = .736) with a mean of 4.14 (*SD* = 3.84). Female students scored significantly higher than male students on the state-MA (F(1, 1105) = 28.637; p < .001; η^2 = .025) and trait-MA (F(56, 1008) = 1.473; p < .001; η^2 = .021) questionnaires. Fourth graders reported significantly higher state-MA levels than fifth graders (F(1, 1105) = 8.741; p = .003; η^2 = .008). However, trait-MA scores did not differ as a function of grade (F(1, 1063) = 1.609; p = .205).

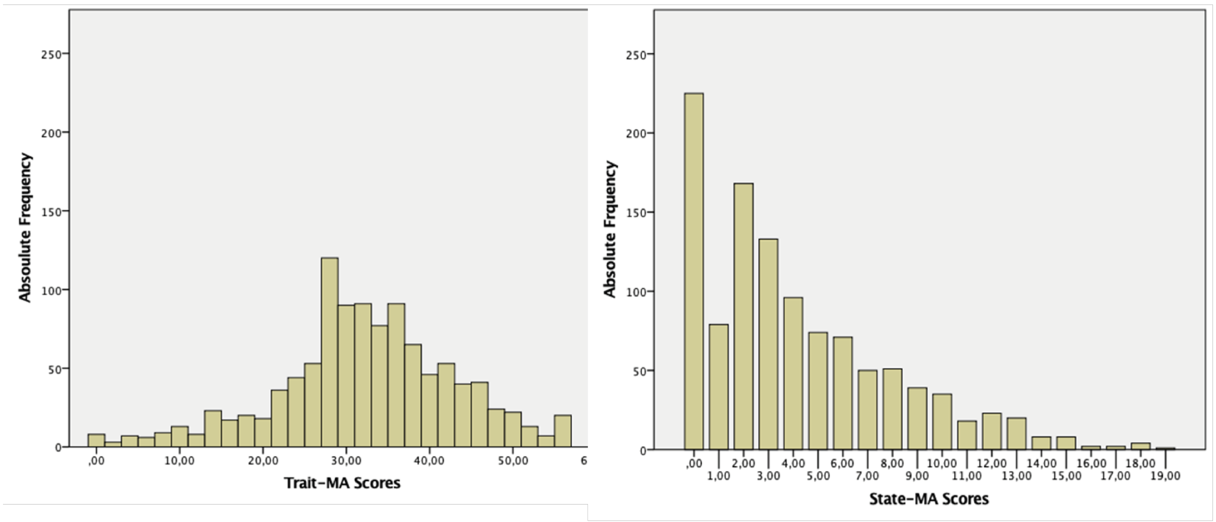

Figure 3. Histogram displaying the distributions of state-MA and trait-MA scores

In general, there was a small correlation between state- and trait-MA (r(1013) = .149; p < .001), which did not differ for state-MA pre-test or post-test scores (z = 1.386; p = .083). To answer the question whether the two MA types are two distinct components, a Principal Component Analysis (PCA) of state-MA and trait-MA items was conducted. The Kaiser-Meyer-Olkin measure of sampling adequacy was .917 and the Bartlett's test of Sphericity was significant (χ^2(496) = 16286.32, p < .001). This indicator shows that correlations between items were suitably large for performing PCA. Only factors with eigenvalues ≥ 1 were extracted. Examination provided empirical justification for a two-factor model of state-and trait-MA, which accounted for 46.10% of the total variance. Thus, two distinct clusters of MA-items, state and trait (varimax-rotated solution) can be identified (Figure 4).

