Hindawi Publishing Corporation
Child Development Research
Volume 2012, Article ID 610192, 10 pages
doi:10.1155/2012/610192

Research Article

Math Anxiety Questionnaire: Similar Latent Structure in Brazilian and German School Children

Guilherme Wood,[1] Pedro Pinheiro-Chagas,[2,3]
Annelise Júlio-Costa,[3] Letícia Rettore Micheli,[4] Helga Krinzinger,[5]
Liane Kaufmann,[6] Klaus Willmes,[5] and Vitor Geraldi Haase[2,3]

[1] *Department of Neuropsychology, Institute of Psychology, Karl-Franzens University of Graz, Universitätsplatz 2/III. 8020, Graz, Austria*
[2] *Developmental Neuropsychology Laboratory, Department of Psychology, Federal University of Minas Gerais, 31270-901 Belo Horizonte, MG, Brazil*
[3] *Neuroscience Graduate Program, Federal University of Minas Gerais, 31270-901 Belo Horizonte, MG, Brazil*
[4] *Donders Institute for Brain, Cognition and Behavior, Radboud University Nijmegen, 106525 GA Nijmegen, The Netherlands*
[5] *Child Neuropsychology Section, Department of Child and Adolescent Psychiatry, RWTH Aachen University, 52074 Aachen, Germany*
[6] *Institute of Applied Psychology, UMIT-The Health and Life Science University, Eduard Wallnöfer Zentrum 1, 6060 Hall in Tyrol, Austria*

Correspondence should be addressed to Guilherme Wood, guilherme.wood@uni-graz.at

Received 21 May 2012; Revised 21 October 2012; Accepted 21 October 2012

Academic Editor: Ann Dowker

Math anxiety is a relatively frequent phenomenon often related to low mathematics achievement and dyscalculia. In the present study, the German and the Brazilian versions of the Mathematics Anxiety Questionnaire (MAQ) were examined. The two-dimensional structure originally reported for the German MAQ, that includes both affective and cognitive components of math anxiety was reproduced in the Brazilian version. Moreover, mathematics anxiety also was found to increase with age in both populations and was particularly associated with basic numeric competencies and more complex arithmetics. The present results suggest that mathematics anxiety as measured by the MAQ presents the same internal structure in culturally very different populations.

1. Introduction

Every student knows how unpleasant life can be when the mathematics test is approaching. Although there is no gold standard to measure the levels of math anxiety (MA) that should be considered maladaptive, depending on their intensity and duration, negative physiological reactions, effects, and thoughts regarding mathematics can be considered a form of performance-related phobia [1]. Correlations between MA and math achievement have been reported [2, 3] as well as bidirectional associations between MA and math performance on several time scales going from online or short-term to long-term effects. On the long term, low math achievement is an antecedent of MA [4, 5] but MA also interferes with math performance. MA leads to hastened performance on math tasks and avoidance of math activities and courses, resulting in lower math skills and choice of careers with less demanding curricular requirements regarding mathematics [6, 7]. Besides, successful treatment of MA leads to significant improvements in math performance [2].

Short-term, online effects of MA on math performance have also been described. Negative emotional and math-related primes have been shown to speed up math performance in children with math learning disability [8]. Other studies indicate that MA negatively interferes with math performance. Initial research showed that online effects of MA on math performance were more pronounced for tasks demanding higher levels of working memory resources, such as those involving transfer between columns [9]. Newer findings demonstrate, however, that MA also interferes with performance in more basic number processing tasks, such as magnitude comparison [10] and counting, but not subitizing [11]. In line with these last results, children with high MA display comparatively lower levels of frontoparietal and higher levels of right amygdala activations performing a simple equation verification task [12]. Moreover, children with high MA also exhibit higher functional correlation levels between right and left amygdala and between right amygdala and ventromedial prefrontal cortex. These results indicate that in children MA is associated to a consistent pattern of activation in brain regions associated to emotion processing and regulation and hypoactivity in brain areas associated with number processing and calculation.

MA is a multilevel construct keeping similarities with disorders such as social phobia and test and computer anxiety [1]. The physiological arousal component of MA has been variously assessed by salivary cortisol measures [13] or experimentally manipulated by breathing of CO_2 enriched air [14]. However, most studies on MA have used self-report scales assessing an affective component of tension, apprehension and fear, and a cognitive component related to negative attitudes, worrisome thoughts, and low self-assessments of performance [1, 4, 15]. The cognitive component of MA is correlated to but psychometrically distinguishable from other self-related constructs such as math self-concept or math self-efficacy [16]. Research investigating the latent structure of MA self-assessments reliably distinguishes the affective from the cognitive component [4]. There is also cross-cultural research with adolescents confirming the differentiation between affective and cognitive components of MA [16, 17].

Although the latent structure of MA has been investigated in adolescents, to our knowledge, there is no research on the latent structure of MA in elementary school children focused on transcultural similarities and differences. This would be important, as evidence suggests that distinct MA components may differentially correlate to math performance and other factors according to age [4, 5]. Besides, although latent structure has been shown to preserve similarity across cultures, there are regional variations in the levels and correlates of different constructs. For instance, students in some Asian countries such as Japan and Korea, exhibit higher levels of math performance, they also endorse lower levels of math self-concept and math self-efficacy [16].

Research on MA has been largely concentrated on high-school and college samples [2, 3]. But MA instruments to assess children of elementary school age are increasingly available [4, 12, 15, 17, 18]. Age differences in the component of MA associated to math performance have been reported by Krinzinger and coworkers [4]. These authors found that lower math performance is a longitudinal predictor of lower math performance self-perceptions but not of negative affective reactions towards math in a sample examined repeatedly from the first to the third elementary school grade. In contrast, Ma and Xu [5] observed that lower math achievement in the 7th grade is predictive of higher levels in the affective component of MA in the 12th grade. These results suggest that correlates of MA may vary according to age but also that more research with elementary school children is still necessary.

Research reported here aimed at comparing MA latent structure, math performance, and sociodemographic correlates in samples of typically developing elementary school children in two countries, Germany and Brazil. While the PISA 2003 math scores of German students are among those with the highest ranks, those of Brazilian students are placed in the lowest ranks [16]. Math anxiety (lower in Germany, higher in Brazil) and math self-efficacy (higher in Germany, lower in Brazil) were found previously to vary accordingly. Interestingly, math concept seems not to be affected by low achievement and high math anxiety in Brazil [16].

