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The Psychometric Properties of the Polish-Language Version of the Mathematical Resilience Scale

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Supplementary Materials: Code, Data [see Index of Supplementary Materials]

Abstract

This study aims to present the psychometric properties of the Polish language version of the Mathematical Resilience Scale (MRS; Kooken et al., 2016), established in a sample of 443 adults. We confirmed the first-order three-factor structure (Value, Struggle, Growth) with the second-order factor (Total Mathematical Resilience) of the MRS and its measurement invariance across gender and field of study and profession. We also confirmed the validity of the scale: negative correlations were found between MRS scores and math anxiety, math avoidance, intellectual helplessness in mathematics; positive correlations were found between MRS scores, mathematical achievement, math learning motivation; no relationship or weak correlations were found between MRS scores, intellectual helplessness in Polish language, Polish language grades obtained in high school. Finally, we observed gender and study and profession differences in some of the MRS scores. However, further research is needed on the nature of mathematical resilience, especially to establish its relationship with general resilience.

Keywords

Mathematical Resilience Scale, math anxiety, math avoidance, math performance, math motivation, psychometric properties

Non-Technical Summary

Background

Mathematical resilience is believed to play a key role in overcoming obstacles in math learning.

Why was this study done?

Measuring mathematical resilience using valid and reliable tools is crucial for both research and developing recommendations in the fields of mathematical cognition and mathematics education.

What did the researchers do and find?

We evaluated the psychometric properties of the Polish version of the Mathematical Resilience Scale (MRS; Kooken et al., 2016). Our analysis revealed that the scale is composed of three distinct dimensions—Value, Growth, and Struggle—that together form the overall resilience score. Additionally, we found that the scale's structure is consistent across different groups, such as

gender and field of study, which enables us to make meaningful comparisons. We also confirmed that the MRS demonstrates strong convergent and discriminant validity, as well as high reliability.

What do these findings mean?
Our findings indicate that the Polish version of the MRS is a suitable for measuring mathematical resilience across diverse populations. Since the structure of the scale is comparable among different demographic groups, it can be effectively used to assess and compare resilience levels in various educational contexts. However, we also recognize the need for further research to deepen our understanding of mathematical resilience, particularly its relationship with general resilience, in order to fully capture how students overcome challenges in mathematics.

Highlights

- The Polish version of the Mathematical Resilience Scale (MRS; Kooken et al., 2016) comprises three dimensions – Value, Growth, and Struggle – that collectively form the overall score.
- The structure of the MRS is comparable across gender and field of study, allowing for comparisons of results based on these variables.
- MRS has confirmed convergent and discriminant validity and high reliability.
- More research is required to explore the concept of mathematical resilience, especially to clarify its relationship with general resilience.

Mathematical Resilience

Mathematical resilience is a specific type of resilience that refers to a student's ability to maintain positive emotions towards mathematics despite facing challenges associated with this subject (Johnston-Wilder & Lee, 2010; Kooken et al., 2016; Lee & Johnston-Wilder, 2017). As mathematical resilience draws from the concept of psychological resilience, it involves exhibiting a constructive reaction to a significant challenge or hardship (Luthar & Cicchetti, 2000; Luthar et al., 2000). Mathematical resilience describes the ability to overcome significant and prolonged obstacles that hinder a learner's mathematical development. Therefore, it can be understood as a unique psychological phenomenon that relates to an individual's capacity to recover from intermittent problems in learning mathematics (Oszwa, 2022).

Two scales were developed to measure mathematical resilience: the Academic Resilience in Mathematics Scale (Ricketts et al., 2017) and the Mathematical Resilience Scale (Kooken et al., 2016). The theoretical framework of the Academic Resilience in Mathematics Scale comes from social cognitive theory (Bandura, 1997) and the concept of academic resilience (Martin & Marsh, 2006, 2008). Ricketts et al. (2017) indicated that mathematical resilience is unidimensional and includes students' perception of their environment and ability to deal with academic challenges. Johnston-Wilder and Lee (2010) based their theory on a well-established theoretical background and initially assumed that mathematical resilience had a four-factor structure: value (Deci et al., 1991; expectancy-value theory), struggle (Bandura, 1989, theory of human agency), growth (Dweck, 2000; Yeager & Dweck, 2012; growth-fixed mindset belief), and resilience (Kooken et al., 2016). However, the last factor was removed after factor analysis because of its strong contribution to other factors.

Consequently, the factors of the Mathematical Resilience Scale were characterized as follows (Kooken et al., 2016). *Value*: This dimension refers to the recognition of the relevance and significance of mathematics in daily life and future aspirations. Those who value mathematics are more likely to perceive the benefit of persistence through difficulties and to be motivated to continue their mathematical learning. *Struggle*: Embracing challenges and persisting through difficulties are the components of the struggle dimension of mathematical resilience. Individuals who possess high levels of mathematical resilience in this dimension acknowledge that struggles and errors are natural parts of the learning process and are willing to put in the effort to overcome obstacles. *Growth:* The growth dimension of mathematical resilience entails having a growth mindset, which means believing that one's mathematical abilities can be enhanced through hard work and dedication. Individuals who exhibit high levels of mathematical resilience in this dimension tend to view setbacks as opportunities to learn and grow, rather than as indications of fixed abilities. They are also more inclined to seek help and support when needed and to engage in deliberate practice to improve their mathematical skills.

The Academic Resilience in Mathematics Scale (Ricketts et al., 2017) and the Mathematical Resilience Scale (Kooken et al., 2016) were developed in U.S. samples. The factor structure and reliability of the scales and some (mostly demographic) information for their validity were provided. However, the Mathematical Resilience Scale has gained international attention and has also been validated in Türkiye (Gürefe & Akçakın, 2018) and Nigeria (Awofala, 2021). The Turkish validation provided information on the structure and reliability of this scale, while the Nigerian study included information on its structure, reliability, and its relationship with mathematical achievement. As studies in both these countries have provided arguments for the accuracy of the three-factor structure of the Mathematical Resilience Scale, and the items of Academic Resilience in Mathematics Scale and the Mathematical Resilience Scale are similar, we decided to focus on the Mathematical Resilience Scale to establish its psychometric properties in a Polish sample.

As mentioned above, in the first version of the scale Kooken et al. (2016) included 'resilience' as a fourth factor but it was removed after factor analysis due to its strong contribution to other factors. However, such a result suggests that value, struggle, and growth could be the first-order factors while mathematical resilience (the primary factor determining the three dimensions) could be the second-order factor. Such an approach would also be consistent with Ricketts et al. (2017) assumption regarding the existence of general mathematical resilience. Because no results have been published that indicate that the two-level model has been tested, this is the first time such a model has been tested. Furthermore, the metric equivalence of the Mathematical Resilience Scale has not been tested either, although cross-group comparisons have been made. For this reason, we want to test whether the structure of the scale is comparable across gender and educational specialization before testing group differences. Finally, we want to determine the scope of application of the scale in a Polish sample, testing convergent and discriminant validity by analysis of Mathematical Resilience Scale correlates.

Correlates of Mathematical Resilience

Mathematical resilience is considered an important factor in mathematics education that is related to socio-demographic, affective, cognitive, and behavioral aspects of students' functioning and their educational outcomes. Indeed, previous research results suggest that mathematical resilience may be related to general resilience (Yeager & Dweck, 2012), math anxiety (Kooken et al., 2016), math avoidance (Johnston-Wilder et al., 2014), intellectual helplessness (Bedyńska et al., 2018), math motivation (Knopik & Oszwa, 2023; Oszwa, 2022), academic achievement (Awofala, 2021), gender (Ricketts et al., 2017), and STEM studies and professions (Kooken et al., 2016). Arguments for the hypothetical relationships are presented below.

The term 'mathematical resilience' is rooted in the general concept of resilience. General resilience is a dynamic process that involves positive adaptation in the face of adversity (Luthar et al., 2000; Sinclair & Wallston, 2004). An important element of resilience is the ability to gain distance from negative events (Luthar et al., 2000; Piórowska et al., 2017), which enables the transition to more adaptive ways of coping. It is likely that no previous studies have tested the relationship between mathematics resilience and general resilience, but presumably both constructs should correlate positively.

Although mathematical resilience refers to a student's resources and its development seems to be fundamental in the mathematics teaching process, researchers' attention has so far been focused more on reducing negative emotions, such as math anxiety. Math anxiety, "a feeling of tension and anxiety that interferes with the manipulation of numbers and the solving of mathematical problems in a wide variety of ordinary life and academic situations" (Richardson & Suinn, 1972, p. 551), should correlate negatively with mathematical resilience (Johnston-Wilder et al., 2014). In contrast to math anxiety, mathematical resilience pertains to the mindset and behavior of individuals who face challenges in their mathematical studies but respond by performing optimally rather than succumbing to anxiety (Kooken et al., 2016). Some researchers perceive mathematical resilience and math anxiety as two sides of the same coin (Johnston-Wilder & Lee, 2010; Lee & Johnston-Wilder, 2017; Oszwa, 2022), which means that developing resilience to cope with math learning difficulties may be crucial for reducing math anxiety.

It is believed that one of the visible behavioral symptoms of low mathematical resilience is math avoidance. Math avoidance is likely negatively correlated with mathematical resilience (Johnston-Wilder et al., 2014). When faced with mathematical challenges, many individuals withdraw their effort as they fear failure. Chinn (2012) noted that this tendency causes many children and adults to give up on mathematics learning. Interestingly, students labeled as 'unmotivated' in mathematics may actually be highly motivated, but their motivation is driven by a fear of failure rather than a desire to learn (Covington, 1992). According to Dweck (2000), the impact of failure on motivation depends on whether students react in a mastery-oriented or helpless manner. Meanwhile, Ashcraft and Krause (2007) observed that math anxiety often leads to avoidance behavior, with students avoiding math classes and situations where mathematics is required.

