



Adaptation of the modified abbreviated math anxiety scale: its relationship with mathematics self-efficacy and academic buoyancy

Ümit Kul¹ · Zeki Aksu¹ · Seydi Ahmet Satıcı²

Accepted: 19 March 2024 / Published online: 16 April 2024
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Abstract

Mathematics anxiety (MA) is a widely recognized phenomenon that refers to the negative thoughts, fears, and stress experienced by individuals when working with numbers. It has a severe impact on individuals ranging from elementary school students to college students across various countries. Despite several instruments available for measuring MA, the majority of them are in English. At this time, we first adapted the Modified Abbreviated Math Anxiety Scale (m-AMAS) to the Turkish culture to be used with early adolescent students. The m-AMAS was administered to 224 students (mean age: 13.35 years, SD = 0.49, 128 girls) and was found to be a valid and reliable tool for measuring MA. The study also explored the link between MA and math self-efficacy (MSE), academic buoyancy (AB). The findings support the validity of the 9-item, two-dimensional structure of the m-AMAS used in this research, as it was found to be comparable to the original scale tested on British students. Intriguingly, the results of the mediation analysis demonstrated that MA significantly predicted MSE, which in turn significantly predicted AB. Notably, the model unveiled a significant indirect effect between MA and AB, with a partial mediating effect of MSE. However, for a comprehensive understanding of this sequence, future research endeavours, encompassing longitudinal and experimental studies, are imperative.

Keywords Math anxiety · Self-efficacy · Academic buoyancy · Scale adaptation

Introduction

In the Programme for International Student Assessment (PISA) study, it was found that approximately 40% of 15-year-olds in Türkiye did not achieve advanced proficiency levels in mathematics, as reported by the OECD in 2023. The students' performance was assessed within a six-tier framework, where the majority were positioned in the second tier. Türkiye's average score in the PISA 2022 mathematics assessment was 453 points, which is below the OECD average of 472 points, indicating that a significant number of Turkish students face challenges in mastering mathematical concepts (OECD, 2023). Beyond cognitive challenges, learning mathematics involves a

complex interaction of emotional and motivational factors (Dowker et al., 2016; Pekrun & Loderer, 2020; Živković et al., 2023). Math anxiety (MA) is a prevalent issue, adversely affecting students' understanding, achievements and attitudes towards mathematics (Ashcraft, 2002; Bayırlı et al., 2021; Hembree, 1990; Kaba & Şengül, 2018; Namkung et al., 2019). As a significant barrier across all educational levels, MA impairs many students' ability to engage effectively with numerical tasks, both in academic settings and daily life (Barroso et al., 2021; Khasawneh et al., 2021; Peker & Ertekin, 2011; Yu et al., 2024). This emotional reaction can have serious long-term consequences, including avoidance of STEM careers and poor academic performance (Daker et al., 2021).

Assessing MA at the onset of students' educational paths is essential for early identification and intervention. It also plays a key role in the development and evaluation of targeted intervention programs (Ciparo et al. 2019). This study aims to address the lack of MA assessment instruments, particularly focusing on the Turkish educational context, where most existing tools are in English. The research involves adapting and validating a MA scale suitable for

✉ Ümit Kul
umitkul@artvin.edu.tr

¹ Department of Mathematics Education, Faculty of Education, Artvin Coruh University, Artvin 08000, Türkiye

² Department of Psychological Counselling, Faculty of Education, Yıldız Technical University, Istanbul, Türkiye

Turkish students, while also exploring the intricate relationships between MA, math self-efficacy (MSE), and academic buoyancy (AB), to deepen our understanding of how these variables interact and influence each other.

