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# Domain-specific and domain-general predictors of math anxiety in adolescents and adults

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ABSTRACT

It is well-established that a negative relation exists between math anxiety (MA) and math performance. However, because there has been no systematic quantitative research on the predictors of MA, we conducted three studies in adolescents and adults to address this gap. Focusing on the Polish population, we tested whether, and to what degree, domain-specific (mathematical resilience, intellectual helplessness in mathematics, math performance) and domain-general (sociodemographic: gender, age; affective: general anxiety, test anxiety; and cognitive: fluid intelligence, working memory, response inhibition) variables predict and explain variance in MA. We found that regardless of the sample and other variables included in the models, intellectual helplessness in mathematics and mathematical resilience are consistent and independent predictors of MA. Moreover, math performance, rather than math grades, serves as a consistent predictor of MA. The findings highlight the relative importance of these variables in understanding MA and indicate a need to focus on domain-specific variables in targeting MA reduction.

## 1. Introduction

For several decades it has been recognised that affective processes are important for mathematical outcomes. One of the most frequently studied affective correlates of mathematics achievement is math anxiety (MA). It is defined as "feelings of tension and anxiety that interfere 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). Understanding of MA has improved significantly over recent years, but gaps remain in understanding its predictors. Understanding the determinants of MA is important from both a theoretical and applied perspective (Delage et al., 2022; Meece et al., 1990; Szczygieł et al., 2024). Here we present three studies that take an original and rigorous approach to better understand what predicts MA in adolescents and adults.

The negative, small-to-moderate relationship between MA and math achievement during and after compulsory math education is well documented (Barroso et al., 2021; Zhang et al., 2019). MA is considered to have a significant negative effect on students' achievement in STEM (Science, Technology, Engineering, and Mathematics; Eidlin-Levy et al., 2023; Luttenberger et al., 2018). Moreover, in today's rapidly evolving technological world, STEM fields are crucial, and proficiency in these fields can directly impact individuals' career opportunities and societal progress. Although MA is commonly studied as an affective predictor of math achievement, relatively little systematic quantitative research has focused on identifying the predictors of MA itself. Therefore, following the theoretical framework model of Luttenberger et al. (2018), we aimed to investigate the relative importance of domain-specific and domain-general predictors of MA. Below we review the literature on correlates and predictors of MA, separated according to domain-specific (math performance, mathematical resilience, intellectual helplessness in mathematics) and domain-general (sociodemographic: gender, age; affective: general anxiety, test anxiety; and cognitive: fluid intelligence, working memory, response inhibition) variables.

### 1.1. Domain-specific predictors of MA

***Math performance.*** Mathematics performance is the level of success individuals show in mathematical tasks. This success can be measured by student grades in mathematics courses, test results, and problem-solving tasks (Kilpatrick et al., 2001). MA is usually studied as a predictor of math performance, however, the direction of the relationship

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between both variables is still under discussion (Carey, Hill, Devine, & Szűcs, 2016; Namkung, Peng, & Lin, 2019; Szczygieł, Szűcs, & Toffalini, 2024). Three main theories are proposed to explain the relationship between MA and math achievement: Deficit Theory, the Debilitating Anxiety Model, and Reciprocity Theory (Carey, Hill, Devine, & Szűcs, 2016). According to the Deficit Theory, failures in mathematics lead to an increase in students' MA. Previous studies have shown that lower math achievement later predicts higher MA in children and adolescents (Ma & Xu, 2004; Sorvo et al., 2019; Wang et al., 2020), more than early MA predicting later math achievement. This pattern suggests that repeated experiences of poor math performance can undermine students' confidence in their math skills, lower their perceived competence, and increase negative emotional reactions to math-related tasks, ultimately leading to the development or exacerbation of MA. The Debilitating Anxiety Model posits that MA affects cognitive load, which limits the working memory resources needed for effective mathematical reasoning (Ashcraft & Faust, 1994; Cargnelutti et al., 2017; Ramirez et al., 2013, 2018; Suárez-Pellicioni et al., 2016). Additionally, MA can lead to the avoidance of math-related activities, contributing to long-term difficulties in mathematics (Carey, Hill, Devine, & Szűcs, 2016). Empirical evidence supports this view, showing that earlier MA predicts lower math achievement or smaller gains over time (Pantoja et al., 2020; Song et al., 2023; Vukovic et al., 2013). Finally, Reciprocal Theory suggests that students' previous math performance shapes their MA and MA affects their future math performance (Carey, Hill, Devine, & Szűcs, 2016). This theory argues that the relationship between MA and math performance is bidirectional, such that both variables affect each other (Aldrup et al., 2020; Du et al., 2021; Pekrun et al., 2017; Szczygieł et al., 2024). On one hand, experiencing repeated difficulties or failure in mathematics can lower students' self-confidence and lead to increased MA when faced with math-related tasks. On the other hand, heightened MA interferes with cognitive processes essential for mathematical reasoning, thereby impairing performance. Over time, this cycle can escalate: poor performance increases MA, and MA further reduces the capacity to perform well, creating a stable and self-perpetuating pattern of avoidance and underachievement. Therefore, we expected higher math performance to be related to lower MA.

***Mathematical resilience.*** Mathematical resilience is defined as maintaining self-efficacy in the face of personal or social threats to mathematical well-being (Johnston-Wilder & Lee, 2010). It relates to how individuals may persist or bounce back in the face of adversity or difficulty in their mathematical learning or testing, underpinned by a growth mindset (Dweck, 2006), a greater perceived importance associated with struggle in mathematics, and the perception of math being of value (Johnston-Wilder & Lee, 2008; 2010). It has been suggested that developing resilience to the difficulties associated with learning mathematics may be crucial for reducing MA (Donolato et al., 2020; Johnston-Wilder & Lee, 2010; Knopik & Oszwa, 2022; Lee & Johnston-Wilder, 2017; Mammarella et al., 2018; Oszwa, 2022). Students with higher mathematical resilience are more likely to interpret difficulties as opportunities to learn rather than as threats, which can help break the cycle of fear and disengagement often seen in math-anxious individuals (Johnston-Wilder & Lee, 2010; Knopik & Oszwa, 2023). Focusing on increasing mathematical resilience should help individuals to manage and protect themselves from unhelpful emotions, such as MA, that may arise when math gets difficult, and to find appropriate support (Johnston-Wilder & Moreton, 2018). Therefore, in line with previous findings (Hunt & Maloney, 2022), we expected higher mathematical resilience to be related to lower MA.