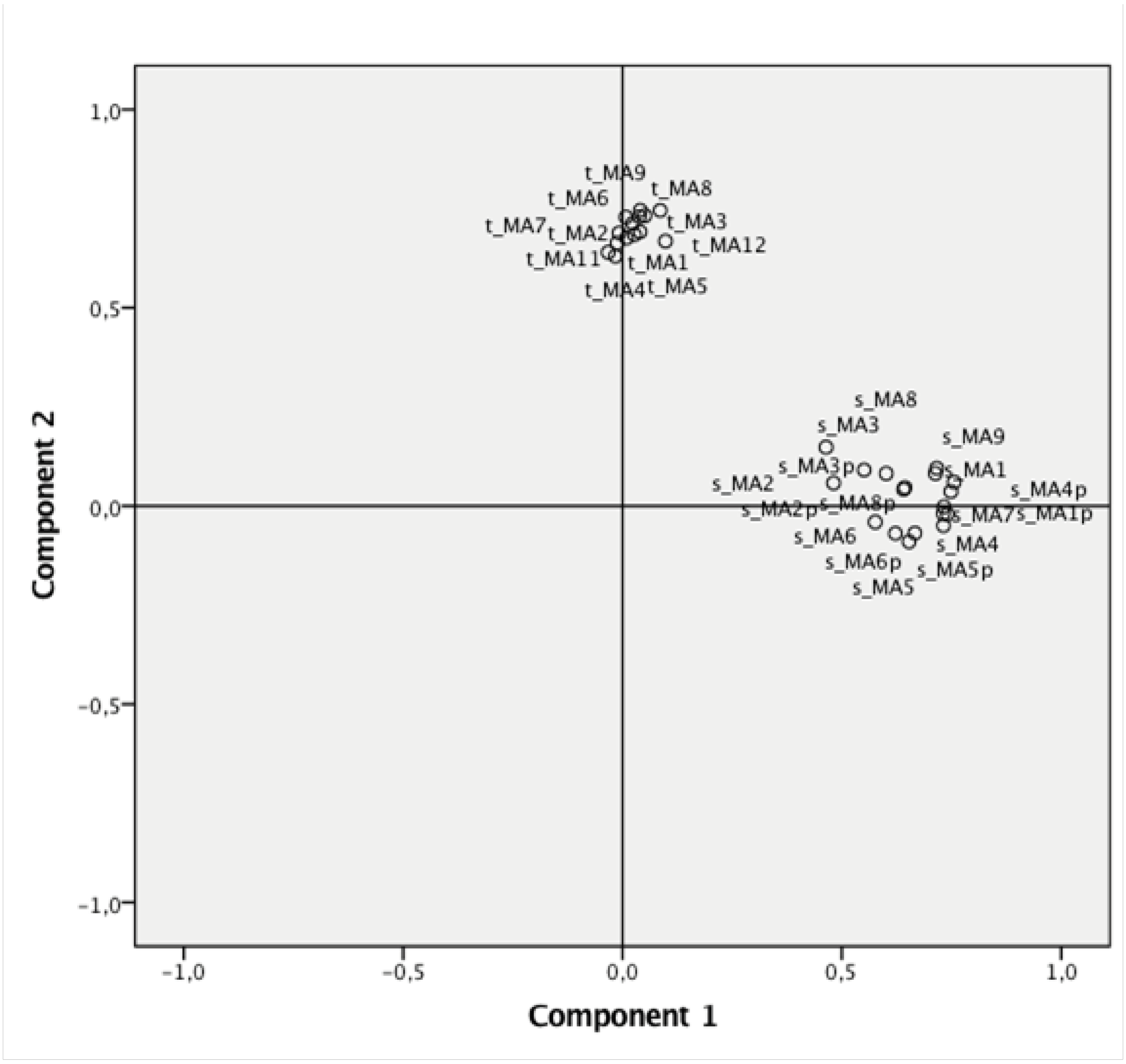

Figure 4. Facets diagram of state- (s_MA) and trait-MA-items (t_MA)

In an additional examination, social- and test-anxiety traits were included in the analysis (Kaiser-Meyer-Olkin = .907; Bartlett-Sphericity-Test: χ^2 (1378) = 20173.26, *p* < .001). The factor analysis provided a three-factor model with separate trait-MA, state-MA and clustered social- and test-anxiety traits, which latter accounted for 31.43% of the total variance. To interpret a likewise possible two-factor model, the Varimax orthogonal rotation grouped all three trait components together (Figure 5). Taken together, the three components accounted for 40.52% of the total variance.

