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Math anxiety assessment within the sate-trait anxiety model: psychometric analysis of the "Mathematics Anxiety Questionnaire" and "State-Mathematics Anxiety Questionnaire" in Chilean school-aged children

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Abstract

The aim of this study is to evaluate the psychometric properties of Mathematics Anxiety (MA) questionnaires based on the psychological state-trait anxiety model. Therefore, the *trait-Math Anxiety Questionnaire* (*trait-MAQ)* and the *state-Math Anxiety Questionnaire* (*state-MAQ*) were examined in a sample of Chilean school-aged children ($N=430$, $M_{age}=10.09$, 259 females and 171 males). Data analysis was performed using Exploratory Structural Equation Modeling (ESEM). Consistent with previous findings, the results corresponding to the selected model for *trait-MAQ* show the presence of two factors: unhappiness and worry, and the results corresponding to the selected model for *state-MAQ* show the presence of a single factor, both immediately prior and after the completion of a mathematical test. Additionally, measurement invariance among participants classified by gender was confirmed by Multigroup Confirmatory Factor Analysis (MCFA), and gender differences were reported with males outperforming females. The correlation among trait- and state-MA scales was moderate. These results are important evidence of the validity of the analyzed questionnaires. To our knowledge, this study is the first adaptation and validation of the *MAQ's* in Spanish. Given the profound state-trait discrepancies in MA research, it is clear that valid diagnostic tools for state and trait MA are needed for the development of MA research in Latin American countries such as Chile. Furthermore, the questionnaires are useful for gaining new insights into gender differences in MA.

Keywords Math anxiety · State-trait model · ESEM · Gender invariance

Introduction

Math Anxiety (MA) has increasingly attracted the interest of scientific research, as several studies have demonstrated its impact on mathematics performance and attitudes toward mathematics (Ashcraft et al., 2007; Haase et al., 2019; Hembree, 1990). This in turn has implications for various life scenarios where reasoning about quantitative premises is relevant (Dowker et al., 2016), both in educational and work contexts.

MA is defined as a "feeling of tension and anxiety that interferes with manipulating numbers and solving mathematical problems in a wide variety of academic and everyday situations" (Richardson & Suinn, 1972, p. 551). It differs from other anxiety forms because it is specifically triggered by stimuli with mathematical content (Carey et al., 2017). It manifests at multiple levels: cognitive (attitudes, concerns, self-assessment), affective (dysphoria), behavioral

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(short-term and long-term avoidance), and physiological (high heart rate, shallow and fast breathing) (Haase et al., 2019). Although MA is not considered a mental diagnosis, its phenomenology is consistent with the classification of a specific phobia (Faust, 1992).

Most of the available information on MA comes from studies with college students, until in recent years it was found that primary and secondary school children also report feelings of stress and fear related to mathematics (Guzmán et al., 2021). However, the available findings are inconsistent, especially among school-aged children, mainly due to the inconsistent definitions and operationalizations of MA (Zhang et al., 2019). A more precise operationalization of MA could potentially shed light on the ongoing scientific debate about this concept, which this article aims to do by dissecting MA in its trait and state dimensions.

Trait anxiety and state anxiety

The distinction between anxiety as a state and anxiety as a personality trait is essential for understanding anxiety disorders (Lazarus, 2001). Anxiety as a state is understood as a temporary anxiety reaction related to a contextual situation, associated with increased autonomic nervous system arousal (Orbach et al., 2019a). This type of anxiety is triggered in direct confrontation with a situation, in which individuals experience feelings of tension, nervousness, and threat. Anxiety as a personality trait, on the other hand, is an acquired and relatively stable and enduring disposition of an individual (Orbach et al., 2019a). Operationalizing fear of failure in mathematics captures the relatively enduring personality disposition (trait-MA), whereas the anxiety experienced in math-related situations (state-MA) focuses on a contextual component (Orbach et al., 2019b).

The state and trait MA components are mutually dependent, meaning that an individual's anxiety core beliefs (trait component), which include the fear of failure (Orbach et al., 2019a), can cause them to perceive math situations as potentially dangerous. Therefore, individuals with a trait-MA tendency tend to experience anxiety, which is likely to lead to an increase in state-MA in various mathematical contexts. Also, Spielberger et al. (1983) stated that the frequency and intensity of state anxieties influence the development of personality traits and thus increases the likelihood of developing trait-MA when state-MA is experienced on a sustained basis.

Currently existing Math Anxiety Scales

According to the literature, several instruments can be used to evaluate MA in children. Scale for Early Math Anxiety (SEMA, Wu et al., 2012), recently validated in a Spanish version (Sánchez-Pérez et al., 2021); Revised Child Math Anxiety Questionnaire (CMAQ-R, Ramirez et al., 2016), also validated in a Spanish version (Guzmán et al., 2021); modified Abbreviated Math Anxiety Scale (mAMAS, Carey et al., 2017), also validated in a Spanish version (Martín-Puga et al., 2022); Math Anxiety Scale for Young Children (MASYC, Harari et al., 2013) and Math Anxiety Scale for Young Children – Revised (MASYC-R, Ganley & McGraw, 2016), which are based on the basic Math Anxiety Rating Scale model (MARS, Richardson & Suinn, 1972) and assess the level of anxiety in situations related to mathematics (traditionally interpreted as state) asking retrospective hypothetical questions. Also, MASYC and MASYC-R include factors of concern, negative reaction, and mathematical confidence, which also allows us to measure aspects of trait-MA. The Mathematics Attitudes and Anxiety Questionnaire (MAQ, Thomas & Dowker, 2000) assesses fear of failure in mathematics (trait-MA), self-assessment of mathematical skills, and attitudes towards mathematics.