More specifically, we aimed at examining if the bifactorial structure described by Krinzinger and coworkers [4, 15] in Germany could be replicated in a Brazilian sample of elementary school children, and if the affective and cognitive MA components varied in level and associations to math performance in the two countries. Based on previous results by Krinzinger and coworkers, we hypothesize that the bifactorial affective-cognitive structure may be reliably identifiable in the two countries and that the cognitive MA component should be more strongly associated to math performance.

2. Materials and Methods

2.1. Participants

2.1.1. Brazilian Sample. The Brazilian sample was constituted by children with ages ranging from 7 to 12 years and attending from 1st to 6th grade. The study was approved by the local research ethics committee (COEP-UFMG). Children participated only after providing informed consent in written form from their parents, and orally from themselves. Children were recruited from schools of Belo Horizonte and Mariana, Brazil. A wide set of evenly geographically distributed schools was sampled. For this reason, the sample is representative of the Brazilian school population, with 80% of children attending public school, and the 20% attending private schools. In a first phase of testing, children with normal intelligence (i.e., who scored above the 16th percentile in the Raven colored matrices test, [19]) were included in the study. These children also solved the Arithmetic and Spelling subtests of the Brazilian School Achievement Test (Teste do Desempenho Escolar, TDE, [20]). Those children scoring above the 25th percentile on both Arithmetic and Spelling subtests of the TDE were assigned to our study. The sample consisted of 171 children (see Table 1 for further details). In a next step, children were evaluated with a neuropsychological battery containing the Digit-span and Corsi-blocks, forward and backward, basic arithmetic operations, addition, subtraction, and multiplication problems, individually.

2.1.2. German Sample. Four hundred fifty children with ages between 6 and 10 years old, attending to grades 1 to 3, who took part in a study aiming to collect norms for the German version of the TEDI-MATH [4, 21] were included in the present study. In this sample, only children without

Table 1: Descriptive data from Brazilian and German children.

	Brazil	Germany
N	171	450
Female (%)	99 (57.9%)	227 (50.4%)
Male (%)	72 (42.1%)	223 (49.6%)
Age (mean (sd))[§]	119.26 (13.2)	96.04 (5.1)

[§]expressed in months.

difficulties in mathematics—as screened by the TEDI-MATH [21]—were selected. Besides the TEDI-MATH, these children have also completed a Digit-span task. Descriptive data are depicted in Table 1. All children come from public schools of the state of North Rhine-Westphalia in Germany. A more detailed description of the sample can be found in Krinzinger et al. [15].

For the purpose of comparing results between the Brazilian and the German samples, a subsample of those children with ages between 7.6 and 10.1 years was selected, which is the age interval common to both samples (Brazilian $n = 101$, German $n = 284$). When subsamples are compared, this will be mentioned explicitly in the results. Importantly, the two subsamples were formed by children attending to 2nd or 3rd grades in school.

2.2. Psychological Instruments. The Math Anxiety Questionnaire (MAQ) was applied both in Brazil as in Germany. Other instruments differed according to country. In Brazil, school achievement was assessed with the TDE and intelligence with the Raven's Colored Progressive Matrices. Besides, basic computation abilities were assessed with Basic Arithmetic Operations, and short-term and working memory with the Digit-span and Corsi-blocks tests. The TEDI-MATH was used in Germany to assess basic math abilities. In the following, these instruments will be described in more detail.

2.3. Brazilian School Achievement Test (TDE) [20]. The TDE is the most widely used standardized test of school achievement with norms for the Brazilian population. It comprises three subtests: Arithmetics, single-word Spelling, and single-word Reading. In the screening phase, the Arithmetics and Spelling subtests were used, which can be applied in groups. Norms are provided for school-aged children between the second and seventh grade. The Arithmetics subtest is composed of three simple verbally presented word problems (i.e., which is the largest, 28 or 42?) and 45 written arithmetic calculations of increasing complexity (i.e., very easy: $4 - 1$; easy: $1230 + 150 + 1620$; intermediate: 823×96; hard: $3/4 + 2/8$). Specific norms for each school grade were used to characterize children's individual performance. The Spelling subtest consists of dictation of 34 words of increasing syllabic complexity (i.e., *toca*; *balanço*; *cristalização*). Reliability coefficients (Cronbach α) of TDE subtests are 0.87 or higher. Children are instructed to work on the problems to the best of their capacity but without time limits.

2.4. Raven's Colored Progressive Matrices. General intelligence was assessed with the age-appropriate Brazilian validated version of Raven's Colored Matrices [19].

Digit-Span (Forward and Backward). Verbal short-term memory was assessed with the Brazilian WISC-III Digits subtest [22]. Performance in the forward order was considered a measure of phonological short-term memory, and the backward order was used to assess verbal working memory.

Corsi Blocks (Forward and Backward). This test is a measure of the visuospatial component of working memory. It is constituted by a set of nine blocks, which are tapped, in a certain sequence by the examiner. The test starts with sequences of two blocks and can reach a maximum of nine blocks. We used the forward and backward Corsi span tasks according to [23]. In the forward condition, the child is instructed to tap the blocks on the same order as the examiner, in the backward condition, in the inverse order. Span is determined by the longest sequence correctly repeated before two successive failures.

Basic Arithmetic Operations. This task consisted of addition (27 items), subtraction (27 items), and multiplication (28 items) operations for individual application, which were printed on separate sheets of paper. Children were instructed to answer as fast and as accurate as they could, time limit per block being 1 minute. Arithmetic operations were organized in two levels of complexity and were presented to children in separate blocks: one consisted of simple arithmetic table facts and the other of more complex ones. Simple additions were defined as those operations with the results below 10 (i.e., $3+5$), while complex additions with the results between 11 and 17 (i.e., $9 + 5$). Tie problems (i.e., $4 + 4$) were not used for addition. Simple subtraction comprised of problems in which the operands were below 10 (i.e., $9 - 6$), while for complex subtractions the first operand ranged from 11 to 17 (i.e., $16 - 9$). No negative results were included in the subtraction problems. Simple multiplication consisted of operations with results below 25 and with the number 5 as one of the operands (i.e., $2 * 7$, $5 * 6$), while for the complex multiplication the result of operands ranged from 24 to 72 ($6 * 8$). Tie problems were not used for multiplication. Reliability coefficients were high (Cronbach's $\alpha > 0.90$).