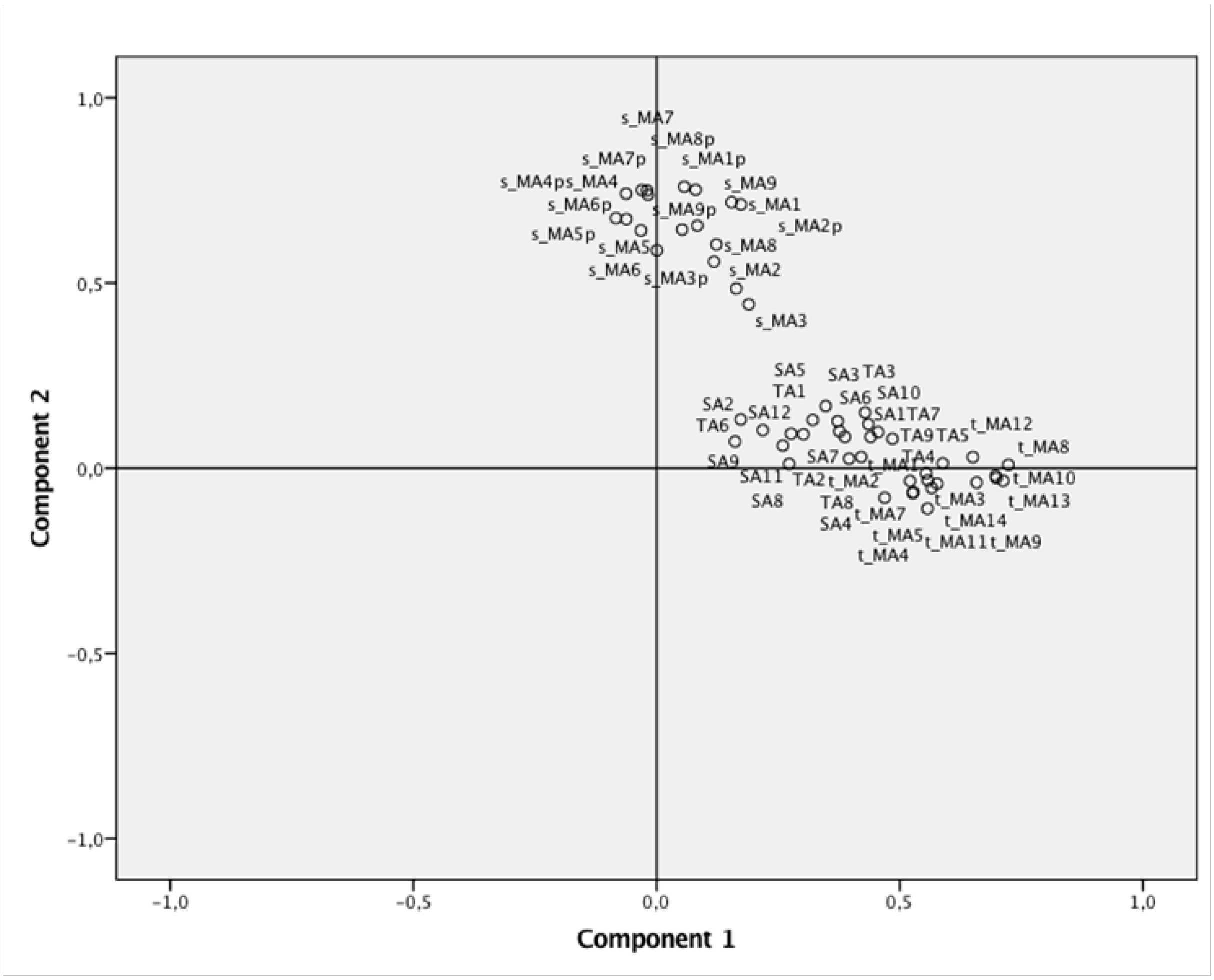

Figure 5. Facets diagram of state-MA- (s_MA), trait-MA- (t_MA), social (SA) and test anxiety trait-items (TA)

Research Question 2: Relation Between State- and Trait-MA and Math Achievement (Controlling for Test- and Social-Anxiety Traits)

As seen in Table 7, all bivariate coefficients between state-MA and math achievement ($r(1003) = -.314$) and between test anxiety and math achievement ($r(996) = -.167$) were significantly different from zero ($p \leq .001$). Even after controlling for test and social anxiety traits the negative correlation between state-MA and math achievement remains significant (*r*(988) = -.297). The correlation coefficient between state-MA and math achievement is significantly higher than the coefficient between test-anxiety traits and math achievement (z = -4.425; $p < .001$). In contrast, the correlation between trait-MA and math achievement (r(992) = .063; $p \leq .05$) is weakly positive and significant smaller than the correlation between state-MA and math achievement (z = -9.446; $p < .001$).

Analysing the pre-test and post-test state-MA scores is of central importance, because a link between state-MA and math performance could be caused by an indirect self-evaluation of math performance in the post-test questionnaire. The discrepancy between the correlation of state-MA pre-test and math achievement (r(1006) = -.264), and between state-MA post-test and math achievement (r(1002) = -.312) was significant (z = 2.039; p = .021). Differences between pre- and post-test scores of state-MA were significant (M = -.41, SD = 1.73), but with a small effect size (t(1097) = 7.95, $p < .001$; d = .24).

Table 7. Correlations between anxiety types and math achievement

Variable	state-MA *(pre/post)*	trait-MA	Math Achievement
Bivariate Correlation			
Trait-MA	.146** (.147**/.113**)		
Math Achievement	-.314** *(-.264**/-.312**)*	.063*	
Test Anxiety	.392** (.416**/.304**)	.255**	-.167**
Partial Correlation Controlling for social- and test-anxiety traits			
Variable	state-MA *(pre/post)*	trait-MA	
Trait-MA	.040 (.040/.032)		
Math Achievement	-.286** (-.210**/-.279**)	.079*	

** $p \leq .01$ (2-tailed) * $p \leq .05$ (2-tailed)

Research Question 3: Relation Between State- and Trait-MA, Intelligence and Math Achievement

The estimated coefficients indicated a negative correlation between state-MA and IQ (pre + post: $r(973) = -.203$; pre: $r(973) = -.182$; post: $r(967) = -.190$; all $p < .001$), whereas trait-MA correlated weakly positively with IQ scores ($r(958) = .086$; $p < .001$). The results of the moderating regression are shown in Table 9. No significant moderating effects could be identified between trait-MA or state-MA in pre-tests and math achievement. However, intelligence was examined as a moderator of the relationship between state-MA post-test and math achievement. For children with relatively low intelligence scores, a slightly more pronounced negative relation could be identified between state-MA after the math test and math performance (Figure 6). The relationship between state-MA (pre + post), intelligence, and math achievement is illustrated in Figure 7.