Regarding the operationalization of MA as a state, most instruments do not measure anxiety in real-time situations but instead ask people to rate how anxious they would feel in a described situation. This is an important distinction, because it could be that the instruments do not directly assess the emotional experience. It is known that when answering retrospective and hypothetical questions about emotions, individuals do not use information from episodic memory, but instead are guided by semantic knowledge and subjective beliefs about emotions (Robinson & Clore, 2002). Therefore, individuals use their emotional semantic knowledge to respond, so that responses are influenced by their core beliefs. In addition, reported findings (Roos et al., 2015) reflect a clear discrepancy between real-time assessments and hypothetical retrospective self-reports of anxiety states, a phenomenon referred to as "impact" or "intensity bias" (Levine et al., 2006). Consequently, instruments using hypothetical and retrospective questions about MA are not exclusively instruments that assess state-MA, but rather a mixture of components of state and trait MA (Orbach et al., 2020). For this reason, it might be important to evaluate state-MA more directly, e.g., through real-time instruments, which should be less influenced by subjective beliefs about emotions (Bieg, 2013).

In the literature, this distinction between assessing both dimensions of MA: state (evaluated online) and trait, has been applied in recent research (Orbach et al., 2019a, b, 2020). In these studies, a paper-pencil adaptation from the original MAQ instrument (Thomas & Dowker, 2000) was used for fourth and fifth graders to evaluate the trait component of MA (*trait-MAQ*), accompanied by a brief additional questionnaire (*state-MAQ*) used immediately before and after completion of a mathematics test to assess the state component of MA. Psychometric results (Orbach et al., 2020) and related research support the importance of accessing both dimensions of anxiety. Furthermore, these dimensions of MA have shown different results regarding the MA-performance link and the relation of MA to intelligence and learning motivation in children (Orbach et al., 2019b; Sorvo et al., 2017).

These questionnaires, based on the psychological state-trait anxiety model (MAQ 4–5 and state-MAQ) are available in German, English, and Portuguese (Krinzinger et al., 2007; Orbach et al., 2019a, b, 2020; Thomas & Dowker, 2000; Wood et al., 2012). Because of the importance of distinguishing between state and trait components, the present study aims to translate and adapt them to contribute to the evolving research on MA in general and especially in Latin America, considering that this region is underrepresented in MA literature.

The MA results from the PISA 2012 report indicate that the participating countries, particularly Latin American countries, are among those with the highest MA levels and the lowest MP. The report also ranks Chile among the ten countries with the highest levels of MA (OECD, 2013). In a nationwide study, more than half of Chilean students at all grade levels reported feelings of apprehension in response to upcoming numerical tasks in school. For example, 52% of children in 4th grade reported feelings of apprehension (Ministerio de Educación de Chile, 2019). Consequently, research on MA at the elementary school age is of great importance, allowing for early intervention to alleviate the MA manifestations and to decrease the likelihood of MA becoming entrenched as part of the self-concept (Lee, 2009).

Gender differences in Math Anxiety

Several researchers have shown that gender can influence MA manifestations, as well as MA and MP relationship, however, the current research findings are not consistent. Firstly, results regarding gender differences in MA have been found in self-reports of MA, with higher scores for the female compared to the male population (Devine et al., 2012; Gunderson et al., 2018; Hopko et al., 2003), indicating that females tend to evaluate themselves less favorably and exhibit greater levels of anxiety regarding mathematics.

Interestingly, in an attempt to differentiate the possible gender impact between state and trait MA components, Bieg et al. (2015) replicated higher trait math anxiety reported by females, but no gender differences were found for state math anxiety. The significance of these findings is high, as most measures of MA assess enduring personality traits rather than situation-related anxieties. A plausible reason may be the greater impact of self-concept and math stereotypes endorsement on personality traits, such as trait-MA, than on more situation-specific evaluation, such state-MA.

It is important to consider gender differences when studying MA in children and to seek more precise measures, such as distinguishing between trait and state components of MA, which is much less represented in current literature and suggests differential outcomes (Bieg et al., 2015). To reduce ambiguity on this issue, it is essential that questionnaires have measurement invariance across gender.

Current investigation

MA is a widely discussed research topic in the field of mathematics, with less representative research findings in the school population. Although MA manifests itself in early stages of schooling, the current state of research is contradictory and theoretical explanatory models are applied that differ in the direction of causality (Carey et al., 2016). Besides the use of different coexisting theories, this could also be due to inconsistencies in the operationalization of MA.

Our study aims to contribute to the explanation of MA by using questionnaires based on the psychological state-trait anxiety model. The trait-MA questionnaire assesses the relatively enduring personality disposition, whereas the state-MA questionnaire assesses the specific experience of an individual in confrontation with a math stimulus. Furthermore, there is an obvious need in research, clinical and educational practice in Latin American countries for a reliable instrument to assess MA in children. Moreover, there is uncertainty regarding gender differences in elementary school. Therefore, the question of the reliability, validity, and measurement invariance of the state- and trait-MA questionnaires (MAQ) for Chilean students arises. To date, the psychometric properties of the trait-MA questionnaire (trait-MAQ) have only been evaluated in one Latin American country (Brazil: Wood et al., 2012), and only a few studies worldwide have analyzed its structure at the item level. For this reason, the present study investigated the factorial structure and reliability of the trait-MA and state-MA questionnaires in 430 Chilean school-age children.

Methods

Participants

The sample included 430 children: 259 females (60.23%) and 171 males (39.77%), 223 in 4th Grade (51.86%), and 207 in 5th Grade (48.14%). The participants' ages ranged from 8 years and 6 months to 12 years and 0 months ($M = 10.09$, $SD = 0.66$). All students were enrolled in the general education system from 7 urban schools in Talca, Maule Region in Chile. To describe our sample concerning economic background, the school vulnerability index (IVE, of its Spanish term *Índice de Vulnerabilidad Escolar*) has been used. This index is calculated on an annual basis by the Junta Nacional de Auxilio Escolar y Becas (JUNAEB), a government institution that provides financial assistance to schools to prevent school dropout and mitigate consequences of poverty among students, using household information on a scale from 0 to 100%. The higher the percentage, the greater the vulnerability, hence IVE was classified as low (IVE < 25%), medium (25%> IVE > 75%), and high (IVE > 75%). In the present data, the prevalence of this classification was low IVE (22.1%), medium IVE (20.0%), and high IVE (57.9%). Students with intellectual disabilities, disorders affecting communication, and language comprehension problems did not appear in the sample, so there was no need to exclude them from the final analysis. The target group for this study was selected because the applied questionnaires have been validated for this age group in international studies (Orbach et al., 2019a, 2020). The data was collected from May to July 2022. Parental consent was obtained for all children.