The cognitive-motivational factor related to mathematical resilience is intellectual helplessness in mathematics. Intellectual helplessness (Sędek & MacIntosh, 1998) is a theoretical construct derived from the informational model of learned helplessness, which has been expanded to include the educational context. In line with the theoretical assumptions, protracted cognitive exertion without any advancement culminates in a distressing psychological state known as 'cognitive exhaustion'. This state inhibits the generation of innovative ideas or plans and particularly impedes task situations that require more intricate information processing, such as initiating unconventional problem-solving or generating mental models. Repeated difficulties in learning new material despite sustained mental effort are a critical condition for the development of symptoms of intellectual helplessness, like decreased motivation or negative emotions, in specific school subjects (Bedyńska et al., 2018). Intellectual helplessness is not solely associated with cognitive impairments such as lower academic achievement, as measured by grades and knowledge tests; within educational contexts, it also gives rise to motivational issues, such as a lack of intrinsic and instrumental motivation and disengagement from subject matter, as well as emotional problems, including negative emotions and anxiety (Bedyńska et al., 2018). Therefore, intellectual helplessness in mathematics may be negatively related to mathematical resilience.

Motivation is considered an important factor related to mathematical resilience. Following Deci et al.'s (1991; Ryan & Deci, 2000) self-determination theory, motivation to learn mathematics may be analyzed on various levels: from amotivation, through extrinsic motivation (external regulation, introjection, identification, integration), to intrinsic motivation. Students' motivation, especially their self-determination in forming intrinsic motivation, may be a key factor in mathematical resilience (Oszwa, 2022). According to Bandura (2000), the level of motivational investment in a group directly impacts students' ability to persist in the face of setbacks and ultimately improve their performance. This theory suggests that students who recognize that experiencing struggles in math is a shared experience in their peer group are more likely to have increased tolerance and stronger perseverance in the face of setbacks (Kooken et al., 2016). Therefore, higher motivation to learn math should be correlated with higher mathematical resilience. Individuals who are motivated to learn math are more likely to persist in the face of challenges and setbacks.

The relationship between mathematical resilience and school achievements has also been tested. Awofala's (2021) study provided evidence for a positive correlation between mathematical resilience and mathematics achievement. This finding is consistent with previous suggestions (Kooken et al., 2016). In contrast, Rokhmah et al. (2019), in a qualitative study in Indonesia, obtained no significant relationship between mathematical resilience and students' mathematics achievement. As students who recognize the relevance of mathematics in their daily lives and are willing to persist through challenges are more likely to achieve better performance in mathematics (Awofala, 2021), it is likely that mathematical resilience and math achievement may be related to each other. On the other hand, mathematical resilience may be key in the math learning process but is less important for achievement level, i.e., performance in math tests or math grades.

Finally, previous studies have examined whether mathematical resilience differs by gender and education profile. Previous studies on the Mathematical Resilience Scale suggest that there are gender differences in the level of mathematical resilience (Ricketts et al., 2017). However, contrasting results were provided by Kooken et al. (2016). Studies on math attitude and math anxiety have also provided contrasting results, e.g., Else-Quest et al. (2013) did not observe a gender gap in value beliefs about math, while Núñez-Peña et al. (2016) found that women's level of math anxiety exceeded that of men. Awofala (2021) did not test gender differences in mathematical resilience. Finally, Kooken et al. (2016) presented results that supported the hypothesis that non-STEM individuals have a lower level of mathematical resilience in comparison to a STEM group. As mathematical resilience includes the ability to overcome obstacles that hinder a learner's mathematical development, people with higher mathematical resilience probably more often choose STEM courses and career paths than those with lower mathematical resilience.

The Current Study

The main purpose of this study is to examine the psychometric properties of the Mathematical Resilience Scale in a Polish sample of adults (Kooken et al., 2016). We want to evaluate the structural validity of this scale by testing its structure and establish measurement invariance across gender and field of study and profession. We assume that the scale consists of three related dimensions (Value, Struggle, Growth) with a second-order mathematical resilience latent factor (Total). We expect that the structure of the scale is comparable across gender (women, men) and field of study and profession (STEM − Science, Technology, Engineering, Mathematics; HSS − Humanistic and Social Science; OTHER − other fields of study and profession, e.g., gardener, sports trainer, cosmetology). We also want to establish the structural validity by testing relationships between Mathematical Resilience Scale Total score and Value, Struggle, and Growth subscales. We expect that all subscales will be positively related to each other and that all items will correlate positively with Mathematical Resilience Scale Total score and the subscale to which it belongs.

Then, we want to establish criterion validity by testing correlates of the Mathematical Resilience Scale. We assume that Mathematical Resilience Scale scores are negatively related to math anxiety, math avoidance, and intellectual helplessness in mathematics and positively related to general resilience and mathematical achievement. However, we expect that the Mathematical Resilience Scale will be not correlated with or weakly related to intellectual helplessness in Polish language and Polish language grades received in high school. We hypothesize that Mathematical Resilience Scale scores will be negatively related to amotivation and external motivation but positively related to introjected, identified, and intrinsic motivation to learn mathematics. Then, we want to test gender differences in the Mathematical Resilience Scale, based on the assumption that men have a higher level of mathematical resilience than women. We also want to test whether the field of study and profession differentiates the level of mathematical resilience. The STEM group probably has greater mathematical resilience than the HSS and OTHER groups, and the OTHER group might have greater mathematical resilience than the HSS group.

Further, we will test the internal consistency of the Mathematical Resilience Scale.

Method

Participants

Four hundred and forty-three adults participated in the study (N = 365 women, N = 73 men, N = 3 non-binary, N = 2 no data, age: M = 21.95, SD = 4.4, range 18–55). The minimum number of participants for correlational analyses was estimated based on a power test (α = .05, β = .20, small effect size, r = .2) conducted with G*Power 3.1.9.7. One hundred and twenty-two adults participated in the study that was conducted in the university laboratory (Study 1), while 321 participated in the online study (Study 2). Participants were recruited through an advertisement posted on the nationwide internet platform olx.pl and social media (e.g., Facebook posts). There was no age or profession restriction to participate. In both studies, partially different data were collected to establish the validity of the Mathematical Resilience Scale (see details in the procedure). Participants in both studies represented STEM (N = 70), HSS (N = 305) and OTHER (N = 71) fields of study and profession.

Measurements

Mathematical Resilience Scale (MRS)

MRS (Kooken et al., 2016) measures general mathematical resilience (Total; MRS-T) and its three components: Value (MRS-V, 9 items, e.g., 'Math is essential for my future'), Struggle (MRS-S, 8 items, e.g., 'Everyone struggles with math at some point'), and Growth (MRS-G, 7 items, e.g., 'Math can be learned by anyone'). Respondents answer on a 7-point scale from 1 = completely disagree to 7 = completely agree. The higher the score in MRS and its subscales, the higher the mathematical resilience. The Polish language version of the scale was prepared in accordance with back-translation rules (see Polish-English language versions of items in the Appendix). Details on the validity and reliability of the MRS are presented in the results section (*N* = 443).

Brief Resilience Coping Scale (BRCS)

The Polish adaptation of BRCS (Sinclair & Wallston, 2004; Piórowska et al., 2017) was used to test resilience, understood as the ability to cope with stress in a highly adaptive manner. It is a 4-item scale (e.g., ‘I look for creative ways to alter difficult situations’) with a 5-point answer scale, from 1 = definitely does not describe me to 5 = definitely describes me. A higher score means higher resilience. The reliability of the BRCS scale in our study is relatively low (Cronbach’s α = .56, *N* = 122), therefore its results should be treated with caution.

The Single-Item Math Anxiety Scale (SIMA)

SIMA (Núñez-Peña et al., 2014) tests general math anxiety by means of one question about the level of math anxiety: ‘On a scale from 1 to 10, how math anxious are you?’ A higher score indicates higher general math anxiety. This test was used in both studies (*N* = 443).

The Abbreviated Math Anxiety Scale (AMAS)

AMAS (Hopko et al., 2003; Cipora et al., 2015) is a 9-item scale to measure anxiety related to math learning (AMAS-L, e.g., ‘Listening to another student explain a math formula’) and math testing (AMAS-T, e.g., ‘Thinking about an upcoming math test 1 day before’). Respondents evaluate their math anxiety on a 5-point scale from 1 = low math anxiety to 5 = high math anxiety. A higher AMAS mean indicates higher learning and testing math anxiety. The reliability of this scale in the current study is satisfactory: learning α = .78, and testing α = .87 (*N* = 443).

Math Anxiety Questionnaire for Adults (MAQA)

MAQA (Szczygieł, 2022) is a 19-item scale intended for adults. The scale was originally developed and validated in Polish adults and has very good psychometric properties. It measures math anxiety related to mathematical problem solving in two contexts: math anxiety related to basic mathematical knowledge (e.g., ‘Determining the probability that today is Wednesday’) and to situations that may take place in everyday life (e.g., ‘Calculation of the average level of fuel consumption of a car’). Participants evaluate the level of math anxiety on a four-point scale, from 1 = I definitely do not feel anxious to 4 = I definitely feel anxious. MAQA is a unidimensional scale in which a higher average score means a higher level of math anxiety related to math problem solving. The reliability of MAQA in the current study is very good: α = .91 (*N* = 443).

Math Avoidance Scale (MAS)

MAS (Szczygieł & Kutt, 2022) measures avoidant behavior related to mathematics. It comprises 6 items (3 reverse, e.g., ‘I’m someone who actively avoids math classes’) and is a unidimensional scale. Participants assessed their level of math avoidance during school years on a 9-point scale, from 1 = definitely not to 9 = definitely yes. The reliability of MAS in the current study is very good: α = 86 (*N* = 443).

Intellectual Helplessness Scale (IHS) in Mathematics and Polish Language

IHS (Sędek & MacIntosh, 1998) measures intellectual helplessness in school and may be adapted to various subjects separately, e.g., mathematics (IHS-M) and Polish language (IHS-PL). The scale was originally developed and validated in Poland. It is a unidimensional scale that comprises 20 items. Participants evaluated their well-being during past math (e.g., ‘I didn’t understand anything in math classes’) and Polish language (e.g., ‘I didn’t understand anything in Polish classes’) classes on a 5-point scale, from 1 = never to 5 = always. A higher sum of points in IHS indicates greater intellectual helplessness (separately for each subject). The reliability of this scale is very good: IHS-M α = .95 (*N* = 321), IHS-PL α = .96 (*N* = 321).