***Intellectual helplessness in mathematics.*** Intellectual helplessness in mathematics (Sędek & Kofta, 1990; Sędek & MacIntosh, 1998) is derived from the concept of learned helplessness introduced by Seligman (1975). Seligman's theory of learned helplessness posits that individuals believe they cannot control the consequences of their actions after repeated failures, thus developing a sense of helplessness. Research shows that when MA is high, students tend to feel helpless in mathematics (Gürefe & Bakalım, 2018; Krejtz & Nezlek, 2016). When students attribute their failures to a lack of skill or difficulty with the task, it increases their sense of learned helplessness (Hwang, 2019). On a cognitive level, intellectual helplessness may result from recurring failures and task-related difficulties, particularly when students cannot find effective strategies or explanations for their struggles. This can undermine problem-solving processes and reduce the motivation to invest cognitive effort. Emotionally, such experiences may trigger frustration, anxiety, and hopelessness, reinforcing avoidance behaviors and negative attitudes toward mathematics. These cognitive and emotional mechanisms are believed to jointly contribute to the emergence and persistence of MA. Therefore, we expected that the greater the sense of intellectual helplessness, the higher the level of MA.

### 1.2. Domain-general predictors of MA

#### 1.2.1. Sociodemographic factors

***Gender.*** Despite gender differences in MA having been tested intensively (Dowker et al., 2016), there are inconsistent results on this topic. Some studies have reported that girls experience more MA than boys in elementary and middle school (Hill et al., 2016; Szczygieł et al., 2024; Williams et al., 2024), high school (Eidlin-Levy et al., 2023; Hill et al., 2016; Williams et al., 2024), and higher education (Eidlin-Levy et al., 2023; McCullagh et al., 2024). In contrast, other studies have reported similar MA scores for boys and girls in elementary school (Ganley & McGraw, 2016; Ramirez et al., 2013; Quintero et al., 2022), middle school (Namkung et al., 2023; Quintero et al., 2022) and higher education (Resnick et al., 1982). Previous research results suggest that individual (trait anxiety, test anxiety, spatial anxiety; Delage et al., 2022; Szczygieł & Hohol, 2024) and environmental (social stereotypes and cultural expectations; Beilock et al., 2010; Dowker et al., 2016; Gunderson et al., 2012) factors explain the presence or absence of a gender gap in MA. Since the prevailing trend in empirical findings indicates a higher likelihood of a gender gap in MA than no gap, we hypothesized that girls and women exhibit slightly higher levels of MA than boys and men.

***Age.*** Previous research shows that MA starts in early childhood (Petronzi et al., 2019; Szczygieł & Pieronkiewicz, 2022), increases with age and grade level (Else-Quest et al., 2010; Krinzinger et al., 2009; Ma & Kishor, 1997; Ma & Xu, 2004; Skagerlund et al., 2024; Sorvo et al., 2019), and slightly decreases in adulthood (Hembree, 1990; Koch, 2018). MA may become more pronounced during middle school and adolescence due to increasing academic demands and social pressures (Luttenberger et al., 2018). Although researchers agree on the developmental trajectory of MA, longitudinal studies on this topic are lacking. It is possible that the change in MA with age is also influenced by the type of MA (e.g., being tested or dealing with everyday mathematics; Barosso et al., 2021). Summing up, it can be expected that MA increases through secondary school, with a slight decline thereafter.

#### 1.2.2. Affective factors

***General anxiety.*** General anxiety refers to an individual's tendency to feel anxious about daily situations (Carey et al., 2017). General anxiety differs conceptually from MA in that it is not related to a specific situation or activity, but rather refers to an individual's general tendency to worry about events, behaviors, and personal abilities (Hill et al., 2016). It is generally agreed that MA has a unique structure that is separate from both general anxiety and test anxiety (Carey et al., 2017; Cargnelutti et al., 2017; Hill et al., 2016; Szczygieł, 2020; Szczygieł et al., 2024; Williams et al., 2024). Evidence also suggests that the role of general anxiety and MA on math performance varies in different age groups (Cargnelutti et al., 2017; Hill et al., 2016; Szczygieł et al., 2024; Williams et al., 2024). However, research evidence has shown that MA is positively related to general anxiety at a moderate level (Hill et al., 2016; Szczygieł, 2020; Quintero et al., 2022; Williams et al., 2024). General anxiety may increase an individual's overall reactivity to stressful or evaluative situations, including those involving mathematics. Individuals with higher levels of general anxiety tend to experience more worry, cognitive interference, and physiological arousal, all of which can amplify the emotional response to math tasks. As a result, general anxiety may heighten the sensitivity to math-related stressors, making individuals more prone to developing MA. Therefore, we expected that higher levels of general anxiety would positively predict MA.

***Test anxiety.*** Test anxiety, broadly speaking, "refers to the set of cognitive, affective, and behavioral reactions that accompany concern over possible negative consequences contingent upon performance in a test or evaluative situation." (Zeidner, 1998, pp. 25-26). Studies have shown that there is a strong correlation between test anxiety and MA (Kazelskis et al., 2000; Zettle & Raines, 2000). For this reason, Kazelskis et al. (2000) state that the relationship between test anxiety and MA is complex and intertwined, and that MA is strongly influenced by test anxiety. On the other hand, Szczygieł (2020) emphasizes that although MA shares much of the variance with general and test anxiety, these structures do not correlate strongly enough to conclude that they are the same factors. Test anxiety is considered a strong predictor of MA due to the overlap in their cognitive, emotional, and behavioural components (Carey et al., 2017). Both involve intrusive thoughts, worry, and heightened arousal in evaluative situations, which can impair concentration and working memory (Ashcraft & Kirk, 2001). The cognitive interference caused by worry and self-doubt limits the resources available for problem-solving, especially during math tasks, which are often perceived as high-stakes. Behaviourally, both anxieties may lead to avoidance or reduced persistence, while affectively they involve similar patterns of physiological tension. Given these shared mechanisms, we hypothesized that test anxiety will positively predict MA.