Instruments

Trait-MAQ

The *trait-MAQ* (Orbach et al., 2019a, b) is a modified paper-pencil version of the MAQ by Thomas and Dowker (2000). It is designed to assess the trait component of MA using 14 items that focus on the fear of failure in mathematics. The questions are rated using a 5-point Likert scale (0 to 4), with lower scores corresponding to a greater expression of the trait-MA.

In the original English version by Thomas and Dowker (2000), this questionnaire includes a total trait-MA scale that consisted of 2 subscales: unhappiness related to problems in mathematics (Scale C) and worry related to problems in mathematics (Scale D), in addition to other scales, self-assessment (Scale A), and attitudes (Scale B), which was used as a one-to-one interview with children aged 6 to 9 years. In a standardization study published in German with children aged 6 to 9 years, the internal consistency (α) was reported to vary between 0.793 and 0.804 for the unhappiness scale, and between 0.830 and 0.865 for the worry scale, depending on the age group (Krinzinger et al., 2007), although Krinzinger et al. (2007) results indicate that the theoretical 2-factor model for scales C and D cannot be maintained in German and that CD forms a common scale Math-Anxiety.

In line with results obtained by Krinzinger et al. (2007), further studies with Brazilian children with ages ranging from 7 to 12 years, German children with ages ranging from 6 to 10 years (Wood et al., 2012); and German children with ages ranging from 8 years and 6 months to 14 years and 2 months (Grades 4th and 5th) (Orbach et al., 2019a) have shown that these two scales are not distinct from each other yielding a single-factor structure described as a trait component (Wood et al., 2012; Orbach et al., 2019a). The reliability (internal consistency) is $\alpha = 0.92$ (Orbach et al., 2019a) in the German norm sample, whereas reliability is $\alpha = 0.88$ (Wood et al., 2012) in the Brazilian sample.

State-MAQ

The *state-MAQ* is designed to assess state-MA through a real-time self-assessment of anxiety prior to a math-related situation (Pre-state-MA: 7 items to answer immediately before starting a mathematics test) and a real-time self-assessment of anxiety after the math-related situation (Post-state-AM: 7 items to respond immediately upon completion of a mathematics test).

The self-evaluation is carried out using a 4-point Likert scale (0 to 3), on which children indicate whether an emotional state applies to them currently (pre) or has done so recently (post). The questionnaire was developed following the State Anxiety Inventory by Spielberger et al. (1983). The suitability for children includes simple, short, and commonly used sentences. Its validity and reliability were evaluated in a sample of 1,369 4th and 5th grade students in Germany (Orbach et al., 2020). The *state-MAQ* assesses a one-dimensional construct. The reliability (internal consistency) of the norm sample is $\alpha = 0.83$.

The application includes instructing children that there is a notebook in front of them with a variety of math problems that they must solve without any time pressure. This instruction is given immediately before the math test, time to fill out the pre-state questionnaire. At the end of the math test, they are asked to rate how they felt during the math test, post-state. To control for other influencing factors, children are asked verbally and in writing to fill out the questionnaire only in relation to the current math test, regardless of other circumstances. In this way, it is aimed that the evaluation focuses on the state of MA in a specific situation of performing a mathematics test without time pressure (Orbach et al., 2020). If a math speed test is used as a math-related situation, children are made aware of the time limit, and the phrase "without any time pressure" is omitted. In this case, the children are instructed to work as quickly and as carefully as possible.

Math tasks

Mathematics tasks were designed for each grade level. These tests comprised tasks with content restricted to the prioritized objectives by the Chilean Ministry of Education as a result of the pandemic (Ministerio de Educación, 2021a, b) to ensure that all children had the opportunity to learn the assessed content. The math tasks were administered between the pre and post *state-MAQ* questionnaires.

Procedure

The data collection was divided into two sessions. In-class paper-pencil assessments were conducted in schools during school hours in the regular classrooms of the participating students. The same investigator conducted the application of the instruments in both sessions, accompanied by an educator.

In the first session, the *trait-MAQ* was administered, which the children could answer without any time restrictions. Completing this questionnaire took an average of 20 min.

In the second session, the *state-MAQ* was administered according to its application protocol: the *state-MAQ* (pre) was followed by the mathematics test, and immediately afterward the *state-MAQ* (post), which the children were asked to complete without any time restrictions. Completing the questionnaires and the mathematics tasks took an average of 60 min.

Translation of the questionnaires

A cross-cultural adaptation translation was conducted to ensure equivalence between the original and Chilean versions of the questionnaires. The questionnaires were translated and adapted to "Chilean" Spanish using the following procedures:

(1) Translation of the questionnaires by a bilingual person from the source language to the target language.
(2) Then, another bilingual person independently translated the items back into the source language.
(3) The translated versions were reviewed by six experts in comparison with the originals to maintain the original meaning of the items, to determine if anything important was changed in the translation process, and to evaluate the items' appropriateness for the Chilean context. The selected experts were bilingual in English and Spanish, and their areas of expertise were evenly distributed between Child Psychology and Education. The experts received the original with the translated and back-translated version to see if anything important had been changed in the translation process.
(4) The experts' responses were analyzed according to the following criteria:

   a. At least 60% of agreement.
   b. Analysis of the relevance of commentaries regardless of their exceptionality.
   c. In case of conflicting comments, the selection was based on majority opinion.

The result of the translation and expert comments confirmed the equivalence of the original and translated versions of the questionnaires. The original and translated versions can be found in the Supplementary Information.

