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PSYCHOMETRIC ANALYSIS AND VALIDATION OF THE *MATH ANXIETY SCALE* FOR TEACHERS/MAST- BR FOR THE BRAZILIAN CONTEXT¹

Rose Lemos de Pinho

Universidade Católica de Pelotas (UCPEL)

Corresponding author: Universidade Católica de Pelotas (UCPEL), Centro de Ciências da Saúde, Programa de Pós-Graduação em Saúde e Comportamento Pelotas, RS, Brasil

ORCID iD 0009-0007-9142-6953

<http://lattes.cnpq.br/7274794917538498>

Vera Lúcia Marques de Figueiredo

Universidade Católica de Pelotas (UCPEL)

Co-author: Universidade Católica de Pelotas (UCPEL), Centro de Ciências da Saúde, Programa de Pós-Graduação em Saúde e Comportamento. Pelotas, RS, Brasil

ORCID iD 0000-0002-3580-0804

<http://lattes.cnpq.br/5129255269141998>

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1. Article based on data from R.L.PINHO's doctoral thesis, entitled "Transcultural Adaptation of the MAST Scale for a Brazilian Context and Factors Associated with Mathematics Anxiety among Primary School Teachers in the Pelotas/RS Public School System". Catholic University of Pelotas, 2024.

Abstract: Background: The phenomenon “Mathematics Anxiety” (MA) is characterized by a set of unpleasant reactions, whether physiological, cognitive or behavioral, in the face of situations that require the use and application of mathematical knowledge. MA occurs in both students and teachers. In Brazil, there are no measuring instruments for MA in teachers. **Objective:** To cross-culturally adapt the “*Math Anxiety Scale for Teachers - MAST*” to the Brazilian context. **Design:** This is a cross-sectional study. The adaptation procedures followed the steps recommended in the literature. **Setting and participants:** 254 teachers working in the Early Years of the Public School System in the city of Pelotas/RS took part. **Data collection and analysis:** The teachers answered a self-administered online questionnaire consisting of the Informed Consent Form, socio-demographic variables and the *Generalized Anxiety Disorder-7* and *MAST-BR* scales. The data was analyzed using the *Statistical Package for the Social Sciences*. The JASP program was used for the confirmatory analysis of the scale. **Results:** The theoretical analysis of the items showed a satisfactory Content Validity Coefficient (total CVC = 0.94). The confirmatory factor analysis showed that the *MAST-BR* can be used in both unidimensional and bifactorial models, with better results in the latter [$c^2 / gl < 1$; CFI= 1.00; TLI= 1.00; RMSEA= 0.000 (0.000 - 0.000); SRMR= 0.049]. Internal consistency indicated good homogeneity. The scale showed a statistically significant correlation with the *GAD-7* ($r= 0.428$), suggesting evidence of criterion validity. **Conclusion:** The *MAST-BR* scale showed adequate psychometric characteristics and is robust for assessing the phenomenon of MA in teachers.

Keywords: cross-cultural adaptation; anxiety; mathematics; teachers.

INTRODUCTION

Math Anxiety (MA) has been discussed and studied internationally for the last 60 years. Various areas, such as psychology, neuroscience and education, are concerned with supporting students and teachers, as mathematics at all grades has been perceived as one of the most difficult components of the academic curriculum. It is therefore not surprising that it arouses strong emotions and can generate symptoms of anxiety in students and teachers. Experts (Haase *et al.*, 2019) consider that mathematical activities can provoke positive and often negative emotions, with high performance being associated with joy, while low performance can be associated with symptoms of frustration, anxiety, fear, tension, shame, low self-esteem and emotional detachment. Therefore, both positive and negative emotions influence math performance.

Research in the field of mathematics education has focused mainly on cognitive factors (executive functions, language) and sociocultural factors (socioeconomic status, gender). Little attention has been paid to emotional and affective factors, which are also crucial for success in mathematics (Haase *et al.*, 2012). One of the main emotional factors related to learning mathematics is anxiety, a feeling that is part of human development and can be accentuated in moments of fear, danger or tension (Mendes & Carmo, 2014; Campos, 2022).

