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Translation, Adaptation, and Validation of the Children's Mathematics Anxiety Scale into Turkish

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Abstract

A Turkish version of the Children's Mathematics Anxiety Scale UK (CMAS-UK) was created to be used with primary school samples (n = 1450). A multistep process was followed, including (1) the translation and adaptation of the scale; (2) exploratory factor analysis and parallel analysis; (3) reliability analysis; (4) confirmatory factor analysis; and (5) convergent and discriminant validity evidence. Unlike the original version of the CMAS, exploratory factor analysis revealed a two-factor internal structure. Comparison of the fit indices for the three models demonstrated that a 19-item two-factor solution was the preferable model. Mathematics anxiety scores at grades 2-4 showed a positive relationship with children's mathematics anxiety at grades 1-5. Multivariate analyses revealed no significant differences in mathematics anxiety by gender whereas significant differences were found across grade levels. The CMAS-TR is the first cultural adaptation with an older sample and sound psychometric properties supporting future cross-cultural research on mathematics anxiety.

Keywords: Adaptation, validation, cross-cultural, mathematics anxiety, primary school

Introduction

Mathematics has been the focus of research due to its importance in preparing a competent workforce in the science, technology, engineering, and mathematics (STEM) subjects (e.g., Wai et al., 2010) and developing competencies necessary for lifelong learning (European Parliament and the Council of European Union, 2006). The foundation of successful learning of mathematics (i.e., strong mathematical skills) during secondary school education is effective mathematics learning during earlier stages of schooling (Clements & Sarama, 2009). Therefore, it is important to investigate the factors that have an impact on the poor mathematics achievement (i.e., weak mathematical skills) of young children.

Mathematics anxiety is one of the most crucial factors that affect mathematics achievement (Dowker et al., 2016; Harari et al., 2013). The most robust finding in math anxiety research is that an increased math anxiety has detrimental effects on students' mathematics performance (see Ma, 1999 for a meta-analysis). It is a serious problem that affects all age groups across the globe as evidenced in the results of international large-scale assessments (e.g., Program for International Assessment (PISA), 2019) documenting that most 15-year-old students have high level of worry in mathematics classes and that they feel in tension when doing mathematics. Mathematics anxiety has been commonly defined as a specific feeling of pressure, worry, fear, or tension that directly interferes with mathematics performance (Ashcraft & Kirk, 2001). It is generated by manipulating the numerical stimuli in academic situations and daily life (Passolunghi et al., 2020) and during mathematics assessments in the classroom (Ramirez et al., 2018).

Mathematics anxiety is considered a multifaceted construct (Lukowski et al., 2019; Namkung et al., 2019) including two interrelated dimensions (Carey et al., 2017; Hopko, 2003; Lukowski et al., 2019): (1) math learning anxiety [i.e., solving mathematical tasks, acquiring math concepts and procedures, talking with peers about mathematics in the classroom, observing the teacher during math classes], and (2) math testing anxiety, [i.e., pop-quizzes that are not announced in advance, planned tests or examinations, and assessment situations]. It is noteworthy, mathematics anxiety must be distinguished from other types of anxiety related to learning (i.e., general academic anxiety) and/or testing (i.e., test anxiety). General academic anxiety refers to the negative feelings experienced in all academic situations, no matter what the subject's specificity is (Krispenz et al., 2019). It influences lifelong academic/vocational development

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and cause voluntary procrastination in intended actions/ decisions related to the academic context (van Eerde, 2003). Unlike general academic anxiety, mathematics anxiety is specifically related to impairments in processing math-related tasks and/or taking math-related actions. On the other hand, test anxiety is a subjective emotional state that includes responses (e.g., cognitive, physiological, and behavioral) to possible concerns about poor performance (i.e., fear of failure) experienced before or during evaluative situations (Bodas et al., 2008). Unlike test anxiety, mathematics anxiety occurs not only during examination contexts but also in other non-academic contexts in daily life (Ashcraft, 2002). Obviously, students suffering from mathematics anxiety show weak progress specifically in mathematical calculations/ computations or evaluative mathematical situations (e.g., Namkung et al., 2019; Shi & Liu, 2016) at all age levels starting from early school-aged children to adulthood. Mathematics anxiety is experienced by children as early as four-years of age (Petronzi et al., 2019) and then in the following years of schooling (Ganley & McGraw, 2016) significantly decreasing students' mathematics performance (Zhang et al., 2019). Highly math-anxious students avoid math (Andrews & Brown, 2015; Namkung et al., 2019), show resistance in taking math-related elective courses (Ashcraft & Krause, 2007), espouse less positive attitudes toward math (Geist, 2010) and exhibit lower self-confidence in mathematical skills (Lim & Chapman, 2013). Although Hembree (1990) indicated in a comprehensive meta-analysis on the trajectory of mathematics anxiety development that the level of mathematics anxiety increases as students move on school years (i.e., reaches its peak in secondary years, and then plateaus until adulthood), none of the 151 studies included results obtained from early school-aged children. However, in recent years, the nature of mathematics anxiety and its origins have changed towards opinions that put forth mathematics anxiety may start earlier as most of the students at grade four and five experience mathematics anxiety (Gunderson et al., 2018). Indeed, the construct of mathematics anxiety in the early years – a pre-requisite phase in later childhood and adulthood – is now on the spot as a rigid educational obstruction (Baptist et al., 2007). This raises the question of how mathematics anxiety in young children can be measured (Petronzi et al., 2019) to provide insights into when mathematics anxiety begins and how it develops in young children (Dowker et al., 2016).