Math and Polish Language Grades (Grade-MATH, Grade-PL)

Participants indicated their most frequently obtained grades in mathematics and Polish language in the last semester of high school (from 1 to 6). Higher grades indicate better math and Polish language achievements.

Math Achievement Test (MATH)

MATH (Szczygieł & Sari, 2024) is a mathematical test for adults developed on the basis of the Polish math curriculum for secondary school students (counting and geometry; based on Karpińska et al., 2019). It consists of 20 closed single-choice questions which are placed in the context of solving everyday problems. The test had no time pressure. For each correct answer, participants received 1 point. A higher sum of points indicates better math performance. Total math score was correlated to all mathematical tasks positively (from r = .20 to r = .60) and significantly (p < .001). The test was found to be reliable (Cronbach's α = .78, N = 122) and rather easy (test difficulty, calculated as the sum of points for all participants divided by the maximum number of points possible to obtain for all participants, was .83; Niemierko, 1999).

Motivation to Learn Mathematics (MOT)

MOT (Góźdź, 2015) is a 30-item scale that measures five dimensions of motivation to learn mathematics in accordance with self-determination theory (Deci et al., 1991; Ryan & Deci, 2000; MOT does not include the 'integrated motivation' dimension). Respondents answered the question 'Why did you learn mathematics?' on the following subscales: amotivation (e.g., 'I don't really know, I feel like I wasted my time during these lessons'), external (e.g., 'I just wanted the teacher to leave me in peace'), introjected (e.g., 'Because I wanted to prove to myself that I was capable of success'), identified (e.g., 'Because it helped me prepare for the profession I had dreamed of'), and intrinsic motivation (e.g., 'Because I just liked it'). Participants answered on a 5-point scale, from 1 = I definitely do not agree to 5 = I definitely agree. A higher sum of points on each subscale means a greater level of amotivation or the aforementioned types of motivation. The reliability of each subscale is very good: MOT-Amotivation α = .92, MOT-External α = .79, MOT-Introjected α = .88, MOT-Identified α = .95, MOT-Intrinsic α = .96 (N = 321).

Procedure

The collection of the data was conducted in two studies: at a university laboratory (N = 122) and online (N = 321). These studies were different in some details regarding the materials used. The order of measures was as follows: at the laboratory – SIMA, MAQA, BRCS, MAS, MRS, AMAS, IHS-M, MATH, gender, age, math and Polish language grades, field of study and profession; online – SIMA, MAQA, MAS, MRS, AMAS, IHS-M, IHS-PL, MOT, gender, age, math and Polish language grades, field of study and profession. The duration of the first study was about 40 minutes, while the second study was about 20 minutes. The laboratory study was conducted by two researchers who had been trained in the procedure, while the online survey was done using the snowball method (link forwarded on social networks). The subjects in both studies participated voluntarily and could ask questions (directly or via email) and withdraw from the study at any time. Laboratory participants were rewarded (€8–12) while online participants did not receive remuneration. Participants in the first study additionally performed other tasks that are not presented in this study (working memory and numerical magnitude tasks). Both studies obtained ethical approval from the Ethical Committee, Institute of Psychology, University of the National Education Commission.

Data Analysis

We analyzed the combined data from the two studies. In the first step of analysis, we established the structural validity by testing the structure of MRS via confirmatory factor analysis (CFA; *lavaan* package; Rosseel, 2012). All variables were ordinal and Mardia's test showed that the assumption of multivariate normality was violated, therefore we used the Diagonally Weighted Least Squares estimator (DWLS; Mîndrilă, 2010). To evaluate the model's fit to the data in CFA, we adopted the following criteria: χ^2 (p > .05), RMSEA and SRMR < .08, CFI and TLI > .95 (Hu & Bentler, 1999; Kline, 2016). We established minimum factor loadings at $\lambda \geq .30$ (Nooteboom & de Jong, 2000; Tabachnick & Fidell, 2001).

Next, to provide more arguments for structural validity, we established zero-order correlations between MRS items and the Value, Struggle, and Growth subscales. Structural validity would be indicated by results showing that items correlate more strongly within the subscale they are included in than within the subscales they are not included in.

Then, we tested invariance measurements via gender and field of study and profession (STEM, HSS, OTHER). Measurement invariance refers to whether measurement is interpreted in the same way across different groups. Establishing measurement invariance is the starting point for comparing means across groups or the strength of the relationship between variables within subgroups (Putnick & Bornstein, 2016). To evaluate measurement invariance, we adopted the principle that the χ^2 to *df* ratio should be less than 3 (Schermelleh-Engel et al., 2003). Based on Chen's (2007) recommendations, we evaluated model fit when testing measurement invariance in the following way: difference-of-fit indices between nested models in a large sample size ($N > 300$) should be less than .015 for RMSEA, less than .03 for SRMR, and less than .01 for CFI and TLI. We tested configural, metric, scalar and strict invariance. Configural invariance assumed no equality constraints imposed on the basis of common model fit indices; metric invariance tests factor loadings that are constrained to be equal for the corresponding items in groups; scalar invariance assumed that constraint intercepts are equal across the groups; strict invariance assumed that factor loadings, intercepts, and residual variances are fixed across groups.

In the next step of analysis, we tested the criterion validity and reliability of the MRS. Based on Evans' (1996) interpretation, we adopted the following criteria to indicate the effect size for Pearson's *r* correlation: $r < .20$ very weak correlation, .20−.39 weak relationship, .40−.59 moderate relationship, .60−.79 strong relationship, and > .80 very strong relationship. In accordance with Cohen's (1988) proposal, we interpreted the effect sizes of mean differences as follows − *d:* .20 small effect, .50 medium effect, .80 large effect; η^2: .01 small effect, .06 medium effect, .14 large effect. We set the minimum acceptable level of Cronbach's α and stratified Cronbach's α values at .70. Stratified Cronbach's α was calculated for the latent second-order factor that consisted of three first-order latent factors.

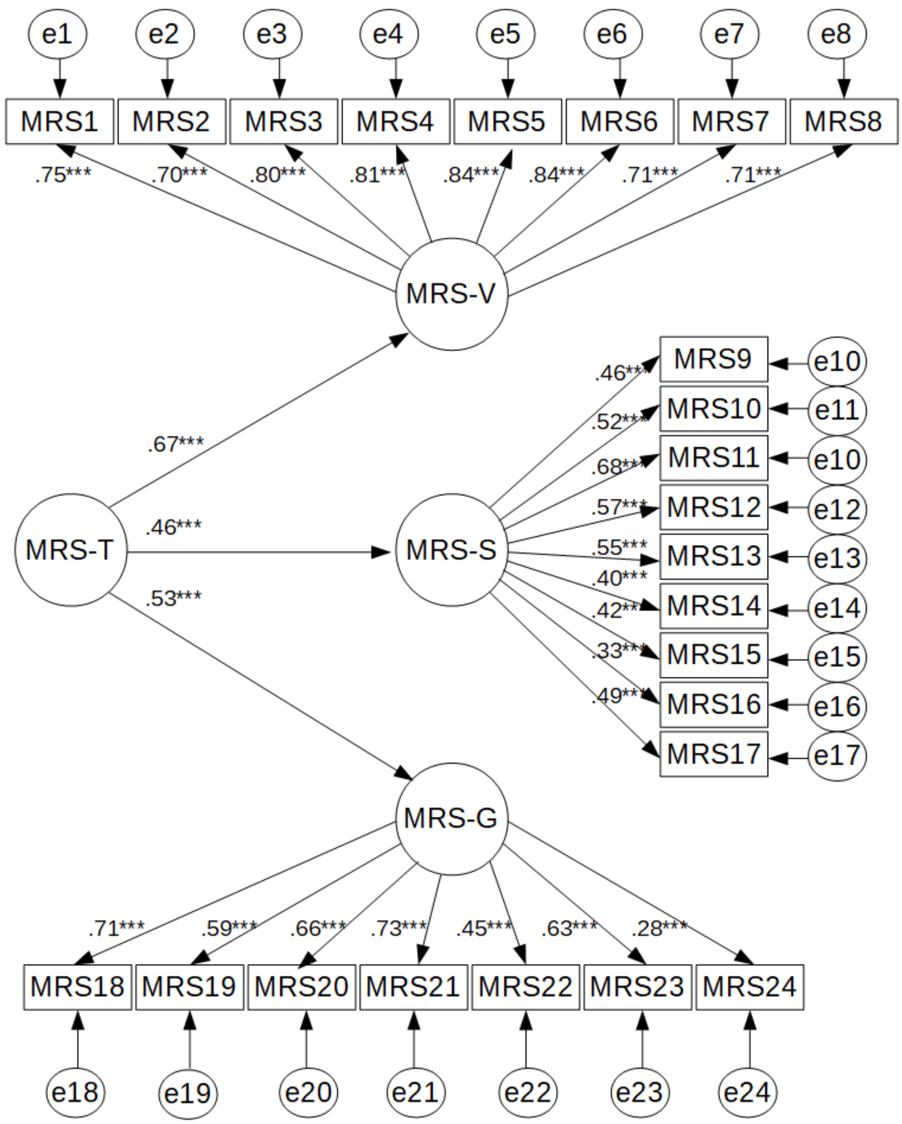
Results

Structural Validity of MRS

In the first step of the analysis, we established structural validity. To test whether the structure of the MRS is two-level, with Value, Struggle, and Growth dimensions at the first level and a latent superfactor of mathematical resilience (Total) at the second level, we conducted CFA (see Figure 1). We noted the following acceptable model fit to the data: $\chi^2(249) = 522.46$, $p < .001$, CFI = .97, TLI = .96, RMSEA = .050 [.044-.056], SRMR = .067. Standardized regression paths for each first-order factor (Value, Struggle, Growth) were significant ($p < .001$). All items showed an acceptable effect size for the whole group, except for one item, MRS24 ($\lambda = .28$), which was slightly below the cutoff. Because this item was moderately and significantly related to the Growth subscale, as were other items in this subscale, we decided not to delete it from the MRS. We also showed that the Total latent factor was significantly, positively, and moderately related to three subscales (Value, Struggle, Growth), which confirmed our expectation that general mathematical resilience contributes to specific dimensions of mathematical resilience. Therefore, the results confirm that the scale consists of three first-order latent factors (Value, Struggle, Growth), which together form a second-order latent factor (Total). This indicates that MRS scores can be analyzed using either the three separate factors or the total factor, as both the higher-order model and the three first-order models are statistically equivalent.