#### 1.2.3. *Cognitive factors*

***Fluid intelligence.*** Fluid intelligence is defined as the ability to be flexible and respond adaptively to new situations (Kent, 2017). Although there are limited studies on the relationship between MA and fluid intelligence (Orbach, Herzog, & Fritz, 2019; Schillinger et al., 2018; Szczygieł et al., 2024), the results suggest that a higher level of general cognitive skills is a protective factor against high MA. It is supposed that high fluid intelligence supports abstract reasoning and learning new problem-solving strategies, making math tasks feel more accessible and less threatening. These students are more likely to experience success, maintain a sense of competence, and interpret difficulties as being part of the learning process. As a result, higher fluid intelligence enhances self-efficacy in mathematics and protects against the development of MA. Therefore, we expected to observe a weak negative relationship between MA and intelligence.

***Executive functions.*** According to Diamond (2013, p. 136), executive functions are "a collection of top-down control processes used when going on automatic or relying on instinct or intuition would be ill-advised, insufficient, or impossible". Executive functions consist of inhibitory control (interference control – attention, cognitive inhibition; response inhibition), switching, and working memory. Evidence suggests a negative relation between MA and working memory (Finell et al., 2022; Pelegrina et al., 2022; Pellizzoni et al., 2022), and inhibitory control (Núñez-Peña & Campos-Rodríguez, 2024; Pizzie et al., 2020; Van den Bussche et al., 2020; Živković et al., 2022). Previous research suggests that MA leads to intrusive thoughts and overwhelming cognitive load, and increases an individual's attention to threat-related factors (Dowker et al., 2016; Finell et al., 2022). As a consequence, worrisome thoughts may deplete learners' cognitive resources leading to a decline in mathematical performance (Finell et al., 2022; Ng & Lee, 2019).

Specifically, higher working memory capacity allows students to efficiently manage the cognitive demands of math tasks. It enables them to hold intermediate results, manipulate symbols, and stay focused without being overwhelmed. Strong working memory also buffers against the intrusive thoughts and worries associated with MA. Thus, students with better working memory are less likely to experience cognitive overload, which reduces the likelihood of developing MA (Finell et al., 2022; Pelegrina et al., 2024; Pellizzoni et al., 2022). Response inhibition – the ability to suppress automatic, impulsive, or incorrect responses – is essential for maintaining focus and accuracy during math tasks. Students with stronger inhibitory control are better able to ignore irrelevant information, avoid rushing through problems, and resist anxiety-driven distractions. As a result, good inhibitory control supports greater task engagement, reduces cognitive interference (e.g., intrusive thoughts or worry), and lowers the likelihood of developing MA (Núñez-Peña & Campos-Rodríguez, 2024; Pizzie et al., 2020; Van den Bussche et al., 2020; Živković et al., 2022). Therefore, we anticipated that greater working memory and response inhibition would be negatively related to MA.

### 1.3. *The current research*

We aimed to establish domain-specific (math resilience, math intellectual helplessness, math achievement) and domain-general (sociodemographic: gender, age; affective: general anxiety, test anxiety; cognitive: fluid intelligence, working memory, response inhibition) predictors of MA in adolescents and adults in a series of three studies, each taking into account previous findings. The first study was conducted in adults and examined whether and to what degree sociodemographic and domain-specific variables predict MA. The second study was conducted in secondary school students and included the same variables as tested in Study 1, plus affective variables. The third study was conducted with adults across a wider age range and tested the same variables included in Study 1 and Study 2, with the addition of cognitive variables.

## 2. Study 1

### Method

### 2.1. *Participants*

One hundred seventy-three adults from the general population in Krakow, Poland, participated in the study (138 women, 34 men, 1 nonbinary; aged 18 to 35 years old, $M = 21.75$, $SD = 3.35$). They represented STEM sciences ($n = 46$), humanities and social sciences ($n = 99$), and other ($n = 28$) areas of studies and/or professions. All participants in Study 1 had completed high school; however, no data were collected regarding their post-secondary education.

### 2.2. *Measures*

The instructions and test items in the Mathematical Resilience Scale and the Intellectual Helplessness in Mathematics Scale were adapted for adults, taking into account that they were no longer attending school. Participants were asked to recall memories of specific math situations and to imagine how they would cope with them in their current lives. The Math Anxiety Questionnaire was developed specifically to measure MA in adults.

Math Anxiety Questionnaire for Adults (MAQA; Szczygieł, 2022). The MAQA was originally developed in Poland and is intended to measure MA related to math problem-solving in adults (e.g., Calculation of the average level of fuel consumption of a car). It is a unidimensional scale that consists of 19 items with a four-point response scale ranging from 1 (*I definitely do not feel anxiety*) to 4 (*I definitely feel anxiety*). The higher the score in the MAQA, the higher the level of MA. The reliability of MAQA in the present study was $\alpha = 0.91$.

Mathematical Resilience Scale (MRS; Kooken et al., 2016; the Polish language version: Szczygieł & Kutt, 2025). The MRS evaluates mathematical resilience in three areas: value of mathematics (the belief about the usefulness and importance of mathematics in everyday life and future aspirations), struggle (facing challenges and persevering through math difficulties), and growth (the belief that mathematical skills can be developed). The total score is based on 24 items with a seven-point response scale from 1 (*completely disagree*) to 7 (*completely agree*). The higher the score in MRS, the higher the mathematical resilience. The reliability of MRS in the present study was α = 0.83.

Intellectual Helplessness in Mathematics Scale (IHMS; Sędek & McIntosh, 1998). The IHMS is a unidimensional scale that tests intellectual helplessness related to mathematical activity (e.g., I have to almost physically force myself to put in mental effort in math classes). It consists of 20 items with a five-point response scale, ranging from 1 (*never*) to 5 (*always*). A higher score in IHMS indicates greater intellectual helplessness related to mathematics. The reliability of IHMS in the present study was α = 0.96.

Math Performance (MATH; based on Karpińska et al., 2019; Szczygieł & Sari, 2024). MATH tests knowledge and competencies in the area of counting and geometry that are typical of the core math curriculum in Poland for secondary school students. It consists of 20 close-ended mathematical word problems related to everyday contexts. A higher sum of points indicates better math performance. The average level of difficulty of MATH was calculated based on the rule proposed by Niemierko (1999): sum of points for all participants divided by the maximum number of points possible for all participants (a higher proportion means an easier test). MATH difficulty varied from very easy (0.99) to moderate (0.52), with an easy level of difficulty on average (0.82). The reliability of MATH was α = 0.76.

### 2.3. Procedure

Participants were recruited by advertisements placed on a local advertisement portal (OLX). The study was conducted in the university laboratory in Krakow (Poland) individually and volunteers received €10 remuneration for taking part in the study. Materials were presented on the computer in a random order: MAQA, MRS, IHMS, MATH, and sociodemographic questions (gender, age, areas of studies/profession). The study lasted approximately 40 min.