Given the consequences over the course of an individual's life of a high level of mathematics anxiety and low level of performance in math-related situations either in academic settings or in daily life situations, it is reasonable to develop and/or adapt reliable and valid instruments to study the origins and nature of mathematics anxiety in young children. Besides, there is a need for multilanguage versions of educational and psychological instruments (Hambleton et al., 2005) as interest in cross-cultural psychology and international comparative studies of achievement grows. An important step forward for research in understanding the causes and correlates of mathematics anxiety as well as for the use of mathematics anxiety in educational research and practice would be to have a multidimensional, reliable, and valid measurement tool to assess the construct. Toward this end, several scales have been developed to measure students' mathematics anxiety (e.g., Fennema & Sherman, 1976; Hopko et al., 2003; Hunt et al., 2011; Núñez-Peña et al., 2014; Plake & Parker, 1982; Suinn et al., 1988; Wigfield & Meece, 1988), many of which are adapted to different languages and cultures. Since the pioneering work of Richardson and Suinn (1972), who proposed the Math Anxiety Rating Scale (MARS) strongly emphasizing mathematics test and numerical anxiety, various scales were developed for the assessment of mathematics anxiety in an attempt to provide shorter version of the original MARS to provide less time-consuming scales to assess math anxiety (e.g., Hopko et al., 2003; Hunt et al., 2011). However, these short versions were all developed with unidimensional representation of negative affect toward mathematics and hence, lacked adequate validity evidence. As an important question concerns whether additional dimensions or facets of mathematics anxiety exist, the multidimensional nature of mathematics anxiety was expressed in the several scales (e.g., Ashcraft, 2002; Bai, 2011). Additionally, there is clearly a long history of adapting (Akın et al., 2011; Baloğlu & Balgalmış, 2010; Kandemir et al., 2016; Özdemir & Gür, 2011; Akçakın et al., 2015) or developing (e.g., Bindak, 2005; Deniz & Üldaş, 2008; Mutlu & Söylemez, 2018; Yıldırım & Gürbüz, 2017) measures of mathematics anxiety in Turkish educational contexts. The bulk of international and national studies traditionally developed and/or adapted measurement scales using Likert-scale response formats to determine the factorial structure of mathematics anxiety frequently in middle school, secondary school, university or in adult populations (e.g., Hunt et al., 2011; Plake & Parker, 1982). Many existing mathematics anxiety scales for older students use response formats that include written labels pertaining to levels of mathematics anxiety (e.g., Ramirez et al., 2018; Suinn et al., 1988), which may be difficult for younger students to comprehend such labels. And those developed or adapted for younger students included advanced concepts that might be compromising to understand and thus, are limited in their use regarding the content and format (e.g., Suinn & Winston, 2003). Another limitation with the existing scales is reserved for the focus on older age ranges such as from Grade 4 (age 9–10) to Grade 6 (age 11–12) (e.g., Suinn et al., 1988) or with age 9–14 (e.g., Chiu & Henry, 1990). One notable exception is Petronzi et al.'s (2019) measure of CMAS-UK, which was built upon previous exploratory factor analysis (n = 307) of the scale and focused on the further development of this scale using simple emoticons with three response choices.

Since prevalent research on the mathematics anxiety dimensions stresses the complex structure of mathematics anxiety (e.g., Wigfield & Meece, 1988), there is a need to explore and validate the factorial structure of mathematics anxiety in young children with accurate measures for different cultures. For choosing the scale to adapt, we first conducted a thorough analysis of the existing instruments presented in meta-analysis of mathematics anxiety (Hembree, 1990), then identified those covering all the dimensions (i.e., affective and cognitive) indicated as essential in the literature (Commodari & La Rosa, 2021), appropriate for young children (Petronzi et al., 2018), and eventually selected the CMAS-UK (Petronzi et al., 2019). As Petronzi et al.'s (2019) scale considers the mathematics anxiety of 4–7 years old children only in numeracy using emoticons, the CMAS-UK seems quite specific in both content and format for young children and has the potential to be particularly suitable for intervention studies that would help researchers address ways to cope with mathematics anxiety in young children. To the best of our knowledge, there have been no adaptation studies that investigated the psychometric properties of the CMAS-UK with a sample of different students. It is also not known whether the CMAS-UK would provide a different factorial structure in different cultural contexts. Accordingly, the purpose of the current study was to adapt the CMAS-UK into Turkish, evaluate the psychometric properties of the CMAS-TR with a Turkish sample, and provide validity evidence for use in Turkish educational contexts. Our overarching research question was: "What are the psychometric properties of the Turkish adaptation of CMAS - UK?"

Method

Research Design and Participants

The study was conducted with a convenience sample (i.e., based on existing contacts with school administrations) from five public primary schools situated in Mersin, Türkiye. The participating schools were all mixed-gender and ranged from medium to large sizes. These schools represented a diverse socio-demographic body of students ranging from low to medium socioeconomic status.

The initial sample included 1492 students (50.1% females and 49.9% males), who were present at the days of data collection. Preliminary analysis revealed that the average percentage of missing data was 0.28% and 0.12% for the scale items and demographic variables, respectively. For the complete data set, the average percentage of missing data was 0.02%. To explore the item non-response in the data set Little's MCAR test (Little, 1988) was conducted. Findings showed that the data were missing completely at random (MCAR) (p= .52, p> .05) and that a listwise deletion procedure, which gives unbiased estimates (Cohen et al., 2003), was used. Regarding that, the scores of 42 students were discarded based on the following criteria: (a) showing insincerity in their responses (11 students; e.g., facial expressions denoted as all "happy" or all "sad"), (b) not completing the items toward the end (18 students; drawings/scratches on the scale), (c) responding less than five items on either of the sub-dimensions (2 students), (d) provided only demographic information (5 students), and (e) not reporting demographic information (3 students; e.g., gender/grade level not specified).

