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ANOTHER PSYCHOMETRIC PROOF OF THE ABBREVIATED MATH ANXIETY SCALE USEFULNESS: IRT ANALYSIS[2]

The aim of this research is the psychometric evaluation of the Abbreviation Math Anxiety Scale (AMAS) on a sample of high school students. AMAS operationalizes math anxiety as a two-dimensional construct, basing its main components on the context model: math learning anxiety (MAL) and math evaluation anxiety (MAE). MAL represents the tendency of manifesting mathematical anxiety during the process of learning mathematics, while MAE represents math anxiety present in all situations that imply formal evaluation of math knowledge. The sample consisted of 514 high school students (45.3% male), aged 15 to 19. Confirmatory factor analysis pointed that AMAS is a one–dimensional scale with two facets, with the bifactorial solution showing the best fit parameters. Psychometric attributes of AMAS were tested by using Item Response Theory. Items and the questionnaire showed appropriate psychometric properties. The AMAS scale has expected patterns of relatedness with mathematical achievement, motivation for learning math, age and gender.

Key words: AMAS, high school, Item Response Theory, math anxiety

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[2] The data collected on the same sample were used in following research:

- Milovanović, I. (2016). Implicitne teorije inteligencije i motivacija za učenje matematike kod učenika srednjih škola [Implicit theories of intelligence and motivation for learning mathematics in high school students]. *Nastava i vaspitanje*. *65(*3), 509–524.
- Milovanović, I., & Kodžopeljić, J. (2018). Faktorska struktura i konvergentna validnost upitnika matematičke anksioznosti za učenike srednjih škola [Factor structure and convergent validity of Math Anxiety Questionnaire for high school students]. *Nastava i vaspitanje, 67*(1), 113-128.

Introduction

Mathematical anxiety (MA) represents negative emotional and behavioral reactions in the situations which include numbers, mathematics and the use of math operations, in contexts of education, employment, as well as in the everyday life (Ashcraft & Moore, 2009; Ma & Xu, 2004; Ramirez, Gunderson, Levine, & Beilock, 2013). Nearly 6-20% of people suffer from a number of psychological symptoms caused by anxiety present in the situations where it is necessary to manipulate with some numerical information (Eden, Heine, & Jacobs, 2013; Glaister, 2007). Math anxiety is a global and international phenomenon (Foley et al., 2017; OECD, 2013), and the results of PISA testing suggest that about 60% of high school students from various countries (e.g., Greece, Serbia, United Arab Emirates) encounter the problem of math anxiety, which is significantly higher compared to the OECD average (Baucal & Pavlović–Babić, 2010; Foley et al., 2017). Additionally, results of some meta–analysis (Hembree, 1990; Ma, 1999) suggest that math anxiety in high school students correlates with most of other anxiety measures, and that it is not a consequence of lower intelligence (Prevatt, Welles, Li, & Proctor, 2010; Wu, Barth, Amin, Malcarne, & Menon, 2012).

In regards to gender differences, most recent results showed a higher prevalence of math anxiety during a high school education in girls (Else–Quest, Hyde, & Linn, 2010; Hunt, Clark–Carter, & Sheffield, 2011; Maloney, Waechter, Risko, & Fugelsang, 2012; Primi, Busdraghi, Tomasetto, Morsanyi, & Chiesi, 2014). On the other hand, Ma (1999) showed that there was no gender difference in the correlation between math anxiety and math achievement. Math anxiety was also shown to be more stable over time in female compared to male individuals. It was important to note that there were also studies reporting no gender differences, or even higher math anxiety in male participants (for a short review see Devine, Fawcett, Szucs, & Dowker, 2012). Results of PISA 2012 study (OECD, 2013) showed that in vast majority of OECD countries, average effect size of gender difference was small, but meaningful (d = .30).

Math anxiety has numerous consequences on educational outcomes since elementary school (e.g., Milovanović, 2018; Ramirez et al., 2013), with the highest negative impact in secondary school (Hembree, 1990; Ma, 1999). Most of researches suggest a negative correlation between math anxiety and achievement on final math tests in a sample of high school students (e.g., Aschcraft & Kirk, 2001; Ashcraft & Moore, 2009). Math anxiety represents a risk factor for lower mathematical achievement (Arambašić, Vlahović–Štetić, & Severinac, 2005; Ashcraft, 2002; Ma & Xu, 2004; Ramirez et al., 2013), and its negative influence on mathematical achievement peaks at the very beginning of the high school (Hembree, 1990). However, there is no consensus on whether senior or junior students have more pronounced mathematical anxiety. Although a large number of studies indicate more pronounced mathematical anxiety among senior secondary school students, there is also a number of studies which results represent the indications of non–existent age differences (for a short review see Dowker, Sarkar, & Looi, 2016).

The high math anxiety also makes negative correlations with motivation to study math (Maloney et al., 2012), the feeling of usefulness of math, satisfaction while applying math, and positive correlations with a lack of interest in math in high school (Milovanović & Kodžopeljić, 2018; Vahedi & Farrokhi, 2011). It is clear that math anxiety has some specific types of patterns with other psychological and educational measurements, which help teachers, parents and counselors in order to help students to overcome its negative consequences. In light of these findings, there is an urgent need to improve the existing tools that assess MA, and deepen our understanding of the relationship between MA and math performance.