2.5. TEDI-MATH. The TEDI-MATH is a battery for the assessment of numerical and arithmetic competencies in 4–9-year primary school children. There are norms for the TEDI-MATH in three different languages: French, Flemish, and German. The TEDI-MATH is a multicomponential dyscalculia test based on cognitive neuropsychological models of number processing and calculation. The German version of the TEDI-MATH [4] was translated of the Belgium Neuropsychological Test for a Developmental Dyscalculia diagnostic [24]. The German version offers in addition to the original version an implementation of a core battery with subtests of the first grade elementary school in the two components of number processing (reading and writing multidigit numbers, size comparison multidigit numbers, recognition of unit and decade, representation of the decimal system), and arithmetic (addition, subtraction, multiplication, word problems, additive decomposition of numbers, understanding of arithmetic concepts).

2.6. Math Anxiety Questionnaire (MAQ). The Math Anxiety Questionnaire is a well-known scale developed by Thomas and Dowker [25] for the assessment of anxiety towards mathematics in primary school children. The present study used a Brazilian Portuguese version developed and standardized by us (this paper). Children answer the questionnaire in individual sessions of 5 to 10 minutes. The Brazilian version of the MAQ contains 24 items that can be answered by children individually or in groups within 5 to 10 minutes. The items can be combined into four basic subscales ("self-perceived performance" (Scale A), "attitudes in mathematics" (Scale B), "unhappiness related to problems in mathematics" (Scale C) and "anxiety related to problems in mathematics" (Scale D)) according to the authors of the original version [25]. Some studies have examined the construct validity of the MAQ [15]. Krinzinger and colleagues [15] have established with help of multidimensional scaling that the latent structure of the MAQ contains two main dimensions. These authors have shown that the four original subscales can be combined into two main scores called "Self-perceived performance and attitudes" and "Mathematics anxiety." The first one, named evaluation of mathematics, includes the first two subscales, while the second one, called math anxiety, combines the last two subscales. Moreover, in a longitudinal study, Krinzinger and colleagues [4] also have shown that the two combined scales of the MAQ show a high stability over time and are useful to predict calculation abilities. Finally, Haase and colleagues [26] showed recently that the different subscales of the MAQ can be differentiated from more general forms of anxiety and are more specifically related to performance in mathematics in school children than general measures of anxiety. The MAQ items have the format of one out of four types of questions: "*How good are you at...*" (Scale A); "*How much do you like...*" (Scale B); "*How happy or unhappy are you if you have problems with...*" (Scale C) and "*How worried are you if you have problems with...*" (Scale D). Each question is to be answered regarding six different categories related to mathematics, namely, mathematics in general (MAQ_G), easy calculations (MAQ_E), difficult calculations (MAQ_D), written calculations (MAQ_W), mental calculations (MAQ_M), and math homework (MAQ_H). Children are encouraged by supportive figures to give their responses according to a Likert scale with 5 points (coded 0 to 4, such as in the study by Krinzinger et al. [15]. The higher the score, the higher is the math anxiety. Reliability coefficient (Cronbach α) of MAQ in the German study ranged between 0.83 and 0.91 for the total scale.

2.7. Testing Procedures. The assessment was performed in an appropriate room in children's schools. Tests as well as their order of application varied in the two countries. In Brazil, the TDE and Raven were applied during the screening phase, while four different pseudo-randomly varying sequences of application were used in the individual testing phase. In Germany, the MAQ was applied immediately after the TEDI-MATH. The data from the Brazilian and German samples were obtained originally for very different purposes and at different time points. The aim of the present study to analyze the latent structure of the MAQ emerged after both data sets have been collected. This is the reason why the choice of measurement instruments was so different in Brazilian and German populations.

2.8. Analyses. The internal consistency of all subscales of the MAQ will be calculated for the first time for the Brazilian version of the MAQ. Because of existing findings in the German population [4], predictive validity over arithmetics achievement will be assessed by means of regression analyses linking basic number magnitude representations and arithmetics performance to the MAQ subscales. The construct validity of the MAQ will be assessed by different methods. To determine the dimensionality of the MAQ, Mokken automatic item classification [27] and multidimensional scaling will be employed. Mokken scaling is based on the Monotone Homogeneity Model (MHM, [27–29]). It tests the assumptions that the traits being measured are unidimensional, that items can be ordered monotonically according to their difficulty, and that responses to single items bear local independence. Mokken analyses provide scalability coefficients H for each item in each scale and for the scales as a whole. Values H can vary from 0 to 1. The higher the H value, the higher is the scalability of an item according to the Monotone Homogeneity Model [27, 28]. To determine the convergent validity of the MAQ, a comparison between a German and a Brazilian versions of the MAQ was carried out.

3. Results

All children in the Brazilian sample reached a score above the 25th percentile in the subtests of the TDE and can be considered as typically achieving children in both arithmetic and spelling abilities. All children in the German sample can be considered as typically achieving children in arithmetics according to their scores in the TEDI-MATH. In the following, results regarding the internal consistency of the MAQ will be presented first. Thereafter, the raw scores of the Brazilian and the German sample will be compared and the predictive validity of the MAQ regarding numeric and arithmetic abilities will be reported. Finally, investigations on the latent structure of the MAQ that employed automatic item classification and multidimensional scaling will be reported.

3.1. Brazilian Sample

Internal Consistency. Means, standard deviations, minimum and maximum and internal consistency (Cronbach's α) of the scores in each MAQ subscale and each composite scale obtained in the Brazilian sample are presented in Table 2. The internal consistency of the different subscales is satisfactory or high in all cases (Table 2). According to the criteria

Table 2: Descriptives of MAQ subscales and composite scales ($n = 171$).

Scales	Mean	Sd	Minimum	Maximum	Cronbach's α
Scale A (6 items)	23.66	3.53	11	30	0.71
Scale B (6 items)	23.00	4.66	8	30	0.71
Scale C (6 items)	17.80	6.13	6	30	0.88
Scale D (6 items)	17.20	5.80	6	30	0.80
Scale AB (12 items)	46.60	7.03	24	59	0.78
Scale CD (12 items)	35.06	10.55	12	58	0.88
Total (24 items)	81.70	14.67	46	116	0.87

Table 3: Regression models for arithmetic abilities.