According to the *American Psychological Association* (APA, 2014), anxiety is an emotion characterized by feelings of tension, thoughts of worry and physiological changes. Math Anxiety (MA), first described in 1957 as anxiety about numbers, plays a central role in math performance. The first definition of MA emerged as a “feeling of tension and anxiety that interferes with manipulating numbers and solving mathematical problems in everyday life and academic situations” (Richardson &

Suinn, 1972). Definitions of MA vary, with a focus on performance (feelings of fear or tension that interfere with mathematical performance) or on oneself (discomfort in situations that involve mathematics and are perceived as threatening to self-esteem) (Chinn, 2009).

Generally, to identify MA, measurement instruments are used, such as assessment scales and clinical observation that can consider affective and cognitive dimensions. The *Math Anxiety Scale for Teachers* (MAST) was developed in Florida in 2019 with the aim of measuring symptoms of MA among practicing teachers who teach mathematics. According to the authors (Ganley *et al.*, 2019), the items were developed based on a systematic review of the construct. The choice was based on the assumption of a distinction between two components or forms of manifestation: General Mathematics Anxiety (GMA) and Anxiety about Teaching Mathematics (AEM). The GMA form would be anxiety about oneself doing mathematics, which could be considered mathematics anxiety in the general population, while MSA refers to the anxiety a person feels about their ability to teach mathematics.

The MAST is a self-administered, self-administered, self-administered instrument made up of fifteen statements. The authors analyzed different factor structures: single-factor, two-factor distributed into two distinct factors AMG (first nine items) and AEM (last six items), and finally a four-factor model. This last model subdivided the AMG factor into three sub-factors (emotionality, worry and social/evaluative anxiety) (Ganley *et al.*, 2019). According to the authors, participants are asked how they react to situations involving math knowledge and teaching and scores are calculated from the total sum and the sum by domain (AMG and AEM). The original version considers some degree of

AM symptom positivity when the results are equal to or greater than sixteen points; if the teacher scores one point on all the questions corresponding to “It’s never true for me”, a total of fifteen points suggests that the educator has no degree of AM (Ganley *et al.*, 2019).

In its construction and validation study, the MAST scale showed good internal consistency (Ganley *et al.*, 2019). When considered as unidimensional or unifactorial, the scale items obtained a *Cronbach’s Alpha* of 0.96; when the AMG and AEM factors were considered separately (bifactorial), the indices were $\alpha = 0.97$ and $\alpha = 0.91$, respectively, and when the AMG factor was subdivided into three subfactors, all of them had high internal consistency (emotionality, $\alpha = 0.94$; worry, $\alpha = 0.94$; social/evaluative anxiety, $\alpha = 0.92$) (Ganley *et al.*, 2019).

Considering that the scale was recently created, no research was found on adapting the instrument in other countries. Similarly, no measuring instruments associated with the phenomenon of MA among teachers have been identified in the Brazilian literature (França & Dorneles, 2021). The aim of this study was to cross-culturally adapt the American *Math Anxiety Scale for Teachers* (MAST) to the Brazilian context.

METHOD

The cross-cultural adaptation study of the MAST to the Brazilian context was carried out in two distinct stages: the first refers to the procedures for translating and validating the content of the scale (Pinho & Figueiredo, 2023); the second stage, which is the subject of this article, refers to the empirical analysis of the MAST-BR, with the aim of verifying its psychometric properties.

TRANSLATION AND CONTENT VALIDATION PROCEDURES

The steps for the process of theoretical analysis of the items were based on Borsa *et al.* (2012), Hungerbühler and Wang (2016) and Pasquali (2010). The process of translating and adapting the *Math Anxiety Scale for Teachers* (MAST) consisted of 7 different stages, which will be described below.

After contacting the authors of the MAST scale (Ganley *et al.*, 2019) and obtaining authorization to adapt the instrument to the Brazilian context, the study of construct equivalence was carried out at the same time by means of bibliographic research in order to verify the existence of studies and articles dealing with the AM phenomenon and its characteristics.

Subsequently, in the semantic equivalence stage, the MAST scale was sent to two bilingual translators to carry out the translations from the source language (English) into the target language (Portuguese). Thus, two translations (T1 and T2) into Brazilian Portuguese were carried out. The T1 translation was done by an English translator, while the T2 translation was done by a specialist in the construct, also fluent in English. The synthesis version of the translations was analyzed by a committee made up of the researcher and two other math professionals, who resolved minor discrepancies between the translators.