Upon completion of this process, the final participants (= 8.5 years) were 1450 primary school students (n = 725 females and n = 725 males) attending to Grade 2 (n = 651; 49.9% females, 50.1% males), Grade 3 (n = 457; 49.7% females, 50.3% males), and Grade 4 (n = 342; 50.6% females, 49.4% males). The sample was split into two random halves using the first half to conduct exploratory factor analyses, followed by using the remaining sample to conduct confirmatory factor analyses.

Prior to the administration process, the Ethical Approval Statement was obtained from the National Education Directorate (Approval Number: 34776202-605.01-E.25639967). Since there was an ongoing Covid-19 pandemic outbreak (2019-2020 academic year), principals of the respected schools were contacted to arrange meetings about the days/hours for data collection. The data were collected by the third researcher and/or by the help of teachers. Informed consent to participate was taken from both students and teachers. Before participating in the study, they were informed about the purpose and process of the study and their rights that participation was completely voluntary. The third researcher was always present so that all students and teachers received the same instructions: Students were emphasized that not participating in the study would not have any negative influence on their relationship with the teachers, whereas teachers were underlined about no negative impact on their relationship with the school administration. Students and teachers were also assured of the anonymity of the data and no personal information (i.e., name/last name) would be collected. The participants were given one class period (40 min) to complete the scale. The duration was adequate that Grade 2 students finished responding the scale in 30-35 *min*, whereas Grades 3 and 4 students finalized their responses in 20-25 min.

Translation and Adaptation Procedures

Along with Merenda (2006), three steps were taken to satisfy item and test equivalence during the adaptation process of the scale. In Step 1, the CMAS-UK items and the three response choices (i.e., emoticons: happy-uncertainty-sad) were first reviewed regarding etic and emic standpoints and then, were translated into Turkish by one English language translator, one English language teacher, and the second and third researchers. In Step 2, the Turkish translation of the scale was then back translated to English by two experts in Turkish Education who had a good command of English. The original and back-translated versions were compared to ascertain that the back-translated version was aligned with the original scale. Equivalency problems were detected with respect to the items including the term 'numeracy' (Items 3, 5, 8, 10, 13, 14, 16, 18, and 19) and the phrases 'number work' (Item 1), or 'numeracy work' (Items 2, 4, 6, 9, 12, 15). Given that some items may not be directly transferrable (Merenda, 2006) and that modification or replacement may be necessary, the two experts in Turkish Education were requested to fill a translation form and clarify the meanings of those words/ phrases to make well-informed suggestions. The two experts agreed on the best expressions to match the original scale that 'numeracy work' does not refer to 'computation' or 'calculation' and that the term 'numeracy' should be revised as 'mathematics' to be more understandable for Turkish students at these grade levels. These modifications were made in collaboration with the two experts in Mathematics Education and a former mathematics teacher who also advised on the term 'mathematics' instead of 'numeracy', 'number', or 'numeracy work'. It was advised that in contrast to children in the UK, Turkish children are more familiar with 'mathematics' at these early grade levels. Although the National Primary School Mathematics Program (Ministry of National Education, 2018) predominantly refers specifically to 'natural numbers/operations with natural numbers' and 'fractions/ operations with fractions' for primary grades (including Grades 1-4), the broader number sense including 'decimals' followed by 'integers, rational and irrational numbers' for middle school grades 5-8 (above the age range of the current research) denoting 'mathematics' frequently. Indeed, within the Turkish education system, children are familiar with the schemes such as 'mathematics class", 'mathematics activities', 'daily life situations in mathematics' or 'typical day-to-day mathematics experiences' and so are accustomed to this consistently used math-related terminology. Henceforth, they may feel more confident in expressing their feelings of fear or tension (i.e., anxiety) in the subject (e.g., mathematics) rather than a specific mathematical content/concept (e.g., number).

Following that, the revised version was presented to two Turkish language teachers to take their opinions about the revisions and the relevant replacement/modification process was found appropriate. Before finalizing the scale, in Step 3, three classroom teachers were interviewed and asked to identify unclear words, ambiguous phrases, or sentences/ statements in the scale. All classroom teachers commented that the phrase 'numeracy work', which was replaced by 'mathematics work' needs clarification and two of them suggested inserting math-related activity explanations into a parenthesis afterwards such as 'mathematics work (homework and problems)' and one of them suggested 'mathematics work (homework, problems, activities etc.)'. Since the latter recommendation was more comprehensive, relevant changes were made in Items 2, 4, 6, 9, and 12 accordingly. The classroom teachers also suggested revising the term 'numeracy' in Item 16, which was replaced by 'mathematics', as 'mathematics work'. After all the revisions were made, they were also requested to check the scale in its entirety to comment on the overall format and design. They emphasized that there were no problematic items, the scale is well-formatted, and the length is appropriate. Given that the evidence based on test content was established by expert judgments, after the interviews, no further revisions or changes were made to the final version of the scale– the CMAS-TR.

Data Collection Tools

*Demographic Information***.** In the study sample, demographic information included students' gender, age, and grade level.