Analysis

First, we computed descriptive statistics. Asymmetry and kurtosis were calculated for each item. The multivariate normality of the data was assessed by computing Mardia's (1970) index (K). The Mardia's skewness for the current data was, $K = 16.88$, $p > 0.05$ (*trait-MAQ*), $K = 2.40$, $p > 0.05$ (*state-MAQ-PRE*) and $K = 2.98$, $p > 0.05$ (*state-MAQ-POST*), and the Mardia's kurtosis was, $K = 265.97$, $p < 0.001$ (*trait-MAQ*), $K = 65.36$, $p < 0.001$ (*state-MAQ-PRE*) and $K = 67.02$, $p < 0.001$ (*state-MAQ-POST*), these lasts indicating a deviation from multivariate normality. The violation of multivariate normality suggests the use of Exploratory Structural Equation Modeling (ESEM) with robust estimators. ESEM has been found to fit the data better and to improve the estimation of factors when there are modest sample sizes (Asparouhov & Muthén, 2009; Marsh et al., 2014). ESEM allows items to be predominantly related to a factor, with non-zero loadings on other factors, which has been identified as the procedure that best respects the proper functioning of psychological attributes (Gomes et al., 2017; Xiao et al., 2019). Moreover, ESEM, as CFA, provides confirmatory tests of a priori factor structures (Marsh et al., 2014), which is the intended goal of the present study. No issues were detected after screening the data; therefore, no participants were excluded from the analyses.

Since the main purpose of the study was to evaluate evidence related to the underlying structure of the questionnaire's *trait-MAQ* and *state-MAQ*, analyses were focused on the factor analysis of the data. The analytical approach included several stages. The first stage was aimed at determining the number of factors to be retained. Two criteria were used for this purpose: theoretical expectations and descriptive comparison of alternative model fit. These options have been selected based on studies (e.g., Gomes et al., 2017; Hayes, (2022), as they have consistently been reported as methods with good associated results. Sampling adequacy and suitability of the data were evaluated with Kaiser–Meyer–Olkin (KMO) and Bartlett's test of sphericity.

The second stage considers the estimation of the model via ESEM. Parameter estimation was examined based on the weighted least square mean and variance adjusted (WLSMV) estimator available in Mplus Version 7.2 software (Muthén & Muthén, 2014). When fewer than five response categories are available, it is recommended to use WLSMV as the method of estimation (Beauducel & Herzberg, 2006), which can be viewed as a suitable analysis to examine fit indices with non-normal, ordered categorical data and to estimate standard errors. WLSMV Model–data fit was based on the chi-square ($\chi 2$), the Comparative Fit Index (CFI), the Tucker–Lewis Index (TLI), and the Root Mean Squared Error of Approximation (RMSEA). Acceptable model–data fit criteria included CFI and TLI values greater than 0.95 and RMSEA less than 0.06 (Hu & Bentler, 1999). Then, if necessary, a series of models suggested in the previous stage were adjusted and compared through the Confirmatory Factor Analysis (CFA). This allows the accumulation of empirical evidence to support the factor structure obtained in the previous stage.

To study the Measurement Invariance/ Equivalence (M/IE), a Factorial Invariance Analysis was performed to evaluate the stability of the factor structure (Labouvie & Ruetsch, 1995), and consequently, the equivalence of the scores between different groups using a Multi-group Confirmatory Factor Analysis (MCFA). Gender was used as a grouping variable since it is a relevant classification variable in the study of MA. M/IE was evaluated with three nested models with increasing constraints (Kline, 2016): (1) configural invariance, the least restrictive model, in which all factor loadings and item intercepts are freely estimated for each group; (2) metric invariance, which assumes configural invariance and requires equality of the unstandardized pattern coefficients; and (3) scalar invariance, which assumes weak invariance and requires equal unstandardized intercepts across groups to confirm that different groups use the indicator's response scale in the same way. Models were statistically compared using the difference between the alternative fit indices (ΔCFI and ΔTLI $\leq$ 0.01 and ΔRMSEA $\leq$ 0.015), as some researchers have shifted from a focus on absolute fit in terms of $\chi 2$ because $\chi 2$ is overly sensitive to small, unimportant deviations from a "perfect" model (Putnick & Bornstein, 2016).

Subsequently, an analysis of the internal reliability of the scales was performed using Cronbach's alpha (α) and McDonald´s omega (ω) indexes, as well as corrected item-total correlations.

Finally, correlational analysis between the questionnaires were conducted to support the scales' validity in terms of their theoretically related underlying constructs. Gender differences were also investigated by independent samples t-tests across the questionnaires.

Statistical analyses were conducted using SPSS Version 14 for descriptive, correlational, gender comparison, and reliability analysis. For the latter, the OMEGA macro developed by Hayes (2018) was used to calculate ω. Mplus 8.7 (Muthén & Muthén, 2014) was employed for the factorial analysis.

Results

The descriptive statistics for the *trait-MAQ* and the *state-MAQ* are reported in Table 1. The corrected item-total correlation estimates for the *trait-MAQ* were higher than 0.40, supporting the internal reliability of the scale (Nunnally & Bernstein, 1994). Regarding the *state-MAQ*, both in its application prior to (PRE) and after (POST) the mathematical task, all items except item 1 were also higher than 0.40 (see Table 1).

The measures of sampling adequacy indicated an adequate fit of the data to the factorial model. For *trait-MAQ*, the KMO measure reaches a value above the recommended criterion (KMO = 0.865) and Bartlett's test of sphericity leads to the rejection of the hypothesis that the empirical matrix

Table 1 Descriptive statistics and corrected item-total correlations for the *trait-* and *state-MAQ*