Models and Structure of Math Anxiety: Aspect of Context

Besides operationalization of math anxiety through affective and cognitive components (Wigfield & Mecce, 1988), recent researches emphasize the importance of the context which reflect, its negative influence on educational outcomes. The aspect of the context implies two contexts in differentiating MA: MA during learning math and MA during the evaluation of mathematical knowledge (Hopko, Mahadevan, Bare, & Hunt, 2003). Math anxiety is operationalized in the literature via several instruments, most commonly via general measure of MA (Aschcraft & Kirk, 2001; Krinzinger, Kaufmann, & Willmes, 2009; Núñez–Peña, Guilera, & Suárez–Pellicioni, 2013; Richardson & Suinn, 1972). An extensive overview of the literature shows the Abbreviated Math Anxiety Scale (AMAS), as the most commonly used in the research of this construct, which was found to have strong test–retest reliability, and good internal consistency and validity (e.g., Hopko, 2003; Hopko et al., 2003). Hopko et al. (2003) have extracted two factors – mathematical anxiety during the process of learning math, and mathematical anxiety during the evaluation of mathematical knowledge. The two–factor structure has been replicated in the research in German (Schillinger, Vogel, Diedrich, & Grabner, 2018), Spanish (Núñez–Peña, Suárez–Pellicioni, Guilera, & Mercadé–Carranza, 2013), Iranian (Vahedi & Farrokhi, 2011), Polish (Cipora, Szczygiel, Willmes, & Nuerk, 2015) and Italian (Primi et al., 2014) sample, and it shows appropriate psychometric characteristics, although there is no a clear evidence about differential functioning of the AMAS items.

The development of contextual measures of MA and their incorporation into the research designs enable a deeper understanding of the correlation among the conceptual measures, such as the cognitive and affective component of MA, and different situational variables. Previous research has shown that the environment, in which learning or evaluation takes place, can play a key role in developing a fear of math (e.g., Dogan, 2008). Therefore, this research contributes to understanding of different potential effects of MA on the educational and motivational outcomes, as well as the possibility of its regulation in the contexts of learning, achievement and evaluation.

The Present Study

The importance of math anxiety beyond the high school sample has been shown in a number of foreign (e.g., Arambašić et al., 2006; Cipora et al., 2015; Hopko et al., 2003; Schillinger et al., 2018), and national (e.g., Milovanović & Kodžopeljić, 2018; Radišić, Videnović, & Baucal, 2018) researches. Most previous MA questionnaires have been tested only for English–speaking students, but the AMAS has been evaluated in other different languages as well. Given the high prevalence rate of MA among these groups of students in Serbia (Baucal & Pavlović–Babić, 2010; OECD, 2013) and the potentially detrimental consequences of MA for their performance in mathematics (Ashcraft & Moore, 2009), it seems important to adapt a questionnaire which will enable easier detection and potential prevention of mathematical anxiety in Serbia, as a part of the international rationale. In comparison to instruments of psychological assessment of anxiety, few research has focused on examining the psychometric properties of math anxiety measures. Given the good psychometric properties of the AMAS (Hopko et al., 2003), and its development towards becoming an international standard for assessing MA (Campbell, 2004), adapting the AMAS into Serbian appeared to be a good choice in order to fill this gap. The test adaptation for local samples is a strategy that may reduce bias and minimize impact on the cross–cultural equivalence of the test scores (van de Vijver & Tanzer, 2004). Based on some previous research, it can be observed that the factorial structure of the questionnaire is stable, but that some researches use AMAS as a one–dimensional scale (e.g., Devine et al., 2012), contrary to versions which separate MA during learning math, and during evaluation of mathematical knowledge. Also, there is no evidence about differential functioning of the AMAS items. This is a very important question, since some of the items saturate both factors of AMAS (Schillinger et al., 2018).

The first goal of this research is the verification of the factor structure of the AMAS scale. The second goal of the research is the psychometric evaluation of the AMAS scale based on the Item Response Theory – IRT. IRT combines confirmatory factor analysis, invariety of item comparison, as well as item precision which allows it to differentiate among the subjects with different levels of the measured trait in different parts of the continuum of the latent trait. Some additional goals of the research are verifying convergent validity of the AMAS scale via correlations with the Math Anxiety Questionnaire (MAQ), mathematical achievement, motivation for learning math, and examination of gender differences. A negative correlation of the dimensions of the AMAS and mathematical achievement (e.g., Ashcraft, 2002; Ma & Hu, 2004), usefulness of math, interest in math, and satisfaction with math, is expected, as well as a positive correlation with the lack of motivation (Milovanović & Kodžopeljić, 2018; Vahedi & Farrokhi, 2011). Moderate positive correlations are expected between dimensions of the two scales of mathematical anxiety (AMAS and MAQ), based on their conceptual similarities. Although this is a pioneering study of the AMAS items differential functioning, we can assume that other psychometrics characteristics would be similar to those obtained in the samples from other linguistic and cultural backgrounds. This includes similarities in psychometric properties, as well as the average scores, and gender/age differences in which female and the first-year students should exhibit higher math anxiety.