Math anxiety

MA, a multifaceted psychological phenomenon, is associated with a range of factors, including biological, educational, cognitive, and neural aspects (Dowker et al., 2016). This form anxiety manifests as a heightened state of mental agitation experienced by learners when faced with mathematical tasks, primarily driven by fear, worry, or a sense of inadequacy in their mathematics abilities (Ashcraft, 2002). Recognized as a distinct and persistent psychological construct, MA is related to, yet distinguishable from, other forms of anxiety (Carey et al., 2016; Cheng et al., 2022). It is characterized by emotional responses such as tension and apprehension in math contexts (Ashcraft & Moore, 2009). These emotional reactions often correlate with lower math achievement (Caviola et al., 2022). Research indicates that there is a bidirectional relationship between mathematics performance and MA: lower performance in mathematics can lead to higher levels of MA, and conversely, elevated MA can contribute to decreased performance in mathematics (Dowker et al., 2016). The nature of this relationship is a subject of debate, with various theories proposed to explain it (Carey et al., 2016). Consequently, studies have shown a significant negative relationship between MA and mathematical achievement across different age groups (Namkung et al., 2019; Zhang et al., 2019). MA not only impacts academic performance in math-related subjects negatively (Barroso et al., 2021) but can also lead to a cycle of avoidance and increased anxiety about math tasks, further impeding mathematical abilities in daily life (Ho et al., 2000; Richardson & Suinn, 1972). This cyclical nature of MA highlights the urgency for effective interventions and support mechanisms in educational settings to mitigate its pervasive and long-lasting effects.

Evaluating individual MA is challenging (Reyes, 1984). However, it holds significance in understanding and decreasing one's MA (Hembree, 1990). Notwithstanding the assessing difficulties, various research studies have been conducted to measure MA for many years (Alkan, 2018; Ciparo et al. 2019; Kazelskis et al., 2000). Different definitions of MA are also reflected in research on self-report questionnaires of MA. Researchers frequently utilize the Abbreviated Mathematics Anxiety Scale (AMAS) to assess MA across various age groups, owing to its optimal number of items and effective approach to measuring anxiety (Caviola et al., 2017; Hopko et al., 2003). The AMAS, originally

developed by Hopko et al. (2003), comprises two dimensions: Learning Math Anxiety (LMA) and Math Evaluation Anxiety (MEA) and is supported by high loading items from MARS, explaining 70% variance in MA. The scale's two-factor structure has been validated with high internal consistency and test-retest reliability, and it has been translated into several languages including Polish, German, and Spanish, consistently maintaining its structural integrity (Cipora et al., 2018; Caviola et al., 2017; Martín-Puga et al., 2020; Schillinger et al., 2018). The current selection of scales for measuring MA, including the AMAS, may not be ideally suited for children or may lack extensive validity evidence. To remedy this, Carey et al. (2017) modified the AMAS to create the m-AMAS, specifically for British children aged 8–13. This revision involved alterations in language and content to more accurately reflect children's experiences with MA. The aim was to craft a version of the scale that resonates more closely with children's experiences with MA. For instance, the items were revised to "Having to complete a worksheet by yourself" and "Thinking about a math test the day before you take it". The m-AMAS, now available in languages such as Arabic and Polish, has retained its two-factor structure and demonstrated good reliability in these various adaptations (Megreya et al., 2023; Szczygieł, 2019). However, there is a noticeable gap in the adaptation of MA scales for Turkish students, with most studies focusing on revisions of MARS instead (e.g., Baloğlu, 2010; Baloğlu & Balgalmış, 2010). This gap becomes increasingly significant as the complexity and cognitive demands of middle school mathematics grow, potentially increasing MA among students in early adolescence. Therefore, adapting a well-validated scale like the m-AMAS for the Turkish context is vital for accurately exploring MA. This study seeks to bridge this gap by assessing the psychometric characteristics of the Turkish version of the m-AMAS, thereby offering a vital tool for measuring MA in children and enhancing our understanding of MA in various educational environments. The forthcoming section explores the dynamic relationship between MA, MSE, and AB, shedding light on how these concepts intertwine to shape students' academic performance.

The relationship between math anxiety, self-efficacy and academic buoyancy

Studies have consistently shown a close connection between MA and constructs such as MSE (Akin & Kurbanoğlu, 2011; Macmull & Ashkenazi, 2019; Gunderson et al., 2018; Unlu et al., 2017), and AB (Lei et al., 2021; Martin & Marsh, 2008). The experiences of difficulties and setbacks in academic life can shape children's confidence or lack thereof in mathematical operations, thereby influencing

their MSE and, consequently, their levels of MA. This suggests that MA can profoundly impact a learner's motivation and ability to engage with mathematical tasks, as well as their capacity to handle academic challenges. Truthfully, the studies on the relevant fields of AB indicates a remarkable connection with MA (Martin & Marsh, 2008).