Task	Adjusted $r^{2\,\S}$	Sample size	Significant predictors in the model
Simple addition	34.7	164	Sex, grade, raven, Corsi backwards, digit-span forward
Complex addition	38.4	164	Grade, Corsi backward, digit-span forward, Corsi backward
Simple subtraction	26.1	164	Sex, grade, Corsi backward, Corsi forward
Complex subtraction	29.9	164	Grade, Corsi backward, digit-span backward, MAQ-scale A
Simple multiplication	53.5	164	Grade, Corsi backward, digit-span forward, MAQ-scale A, MAQ-scale D
Complex multiplication	42.9	164	Corsi forward, digit-span forward, digit-span backward, MAQ-scale A

§ expressed as the proportion of variance in the dependent variable explained by the model.

established by Willmes [30], scales C and D as well as CD and MAQ-total are practically invariant for the sample size $n = 171$ and alpha-error probability of 5%. Composite scale AB is very close to practical invariance. The optimal sample size would be reached with 30 more children in the normative sample (see [30]).

To investigate the predictive validity of the MAQ, regressions analyses entering the four MAQ subscales as predictors of numeric and arithmetic abilities were calculated.

Numeric and Arithmetic Abilities. The impact of math anxiety on simple and complex addition, subtraction, and multiplication tasks was examined in the Brazilian sample. Hundred sixty four children from the Brazilian sample completed all these tasks. In order to ascertain the specificity of the contribution of MAQ scales to explaining variance in the arithmetic tasks, age, sex, grade, general intelligence, verbal and nonverbal short-term memory and working memory (digit span and Corsi span, both of them forward and backward) were entered in the model as well. Age, sex, grade, and general intelligence were entered first in the model using the method "enter," while the measures of short-term memory and working memory were entered using the method "stepwise." This regression method was adopted to ascertain that the impact more general sociodemographic and cognitive functions has been removed before analyzing the impact of math anxiety on numeric and arithmetic abilities and competencies was investigated. A summary containing the adjusted r^2 and significant predictors in each single model is presented in Table 3.

As depicted in Table 3, scale A of the MAQ has a significant impact on more complex arithmetic operations such as complex subtraction, simple, and complex multiplication. Moreover, verbal and visuospatial working memory measures (digit-span and Corsi blocks backwards) are significant predictors of individual differences in performance in addition, subtraction, and multiplication problems but they cannot account for the impact of different aspects of MA on arithmetics performance.

3.2. German Sample

Internal Consistency. The internal consistency of the MAQ in the German population has been reported in detail elsewhere [15]. The Cronbach's alpha coefficient of single subscales ranges between .65 and .86.

To investigate the predictive validity of the MAQ, regressions analyses entering the four MAQ subscales as predictors of seven different subtests of the TEDI-MATH, which measure numeric and arithmetic abilities, were calculated.

Numeric and Arithmetic Abilities. The impact of math anxiety on seven subtests of the TEDI-MATH was examined in the German sample. Between 279 and 284 children from the German sample completed all these tasks. In order to ascertain the specificity of the contribution of MAQ scales to explaining variance in the arithmetic tasks, age, sex, grade, and verbal short-term memory (digit span forward and backward) were entered in the model as well. Age, sex, and grade were entered first in the model using the method "enter," while the measures of short-term memory and were entered using the method "stepwise". This regression method was adopted to ascertain that the impact more general sociodemographic and cognitive functions has been removed before analyzing the impact of math anxiety on numeric and arithmetic abilities and competencies was investigated. A summary containing the adjusted r^2, sample sizes, and significant predictors in each single model is presented in Table 4.

Table 4: Regression models for numeric and arithmetic abilities.

Task	Adjusted $r^{2\,\S}$	Sample size	Significant predictors in the model
Addition decomposition	5	284	Age, MAQ-scale A
Text problems	8	284	Age, grade, MAQ-scale A
Magnitude comparison Arabic	2.6	284	MAQ-scale A
Magnitude comparison number words	3.3	284	MAQ-scale A
Writing number	6.7	284	Age
Reading number	6.8	284	Age
Arithmetic concepts	9.6	279	MAQ-scale A

§expressed as the proportion of variance in the dependent variable explained by the model.

As depicted in Table 4, scale A of the MAQ has a significant—although small—impact on fundamental numeric and arithmetic abilities measured by the TEDI-MATH such as magnitude comparison (Arabic numbers and number words) as well as more complex abilities such as addition decomposition, text problems, and arithmetic concepts.

3.3. Comparisons between Raw Scores. To compare data between the Brazilian and the German sample, a subsample of each group was selected (Brazilian sample, $n = 101$; German sample $n = 284$), which had ages between 7.5 and 10.1 years in both groups. t-tests revealed no difference between both samples in the subscale A "self-perceived performance" ($t(383) = 0.45$; se $= 0.49$; $P = 0.65$; Cohen's $d = 0.05$). The Brazilian sample showed higher scores that the German sample in the subscale B "attitudes in mathematics" ($t(383) = 2.81$; se $= 0.63$; $P = 0.0053$; Cohen's $d = 0.34$), subscale C "unhappiness related to problems in mathematics" ($t(383) = 5.30$; se $= 0.62$; $P = 0.0001$; Cohen's $d = 0.61$) and subscale D "anxiety related to problems in mathematics" ($t(383) = 2.22$; se $= 0.68$; $P = 0.03$; Cohen's $d = 0.26$) although the effect sizes of these differences were small or moderate.

3.4. Automatic Item Classification Analysis [27]. To investigate the latent structure of the MAQ, an automatic item classification analysis was employed [27]. Based on the Loevinger H-index of scalability, items were automatically assigned to a one-dimensional scales [28]. Only items reaching an H-index of at least 0.3 were assigned to a scale, while items with lower scalability are dropped automatically from the analysis [27]. Results were quite similar in both Brazilian and German samples. In both cases, three scales were disclosed by the Mokken analysis (Table 5). MAQ scales C and D were subsumed under a single unidimensional scale in both Brazilian and German samples. However, in both samples subscales A and B could not be assigned to one single composite scale, but to two separate scales in which items from both subscales A and B were mixed. Closer inspection of items being classified in scales 2 and 3 reveals that in the German sample "written calculations" drove the process of item classification in scale 3. In contrast, in the Brazilian sample the items being assigned to scale 3 originate from the original scale B measuring "attitudes towards mathematics".

Three items could not be classified in the Brazilian sample, while all items could be assigned to a scale in the German sample. Results were replicated when considering only children with ages between 7.5 and 10.1 years. For this reason, these analyses will not be reported here.