Figure 1

CFA Model of MRS



Note. MRS-T = Mathematical Resilience Total (second order factor); MRS-V = Value; MRS-S = Struggle; MRS-G = Growth (first-order factors). The values at the arrows represent the λ.

***$p < .001$.

To provide more arguments for structural validity, we examined the relationships between individual scale items and the three factors. The results indicated that items from each subscale (Value: MRS1-MR9, Struggle: MRS10-MRS17, Growth: MRS18-MRS24) are moderately or strongly positively related to the corresponding subscales, while they are not related or weakly related to the other subscales (see Table 1; The correlation with the exclusion of a given item is presented in brackets). Moreover, all items (MRS1-MRS24) were significantly related to Total score (see Table 1). Finally, the subscales were significantly, positively and weakly related to each other, respectively: Value and Struggle $r = .26$, $p < .001$, Value and Growth $r = .29$, $p < .001$, Growth and Struggle $r = .18$, $p < .001$. The results support the hierarchic structure of MRS.

Table 1

Item-Scale Zero-Order Pearson's Correlations (Item Excluded)

Dimension / Item	Correlation with MRS-T	Correlation with MRS-V	Correlation with MRS-S	Correlation with MRS-G
MRS-V				
MRS1	.65 (.59)***	**.80 (.73)*****	.14*	.22***
MRS2	.61 (.54)***	**.76 (.68)*****	.10*	.23***
MRS3	.73 (.68)***	**.81 (.75)*****	.29***	.27***
MRS4	.69 (.64)***	**.84 (.78)*****	.20***	.22***
MRS5	.72 (.67)***	**.85 (.80)*****	.24***	.23***
MRS6	.73 (.68)***	**.85 (.79)*****	.25***	.25***
MRS7	.64 (.57)***	**.76 (.68)*****	.22***	.19***
MRS8	.65 (.59)***	**.75 (.67)*****	.25***	.21***
MRS-S				
MRS9	.39 (.31)***	.29***	**.48 (.28)*****	.08
MRS10	.33 (.25)***	.13**	**.64 (.46)*****	.06
MRS11	.42 (.37)***	.18***	**.68 (.58)*****	.16***
MRS12	.38 (.34)***	.14***	**.57 (.47)*****	.23***
MRS13	.34 (.29)***	.16***	**.60 (.48)*****	.08
MRS14	.34 (.27)***	.22***	**.44 (.26)*****	.11*
MRS15	.30 (.22)***	.09	**.58 (.38)*****	.10*
MRS16	.22 (.16)***	.01	**.52 (.39)*****	.09
MRS17	.33 (.26)***	.13**	**.62 (.45)*****	.09*
MRS-G				
MRS18	.54 (.47)***	.36***	.17**	**.64 (.46)*****
MRS19	.41 (.34)***	.15***	.08	**.74 (.61)*****
MRS20	.47 (.41)***	.22***	.15**	**.70 (.59)*****
MRS21	.51 (.44)***	.25***	.15**	**.75 (.62)*****
MRS22	.33 (.26)***	.08	.11*	**.61 (.47)*****
MRS23	.46 (.38)***	.23***	.09	**.71 (.55)*****
MRS24	.23 (.16)***	-.03	.12*	**.53 (.38)*****

Note. Bold font indicates correlations describing the items included in a given subscale. $N = 443$; MRS-T = Mathematical Resilience Total; MRS-V = Value; MRS-S = Struggle; MRS-G = Growth.
*$p < .05$. **$p < .01$. ***$p < .001$.

In the further step of analysis, we tested CFA and the measurement invariance of the MRS across gender and field of study and profession (see Table 2). λ values for each item and each subgroup are presented in Table 3.

First, we tested the measurement invariance across gender (see Table 2). Based on model fit, we observed that the structure of MRS is acceptable for women and men. Only the SRMR value (.098) for men slightly exceeded the criterion. Then, we noted that configural, metric, scalar, and strict measurement was confirmed (in each step of analysis, the adopted criteria were met; difference-of-fit indices between subsequent models were less than .015 for RMSEA, .03 for SRMR, .01 for CFI, .01 for TLI). Therefore, we conclude that MRS scores are comparable across gender. Factor loadings for women were satisfactory except for Item 24, while for men there were more items (Items 9, 12, 14, 15) with factor loadings below .3 (see Table 3).

Then, we investigated whether MRS fulfilled the measurement invariance criterion across field of study and profession (see Table 2). We observed that the model fit was very good for HSS students but exceeded the criteria for SRMR (≤ .12) in the STEM and OTHER groups. However, RMSEA, CFI, and TLI values met the criterion in STEM and OTHER groups. Thus, we tested measurement invariance. Only ΔRMSEA (.019) between configural and metric invariance slightly exceeded the defined criteria, but other indicators fully confirmed measurement invariance across the field of study and profession. Therefore, configural, metric (partially), scalar, and strict invariance were confirmed for the field of study and profession. Factor loadings mostly exceed the cutoff value .3 (see Table 3), but there were exceptions for STEM (Items 14, 17, 18), HSS (Items 16, 24), and OTHER (Item 24).

Table 2

Measurement Invariance of MRS Across Gender and Field of Study and Profession

Variable	*N*	*df*	χ^2	χ^2/df	RMSEA [90% CI]	SRMR	CFI	TLI
Gender								
Women	365	249	484.30***	1.94	.051 [.044, .058]	.073	.97	.96
Men	73	249	205.45	.83	0 [0, 0]	.098	1	1.05
Configural	–	443	522.46***	1.18	.050 [.044, .056]	.067	.97	.96
Metric	–	521	816.69***	1.57	.051 [.044, .058]	.078	.96	.96
Scalar	–	541	852.84***	1.58	.051 [.045, .058]	.079	.96	.96
Strict	–	565	897.46***	1.59	.052 [.045, .058]	.083	.96	.96
Field of Study and Profession								
STEM	69	249	271.11	1.09	.036 [0, .063]	.12	.96	.95
HSS	304	249	416.66***	1.67	.047 [.039, .055]	.072	.97	.97
OTHER	70	249	203.18	.82	0 [0, 0]	.11	1	1.04
Configural	–	443	522.46***	1.18	.050 [.044, .056]	.067	.97	.96
Metric	–	793	1030.16***	1.30	.045 [.037, .053]	.086	.97	.97
Scalar	–	833	1113.12***	1.34	.048 [.040, .055]	.089	.96	.96
Strict	–	881	1186.46***	1.35	.049 [.041, .056]	.094	.96	.96

***p < .001.

Table 3

Factor Loadings in MRS Across Groups

	λ				
Dimension / Item	**Women**	**Men**	**STEM**	**HSS**	**OTHER**
MRS-V					
MRS1	.76***	.69***	.63***	.70***	.79***
MRS2	.69***	.70***	.73***	.64***	.62***
MRS3	.82***	.74***	.67***	.82***	.85***
MRS4	.82***	.80***	.71***	.78***	.88***
MRS5	.84***	.84***	.66***	.82***	.86***
MRS6	.83***	.88***	.73***	.83***	.78***
MRS7	.74***	.54***	.52***	.72***	.69***
MRS8	.75***	.48***	.44***	.74***	.78***
MRS-S					
MRS9	.48***	.18*	.38***	.44***	.58***
MRS10	.52***	.53*	.32**	.48***	.66***
MRS11	.66***	.77*	.67***	.58***	.86***
MRS12	.58***	.22	.62***	.56***	.67***
MRS13	.54***	.49*	.71***	.52***	.56***
MRS14	.46***	.009	.04	.48***	.32***
MRS15	.45***	.14	.38**	.46***	.44***
MRS16	.33***	.38*	.68***	.29***	.42***
MRS17	.51***	.43*	.28**	.56***	.67***

	λ				
Dimension / Item	**Women**	**Men**	**STEM**	**HSS**	**OTHER**
MRS-G					
MRS18	.75***	.57***	.25**	.71***	.69***
MRS19	.61***	.60***	.71**	.66***	.39**
MRS20	.63***	.79***	.73**	.68***	.39**
MRS21	.71***	.71***	.51**	.77***	.69***
MRS22	.42***	.49***	.67**	.46***	.46***
MRS23	.66***	.48***	.30*	.66***	.55***
MRS24	.24***	.49***	.36**	.28***	.25*

Note. $N = 443$. MRS1-MRS24 – Mathematical Resilience Scale Items; MRS-V – Value; MRS-S – Struggle; MRS-G – Growth.
*$p < .05$. **$p < .01$. ***$p < .001$.

Summing up, although the comparability of the structure of the MRS was confirmed across gender and field of study and profession, we observed some items across groups that had a λ value below the .3 cutoff or were insignificant (see values in Table 3). However, none of these results indicates the need to delete items from the MRS scale.

Convergent and Discriminant Validity of MRS

In the next step of analysis, we established the criterion validity of MRS. We examined convergent and discriminant validity by determining whether the MRS Total score and the Value, Struggle, and Growth subscales correlated as expected (see Table 4). First, we tested convergent validity. We observed that resilience coping was not associated with either the MRS Total score or any of MRS subscales, which did not support of our hypothesis. Then, we confirmed that math anxiety was related to MRS Total score and all subscales in accordance with expectations. Math anxiety scales were negatively related to MRS Total score and all subscales, with the exception of the math testing anxiety and Struggle subscales. The strength of the correlation between the math anxiety scales and MRS was varied: strongest for the Total score, weakest for the Struggle subscale. Math avoidance also was negatively related to MRS Total score and all subscales, which confirms initial assumptions. Another argument in favor of convergent validity was the result indicating a negative relationship between intellectual helplessness in mathematics and MRS Total score and all subscales. Partial support for convergent validity was found for the relationship between MRS scores and mathematical achievement. We observed that math performance and math grades were weakly and positively related to MRS Total score and Value but not to Struggle and Growth. Finally, the results on the relationship between motivation and MRS mostly confirmed convergent validity. MRS Total score and all subscales were negatively related to amotivation and external motivation (with the exception of Struggle and external motivation) and positively to introjected, identified, and intrinsic motivation. Discriminant validity was tested by correlations between MRS and Polish outcomes. We noted that Value was positively and weakly related to intellectual helplessness in Polish, and MRS Total score and Value were negatively and weakly related to Polish language grade in high school. Other relationships between MRS and Polish intellectual helplessness and grades were nonsignificant. The results support the discriminant validity of MRS.