*Children's Mathematics Anxiety Scale UK***.** The initial 26-item CMAS-UK was originally developed by Petronzi et al. (2018) for the use of children at ages 4-7 (n = 307). It is a multifaceted self-report instrument measuring two components of mathematics anxiety: Prospective Mathematics Task Apprehension (14 items; e.g., "Walking into the numeracy class makes me feel…") and Online Mathematics Anxiety (12 items; e.g., "If I answer questions and get them wrong, I feel…"). Students respond to each item on a 3-point Likert-scale using an emoticon, with one face representing 'happy', following an 'uncertainty' (i.e., neutral) facial representation, and the final face signifying 'sad', for instance, "If other children finish their numeracy very quickly, I feel…". The internal consistency of the scale was substantial (α = .89). Further validation study (Petronzi et al., 2019) was conducted with a sample of 163 children (ages 4 - 7). Results of the exploratory and confirmatory factor analyses yielded a single-factor solution, indicating that the scale captures mathematics anxiety as a one-dimensional construct that includes various experiences, from interacting with their peers and the teacher to solving mathematics problems:

Online Mathematics Anxiety. The internal consistency of the scale was strong ($\alpha = .88$). The total scores on the scale ranged from 19 (low mathematics anxiety) to 57 (high mathematics anxiety).

Children's Anxiety in Math Scale. In addition to CMAS-TR, the Children's Anxiety in Math Scale (CAMS) was administered to participants to provide evidence based on relations to other variables. The 16-item CAMS was originally developed by Jameson (2013) and adapted into Turkish by Author et al. (2016) to measure primary school students attending to Grades 1 - 5 ($n = 1587$). The Turkish version of the CAMS (TR-CAMS) was designed to have a three-point scale with facial expressions/images varying from 'very anxious' scored as a 3 to 'not at all anxious' scored as a 1. Scores on the scale were summed, with higher scores indicating higher levels of math anxiety.

Although the exploratory factor analysis (EFA) on the original CAMS revealed a three-factor solution - general math anxiety, math performance anxiety, and math error anxiety -, the EFA on the TR-CAMS yielded a one-factor solution with a reduced 11 items, which was further validated by the confirmatory factor analysis (CFA). A specimen item from the scale is: "When I solve math puzzles, I feel:"). The Cronbach's alpha estimate was .85 for the total scale.

Data Collection

Information regarding how, when and under which conditions data collection tools are used should be explained here. If it is experimental research, the experiment or the manipulation conducted should be explained in detail. The procedures applied not only on the experimental group(s) but also on the control group(s) should be explained.

Data Analysis

Along with the Standards for Educational and Psychological Testing (AERA, APA, & NCME, 1999), the data for the current study were analyzed using a multistep process to provide evidence that scores on the CMAS-TR were reliable and valid. Three sources of validity evidence based on content, internal structure, and relation to other variables were provided throughout five stages, in addition to reliability.

Turning first to Stage 1, descriptive statistics were calculated using means and standard deviations to provide a general description of the sample. As the present study represents the first attempt to test the CMAS-UK with a Turkish sample, in Stage 2, we employed EFA to explore the underlying factor structure of the CMAS-TR, as a form of replication analysis. The EFA was also conducted to be able to detect a factorial structure of the scale, especially valid for Turkish populations. We used principal component analysis with varimax rotation as factors may be uncorrelated and subsequent principal axis factoring with promax rotation as factors may be correlated (Tabachnick et al., 2013). Prior to the EFA, we conducted a Kaiser-Meyer-Olkin test for sampling adequacy and Bartlett test of sphericity. We then checked for normality of distribution and computed item-total correlations for each factor to analyze the psychometric properties of the identified factors. Lastly, we calculated intercorrelations.

Following that, in Stage 3, CFA was conducted on the two factors identified in the second stage to validate the factorial structure of CMAS-UK in Turkish educational contexts. Additional CFAs were also performed to be consistent with all versions (e.g., 26 vs. 19 items) of the original scale (Petronzi et al., 2019). Employing the maximum likelihood estimation method one-factor model (Online Mathematics Anxiety-Model 1), a two-factor model (Prospective Mathematics Task Apprehension and Online Mathematics Anxiety-Model 2), and the null model (each item represents a single factor-Model 3). Schreiber et al. (2016) recommends using different indices to evaluate the model fit: Chi-Square degree of freedom ratio (χ^2/df), Goodness-of-Fit Index (GFI), Comparative Fit Index (CFI), Standardized Root-Mean-Square Residual (SRMR), and Root-Mean-Square Error of Approximation (RMSEA). Since each criterion has certain limitations (Byrne, 2013), different indices should be used for the model fit. Schermelleh-Engel et al. (2003) suggested criterion values for fit indices by model < 5, .90 ≤ CFI ≤ .95, .90 ≤ GFI ≤ .95, .90 ≤ AGFI ≤ .95, .05 ≤ SRMR ≤ .10, and .05 ≤ RMSEA ≤ .10 as adequate fit; whereas 0 ≤ ≤ 2, .95 ≤ CFI ≤ 1.00, .95 ≤ GFI ≤ 1.00, .95 ≤ AGFI ≤ 1.00, .00 ≤ SRMR ≤ .05, and .00 ≤ RMSEA ≤ .05 as perfect fit. The alternative models were compared using a chi-square difference test.

Moving to Stage 4, internal consistency of the scores on the scale was evaluated by computing Cronbach's alphas for reliability. Finally, in Stage 5, to provide further evidence based on relationships to other variables, a correlational analysis (i.e., convergent evidence) was performed using the data for CFA. In light of the proposed interrelations within and among general mathematics anxiety and components of mathematics anxiety (e.g., Jameson, 2013; Wigfield & Meece, 1988) that bring the mathematics anxiety on the scene as a multidimensional construct (Bai, 2011), the relationship between TR-CAMS (i.e., general mathematics anxiety) and CMAS-TR (i.e., prospective mathematics task apprehension and online mathematics anxiety) was investigated. Also, comparison tests (i.e., discriminant evidence) employing Multivariate Analysis of Variance (MANOVA) was conducted to understand whether there were differences in students' mathematics anxiety based on gender and grade level, respectively.