Table 8. Moderated regression analysis of math achievement with the predictor state-MA or trait-MA and the moderating variable intelligence

	B	*SE* B	*t*	*p*	R^2
state MA (Pre + Post) x intelligence	.013	.007	1.77	.07	.27
state MA (Pre) x intelligence	.013	.013	1.00	.32	.25
state MA (Post) x intelligence	.033	.014	2.34	.02	.28
trait MA x intelligence	.002	.003	.64	.53	.21

** $p \leq .01$ (2-tailed) * $p \leq .05$ (2-tailed)

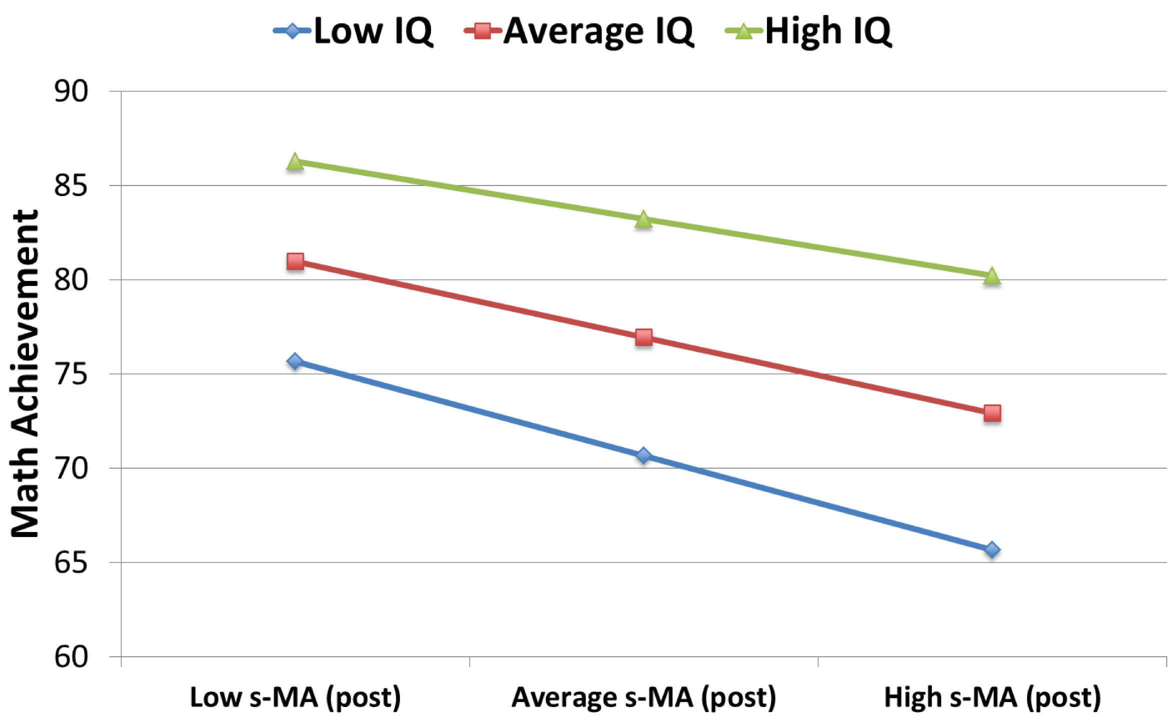

Figure 6. Moderation graph state-MA post-test x intelligence

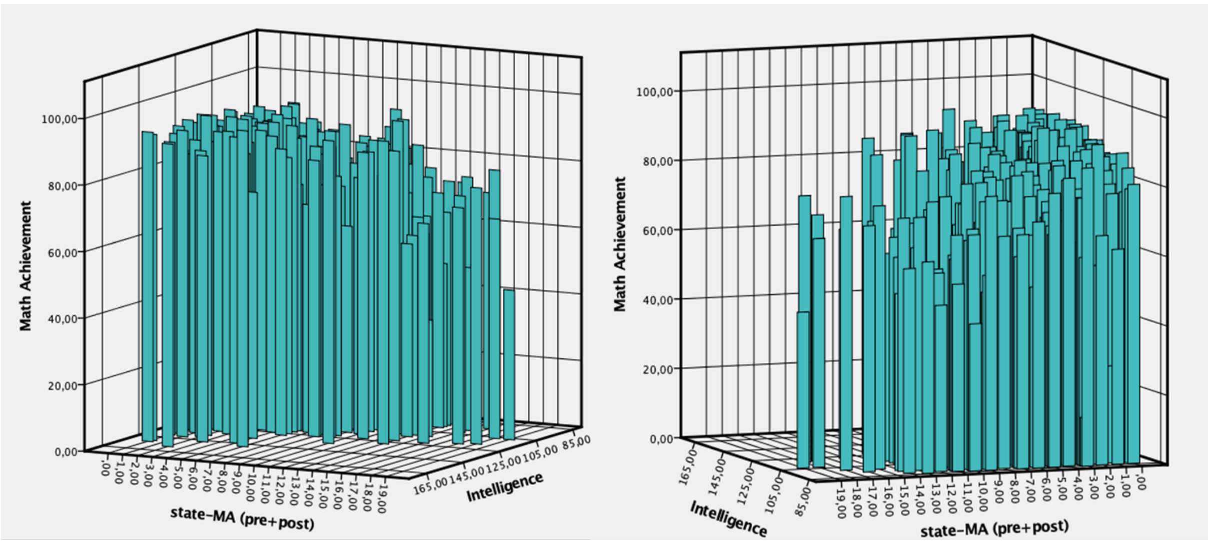

Figure 7. Bar chart of state-MA (pre + post), intelligence, and math achievement means from two different angles

