A latent profile analysis of math anxiety and core beliefs towards mathematics among children

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Abstract

Recent findings on the negative impacts of math anxiety (MA) in children raised outstanding issues for educational and clinical research, regarding effective intervention programs. One basic approach to develop intervention programs in field of cognitive behavioral therapy is to gain an in-depth understanding of the cognitive beliefs (CB) of children with a specific mental problem. By applying latent profile analysis (LPA), the present study aimed at identifying different patterns of MA and to provide more insights into its cognitive phenomenology. For this purpose, trait-MA, state-MA, attitudes towards math, academic self-concepts (math, language, general), fixed/growth mindsets, executive functions and math performance of 475 fourth and fifth graders (48.2% girls) were assessed. LPA indicated seven distinct profiles characterized by different dimensions and patterns of state-MA, trait-MA and core beliefs towards math. Furthermore, the profiles showed clear different math performances. The weakest performances were found for a profile with highest state-MA, high trait-MA and negative CB towards math and a profile with average state-MA, high trait-MA and negative CB towards math, whereas the highest achieving profile had no state-MA, high trait-MA and very positive CB towards math. The findings underline the complexity of MA and emphasize the necessity to develop interventions with careful consideration of the heterogeneous patterns.

Keywords

math anxiety; academic self-concepts; primary school children; core beliefs; latent profile analysis

1. Introduction

In the last decade, a large number of studies have emphasized the negative short- and long-term repercussions of math anxiety (MA) on children's functioning in academic and daily life (Barroso et al., 2021). These findings have raised outstanding questions for educational and clinical research concerning the development of prevention and intervention approaches (Ramirez et al., 2018; Dowker et al., 2016). Although MA is not classified in diagnostic systems for mental disorders (DSM-V and ICD-10), research provided evidence that the phenomenology complies with the classification criteria of specific phobia (Faust, 1992; Hopko et al., 2003; Malanchini et al., 2017). In line with this classification, MA can be described as a cognitive, affective, behavioral and physiological anxiety state induced by math-related stimuli and as a trait-disposition, referring to a relatively enduring math anxious characteristic of a human individual. Thus, the phenomenology of MA involves physiological symptoms as sweating, or a faster heartbeat as well as symptoms such as fear (affective level), avoidance behavior (behavioral level) or worrisome thoughts and beliefs (cognitive level) towards mathematics (Haase et al., 2019).

Cognitive behavioral therapy (CBT) covers a widely used and evidence-based group of interventions, which is regarded as the gold standard in the treatment of anxiety disorders (Hofmann et al., 2012). Based on the work by Beck (1970) and Ellis (1962), CBT focuses the interactions between thoughts, emotions and actions. One basic approach to develop interventions in field of CBT is to gain an in-depth understanding of the cognitive beliefs (CB) of individuals with a specific mental problem, as maladaptive cognitions are seen as the cause of emotional and behavioral difficulties (Beck, 2011). Until now, research on MA is mostly realized by correlation and regression analyses, which are predominately based on assessments of one MA-variable. Besides the fact that MA-assessments for children differ in relation to their conceptualization of MA (Orbach et al., 2019b) – making comparability of study results difficult –, these one-variable-centered analyses are not able to examine

multidimensional interrelationships between anxiety states and trait-dispositions (Wang et al., 2018). As a result, the current research status provides only weak information about anxiety-beliefs-interrelationships and does not take different heterogeneous groups of math-anxious children into account.

In light of this research gap, the necessity of a more holistic approach to investigate relations of different MA and CB dimensions becomes apparent. By applying latent profile analysis (LPA) on basis of state-, trait-MA, self-concepts and attitudes towards mathematics, the present study aimed at identifying different patterns of MA and to provide more insights into its cognitive phenomenology. These findings would help to develop and customize effective intervention approaches. In further steps, the study examines the relationships between the different combinations of MA and CB to math achievement, executive functioning (EF), other academic self-concepts and fixed/growth mindsets.

1.1. Math anxiety and cognitive beliefs towards math

MA and its negative impacts on numerical reasoning and number manipulation can already be identified in the first years of primary school (e.g., Cargnelutti et al., 2017; Gunderson et al., 2018). Although MA is related to other anxiety forms, its phenomenology is distinct (Ashcraft & Ridley, 2005; Malanchini et al., 2017), and the negative impacts cannot be reduced to social, test and general anxiety (Wu et al., 2012; Orbach et al., 2019b). Recent meta-analyses (Namkung et al., 2019; Zhang et al., 2019; Barroso et al., 2021) found small to moderate negative correlations ($r = -.28$ to $-.34$) between MA and math performance but also indicated that math tests and MA-assessments modulate the MA-performance link. In general, the negative repercussions of MA are explained by avoidance behavior of math-anxious individuals (Ashcraft & Moore, 2009) and effects of cognitive interferences (Eysenck

et al. 2007), as WM resources are blocked for task-processing due to an attention shift to threat-related stimuli.