To accomplish Stages 2, 3, and 4, the above-mentioned large sample of Turkish primary school students (n = 1450) was split into two random halves. The first half of the sample (n = 725) was used to conduct EFA and reliability analysis, followed by a CFA with the remaining sample (n = 725). To perform the analyses at Stages 1, 2, 4, and 5 we used IBM SPSS Version 28, whereas we used LISREL 12 at Stage 3.

Findings

Stage I: Descriptive Statistics

Descriptive statistics for the sample are presented in Table 1. The results indicated that the participants had a mean mathematics anxiety score of 44.27 (SD = 6.40). The participants reported that they had higher levels of online mathematics anxiety (M = 20.03, SD = 3.51) and lower levels of prospective mathematics task apprehension (M = 10.88, SD = 2.88). These results indicated that Turkish primary school students felt more anxious feelings during the moment-to-moment experience of performing a mathematics task such as making mistakes while problem solving and getting the wrong solution, being the last to finish a mathematics task, or explaining a mathematical solution to the teachers. Females (M = 31.01, SD = 4.95) reported slightly higher levels of mathematics anxiety than did males (M = 30.81, SD = 5.17). Similarly, they felt slightly more anxious within an entire mathematics lesson (online mathematics anxiety; M = 20.17, SD = 3.45) and within a particular mathematical task completion (prospective mathematics task apprehension; M = 10.84, SD = 2.77) than did males (M = 19.90, SD = 3.57 and M = 10.91, SD = 2.99, respectively).

In addition, findings revealed that Turkish primary school students felt more tense while observing the teacher during mathematics classes or talking with peers about mathematics as they move on to higher grades: Grade 2 (M = 30.85, SD = 5.20), Grade 3 (M = 30.89, SD = 5.15), and Grade 4 (M = 31.12, SD = 4.68). This incremental trend was also evident in their instantaneous anxious feelings about mathematics (online mathematics anxiety; M = 19.84, SD = 3.60; M = 19.97, SD = 3.58; and M = 20.48, SD = 3.20). Interestingly, however, Turkish students reported showing less anxious reactions towards a forthcoming math-related work as they move through primary school years (prospective mathematics task apprehension; M = 11.00, SD = 2.92; M = 10.87, SD = 2.93; and M = 10.63, SD = 2.75).

Stage II: Exploratory Factor Analysis

Examination of the data showed that the Kaiser-Meyers-Olkin test (KMO = .83) and the Bartlett's test of sphericity, (= 2110.174, $p < .05$). The KMO exceeding the recommended value of .60 (Kaiser, 1974) and the Bartlett's sphericity test reaching statistical significance (Bartlett, 1954) indicated that the data were suitable to conduct factor analysis (i.e., verified the appropriateness of 19 items, showed significant correlations among items, and supported the factorability of the correlation matrix).

Subsequent investigations demonstrated the presence of five factors with eigenvalues exceeding 1, explaining 20.16%, 11.49%, 5.69%, 5.46%, and 5.28% of the variance, respectively. The total variance explained by these five factors was 48.11%. The rotated component matrix indicated that all items correlated highly with factor loading of at least .30. Additionally, Monte Carlo PCA for Parallel Analysis (Watkins, 2000) was used to compare the initial eigenvalues obtained in the first EFA with the corresponding values of the random eigenvalues. The results revealed two factors with eigenvalues of 3.83 and 2.18 exceeding the corresponding values of the random eigenvalues (1.29 and 1.24, respectively) generated for 19 items, 725 subjects and 100 replications.

Table 1: Descriptive Statistics for the CMAS-TR and Its Subdimensions across Gender and Grade Level

			Online Mathematics Anxiety		*Prospective Mathematics Task Apprehension*		*Total Mathematics Anxiety*	
		n	*M*	*SD*	*M*	*SD*	*M*	*SD*
Gender	Female	725	20.17	3.45	10.84	2.77	31.01	4.95
	Male	725	19.90	3.57	10.91	2.99	30.81	5.17
Grade Level	Grade 2	651	19.84	3.60	11.00	2.92	30.85	5.20
	Grade 3	457	19.97	3.58	10.87	2.93	30.89	5.15
	Grade 4	342	20.48	3.20	10.63	2.75	31.12	4.68
Total		1450	20.03	3.51	10.88	2.88	44.27	6.40

Supported by the parallel analysis, the second EFA was conducted by 19 items using an extraction to two factors. The two-factor structure explained 31.66% of the total variance, with Factor 1 and Factor 2 contributing 20.16% and 11.49%, respectively. It is noteworthy that the two factors were coherent and easily defined. As anticipated, there was a statistically significant positive correlation between the two factors (r = .30, $p < .01$). A further examination of the pattern matrix for the two factors showed satisfactory coefficients as all factor loadings (from .30 to .68) and communality values (from .33 to .47) were above .30 (Hair et al., 2006). This analysis revealed that 9 items (items 5, 7, 8, 9, 10, 14, 17, 18, and 19) constituted the first factor revolving around Prospective Mathematics Task Apprehension, and 10 items (items 1, 2, 3, 4, 6, 11, 12, 13, 15, and 16) constituted the second factor working together in Online Mathematics Task Anxiety (see Table 2).