Item	Mean	SD	Skewness	Kurtosis	Corrected item-total correlation
Trait Math Anxiety: MAQ 4–5					
1	1.79	1.053	0.289	0.096	0.563
2	2.03	1.070	0.271	-0.272	0.541
3	1.78	1.199	0.191	-0.671	0.507
4	1.96	1.340	0.071	-1.068	0.470
5	1.67	1.169	0.291	-0.538	0.489
6	1.78	1.151	0.217	-0.477	0.546
7	1.68	1.174	0.424	-0.507	0.466
8	1.39	1.141	0.56	-0.388	0.503
9	1.66	1.105	0.383	-0.361	0.382
10	1.53	1.307	0.548	-0.725	0.458
11	1.71	1.340	0.328	-0.966	0.387
12	1.56	1.162	0.452	-0.444	0.468
13	1.46	1.172	0.572	-0.356	0.537
14	1.27	1.205	0.858	-0.069	0.434
State Math Anxiety: *state-MAQ*-PRE					
1	0.95	1.040	0.712	-0.773	0.280
2	1.72	1.230	-0.335	-1.497	0.646
3	1.29	1.203	0.268	-1.486	0.682
4	1.43	1.254	0.097	-1.633	0.603
5	1.33	1.259	0.215	-1.615	0.570
6	1.25	1.232	0.318	-1.521	0.411
7	1.27	1.275	0.319	-1.593	0.665
State Math Anxiety: *state-MAQ*-POST					
1	1.23	1.212	0.381	-1.436	0.070
2	1.78	1.254	-0.396	-1.509	0.638
3	1.50	1.295	0.009	-1.713	0.706
4	1.31	1.269	0.259	-1.612	0.649
5	1.46	1.30	0.031	-1.723	0.577
6	1.40	1.301	0.146	-1.705	0.540
7	1.26	1.326	0.327	-1.679	0.693

is equal to an identity matrix ($\chi 2 = 1832.538$; $p < 0.01$). For the *state-MAQ-PRE*, the KMO measure reaches a value above the recommended criterion (KMO = 0.833) and Bartlett's test of sphericity leads to the rejection of the hypothesis that the empirical matrix is equal to an identity matrix ($\chi 2 = 872.035$; $p < 0.01$) and for the *state-MAQ-POST*, the KMO measure reaches a value above the recommended criterion (KMO = 0.832) and Bartlett's test of sphericity leads to the rejection of the hypothesis that the empirical matrix is equal to an identity matrix ($\chi 2 = 1032.861$; $p < 0.01$).

The factor retention strategy was conducted by the comparison of ESEM models fit using the previously mentioned parameters ($\chi 2$, CFI, TLI, and RMSEA). One- and two-factor models, if applicable, depending on theoretical expectations, were respectively fit to each questionnaire. Table 2 shows the summary of the goodness-of-fit indices of the alternative models.

Important results are derived from Table 2 regarding trait anxiety evaluated through the *trait-MAQ*. First, the one-factor model presents a clear misfit to the data while the two-factor model when covarying the items recommended in the modification indexes, shows an adequate fit. When evaluating the strength of the *trait-MAQ* questionnaire models, it is important to consider their capacity to match a theoretical model, which in this case are two: one-factor model, which represents a combined one-factor model for scales C (unhappiness) and D (worry) (Krinzinger et al., 2007; Orbach et al., 2019a; Wood et al., 2012) and a two-factor model (Thomas & Dowker, 2000) and also, their capacity to explain the data (Hayes, 2022; Kline, 2016). Kline (2016) emphasizes the importance of theoretical models in guiding the development and evaluation of statistical models, arguing that models that conform to theoretical expectations are generally preferred. Likewise, Hayes (2022) states that models that are consistent with established theory are more likely to provide accurate and reliable estimates of parameters. Therefore, the decision was made in favor of the two-factor model, as it has a high explanatory power for both the data due to the strong fit of this model, and one of the theoretical expected models, as the two-factor model corresponds to the structure presented in the original design of the questionnaire for the English student population (Thomas & Dowker, 2000).

In this solution, there is cross-loading in item 12 on the two factors. To determine the contribution of the cross-loadings in the model fit, the two-factor models with and without cross-loading in item 12 were fit using CFA. Results indicate that ΔRMSEA = 0.004, ΔCFI and ΔTLI = 0.002, which are not significant variations in fit (ΔCFI < 0.01; RMSEA < 0.01 and TLI < 0.01) (Putnick & Bornstein, 2016), therefore, the simpler two-factor model without cross-loading is the one selected.

As for Table 2 regarding state anxiety assessed by the *state-MAQ*, the one-factor model fits the data according to the theoretically supported expectation when the items recommended in the modification indices are covariated. Item 1 was specially revised because the corrected item-total correlation indicated inconsistencies with the average behavior of the other items. For both application moments, pre and post, the R-square associated with item 1 ranked from 0.01 to 0.13, indicating a poor contribution to the model. Therefore, the single-factor model without this item was the chosen for this questionnaire. It is important to notice that even the $\chi 2$ statistic met the criteria for the single-factor solution, which is also the expected model based on previous results (Orbach et al., 2020). Therefore, more factors solutions were not necessary to test.

To evaluate the factor structure, the matrices corresponding to the selected ESEM models for each questionnaire were used: a two-factor model for the *trait-MAQ* and

Table 2 Summary of goodness-of-fit indices for the ESEM models

Models	$\chi 2$	gl	p-value	RMSEA (CI90)	CFI	TLI
Trait Math Anxiety: *trait-MAQ*						
1 Factor	851.99	77	0.00	0.16 (0.15–0.17)	0,74	0,69
2 Factors	272.21	64	0.00	0.09 (0.08–0.10)	0,93	0,90
2 Factors*[1]	165.37	63	0.00	0.06 (0.05–0.08)	0,97	0,95
State Math Anxiety: *state-MAQ*-PRE						
1 Factor, 7 items	140.94	14	0.00	0.15 (0.13–0.18)	0.94	0.91
1 Factor, 7 items*[2]	57.33	13	0.00	0.09 (0.07–0.12)	0.98	0.97
1 Factor, 6 items*[2]	12.19	8	0.14	0.04 (0.00–0.08)	0.99	0.99
State Math Anxiety: *state-MAQ*-POST						
1 Factor, 7 items	163.61	14	0.00	0.17 (0.14–0.19)	0.95	0.93
1 Factor, 7 items*[2]	44.61	13	0.00	0.08 (0.05–0.11)	0.99	0.98
1 Factor, 6 items*[2]	15.06	8	0.06	0.05 (0.00–0.08)	0.99	0.99