Next, the synthesized version of the translations, after a Portuguese revision, was submitted to five experts for them to evaluate the items “verbal comprehension” and “relevance” of each item on the scale. The experts (a psychiatrist, a psychologist, a pedagogue, a mathematics professional and a statistics professional) were invited to participate via telephone and/or digital contact. These professionals were asked to indicate on a five-point *Likert* scale how clear and relevant each item on the scale was to the construct, ranging from 1 - unclear/pertinent to 5 - very clear/pertinent (Pasquali, 2017).

Based on the suggestions and/or considerations put forward by the experts, minor adjustments were made to the synthesis version of the scale. A pilot study was then carried out with the experimental version of MAST-BR, which was submitted to representatives of the target population as a pre-test, consisting of twenty Early Years teachers from different districts and public schools in the city of Pelotas. At this stage, an electronic form was used to assess the acceptance and understanding of the instrument by the teachers in the target population. The teachers were asked to give *feedback* on the clarity and comprehension of each of the items on the scale, and to make suggestions for improving the wording of the item if it wasn't clear enough.

Subsequently, the MAST-BR scale was back-translated into its original language (English) by a bilingual professional (English/Portuguese) who was unfamiliar with the original instrument (MAST). Finally, once the back-translation had been completed, the scale was sent to the authors of the original version for appraisal. With a favorable opinion, the experimental version (MAST-BR) was completed and used for data collection.

PARTICIPANTS

The sample complied with the recommendations in the literature for the process of cross-cultural adaptation of mental health instruments (Pasquali, 2010; Hungerbühler & Wang, 2016), which indicate an approximate size of 10 individuals per item or 100 individuals per factor/dimension of the instrument. Considering that the MAST scale has fifteen items and two dimensions, the required sample size would be between 150 and 200 individuals, respectively. There were 254 teachers, following the inclusion criterion of being from the Pelotas public school system and teaching mathematics in the Early Years of Primary School.

The teachers were invited to answer a self-administered *online* questionnaire on the Google Forms Platform, consisting of the Informed Consent Form (ICF), sociodemographic questions and the GAD-7 instruments and the MAST-BR version.

INSTRUMENTS

Generalized Anxiety Disorder-7 - GAD-7 - the Generalized Anxiety **Disorder** scale was used as a measure to assess anxiety. The instrument was developed by Spitzer (2006) and validated for Brazil by Moreno *et al.* in 2016. The scale consists of seven items, measured on a four-point *Likert* scale, ranging from “Not at all” (0 points) to “Almost every day” (3 points), with a total score ranging from 0 to 21 points. Participants are asked how often they feel bothered by the situations presented in the items on the scale, considering the last few weeks. Although this instrument has been validated for Portuguese, it does not have a defined cut-off point for Brazilian populations.

Math Anxiety Scale for Teachers - MAST - the Math Anxiety Scale for Working Teachers (MAST) is a self-administered, self-administered, self-administered instrument. Initially composed of nineteen statements, the original version had four items removed, leaving its short version consisting of fifteen statements in order to measure teachers' level of MA. The instrument allows responses on a five-point *Likert* scale, ranging from 1 to 5: (1) never true for me, (2) usually not true for me, (3) sometimes true for me, (4) usually true for me and (5) always true for me, where the higher the score, the higher the level of MA (Ganley *et al.*, 2019). Participants are asked how they react to situations involving math knowledge and teaching. The scores are calculated from the total sum and the sum by domain (AMG and AEM) (Ganley *et al.*, 2019).

STATISTICAL ANALYSIS PROCEDURES

The analyses were carried out using the *Statistical Package for the Social Sciences* (SPSS) version 20. Initially, adjustments were made to the database to check the distributions of the variables. After calculating all the variables and the final scores of the scales, absolute and relative frequencies, means and standard deviations were obtained.

To study the evidence of validity based on the scale's internal structure, the *Factor 10.9.02* program was initially used to carry out the Exploratory Factor Analysis (EFA). The results of Bartlett's sphericity test and the Kaiser - Meyer - Olkin (KMO) test were observed to ensure that the data could be factored (Damásio & Borsa, 2017). To investigate its dimensionality, Parallel Analysis (PA) was used, with random permutation of the observed data (*boot strapping*; 95% CI), in addition to the Hull Method. The following unidimensionality parameters were also observed: *Uni-dimensional Congruence* (UniCo), *Explained Common Variance* (ECV) and *Mean of Item Residual Absolute Loadings* (MIREAL). The JASP 0.16.1.0 program was then used to investigate the Confirmatory Factor Analysis (CFA). In both Factor Analyses, the *Robust Diagonally Weighted Least Squares* (RDWLS) estimator was used, based on a polychoric matrix (Damásio & Borsa, 2017).