Stage III: Confirmatory Factor Analysis

The purpose of CFA was to investigate whether the two-factor solution that emerged from the EFA in the first phase was supported and estimate the fit of three alternative models: (i) Model 1 (a two-factor 19-item scale including both Prospective Mathematics Task Apprehension and Online Mathematics Anxiety), (ii) Model 2 (the original one-factor 19-item Online Mathematics Anxiety scale), and (iii) Model 3 (a 19-item single factor scale). As expected, based on the EFA, Model 2 and Model 3 did not have acceptable indices of fit (see Table 3). Overall, the indicators for goodness of fit for the data demonstrated minimal differences between Model 1 and Model 3 whereas large differences between Model 1 and Model 2. Results of the two-factor Model 1 showed a good fit to the data and the relation yielded = 516.89, df = 121, / df= 4.27, CFI= .96, GFI= .93, AGFI= .90, SRMR= .05, and RMSEA= .06.

Given the fact that other theoretically plausible models (Model 2 and Model 3) were shown to fit worse to the data than the target model (Model 1), chi-square difference tests hold merit in making the final judgment. The more parsimonious, one-factor Model 2 proposing that the two a priori factors of the CMAS-TR are not conceptually or statistically distinct showed slightly a poorer fit to the data than the two-factor Model 1 with significant Δ= 1199.13 and Δdf = 1. As is demonstrated in Table 3, the two-factor Model 1 again had a better fit to the data than the null Model 3, proposing that each item on the CMAS-TR is a single factor (Δ= 1119.13 and Δdf= 31).

Furthermore, comparing the standardized coefficients, t-values, and squared multiple correlation () of the three

Table 2: EFA Pattern Matrix for the 19-Item CMAS-TR

Item	*Factor 1*	*Factor 2*	*Communality*
Item 19	.68		.47
Item 10	.65		.45
Item 17	.62		.38
Item 5	.58		.35
Item 14	.58		.33
Item 8	.56		.33
Item 18	.56		.32
Item 9	.48		.36
Item 7	.30		.36
Item 11		.67	.45
Item 15		.59	.35
Item 13		.58	.33
Item 4		.56	.32
Item 2		.53	.38
Item 3		.52	.38
Item 16		.51	.38
Item 1		.47	.35
Item 6		.43	.39
Item 12		.30	.36
Explained Variance	20.16	11.49	-
Eigenvalues	3.83	2.18	-

Table 3: Model Fit Indices for the Three Models

Model		*df*		*RMSEA*	*SRMR*	*GFI*	*AGFI*	*CFI*		*Δdf*
2-Factor Model 1	516.89	121	4.27	.06	.05	.93	.90	.96		
1-Factor Model 2	1716.02	122	14.06	.13	.12	.80	.60	.88	1199.13	31
Null Model 3	895.07	152	5.88	.08	.11	.88	.86	.92	378.18	1

alternative models revealed that in only the two-factor Model 1 (see Figure 1) do the estimate values all exceed the value .40, *t*-values were all significant (> 1.96) at $p < .05$, and that all squared multiple correlations of individual items were substantial in size exceeding the value .30 (Hu & Bentler, 1995). Additionally, two subdimensions of the CMAS-TR which were allowed to correlate to each other, yielded a significant (> .50) association (Kline, 2023).

Testing alternative models provided further validity evidence based on internal structure (i.e., discriminant validity) of the CMAS-TR. Taking into consideration the differences in the models, the acceptable fit for the 19-item scale and the interest in maintaining the parsimony with the multidimensional construct of mathematics anxiety, the selection of the two-factor version was the most desirable for future uses with the CMAS-TR.