(*[1]) refers to a model with covariance between items 4 and 11 and (*[2]) refers to a model with covariance between items 5 and 6

Table 3 Factor loadings of the 2-factor ESEM model corresponding to *trait-MAQ*

	Factor 1: Unhappiness	Factor 2: Worry
How happy or unhappy are you if…		
You have problems with math in general?	0.854**	-0.054
You have problems with written calculation?	0.708**	0.028
You have problems with mental calculation?	0.717**	-0.013
You have problems with easy calculation?	0.553**	0.029
You have problems with difficult calculation?	0.666**	0.020
You have problems with math homework?	0.760**	0.003
You have problems with listening and understanding during math lessons?	0.657**	-0.002
How worried are you if…		
You have problems with math in general?	0.005	0.740**
You have problems with written calculation?	-0.075	0.614**
You have problems with mental calculation?	0.068	0.614**
You have problems with easy calculation?	-0.003	0.489**
You have problems with difficult calculation?	0.104*	0.556**
You have problems with math homework?	-0.039	0.826**
You have problems with listening and understanding during math lessons?	0.056	0.561**

(**) The parameters are statistically significant at 0.01 level. (*) The parameters are statistically significant at 0.05 level

Table 4 Factor loadings of the 1-factor ESEM model corresponding to *state-MAQ*

	Factor 1: state-MA	
	PRE	POST
I am/was nervous	0.833**	0.857**
I am/was worried	0.860**	0.888**
All I can/could think about was what might go wrong	0.702**	0.791**
I am/was restless	0.623**	0.652**
I am/was impatient	0.492**	0.613**
I am/was afraid	0.834**	0.880**

(**) The parameters are statistically significant at 0.01 level. All saturations correspond to the single factor and are displayed in gray

a single-factor model for the *state-MAQ*. Tables 3 and 4 present the factor loadings for the respective questionnaires.

As shown in Tables 3 and 4, the factors were well-defined by the presence of target loadings greater than 0.40 for all items in both questionnaires. For the *trait-MAQ*, which is the questionnaire with more than one factor, the correlation among them is moderate (r = 0.42, $p < 0.001$).

Subsequently, to determine the existence of M/IE, a factorial invariance analysis was performed using the gender of the participants (female vs. male) as a grouping variable. Results are presented in Table 5.

As represented, even $\chi 2$ denotes the absence of significant fit changes in most of the models, except for the difference between metric and scalar models in the *trait-MAQ*

Table 5 Goodness-of-fit indices for the factorial invariance analysis

	$\chi 2$	gl	p-value	$\Delta\chi 2$	Δgl	Δp-valor	RMSEA (CI90)	CFI	TLI
Trait Math Anxiety: *trait-MAQ*									
Configural	249.021	150	0.000				0.058 (0.045–0.070)	0.965	0.958
Metric	254.505	162	0.000	11.253	12	0.507	0.054 (0.041–0.066)	0.968	0.964
Scalar	313.85	202	0.000	67.911	40	0.004	0.053 (0.041–0.064)	0.961	0.965
State Math Anxiety: *state-MAQ*-PRE									
Configural	22.258	16	0.135				0.045 (0.000–0.086)	0.997	0.994
Metric	24.988	21	0.248	2.73	5	0.740	0.031 (0.000–0.071)	0.998	0.997
Scalar	37.229	32	0.241	12.241	11	0.350	0.029 (0.000–0.063)	0.997	0.997
State Math Anxiety*: state-MAQ*-POST									
Configural	20.869	16	0.184				0.040 (0.000–0.082)	0.998	0.997
Metric	30.162	21	0.089	9.293	5	0.100	0.047 (0.000–0.083)	0.997	0.996
Scalar	48.025	32	0.034	17.863	11	0.080	0.051 (0.014–0.079)	0.995	0.995

and the *state-MAQ-POST*. Nonetheless, the remaining indicators in both questionnaires demonstrate that there is no significant loss in fit at both the metric and scalar invariance levels (ΔCFI and ΔTLI < 0.01 and ΔRMSEA < 0.015), as mentioned above (Putnick & Bornstein, 2016). These results prove that not only the rate of change of the latent factors (factor loadings) are equivalent, but also the means of the factors have the same meaning between groups (intercepts). Therefore, it is possible to assert the existence of invariance of the factor models in both questionnaires between male and female participants, which means that they have a similar fundamental understanding of *trait- and state-MAQ* and interpret the items for each questionnaire in a comparable manner.

Subsequently, as for the reliability analyses, both questionnaires obtained adequate corrected item-total correlations (see Table 1), Cronbach's alpha (α) and McDonald´s omega (ω) coefficients, considering the totality of the considered items, the original items for the *trait-MAQ*, and reduced items for the *state-MAQ*: α*(trait-MAQ)* = 0.842, α*(state-MAQ-PRE)* = 0.828 and α(*state-MAQ-POST)* = 0.859; ω*(trait-MAQ)* = 0.830, ω*(state-MAQ-PRE)* = 0.828 and ω(*state-MAQ-POST)* = 0.859. As for the factors of the *trait-MAQ* questionnaire, the values of the α and ω coefficients were also appropriate: α(Factor 1: Unhappiness) = 0.844, α(Factor 2: Worry) = 0.798; ω(Factor 1: Unhappiness) = 0.844, ω(Factor 2: Worry) = 0.800. In summary, the results show that the scales of both questionnaires present an adequate level of reliability.

The results of the bivariate Pearson's correlations between the questionnaires showed a significant negative association between *trait-MAQ* and *state-MAQ* in both application moments. The correlation coefficients were, between *trait-MAQ* and *state-MAQ-PRE*: r = -0.36, $p < 0.001$, and between *trait-MAQ* and *state-MAQ-POST*: r = -0.28, $p < 0.001$, indicating a moderate correlation. The negative direction is explained by the fact that the scales are reversed. The *trait-MAQ* lower scores are associated with higher MA-trait presence, while the higher *state*-MAQ scores are associated with higher MA-state presence, hence a negative association means a direct relation between the evaluated MA components: trait and state. The PRE and POST application moments of the *state-MAQ* have a high correlation of $r = 0.688$ ($p < 0.01$), also indicating a direct relationship between both moments.