Research Question 4: Magnitudes of Influence on Math Achievement

A multiple linear regression model of math achievement was calculated with the potential predictors being state-MA (pre + post), trait-MA, self-rating, attitudes, test anxiety, social anxiety, IQ and mastery approach goal (learning motivation; Table 9). Models 1 and 2 analyse the two MA types separately, whereas model 3 was formed out of both MA types. It is evident that state-MA (model 1: β = -.314, p < .001) had a significantly negative impact on math achievement, while trait-MA (model 2: β = .063, p = .048) had a weakly positive effect. Both models have a small R^2 of 9.9% (model 1) and 0.4% (model 2). In the common model only state-MA (pre + post) was a significant predictor (R^2 = 13.3%). When self-rating and attitudes were included into the model according to the appraisal model, R^2 increased to 23.3%. State-MA (pre + post) was a significantly negative predictor (β = -.259, p < .001), while trait-MA (β = .124, p < .001) and self-rating (β = .316, p < .001) had a positive impact. When IQ and test anxiety were added to the model, R^2 was 34.3%. In this model IQ (β = .346, p < .001) and self-rating (β = .242, p < .001) are strong positive predictors, while state-MA (β = -.198, p < .001) has a negative effect. Trait-MA had only a weakly positive impact (β = .072, p = .013). Test anxiety was no predictor of math achievement. In model 6 social anxiety was included but had no significant impact. Finally, in model 7 learning motivation (scale: mastery performance goal) completes the linear regression model. The overall model fit was R^2 = 34.9%. In this model, significant predictors of math achievement were state-MA (pre + post) (β = -.193, p < .001), self-rating (β = .227, p < .001) and IQ (β = .343, p < .001). Trait-MA (β = .081, p = .006) and mastery approach goal (β = .072, p = .013) have weakly positive impacts. A significant increase in R^2 can be observed when the factors of model 4 (self-rating and attitudes: p < .001), model 5 (IQ and test anxiety: p < .001) and model 7 (mastery approach goal: p = .006) are added to the model.

Table 9. Stepwise linear regression model of math achievement

	B	*SE B*	*ß*	*p*	R^2	*F*
Model 1					.099	109.438
state-MA (pre + post)	-1.337	.128	-.314**	≤ .001		
Model 2					.004	3.915
trait-MA	-.094	.047	.063*	.048		
Model 3					.133	66.943
state-MA (pre + post)	-1.445	.125	-.369**	≤ .001		
trait-MA	.110	.046	.076	.017		
Model 4					.233	66.179
state-MA (pre + post)	-.1.013	.125	-.259**	≤ .001		
trait-MA	.179	.044	.124**	≤ .001		
Attitudes	.100	.102	.038	.330		
Self-Rating	.991	.127	.316**	≤ .001		
Model 5					.343	75.374
state-MA (pre + post)	-.774	.124	-.198**	≤ .001		
trait-MA	.104	.042	.072*	.013		
Attitudes	.127	.095	.048	.189		
Self-Rating	.762	.121	.242**	≤ .001		
Test Anxiety	-.052	.120	-.014	.802		
IQ	.359	.030	.346**	≤ .001		
Model 6					.344	64.732
state-MA (pre + post)	-.756	.125	-.193**	≤ .001		
trait-MA	.104	.042	.072*	.013		
Attitudes	.125	.095	.047	.189		
Self-Rating	.753	.121	.240**	≤ .001		
Test Anxiety	-.038	.152	-.010	.802		
Social Anxiety	-.141	.147	-.038	.336		
IQ	.361	.030	.347**	≤ .001		
Model 7					.349	58.049
state-MA (pre + post)	-.755	.125	-.193**	≤ .001		
trait-MA	.095	.042	.066*	.023		
Attitudes	.078	.096	.030	.414		
Self-Rating	.712	.121	.227**	≤ .001		
Test Anxiety	-.025	.151	-.007	.870		
Social Anxiety	-.156	.146	-.042	.286		
IQ	.356	.030	.343**	≤ .001		
Mastery Approach Goal	.229	.082	.081**	.006		

** p ≤ .01 (2-tailed) * p ≤ .05 (2-tailed)

Research Question 5: Relation Between State- and Trait-MA and Non-Cognitive Predictors of Academic Achievement