### 2.4. Data analysis

The relationships between all variables were tested by Pearson's zero-order correlation tests, while predictors of MA (gender, age, mathematical resilience, intellectual helplessness, math performance) were tested by multiple linear regression. No missing data were observed, but one participant (non-binary person) was excluded from gender analyses given the limited number of non-binary participants for meaningful analyses, thus leaving gender as a binary variable for the purpose of data analysis.

## 3. Results

Table 1 presents descriptive statistics and correlations between all variables. Women reported a significantly higher level of MA than men, and no other gender differences were observed. No significant relationship was found between age and MA, although age was found to be significantly negatively related to math performance. Both mathematical resilience and math performance were significantly negatively related to MA, each with a moderate-to-strong correlation, and a significant, moderate positive correlation was observed between intellectual helplessness and MA. Finally, intellectual helplessness was found to be significantly negatively and moderately related to mathematical resilience and math performance, while a significant moderate positive correlation was found between mathematical resilience and math performance.

Then, we tested predictors of MA (see Table 2) and observed that the strongest predictor was intellectual helplessness, followed by mathematical resilience, math performance, and gender. Age was not a significant predictor of MA in adults. All predictors together explained 56 % of the variance in MA.

## 4. Discussion

The results indicated that a higher level of MA was observed in women, in those with a lower level of mathematical resilience and mathematical skills, and in those who report a higher level of intellectual helplessness in mathematics. However, we did not observe a relationship between age and MA.

Intellectual learned helplessness was the strongest (positive and moderate) predictor of MA. This result is in line with previous observations showing that intellectual learned helplessness (in mathematics or language) is related to anxiety (in mathematics or language) and is domain-specific (Krejtz & Nezlek, 2016). Thus, if individuals are resigned and do not feel that their further efforts in mathematics make sense, this may be a contributing factor to how anxious they feel about math.

The second strongest (negative and moderate) predictor of MA in our model was mathematical resilience, conceptualised as a combination of a growth mindset in the math domain, the belief that math is needed in everyday life, and the perceived importance of struggle, i.e. the belief that everyone can face difficulties with math and that mistakes are crucial to the learning process (Kooken et al., 2016). Whilst mathematical resilience and intellectual helplessness were shown to be related, they were both independent predictors of MA, suggesting that people need to not only work on developing a growth mindset, but that

**Table 2**
Predictors of MA in Study 1.

| | β | β SE | *p* |
|---|---|---|---|
| Slope | | | < 0.001 |
| Gender | 0.13 | 0.05 | 0.015 |
| Age | 0.09 | 0.05 | 0.082 |
| MRS | −0.28 | 0.06 | < 0.001 |
| IHMS | 0.46 | 0.06 | < 0.001 |
| MATH | −0.17 | 0.06 | 0.003 |

MAQA – math anxiety (outcome variable), Gender (coded as 1 – women, 0 – men), Age – in years, MRS – mathematical resilience, IHMS – intellectual helplessness in mathematics, MATH – math performance. Model: $N = 172$, $F(5,166) = 44.69$, corrected$R^2 = 0.56$.

**Table 1**
Descriptive statistics and zero-order correlations between all variables in Study 1.

| | *M* | *SD* | Gender | Age | MAQA | MRS | IHMS |
|---|---|---|---|---|---|---|---|
| Age | 21.77 | 3.35 | – | – | | | |
| MAQA | 1.89 | 0.57 | 0.18* | 0.03 | – | | |
| MRS | 4.97 | 0.75 | −0.07 | 0.04 | −0.61*** | – | |
| IHMS | 2.87 | 4.95 | 0.06 | −0.13 | 0.67*** | −0.59*** | – |
| MATH | 16.50 | 2.93 | −0.10 | −0.15* | −0.42*** | 0.31*** | −0.31*** |

****p* < 0.001, ***p* < 0.01, **p* < 0.05, Gender (coded as 1 – women, 0 – men), Age – in years, MAQA – math anxiety, MRS – mathematical resilience, IHMS – intellectual helplessness in mathematics, MATH – math performance.

they feel they are capable of achieving success in math in order to overcome MA (Johnston-Wilder & Lee, 2010; Knopik & Oszwa, 2023; Lee & Johnston-Wilder, 2017).

Consistent with findings from existing meta analyses (Barroso et al., 2021; Zhang et al., 2019), we observed that math performance and MA are related to each other (negatively and weakly). Since the study was conducted among young adults, it can be concluded that the relationship between these variables is long-lasting and persists even in a sample of people who have graduated from school. As hypothesized, we observed that women, compared to men, were characterized by a higher level of MA, albeit weakly. Research findings on this topic so far are somewhat inconsistent, with some studies finding no gender difference in MA, but other studies indicating a trend whereby girls/women report higher MA than boys/men (Delage et al., 2022; Devine et al., 2012; OECD, 2013; Xie et al., 2019). Whilst little work on gender differences in MA in the general adult population has been carried out, Hart and Ganley (2019) found that women reported greater MA than men in the general adult population in the U.S., which is consistent with the current findings in our Polish sample. Recent work has provided evidence that might explain which factors account for these gender differences in adults (Szczygieł & Hohol, 2024), including spatial anxiety, neuroticism, state anxiety, test anxiety, and math performance. Thus, future work should account for these variables when differences in MA are assessed according to gender.

Finally, we did not observe a relationship between age and MA, likely because our sample was a homogeneous group of young adults. However, previous research conducted online in a wide age group of English-speaking U.S. adults (18–74 years-old) did not find a significant relationship between MA and age (Hart & Ganley, 2019). It is believed that MA increases from elementary school until high school and then remains stable in adulthood, declining in late adulthood (Hembree, 1990). As Hembree's meta-analysis dates back to the 1990 s, further research is needed on the trajectory of MA development over the life course.

In summary, our study supports the role of gender and domain-specific variables in predicting MA among young adults in Poland. However, we were interested in whether the same pattern of results would be observed in secondary school students. They not only have extensive experience with learning mathematics, but also remain actively engaged in formal math education. This group is still embedded in the school system, regularly exposed to math-related assessments, feedback, and peer comparison, all of which may shape their levels of MA differently than in adults. In contrast to young adults, who have typically completed their formal mathematical education and may have distanced themselves from math-related pressures, secondary school students are still in a context where MA can be reinforced or reduced through ongoing classroom experiences. In our first study, all variables explained 56 % of MA variance, suggesting other important factors were not tested, e.g. affective variables such as trait anxiety or test anxiety (Carey et al., 2017; Szczygieł & Hohol, 2024). Next, we wanted to test whether predictors of MA observed in Study 1 remained so after controlling for more general anxieties, including trait anxiety and test anxiety. Additionally, we were interested in whether the explained variance in MA increases when affective variables are included.