The experience of failure in school might play an important role for the development of maladaptive cognition. Longitudinal studies were able to discover that students' beliefs about their own academic competences and abilities have a bidirectional relationship to academic performances and school grades over time (Marsh & Martin, 2011). However, with regard to the specificity-matching principle (Swann et al., 2007), domain-specific self-concepts (SC) are higher related to domain-specific outcomes than general SC or global constructs (McWilliams et al., 2013). Overall, math-SC (MSC) of school-aged children has a reciprocal relation to math outcomes (Marsh et al., 2018) and is negatively associated with MA ($r = -0.14$ to -0.48 ; Lee, 2009; Ahmed et al., 2012; Justicia-Galiano et al., 2017; Mammarella et al., 2018; Orbach et al., 2019b). Longitudinal analysis indicate that higher levels of MA predict lower MSC and vice versa (Ahmed et al., 2012), while mediation analysis found a mediation effect of MSC on the MA-performance link (Justicia-Galiano et al., 2017). These findings underline the dynamic interplay between affect, cognition and performance in the course of time, which can be explained by cognitive appraisal models (Lazarus, 2001; Pekrun, 2006). MSC could function as an antecedent of MA, as children with poorer MSC might evaluate math situations as less controllable and, in reaction, they will experience more MA. In a vicious circle, lower math proficiency could be the cause and effect of this interplay.

Partly different assumptions are made about another cognitive disposition: attitudes towards math. According to Aiken (1970, p. 551) attitudes can be described as “a learned predisposition (...) of an individual to respond positively or negatively to some object, situation, concept or another person”. Studies in primary schools indicate that young students mostly have positive attitudes towards math (Dowker, 2005; Krinzinger et al., 2009),

while during secondary school these positive attitudes deteriorate (Mata et al., 2012). It could be hypothesized that this effect is related to a clearer negative math attitudes-math performance association in older students (Ma & Kishor, 1997). In contrast to MSC, longitudinal data suggests that math achievement predicts negative attitudes later on, but no reverse effect of attitudes to performance exists (Ma & Xu, 2004). Generally, math attitudes are negatively related to MA ($r = -0.10$ to -0.47) and positively associated with math performance ($r = 0.15$ to 0.54) in young children (Dowker et al., 2012, 2019; Reber et al., 2018; Orbach et al., 2019b), even when controlling for intelligence, working memory (WM) and MA (Chen et al., 2018). Interestingly, recent findings indicate that the neurocognitive mechanism differ between math attitudes and MA. Contrary to the findings on MA (Young et al., 2012), attitudes were not associated with affective-motivational brain areas but children with positive attitudes showed enhanced hippocampal activation (Chen et al., 2018). Therefore, it is assumed that attitudes might influence memory processes during learning activities and task-solving.

A frequently discussed (Moore et al., 2014; Ramirez et al., 2018) but not as often studied core belief in MA-research is the social-cognitive mindset theory (Dweck 1986, 2008). This model addresses individuals' belief sets about the nature of intelligence and abilities by distinguishing two theory types: fixed or entity theory vs. growth or incremental theory. Dweck refers to a continuum between individuals with the belief that intelligence is malleable through practice, experience of failure or feedback, and individuals, who belief that intelligence is unchangeable. Longitudinal data signify that fixed mindsets affect math proficiency of school-aged children negatively over time, while growth mindsets are linked to more adaptive learning behavior, stronger learning goals and more positive beliefs about effort (Blackwell et al., 2007; McCutchen et al., 2016; Gunderson et al., 2018). Although the rare MA-studies reported no or only weak correlations between MA and fixed mindsets ($r = -0.05$ to 0.14 ; Huang et al., 2019; Gunderson et al, 2018), Gunderson et al. (2018) were able

to identify that fixed mindsets function as a predictor of later MA. Thus, it is hypothesized that mindsets are foundational core beliefs with great influence on emotional states, highlighting their potential key role for the development of effective intervention programs (Burns & Isbell, 2007; Ramirez et al., 2018).

Based on the reported research findings, it can be assumed that academic SC, attitudes towards math and mindsets are related but distinct variables, which mutual interact with emotional states and cognitive dispositions of MA (Luttenberger et al., 2018). Until now, less studies used a holistic LPA-approach to explore how these variables interact with each other in relation to math performance.

1.3. Research questions in the present study

The present study aims at identifying different patterns of MA and to provide more insights into its cognitive phenomenology by applying LPA, considering individual scores on measures of state-, trait-MA and CB towards mathematics. Currently, research on MA is mainly applied by correlation and regression analyses, which are often based on only one MA-variable and therefore are not able to take different – per chance heterogeneous – groups of math-anxious children into account (Wang et al., 2018). The first aim of the study is to examine whether there are different MA-subgroups. Is it possible to classify distinct profiles of children who exhibit similar patterns across state-MA, trait-MA, attitudes and SC towards math (research question 1, RQ1)? If it is possible to identify different patterns, the second aim is to explore their relationships to math achievement and EF. In which way do the MA-profiles relate to math achievement and executive functions (RQ2)? Finally, the third study aim is to investigate whether distinct MA-patterns are differentially related to other academic SC and fixed/growth mindsets (RQ3).

2. Material and Methods

2.1. Participants

The study described formed part of a wider research project on the interplay of MA and EF (XXXX, 2020). The study originally involved 646 students. 475 students of fourth and fifth grade (48.2% girls; $127,10 \pm 9.4$ months old) remained in the final sample after data cleaning. Students with intellectual disabilities, disorders affecting communication, language comprehension problems and participants with items missing from their MA or CB questionnaires were not included into the final sample. All children attended grades 4 and 5 in regular comprehensive schools. The data was collected on two days in winter 2018. The study was conducted in accordance with human subject guidelines of national research

committees and the regional school law. For all participants, opt-out parental consent was obtained after guardians were informed that the participation is voluntary and that they can easily opt-out by a verbal or written notification to a teacher or school administrator without any justification.