Table 10 shows the correlations between both MA types and non-cognitive predictors of academic achievement. In addition, a group comparison of higher ($x \geq M + SD$) and lower anxiety levels ($x \leq M$) is reported. The findings reveal some differences between state- and trait-MA. State-MA has a stronger negative relation to attitudes towards math than did trait-MA. Although no differences can be observed between both negative correlations to self-rating ($z = .549$; $p = .291$), the discrepancy between higher and lower levels in state-MA is more distinct. Performance approach goals had no relation to both MA types, whereas performance and work avoidance goals were associated with higher state-MA levels. No connection to trait-MA can be identified. The correlations between both MA types and mastery approach goals were in opposite directions and differed significantly ($z = -4.275$; $p < .001$). Thus, trait-MA had a weak positive relation to the learning goal of acquiring new knowledge and skills.

Table 10. Correlations between both MA types and predictors of academic achievement and group comparisons of different MA-levels

Variable	**state-MA** (pre + post) r	M (SD) Group x ≥ M + SD	M (SD) Group x ≤ M		**trait-MA** r	M (SD) Group x ≥ M + SD	M (SD) Group x ≤ M	
Self-Rating	-.201**	17.90 (5.0)	21.44 (4.5)	F(1, 755) = 83.691; p < .001; η^2 = .100	-.179**	19.75 (5.3)	20.97 (4.5)	F(1, 730) = 8.759; p = .003; η^2 = .012
Attitudes	-.325**	16.70 (5.5)	19.57 (5.5)	F(1, 755) = 36.930; p < .001; η^2 = .047	-.136**	18.83 (6.0)	19.43 (5.8)	F(1, 731) = 1.347; p = .246; η^2 = .002
Mastery Approach Goal	-.087**	32.06 (5.8)	33.06 (5.1)	F(1, 783) = 5.407; p = .020; η^2 = .007	.091**	33.48 (5.6)	31.96 (6.2)	F(1, 676) = 7.598; p = .006; η^2 = .011
Performance Approach Goals	-.025	24.82 (5.9)	24.29 (6.3)	F(1, 785) = 1.098; p = .295; η^2 = .001	-.019	25.21 (5.6)	24.86 (6.5)	F(1, 675) = .371; p = .542; η^2 = .001
Performance Avoidance Goals	.115**	24.63 (7.8)	22.05 (7.8)	F(1,785) = 16.748; p < .001; η^2 = .021	-.011	22.92 (7.7)	23.14 (7.7)	F(1, 675) = .103; p = .748; η^2 = .000
Work Avoidance Goals	.096**	23.59 (7.3)	21.17 (8.1)	F(1, 784) = 13.954; p < .001; η^2 = .017	-.067*	21.51 (7.8)	22.57 (8.0)	F(1, 674) =2.159; p = .142; η^2 = .003

** p ≤ .01 (2-tailed) * p ≤ .05 (2-taile

Discussion

In the light of surveys reporting great differences between self-report questionnaires and real-time assessments of emotions (Robinson & Clore, 2002) the aim of the present study was to investigate differences between trait- and state-components of MA by assessing situational anxiety responses in acute math situations. One main concern, due to the disparate findings in children (Sorvo et al., 2017). was to examine the link between MA and performance. The data are consistent with previous research on academic emotions and MA (Buehler & McFarland, 2001; Wilson & Gilbert, 2005; Levine et al., 2006; Goetz et al., 2013; Bieg et al., 2014; Bieg et al., 2015; Roos et al., 2015) in revealing pronounced discrepancies between state- and trait-assessments. MA can be distinguished on the basis of two separate and continuous components: state-MA as a temporary and math situation-related anxiety reaction, and trait-MA as a personality trait of math specific anxiety. PCA indicates that trait-MA is connected to social- and test-anxiety traits, but can be distinguished from the cluster of social- and test-anxiety items.

These findings confirm earlier results, in which higher correlations were detected between different measures of MA than between MA and other types of anxiety (Hembree, 1990; Baloglu, 1999; Kazelskis et al., 2000; Ashcraft & Ridley, 2005). In contrast to earlier research on gender differences, which documented higher levels of trait-MA but not of state-MA in female secondary school students (Goetz et al., 2013; Bieg et al., 2015), our data provides evidence for gender differences in both MA types. Girls reported higher levels of state- and trait-MA than boys, but with a similar effect size. In general, the research regarding gender differences in children is also inconsistent. In conflict with studies that did not identify gender differences in primary school (Dowker, Bennett, & Smith, 2012; Wu et al., 2014) other surveys have reported higher anxiety levels in girls (Krinzinger et al., 2007; Hill et al., 2016; Carey et al., 2014). Although Sorvo et al. (2017) noticed gender differences only when children had to rate items relating to anxiety in math-related situations (statelike) and not on fear of failure in math (trait), the contrasting results cannot be fully explained by the operationalisation of MA. Studies with identical assessments have found divergent results (Dowker et al., 2012; Krinzinger et al., 2007). An alternative explanation could however be sought in the different sample compositions.