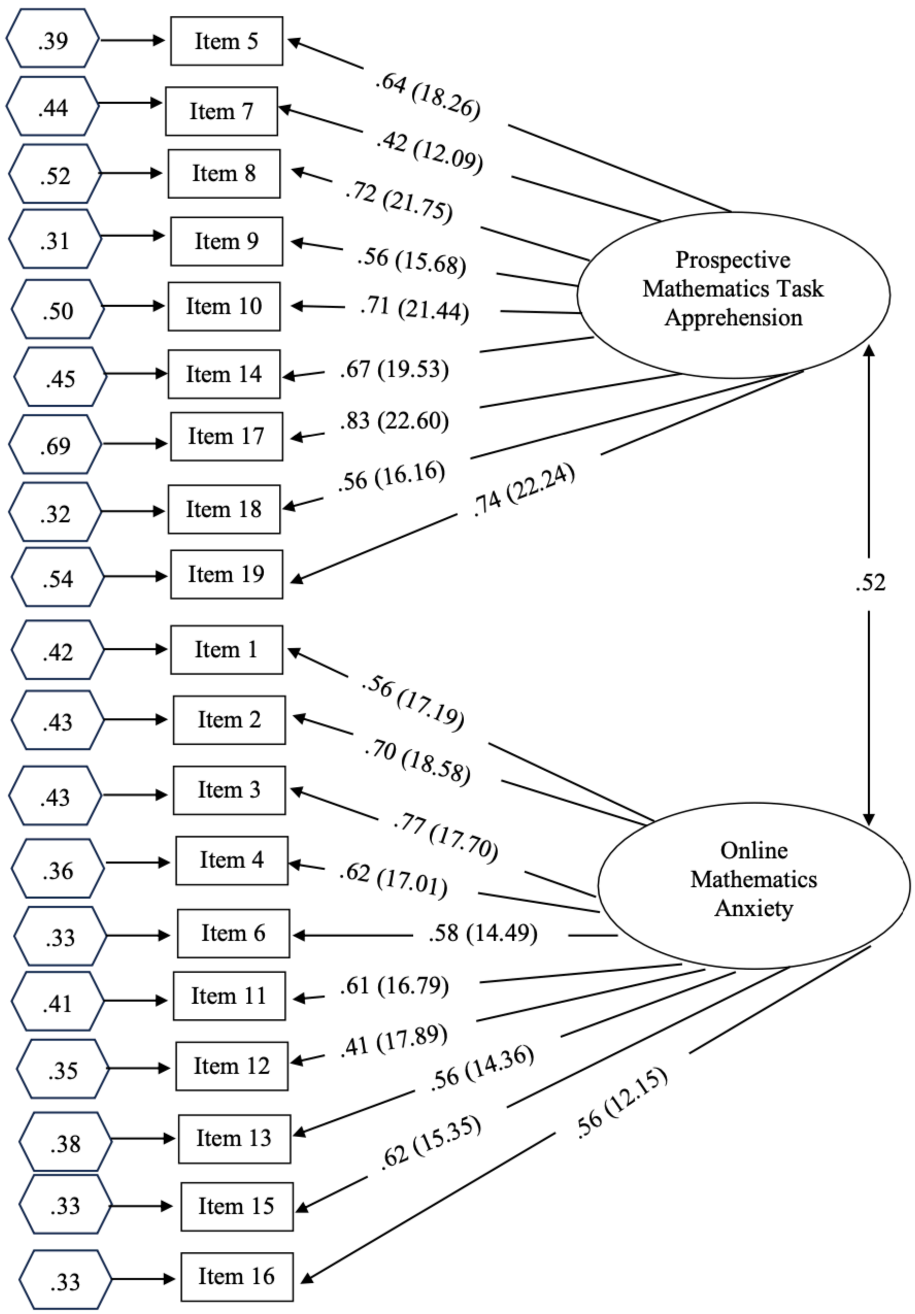

Figure 1. **Reliabilities*, standardized estimates and *t*-values** of the CMAS-TR (2-factor 19-item model)**
* Squared multiple correlations (are presented in hexagons. ** *t*-values are presented in parenthesis.

Stage IV: Reliability Analysis

Internal consistency estimates (Cronbach's alpha coefficients) of scores for the Prospective Mathematics Task Apprehension, Online Mathematics Anxiety, and total scale were .76, .77, and .79, respectively. All these estimates indicated satisfactory reliability (> .60) for both the entire scale and its sub-dimensions (Tabachnick et al., 2013) and that none of the items served as a drag on reliability (Cohen, 1988).

Item-total correlations ranged from .34 to .44 for the Prospective Mathematics Task Apprehension, and from .31 to .46 for the Online Mathematics Anxiety. All correlations were greater than .30 (Crocker & Algina, 1986), denoting the homogeneity of the items in relation to the entire scale and its sub-dimensions.

Stage V: Further Validity Evidence

To test for convergent validity, we verified whether our two factors Online Mathematics Anxiety and Prospective Mathematics Anxiety as well as General Mathematics Anxiety (i.e., total scores on the CMAS-TR) correlated to the score of Anxiety in Math (TR-CAMS; Author et al., 2016), which reflected general math anxiety, math performance anxiety, and math error anxiety (CAMS; Jameson, 2003) as a whole, using a two-tailed Pearson coefficient. Consistent with our prediction, results revealed a statistically significant and positive correlation between TR-CAMS and CMAS-TR (r = .45, p < .001). Specifically, TR-CAMS positively and moderately correlated with Prospective Mathematics Task Apprehension (r = .49, p < .001), whereas there was a small positive correlation with Online Mathematics Anxiety (r = .26, p < .001).

To test for discriminant validity, we verified whether there were differences in primary school students' Prospective Mathematics Task Apprehension, Online Mathematics Anxiety, and General Mathematics Anxiety based on gender and grade level. Results of the MANOVA revealed no significant differences between females and males on the combined dependent variables, F(2, 722) = .033; p = .968; Wilks' = 1.000; partial = .000. This was also evident when the results for the dependent variables were considered separately: Prospective Mathematics Task Apprehension [F(1, 723)= .046; p = .830; partial = .000], Online Mathematics Anxiety [F(1, 723)= .005; p= .942; partial = .000], and General Mathematics Anxiety [F(1, 723)= .005; p = .945; partial = .000]. On the other hand, results of the multivariate analysis showed that there was a statistically significant difference among Grade 2, Grade 3, and Grade 4 students on the combined dependent variables, F (4, 1442) = 3.864; p = .004; Wilks' = .979, however the effect size was small (partial = .011). Post-hoc comparisons using the Tukey HSD test indicated that the mean score for Grade 2 (M = 12.69, SD = 3.17) was significantly different from Grade 3 (M = 11.99, SD= 2.83) on Prospective Mathematics Task Apprehension, whereas the mean score for Grade 1 (M = 21.67, SD = 4.09) differed significantly from Grade 3 (M = 22.52, SD = 3.36) on Online Mathematics Anxiety.

Discussion

The present study is the first to provide support for the cross-cultural validity of the CMAS-UK. It was designed to adapt and validate the CMAS-UK with a developmentally appropriate sample from a different cultural context (Turkish), grade levels (Grades 2 - 4), and age groups (from 7 to 10), while also seeking to verify the internal structure of the Turkish version. Following the widely accepted norms about instrument translation, the adaptation process and validation procedures confirmed that the CMAS-TR was a reliable and valid measure of mathematics anxiety in the [Turkish primary school students. Using sufficiently large sample sizes, the results of this study not only evidence to support using the scale but also revealed a new factor structure that promotes the use of a multidimensional form. As part of the validation process, two factors (Prospective Mathematics Task Apprehension and Online Mathematics Anxiety) were retained based on the careful examination of findings from the exploratory and parallel analyses followed by CFAs with three alternative models.