2.2. Procedure

The in-class assessments were administered by grad students in winter 2018. The data collection was conducted on two consecutive days and took place in sessions of 2 hours. On the first day, state-MA was assessed immediately prior to and after the math test. Afterwards the participants responded to the academic self-concept items. On the second day, children filled out the trait-MA, attitudes towards math and mindsets questionnaires before the class was split into groups of 10 children for assessing their EF by means of a 10,8" computer tablet.

2.3. Materials

Sample items of all questionnaires are reported in Supplementary Table 1.

2.3.1. Trait-MA

The Math Anxiety Questionnaire (MAQ; Thomas & Dowker, 2000) is a self-report questionnaire for trait-MA. The 14-item questionnaire assesses fear of failure towards 7 different math situations (e.g., math homework, easy calculations). Children were asked to mark their answers on a 5-point Likert-type scale (0 to 4). The reliability (internal consistency) of the adapted German version is $\alpha = .92$ for the norm sample (Orbach et al., 2019a), while the reliability in the present sample was $\alpha = .93$. Higher values refer to greater trait-MA.

2.3.2. State-MA

Children were asked immediately prior to and after the basic number skill test to fill out the state-Mathematics Anxiety Questionnaire (state-MAQ: Orbach et al., 2020). The self-evaluation questionnaire consists of 7 items for rating current state-anxiety and 7 items for rating state-anxiety retrospectively. Children respond on a 4-point-Likert scale (0 'no' to 3 'yes'), measuring whether an anxiety state applies to them presently (pre) or has done so recently (post). The instrument has standardized instructions to control other influential factors (Supplementary File X). The reliability (internal consistency) is $\alpha = .83$ for the norm sample (Orbach et al., 2020), while the reliability in the current sample was $\alpha = .82$. Higher values refer to greater state-MA.

2.3.3. Attitudes towards mathematics

Attitudes towards mathematics were measured applying the 7-item attitude scale of the MAQ (Thomas & Dowker, 2000). Children were asked to evaluate on a 5-point Likert-type scale (0 to 4), how much they like 7 different areas of math. The reliability (internal consistency) of the adapted German version is $\alpha = .84$ for the norm sample (Orbach et al., 2019a), while the reliability in the present sample was $\alpha = .86$. Higher values refer to more positive attitudes.

2.3.4. Academic self-concepts

Academic self-concepts were measured with the self-report questionnaires of the DISC-Grid (Rost et al., 2007). This inventory includes a general academic self-concept scale and different subject-specific scales, each containing 8 similar item types. The present study administered the general scale and the scales for German and mathematics. Children were asked to respond on a 6-point Likert-type scale (1 'not at all true' to 6 'perfectly true') as to whether a statement correspond to them. The reliability (internal consistency) is $\alpha = .82$ to

.88 for the norm sample, whereas the reliability in the present sample was $\alpha = .81$ to $.91$. Higher values refer to a more positive self-concept.

2.3.5. Fixed/growth Mindsets

Dweck Mindset Instrument (DMI; Dweck, 2008) is a self-report questionnaire, assessing fixed/growth mindsets with 16 items. The instrument has two subscales, focusing mindsets about intelligence (8 items) or talent (8 items). Children are instructed to respond to statements on a 6-point Likert-type scale (0 'strongly disagree' to 6 'strongly agree') as to whether they agree to a statement that focused either fixed or growth mindsets. The assessment was evaluated in the framework of this study and can be considered as reliable and valid (Supplementary Table 2). The reliability (internal consistency) was $\alpha = .76$ for both subscales in the current sample. Higher values refer to a more fixed mindset.

2.3.6. Math achievement

The basic number skill test (Ehlert, Herzog, & Fritz, in press) measures math abilities in the domains of the part-part-whole concept (8 items), multiplication/division (8 items) and understanding of the place value system (10 items). The test situation had no time pressure, and the inventory was designed to evaluate basic abilities, which children should have developed before starting secondary school in accordance with the National Curriculum for Germany. The total score was computed as the sum of all correct item responses. The reliability (internal consistency) is $\alpha = .87$.

2.3.7. Executive functions

The Yellow-Red-Test by Rosas et al. (2021) is a tablet-based assessment of EF, which was used to evaluate inhibition control, cognitive flexibility, working memory capacities and a global index of EF by means of four task types. The inventory is detailed described in a

previous paper (XXX, 2020). The reliability (internal consistency) is $\alpha = .80$ to $\alpha = .86$. Higher values refer to higher abilities.

2.4. Data analysis

Statistical analyses were performed using R (R Core Team, 2020). To investigate relations between the variables, Pearson's correlation analyses were applied. According to Cohen (1988), correlation values of $r \geq .1$ were considered small, $r \geq .3$ medium and $r \geq .5$ large. To identify and investigate patterns of MA, LPA was used by means of R and the tidyLPA package. The number of profiles was determined according to the Bayesian information criterion (BIC), the Akaike information criterion (AIC), the bootstrap likelihood ratio test (BLRT) and the value of entropy. To examine differences between the profiles, one-way analyses of variance (ANOVA) were conducted and evaluated using η^2 . T-tests were applied to compare general and subject-related SC and chi-square test of independence were used to compare gender ratio of MA profiles. According to Cohen (1988), values of $\eta^2 \geq .01$ were considered small, $\eta^2 \geq 0.06$ a medium and $\eta^2 \geq 0.14$ large, while values of $d \geq 0.2$ represent small, $d \geq 0.5$ medium and $d \geq 0.8$ large effect size. In line with Cohen (1994) an alpha level of .05 was applied in this research.