AB, described as learners' capacity to successfully overcome academic difficulties and impediments that are faced during daily school life such as low grades, feelings of failure in exams, and challenging homework (Martin, 2013). This concept, rooted in positive psychology and part of the Motivation and Engagement Wheel model by Martin and Marsh (2008), encompasses elements like self-efficacy, persistence, and low anxiety, all of which are crucial in fostering AB and mediating its impact on academic achievements. These elements are not only crucial in predicting AB (Martin et al., 2010), but they also play a mediating role in the influence of AB on future academic achievements. This framework becomes increasingly relevant during the early years of secondary school, a period typically marked by heightened academic challenges.

The overlap between AB and MSE is particularly noteworthy. Grounded in Social Cognitive Theory, both buoyancy and self-efficacy play a vital role in determining a student's effort and persistence in the face of academic adversity (Smith, 2020; Schneider & Preckel, 2017). Self-efficacy, as defined by Bandura (1997, 2012), refers to an individual's belief in their capability to successfully complete specific tasks, like solving a math problem. This self-belief is crucial for motivation in tasks like mathematics (Pintrich & Schunk, 2002), with studies showing that low MSE is often associated with high MA (Hackett & Betz, 1989).

The relationship between MA, MSE, and AB has been studied, revealing important insights. Pajares and Graham (1999) investigated this connection and found a negative correlation between MA and MSE among middle school students. Their study showed that students with lower levels of MA tended to exhibit higher MSE, which in turn, enhanced their competence in mathematical calculations and performance in cognitively demanding tasks. Further reinforcing this relationship, Akin and Kurbanoglu (2011) identified MSE as a strong inverse predictor of MA. This implies that an increase in a student's self-belief in their mathematical abilities can significantly reduce their experience of MA. Martin and Marsh (2008) extended the discussion to include AB, identifying anxiety, alongside self-efficacy, as a crucial predictor of AB. Smith (2020) supported the notion that self-efficacy, akin to AB, bolsters the ability to rebound from academic challenges. They noted that students with high levels of AB and self-efficacy tend to be more resilient, open to feedback, and realistic in setting

goals, thus better equipped to handle academic setbacks. Martin and Marsh (2008) determined that along with self-efficacy, anxiety is regarded as a powerful predictor of AB. Likewise Smith (2020) sustains the idea that self-efficacy, like AB, enhances the capacity to recover from academic difficulties. The researcher also continues that learners with high buoyancy and self-efficacy are more demanding, open-minded to recommendations, and more reasonable in their goal expectations, hence learners are more disposed to deal with setbacks if a target is not successful. Weißenfels et al. (2023) found that the correlation between math performance and AB has been firmly established, and this relationship is further explained through the concept of MSE. This finding underscores the significance of AB as a construct and the importance of identifying its predictors to assist researchers and educators in developing strategies to enhance students' AB. Given these findings, it becomes clear that there is an imperative need to deepen our understanding of the interplay between MA, MSE, and AB.

Purpose of the present study

The m-AMAS instrument has been successfully adapted into various languages and applied across diverse populations (Carey et al., 2017; Megreya et al., 2023; Szczygieł, 2019). However, the absence of a Turkish version of the m-AMAS restricts the capacity to compare and generalize findings from international studies on MA to the Turkish educational context. Recognizing the need for a concise and relevant scale to measure MA in students, the current study seeks to address this research gap in Türkiye. It aims to translate and validate the m-AMAS in Turkish, using a sample of Turkish students. This endeavour is expected to enhance understanding of the factor structure of MA measures in Turkish and assess their efficacy in this specific population. Furthermore, there is scant research on how MA relate to individual constructs such as AB and MSE, particularly in a mediational path model. Recognizing the potential influence of MA on both MSE and AB, it becomes crucial to examine their interrelationships. The current research aims to investigate the combined effect of these variables, integrating them in a comprehensive model. Drawing upon the established relationships between MA, MSE, and AB (Adal & Yavuz, 2017; Akin & Kurbanoglu, 2011; Lee, 2009; Martin & Marsh, 2008; Macmull & Ashkenazi, 2019), this study hypothesizes a negative association between MA and both MSE and AB. To systematically investigate these relationships, the following hypotheses are proposed:

H1. The Turkish version of the m-AMAS is expected to exhibit a two factor structure.

H2. MA is significantly negatively correlated with academic achievement, MSE, and AB.

H3. MSE acts as a mediator in the relationship between MA and AB.

Method

Research design

The research design of this study is centred around a quantitative methodology, utilizing self-report instruments within a descriptive-correlational method. This method is particularly effective for exploring the relationships and associations between different variables. The primary method of data collection in this study was a cross-sectional survey. Such a survey is advantageous in providing a snapshot of the current state and characteristics of the sampled population at a single point in time.