Method

The Sample and Procedure

A total number of 514 high school students (45.3% male) from Serbia participated in the research. Participants were aged 15 to 19 (the average age was 16.7); 33.2% of participants attended the first grade, 21.7% of participant attended the second grade, 23% of participants attended the third grade, and 22.1% of participants attended the fourth grade of grammar (45.7%) or vocational (54.3%) high school. The minimum sample size required to identify medium–sized effects in SEM studies was calculated in accordance with the recommendations (Westland, 2010). The estimated minimum sample size, corrected for Likert type response items, was 400, indicating that the size of the sample in this study was appropriate. The research was conducted by using a pen–and–paper method. Before administering questionnaires, the purpose of the research was explained to the students, as well as the procedure of data protection and the anonymity of their responses. The authors of the research presented the problem of mathematical anxiety to the students, and explained that the aim of the research was to adapt the questionnaire for use in Serbian population of students in order to detect and overcome the problem of math anxiety in the future. The parents of the students and the principals of all schools gave their consent for conducting the research prior to the start of the research itself.

Instruments and Measures

Abbreviated Math Anxiety Scale (AMAS*:* Hopko et al., 2003, items presented in Table 3, Serbian version presented in Table A in Appendix). This scale consists of 9 items with a five–point Likert scale (ranging from 1 – *not nervous at all* to 5 – *very nervous*). The authors of the scale suggest two dimensions of the AMAS questionnaire: math anxiety during learning math (MAL), and math anxiety during the evaluation of math knowledge (MAE). The questionnaire was translated from English to Serbian using a forward–translation method. Two professional bilingual translators, with knowledge of education and psychology, worked independently, and then they compared their translations to identify any variance in translation, in order to assess equivalence. Translators have been employed as assistant professors/lectures at University of Novi Sad. Minor differences in back–translation of AMAS have been solved by consensus between translators.

Mathematical Anxiety Questionnaire (MAQ: Wigfield & Meece, 1988, Serbian version: Milovanović & Kodžopeljić, 2018). Serbian version of the scale contains 11 items, with a seven–point Likert scale (ranging from 1 – *I completely disagree* to 7 – *I completely agree*). The previous research on Serbian samples shows a two–factorial structure of MAQ: Worry (α = .86) which measures the level of the student's concern in regards to math achievement, and Negative Affective Reaction (α = .85), which measures negative emotional states during math activity at school (Milovanović & Kodžopeljić, 2018).

Student Motivation to Learn Mathematics Scale (SMOT; Githua & Mwangi, 2003, Serbian version: Milovanović, 2016). This scale contains 28 items, with a five–point Likert scale (ranging from 1 – *I completely disagree* to 5 – *I completely agree*). A factor analysis in the previous research has shown that SMOT contains 4 subscales (Milovanović, 2016). Usefulness (α = .85) implies the relevance of math in the everyday life; Satisfaction (α = .83) implies satisfaction during learning math; Lack of Motivation (α = .79) implies unconcern about math achievement, and Interest (α = .83) implies the interest in pursuing math. We used SMOT and MAQ to provide estimates of convergent validity for the AMAS scores.

Mathematical achievement. This measure was calculated for every student by applying the average of math grades at half–term and the end of the school year.

Data Analysis

Statistical and psychometric data analysis was conducted in R environment, version 3.3.0 (R CoreTeam, 2016). Descriptive parameters, correlation coefficients and confirmatory factor analysis were calculated in *psych* package, version 1.5.8 (Revelle, 2015). The calculation of the omega function and reliability coefficients (ω) was conducted by using the *Omega* program (Watkins, 2013). The omega coefficient should be higher than .75, and minimally higher than .50 (.41 –.60 is satisfactory, .61. – .80 is moderately high, and .81 – 1.0 extremely high) (Zinbarg, Revelle, Yovel, & Li, 2005). Internal validity of the AMAS questionnaire was verified by using a confirmatory factor analysis in the statistical package *lavaan* (Rosseel, 2012). Analysis parameters were calculated by using the method of maximum likelihood (ML). Model evaluation was conducted based on the comparative fit index and the Tucker–Lewis index (CFI and TLI – optimal values higher than .95, acceptable higher than .90), the root mean square error of approximation (RMSEA), and the standardized root mean square residual (SRMR) (RMSEA and SRMR – optimal values lower than .05, acceptable lower than .08) and the quotient $\chi 2/df$ (recommended < 2) (Ching–Yun, 2002; Kline, 2010). Psychometric characteristics of the items and the AMAS scale were analyzed by using Item Response Theory (IRT). A two–parameter model (2PL) was used for items with gradated response (GRM; Samejima, 1969). Item discrimination (α – slope parameter), represents the ability of an item to differentiate persons with different levels of a latent trait, and the weight parameter (β – the value of the latent trait of the participant on which the participant with a certain level of the trait has a 50% chance to select a lower or higher category of response) represent basic 2PL parameters of GRM model (DeMars, 2010; Morizot, Ainsworth, & Reise, 2007). The analysis was conducted in the *Itm* package (Rizopoulos, 2006).