3. Results

Descriptive statistics (means and standard deviation) for and bivariate correlations among the variables are reported in Table 1. The data were adequately distributed and no floor- or ceiling effects were identified.

3.1. Correlation analysis

All correlations between state-MA and SC were significantly greater from zero ($p \leq .001$), while trait-MA was only negatively associated to MSC. The coefficient between state-MA and German-SC (GSC) was significantly lower than the coefficients between state-MA and SC-General ($z = 2.10$; $p = .02$) and MSC ($z = 2.14$; $p = .02$). No correlations were found between both MA-types and fixed/growth mindsets, while all SC scores and math attitudes negatively correlated with fixed mindsets. All EF measures, SC scores and math attitudes were positively related to math achievement; in contrast, state-MA and fixed mindsets were negatively associated to math achievement. No correlation was found between trait-MA and math achievement.

Table 1. Descriptive statistics and bivariate correlation for the sample as a whole.

Variable	M (SD)	Correlations										
		2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
1. State-MA (Pre + Post)	13.93 (9.5)	.17**	-.22**	-.23**	-.14**	-.22*	.04	-.03	-.03	-.05	-.06	-.23**
2. Trait-MA	30.41 (12.9)	-	-.06	-.18**	.01	-.31**	.03	.05	.12*	.02	-.00	.04
3. SC-General	28.84 (8.8)	-	-	.64**	.59**	.41**	-.15**	.07	.04	.07	.04	.35**
4. MSC	30.60 (10.6)	-	-	-	.50**	.47**	-.11*	.13**	.06	.07	.08	.36**
5. GSC	28.89 (9.2)	-	-	-	-	.22**	-.13**	-.05	-.01	.08	.00	.22**
6. Math Attitudes	19.22 (6.3)	-	-	-	-	-	-.12*	-.05	.03	.04	.00	.26**
7. Mindsets (total)	37.67 (11.3)	-	-	-	-	-	-	-.03	-.00	-.03	-.08	-.10*
8. Inhibition	27.42 (5.2)	-	-	-	-	-	-	-	.15**	.15**	.37**	.24**
9. Cognitive flexibility	15.16 (4.1)	-	-	-	-	-	-	-	-	.16**	.20**	.20**
10. WMC	10.12 (2.4)	-	-	-	-	-	-	-	-	-	.25**	.22**
11. Global EF	24.34 (5.8)	-	-	-	-	-	-	-	-	-	-	.27**
12. Math achievement	16.23 (6.7)	-	-	-	-	-	-	-	-	-	-	-

Note. SC, self-concept; MSC, math self-concept; GSC, German self-concept; WMC, working memory capacities; * $p \leq .05$ (2-tailed) ** $p \leq .01$ (2-tailed)

3.2. Latent profile analysis

To investigate different patterns of MA, a latent profile analysis (LPA) was conducted on the basis of scaled scores of state-MA (state-MAQ), trait-MA (MAQ), attitudes towards math (MAQ) and MSC (DISK-Gitter). If both CB, attitudes and SC towards math, are addressed, the term 'math beliefs' (MB) is used. Table 2 shows the model fit information. The number of profiles was determined according to the BIC, AIC, BLRT and the value of entropy. The BIC and AIC were smallest for the seven-profile solution, while the entropy value was highest (.78) for the seven-profile solution and BLRT tests were all statistically significant until the eight-profile solution. Thus, the seven-profile model was selected as the best fitting model based on all indices.

Table 2. Model Fit Indices for Latent Profile Solutions.

	LL	BIC	AIC	BLRT <i>p</i> -value	Entropy <i>R</i> ²
1-Profile	-.3357	.6797	.6755	≤ .001	1
2-Profile	-.3222	.6543	.6476	≤ .001	.76
3-Profile	-.3160	.6455	.6363	≤ .001	.70
4-Profile	-.3143	.6459	.6343	≤ .001	.67
5-Profile	-.3109	.6427	.6285	≤ .001	.70
6-Profile	-.3075	.6397	.6231	≤ .001	.75
7-Profile	-.3043	.6369	.6177	≤ .001	.78
8-Profile	-.3058	.6437	.6220	.446	.74

Note. Bold test indicates information criteria best fit. LL, Log Likelihood; BIC, Bayesian Information Criterion; AIC, Akaike Information Criterion; BLRT, Bootstrapped Likelihood Ratio Test.

The descriptive statistics for each profile are reported in Table 3 and Figure 1 illustrates the z-scored data of each of the 7 profiles. The profiles have been termed descriptively to increase the readability.

Figure 1. Pattern of boxplots on MA and MB variables as a function of latent profiles.

Profile 1: No MA/very positive MB. About 14% of the sample belonged to profile 1, which was characterized by low MA levels and very high MB scores. All scores differ from the sample means, $t(63) = 2.7$ to 16.9 , $p < .001$; $d = 0.85$ to 2.7 .