In both analyses, the model's fit parameters were observed, such as: χ^2 / gl , *Comparative Fit Index* (CFI) and *Tucker-Lewis Index* (TLI). Residual indices were also analyzed, such as *Root Mean Square Error of Approximation* (RMSEA) and *Standardized Root Mean Square of Residuals* (SRMR). The criteria used to assess these parameters were: RMSEA p-values ≤ 0.05 , with the upper limit of the confidence interval being < 0.10 ; TLI and CFI values ≥ 0.95 ; SRMR values < 0.10 ; $c^2 / gl \leq 5$ and item factor loadings ≥ 0.30 . *Cronbach's*

Alpha (α), *McDonald's Omega* (ω) and *Greast Least Bownder* (GLB) were used as reliability parameters, with results expected to be ≥ 0.70 . (Damásio & Borsa, 2017; Kalkbrenner, 2023).

Validity based on the relationship with external variables was carried out using *Spearman's* correlation (r), given the non-normal distribution of the data. Using SPSS software version 20, the correlation (convergent validity) of the MAST-BR with the GAD-7 scale was analyzed. Interpretation of the magnitude of the correlations followed the parameters recommended by Hinkle, Wiersma and Jurss (Espírito Santo & Daniel, 2017) very high (≥ 0.9), high (0.7 - 0.89), moderate (0.5 - 0.69), low (0.3 - 0.49) and small (0.1 - 0.29).

The study received a favorable opinion from the Research Ethics Committee as it complied with all the ethical procedures adopted in research according to the CEP (Opinion No. 5.541.636).

RESULTS

THEORETICAL ANALYSIS OF THE ITEMS

In the experts' analysis, the scale obtained a total Content Validity Coefficient (CVC) of 0.93, considered very satisfactory. With regard to changes to the scale items, there were few suggestions from the experts, only minor adjustments related to the inclusion/exchange of pronouns, verb tenses, the addition of words and standardization of the text. In the pilot study, the teachers had no difficulties understanding the questions and did not suggest any changes.

EMPIRICAL ANALYSIS OF THE ITEMS

Initially, the sample was made up of 265 teachers, but considering that 11 were excluded from the database due to unanswered items, there were 254 participants. The majority of the participants were female (96.9%), with an average age of 45.7 years ($SD= 9.2$), white (78.3%); belonging to socioeconomic class D - from 2 to 4 minimum wages (51.2%), whose current national minimum wage is R\$ 1,412.00. The teachers had an average length of service of 13.8 years ($SD= 9.5$) and were mostly professionally satisfied (53%). They work mainly in the literacy cycle (1st, 2nd and 3rd grade) (64.1%) and in the municipal education network (65.4%). The most prevalent postgraduate degree for most of them was specialization (58.7%); however, they do not have specific training for teaching mathematics (90.1%), although almost half of the sample considers that they have a good relationship with mathematics and its teaching (49.6%). In general, the teachers said that their relationship with mathematics had not changed during the pandemic (66.9%). The data is shown in Table 1.

EVIDENCE OF VALIDITY OF THE MAST-BR SCALE BASED ON INTERNAL STRUCTURE

Initially, the EFA showed the results of the Bartlett (3268.2; $p < 0.001$) and KMO (0.953) tests, suggesting the factorability of the data matrix. Both the Parallel Analysis and the Hull Method and the indicators of unidimensionality (UniCo= 0.986; ECV= 0.885; MIRE-AL= 0.266) initially indicated the presence of a single-factor model. The variance explained by the first factor was 71.6%. The model fit indicators were favorable (CFI= 0.991; TLI= 0.990) and the residuals were partially acceptable [RMSEA= 0.096 (0.063 - 0.125); SRMR= 0.0912], considering that the RMSEA did not

pass the confidence interval criterion. The factor loadings of the items varied between 0.785 and 0.896 and the reliability indicators were all above 0.96, as shown in Table 2.