Next, we tested whether there are gender differences in MRS using the Student's *t*-test (see Table 5). The results indicate that men have a significantly higher score in Value than women (small effect). We did not observe significant differences in MRS Total score and the other subscales. The results are partially in accordance with our assumptions. Then, we conducted the *F* test (with Welch correction if the assumption of homogeneity of variance was violated; see Table 5) to test whether the STEM, HSS, and OTHER groups differed in MRS. The results indicate that the STEM group in comparison to the HSS and OTHER groups had a higher score in MRS Total (medium effect) and the Value subscale (large effect). There were no differences between STEM, HSS, and OTHER groups in the Struggle and Growth subscales. HSS and OTHER did not differ in any dimensions. The results partially support our expectations.

Table 4

Matrix Zero-Order Pearson Correlation Between MRS and Other Variables

Variable	Measurement	*N*	MRS-T	MRS-V	MRS-S	MRS-G
Convergent validity						
Resilience coping	BRCS	122	.06	.08	-.07	.07
Math anxiety	SIMA	443	-.56***	-.49***	-.24***	-.39***
	AMAS-L	443	-.39***	-.29***	-.18***	-.35***
	AMAS-T	443	-.33***	-.32***	-.09	-.23***
	MAQA	443	-.54***	-.52***	-.21***	-.33***
Math avoidance	MAS	443	-.31***	-.28***	-.13*	-.21***
Intellectual helplessness in mathematics	IHS-M	443	-.48***	-.47***	-.21***	-.28***
Math achievement	MATH	122	.24**	.24*	.01	.18
	Grade-MATH	442	.15**	.15**	.05	.09
Math motivation	MOT-Amotivation	321	-.61***	-.61***	-.17**	-.41***
	MOT-External	321	-.18***	-.14*	-.02	-.21***
	MOT-Introjected	321	.31***	.31***	.16*	.16**
	MOT-Identified	321	.53***	.60***	.21**	.21***
	MOT-Intrinsic	321	.59***	.58***	.23***	.36***
Discriminant validity						
Intellectual helplessness in Polish	IHS-PL	321	.09	.15**	-.08	.04
Polish achievement	Grade-PL	442	-.12**	-.20***	.02	-.01

Note. MRS-T = Mathematical Resilience Total; MRS-V = Value; MRS-S = Struggle; MRS-G = Growth.
$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

Table 5

Group Comparison of MRS

	Women	Men			1. STEM	2. HSS	3. OTHER					
Dimension	*M* (*SD*)	*M* (*SD*)	*t* (*df*)	*d*	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)	*F*(*df*)	η^2	1 vs 2	1 vs 3	2 vs 3
MRS-T	119.66 (18.83)	123.07 (17.04)	(436) = 1.43	.18	131.68 (13.56)	117.06 (18.86)	121.81 (17.55)	(2, 140,39) = 27.77**	.08	< .001	.004	.14
MRS-V	30.17 (12.02)	34.44 (11.34)	(436) = 2.79**	.36	41.51 (8.77)	28.37 (11.37)	31.09 (11.85)	(2, 134,33) = 55.95**	.15	< .001	< .001	.20
MRS-S	53.32 (6.57)	53.89 (5.59)	(436) = .69	.09	53.38 (6.17)	53.17 (6.59)	54.11 (6.30)	(2, 440) = .60	.003	1.00	1.00	.82
MRS-G	36.16 (7.24)	34.74 (7.63)	(436) = 1.52	.20	36.80 (6.07)	35.51 (7.59)	36.61 (7.08)	(2, 440) = 1.29	.006	.56	1.00	.76

Note. MRS-T = Mathematical Resilience Total; MRS-V = Value; MRS-S = Struggle; MRS-G = Growth; Women *N* = 365; Men *N* = 73; HSS students *N* = 304: STEM students *N* = 69; OTHER students *N* = 70. Welch's correction was used in comparisons of MRS-T and MRS-V.
$^{**}p < .01$. $^{***}p < .001$.

Reliability of MRS

Then, we tested the reliability of MRS using stratified Cronbach's α for second-order latent score and Cronbach's α for subscales (see Table 6). The internal consistency of MRS across the whole sample and the tested groups was mostly satisfactory. However, we observed reliability lower than .7 in men and STEM groups in the Struggle subscale.

Table 6

Reliability of MRS

Dimension	Whole sample	Women	Men	STEM	HSS	OTHER
MRS-T	.90	.84	.86	.80	.91	.90
MRS-V	.92	.93	.89	.84	.91	.93
MRS-S	.72	.74	.57	.65	.73	.80
MRS-G	.79	.80	.79	.71	.82	.75

Note. MRS-T = Mathematical Resilience Total; MRS-V = Value; MRS-S = Struggle; MRS-G = Growth. Stratified Cronbach's α was calculated for MRS-T; Cronbach's α was calculated for subscales (MRS-V, MRS-S, MRS-G).

Discussion

Mathematical Resilience Scale in a Polish Sample

While some may perceive math ability as innate, those familiar with the subject recognize that it requires substantial effort and struggle. The process of learning mathematics involves combining various cognitive functions and using trial and error to solve problems (Johnston-Wilder & Lee, 2010; Kooken et al., 2016). The concept of mathematical resilience proves useful in understanding why some students are better than others in coping with learning difficulties in mathematics and why others withdraw from STEM education. Nevertheless, empirical studies on the nature of mathematical resilience are rare, which may be due to the lack of adequate scales.

Previous studies in the U.S. (Kooken et al., 2016) and with Turkish (Gürefe & Akçakın, 2018) and Nigerian (Awofala, 2021) samples confirmed the usefulness of the three-factor Mathematical Resilience Scale. The current study was designed to test the validity and reliability of this scale in a Polish sample of adults. We established the psychometric properties of the Mathematical Resilience Scale by testing the factor structure and measurement invariance across gender and field of study and profession. Compared with previous studies, we revised the scale structure based on the assumption that the three dimensions of the Mathematical Resilience Scale, namely Value, Struggle, and Growth, are related to a second-order factor, i.e., Total (general mathematical resilience). We were also the first to check the invariance equivalence of the Mathematical Resilience Scale. We tested the convergent and discriminant validity of the scale, showing correlations between scale scores and general resilience, math anxiety, math avoidance, math motivation, intellectual helplessness in mathematics and Polish, mathematical and Polish achievement, gender, and field of study and profession. Finally, we tested the reliability of the Mathematical Resilience Scale.

Similarly to previous studies (Awofala, 2021; Gürefe & Akçakın, 2018; Kooken et al., 2016), we confirmed the three-factor structure of the Mathematical Resilience Scale; however, we also indicated that there is a superordinate factor behind these three factors. This result indicates that Mathematical Resilience Scale scores can be analyzed using either three factors or a general factor, as both the higher-order model and the three first-order models are statistically equivalent, with the two-level structure providing a similarly good fit whether or not a superordinate second-order factor is included. This factor solution is reflected in the concept of mathematical resilience as a trait that manifests itself in various areas. The first version of the Mathematical Resilience Scale consisted of four factors, including resilience, but this factor was removed after factor analysis because items related to resilience were highly related to other factors (Kooken et al., 2016). This result additionally justified the inclusion of mathematical resilience as a second-order latent factor.

Similarly to Kooken et al. (2016), we obtained almost identical correlations between the three factors and similar results regarding the importance of each factor (value – the most effective factor; growth – the least effective factor;

Gürefe & Akçakın, 2018). The Value subscale has the strongest factor loadings, perhaps because of its content, which is largely about the respondent, while Struggle and Growth are more about people's beliefs in general. This may also explain the relatively weaker correlations between the Struggle and Growth subscales and other variables.

We also provided additional arguments for the structural validity of the scale by showing that items within a given scale are more strongly associated with the subscale they are part of than with other subscales. Moreover, all scale items are associated with the overall score, which indicates the existence of a general factor determining the scores on the three subscales.

We also provided some arguments for the comparability of the structure of the Mathematical Resilience Scale across gender and field of study and profession. Configural, metric, scalar, and strict measurement invariance was confirmed, although we observed that factor loadings on some items in some groups were below the established cut-off value. As no items significantly stood out from the other items in the different groups, we decided to not exclude any items from the final version of the Mathematical Resilience Scale. Moreover, it should be emphasized that a relatively small number of participants ($\approx$ 70) represented groups of men, STEM, and HSS. Therefore, further psychometric studies should focus on larger samples and better group equality. We further note that the measurement equivalence of the Mathematical Resilience Scale was better when testing a two-level structure compared to when testing a structure without a second-order factor. In summary, the obtained results demonstrate the structural validity of the scale, supporting its two-level structure.