Profile 2: No MA/Worst Attitudes. Approximately 2% of the sample was in profile 2, which is the smallest profile. Children in this profile reported low MA level, lowest attitudes towards math but positive MSC.

Profile 3: Average. 36% of the sample were classified to the largest profile 3, which was characterized by average to slightly below average scores of MA and MB.

Profile 4: Trait-MA/Very Positive MB. About 14% of the sample were categorized to profile 4, which had the highest SC scores of all extracted profiles and very positive attitudes towards math. Students in this profile reported low state-MA levels, while the trait-MA scores were the second highest of all profiles. All scores differ from the sample means, $t(65) = 6.2$ to 19.7 , $p < .001$; $d = 0.7$ to 2.7 .

Profile 5: Trait-MA/Negative MB. Approximately 10% of the sample belonged to profile 5. The similarity to profile 4 is the high level of trait-MA. Despite of this, the profile was characterized by average levels of state-MA and the lowest scores on MB measures.

Profile 6: State-MA/Positive MB. About 14% of the sample were classified to profile 5, which is one of two profiles with high state-MA levels. Students of this profile reported average trait-MA and positive MB.

Profile 7: State-MA/Negative MB. 12% of the sample belonged to profile 7, which was characterized by high levels of MA on state- and trait-measures. Furthermore, the children of this profile reported negative attitudes towards math and weak MSC. All scores differ from the sample means, $t(56) = 5.9$ to 19.4 , $p < .001$; $d = 0.8$ to 2.6 .

In Table 3, gender ratio and age (in months) are compared across profiles. ANOVA revealed no differences in age between profiles, while chi-square tests of independence indicated interaction between profile membership and gender ($\chi^2(6) = 32.141$, $p < .001$; Cramer's $V = .263$). Girls were more likely to be in profile 7 'state-MA/negative MB', while boys seem to be more likely in profiles with no MA (profile 1, 2) and profile 4 'trait-MA/very positive MB'.

Table 3. Descriptive Data and Analysis of Variance Between Profiles.

Variable	M (SD)							ANOVA			
	Profile 1 n = 64 (13.5%)	Profile 2 n = 10 (2.1%)	Profile 3 n = 169 (35.6%)	Profile 4 n = 66 (13.9%)	Profile 5 n = 45 (9.5%)	Profile 6 n = 64 (13.5%)	Profile 7 n = 57 (12.0%)	Overall n = 475	F(6, 468)	p	η^2
1. State-MA pre	3.63 (3.4)	2.80 (2.8)	5.21 (3.2)	3.98 (3.4)	6.49 (3.8)	10.86 (3.6)	12.60 (3.3)	6.54 (4.6)	69.59	<.001	.471
2. State-MA post	3.31 (3.6)	4.60 (4.2)	5.66 (3.4)	2.85 (2.7)	5.93 (3.9)	14.23 (3.6)	16.28 (3.5)	7.39 (5.8)	148.4 0	<.001	.655
3. Trait-MA	10.05 (7.6)	22.20 (9.8)	30.93 (9.1)	38.79 (10.4)	40.60 (8.1)	29.36 (11.3)	36.61 (8.0)	30.41 (12.9)	57.62	<.001	.492
4. MSC	38.75 (8.4)	38.50 (8.5)	27.11 (7.6)	42.53 (4.9)	18.82 (8.7)	33.31 (8.6)	22.93 (7.1)	30.60 (10.6)	76.18	<.001	.494
5. Math Attitudes	25.20 (2.8)	2.80 (2.5)	18.73 (3.3)	24.88 (2.7)	9.64 (2.5)	23.19 (2.7)	13.35 (3.8)	19.22 (6.3)	248.3 8	<.001	.761
Age in months	126.00 (9.8)	130.10 (7.1)	127.97 (8.8)	126.71 (8.1)	127.6 (8.5)	123.97 (8.5)	128.39 (11.9)	127.09 (9.4)	1.97	.069	.025
Gender ratio (percentage girls)	37.5%	40%	50.3%	29.2%	57.8%	45.3%	72.7%	48.2%	-	-	-

Note. MSC, math self-concept.

3.3. Relations between profiles and math performance and EF

In Table 4 and Figure 2, math performances are compared across MA-profiles. One-way ANOVA indicated that profile membership was associated with performance in the basic number skill test. The weakest math performances were observed for profile 7 'both-MA/negative MB' and profile 5 'trait-MA/negative MB', whereas profile 4 'trait-MA/very positive MB' showed the highest math performances. All three profiles (4, 5, 7) differ from the sample mean, $t(44 \text{ to } 65) = 2.90 \text{ to } 5.25$, $p < .001 \text{ to } .006$; $d = 0.43 \text{ to } 0.65$, while all other profiles (1, 2, 3, 6) exhibited scores near the mean value of the whole sample, $t(10 \text{ to } 168) = 0.27 \text{ to } 1.70$, $p = .095 \text{ to } .784$.

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

Figure 2. Boxplots of math performance among LPA profiles.

Results of one-way ANOVAs showed that profile membership was only associated with performance on the cognitive flexibility task (Table 4). Scheffé post-hoc analyses demonstrated that profile 4 'trait-MA/very positive MB' had significantly higher cognitive flexibility scores than profile 1 'no MA/very positive MB' ($p = .036$). Thus, only one mean difference among profiles was identified.