## 5. Study 2

**Method**

### 5.1. Participants

To reflect the secondary school population in Poland, 10 counties were randomly selected for high schools, and 5 for technical and vocational schools. Within each county, 3 schools were randomly invited to participate. Initially, 830 students completed the survey. After removal of incomplete responses along with data from a further 11 students due to declaring a lack of sincerity in providing answers, data from 554 students remained (282 girls, 260 boys, 3 non-binary, 9 chose not to answer the question) aged 13–23 years old ($M = 16.36$, $SD = 1.74$). The students came from all voivodeships in Poland and attended high school ($n = 334$), technical secondary school ($n = 209$), and vocational school ($n = 11$). Their profile in the school was related to STEM sciences ($n = 384$) or to other areas ($n = 170$).

### 5.2. Measures

Abbreviated Math Anxiety Scale (AMAS; Hopko et al., 2003; the Polish language version Cipora et al., 2015). AMAS is intended to measure MA related to math learning anxiety (e.g., Listening to another student explain a math formula) and math testing anxiety (e.g., Thinking about an upcoming math test 1 day before). It has a total score based on 9 items with a five-point response scale: 1 (*low anxiety*), 5 (*high anxiety*). The higher the score in the AMAS, the higher the level of MA. The reliability of AMAS in the present study was $\alpha = 0.88$. We decided to use the AMAS (rather than the MAQA, as per Study 1) given its suitability for use with secondary school students, including the comparatively small number of items and on the basis that items relate to MA associated with learning and testing in a school context.

Mathematical Resilience Scale (MRS; Kooken et al., 2016; the Polish language version: Szczygieł & Kutt, 2025). The MRS items were the same as in Study 1 and the reliability in the present study was $\alpha = 0.91$.

Intellectual Helplessness in Mathematics Scale (IHMS; Sędek & McIntosh, 1998). We selected 10 items (1, 2, 4, 6, 9, 13, 16, 17, 18, 20) from the scale used in Study 1 to shorten the number of items and maintain motivation to complete the survey. Item selection was made using content analysis and item reliability after removal based on the results of Study 1. The reliability of IHMS in the present study was $\alpha = 0.94$.

Math grade (MATH). Because we tested students in different schools and grades, a single standardized math test was not suitable. Moreover, because we wanted to reach as representative a group of students in Poland as possible, we conducted an online survey that had to be relatively short to keep students motivated to complete their answers. Therefore, we asked participants to report their average math grade in the current semester as an indicator of math achievement. Usually, the rating scale for grades in Poland ranges from 1 to 6, where a higher number means a better rating. However, in some schools, grades are not on a scale of 1–6, but in percentages (0–100). To make math results comparable, we converted the results of students who had percentage scores in math into grades, and the results of students who reported average grades were rounded (see rules in the Appendix, Table A).

State and Trait Anxiety Inventory (STAI; Spielberger, 1983; STAI-6-item; Marteau & Bekker, 1992). We used a six-item version of STAI to test trait anxiety. Students answered how they usually feel (e.g. I feel calm) on a four-point scale: 1 (*not at all*), 2 (*a little*), 3 (*moderately*), 4 (*much*). A higher score in STAI means a higher level of trait anxiety. The reliability of the short version of STAI in the present study was $\alpha = 0.81$.

Cognitive Test Anxiety Scale (CTAS; 2nd, Cassady, 2023). We selected 7 items (2, 8, 12, 13, 14, 16, 18) from the scale to maintain motivation to participate in the whole study. Selection of specific items was based on previous research results conducted in Poland and on items with the highest reliability and content validity. Students answered how typical a given statement was for them (e.g. I worry more about doing well on tests than I should) on a four-point scale: 1 (*not at all typical of me*), 2 (*somewhat typical of me*), 3 (*quite typical of me*), 4 (*very typical of me*). A higher score in CTAS means higher cognitive test anxiety. The reliability of the short version of the CTAS in the present study was $\alpha = 0.92$.

### 5.3. Procedure

The second study was conducted online to reach the most representative group of secondary school students in Poland. Parents consenting to their child's participation in the study provided the student with a link to the survey prepared in Qualtrics. Questionnaires were presented in a random order: IHMS, STAI, CTAS, AMAS, MRS, MATH, and sociodemographic questions (gender, age, voivodeship, school type, class profile, honesty in answering questions). We also asked about math avoidance, motivation to learn mathematics, and MA measured by a newly developed scale, but answers to these questions were not analyzed for the objective of the current study (results were analyzed for establishing the validity of a new MA scale). The study lasted approximately 15 min.

### 5.4. Data analysis

We chose not to include non-binary participants in gender analyses given the small number of non-binary participants. We performed Pearson's zero-order correlation tests between all variables and multiple linear regression to test predictors of MA: Model 1: gender, age, MRS, IHMS, MATH; Model 2: gender, age, MRS, IHMS, MATH, STAI, CTAS. We used pairwise deletion to deal with missing data in cases where students did not report their gender or math grade.

## 6. Results

Table 3 presents descriptive statistics and a correlation matrix between all variables. We observed significantly higher levels of MA, state anxiety, and test anxiety in women compared to men, and a negative, small relationship between age and MA and test anxiety. In addition, a significant, positive, and moderately strong relationship was shown between MA and intellectual helplessness in mathematics, state anxiety, and test anxiety. Furthermore, mathematical resilience and math performance were found to be significantly, negatively, and moderately strongly related to MA. Mathematical resilience was significantly, positively and moderately related to math performance, and significantly, negatively and weakly/moderately related to intellectual helplessness, state anxiety, and test anxiety. Intellectual helplessness was found to be significantly, negatively and moderately related to performance, and significantly, positively and moderately correlated with state anxiety and test anxiety. State anxiety and test anxiety were significantly, positively and moderately related to each other and significantly, negatively and moderately related to math performance.