Table 11. Previous research on MA-performance link in children

	Math tasks	Measure MA	MA-type	MA-performance link?	Sample: N
Thomas & Dowker, 2000; Krinzinger et al., 2007; Krinzinger et al., 2009; Haase et al., 2012; Wood et al. 2012	Basic number skill	MAQ	Trait	No	Grade 1-6: approx.. 900
Punaro & Reeves, 2012	Addition equations	Faces Worry Scale	State	Yes	Grade 4: 58
Wu et al., 2012	Subtest WIAT-II	SEMA	Statelike	Yes	Grades 2-3: 162
Vukovic et al., 2013	Story problems, algebra, Data analysis	MASYC	Statelike & Trait	Yes	Grades 2-3: 113
Harari et al., 2013	Foundational mathematical concepts	MASYC	Statelike & Trait	Yes, but not worry-component (trait)	Grade 1: 106
Ramirez et al., 2013	Subtest WJ-III	CMAQ	Statelike	Yes, but only for high WMC	Grades 1-2: 154
Wu et al., 2014	Subtest WIAT-II	SEMA	Statelike	Yes	Grades 2-3: 366
Ramirez et al., 2016	Subtest WJ-III	CMAQ-R	Statelike	Yes, but only for high WMC	Grades 1-2: 564

Ganley & McGraw, 2016	Measurement, number, algebra	MASYC-R	Statelike & Trait	Yes	Grades 1-3: 296
Hill et al., 2016	Arithmetic test	AMAS	Statelike	Grades 3-5 boys no girls yes Grades 6-8 yes	Grades 3-5: 639 Grades 6-8: 342
Cargnelutti et al., 2017	Arithmetic tests	SEMA	Statelike	Yes	Grade 2-3: 203
Caviola et al., 2017	Calculation and number comprehension	AMAS	Statelike	Yes	Grade 3-5: 1013
Sorvo et al., 2017	Basic arithmetic skills	3 items anxiety about failure in math 3 items anxiety in math-related situations	Statelike & Trait	Statelike: yes Trait: no	Grade 2-5: 1327
Gunderson et al., 2018	WJ-III	CMAQ-R	Statelike	Yes	Grade 1-2: 634

Until now, it has been unclear as to whether MA relates to lower math performances in young children. On the basis of studies that did not find a MA-performance link in the first years of school (Thomas & Dowker, 2000; Krinzinger et al., 2007; Krinzinger,et al., 2009; Haase et al., 2012; Wood et al. 2012) the assumption was made that such relationships do not occur until secondary school (Dowker, 2005). This assumption is contrary to studies reporting low to moderate negative correlations in primary school students (Punaro & Reeves, 2012; Vukovic et al., 2013; Harari et al., 2013; Ramirez et al., 2013; Ramirez et al., 2016; Ganley & McGraw, 2016; Cargnelutti et al., 2017; Caviola et al., 2017; Gunderson et al., 2018). As seen in Table 11, previous research findings differ in regard to operationalising trait-MA and/or statelike-MA. Most studies using statelike assessments found a negative relation between MA and performance, while studies using trait assessments could not find any connection. Consistently with these previous findings, the data of the current study did not reveal a negative connection between trait-MA and math achievement in a basic number skill test, whereas situational anxiety responses in acute math situations (state-MA) were negatively related to basic number skill performances, even after controlling for test- or social-anxiety traits. Moreover, none of the measures of trait anxiety (MA, test, social anxiety) predicted low math achievement in the regression model. These outcomes are in line with the findings of Sorvo et al. (2017), where questionnaires with hypothetical/retrospective items regarding anxiety related to math-related situations (statelike) correlated negatively with math performance in contrast to items concerning anxiety about failure in math. It can be presumed that the state-trait-discrepancy caused this outcome. The general tendency to overestimate trait-anxieties could lead to distortions, because children do not evaluate their actual state-emotions in math-related situations realistically (Goetz et al., 2013; Bieg et al., 2014, 2015). Thus, trait-MA is more likely influenced by subjective beliefs (Robinson & Clore, 2002) and does not cover the specific anxiety reaction that leads to performance-inhibiting effects, as explained by the attentional-control theory (Eysenck, Deakshan, Santos, & Calvo, 2007).

According to attentional-control theory, MA affects the working memory by impairing the inhibition function, so that math anxious individuals are more vulnerable to task-irrelevant stimuli (e.g. worries). Therefore, WMC is limited, and some resources are deprived of task processing (Suárez-Pellicioni et al., 2016). One important finding in adults and children is that MA especially affects individuals with high WMC (Beilock & Carr, 2005; Beilock & DeCaro, 2007; Materella-Micke et al., 2011; Ramirez et al., 2013; Vukovic et al., 2013; Ramirez et al., 2016). This phenomenon, which is termed the "choking" effect (Beilock & Carr, 2005), has been explained by the tendency of individuals with high WMC to rely on advanced problem-solving strategies that require more WMC. In contrast, individuals with lower WMC stick to rudimentary and less WM-demanding problem-solving strategies (Ramirez et al., 2016). Considering that WMC and intelligence are highly related (Conway, Kane, & Engle, 2003), the present study analysed intelligence as a potential moderating variable of the MA-performance link. This research could not find a similar "choking" effect for intelligence. All intelligence levels showed a negative relation between trait- or state-MA and math achievement. As a matter of fact, lower intelligence levels exhibited slightly more pronounced negative connections between reported state-MA after the test, and performance. A possible explanation is that arousal during task processing was high, due to self-perceived problems in solving the tasks.