3.5. Dimensionality of the MAQ. To investigate the construct validity of the Brazilian version of the MAQ, multidimensional scaling was employed. The facets diagram (see Figure 1) depicts the projection of the distances between the different items on a two-dimensional space. As can be easily recognized, Items from scales A and B cluster together as well as items from scales C and D. These results replicate those reported by Krinzinger et al. [15].

4. Discussion and Conclusion

In the present study, the psychometric properties of a Brazilian version of the MAQ were investigated for the first time as well as its transcultural validity in German Brazilian samples. The internal consistency of all subscales and composite scales obtained in the Brazilian sample is throughout satisfactory or even high. A direct comparison of the raw scores obtained in the Brazilian sample with those obtained in the German sample reveal no differences in the subscale representing "self-perceived performance". However, the Brazilian sample showed higher scores in the subscales "attitudes towards mathematics," "unhappiness related to problems in mathematics," and "anxiety related to problems in mathematics" when compared to the German sample. The investigation of the predictive validity of the MAQ revealed that "self-perceived performance" is a significant predictor of basic numeric abilities such as magnitude comparison as well of more complex arithmetic abilities and competencies. Importantly, "self-perceived performance" remains a significant predictor even after removing the specific effects of grade, age, sex, verbal, and nonverbal short-term memory and working memory on these abilities. Finally, automatic item selection as well as multidimensional scaling procedures revealed the similarities in the structure of the MAQ between both Brazilian and German samples. In the following, these results will be discussed in more detail.

Table 5: Results of the automatic classification of items (Mokken analysis).

Scale	Brazilian sample ($n = 171$)		German sample ($n = 450$)	
	Items (scale)[§]	Loevinger's H-score	Items (scale)[§]	Loevinger's H-score
Scale 1	MAQ_M(C)	($H = 0.64$)	MAQ_M(D)	($H = 0.57$)
	MAQ_D(C)	($H = 0.64$)	MAQ_D(D)	($H = 0.57$)
	MAQ_G(C)	($H = 0.62$)	MAQ_H(D)	($H = 0.55$)
	MAQ_H(C)	($H = 0.60$)	MAQ_G(D)	($H = 0.52$)
	MAQ_E(C)	($H = 0.59$)	MAQ_E(D)	($H = 0.51$)
	MAQ_W(C)	($H = 0.58$)	MAQ_W(D)	($H = 0.49$)
	MAQ_H(D)	($H = 0.54$)	MAQ_D(C)	($H = 0.46$)
	MAQ_W(D)	($H = 0.50$)	MAQ_H(C)	($H = 0.44$)
	MAQ_E(D)	($H = 0.48$)	MAQ_E(C)	($H = 0.43$)
	MAQ_M(D)	($H = 0.46$)	MAQ_G(C)	($H = 0.42$)
	MAQ_D(D)	($H = 0.43$)	MAQ_W(C)	($H = 0.40$)
	MAQ_G(D)	($H = 0.42$)	MAQ_M(C)	($H = 0.39$)
Scale 2			MAQ_M(A)	($H = 0.61$)
	MAQ_H(A)	($H = 0.54$)	MAQ_G(A)	($H = 0.61$)
	MAQ_G(A)	($H = 0.54$)	MAQ_D(A)	($H = 0.57$)
	MAQ_D(A)	($H = 0.46$)	MAQ_M(B)	($H = 0.53$)
	MAQ_D(B)	($H = 0.43$)	MAQ_D(B)	($H = 0.51$)
	MAQ_M(A)	($H = 0.41$)	MAQ_G(B)	($H = 0.48$)
	MAQ_M(B)	($H = 0.39$)	MAQ_H(B)	($H = 0.45$)
	MAQ_G(B)	($H = 0.37$)	MAQ_H(A)	($H = 0.43$)
			MAQ_E(B)	($H = 0.40$)
			MAQ_E(A)	($H = 0.39$)
Scale 3	MAQ_W(B)	($H = 0.42$)		
	MAQ_W(A)	($H = 0.42$)	MAQ_W(B)	($H = 0.30$)
	MAQ_E(B)	($H = 0.37$)	MAQ_W(A)	($H = 0.30$)
	MAQ_H(B)	($H = 0.35$)		

[§]Item description is composed of the content of each item, that is: mathematics in general (MAQ_G); easy calculations (MAQ_E); difficult calculations (MAQ_D); written calculations (MAQ_W); mental calculations (MAQ_M); math homework (MAQ_H) and its scale (A), (B), (C), or (D).

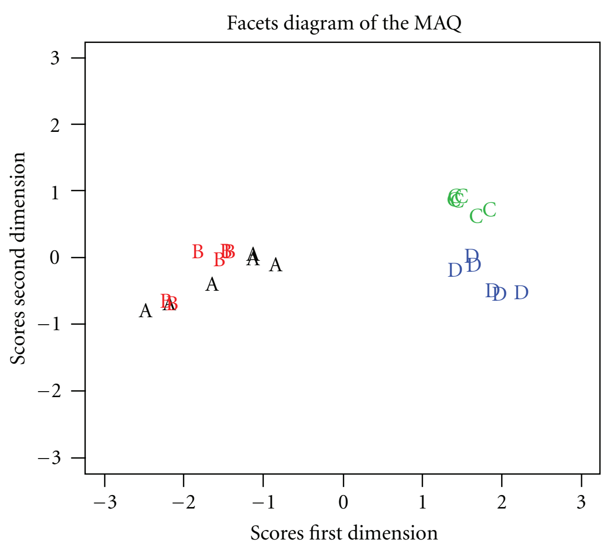


Figure 1: Configuration of MAQ items represented in a two-dimensional space using multidimensional scaling. Symbols A, B, C, and D represent the different scale items according to their scale assignment. The scale of axes x and y is arbitrary.

4.1. Internal Consistency and Diagnostic Properties of the MAQ. In Brazil, a raw sample covering a broad spectrum of ages was investigated. The degree of accuracy to describe MA in children is lower than in the larger German sample, where specific norms for children in first and second halves of each grade were obtained [15]. However, the Brazilian data on the MAQ still have some very useful psychometric properties. The internal consistency was satisfactory for all scales. Especially subscales C and D as well as the composite scales CD and Total were found to be practically invariant. This means, the reliability estimations obtained for these scales are sufficient for the construction of stable confidence intervals on the individual performance and specially for testing intervention-related changes in the levels of MA. Moreover, the composite scale AB presents an internal consistency high enough to be very close to practical invariance as defined by Willmes [30] Since investigations on the dimensionality of the MAQ support the view that scales A and B can be grouped into a composite scale AB it is unproblematic to consider scale AB as equally useful for individual diagnostics purposes.