The two-factor solution was consistent with Petronzi et al.'s (2018) original conceptualization of mathematics anxiety developed through an exploratory work with the 26-item English version of the CMAS-UK with younger children (< 7 years of age). The model did not provide support for combining the mathematics anxiety construct into a single component - Online Mathematics Anxiety – as suggested in the further validation study (Petronzi et al., 2019). The original 19-item CMAS-UK included merged items that measure the proposed single-factor, but our data maintained a strong fit with the two-factor model with older children (≥ 7 years of age). The reliability coefficients were also above the cut-off criterion (> .70) for both two subdimensions as well as the entire scale (Nunnally, 1978). Naturally, further research comparing the multi-factor and single-factor models directly is warranted to establish that the results of the present study apply with younger Turkish children at the ages 4-7 years or replicate with the older ones at the ages 7 - 10 years. In this context, it seems that the method effects related to the sample characteristics in the CMAS-TR could therefore be further researched. Until then, it seems that the findings from the CFA could provide substantial evidence which takes into account both the factorial structure of children's mathematics anxiety and the methodological effects, thus contributing to the construct validation of the CMAS-TR. Adaptations to other languages also merit future research to cross-validate the findings by conducting studies to test different models of the mathematics anxiety construct with multi-national samples at different age groups.

The 19-item CMAS-TR was a multidimensional but equivalent version of the full scale with retaining all the original items. All the items that functioned appropriately in the Turkish version were likely operating in the same way as in the original English version. Up to our knowledge, there is no existing research investigating whether the CMAS-UK meets the cultural norms of a different country. Henceforth, the bulk of work in this study drew attention to both a cultural (e.g., Turkish vs. English) and a methodological (e.g., older children vs. younger children) effect in the process of translating an existing and validated measure into a different language. Considering this specific attention, the findings supported previous scale adaptation/validation studies for the need to tailor items into a new language and the developmental levels of the target population through using careful translation procedures. In addition to establishing transliteral equivalence with experts ($n = 11$) in relevant areas of education and research, our experience validated the value of communicating and clarifying the intent of the CMAS-UK with the first author of the original scale. This collaboration facilitated the development of a truly equivalent measure during and after the data analysis processes.

Research findings on gender and grade level differences in mathematics anxiety vary widely [for details see the meta-analysis studies of Barroso et al. (2021); Hembree (1990); Ma (1999); Namkung et al. (2019)]. Although significant differences in students' mathematics anxiety regarding gender (e.g., Else-Quest et al., 2010; Ma & Xu, 2004) and grade level (e.g., Vukovic et al., 2013; Xie et al., 2019) have been found in some studies, many have indicated little or no difference (e.g., Dowker et al., 2016; Hyde, 2005; Sorvo et al., 2017; Spelke, 2005). Given these mixed findings, no conclusions can be drawn in the literature about gender and grade level differences in students' mathematics anxiety. Significant grade level differences in mathematics anxiety were found among second to fourth grade students, specifically in Online Mathematics Anxiety between second and fourth grade students and in Prospective Mathematics Task Apprehension between third and fourth grade students. These results indicated that the CMAS-TR was assessing the same mathematics anxiety constructs in different grade levels. Therefore, the mathematics anxiety scores can be effectively compared across grade levels. No significant gender differences were found based on the multivariate analysis, providing additional support for the use of the CMAS-TR.

Evidence based on relationship with other variables was also examined by looking at the relationship between student mathematics anxiety at grades 1-5 (TR-CAMS) and at grades 2-4 (CMAS-TR): Prospective Mathematics Task Apprehension had a higher positive relationship with general mathematics anxiety than did Online Mathematics Anxiety. In support of many previous studies (e.g., Dowker et al., 2016), we found evidence that mathematics anxiety is distinct from test anxiety or general anxiety, and further extended studies (e.g., Jameson, 2013) that revealed associations among mathematics performance anxiety, mathematics error anxiety, and general mathematics anxiety.

Limitations and Future Research Direction

There are some limitations that raise questions for further investigations. First, participants were selected through convenience sampling; future research could include random samples from different populations to improve the generalizability of the results. Second, an instrument that measures the similar mathematics anxiety construct was used to test convergent validity. Future studies could use instruments that measure different cognitive and/or affective constructs (emotions, metacognition, etc.) to provide further evidence based on relations to other variables. Third, only gender and grade level differences were investigated to test discriminant validity. Comparison studies could also look at socio-economic or school type differences in mathematics anxiety to provide further external validity evidence of the CMAS-TR. Fourth, even if restricted to a small sample data on test-retest reliability are missing due to the ongoing pandemic at the time of scale administration. This merits future research to confirm the stability of the findings. Last, as the first adapted version of the original CMAS-UK to systematically measure primary school students at early ages in a different cultural context, replication and/or cross-cultural adaptation studies are warranted to provide more evidence about the universal nature of mathematics anxiety.

Educational Implications

Notwithstanding these limitations, this study showed that the adapted multidimensional Turkish version of the CMAS-UK is a valid and appropriate tool to be used in determining the emotional response of primary school students to a current or prospective mathematical situation. We believe that the CMAS-TR has sufficient psychometric qualities to be used in collaboration with teachers or guidance and psychological counsellors, which would allow to constantly monitor mathematics-specific strengths and weaknesses and take immediate actions before students start exhibiting increased mathematics anxiety in their transition from primary to the high school. The CMAS-TR is, therefore a promising scale to support schools for the educationally debilitating effects of mathematics anxiety as it can also be useful for researchers to better understand why mathematics anxiety sufferers have, for instance, decreased self-confidence, have less enjoyment, get more bored in mathematics, and may even avoid enrolling in math-related subjects.

Ethics Approval

The data that support the findings of this study are available from Mersin University Ethics Commission (Decision Number: 03/03/2019-25/03/2020-034) and Governorship of Mersin (Approval Number: 34776202-605.01-E.25593958).

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