Participants

The sample for this study was selected using a convenience sample technique, common approach in educational research where participants are chosen based on their availability and willingness to take part. This technique was utilized to recruit 224 adolescents students from north-eastern region of Türkiye. The N: q rule, a useful guideline for the relationship between sample size and model complexity, was employed using a scale adaptation sample (Kline, 2010). Considering Kline's expectation of a 20:1 ratio as the N: q ratio, a sample size of 180 for a 9-item scale was deemed more than sufficient in the current study. In addition to this rule, G*Power (Faul et al., 2009) was utilized to determine the required sample size. According to G*Power, having a sample of 218 participants is deemed sufficient for three predictor variables with a real power of 0.95. This further signifies the adequacy of the sample size in the current study.

Procedure

Prior to participation, students, their parents, and school principals were informed about the study's objectives and assured of data anonymity. Consent was obtained from all parties. The research was conducted exclusively with participants who volunteered. They were informed that they had the option to withdraw from the study at any point. Informed consent was secured from all participants prior to their involvement in the study. The study received ethics approval from the University Ethical Review Board (Approval No: E-18457941-050.99-72860, Date: 05.12.2022), ensuring compliance with the Declaration of Helsinki guidelines for research ethics. The survey was conducted in a group

setting within a 40-minute class period at schools, utilizing a paper-pencil format. Mathematics scores were gathered from school records at the end of the term. To maintain measurement reliability, only the final mathematics grades were used, as they are influenced by the initial half-term grades. The correlation found between these half-term and year-end grades was 0.89, indicating satisfactory consistency in the assessment method.

Instruments

This section describes the measures employed for data collection, focusing on specific constructs. Students were respond to items in the measures using a five-point Likert scale. This scale was designed to assess the degree of their agreement or disagreement with each statement, where the responses ranged from 1, indicating “strongly agree, low anxiety,” to 5, signifying “strongly disagree, high anxiety”. To clarify interpretation, items were reverse-coded, ensuring that higher scores reflected greater levels of the measured factor. Average scores were computed for each measures.

The modified abbreviated mathematics anxiety scale

The Abbreviated Math Anxiety Scale (AMAS) is a robust psychometric tool designed to assess MA in undergraduate students, as established by Hopko et al. (2003). This widely recognized scale includes 9 items, evaluating two dimensions of MA. The validity of the AMAS's two-factor structure was confirmed through exploratory and confirmatory factor analyses, highlighting strong internal consistency (α s=0.90, 0.85, and 0.88) and test-retest reliability (r s=0.85, 0.78, and 0.83) for the total score, LMA, and MEA, respectively. The scale's scoring ranges from 9 to 45, with higher scores indicating greater MA, and is divided into two factors: LMA (5 items) and MEA (4 items).

m-AMAS, developed by Carey et al. (2017), is a version of the original AMAS. It's specifically designed for a large cohort of British children, particularly for assessing MA in year 7/8 students. The m-AMAS, which has demonstrated reliability and validity, as evidenced by a high Cronbach's alpha value of 0.86 for the total scale. This version is also considered suitable for Turkish adaptation. Respondents rate these items on a 5-point scale, ranging from 1 (low anxiety) to 5 (high anxiety), in relation to their anxiety levels in different math-related scenarios. For Turkish adaptation, the questionnaire, originally in English, was translated using a forward-translation approach by two professional bilingual translators with expertise in psychology and math education. Any minor discrepancies in the translation were addressed and resolved through mutual agreement.

Math self efficacy scale

The Math Self-Efficacy scale was designed by Umay (2001) to measure an individual's level of confidence in their mathematical abilities. This scale consists of three factors as; five items on “mathematics self-perception”, six items on “awareness regarding mathematical behaviour”, and three items on “the ability to transform mathematics into life skills”. The reliability coefficient of the 5-point Likert scale ranging from 1 to 5, was 0.88, and the median of the validity coefficients of the scale items was 0.64. It was thought that this median value could provide validity for the entire scale. In this study, the MSE also demonstrated very good reliability ($\alpha=0.84$).