4.2. Comparisons between the Brazilian and the German Samples. The Brazilian sample showed higher scores on "attitudes towards mathematics," "unhappiness related to problems in mathematics," and "anxiety related to problems in mathematics" when compared to the German sample. These results reveal higher levels of MA in the Brazilian sample when compared to the German sample. This replicates evidence from the recent literature [16]. Lee [16] reported that Brazilian students present levels of math anxiety much higher than those presented by German students (i.e., Brazilian students report math anxiety levels 0.4 standard deviations above the average of the 41 nations examined in that study, while German students report levels below −.35 standard deviations, [16, Figure 3, p. 361]. Interestingly, these differences were not found in the subscale "self-perceived performance". These results are in line with the study by Lee [16], where the levels of self-concept presented by both Brazilian and German students were comparable [16, Figure 1, p. 360].

One possible interpretation of these results can be derived from the view that there are at least two different ways for MA to impact math performance [31]. Chinn [31] argues that feelings of tension, apprehension, and fear may interfere directly with math performance but the state of discomfort associated to math activities may impact on the more intern driven constructs of self-esteem, self-concept, which also impact on math performance. The higher levels of "unhappiness related to problems in mathematics" and "anxiety related to problems in mathematics" as well as the lower levels of "attitudes towards mathematics" observed in the Brazilian sample can be directly attributed to the less efficient Brazilian educational system. However, independently of the prejudice in educational resources to which Brazilian children are exposed, their self-perceived performance may still be relatively high because of some compensatory factors and coping strategies. This could explain why comparable levels of self-perceived performance were observed in Brazilian and German samples in the present study. According to the framework conceived by Chinn [31], one could argue that particularly MAQ scales B, C, and D reflect more directly environmental influences such as a bad educational system, less motivated teachers on math performance indicate larger differences between countries. In contrast, the scale A seems to reflect the more self-oriented aspects of MA, which reveal no difference between countries because this dimension of MA is more internally regulated and less driven by the environment. In summary, the MAQ offers a fine-grained evaluation of both environment driven and self-oriented aspects of MA, which contribute to refine the diagnostics of MA in its different dimensions and aspects.

4.3. Predictive Validity of the MAQ. Investigation on the predictive validity of the MAQ revealed specific effects of self-perceived performance on basic number processing abilities such as magnitude comparison. These results replicate those obtained by Maloney and colleagues [11] regarding magnitude comparison (Arabic numbers and number words) as well as more complex abilities such as addition decomposition, text problems, and arithmetic concepts. Interestingly, no effect of self-perceived performance on number reading and writing was observed in the present study. Moreover, self-perceived performance also explained variance of simple and complex arithmetics. In the Brazilian sample, the effect of self-perceived performance could be distinguished from the more general factors such as age, general intelligence, short-term memory, and working memory. This is direct evidence on the specificity of the contribution of self-perceived performance to the diagnostics of performance in both simple and complex arithmetics. Interestingly, self-perceived performance contributes to explain variance of complex subtraction as well as simple and complex multiplication problems but is not associated with the performance in addition tasks and simple subtraction. Therefore, one may conclude that the impact of self-perceived performance on arithmetics is more pronounced in more demanding tasks. These findings reflect probably the fact that more demanding tasks may differentiate better children's performance than easier tasks and may reveal more about the self-perceived performance in mathematics than less demanding arithmetics tasks.

In general, these results suggest that the self-perceived performance is to some extent objectively associated to the actual level of performance observed in school children. This is indicative that the self-perceived performance may be assessed and used to complement the diagnostics of difficulties not only with the most elementary abilities in magnitude processing but also in those arithmetics tasks more typical of the academic context.

4.4. The Latent Structure of the MAQ. Automatic item classification after Mokken produced similar results in both samples. Scales A and B, on the one side, and scales C and D, on the other side, can be grouped into scales AB and CD. Items from scales A and B as well as items from scales C and D seem to load in the same latent dimensions in a way that item difficulty and individual competency are sufficient to describe the properties of the scale. The most central evidence provided by the Mokken analysis is that the items of the MAQ measure a broad spectrum of difficulty regarding MA. These findings are quite intuitive and can be related in a very transparent fashion to the contents of the MAQ items. In other words, the kind of question asked in the MAQ is related to a broad spectrum of expressions of the different facets of the construct "mathematics anxiety." While items asking for "easy problems" are easy for everyone and have a high probability of being responded positively even by children with high levels of MA, items representing the more complex categories such as "written calculations," "mental calculations," or "difficult calculations" have a decreasing probability of being answered positively by children with increasing levels of MA. Moreover, the good scalability of most items of the MAQ put in evidence the property of monotonicity found within each the MAQ scales. The high monotonicity found the different scales of the MAQ reflects the fact that only children with low levels of MA respond positively to more difficult items, while all children (those with low levels of MA as well as those with high levels of MA) tend to respond positively to easier items.

Finally, data from the multidimensional scaling analysis revealed clear similarities between the German and the Brazilian version of the MAQ. In both samples, a clear separation between subscales A and B, on the one side, and C and D, on the other side was observed. Two latent dimensions have been found in the German version of the MAQ by Krinzinger at al. [15] as well as in the present data. For the objectives of the present study, the substantial differences between samples should not be considered a drawback when comparing the latent structure of the MAQ obtained in the two populations but a strength of the study, since they reinforce the conclusions about the invariance of the latent structure of the MAQ even when comparing datasets from Brazilian and German populations obtained under very different circumstances and for very different purposes.

4.5. Final Considerations. The MAQ is a valid and useful scale for measuring mathematics anxiety in children with diverse cultural backgrounds with useful psychometric properties. The MAQ also specifically predicts basic number processing abilities as well as arithmetics performance and should, for this reason, be included in the assessment protocols used in the diagnostics of mathematics difficulties [32]. Studies on the psychophysiological correlates of math anxiety [33] could benefit from the use of the MAQ as well. Moreover, the latent structure of the Brazilian version of the MAQ seems to be two dimensional such as in the German version. Finally, probabilistic analyses revealed that the MAQ shows properties of monotonic organization, which are valuable to characterize a broad spectrum of variation in the different dimension of math anxiety.