Results

Descriptive Parameters of the AMAS Scale

Based on the skewness and kurtosis parameters (Table 1), it could be concluded that the distribution of scores followed the assumptions of a normal distribution (Tabachnick & Fidell, 2013). Comparing theoretical and empirical arithmetical means, it could be established that the participants more tended to disagree with the items. The same results could be seen for individual dimensions of the AMAS scale.

Table 1
Descriptive parameters for sub–dimensions and the overall score of the AMAS scale

	Item number	*Min*	*Max*	*M*	Theoretical *M*	*SD*	*Sk*	*Ku*
MAL	5	5	25	10.44	15	4.81	0.78	-0.01
MAE	4	4	20	10.92	12	4.28	0.11	-0.80
MA	9	9	45	21.36	27	8.12	0.48	-0.17

Notes.: *Min* – minimum, *Max* – maximum, *M* – arithmetical mean, *SD* – standard deviation, *Sk* – skewnees, *Ku* – kurtosis.

Dimensionality and Model Construct Validity Verification

Five models were evaluated to test the concordance of the structural model with the empirical data: a one–factor model (1); a two–factor model with correlated dimensions (2), a two–factor model with orthogonal dimensions (3); a hierarchical model with two lower–level factors (4) and a bifactorial model with one general factor and two specific factors (5). Results of Confirmatory Factor Analysis (Table 2) point to the conclusion that models 2, 4 and 5 could describe the structure of empirical data more adequately in comparison to models 1 and 3. The comparison of AIC and BIC coefficients, and the values of CFI and RMSEA fit index differences for models 2, 4 and 5 leads to the conclusion that the model 5 most adequately describes empirical data (Hirschfeld & von Brachel, 2014).

Table 2
Confirmatory models fit indexes

	CFI	TLI	RMSEA (95 CI)	SRMR	χ2	*df*	χ2/*df*	AICc	BIC
M1	0.81	0.75	0.15 (.14 – .17)	0.08	346.6	27	12.84	14473	14548
M2	0.88	0.84	0.09 (.07 – .10)	0.06	225	26	8.7	14353	14432
M3	0.79	0.72	0.12 (.11 – .14)	0.08	385.5	27	14.3	14511	14586
M4	0.88	0.83	0.12 (.11 – .14)	0.08	225	25	9.0	14355	14438
M5	0.97	0.94	0.07 (.05 – .09)	0.03	65.6	18	3.6	14213	14322

Notes. M1 – a one–factor model, M2 – a two–factor model with correlated factors, M3 – a two–factor model with orthogonal factors, M4 – a hierarchical model with two lower–level factors, M5 – a bifactorial model.

The bifactorial model, with one main and two specific factors for the AMAS scale, has satisfactory indices of fit. The RMSEA coefficient is borderline, while SRMS, TLI and CFI coefficients have satisfactory values. The quotient of χ^2/df is higher than 2 and not satisfactory, but overall, this model shows best indicators of fit. The value of the omega reliability coefficient for specific factors (MAL_s = .62, MAE_s = .60) is satisfactory, and extremely high for the general factor (MA_g = .84), i.e. the general factor contrives a high percentage of total explained variance of the construct. Cronbach's α reliability coefficients of MA factors are on a satisfactory level (MAL_s = .80, MAE_s = .76; MA_g = .85).

Table 3
Loadings of individual items on the AMAS scale factors

No	Item content	MA_g	MAL_s	MAE_s
1	Having to use the tables in the back of a math book.	.42	**.09**	
3	Watching a teacher work an algebraic equation on the blackboard.	.65	.34	
6	Listening to the lecture in math class.	.61	.59	
7	Listening to another student explaining a math formula.	.50	.43	
9	Starting a new chapter in a math book.	.58	.44	
2	Thinking about an upcoming math test 1 day before.	.61		.84
4	Taking an examination in a math course.	.56		.41
5	Being given a homework assignment of many difficult problems that is due the next class meeting.	.79		**-.15**
8	Being given a “pop” quiz in math class.	.53		.13

The loadings of the AMAS scale items on the general factor (Table 3) are moderate and satisfactory, while certain items have higher loadings on the respective specific factors MAL and MAE. Most items have highest loadings on the general factor of mathematical anxiety.

Item Response Theory (IRT) Models Implemented on the AMAS

Correlations between items' residuals after calculating the bifactorial model are shown in Table B in Appendix. No correlations surpassing the critical value of .20 were observed (Morizot et al., 2007). Accordingly, it could be assumed that the condition of local independence has been fulfilled. Both conditions (one–dimensionality and local independence) for the implementation of Item Response Theory models have been fulfilled.

Based on the aforementioned, IRT analysis was conducted on all items of the AMAS scale, with a single overall measure of MA. A 2PL model was used for the analysis of items with defined categories. A free discrimination parameter model was used (Table C in Appendix). LRT (Likelihood Ratio Test) showed a significant difference among the models of limited and free discrimination parameter. The free discrimination parameter model showed the lower AIC and BIC coefficient values, thus showed to be a model with better indicators of fit.

Table 4 shows 2PL model parameters for items with defined response categories for the AMAS scale overall.