Academic buoyancy scale

The Academic Buoyancy scale (ABS), developed by Martin and Marsh (2008), comprises four items. The Cronbach's α coefficient for Time 1 and Time 2 was respectively 0.80 and 0.82. Children assess themselves on these items using a 5-point Likert scale, ranging from 1 (Strongly Disagree) to 5 (Strongly Agree), with an example item being “I don't let a bad mark affect my confidence”. The total score on this scale, with a maximum of 20, reflects the level of academic buoyancy, where a higher score indicates greater buoyancy. In this study, the internal consistency of the ABS, as measured by Cronbach's Alpha, was found to be 0.75. This consistency aligns with previous research by Martin et al. (2017), which has validated the ABS as a reliable and valid tool across various cultural contexts.

Data analysis

The present study employed Confirmatory Factor Analysis (CFA) with Maximum Likelihood Estimation, as implemented in AMOS Graphics, to evaluate both the 9-item and two-dimensional versions of the mAMAS. To assess the adequacy of the models, the following indices were utilized: Comparative Fit Index (CFI), Incremental Fit Index (IFI), Goodness-of-Fit Index (GFI), and Standardized Root Mean Square Residual (SRMR). Moreover, the item-total correlations of the scale were scrutinized, and a range of reliability coefficients, including Cronbach's alpha (α) and McDonald's omega (ω), were computed to assess the internal consistency of the scale. Additionally, the correlation coefficient was employed to examine the association between MA and other variables, such as MSE, AB, and demographic factors, including gender, class level, and academic achievement. Furthermore, a network analysis was conducted using JASP to illustrate the interrelationships among all variables. Subsequently, bootstrapping mediation models were tested,

with 5,000 bootstrapped samples, to investigate the potential mediating effect of MSE on the relationship between MA and AB. The models also considered gender, class level, and academic achievement as covariates.

Results

This study was utilized to recruit 224 adolescents from northeastern region of Türkiye. The participants' mean GPA was 71.01 (SD=19.94, on a 10-100-point scale). Of the participants, 126 were in 7th grade (56.3%) and 98 were in 8th grade (43.8%). The average age of the participants was 13.35 (SD=0.49) years.

CFA revealed satisfactory model fit for the two-dimensional m-AMAS, with the following indices: $\chi^2_{(26, N=224)}=75.54, p<.001$; $\chi^2/df=2.90$, CFI=0.917, IFI=0.918, GFI=0.933, SRMR=0.079. The factor loadings ranged from 0.454 to 0.807. These findings confirm the validity of the 9-item and two-dimensional structure of the m-AMAS. The values for skewness, which varied between -0.63 and 0.95 , and for kurtosis, ranging from -1.18 to 0.63 , indicate a normal distribution of the data. Furthermore, all the correlations in the study were found to be statistically significant. A comprehensive summary of the factor loadings, descriptive statistics, and item-total correlation can be found in Table 1.

To assess the reliability of the m-AMAS, various coefficients were computed, including Cronbach's alpha and McDonald's omega. The results of these analyses revealed acceptable levels of reliability, as evidenced by Cronbach's alpha values of $\alpha=0.719$ for MEA, 0.799 for LMA, and 0.820 for the total score. Similarly, McDonald's omega coefficients were calculated to be $\omega=0.733$ for MEA, 0.804 for LMA, and 0.815 for the total score, which also suggests satisfactory levels of internal consistency. Table 2 displays the descriptive statistics (i.e., range, mean, and standard deviation) and correlations among the study variables. As hypothesized, MA exhibited significant negative correlations with academic achievement ($r=-.455, p<.001$), MSE ($r=-.659, p<.001$), and AB ($r=-.532, p<.001$). These negative associations were also observed between the sub-dimensions of MA and the aforementioned constructs. However, there were no significant associations between MA and gender or class level.

The findings from the network analysis are presented in Fig. 1, which displays the associations among MA and other variables. The results revealed a robust connection between MA and MSE.