In conclusion, children of all intelligence levels seem to be roughly identically influenced by MA in their math performance. However, in this survey math performance was assessed with a basic number skill test, so it could be possible that tasks of higher complexity demand more sophisticated problem-solving strategies, which hypothetically would cause similar "choking" effects. One further outcome regarding intelligence replicates previous findings (Hembree, 1990; Young, Wu, & Menon, 2012) in showing no relation between trait-MA and intelligence. Extending previous research, these data have provided evidence that situational anxiety responses in acute math situations relate to intelligence. Children with lower IQ scores experience state-MA more frequently; the appraisal model can contribute to explaining this result. Children with lower IQ scores, compared to children with higher IQ scores, experience state-MA more frequently, because they perceive math-related situations as less controllable than it is for those who experience more success in school due to their good cognitive capabilities (secondary appraisal). It can be expected that children with lower intelligence scores make opposite experiences in daily school life (Deary, Strand, Smith, & Fernandes, 2007), wherein the experience of failure more often leads to the evaluation of math situations as less controllable. According to Spielberger's state-trait-model

(1972), children in this case would not believe that they are able to cope with the task and, in reaction, more state-MA will appear.

Besides these deficits in the attention control system in an acute math situation, avoidance behaviour is regarded as an important factor in the difficulties of math anxious individuals. Individuals with MA will avoid math-related situations and consequently will have fewer opportunities to learn math (Ashcraft & Moore, 2009). One further aim of the present survey was to investigate whether both MA types have a similar relation to general non-cognitive predictors of academic achievement, such as learning motivation. On the basis of earlier research on avoidance behaviour (Ashcraft & Faust, 1994; Ashcraft & Moore, 2009) and taking into consideration neuroscientific findings in math anxious individuals (Young et al., 2012; Lyons & Beilock, 2012; Hartwright et al., 2018), the hypothesis could be advanced that – in the case of generalization effects – math anxious children are less motivated to learn and more likely to avoid academic situations that require them to perform in front of others.

The present data reveal significant differences between state-and trait-MA. While the situational anxiety response correlates positively with performance avoidance goals and work avoidance goals, and – as expected – relates negatively to mastery approach goals, the cognitive disposition of MA (trait-MA) shows correlations in the opposite direction to mastery approach goals and work avoidance goals. Children with trait-MA seem to be more motivated to acquire new skills and to put effort into task processing. For some children, fear of failure in math may positively impact learning behaviour. One explanation for this could be that they are more able to offset their negative responses by reducing their avoidance behaviour and facing math situations (Chang & Beilock, 2016). Another explanation is that trait-MA cannot be interpreted as a typical type of anxiety, because of the pronounced state-trait discrepancy and the fact that trait assessments are more likely influenced by subjective beliefs (Robinson & Clore, 2002). That being the case, trait-MA should be considered as a conglomerate of subjective beliefs and worrying thoughts.

All these findings raise important questions for research on MA and current assessments of MA in children. Although paper-pencil-assessments are not a direct approach to assessing physiological arousal, real-time state-MA questionnaires appear to be a suitable research instrument for situational anxiety reactions. The results are firstly in line with attentional-control theory, as state anxieties have an impact on performance, and secondly relate to academic learning behaviour in a way that could be expected for anxious students. One limitation of the present research is that the design cannot check for other influences on state anxieties, such as general social- or test-anxiety states. Thus, it is possible that anxiety arousal was caused not only by math-related stimuli, despite the instruction to rate the items solely in the light of the math test. Generally, the great state-trait-discrepancy underlines the necessity of research using real-time assessments. Directions for further research could be the examination of differences between statelike instruments and real state assessment or longitudinal designs. Such examinations would be able to explain the direction of cause-effect relationships between state-, trait-MA and math performance. In conclusion, the findings emphasise the benefit of the state-trait-anxiety model for research on MA and assessment of MA. The previous lack of differentiation between these two anxiety types appears to be one of the reasons for inconsistent findings in research on MA in children, and warrants further investigation. Because of these findings, previous and future research results need to be interpreted with careful consideration of their operationalisation.

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[i] For the sake of completeness, in the survey by Hill et al. (2016), which also assessed a mixture of state- and trait-MA components, no connection was found between MA and math achievement in primary schoolboys, whereas AMAS scores negatively related to arithmetic scores in primary schoolgirls.