Table 4
Response threshold difficulty (β), discrimination/slope (a) and informativeness (I) of the AMAS scale

		Threshold difficulty				Informativeness (logit range)					
Item	*a*	β1	β2	β3	β4	-3/-1	-1/1	1/3	*I(o)*	(-3/3)	% *I(o)*
amas1	1.02	0.03	0.63	2.75	3.38	0.22	0.55	0.61	1.38		66.87
amas2	1.54	-1.28	-0.31	0.35	1.18	0.89	1.48	0.83	3.20		94.42
amas3	2.05	-0.14	0.44	1.07	1.62	0.27	3.08	2.30	5.65		98.55
amas4	1.40	-1.45	-0.54	0.22	1.17	0.84	1.21	0.72	2.77		91.87
amas5	1.99	-0.11	0.51	1.11	1.77	0.28	2.10	1.80	4.19	35.28	96.21
amas6	2.05	-0.05	0.49	1.06	1.44	0.18	3.87	2.52	6.58		99.49
amas7	1.85	-0.02	0.60	1.31	1.92	0.25	1.78	1.71	3.74		94.26
amas8	1.25	-0.74	0.03	0.92	1.61	0.47	0.96	0.75	2.18		89.44
amas9	2.04	-0.07	0.55	1.16	1.61	0.16	2.99	2.44	5.59		98.69

Note. I(o) – overall informativeness in logits, %*I(o)* – overall informativeness in percentages, amas1…9 – items as numerated in AMAS.

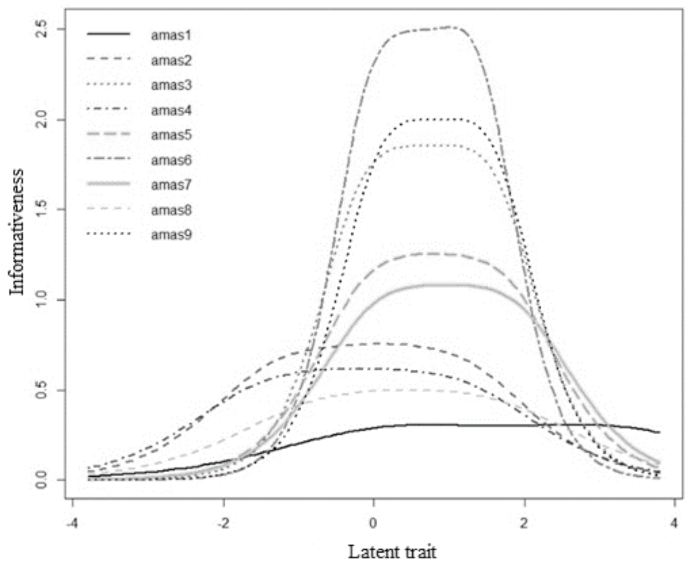
Discrimination of all items is either high (amas8 – 1.25) or very high (amas3, amas6 – 2.05). Therefore, all items discriminate participants with low or high levels of mathematical anxiety. Threshold difficulty of all items rises between higher item categories, i.e. it takes a higher level of trait for the participant to agree with the statement. For lower levels of MA trait, thresholds are of a lower difficulty, while highest thresholds can be observed moving from the fourth to the fifth category of response (threshold β4 – "*I'm usually nervous*" to "*I'm very nervous*"). It can be concluded that thresholds for lower categories are generally lower, and higher for higher thresholds, which is expected considering that the test is generally more suited for participants with a higher trait level.

Almost all the items relating to mathematical anxiety are most informative in the moderate to high levels of the MA trait (from –0.05 to 2 logits), except the item "Having to use the tables in the back of a math book", which also has the lowest loadings on the main factor. This item is most informative in the highest logit range (from 1 to 3), and it generally shows the lowest discrimination, as well as the overall informativeness (1.38), even though both its parameters are satisfactory. However, the model of AMAS with 8 items did not appear significantly better (Table 5).

Table 5
Indexes of fit of the tested models with the empirical data

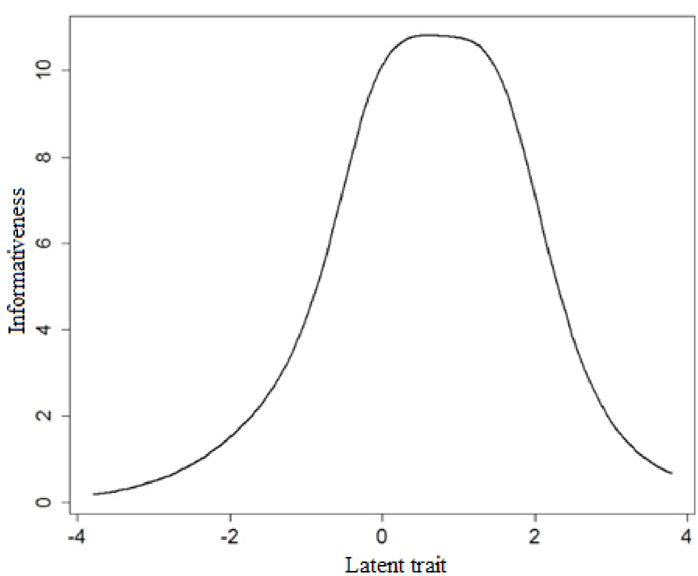
	CFI	TLI	RMSEA	SRMR	AICc	BIC
Bifactorial model	.97	.96	.07 (.05 – .08)	.03	14213	14322
Bifactorial model AMAS8	.98	.95	.07 (.05 – .10)	.03	12683	12780

The informativeness function of individual items of the AMAS scale is represented on Graph 1. It is observable that items are generally most informative in the moderate to high range (–0.5 – 2 logits). The functions are mildly skewed to the right, i.e. towards higher levels of the latent trait, which is in accordance with the conclusion that the scale is generally more suited for participants with a higher trait level.