Acknowledgments

G. Wood was supported by Grant (P22577-B18 of the Austrian Wissenschaftsfond FWF). Research by the V. G. Haase during the elaboration of this paper was funded by grants from CAPES/DAAD Probral Program, Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq, 307006/2008-5, 401232/2009-3), and Fundação de Amparo à Pesquisa do Estado de Minas Gerais (FAPEMIG, APQ-02755-SHA, APQ-03289-10, PPM-00280-12).

References

[1] M. H. Ashcraft, J. A. Krause, and D. R. Hopko, “Is math anxiety a mathematical learning disability?” in *Why Is Math so Hard for Some Children? The Nature and Origins of Mathematical Learning Difficulties and Disabilities*, D. B. Berch and M. M. M. Mazzocco, Eds., pp. 329–348, Brookes, Baltimore, Md, USA, 2007.

[2] R. Hembree, “The nature, effects, and relief of mathematics anxiety,” *Journal for Research in Mathematics Education*, vol. 21, no. 1, pp. 33–46, 1990.

[3] X. Ma, “A meta-analysis of the relationship between anxiety toward mathematics and achievement in mathematics,” *Journal for Research in Mathematics Education*, vol. 30, no. 5, pp. 520–540, 1999.

[4] H. Krinzinger, L. Kaufmann, and K. Willmes, “Math anxiety and math ability in early primary school years,” *Journal of Psychoeducational Assessment*, vol. 27, no. 3, pp. 206–225, 2009.

[5] X. Ma and J. Xu, “The causal ordering of mathematics anxiety and mathematics achievement: a longitudinal panel analysis,” *Journal of Adolescence*, vol. 27, no. 2, pp. 165–179, 2004.

[6] M. H. Ashcraft and M. W. Faust, “Mathematics anxiety and mental arithmetic performance: an exploratory investigation,” *Cognition and Emotion*, vol. 8, no. 2, pp. 97–125, 1994.

[7] J. A. LeFevre, A. G. Kulak, and S. L. Heymans, “Factors influencing the selection of university majors varying in mathematical content,” *Canadian Journal of Behavioural Science*, vol. 24, no. 3, pp. 276–289, 1992.

[8] O. Rubinsten and R. Tannock, “Mathematics anxiety in children with developmental dyscalculia,” *Behavioral and Brain Functions*, vol. 6, article no. 46, no. 1, p. 46, 2010.

[9] M. H. Ashcraft and E. P. Kirk, “The relationships among working memory, math anxiety, and performance,” *Journal of Experimental Psychology*, vol. 130, no. 2, pp. 224–237, 2001.

[10] E. A. Maloney, D. Ansari, and J. A. Fugelsang, “The effect of mathematics anxiety on the processing of numerical magnitude,” *The Quarterly Journal of Experimental Psychology*, vol. 64, no. 1, pp. 10–16, 2011.

[11] E. A. Maloney, E. F. Risko, D. Ansari, and J. Fugelsang “Mathematics anxiety affects counting but not subitizing during visual enumeration,” *Cognition*, vol. 114, no. 2, pp. 293–297, 2010.

[12] C. B. Young, S. S. Wu, and V. Menon, “The neurodevelopmentalbasis of math anxiety,” *Psychological Science*. In press.

[13] A. Mattarella-Micke, J. Mateo, M. N. Kozak, K. Foster, and S. L. Beilock, “Choke or thrive? The relation between salivary cortisol and math performance depends on individual differences in working memory and math-anxiety,” *Emotion*, vol. 11, no. 4, pp. 1000–1005, 2011.

[14] D. R. Hopko, D. W. McNeil, C. W. Lejuez, M. H. Ashcraft, G. H. Eifert, and J. Riel, “The effects of anxious responding on mental arithmetic and lexical decision task performance,” *Journal of Anxiety Disorders*, vol. 17, no. 6, pp. 647–665, 2003.

[15] H. Krinzinger, L. Kaufmann, A. Dowker et al., “German version of the math anxiety questionnaire (FRA) for 6- to 9-year-old children,” *Zeitschrift fur Kinder- und Jugendpsychiatrie und Psychotherapie*, vol. 35, no. 5, pp. 341–351, 2007.

[16] J. Lee, “Universals and specifics of math self-concept, math self-efficacy, and math anxiety across 41 PISA 2003 participating countries,” *Learning and Individual Differences*, vol. 19, no. 3, pp. 355–365, 2009.

[17] H. Z. Ho, D. Senturk, A. G. Lam et al., “The affective and cognitive dimensions of math anxiety: a cross-national study,” *Journal for Research in Mathematics Education*, vol. 31, no. 3, pp. 362–379, 2000.

[18] A. Wigfield and J. L. Meece, “Math anxiety in elementary and secondary school students,” *Journal of Educational Psychology*, vol. 80, no. 2, pp. 210–216, 1988.

[19] L. Angelini, I. C. B. Alves, E. M. Custódio, W. F. Duarte, and J. L. M. Duarte, *Matrizes Progressivas Coloridas de Raven*, Centro Editor de Testes e Pesquisas em Psicologia, São Paulo, Brazil, 1999.

[20] L. M. Stein, *Teste de Desempenho Escolar: Manual para Aplicação e Interpretação*, Casa do Psicólogo, São Paulo, Brazil, 1994.

[21] L. Kaufmann, H.-C. Nuerk, M. Graf, M. Delazer, and K. Willmes, *TEDI-MATH: Test Zur Erfassung Numerisch-Rechnerischer Fertigkeiten Vom Kindergarten Bis Zur 3*, Hans-Huber, Zürich, Switzerland, 2009.

[22] V. L. M. Figueiredo, *WISCIII: Escala de Inteligência Wechsler para Crianças. Manual Adaptação e Padronização Brasileira*, Casa do Psicólogo, São Paulo, Brazil, 2002.

[23] R. P. C. Kessels, M. J. E. Van Zandvoort, A. Postma, L. J. Kappelle, and E. H. F. De Haan, "The Corsi Block-Tapping Task: Standardization and normative data," *Applied Neuropsychology*, vol. 7, no. 4, pp. 252–258, 2000.

[24] C. Van Nieuwenhoven, J. Grégoire, and M. P. Noël, *Test Diagnostique des Compétences de Base en Mathématiques (Tedi-Math)*, Edition du Centre de Psychologie Appliquée, Paris, France, 2001.