Table 4. Math Performance and EF in each LPA profile.

Variable	M (SD)				
	Math Performance	Inhibition	Cognitive Flexibility	WMC	Global EF
Profile 1 (n = 64) No MA/very positive MB	17.66 (6.7)	27.13 (5.6)	13.84 (4.4)	10.05 (2.2)	24.70 (6.1)
Profile 2 (n = 10) No MA/worst attitudes	14.50 (7.3)	31.11 (3.8)	16.00 (5.5)	10.22 (2.2)	25.56 (5.9)
Profile 3 (n = 169) average	16.36 (6.2)	27.27 (5.0)	15.25 (3.8)	10.22 (2.5)	24.42 (5.6)
Profile 4 (n = 66) Trait-MA/very positive MB	20.03 (5.9)	27.94 (5.4)	16.53 (4.1)	10.23 (2.3)	24.56 (5.9)
Profile 5 (n = 45) Trait-MA/negative MB	13.16 (7.1)	27.14 (5.3)	15.18 (4.4)	9.63 (2.1)	23.95 (5.4)
Profile 6 (n = 64) State-MA/positive MB	15.67 (6.4)	27.33 (5.3)	15.19 (4.3)	10.33 (2.4)	23.89 (6.4)
Profile 7 (n = 57) Both MA/negative MB	13.19 (6.1)	27.36 (5.2)	14.63 (3.6)	9.93 (2.5)	24.07 (5.4)
Overall	16.23 (6.7)	27.42 (5.2)	15.16 (4.1)	10.12 (2.4)	24.34 (5.8)
ANOVA	$F(1, 468) = 8.579$; $p < .001$; $\eta^2 = .100$	$F(1, 453) = 0.936$; $p = .469$; $\eta^2 = .012$	$F(1, 453) = 2.512$; $p = .021$; $\eta^2 = .032$	$F(1, 453) = 0.527$; $p = .788$; $\eta^2 = .007$	$F(1, 453) = 0.245$; $p = .961$; $\eta^2 = .003$

Note. MB, math beliefs

3.4. Relations of profiles to academic self-concepts and mindsets

To examine whether the profiles were associated with other academic self-concepts and fixed/growth mindsets, one-way ANOVAs and t-tests were calculated (Table 5). While no relation between membership and mindsets was found, SC-General and GSC were significantly associated with profile membership. The weakest SC's were observed for profile 7 'both-MA/negative MB' and profile 5 'trait-MA/negative MB', while profile 4 'trait-MA/very positive MB' showed the most positive SC's. T-tests revealed that only children of profile 5 reported more negative MSC compared to their rated SC-General and GSC. For profile 7, the other low-performing group, differences between the means were not statistically significant.

Table 5. Academic self-concepts and mindsets in each LPA profile.

Variable	T-Test		M (SD)			
	SC-Math vs. SC- German	SC-Math vs. SC- General	SC-Math	SC-General	SC-German	Fixed/Grow th Mindsets
Profile 1 (n = 64) No MA/very positive MB	$t(63) = 6.29, p < .001; d = .79$	$t(63) = 5.25, p < .001; d = .66$	38.75 (8.4)	32.56 (10.4)	31.45 (10.1)	36.91 (11.1)
Profile 2 (n = 10) No MA/worst attitudes	$t(9) = 2.09, p = .067; d = .66$	$t(9) = 1.37, p = .20; d = .43$	38.50 (8.5)	33.10 (8.6)	33.30 (10.3)	39.00 (8.9)
Profile 3 (n = 169) average	$t(168) = -0.33, p = .73$	$t(168) = -0.87, p = .39$	27.10 (7.6)	27.61 (6.7)	27.32 (7.4)	38.17 (10.7)
Profile 4 (n = 66) Trait-MA/very positive MB	$t(65) = 6.49, p < .001; d = .80$	$t(65) = 6.56, p < .001; d = .81$	42.54 (4.9)	37.11 (6.3)	35.29 (8.1)	35.3 (14.5)
Profile 5 (n = 45) Trait-MA/negative MB	$t(44) = -4.27, p < .001; d = .64$	$t(44) = -2.64, p = .011; d = .39$	18.82 (8.7)	21.71 (7.8)	25.42 (10.0)	39.64 (10.2)
Profile 6 (n = 64) State-MA/positive MB	$t(63) = 2.97, p = .004; d = .37$	$t(63) = 3.02, p = .004; d = .38$	33.31 (8.6)	30.00 (8.0)	29.63 (9.5)	36.70 (12.5)
Profile 7 (n = 57) Both MA/negative MB	$t(56) = -1.27, p = .209$	$t(56) = 0.82, p = .414$	22.93 (7.5)	22.26 (5.5)	24.39 (7.6)	39.11 (11.3)
Overall			30.60 (10.6)	28.84 (8.8)	28.89 (9.2)	37.67 (11.3)
ANOVA			$F(1, 468) = 76.179; p < .001; \eta^2 = .494$	$F(1, 468) = 31.759; p < .001; \eta^2 = .289$	$F(1, 468) = 12.456; p < .001; \eta^2 = .138$	$F(1, 468) = 1.080; p = .373; \eta^2 = .014$

Note. SC, self-concept

4. Discussion

Over the last years, intensified research in school-aged children highlighted the negative influences of MA on children's math task-processing and also on relatively enduring math learning behavior (Gunderson et al., 2018). However, there is a research gap, as previous studies have been predominately realized by correlational designs and did rarely cover different CB towards mathematics (Wang et al., 2018). The reported negative

repercussions raised outstanding issues for the development of prevention and intervention programs. CBT is considered as the gold standard for the treatment of anxieties and focuses the role of maladaptive cognitions in the development of emotional and behavioral problems (Beck, 2011). By applying LPA, this study was able to identify different patterns of MA and to provide novel insights into its cognitive phenomenology. The results suggested that four different patterns of MA existed in this sample of four and fifth graders.