The analysis of the correlates of the Mathematical Resilience Scale provides many arguments in favor of the criterion validity of the scale, although there are also exceptions. The most theoretical challenge regarding the Mathematical Resilience Scale is its lack of a significant relationship with resilience coping. Although previous validation studies in the USA (Kooken et al., 2016), Türkiye (Gürefe & Akçakın, 2018) and Nigeria (Awofala, 2021) did not test this relationship, we assumed that mathematical resilience should be related to resilience coping because of their common theoretical foundations. However, we used the Brief Resilience Coping Scale (Sinclair & Wallston, 2004; Piórowska et al., 2017), which consists of four items and had low reliability in our first study. We stopped using the Brief Resilience Coping Scale in the second study because of its low internal consistency. Therefore, our results regarding the relationship between mathematical resilience and resilience coping should be treated with caution. Another explanation for the results is that resilience coping measured by the Brief Resilience Coping Scale focuses on difficult life situations and self-control of one's own actions. As we surveyed adults, perhaps they did not perceive mathematics as a difficult life situation because most of them were no longer involved in any mathematical education. Further studies should continue testing the relationship between general resilience and mathematical resilience in math learners. Although our results should be treated with caution, it is likely that mathematical resilience is rooted in math-related domains. Indeed, other research results support the idea that there is a relationship between mathematical resilience and various 'mathematical constructs', like intellectual helplessness in mathematics, math anxiety, and math motivation. Moreover, the theoretical background of the Mathematical Resilience Scale is related to expectancy-value theory (Deci et al., 1991), the theory of human agency (Bandura, 1989), and growth-fixed mindset belief (Dweck, 2000; Yeager & Dweck, 2012), but not directly to resilience coping (Kooken et al., 2016). The results suggest that resilience is context-dependent (Assarkhaniki et al., 2020). Since the process of learning mathematics is not such a difficult experience as a serious illness or the death of a loved one, the lack of a relationship between the Mathematical Resilience Scale and the Brief Resilience Coping Scale may result from the intensity of the manifestation of resilience in a given situation.

Strong evidence for the criterion-related validity of the Mathematical Resilience Scale is provided by the results concerning the associations between the Mathematical Resilience Scale and math anxiety, math avoidance, intellectual helplessness in mathematics, and math motivation. In accordance with expectations (Johnston-Wilder et al., 2014; Kooken et al., 2016; Oszwa, 2022), we observed negative correlations between Mathematical Resilience Scale scores and math anxiety (except math testing anxiety and Struggle), math avoidance, and intellectual helplessness in mathematics. Those who believe that mathematics is useful and can be mastered by any hard-working person feel less apprehension related to various math activities (learning, testing, and math problem solving), engage in mathematics activities more, and feel higher math self-efficacy. The lack of a relationship between math testing anxiety and Struggle may be explained by the fact that the situation of being tested requires mastery in math, while Struggle items are related to the math learning process.

We tested whether math motivation is positively correlated with mathematical resilience (Bandura, 1989; Oszwa, 2022). Indeed, we confirmed that individuals who are motivated to learn math are more likely to persist through challenges and setbacks. In particular, we observed a moderate to strong relationship between amotivation-intrinsic motivation and Mathematical Resilience Scale Total score and the Value dimension. This means that people who value mathematics highly are also internally motivated to learn it. Important practical implications stem from this observation. If students drop out from the STEM area because of their low motivation to learn math, interventions directed towards math-related beliefs (e.g., that math is impossible to understand) would increase interest and participation in STEM. However, this hypothesis needs verification in a well-designed experiment. We noted that external motivation did not correlate with mathematical resilience in the struggle dimension. It is likely that external-oriented people do not see the value of overcoming difficulties in the math learning process as they are motivated by other stimuli.

We also obtained results that indicate only partial criterion validity, although our initial expectations regarding the relationships between variables may have been incorrect. We observed an inconsistent pattern of results regarding the relationship between the Mathematical Resilience Scale and math achievement. The math achievement test result correlated weakly and positively with Mathematical Resilience Scale Total score and the Value subscale, while math grades correlated only with the Value subscale. However, the significant relationship between Mathematical Resilience Scale Total score and math achievement likely depends on the Value subscale items (there is no relationship between math achievement and Struggle and Growth). This suggests that beliefs about the value of mathematics are more important for math achievement than beliefs about the role of struggle in math and about mathematical abilities. However, it should be noted that the study was conducted in adults who had mostly finished their math education, thus the results may be biased by many issues, e.g., participants did not remember their school grades and were not motivated enough to solve math problems. Moreover, as the sample consisted of people of various ages, their beliefs regarding math could have changed over time. We tested adults who mostly were not related to math activity in their fields of study and profession (the STEM group was underrepresented in comparison to the HSS and OTHER groups). Moreover, the mathematical achievement test we used, although previously tested on a sample of adults and having good psychometric properties, could also have influenced the results. The content of the tasks did not go beyond high school level and the average level of difficulty was quite easy. Previous studies conducted on senior secondary students (Awofala, 2021) indicated that results on the Mathematical Resilience Scale predict math achievement. Being engaged in constant math activity is likely key to observing a significant relationship between mathematical resilience and math outcomes. Therefore, in future studies it is worth examining the level of the sense of mathematical resilience during the process of solving mathematical problems instead of the results of the achievement test.

Further results that partially demonstrate the validity of the scale concern intergroup differences. In accordance with our assumptions, we observed that women have lower mathematical resilience than men, but only in the Value dimension. This result contrasts with the previous findings of Else-Quest et al. (2013), who indicated no gender differences in the evaluation of the importance of mathematics. We also observed that the STEM group in comparison to the HSS and OTHER groups had higher scores in Mathematical Resilience Scale Total score and the Value subscale. HSS and OTHER did not differ in any score. These results partially confirmed what is known from previous studies on math anxiety (Núñez-Peña et al., 2016) and math attitude (Szczygieł, 2023): women and non-STEM individuals feel more negative emotions and present more negative beliefs related to mathematics than other groups (men and STEM individuals). The obtained results allow us to state that the differences between groups (women and men; STEM, HSS, OTHER) in the level of mathematical resilience are not so obvious. At the same time, this means that the obtained results should not be treated as an argument against the validity of the scale. Rather, further research on the phenomenon of mathematical resilience in different contexts is necessary.

We assumed that the Mathematical Resilience Scale would be unrelated or only very weakly related to Polish grades and intellectual helplessness in Polish. Indeed, our results confirmed these expectations. The Value subscale correlated weakly and positively with intellectual helplessness in Polish and weakly and negatively with grades in Polish. People who value mathematics more may spend less time learning Polish, obtain worse grades in Polish, and feel helplessness in the face of humanistic problems, like writing essays. Young people often choose their education path before high school and then focus on their primary subject, like mathematics, language, sport, etc. The Struggle and Growth subscales were not related to Polish grades and intellectual helplessness in Polish. These results can be explained by the fact that beliefs that it is important to struggle with tasks and that special abilities are necessary to understand problems are specific to mathematics. In other words, there is no relationship between Polish language grades and the feeling of intellectual helplessness in Polish and mathematical resilience in the area of Struggling and Growth, because students who have difficulties with Polish do not attribute the same explanations as for mathematics. Many people believe that overcoming difficulties in solving math problems and possessing special mathematical abilities are important for learning mathematics, while the same features are not attributed to learning the native language.

The reliability of the whole scale and subscales was mostly satisfactory (except men and STEM in Struggle subscale) and similar to previous studies (Awofala, 2021; Gürefe & Akçakın, 2018; Kooken et al., 2016). Therefore, the usefulness of the Mathematical Resilience Scale in men and STEM individuals is limited. However, further studies should test the internal consistency of the Mathematical Resilience Scale in a larger group of men and STEM individuals and establish whether the results are stable over time.

Limitations and Further Directions

The study was conducted among Polish volunteers in laboratory and online studies. The snowball method of data collection was applied and we did not collect information on participants' place of residence, therefore we can only suppose that the sample is representative of the adult Polish population. However, we observed gender inequality in the study (men were underrepresented) and a disproportion in age distribution (most of the participants were young adults). Future studies should collect more detailed demographic data and focus on the representativeness of the sample. We asked participants about their area of study and profession, but this only extended as far as which group was relevant: STEM, HSS or OTHER. As we did not provide detailed descriptions of the fields, there is a risk that some participants actually worked or studied in more than one group or in a group that could not be indicated. Kooken et al. (2016) and Gürefe and Akçakın (2018) validated the Mathematical Resilience Scale on undergraduate students, and Awofala (2021) tested senior secondary students, while our study was conducted among a diverse group of students and non-students. In our opinion, studies on mathematical resilience using the Mathematical Resilience Scale should be continued particularly in groups of STEM students, teachers and pre-service STEM and early education teachers. The mathematical resilience construct combines cognitive, affective, and behavioral aspects of math activity and may be a key aspect of the narrative on mathematics that is presented for future generations. Although we see huge value in testing mathematical resilience in various groups of adults, future studies should also focus on adolescents and children. Early identification of those who value math negatively and hold unfavorable views on the role of struggles and the nature of growth in math may reduce mathematical resilience and, in turn, increase engagement in mathematics.

We checked participants' math grades and math performance; however, further validation studies should include a multidimensional standardized mathematical achievement test in order to establish robust correlations between mathematical resilience and mathematical outcomes. The internal consistency of the Mathematical Resilience Scale was satisfactory, but further tests are needed to provide test-retest reliability. It should be emphasized that more theoretical analyses on mathematical resilience are also needed. As the results showed moderate to strong relationships between the Mathematical Resilience Scale and math anxiety and math motivation, the question regarding the independence of these constructs arises. On the other hand, the results show no relationship between the Mathematical Resilience Scale and general resilience, thus they challenge assumptions that mathematical resilience is rooted in general resilience. However, caution should be exercised with this latter conclusion because the reliability of the Brief Resilience Coping Scale was low.

Conclusion

The Polish-language version of the Mathematical Resilience Scale for adults has satisfactory psychometric properties. The three-factor structure of the scale (Value, Struggle, Growth) with a superior factor (Total) and measurement invariance across gender and field of study and profession was confirmed. We established the convergent and discriminant validity of the scale, showing negative correlations between mathematical resilience and math anxiety, math avoidance, and intellectual helplessness in mathematics, and a positive correlation between mathematical resilience and mathematical achievement (partially) and math learning motivation. Mathematical Resilience Scale scores were not or were weakly associated with intellectual helplessness in Polish and Polish high school grades, as expected. We also observed gender and academic and professional differences in mathematical resilience, albeit only for Value. We believe it is valuable to examine mathematical resilience among adults – particularly parents and early childhood educators – as their narratives about mathematics can significantly influence students' mathematical attitudes and outcomes. Screening mathematical resilience using the Mathematical Resilience Scale could be an easy and useful method to select those who need more support in the field of STEM education. However, further studies on the nature of mathematical resilience are needed as we have provided arguments regarding the independence of mathematical resilience from resilience and its strong relationship with math motivation and math anxiety.