Items	Unifactorial	Bifactorial	
		AMG	AEM
01	0.785	0.948	
02	0.797	1.001	-0.313
03	0.793	0.949	
04	0.854	1.080	-0.359
05	0.854	1.019	
06	0.862	0.926	
07	0.845	0.809	
08	0.865	0.848	
09	0.896	0.850	
10	0.830	0.635	0.326
11	0.831	0.609	0.369
12	0.815	0.541	0.446
13	0.802	0.451	0.568
14	0.855	0.533	0.524
15	0.864	0.586	0.453
α	0.968	0.968	
ω	0.968	0.968	
GLB	0.988	0.988	
CFI	0.991	0.996	
TLI	0.990	0.995	
RMSEA	0.096 (0.063 - 0.125)	0.067 (0.033-0.077)	
SRMR	0.0912	0.0393	

Table 2 - Item factor loadings, reliability parameters, fit and residual indices for the uni- and bifactor models, according to EFA

Thus, a new EFA was performed, this time proposing a two-dimensional model, as expected according to the literature (Ganley *et al.*, 2019). The results indicated a better-fitting model [CFI= 0.996; TLI= 0.995; RMSEA= 0.067 (0.033-0.077); SRMR= 0.0393], with factor loadings ranging from 0.326 to 1.080 and a correlation between the factors of 0.524.

Considering the best fit of the two-factor model, in addition to the recommendations

in the literature regarding the structure of the MAST scale, the CFA was then carried out, with the first nine items of the scale allocated to the first factor (General Mathematics Anxiety - GMA) and the others to the second (Anxiety about Mathematics Teaching - AEM). The fit and residual indices showed excellent results [$\chi^2 / gl < 1$; CFI= 1.00; TLI= 1.00; RMSEA= 0.000 (0.000 - 0.000); SRMR= 0.049], as did the reliability parameters, all above 0.93. The factor loadings of the items varied between 0.71 and 0.89 for the first factor (AMG) and between 0.77 and 0.87 for the second (AEM), as can be seen in Table 3.

Items	Unifactorial	Bifactorial	
		AMG	AEM
01	0.695	0.726	
02	0.680	0.713	
03	0.725	0.747	
04	0.749	0.784	
05	0.766	0.802	
06	0.810	0.838	
07	0.820	0.844	
08	0.825	0.849	
09	0.869	0.893	
10	0.776		0.843
11	0.789		0.858
12	0.749		0.813
13	0.704		0.773
14	0.762		0.834
15	0.795		0.872
α	0.956	0.942	0.931
ω	0.957	0.944	0.931
GLB	0.979	0.964	0.946
χ^2 / gl	141.367/90	53.068/89	
CFI	0.993	1.000	
TLI	0.992	1.006	
RMSEA	0.047 (0.032 - 0.062)	0.000 (0.000 - 0.000)	
SRMR	0.079	0.049	

Table 3 - Item factor loadings, reliability parameters, fit and residual indices for the uni- and bifactor models, according to the CFA

Variables	N (%)
Biological sex	
Female	246 (96,9)
Male	8 (3,1)
Skin color ^a	
White	198 (78,3)
Brown/Yellow or Indigenous	22 (8,7)
Black	33 (13,0)
Age^b	45,7 (9,2)
Socio-economic class ^a	
A+B (above 10 minimum wages)	8 (3,2)
C (from 4 to 10 minimum wages)	79 (31,3)
D (from 2 to 4 minimum wages)	129 (51,2)
E (up to 2 minimum wages)	36 (14,3)
Higher Education ^a	
Teaching	7 (2,8)
Degree in Pedagogy	71 (28,2)
Specialization	148 (58,7)
Master's + Doctorate	26 (10,3)
Length of service ^{a,b}	13,8 (9,5)
Year/grade of performance ^a	
Literacy cycle (1st, 2nd and 3rd year)	148 (64,1)
4th year	44 (19,0)
5th year	39 (16,9)
Networking	
Municipal	166 (65,4)
State	88 (34,6)
Professional satisfaction¹	
Not satisfied / Not very satisfied	102 (40,3)
Satisfied	134 (53,0)
Very satisfied	17 (6,7)
Training for teaching mathematics²	
No	227 (90,1)
Yes	25 (9,9)
Relationship with mathematics and its teaching	
Bad / Fair	40 (15,8)
Very good	63 (24,8)
Great	25 (9,8)
Relationship with mathematics during the pandemic³	
It's gotten worse	63 (25,1)
No change	168 (66,9)
Improved	20 (8,0)
TOTAL	254 (100%)

Table 1 - Sociodemographic and educational characteristics of the sample (N = 254)

Note.^a variables with *missing*;¹ 01 *missing*,² 02 *missing*,³ 03 *missing*;^b variable presented in mean and standard deviation; current value of the national minimum wage is R\$ 1,412.00

Despite this, as shown in Table 3, the scale, when considered as a unidimensional measure, also showed good psychometric characteristics in the CFA, suggesting that the MAST-BR can be analyzed both as a general measure (unifactorial) and as a composite measure (bifactorial).