4.1. Patterns of MA

Contrary to the assumption that MA is generally linked to poorer CB towards math (Moore et al., 2014; Dowker et al., 2016), the data revealed heterogenous groups of predominately state- or trait-MA individuals. These findings support the LPA-results by Wang et al. (2018), who identified similar patterns of MA and math motivation. Two profiles of the present study were characterized by solely higher levels of trait-MA (profile 3 and 4), which differ in relation to their reported MB. While profile 4 included children with very positive MB, children of profile 5 reported the worst MB. A similar observation was made for the two profiles with higher levels of state-MA (profile 6 and 7). One profile (6) was characterized by positive MB and average levels of trait-MA, contrariwise children of profile 7 reported high levels of trait-MA and negative MB. The four patterns had nearly similar proportions of children with approximately 10% to 14%. In line with prior research findings on gender differences in MA (Devine et al., 2012; Ramirez et al., 2018; Luttenberger et al., 2018), boys were more likely in profiles without MA or in the MA-profile with positive MB compared to girls, who were more often in profile 7 with manifestations of both MA-types and more negatively CB towards math.

4.2. The relation of MA-subtypes to math performance

The second goal of the study was to investigate how the different patterns of MA relate to math performance in a basic number skill test. Conforming previous studies on the state-trait-discrepancy (Orbach et al., 2019b; Sorvo et al. 2017), the correlation analyses on basis of the whole sample discovered negative coefficients between state-MA measures and math achievement, whereas no correlation of trait-MA to math scores was found. However, LPA indicated a quite more complex interplay between MA and math performance, as MA-profiles were disparately associated to math performance. Contrary to the assumption of a general performance-inhibiting effect, the analysis disclosed some math anxious children, which performed well, while other MA-subgroups exhibited the expected weaknesses. Children of profile 7, who reported high levels of both MA-types and weak MB, performed poor as expected, while MA-profile 4 had the best performance of all – also non-anxious – profiles. This group was characterized by solely trait-MA and very positive MB. A second MA-subgroup, which performed equally bad as profile 7, was profile 5 with children, who reported high trait-MA levels and worst MB but average state-MA. In contrast to the other three extremely performing MA-subgroups, profile 6 with children, who reported high state-MA, average trait-MA and positive MB, revealed scores near the mean value of the whole sample.

Besides of the common problem to identify negative linear relations between assessments of fear for failure in math and math proficiency in children (Sorvo et al., 2017; Orbach et al., 2019b), some researchers generally questioned the widespread assumption of a linear MA-performance link (Wang et al., 2015). For example, Devine et al. (2018) found 77% average to above average performing students with high MA in a large sample of primary and secondary school children. The present data also provide evidence for a more complex MA-performance link and allow fruitful hypothesis about cause-and-effect relationships. One subgroup of MA (profile 4) seems to be highly achievement-oriented and

might invest more efforts into math learning. These children are not only characterized by generally positive SC's and attitudes, they showed also higher cognitive flexibility. In general, this is a novel finding, but a previous study by Wang et al. (2018) observed a comparable pattern of children with higher math motivation and higher levels of exam MA, who exhibited above average math grades.

For two MA-subgroups (profile 5 and 7) the expected performance weaknesses were identified. Nonetheless, different explanations for these low achievements can be assumed. In line with the state-trait-model by Spielberger (1972), children of profile 7 reported high levels of both MA-types, generally negative SC's and attitudes. Thus, it can be hypothesized that these children often experienced intense state-MA in the past, which led to the development of personality MA-traits and maladaptive cognition towards math. As children of this profile also have negative SC-German and SC-General, a generalization effect might be presumed. Due to these dispositions' children evaluate a variety of academic situations as threatening. Interestingly, clear discrepancies between MSC and other SC's, and average to below average state-MA levels were found for profile 5, indicating a different cause-effect relation for the second low-achieving group. Perchance this profile can be termed as 'avoidance'-subgroup, which tries to avoid math-related situations, causing fewer opportunities to learn math and lower math performances. This profile with highest trait-disposition and lowest MB scores does not experience state-MA in the math test situation. It can be assumed that this phenomenon covers learned helplessness (Seligman, 1972), due to possible long-term experiences of specific failure in math. According to Dweck (2017) children with learned helplessness attribute their failure to fixed internal factors as intelligence or abilities. Hence, the tendency of children in this subgroup to report high fixed mindset scores supports the hypothesis of an 'avoidance'-group. Another unlikely explanation might be that these children were not triggered by the basic number skill test situation.