Graph 1. Function of informativeness of the AMAS scale items.

Graph 2 shows the function of informativeness of the complete AMAS scale. This function also shows that the informativeness of the scale overall is highest in the range of moderate to high trait scores, mildly skewed to the right (-2 – 2 logits).



Graph 2. Function of informativeness of the entire AMAS scale

In regards to comparing items fits, the results by item pairs are given in Table D in Appendix. The results show that items overall show good fit, and that misfit is present only in one pair of items: “amas2” and “amas4”.

Convergent Validity of the AMAS Scale

The factors of the AMAS scale have significant correlations with all used measures (Table 6). Correlations with mathematical achievement are weak and negative, and correlations with the dimensions of the MAQ scale are positive and moderate, while correlations with motivation measures and the AMAS scale are weak to moderate (Evans, 1996). All correlations of the AMAS scale with the dimensions of motivations are negative, except those with the Lack of Motivation.

Table 6
Correlations of the AMAS scale with math achievement, dimensions of MAQ and SMOT

	MA_g	MAL_s	MAE_s
Mathematical Achievement	-.22**	-.21**	-.16**
Worry (MAQ)	.45**	.44**	.55**
Negative Affective Reaction (MAQ)	.35**	.35**	.50**
Relevance (SMOT)	-.17**	-.17**	-.11*
Satisfaction (SMOT)	-.26**	-.26**	-.24**
Lack of Motivation (SMOT)	.40**	.38**	.38**
Interest (SMOT)	-.18**	-.18**	-.20**

Note. * $p < .05$. ** $p < .01$.

Relations of the AMAS Scale with Demographical Characteristics

The observation of data in Table 7 leads to the conclusion that girls achieve significantly higher scores on MAE than boys, also achieving higher math grades than boys, $t = -3.37$; $df = 512$; $p < .001$. Results also point to significantly higher scores on the general measure of mathematical anxiety in first–graders in comparison to fourth–graders.

Table 7
Relations of AMAS scale dimensions with age and gender

	Gender differences				Age differences				
	Gender	*M*	*SD*	*t*	Grade	*M*	*SD*	*F*	G–G
Math Learning Anxiety				1.26				3.07**	1–2
	Male	10.73	4.89		1	10.83	5.21		1–3
					2	10.57	4.63		1–4*
					3	10.90	4.64		2–3
	Female	10.20	4.73		4	9.26	4.37		2–4
									3–4
Math Evaluation Anxiety				-2.28*				1.80	1–2
	Male	10.45	4.20		1	11.23	4.46		1–3
					2	10.94	4.33		1–4
					3	11.21	4.26		2–3
	Female	11.31	4.31		4	10.12	3.91		2–4
									3–4
Math anxiety (general)				-0.45				3.05**	1–2
	Male	21.18	8.16		1	22.05	8.95		1–3
					2	21.51	7.79		1–4*
					3	22.11	7.90		2–3
	Female	21.51	8.10		4	19.39	7.06		2–4
									3–4

Notes. t – *t* test, *F* – *F* test, G–G – comparison of students by grade.
* $p < .05$. ** $p < .01$.

Given gender differences in performance were further examined within a framework of a multigroup CFA to test for configured measurement invariance between the genders. The fit of the multi–group model was acceptable, CFI = 0.981, TLI = 0.955, RMSEA = 0.064, CI = [0.040, 0.086], SRMR = 0.028, suggesting that the factor structure and the loading pattern were similar across both genders. Testing for weak measurement invariance (i.e. constraining the loadings) slightly improved the model fit, CFI = 0.983, TLI = 0.973, RMSEA = 0.049, CI = [0.027, 0.040], SRMR = 0.040, compared to the multi–group model. Testing for strong measurement invariance (i.e. constraining the loadings and thresholds) reduced the model fit CFI = 0.973, TLI = 0.962, RMSEA = 0.059, CI = [0.040, 0.077], SRMR = 0.039, compared to the weak measurement invariance model. The reduction in CFI between this model and the weak measurement invariance model (ΔCFI = 0.010) reached the cut–off of 0.010 (Hirschfeld & von Brachel, 2014), suggesting that the model was non–invariant. Items 2 and 4 have large modification items for loading and threshold.

Discussion

The verification of the AMAS based on confirmatory models suggests that it is a one–dimensional construct, while the bifactorial model shows the best parameters of fit. The questionnaire generally shows good metric characteristics and solves the dilemma of whether the AMAS scale has a one–dimensional or a two–dimensional structure to a certain degree (Ashcraft & Kirk, 2001; Hopko et al., 2003). In this research it has been shown that the AMAS scale is one–dimensional with one general and two specific factors, as well as that math learning anxiety and math evaluation anxiety are facets of the dimension of mathematical anxiety.