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Competing Interests: The authors have declared that no competing interests exist.

Data Availability: The research data and analysis code for this study are publicly available (see Szczygieł, 2024S).

Supplementary Materials

The Supplementary Materials contain the following items (for access, see Szczygieł, 2024S):

- Research data
- Analysis code

Index of Supplementary Materials

Szczygieł, M. (2024S). *The psychometric properties of the Polish-language version of the Mathematical Resilience Scale* [Research data and analysis code]. OSF. https://doi.org/10.17605/OSF.IO/P45QZ

References

Ashcraft, M. H., & Krause, J. A. (2007). Working memory, mathematics performance and math anxiety. *Psychonomic Bulletin & Review, 14*(2), 243–248. https://doi.org/10.3758/BF03194059

Assarkhaniki, Z., Rajabifard, A., & Sabri, S. (2020). The conceptualisation of resilience dimensions and comprehensive quantification of the associated indicators: A systematic approach. *International Journal of Disaster Risk Reduction, 51*, Article 101840. https://doi.org/10.1016/j.ijdrr.2020.101840

Awofala, A. O. A. (2021). A validation of the Mathematical Resilience Scale for twelfth graders through confirmatory factor analysis and its relationship with achievement in mathematics in Nigeria. *SN Social Sciences, 1*(8), Article 204. https://doi.org/10.1007/s43545-021-00212-8

Bandura, A. (1989). Human agency in social cognitive theory. *American Psychologist, 44*(9), 1175–1184. https://doi.org/10.1037/0003-066X.44.9.1175

Bandura, A. (1997). *Self-efficacy: The exercise of control.* W. H. Freeman.

Bandura, A. (2000). Exercise of human agency through collective efficacy. *Current Directions in Psychological Science, 9*(3), 75–78. https://doi.org/10.1111/1467-8721.00064

Bedyńska, S., Krejtz, I., & Sedek, G. (2018). Chronic stereotype threat is associated with mathematical achievement on representative sample of secondary schoolgirls: The role of gender identification, working memory, and intellectual helplessness. *Frontiers in Psychology, 9*, Article 428. https://doi.org/10.3389/fpsyg.2018.00428

Chen, F. F. (2007). Sensitivity of goodness of fit indexes to lack of measurement invariance. *Structural Equation Modeling, 14*(3), 464–504. https://doi.org/10.1080/10705510701301834

Chinn, S. (2012). Beliefs, anxiety, and avoiding failure in mathematics. *Child Development Research, 2012*, Article 396071. https://doi.org/10.1155/2012/396071

Cipora, K., Szczygieł, M., Willmes, K., & Nuerk, H.-C. (2015). Math anxiety assessment with the Abbreviated Math Anxiety Scale: Applicability and usefulness: Insights from the Polish adaptation. *Frontiers in Psychology, 6*, Article 1833. https://doi.org/10.3389/fpsyg.2015.01833

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences.* Routledge Academic.

Covington, M. V. (1992). *Making the grade: A self-worth perspective on motivation and school reform.* Cambridge University Press. https://doi.org/10.1017/CBO9781139173582

Deci, E., Vallerand, R., Pelletier, L., & Ryan, R. M. (1991). Motivation and education: The self-determination perspective. *Educational Psychologist, 26*(3–4), 325–346. https://doi.org/10.1080/00461520.1991.9653137

Dweck, C. S. (2000). *Self-theories.* Psychology Press.

Else-Quest, N. M., Mineo, C. C., & Higgins, A. (2013). Math and science attitudes and achievement in the intersection of gender and ethnicity. *Psychology of Women Quarterly, 37*, 293–309. https://doi.org/10.1177/0361684313480694

Evans, J. (1996). *Straightforward statistics for the behavioral sciences.* Brooks/Cole.

Góźdź, J. (2015). Konstrukcja kwestionariusza motywacji do nauki w oparciu o koncepcję self-determination theory E. Deciego, R.M. Ryana [Construction questionnaire on motivation in education in the basis self-determination theory E. Deci's, R.M. Ryan's]. *Przegląd Pedagogiczny* [Pedagogical Review], *2*, 263–270.

Gürefe, N., & Akçakın, V. (2018). The Turkish adaptation of the Mathematical Resilience Scale: Validity and reliability study. *Journal of Education and Training Studies, 6*(4), 38–47. https://doi.org/10.11114/jets.v6i3.2992

Hopko, D. R., Mahadevan, R., Bare, R. L., & Hunt, M. K. (2003). The Abbreviated Math Anxiety Scale (AMAS): Construction, validity, and reliability. *Assessment, 10*(2), 178–182. https://doi.org/10.1177/1073191103010002008

Hu, L.-t., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling, 6*(1), 1–55. https://doi.org/10.1080/10705519909540118

Johnston-Wilder, S., Brindley, J., & Dent, P. (2014). *A survey of mathematics anxiety and mathematical resilience among existing apprentices.* Gatsby Charitable Foundation.

Johnston-Wilder, S., & Lee, C. (2010). Mathematical resilience. *Mathematics Teacher, 218*, 38–41.

Karpińska, E., Radtke, B. M., & Wierzbowski, J. (2019). *Zestaw Sprawdzianów Umiejętności Szkolnych dla Poradnictwa Psychologiczno-Pedagogicznego. Matematyka – Szkoła Podstawowa Klasy IV-VIII.* [Set of School Skills Tests for Psychological and Pedagogical Counseling. Grade IV-VIII.] Gdańsk: Pracownia Testów Psychologicznych i Pedagogicznych.

Kline, R. B. (2016). *Principles and practice of structural equation modeling*. The Guilford Press.

Knopik, T., & Oszwa, U. (2023). Mathematical resilience and motivation to study in mathematically gifted students – Self-determination approach. *Przegląd Badań Edukacyjnych* [Educational Studies Review], *1*(41), 5–24. https://doi.org/10.12775/PBE.2023.001

Kooken, J., Welsh, M. E., McCoach, D. B., Johnston-Wilder, S., & Lee, C. (2016). Development and validation of the Mathematical Resilience Scale. *Measurement & Evaluation in Counseling & Development, 49*(3), 217–242. https://doi.org/10.1177/0748175615596782

Lee, C., & Johnston-Wilder, S. (2017). The construct of mathematical resilience. In U. X. Eligio (Ed.), *Understanding emotions in mathematical thinking and learning* (pp. 269-291). Academic Press.

Luthar, S. S., & Cicchetti, D. (2000). The construct of resilience: Implications for interventions and social policies. *Development and Psychopathology, 12*(4), 857–885. https://doi.org/10.1017/S0954579400004156

Luthar, S. S., Cicchetti, D., & Becker, B. (2000). The construct of resilience: A critical evaluation and guidelines for future work. *Child Development, 71*(3), 543–562. https://doi.org/10.1111/1467-8624.00164

Martin, A. J., & Marsh, H. W. (2006). Academic resilience and its psychological and educational correlates: A construct validity approach. *Psychology in the Schools, 43*(3), 267–281. https://doi.org/10.1002/pits.20149

Martin, A. J., & Marsh, H. W. (2008). Academic buoyancy: Towards an understanding of students' everyday academic resilience. *Journal of School Psychology, 46*(1), 53–83. https://doi.org/10.1016/j.jsp.2007.01.002

Mîndrilă, D. (2010). Maximum Likelihood (ML) and Diagonally Weighted Least Squares (DWLS) estimation procedures: A comparison of estimation bias with ordinal and multivariate non-normal data. *International Journal of Digital Society, 1*(1), 60–66. https://doi.org/10.20533/ijds.2040.2570.2010.0010

Niemierko, B. (1999). *Pomiar wyników kształcenia* [Measuring educational outcomes]. WSiP.

Nooteboom, B., & de Jong, G. (2000). *The causal structure of long-term supply relationships: An empirical test of a generalized transaction cost theory.* Kluwer Academic.

Núñez-Peña, M. I., Guilera, G., & Suárez-Pellicioni, M. (2014). The Single-Item Math Anxiety Scale (SIMA): An alternative way of measuring mathematical anxiety. *Journal of Psychoeducational Assessment, 32*(4), 306–317. https://doi.org/10.1177/0734282913508528

Núñez-Peña, M. I., Suárez-Pellicioni, M., & Bono, R. (2016). Gender differences in test anxiety and their impact on higher education students' academic achievement. *Procedia: Social and Behavioral Sciences, 228*, 154–160. https://doi.org/10.1016/j.sbspro.2016.07.023

Oszwa, U. (2022). Mathematical resilience as a conceptual framework for school practice. *Multidisciplinary Journal of School Education, 11*(1), 99–114. https://doi.org/10.35765/mjse.2022.1121.05

Piórowska, A., Basińska, M. A., Piórowski, K., & Janicka, M. (2017). The Polish adaptation of the Brief Resilient Coping Scale. *Przegląd Pedagogiczny, 1*, 178–192.

Putnick, D. L., & Bornstein, M. H. (2016). Measurement invariance conventions and reporting: The state of the art and future directions for psychological research. *Developmental Review, 41*, 71–90. https://doi.org/10.1016/j.dr.2016.06.004

Richardson, F. C., & Suinn, R. M. (1972). Mathematics Anxiety Rating Scale: Psychometric data. *Journal of Counseling Psychology, 19*(6), 551–554. https://doi.org/10.1037/h0033456

Ricketts, S. N., Engelhard, G., Jr., & Chang, M.-L. (2017). Development and validation of a scale to measure academic resilience in mathematics. *European Journal of Psychological Assessment, 33*(2), 79–86. https://doi.org/10.1027/1015-5759/a000274

Rokhmah, K. N., Retnawati, H., & Solekhah, P. (2019). Mathematical resilience: Is that affecting the students' mathematics achievement? *Journal of Physics: Conference Series, 1320*(1), Article 012036. https://doi.org/10.1088/1742-6596/1320/1/012036

Rosseel, Y. (2012). lavaan: An R package for structural equation modeling. *Journal of Statistical Software, 48*(2), 1–36. https://doi.org/10.18637/jss.v048.i02

Ryan, R. M., & Deci, E. L. (2000). Intrinsic and extrinsic motivations: Classic definitions and new directions. *Contemporary Educational Psychology, 25*(1), 54–67. https://doi.org/10.1006/ceps.1999.1020

Schermelleh-Engel, K., Moosbrugger, H., & Müller, H. (2003). Evaluating the fit of structural equation models: Tests of significance and descriptive goodness-of-fit measures. *Methods of Psychological Research Online, 8*(2), 23–74.