[25] G. Thomas and A. Dowker, "Mathematics anxiety and related factors in young children," in *Proceedings of the Developmental Section Conference*, British Psychological Society, Bristol, UK, 2000.

[26] V. G. Haase, A. Júlio-Costa, P. Pinheiro-Chagas, L. F. S. Oliveira, L. Rettore-Micheli, and G. Wood, "Math self-assessment, but not negative feelings, predicts mathematics performance of elementary school children," *Child Development Research*, vol. 2012, Article ID 982672, 10 pages, 2012.

[27] R. J. Mokken, *A Theory and Procedure of Scale Analysis*, De Gruyter, Berlin, Germany, 1971.

[28] R. J. Mokken and C. Lewis, "A nonparametric approach to the analysis of dichotomous item responses," *Applied Psychological Measurement*, vol. 6, no. 4, pp. 417–430, 1982.

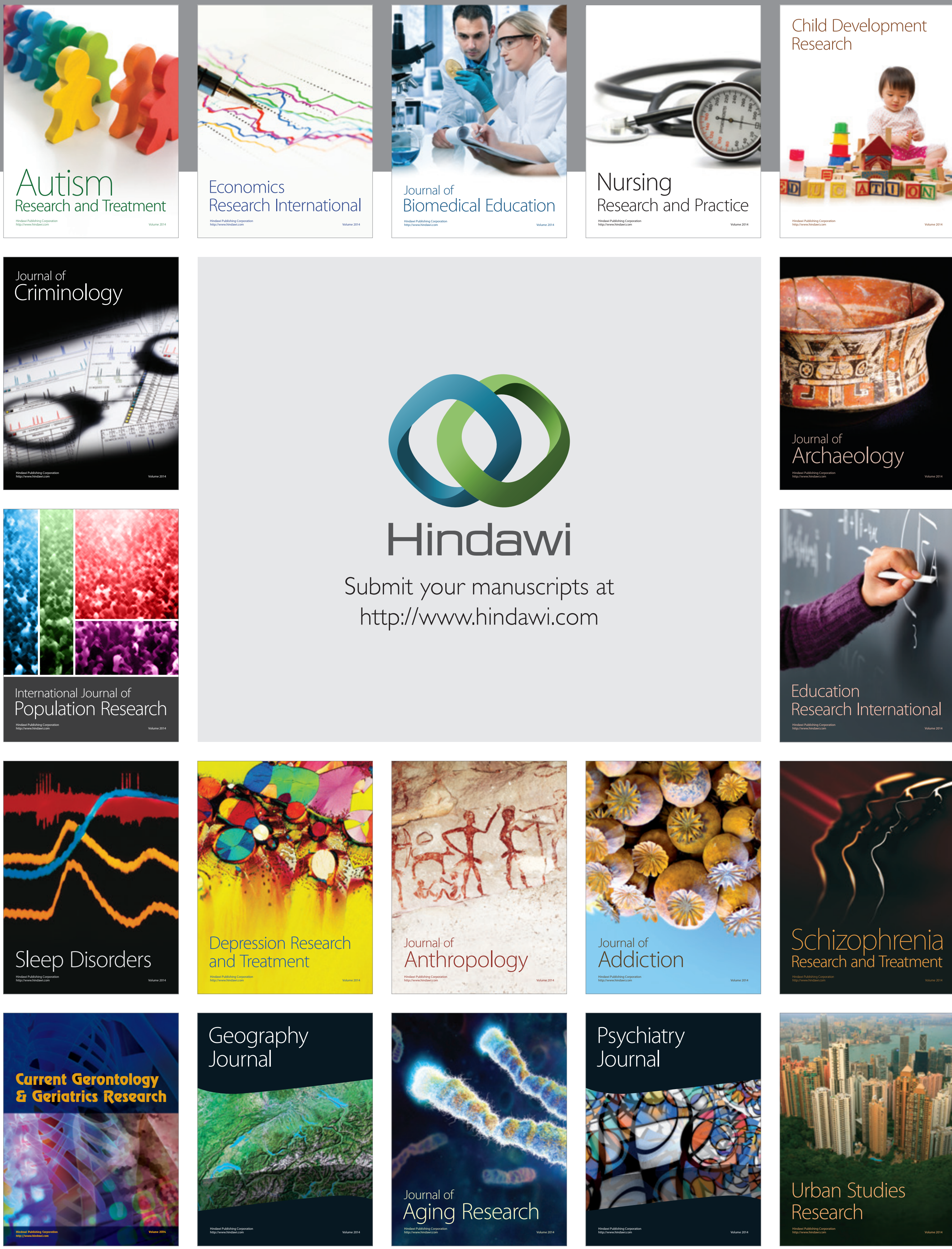
[29] K. Sijtsma and I. W. Molenaar, *Introduction to Nonparametric Item Response Theory*, Sage, Thousand Oaks, Calif, USA, 2002.

[30] K. Willmes, "An approach to analyzing a single subject's scores obtained in a standardized test with application to the Aachen Aphasia Test (AAT)," *Journal of Clinical and Experimental Neuropsychology*, vol. 7, no. 4, pp. 331–352, 1985.

[31] S. Chinn, "Mathematics anxiety in secondary students in England," *Dyslexia*, vol. 15, no. 1, pp. 61–68, 2009.

[32] F. de O. Ferreira, G. Wood, P. Pinheiro-Chagas et al., "Explaining school mathematics performance from symbolic and non-symbolic magnitude processing: similarities and differences between typical and low-achieving children," *Psychology & Neuroscience*, vol. 51, pp. 37–46, 2012.

[33] B. Pletzer, G. Wood, K. Moeller, H. C. Nuerk, and H. H. Kerschbaum, "Predictors of performance in a real-life statistics examination depend on the individual cortisol profile," *Biological Psychology*, vol. 85, no. 3, pp. 410–416, 2010.


Autism
Research and Treatment
Economics
Research International
Journal of
Biomedical Education
Nursing
Research and Practice
Child Development
Research
Journal of
Criminology
Hindawi
Submit your manuscripts at
http://www.hindawi.com
Journal of
Archaeology
International Journal of
Population Research
Education
Research International
Sleep Disorders
Depression Research
and Treatment
Journal of
Anthropology
Journal of
Addiction
Schizophrenia
Research and Treatment
Current Gerontology
& Geriatrics Research
Geography
Journal
Journal of
Aging Research
Psychiatry
Journal
Urban Studies
Research