In concordance with the theory of the math anxiety concept, participants showed a slightly lower level of agreement with statements of the AMAS scale. Accordingly, the facets of math learning anxiety and math evaluation anxiety as well as the general factor of math anxiety, appeared to be somewhat more suited for participants with a higher trait level. The authors stated that increased MA was a widespread problem, especially in the context of educational outcomes, equally observed abroad (e.g., Chinn, 2009), as well as in Serbian sample (Baucal & Pavlović–Babić, 2010). Gender differences were observed only on the dimension of math evaluation anxiety. High school girls achieved higher grades in math, and experienced a higher level of mathematical anxiety in situations of evaluation. It is possible that they were more achievement-oriented, striving for good results, hence anticipation of failure in achieving these goals led to more concern, which was partly in accordance with the assumptions of some researchers (Else–Quest et al., 2010, Maloney et al., 2012; Primi et al., 2014). Observed age differences between the first and the fourth year of high school are in accordance with some research of mathematical anxiety in high school students (e.g., Hembree, 1990). It appears that students of the first year are generally more concerned about their achievement in comparison to the fourth–graders; the first grade is also the grade of adaptation to the new conditions of education. Besides adaptation to the new conditions, it is possible that the first–graders do not have fully formed expectations about their math achievement and competencies in general: the first–graders potentially observe the levels of their knowledge most unsteadily, which is in accordance with the transitional period they are going through on their transgression between elementary and high school education.

AMAS scale best discriminates participants with moderate to mildly increased levels of trait, i.e. it is most informative in the mildly above–average range of trait. The distribution of informativeness is skewed mildly to the right, towards somewhat higher levels of trait. Considering that mathematical anxiety is generally enhanced in the population (Ashcraft & Moore, 2009), it is necessary to devise a test which will be most informative precisely in the range of average to mildly increased levels of the MA trait. It is observed that the most informative trait is "Listening to the lecture in math class", followed by "Watching a teacher work an algebraic equation on the blackboard". Content analysis of items shows that those traits represent MA in connection with misunderstanding or partially understanding math content. It is possible that this mathematical anxiety refers to a state, or feelings and cognition during math lessons. These items best differentiate participants with lower and higher levels of the MA trait, i.e. they have the highest discrimination. This information potentially points to MA, not depending mostly on the test situation, or the process of learning math, but the perception of students that they cannot understand the material they are listening to, or their belief that they will not be able to learn and reproduce it later. These cognitions have their emotional consequences, such as feelings of helplessness and passive (lack of) participation in math class, which has been confirmed by the previous research (Prevatt et al., 2010). Observing the levels of informativeness of individual items, it can be concluded that the item "Having to use the tables in the back of a math book" deviates from other items in such a way that it is the most informative in the above–average levels of the MA trait: the content of this item provokes MA, especially in those participants who already have the above–average levels of MA. It can be assumed that the content of this item partially is not suitable for the measuring math anxiety in students, which is also shown on other local samples (Caviola, Primi, Chiesi, & Mammarella, 2017). Additionally, it remains unclear whether this item references anxiety due to the (in)ability to understand the table or the fact that the student requires an additional information from the back of the book to solve a mathematical problem independently. Considering the satisfactory fit parameters for this item, and the fact that the shortened model has not been observed as better, the decision is made to keep the item as a part of the test. Another reason for keeping the item would be the possibility of comparing results obtained on the Serbian sample with those obtained in other countries. Item fit verification suggests that somewhat more problematic turns out to be the item pair "Thinking about an upcoming math test 1 day before" and "Taking an examination in a math course". The content of these items shows that these items refer to the formal evaluation of knowledge.

The results of convergent validity verification of the MA construct show that the patterns of correlation of general factor of math anxiety, math learning anxiety and math evaluation anxiety with: worry, negative affective reaction, mathematical achievement, and motivation for learning math are in concordance with previous research and theoretical concepts (Ashcraft, 2002; Ashcraft & Kirk, 2001; Ma & Hu, 2004; Vahedi & Farrokhi, 2011). Namely, high mathematical anxiety is negatively correlated with mathematical achievement in high–school students. It is possible that in contact with mathematical material, with the increase of MA, a hyper tenacity of attention is activated, operational memory becomes overburdened, leaving little free space for the execution of the mathematical problem itself. Consequently, this leads to a decrease in achievement. It is also possible that high–school students with generally lower math achievement are also more anxious in regards to math studying and achievement. Consequences to the motivation for learning math are also a serious problem which can indirectly lead to a decrease in achievement. The result about the relation of the two MA scales is also interesting: the results show their moderate positive correlation, which speaks to the fact about some similarities of their core content. At the same time, moderate correlations between AMAS and MAQ also indicate that these two questionnaires do not measure the identical latent space of mathematical anxiety. Both questionnaires measure anxiety in mathematics learning, but in a different context: generally (AMAS) or during school–based learning (MAQ). The less subtle difference between these questionnaires is reflected in the measurement subject of the second dimension of each questionnaire: anxiety during the evaluation of knowledge (AMAS), and worry in relation to the achievement in mathematics (MAQ). Finally, the base of moderate and positive correlation between the dimensions of these two questionnaires is the general common subject of measurement, mathematical anxiety, while a different contextualization of mathematical anxiety influences that these two questionnaires, as well as their dimensions, cannot be reduced to one another.