Next, we tested predictors of MA (see Table 4). In Model 1, we observed that all domain-specific and sociodemographic predictors of MA were significant. The strongest predictor of MA was intellectual helplessness in mathematics, followed by gender, age, mathematical resilience, and finally math performance. All predictors together explained 46 % of the variance in MA. In Model 2, state anxiety and test anxiety were added. The results showed that, with the exception of math performance, domain-specific, sociodemographic, and affective variables significantly predicted MA. Test anxiety was the strongest predictor, followed by intellectual helplessness in mathematics, state anxiety, mathematical resilience, age, and gender. When state anxiety and test anxiety were added, the explained variance in MA increased to 59 %.

**Table 4**
Predictors of MA in Study 2.

| | Model 1 | | | Model 2 | | |
|---|---|---|---|---|---|---|
| | β | β SE | *p* | β | β SE | *p* |
| Slope | | | < 0.001 | | | < 0.001 |
| Gender | 0.14 | 0.03 | < 0.001 | 0.06 | 0.03 | 0.044 |
| Age | −0.11 | 0.03 | < 0.001 | −0.06 | 0.03 | 0.046 |
| MRS | −0.10 | 0.04 | 0.018 | −0.09 | 0.04 | 0.012 |
| IHMS | 0.53 | 0.05 | < 0.001 | 0.30 | 0.05 | < 0.001 |
| MATH | −0.09 | 0.04 | 0.034 | −0.06 | 0.04 | 0.13 |
| STAI | | | | 0.14 | 0.04 | < 0.001 |
| CTAS | | | | 0.36 | 0.04 | < 0.001 |

AMAS – math anxiety (outcome variable), Gender (coded 1 – women, 0 – men), Age – in years, MRS – mathematical resilience, IHMS – intellectual helplessness in mathematics, MATH – math performance, STAI – trait anxiety, CTAS – cognitive test anxiety.
Model 1: $N = 522$, $F(5,516) = 90.92$, $p < 0.001$; corrected$R^2 = 0.46$.
Model 2: $N = 522$, $F(7,514) = 108.47$, $p < 0.001$; corrected$R^2 = 0.59$.

## 7. Discussion

In Study 2, we observed that all domain-specific (intellectual learned helplessness in mathematics, mathematical resilience, math achievement) and sociodemographic (gender, age) predictors of MA were significant in secondary school students (Model 1). When we added affective variables (trait anxiety, test anxiety; Model 2), we found that math achievement was no longer a significant predictor, but other domain-specific, sociodemographic, and affective variables remained significant predictors of MA. Thus, our results largely replicated those observed in Study 1 with the exception that in Study 2 we observed a negative (albeit weak) relationship between age and MA. Study 2 further demonstrated that, in addition to sociodemographic and domain-specific variables, affective variables also predict MA in secondary school students.

The strength of the relationship between age and MA in the first and second studies was similar (very weak). After adding affective variables, the age-MA relationship in Study 2 was still significant. Older adolescents participate in an education system that requires passing the high school leaving examination in mathematics in order to continue their education, whether that is in STEM or in non-STEM fields. As such, it could be assumed that anxiety and pressure increases at this later stage of compulsory math education. However, the negative relationship between age and MA observed in Study 2 could suggest that soon-to-graduate students feel less MA than younger students because they have already made the decision not to pursue a STEM path and are no longer concerned about having to learn math. It is also possible that time in continuous math education increases math self-efficacy, which acts as a buffer against MA. It should be reiterated, however, that the relationship between age and MA was very weak.

Turning to gender, as in Study 1, there was a small difference in MA,

**Table 3**
Descriptive statistics and zero-order correlations between all variables in Study 2.

| | *M* | *SD* | Gender | Age | AMAS | MR | IHMS | MATH | STAI |
|---|---|---|---|---|---|---|---|---|---|
| Age | 16.36 | 1.74 | – | – | | | | | |
| AMAS | 2.53 | 0.99 | 0.18*** | −0.13** | – | | | | |
| MRS | 4.77 | 1.05 | 0.05 | −0.03 | −0.43*** | – | | | |
| IHMS | 2.82 | 1.20 | 0.07 | −0.01 | 0.65*** | −0.59*** | – | | |
| MATH | 3.20 | 1.27 | 0.04 | −0.01 | −0.46*** | 0.45*** | −0.64*** | – | |
| STAI | 2.39 | 0.69 | 0.24*** | −0.01 | 0.53*** | −0.27*** | 0.44*** | −0.28*** | – |
| CTAS | 2.55 | 0.94 | 0.19*** | −0.15*** | 0.68*** | −0.32*** | 0.57** | −0.40*** | 0.58*** |

****p* < 0.001, ***p* < 0.01, **p* < 0.05, *N* = 522–554, AMAS – math anxiety, Gender (coded as 1 – women, 0 – men), Age – in years, MRS – mathematical resilience, IHMS – intellectual helplessness in mathematics, MATH – math performance, STAI – trait anxiety, CTAS – cognitive test anxiety.

whereby girls reported higher MA than boys (even when controlling for trait and test anxiety). Consistent with the assumptions and results of previous studies (Delage et al., 2022; Szczygieł & Hohol, 2024), the size of the gender difference in MA decreased when other anxieties were controlled. This means that the gender difference in MA may be explained by individuals' predisposition to anxiety.

Consistent with the findings from Study 1, intellectual helplessness was the strongest (positive and moderate) predictor of MA in secondary students when affective variables were not controlled. After controlling for other anxieties, the strongest predictor of MA was cognitive test anxiety, although intellectual helplessness remained the next strongest predictor. These results suggest that the feeling that mathematics is impossible to learn and that it is not worth trying, combined with test anxiety, is key to students' negative math-related emotions. Because previous longitudinal analysis showed that intellectual helplessness and test anxiety levels are stable in time and predict further levels of them two years later (Fincham et al., 1989), failure to take action to break this vicious circle could contribute to deepening students' problems.

Mathematical resilience was significantly negatively related to MA in both studies. Although the zero-order correlation between mathematical resilience and MA was moderate, it seems that the role of resilience decreases once intellectual helplessness is considered. It suggests that intellectual helplessness, compared to mathematical resilience, plays a larger role when it comes to MA. Mathematical resilience is thought to counterbalance MA (Johnston-Wilder & Lee, 2010; Lee & Johnston-Wilder, 2017; Oszwa, 2022), but probably in its cognitive rather than affective dimensions. Mathematical resilience mainly concerns beliefs: the belief that mathematics is important in life, that it requires overcoming difficulties regardless of one's abilities, and that it is possible to understand it with hard work (Johnston-Wilder & Lee, 2010; Lee & Johnston-Wilder, 2017).