Sędek, G., & MacIntosh, D. N. (1998). Intellectual helplessness: Domain specificity, teaching styles, and school achievement. In M. Kofta, G. Weary, & G. Sędek (Eds.), *Personal control in action: Cognitive and motivational mechanisms* (pp. 419–443). Springer.

Sinclair, V. G., & Wallston, K. A. (2004). The development and psychometric evaluation of the Brief Resilience Coping Scale. *Assessment, 11*(1), 94–101. https://doi.org/10.1177/1073191103258144

Szczygieł, M. (2022). Not only reliability! The importance of the ecological validity of the Math Anxiety Questionnaire for adults. *European Journal of Psychological Assessment, 38*(2), 78–90. https://doi.org/10.1027/1015-5759/a000646

Szczygieł, M. (2023). The psychometric properties of the Mathematics Attitude Scale for Adults (MASA). *Current Psychology, 42*(21), 18447–18458. https://doi.org/10.1007/s12144-022-02980-9

Szczygieł, M., & Kutt, M. (2022). *Math anxiety – A key factor in math education* [Poster presentation]. ECP – 17th European Congress of Psychology, Ljubljana, Slovenia.

Szczygieł, M., & Sari, M. H. (2024). The relationship between numerical magnitude processing and math anxiety, and their joint effect on adult math performance, varied by indicators of numerical tasks. *Cognitive Processing, 25*(3), 421–442. https://doi.org/10.1007/s10339-024-01186-0

Tabachnick, B. G., & Fidell, L. S. (2001). *Using multivariate statistics.* Allyn and Bacon.

Yeager, D., & Dweck, C. (2012). Mindsets that promote resilience: When students believe that personal characteristics can be developed. *Educational Psychologist, 47*(4), 302–314. https://doi.org/10.1080/00461520.2012.722805

Appendix

Table A1

Polish-English Language Version of the MRS and Descriptive Statistics

			Whole sample			
Item	**Polish Item Wording**	**Original English Item Wording**	***M***	***SD***	**Skew**	**Kurt**
MRS1	Matematyka jest kluczowa dla mojej przyszłości	Math is essential for my future	3.49	1.76	.26	-.97
MRS2	Matematyka będzie przydatna w mojej pracy zawodowej	Math will be useful to me in my life's work	3.72	1.88	.21	-1.13
MRS3	Lekcje matematyki są bardzo pomocne niezależnie od tego, co zdecyduję się studiować	Math courses are very helpful, no matter what I decide to study	4.59	1.83	-.38	-.91
MRS4	Znajomość matematyki w dużym stopniu przyczynia się do osiągnięcia założonych przeze mnie celów	Knowing math contributes greatly to achieving my goals	3.29	1.85	.44	-.93
MRS5	Posiadanie solidnej wiedzy matematycznej pomaga mi zrozumieć bardziej złożone tematy	Having a solid knowledge of math helps me understand more complex topics in my field of study	3.92	1.94	-.02	-1.18
MRS6	Myślenie matematyczne może mi pomóc w sprawach, które są dla mnie ważne	Thinking mathematically can help me with things that matter to me	4.11	1.98	-.11	-1.23
MRS7	Trudno byłoby odnieść sukces w życiu bez matematyki	It would be difficult to succeed in life without math	3.35	1.87	.34	-1.04
MRS8	Matematyka dobrze rozwija umiejętności myślenia, które są niezbędne do odniesienia sukcesu w każdej karierze	Math develops good thinking skills that are necessary to succeed in any career	4.38	1.87	-.26	-1.00
MRS9	Każdy zmaga się z matematyką w pewnym momencie	Everyone struggles with math at some point	5.77	1.51	-1.36	1.42
MRS10	Dobrzy matematycy doświadczają trudności w rozwiązywaniu problemów matematycznych	Good mathematicians experience difficulties when solving problems	5.30	1.53	-.71	-.24
MRS11	Osoby pracujące w dziedzinach związanych z matematyką czasami napotykają na wyzwania matematyczne	People who work in math-related fields sometimes find math challenging	6.13	1.04	-1.27	1.36
MRS12	Podczas wykonywania obliczeń matematycznych każdy czasami popełnia błędy	Everyone makes mistakes at times when doing math	6.56	.84	-2.20	4.97
MRS13	Zmaganie się z zadaniem jest normalnym elementem pracy na matematyce	Struggle is a normal part of working on math	6.20	1.05	-1.34	1.65
MRS14	Ludzie w mojej grupie rówieśniczej czasami zmagają się z matematyką	People in my peer group struggle sometimes with math	5.95	1.25	-1.18	.91
MRS15	Osoby, które są dobre z matematyki, mogą oblać trudny test z matematyki	People who are good at math may fail a hard math test	5.48	1.61	-.86	-.31
MRS16	Kiedy ktoś zmaga się z matematyką, nie oznacza to, że zrobił coś złego	When someone struggles in math, it doesn't mean they have done something wrong	6.29	1.08	-1.84	3.84
MRS17	Popełnianie błędów jest konieczne, aby stać się dobrym z matematyki	Making mistakes is necessary to get good at math	5.68	1.45	-1.08	.67
MRS18	Każdy może się nauczyć matematyki	Math can be learned by anyone	4.66	1.73	-.46	-.62

Item	Polish Item Wording	Original English Item Wording	Whole sample			
			M	*SD*	Skew	Kurt
MRS19	Jeśli ktoś nie jest osobą uzdolnioną matematyczną, nie będzie w stanie się wiele nauczyć	If someone is not a math person, they won't be able to learn much math	4.91	1.60	-.58	-.38
MRS20	Jeśli ktoś nie jest dobry z matematyki, nic nie można zrobić, aby to zmienić	If someone is not good at math, there is nothing that can be done to change that	5.85	1.32	-1.36	1.67
MRS21	Ludzie albo są dobrzy z matematyki, albo nie	People are either good at math or they aren't	4.90	1.70	-.52	-.58
MRS22	Umiejętności matematyczne każdego człowieka są określone w chwili urodzenia	Everyone's math ability is determined at birth	5.82	1.40	-1.22	1.02
MRS23	Niektórzy ludzie nie potrafią nauczyć się matematyki	Some people cannot learn math	3.77	1.79	.20	-.96
MRS24	Tylko mądrzy ludzie potrafią wykonywać obliczenia matematyczne	Only smart people can do math	5.98	1.30	-1.43	1.73

Note. Items MRS19-MRS24 are revised. Skew = Skewness; Kurt = Kurtosis.

Table A2

Zero-Order Pearson's Correlations Between All MRS Items

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1. MRS1																							
2. MRS2	.74***																						
3. MRS3	.57***	.49***																					
4. MRS4	.67***	.66***	.63***																				
5. MRS5	.63***	.56***	.65***	.70***																			
6. MRS6	.57***	.54***	.68***	.67***	.79***																		
7. MRS7	.51***	.48***	.55***	.56***	.57***	.56***																	
8. MRS8	.46***	.41***	.65***	.51***	.57***	.61***	.63***																
9. MRS9	.22***	.15**	.23***	.24***	.26***	.23***	.25***	.26***															
10. MRS10	.04	.03	.17***	.08	.14**	.15**	.11*	.13**	.15**														
11. MRS11	.05	.03	.22***	.13**	.17***	.19***	.17***	.19***	.20***	.59***													
12. MRS12	.06	.06	.14**	.11*	.14**	.15**	.11*	.10*	.25***	.34***	.44***												
13. MRS13	.10*	.07	.15**	.16**	.15**	.14**	.12*	.15**	.26***	.27***	.41***	.31***											
14. MRS14	.15**	.13**	.22***	.16**	.18***	.18***	.19***	.20***	.12*	.10*	.19***	.21***	.20***										
15. MRS15	.06	.03	.14**	.06	.07	.09	.06	.06	.07	.25***	.27***	.21***	.25***	.17***									
16. MRS16	-.04	-.02	.01	-.07	.01	.01	.04	.03	.08	.24***	.25***	.16**	.23***	.20***	.32***								
17. MRS17	.05	.02	.18***	.12*	.11*	.12*	.06	.15**	.24***	.28***	.30***	.26***	.30***	.13**	.28***	.30***							
18. MRS18	.25***	.24***	.34***	.29***	.26***	.28***	.29***	.34***	.19***	.03	.09*	.13**	.04	.09	.11*	-.03	.16**						
19. MRS19	.15**	.15**	.12*	.15**	.13**	.13**	.08	.08	.04	.00	.05	.14**	.04	.06	.03	.10*	.02	.43***					
20. MRS20	.18***	.19***	.22***	.17***	.20***	.22***	.14**	.12*	.09	.00	.10*	.18***	.04	.12*	.11*	.13**	.04	.35***	.49***				
21. MRS21	.19***	.20***	.25***	.18***	.22***	.26***	.12*	.18***	.07	.05	.16**	.20***	.07	.10*	.06	.08	.05	.33***	.45***	.54***			
22. MRS22	.08	.06	.11*	.04	.08	.09	.01	.05	.05	.08	.13**	.17***	.06	.05	.03	.06	.02	.16***	.35***	.36***	.48***		
23. MRS23	.17***	.18***	.20***	.17***	.19***	.17***	.21***	.21***	.01	.04	.12*	.10*	.07	.06	.06	-.04	.06	.48***	.36***	.33***	.45***	.30***	
24. MRS24	-.05	.05	-.01	-.05	-.04	.00	-.02	-.06	-.08	.09	.10*	.17***	.03	.04	.09	.19***	.07	.11***	.37***	.32***	.26***	.30***	.26***

Note. N = 443.
$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

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