The correlation of the AMG factor with the general scale was $r = 0.950$ and with AEM was $r = 0.917$. The correlation between the AMG and AEM factors was $r = 0.760$. All of them showed a p -value < 0.001 . There were no significant modification indices (covariances) for this model. The correlation proved to be very high (≥ 0.9) with the factors separately and high ($0.7 - 0.89$) between the factors.

VALIDITY BASED ON THE RELATIONSHIP WITH EXTERNAL VARIABLES

The raw MAST-BR results were correlated with the GAD-7 scores using *Spearman's* correlation. A statistically significant correlation was observed ($p < 0.001$), both with the total MAST-BR score ($r = 0.428$) and the factor scores: AMG and AEM ($r = 0.435$ and $r = 0.360$). Thus, the more anxious the teacher (GAD-7), the greater the tendency to have high levels of MA (MAST-BR).

DISCUSSION

Hembre (1990) identified MA as a potentially important emotion to consider, especially among elementary school teachers. The aim of this study was to cross-culturally adapt the *Math Anxiety Scale for Teachers* and investigate the evidence of its validity in Brazilian Portuguese.

VALIDITY BASED ON INTERNAL STRUCTURE

According to the results of the one-dimensional [RMSEA= 0.171 (0.162 - 0.180), CFI= 0.970, TLI= 0.965] and two-dimensional [RMSEA= 0.091 (0.082 - 0.101), CFI= 0.992, TLI=0.990] models of the original scale (Ganley *et al.*, 2019), the two-dimensional model in this study showed more satisfactory results. Thus, both the original version and the one adapted for the Brazilian context showed better performance when considering two dimensions - AMG and AEM. Despite this, the results suggest that both forms can be considered.

This study used other indicators, in addition to the *Cronbach's alpha* coefficient (α) used by Ganley *et al.* (2019), in order to verify evidence of the scale's reliability. *McDonald's Omega* (ω) and GLB (*Greast Least Brwnder*) indicators were used as complementary evidence to verify the internal consistency of the MAST-BR. All the α , ω and GLB indices found in the CFA, both in the uni and bifactor models, are above 0.93, i.e. similar to those found in the MAST scale, which was $\alpha = 0.96$.

VALIDITY BASED ON THE RELATIONSHIP WITH EXTERNAL VARIABLES

To determine construct validity through convergent validation, it is necessary for the test to correlate significantly with other variables with which the measured construct should, according to the literature, be related (Pasquali, 2017). In the case of MAST-BR, evidence of convergent validity can be seen in the association with GAD-7. Although the study by Ganley *et al.* (2019) does not use the association with the GAD-7, other results have been found in the international literature (Hart & Ganley, 2019), when MA was significantly correlated with general anxiety, assessed by the DASS 21 and with four items from the Cognitive Test Anxiety Scale. MA may be

more prevalent among individuals who have some symptoms of Generalized Anxiety Disorder (GAD), since both share underlying cognitive mechanisms in relation to performance and physiological indicators such as tachycardia, palpitations, dizziness and tension headaches (Adams, 2001).

Although the similarities between Generalized Anxiety and Mathematics Anxiety have been identified both from a physiological and neurofunctional point of view, the study conducted by Ray Hembree reported a moderate correlation ($r = 0.35$) between the two constructs (Hembree, 1990). The results of the current studies by Hart and Ganley (2019), with North American adults, were also remarkably similar to those of Hembree (1990), finding a moderate correlation of $r = 0.44$ between Generalized Anxiety and MA. These findings replicate and extend the work with a sample of

teachers, as well as this study, reinforcing that MA, although distinct, is related to Generalized Anxiety.

CONCLUSION

This study has provided evidence of the validity of the MAST-BR scale to track the phenomenon of MA among teachers who teach mathematics in the Early Years of Primary School, as well as contributing to the development of theory on MA in the Brazilian context. The MAST-BR scale will serve as the first adapted and validated Brazilian instrument to measure MA among teachers, especially those working in the Early Years of Primary School. In this way, an instrument is presented which, as well as being used in research, could help to develop intervention strategies in the field of MA.

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