The observed relationship between math achievement and MA in Study 2 was weaker than in Study 1, but it is often observed that math grades are more weakly related to MA than performance on math tests (Zhang et al., 2021). Nevertheless, as in Study 1, math achievement was significantly related to MA, but when we controlled for trait and test anxiety, the relationship became nonsignificant. Although the zero-order relationship between MA and mathematics performance is robust (Barroso et al., 2021; Zhang et al., 2019), less is known about this relationship when other factors are controlled. Given that meta analyses have reported an overall relationship between MA and math attainment that is perhaps weaker than expected ($r \sim -0.30$), it is important that attention is turned to other variables that are associated with MA. In our first two studies, it is clear that the belief in the possibility of success/failure is an important predictor of MA.

Both affective variables added to the first model were significant predictors of MA. Test anxiety was the strongest predictor of MA (positive and moderate) suggesting overlap between MA and anxiety about taking tests more generally. Indeed, various studies that have factor analyzed MA scales have demonstrated math evaluation/testing to be a dominant component of MA. Carey et al. (2017) carried out a study in a large sample of 8–13 year-olds and found that distributions of data pertaining to the math evaluation anxiety and math learning anxiety subscales of the modified AMAS were quite different. They reported a much more even spread of scores on the math evaluation anxiety subscale, compared to the math learning anxiety subscale, in which there was a tendency for young people to score lower. This suggests that anxiety around math evaluation/testing appears quite early and anxiety associated with being tested more generally appears or increases in importance as a predictor of MA in older adolescence. Trait anxiety was a significant predictor of MA even when test anxiety was included in the model, suggesting a unique contribution to the variance in MA. Nevertheless, a key finding in this study is that intellectual helplessness was a significant predictor of MA even when other anxieties were controlled for. Thus, belief in self-abilities for achieving success in mathematics is crucial in understanding MA. Together, these results suggest that MA is closely related to, but not reducible to, general and test anxiety (Carey et al., 2017). Intellectual helplessness was a consistent predictor of MA across both studies. Sociodemographic and domain-specific predictors explained a total of 46 % of the variance in MA, and the addition of affective variables increased the explained variance to 59 %. These results are interesting when compared to the results of Study 1, where the same variables explained 56 % of the variance in MA in adults. The results suggest that MA in adults may be more domain-specific than in adolescents. It should be noted, however, that due to the need to adapt measures to the age group, differences in obtained results may be also the result of methodological differences.

In summary, the results in Study 2 mostly confirmed the pattern of MA predictors observed in Study 1. One difference was age as a significant and very weak negative predictor of MA among students, although this is likely due to the increased statistical power observed in Study 2. In Study 3, we were interested in testing predictors of MA in adults again, expanding the age group to late adulthood as well. Indeed, MA is thought to persist into adulthood even many years after leaving school, and little previous research has investigated predictors of MA in older adults. Additionally, we wanted to establish whether the pattern of results found in secondary students and young adults, including domain-general and domain-specific predictors of MA, persist when domain cognitive variables are controlled for. In particular, based on our results suggesting that feelings of intellectual helplessness are a strong and consistent predictor of MA, we wished to test whether the pattern of predictors is the same when intelligence, working memory, and response inhibition are taken into account. When testing adults, we again included math tasks rather than grades as a measure of math performance. Because the difficulty level of the math test in Study 1 was comparatively easy, we decided to make the math test more difficult by increasing the difficulty of some items and introducing time pressure. We hypothesized that time pressure should result in a stronger correlation between MA and performance. We also decided to conduct the study in the laboratory rather than online due to the greater control of the mathematical and cognitive computer-based tasks afforded by this approach. Additionally, to make the study as comparable as possible to Study 1, we used full (rather than abbreviated) measures of the adult survey instruments. The only exception was the fluid intelligence measure, in which we selected items to reduce testing time.

## 8. Study 3

### Method

#### 8.1. Participants

One hundred sixty-four Polish adults (107 women, 48 men, 7 non-binary, 2 people refused to answer) aged 18 to 55 years old ($M$ = 24.52, $SD$ = 7.32) participated in the study. They represented STEM sciences ($n$ = 84) and humanities and social sciences ($n$ = 61), did not study and did not work ($n$ = 17), or did not answer ($n$ = 2). Adults were varied in their education: primary education ($n$ = 4), junior high school ($n$ = 1), secondary education ($n$ = 88), vocational education ($n$ = 3), bachelor or engineering degree ($n$ = 43), master's degree ($n$ = 21), doctoral studies ($n$ = 4).

#### 8.2. Measures

As in Study 1, all instructions and test items were adapted to adults.

Math Anxiety Questionnaire for Adults (MAQA; Szczygieł, 2022). The MAQA was the same as in Study 1 and reliability in the present study was α = 0.92.

Mathematical Resilience Scale (MRS; Kooken et al., 2016). The MRS was the same as in Study 1 and reliability in the present study was α = 0.88.

Intellectual Helplessness Scale (IHMS; Sędek & McIntosh, 1998). The

IHMS was the same as in Study 1 and reliability in the present study was α = 0.96.

Math Performance (MATH; based on Karpińska et al., 2019; Szczygieł & Sari, 2024). The MATH test consists of 16 tasks, 10 of which are derived from the MATH test used in Study 1. We modified the test from Study 1 to increase its difficulty by increasing the response options to 5 response options, added six new mathematical problems, and introduced time pressure (20 min). All tasks measured knowledge and competencies in the area of counting and geometry that are typical of the core math curriculum in Poland for secondary school students. Similarly to Study 1, we tested the average level of task difficulty and the results indicated that the test average difficulty was moderate (0.61) with tasks from easy (0.89) to difficult (0.21). Reliability of MATH in the present study was α = 0.76.

State and Trait Anxiety Inventory (STAI; Polish language version, Spielberger et al., 2011). To test trait anxiety, we used the twenty-item version of the STAI. Respondents answered on a four-point scale from 1 (*definitely not*) to 4 (*definitely yes*). A higher score in STAI means a higher level of trait anxiety. The reliability of STAI in the present study was α = 0.92.

Cognitive Test Anxiety Scale (CTAS; 2nd, Cassady, 2023). We used a 24-item scale with four-point response options from 1 (*not at all typical of me*) to 4 (*very typical of me*) to test cognitive test anxiety. A higher score in CTAS means higher cognitive test anxiety. The reliability of the CTAS in the present study was α = 0.91.