A bootstrapping analysis, depicted in Fig. 2, was conducted utilizing Model 4, facilitated by Hayes's (2022) PROCESS version 4.2 macro, to examine the effect of MA

Table 1 Factor loadings, descriptive statistics, and item-total correlations

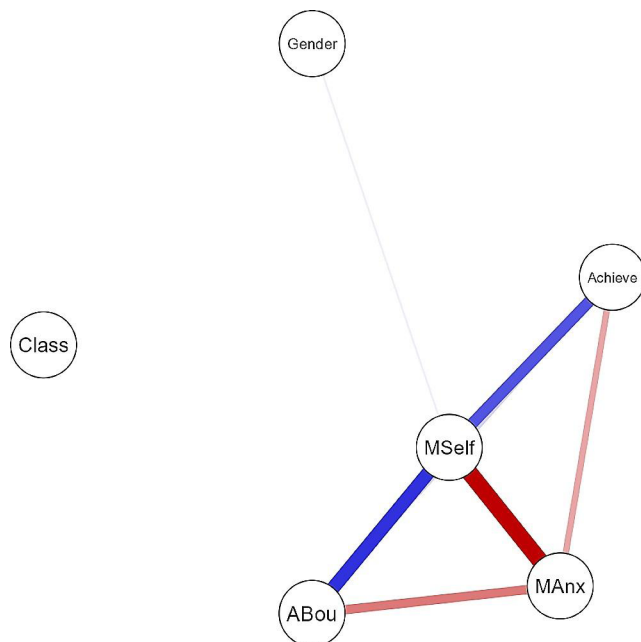
Item	Factor loadings	Mean	SD	Skewness	Kurtosis	Item-total correlations
Item 1 ^L	0.539	2.455	1.362	0.498	−0.992	0.562
Item 2 ^E	0.757	3.580	1.468	−0.533	−1.180	0.506
Item 3 ^L	0.725	2.134	1.329	0.931	−0.454	0.542
Item 4 ^E	0.763	3.665	1.375	−0.631	−0.927	0.531
Item 5 ^E	0.454	3.491	1.379	−0.385	−1.157	0.460
Item 6 ^L	0.807	2.156	1.294	0.795	−0.634	0.615
Item 7 ^L	0.639	2.094	1.317	0.954	−0.386	0.487
Item 8 ^E	0.556	3.580	1.347	−0.556	−0.944	0.443
Item 9 ^L	0.657	2.424	1.296	0.480	−0.993	0.540

Note. E evaluation; L learning

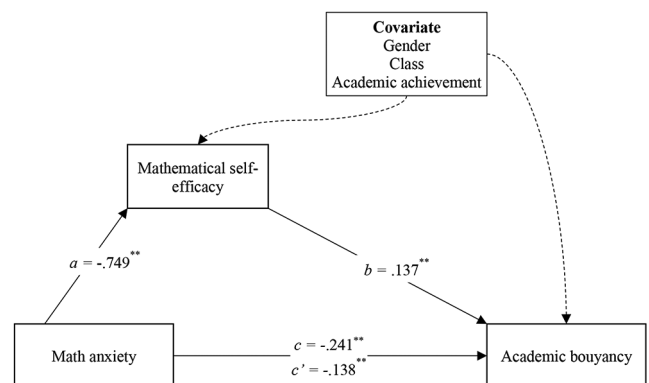
Table 2 Relationship of the Math Anxiety with the Variables

Variable	<i>M</i>	<i>SD</i>	Correlation with MA		<i>r</i>	<i>p</i>	<i>r</i>	<i>p</i>	<i>r</i>	<i>p</i>
			Evaluation	Learning					Total point	
Gender (dichotomous)	1.26	0.44	−0.098	0.144	0.057	0.400	−0.016	0.813		
Class Level	3.95	2.38	−0.110	0.101	−0.035	0.607	−0.080	0.235		
Academic achievement	3.83	1.83	−0.435	<0.001	−0.360	<0.001	−0.455	<0.001		
MSE	1.37	0.48	−0.529	<0.001	−0.604	<0.001	−0.659	<0.001		
AB	2.98	0.65	−0.435	<0.001	−0.481	<0.001	−0.532	<0.001		

Note. 1 = girls for gender

**Fig. 1** Network Analysis for Math Anxiety. Note. The blue lines in the figure denote positive correlations, while the red lines represent negative correlations between variables

on AB through MSE. This analysis generated bias-corrected 95% confidence intervals for these effects, based on 5,000 resamples from the dataset. This procedure ensures a robust examination of the proposed mediation model by addressing potential biases and providing a reliable estimate of the indirect effects within the model.

**Fig. 2** Mediated Outcomes on AB Showing Indirect Effects of MA through MSE. Note. ** $p < .01$. Values shown are unstandardized coefficients

The results of the analysis indicated that MA significantly predicted MSE ($B = -0.749$, $p < .001$), which in turn significantly predicted AB ($B = 0.137$, $p < .001$). The model revealed a significant indirect effect between MA and AB, with a partial mediating effect of MSE ($B = -0.103$, $SE = 0.03$, 95% $CI = -0.156, -0.044$).