Independent-samples t-tests were conducted comparing both questionnaires across gender. Regarding *trait-MAQ*, the mean scores of the boys (M = 26.27, SD = 8.53) and the girls (M = 21.25, SD = 9.62) yielded a significant difference between the two groups, t(394) = 5.32, $p < 0.05$. As *trait-MAQ* lower values are associated with a higher presence of MA-trait, the boys obtained significantly better results than the girls. Cohen's d effect size was 0.55, indicating a medium effect. As per *state-MAQ*, in both application moments boys obtain significantly lower values (PRE: M = 1.05, SD = 0.78; POST: M = 1.12, SD = 0.92) than girls (PRE: M = 1.61, SD = 0.95; POST: M = 1.66, SD = 0.97), for the previous assessment: t(386) = -6.09, $p < 0.05$, with a Cohen's d effect size of -0.64, indicating a medium effect; and for the latter assessment: t(386) = -5.44, $p < 0.05$, with a Cohen's d effect size of -0.57, indicating a medium effect.

Discussion

In recent years, anxiety toward mathematics is a frequently discussed topic in research and school practice, as research findings highlight its long- and short-term repercussions for individuals (Dowker et al., 2016). This fact illustrates the necessity of adequate diagnostic tools for young children. Since recent evidence suggests that differentiating between trait-MA and state-MA is important to evaluate the effects of MA on math proficiency, attitudes, and learning motivation (Orbach et al., 2019b; Roos et al., 2015), the aim of the present study was to adapt and validate state- and trait-MA questionnaires for Chilean students. Therefore, the internal structure of the *trait-MAQ*, assessing the trait dimension of MA, and the *state-MAQ*, assessing the state dimension of MA, in a sample of Chilean school children were examined. The results are thus a continuation of previous research (Krinzinger et al., 2007; Orbach et al., 2019a, 2020; Thomas & Dowker, 2000; Wood et al., 2012) conducted in other cultural contexts with substantial language differences. The present research is the first analysis for Spanish-speaking schoolchildren from a Latin American country and in this way simplifies their adaptation to other Spanish-speaking cultures for future cross-cultural studies. Since the math-related situations and emotions described in the questionnaires are not formulated in an age-specific manner (Orbach et al., 2019a), they can also be used in other age groups, provided that reading comprehension is given.

The present research aims to gain further empirical insights into validity with respect to the underlying factorial structure of both questionnaires. Specifically, it aims to achieve two goals: first, to evaluate the dimensionality of the scales using techniques currently recommended for assessing evidence of internal structure validity, and second, to study the generalization of these metric properties by evaluating the M/IE, through the MCFA between boys and girls. This property is a necessary condition for the validity of comparisons between different groups (Putnick & Bornstein, 2016), and comparison between groups classified by gender is highly relevant because of the heterogeneity nature of research findings on MA.

The results support the rationale and internal structure described in previous studies in assessing both trait and state dimensions of MA. The solutions of questionnaires studied yield factor loadings that clearly distinguish the corresponding factor structures. In addition, only one item in *trait-MAQ* had significant cross-loading, and after testing models with and without cross-loading, the insignificant variation in the models fit led to the selection of the most parsimonious model previously reported in the literature.

These results replicate the two dimensions of the *trait-MAQ* corresponding to the scales in the original questionnaire for the English student population (Thomas & Dowker, 2000), from which it is derived, in contrast with previous empirical studies that validated versions of the *trait-MAQ* in Portuguese (Wood et al., 2012) and German (Krinzinger et al., 2007; Orbach et al., 2019a; Wood et al., 2012). The reduced presentation of the scales originally designed to assess MA, namely unhappiness and worry (Thomas & Dowker, 2000) may have played a role in identifying the 2-factors solution. This shorter form has been applied in research specifically targeting MA (Orbach et al., 2019b, 2020; Orbach & Fritz, 2022). The obtained 2-factor solution contrasts with previous empirical studies that employed all 4 scales (also including self-assessment and attitudes) and obtained a single-factor combination (trait-MA) of the unhappiness and worry scales (Krinzinger et al., 2007; Orbach et al., 2019a; Wood et al., 2012).

The first dimension corresponds to questions aimed at evaluating the unhappiness component related to poor mathematical performance. These questions have the same heading ("How happy or unhappy are you if …") and refer to seven different scenarios related to mathematics such as math homework, mental and written calculation, and listening and understanding during math lessons. The second dimension consists of questions aimed at assessing the component of worry related to poor mathematical performance. These questions differ from the previous ones in their heading ("How worried are you if…") and refer to seven scenarios related to poor mathematical performance. Unhappiness or sadness and worry have been defined as being linked to mathematical self-concept (David et al., 2022), and it is suggested that they lead to avoidance behaviors towards a mathematical situation.

In addition to this, the results replicate the unidimensional structure of the *state-MAQ* previously reported in the German norm sample (Orbach et al., 2020). Our data provided evidence that the questions have a stable structure in both application moments (pre and post). This is the first time that a detailed analysis of both application moments is reported, because although the questions refer to the same anxiety dimensions – emotional (nervous and afraid), cognitive (worries and thinking), and physical (restless and impatient) –, one could argue that the results could be influenced by some characteristics, such as the difficulty of the mathematics test, which at the same time may influence the different MA-state manifestations associated with the application moments. In the present study, the attainability level of the mathematics tasks was considered as a criterion for the research design.