The AMAS scale has satisfactory metrical characteristics and shows satisfactory reliability, internal, construct and convergent validity, as well as informativeness. These findings may be important for future cross–cultural researches of the AMAS scale, if researchers from other cultures apply appropriate results on local samples. Future research should include indicators of divergent validity, such as anxiety measures, test anxiety and numerical intelligence factors, used in some research, as well as make the variable of mathematical achievement a more objective measure by using standardized knowledge tests of different mathematical domains in high–school students.

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Appendix

Table A
Serbian version of AMAS

Koliko si uznemiren kada:					
1. … slušaš kako drugi učenik objašnjava neku matematičku formulu?	1	2	3	4	5
2. … posmatraš kako nastavnik rešava zadatke iz matematike na tabli?	1	2	3	4	5
3. … slusaš nastavnika kako objašnjava matematiku na času?	1	2	3	4	5
4. … moraš da koristiš tablice sa kraja knjige iz matematike?	1	2	3	4	5
5. … slušaš novu lekciju na času matematike?	1	2	3	4	5
6. … radiš kontrolni iz matematike?	1	2	3	4	5
7. … razmišljaš o predstojećem kontrolnom zadatku iz matematike?	1	2	3	4	5
8. … nastavnik organizuje iznenadni „kviz“ na času matematike?	1	2	3	4	5
9. … radiš težak domaći zadatak iz matematike za sledeći čas?	1	2	3	4	5

Table B
Local independence – correlations of the AMAS questionnaire items residuals

	amas1	amas3	amas5	amas6	amas7	amas9	amas2	amas4	amas8
amas1	.00								
amas3	.02	.00							
amas5	.03	.01	.00						
amas6	.00	.00	–.00	.00					
amas7	–.03	.00	–.02	.00	.00				
amas9	.02	–.00	–.05	.00	.05	.00			
amas2	.02	.04	–.01	–.01	–.04	–.03	.00		
amas4	–.05	.01	.05	–.00	–.05	–.01	.00	.00	
amas8	–.09	–.07	.04	.01	.04	.06	.00	.00	.00

Table C
The comparison of models with limited and free discrimination parameter

	AIC	BIC	log.Lik	LRT	*df*	*p*
MOPD	11963.94	12120.91	–5944.97			
MSPD	11877.96	12068.86	–5893.98	101.98	8	<.001

Note. MOPD – limited discrimination parameter model, MSPD – free discrimination parameter model, LRT – Likelihood Ratio Test for model comparison.

Table D
Comparison of item fit – pairs

	amas1	amas2	amas3	amas4	amas5	amas6	amas7	amas8	amas9
amas1	–	28.12	34.51	24.01	31.47	32	30.31	22.03	31.61
amas2		–	38.28	156.84	23.99	51.89	46.47	47.38	26.7
amas3			–	38.57	28.26	39.61	37.62	32.97	52.39
amas4		***		–	28.77	55.39	49.42	52.39	51.79
amas5					–	31.94	40.08	22.01	46.84
amas6						–	64.15	41.41	48.03
amas7							–	20.91	62.59
amas8								–	25.92
amas9									–

Note. *** $p < .001$.

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JOŠ JEDAN PSIHOMETRIJSKI DOKAZ O KORISNOSTI SKRAĆENE SKALE MATEMATIČKE ANKSIOZNOSTI: IRT ANALIZA

Cilj ovog istraživanja usmeren je na ispitivanje psihometrijskih svojstava Skraćene skale matematičke anksioznosti (AMAS) kod učenika srednjih škola. AMAS operacionalizuje matematičku anksioznost, po modelu konteksta, kao dvodimenzionalni fenomen, koji se sastoji od anksioznosti tokom učenja (MAL) i anksioznosti tokom evaluacije znanja (MAE). MAL predstavlja tendenciju ispoljavanja matematičke anksioznosti prilikom učenja matematike, dok MAE predstavlja tendenciju njenog ispoljavanja u svim situacijama koje uključuju formalnu evaluaciju znanja iz matematike. Uzorak je činilo 514 učenika srednjih škola (45.3% mladića), uzrasta od 15 do 19 godina. Konfirmatorna faktorska analiza ukazuje na to da je AMAS jednodimenzionalna skala sa dve facete, kao i na to da bifaktorsko rešenje poseduje najbolje pokazatelje podesnosti modela. Psihometrijska svojstva AMAS skale ispitana su korišćenjem Teorije ajtemskog odgovora (Item Response Theory – IRT). IRT analiza ukazuje na adekvatne psihometrijske karakteristike ajtema i skale u celini. AMAS skala je takođe ostvarila očekivane relacije sa matematičkim postignućem, motivacijom za učenje matematike, uzrastom i polom ispitanika.

Ključne reči: AMAS, srednja škola, Teorija ajtemskog odgovora, matematička anksioznost