Discussion

Our research explored the psychometric properties of the Turkish version of the m-AMAS and its relationship with MSE and AB, engaging a cohort of 224 students in Türkiye.

This adaptation, inspired by the original m-AMAS developed by Carey et al. (2017), was designed to assess its validity for early adolescents within the Turkish educational context. Consequently, our findings significantly contribute to the broader discourse on MA across varied cultural contexts. The findings of this study highlight the critical importance of early detection and intervention in MA, facilitated by reliable instruments such as the m-AMAS. By confirming the validity and reliability of the m-AMAS in a non-British context, this study expands our understanding of MA across diverse cultural settings. The satisfactory model fit obtained through CFA and the consistent factor loadings underscore the m-AMAS's structural integrity, supporting its two-factor solution across cultural contexts. The reliability assessment for the overall MA score and its subscales indicated good to adequate reliability, confirming the scale's robustness in measuring MA among Turkish students. These outcomes are consistent with global findings from various cultural contexts (e.g., Qatar, United Kingdom, Poland), reinforcing the cross-cultural validity of MA construct (Carey et al., 2017; Megreya et al., 2023; Szczygieł, 2019).

The study's results validate Hypothesis 2 by demonstrating a significant negative correlation between MA and crucial academic variables, including academic achievement, MSE, and AB. This finding aligns with the hypothesis that higher levels of MA are associated with lower academic performance, increased MSE, and decreased ability to cope with academic challenges and pressure. Furthermore, the study extends this understanding by exploring the relationships between various MA subscales and these academic variables. Consistent negative associations were observed between the sub-dimensions of MA and academic achievement, MSE, and AB. This correlation underscores the detrimental impact of MA on students' academic performance and their resilience in facing academic challenges. The literature supports our findings of a negative linear relationship between MA and academic achievement (Hembree, 1990; Wu et al., 2012), with Carey et al. (2016) suggesting a bidirectional relationship where high MA can lead to lower performance and vice versa. Interestingly, our study found no significant gender differences in MA levels, diverging from previous research indicating higher MA among women (Gözel, 2022; Hembree, 1990). This discrepancy might be attributed to the distinct characteristics of our sample, primarily early adolescent students, as opposed to studies focusing on young adults engaged in advanced mathematics. The presence of MA across various developmental stages, with its intensity growing over time (Caviola et al., 2022), underscores the necessity for early intervention.

Our findings further demonstrate that MA is inversely related to MSE. The strong negative correlation between these two variables suggests that an increase in one is

significantly associated with a decrease in the other. This is in line with previous research (Akin & Kurbanoglu, 2011; Macmull & Ashkenazi, 2019; Gunderson et al., 2018; Unlu et al., 2017), highlighting the pivotal role of MSE in mitigating MA. Students who are confident in their numerical abilities and perform well on complex tasks are less likely to experience MA, fostering a positive disposition towards mathematics. Research evidence also suggests that children with higher MA obtain lower mathematics achievement (Carey et al., 2016), and tend to have less MSE. Gunderson et al. (2018) have reported that low performance in mathematics can have negative impacts on students' levels of MSE, which, in turn, can lead to an increase in their level of MA. Eventually, MSE could contribute to a reduction in MA. Students who possess high levels of self-efficacy may develop the ability to engage with mathematical tasks with greater ease, leading to decreased levels of MA. However, the fact remains that motivational factors such as MSE and MA are inevitably connected with the cultural and educational environment of countries (Lee, 2009). Secondly, MA's negative association with AB indicates that anxiety experienced in mathematical contexts can diminish students' resilience and willingness to engage with academic challenges (Smith, 2020; Daker et al., 2021). This finding suggests that addressing MA could enhance students' AB, potentially influencing their academic and professional choices.