In both application times, *state-MAQ* pre and post, a correlation between items 5 and 6 was found. These items refer to the physical dimension, and this could be evidence that physical manifestations of anxiety are often easier to recognize and associate than cognitive or emotional ones because they are more visible and tangible. Contrary to the German version of the *state-MAQ*, the analysis showed that the Chilean adaption of item 1 does not fit into the existing factor structure. One explanation for this could lie in the connotation of the German word "aufgeregt", which literally translated as "exciting" in English. In German, "aufgeregt" means something like "in agitation, heated, dissolved" (Duden editors, 2022), while the Spanish and English version means something more positive like "excited, eagerly awaiting". Given that the results clearly indicate that the selected term was not appropriate, it is recommended to exclude item 1 for future users of the scale. According to the explanatory models of MA: Processing Efficiency Theory (Eysenck & Calvo, 1992) and Attention Control Theory (Eysenck et al., 2007), arousal of the autonomic nervous system –involving worrisome thoughts in an actual math situation – functions as a resource-demanding secondary task, inhibiting the cognitive processing and causing an important decrease in MP.

According to Lazarus' transactional model (2001), students with higher trait dispositions of math-related worries are more likely to perceive math situations as threatening and to believe that they cannot cope with them. Consequently, they are more likely to experience state-MA when confronted with math-related stimuli. The moderate correlation between the trait- and state-MA scales is in line with this model and the theoretical expectation of the state-trait-anxiety model (Spielberger et al., 1983): the higher the trait-MA, the more likely individuals are to experience state-MA in a specific mathematical task; and vice versa, the more frequent and intense state-MA is, the greater chance of matching a trait-MA personality profile.

When testing the factorial structure in a multigroup analysis across gender, all levels of constraint supported the invariant nature of the factor structure. The results of the M/IE analysis show the existence of metric invariance between boys and girls in both questionnaires. This finding ensures the equivalence of the relationship between the item's scores leading to the factor loadings (invariance of the factor loadings) and the mean of the factors (invariance of the intercepts). These results are evidence supporting the validity of comparisons that can be made between groups divided by gender. This certainty is particularly important for subsequent research aimed at assessing gender differences in MA in the school-age population.

Gender differences in trait MA were found in the present sample, replicating previous findings that females perform worse than males (Bieg et al., 2015; Devine et al., 2012; Gunderson et al., 2018; Hopko et al., 2003), suggesting that even from early academic years (primary education) children demonstrate gender-based differences. In contrast to Bieg et al. (2015), differences between state-MA were also reported, again with worse results for females. This may be partly because Chile has the second-highest MA rate among secondary school students, surpassed only by Mexico, while also having one of the largest MP gender gaps in the world, with males outperforming females (OECD, 2013). Therefore, the study of gender and MA in Chile is of great interest, with future directions including MP.

Also in the present study, the results of the corrected item-total correlation (except in item 1 in the state-*MAQ*, which was excluded from the selected models) and Cronbach's alpha and McDonald's omega coefficients indicated adequate internal consistency reliability of the questionnaires and the respective dimensions.

The available instruments for assessing MA in children face challenges, especially when it comes to evaluating state emotions. Most available instruments do not measure acute state anxieties (reported online), but instead, assess how children might feel in hypothetical situations. In this sense, the use of the evaluated questionnaires, covering the dimensions of state- and trait-MA, can be an additional tool in research and educational settings, to other MA classifications mainly focused on diverse scenarios or domains of mathematics. Such previous classifications are available in other scales, such as the mAMAS (Carey et al., 2017) which has the same underlying factor structure as the original AMAS (Hopko et al., 2003), with subscales measuring learning and assessment anxiety in mathematics; the SEMA (Sánchez-Pérez et al., 2021; Wu et al., 2012) that distinguishes numerical processing and performance anxiety, and the CMAQ-R (Guzmán et al., 2021), conceived as two subscales: MA to explicit numerical situations and general math situations. The incorporation of state- and trait-MA variables into the current state of MA research provides an alternative and less used operationalization of MA that can be studied in combination with cognitive variables relevant to MP.

Limitations

Some limitations may have influenced the present results. This is the case because there is no representative sample in terms of gender. In the present sample, there is a greater representation of female than male participants. However, this figure does not correspond to the frequency of each gender in the Chilean population at the obligatory education levels (from 6 to 18 years of age) in Talca, Maule Region in Chile: 51.62% of males and 48.38% of females out of the total enrollment (Biblioteca del Congreso Nacional de Chile [BCN], 2022). Although the available data cover a much wider age range than the present sample, they suggest a lack of representativeness.

The study is exclusively focused on the factor structure and the internal consistency of the questionnaires. Evidence of temporal stability (i.e., test-retest reliability), and concurrent and discriminant validity (i.e., relations with other scales) remain the focus of future research. Likewise, although it is a known that MA cannot be explained by general anxiety or test anxiety (Carey et al., 2017; Hembree, 1990; Hopko et al., 2003; Orbach et al., 2019a), a domain-specific form of anxiety should be related to general anxiety tendency (Luttenberger et al., 2018), and more general forms of anxiety were not controlled for in this study. Thus, the individual variability in the questionnaires could be due to general anxiety in addition to MA. It would be interesting to examine or control for variables of general anxiety in future studies.

Conclusions

To the best of our knowledge, the present study is the first to adapt and validate Spanish versions of the *trait-MAQ* and *state-MAQ* to assess the trait and state components of MA, which will facilitate future comparative research on this topic. The results are supported by the use of rigorous statistical methods and approaches that confirm the underlying structure in line with previous studies and indicate subtle changes that apply to the Chilean sample, such as the elimination of item 1 (excited) in the *state-MAQ*. Overall, the current findings suggest that questionnaires are psychometrically sound for assessing MA in the Chilean context. Furthermore, the models selected for each questionnaire exhibited gender invariance, which made it possible to find significant gender differences in both trait- and state-MA in the present sample, with males outperforming females. M/IE will allow future research to gain more insight into the influence of gender on MA and other variables that affect MP.

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Data availability The datasets generated during and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Declarations

Ethical approval The study protocol was approved by the Scientific Ethics Committee of the University of Talca, Chile (Ethics Approval Number: 27-2021).

Informed consent Informed consent was obtained from the legal guardians of all children included in the sample. Additionally, all children provided verbal assent to the assessments.

Conflict of interest On behalf of all the authors, the corresponding author states that there is no conflict of interest.

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