Finally, children of the last MA-subgroup (profile 6) achieved average math scores, while reporting high levels of state-MA and positive MB scores. Despite of the high arousal, children might not yet have developed relatively enduring trait-dispositions and maladaptive cognitions or otherwise they could experience a level of anxiety, helping them to focus attention according to the Yerkes-Dodson law (Yerkes & Dodson, 1908). The last hypothesis is in accordance with Wang et al. (2015), who were able to identify an inverted-U relation between MA and performance in adolescents with high intrinsic math motivation. Nonetheless, it could also be possible that this subgroup suffers an affective drop from above-average performance levels.

4.3. Educational and clinical implications

Generally, the reported findings underline the necessity of holistic diagnostic clarifications prior to an intervention, which would allow to address the heterogenous phenomenology and to customize the intervention approach. Overall, four different MA-patterns were identified in this sample and each profile might benefit from a different intervention focus. For example, the primary focus of interventions for profile 5 – characterized by individuals with trait-dispositions, maladaptive CB and without any clinically relevant levels of state-MA – should not be on emotion-regulation strategies to cope stressful math situation. For this specific subgroup with the tendency to avoid math situations, programs could provide exposure frameworks to increase math engagement and CBT-methods to modify maladaptive CB. Within these CBT-methods the reappraisal of failure might play an important role, as children with learned helplessness will only change their behaviour if they realize that math activities can offer experiences of self-efficacy (Dweck & Yeager, 2019). Contrary to usual exposure interventions with their main focus on fear reactions (e.g., physiological arousal), the exposure design for the ‘avoidance’-subgroup

should allow corrective emotional experiences (e.g., joyful math time; Berkowitz et al., 2015) and the fostering of math skills (Passolunghi et al., 2020; Supekar et al., 2015).

Although these interventions can be combined into the treatment plan for children of profile 7 – characterized by typical anxiety expressions with high levels of both MA-types and negative MB –, the primary focus for this subgroup should be on treatments, allowing the individual to cope with stressful math situations. On the one hand this goal might be achieved by the promotion of adaptive emotion-regulation strategies (see Garnefski & Kraaj, 2018) or standard exposure therapy (e.g., extinction learning), and on the other hand, on the enhancement of math strategies. Students' strategy choice has a key role for math performance in pressure evoking situations, as higher demanding strategies cannot be used readily in light of anxiety states (Wang & Shah, 2014; Ramirez et al., 2016). Especially students with higher EF seem to be affected by this 'choking under pressure' phenomenon (Ramirez et al., 2013; Ching, 2017; Orbach et al., 2020), which led to the hypothesis that interventions aimed at fostering the adaptive use of strategies are beneficial for children with MA. A new study (Passolunghi et al., 2020) reported that children, who participated in math strategy training, had higher math achievement and decreased MA after an 8-week intervention, while the exclusively affective-intervention was only associated with a decrease of MA. These findings could be caused by the enhancement of flexible strategy-use and improved math skills, but also by exposure effects. The repeated in vivo confrontation with fear-provoking math stimuli can lead to extinction learning by means of habituation and inhibitory learning. With regard to novel findings on exposure therapy (Craske et al., 2014), indicating that individuals with greater trait-anxieties have deficits in inhibitory learning, some modifications need to be considered (e.g., different contexts, occasional and/or multiple fear stimuli, expectancy violation) to enhance the success of exposure interventions for children with high levels of state- and trait-MA. Therefore, this exposure design differs significantly from the corrective emotional experience design for the 'avoidance'-profile 5.

Profile 4 is classified as a MA-pattern, but these highly achievement-oriented students do not need educational or clinical treatments, aiming to reduce their trait-MA dispositions – unless other psychopathological problems would arise due to their high achievement goals.

Finally, subgroup 6 – including children with high state-MA and positive MB – raises outstanding questions for future research and emphasizes the necessity for longitudinal data. If these children benefit from their state-arousal, it would be contraindicated to promote emotion-regulation strategies, while it might be also critical to disregard them, in case of a typical anxiety development over time. Thus – until more data about profile 6 is available – these children might benefit from preventions, focusing individual's resources to strengthen their positive CB (e.g., Siegle & McCoach, 2007).

4.4. Limitations

The present study has some limitations, which point to directions for future studies. First, the cross-sectional design did not allow conclusions about the cause-effect relationships over time and provides only data about fourth and fifth graders. It would be beneficial to widen the age range in future studies. Furthermore, future research should include different performance measures and attempt to replicate the patterns of MA, as LPA are often influenced by sample compositions. Another potential point of criticism is in the nature of self-reports, which could be common-method biased. Multi-method-designs might be a useful approach in this matter.

5. Conclusion

The present study pointed out the complex phenomenology of MA and its ambiguous relationship to math performance. The data revealed different patterns of MA, which might have dissimilar impacts on the performance in exam situations and perchance also long-term learning behavior. Contrary to the assumption of a general performance-inhibiting effect, the analysis showed some math anxious children, which performed well, while other MA-subgroups exhibited the expected weaknesses. These results emphasize the benefit of more holistic assessment approaches, including state- and trait-assessments of MA and CB towards math. Educational and clinical implications can be derived from the study outcomes. They underline the necessity of diagnostic clarifications prior to an intervention, which would allow to address the heterogenous phenomenology and to customize the intervention approach. Directions for further research could be longitudinal investigations of cause-effect relationships between the variables.

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