The study also supports Hypothesis 3, indicating that MSE mediates the relationship between MA and AB. This mediating role of MSE suggests that the negative effects of MA on a student's ability to navigate academic challenges are, at least partially, channeled through their self-efficacy in mathematics. In other words, MA undermines students' confidence in their mathematical abilities, which in turn adversely affects their AB. This mediation is a crucial finding, underscoring the interdependent nature of these constructs and their collective influence on students' academic experiences. Interestingly, our analysis revealed no significant correlations between MA and demographic factors, such as gender or class level, suggesting that the influence of MA might be universally consistent across these demographics within our sample's context. This finding contributes to the ongoing discourse on the pervasive nature of MA, indicating its widespread effects irrespective of demographic distinctions. Our study demonstrates that a significant indirect effect between MA and AB for children, with a partial mediating effect of MSE. Due to the novelty of the concept being studied, research on the role of AB on the link between MA and MSE still continues to increase. Few studies have explored academic outcomes such as self-efficacy and anxiety in students regarding AB (e.g., Lei et al., 2021; Martin & Marsh, 2008; Weißenfels et al., 2023). It might be

said that AB, MSE and MA plays a role for all individuals in achievement situations (Carey et al., 2018; Datu & Yang, 2021). Specifically, Weißenfels et al. (2023) identify AB as a pivotal determinant of math performance, elucidating the significance of self-efficacy in this dynamic. The observed patterns suggest that diminished AB could lead students to feel less confident when confronting mathematical challenges, consequently lowering their MSE and heightening their MA. This dynamic could, in turn, deter students with lower AB from engaging in math-intensive situations, potentially steering them away from STEM fields due to the heightened anxiety and reduced self-confidence.

This chain of effects underscores the critical need to bolster AB as a means to enhance MSE and mitigate MA, thereby supporting students in navigating academic challenges more effectively. By addressing these interconnected factors, educators and practitioners can significantly improve students' academic resilience and performance, particularly in mathematics, fostering a conducive environment for pursuing STEM careers without the constraints of anxiety and self-doubt.

Limitations

This research, while providing valuable insights into the application of the m-AMAS within the Turkish educational context, is not without its limitations. Firstly, the reliance on self-reported data might introduce bias, as it captures only participants' perceptions, possibly overlooking the studied phenomena's complexity. Future studies could benefit from incorporating diverse research methods such as observation, interviews, or peer reviews to gain a broader and more nuanced understanding of MA. These methods can provide additional insights and perspectives that may not be captured by self-report measures alone. Moreover, the cross-sectional design also restricts our ability to establish causal links between MA, MSE, and AB. Longitudinal research is encouraged to examine the evolution of these relationships over time, offering deeper insights into their causal pathways. Although our study's robust sample size strengthens our findings, a more diverse sample across different age groups and populations could improve result generalizability, broadening the m-AMAS's applicability across cultural and educational contexts. Conducted with a non-clinical sample, our findings require cautious application to populations experiencing severe levels of MA, necessitating more specialized assessments and interventions.

Conclusions

Our exploration of the Turkish m-AMAS's psychometric properties and its relationship with MSE and AB has validated the tool's reliability and validity for assessing MA in early adolescents. This significantly contributes to global discussions on MA, underscoring the importance of early detection and intervention. The research outcomes affirm that reducing MA could enhance MSE and AB, suggesting that boosting students' MSE and AB might effectively reduce MA. These findings highlight the critical role of reliable tools like the m-AMAS in early MA intervention. This sequence underscores the pivotal role of mathematics education in fostering not just competence but also resilience in students facing academic challenges.

Future research should adopt longitudinal and experimental designs to clarify causality and identify effective MA reduction strategies. Understanding MA's contributing factors is crucial for developing educational practices that help individuals overcome this challenge. By identifying MA's root causes, educators and practitioners can create targeted interventions and strategies to mitigate its negative impacts, thereby enhancing MSE and AB. In conclusion, this study's revelation of the interplay between MA, MSE, and AB lays a groundwork for future research and interventions. Addressing MA with evidence-based strategies can help the educational community support students in overcoming mathematics challenges, fostering a more confident and resilient learner demographic. Our findings not only enrich the literature on MA but also have practical implications for educational practices and policies, advocating for a proactive and holistic approach to mathematics education.

Funding The authors received no financial support for the research, authorship, and/or publication of this article. Open access funding provided by the Scientific and Technological Research Council of Türkiye (TÜBİTAK).

Data availability Data will be available on request.

Declarations

Ethical approval All studies included in this research adhered to the ethical principles outlined in the Helsinki Declaration of 1975, as revised in 2000. The study received ethical approval from the University Scientific Research and Ethical Review Board [Report No: E-18457941-050.99-72860].

Consent to participate Informed consent was obtained from all the individual participants that were included in the study.

Conflict of interest No conflict of interest exists for this manuscript for any of the authors.

Pre-registration statement This study was not pre-registered.

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