Raven's Advanced Progressive Matrices (RAVEN; Raven et al., 1988; the Polish language version, Jaworowska, 2017). We selected 18 matrices from series II (1, 2, 5, 8, 10, 12, 13, 17, 18, 19, 20, 21, 22, 24, 27, 28, 30, 32), based on the difficulty level in Polish adaptation (the average level of difficulty of the selected matrices according to the textbook was 0.51), and introduced a 15-minute time pressure to shorten the total time of the study and best differentiate participants' fluid intelligence level. The average level of RAVEN was moderate (0.61) with items from very easy (0.93) to difficult (0.24). The reliability of the test in the present study was α = 0.75.

N-back Working Memory Test (N-BACK; Kane et al., 2007). N-back is a computerized task in which participants are presented with a sequence of letters and are asked to press (or not press) the space key on a keyboard each time the currently presented letter is the same (or different) to ones presented n items ago. The n-back task belongs to the signal detection theory in which participants' decisions may be classified as correct (hit: reaction if reaction needed; correct rejection: no reaction if no reaction is required) or incorrect (false alarm: reaction if reaction is not required; omission: no reaction if reaction is required). A single training session included feedback, while the testing session did not. In the testing session, we used two blocks n = 1 and n = 2 lasting 100 and 200 s respectively (one letter per second). Calculating the indicator of working memory – F-score, we included only the results from the n = 2 block because of the observed ceiling effect in the n = 1 block. F-score (the harmonic mean of precision and recall) was calculated based on the following formula: $[2/(recall^{-1} + precision^{-1})$. The recall is calculated as the proportion of correct detection to the sum of correct detection and omission, while precision is calculated as the proportion of correct detection to the sum of corrected detection and false alarms. A higher sum of points in n-back means better working memory.

Go/No-Go response inhibition task (GO/NO-GO; Fryt et al., 2023; Logan, 1994). Go/No-Go is a computerized task in which participants categorize numbers as even or odd in the "go" condition, and refrain from the reaction in the "no-go" condition. Stimuli were displayed once per second. Based on signal detection theory, we calculated d' as an indicator of participants' response inhibition, in the following way: z(H)-z(F) where z is a standardized score, H (hits/[hits + omission]) is the hit rate, and F (false alarm/[false alarm + correct rejection]) is the false alarm rate. A higher d' score means better inhibition. R script is available in OSF: https://osf.io/tgsvp/ [DOI https://doi.org/10.17605/OSF.IO/TGSVP].

### 8.3. Procedure

The study was conducted in the university laboratory, Krakow (Poland), following advertisements placed on the local advertisement portal (OLX). Participants took part individually and received remuneration of €8-12 for their participation. Materials were presented in a random order. MAQA, MRS, IHMS, MATH, STAI, CTAS, N-BACK, GO/NO-GO, and sociodemographic questions (gender, age, areas of study/profession) were presented via computer and RAVEN in paper-and-pencil form. The study lasted approximately 80 min.

### 8.4. Data analysis

Pearson's correlation tests were used to test the zero-order correlation between all variables. Multiple linear regression was used to test predictors of MA (Model 1: gender, age, MRS, IHMS, MATH; Model 2: gender, age, MRS, IHMS, MATH, STAI, CTAS; Model 3: gender, age, MRS, IHMS, MATH, STAI, CTAS, RAVEN, N-BACK, GO/NO-GO). We used pairwise deletion to deal with missing data. One participant (non-binary gender) was excluded from gender analyses due to the limited data for meaningful analyses.

## 9. Results

Descriptive statistics and zero-order correlations between all variables are presented in Table 5. The results indicate that women reported significantly higher MA, general trait anxiety, test anxiety, and intellectual helplessness than men. Women also had significantly lower scores in math performance, fluid intelligence, and response inhibition. Age was significantly positively related to MA, and significantly negatively related to intellectual helplessness, test anxiety, math performance, fluid intelligence, and response inhibition. MA was shown to be significantly positively and moderately correlated with intellectual helplessness, trait anxiety, and test anxiety. MA was also significantly negatively and moderately related to mathematical resilience, math performance, fluid intelligence, and response inhibition. Mathematical resilience demonstrated a significant negative and weak-to-moderate relationship with intellectual helplessness, trait anxiety, and test anxiety, whereas it was significantly positively related to math performance, fluid intelligence, and response inhibition. Intellectual helplessness was significantly negatively and moderately correlated with math performance, fluid intelligence, and response inhibition. Intellectual helplessness was also found to be significantly positively and moderately correlated with trait anxiety and test anxiety. Both trait anxiety and test anxiety were significantly negatively related to math performance, fluid intelligence, and response inhibition, as well as being significantly positively related to each other. Finally, we observed that math performance, fluid intelligence, working memory, and response inhibition scores were significantly positively and moderately related to each other.

In the next step, we tested predictors of MA (Table 6). In Model 1, we observed that age, mathematical resilience, intellectual helplessness, and math performance were significant predictors of MA, whereas gender was not. Intellectual helplessness was the strongest predictor, followed by math performance, age, and mathematical resilience. All predictors together explained 47 % of the variance in MA. The same significant predictors were observed in Model 2 and Model 3, after adding affective and cognitive variables, respectively. Trait anxiety and test anxiety failed to predict MA in Model 2 and Model 3, and fluid intelligence, working memory, and response inhibition failed to predict MA in Model 3. Model 2 explained 47 % in MA, and Model 3 explained 46 %.

## 10. Discussion

When only sociodemographic and domain-specific variables were

**Table 5**
Descriptive statistics and zero-order correlations between all variables in Study 3.

| | *M* | *SD* | Gender | Age | MAQA | MRS | IHMS | MATH | STAI | CTAS | RAVEN | N-BACK |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Age | 24.52 | 7.32 | | | | | | | | | | |
| MAQA | 2.14 | 0.65 | 0.25** | 0.23** | | | | | | | | |
| MRS | 5.00 | 0.85 | −0.12 | −0.15 | −0.51*** | | | | | | | |
| IHMS | 3.07 | 0.98 | 0.22** | −0.17* | 0.56*** | −0.54*** | | | | | | |
| MATH | 9.78 | 3.40 | −0.30*** | −0.26*** | −0.53*** | 0.36*** | −0.45*** | | | | | |
| STAI | 1.89 | 0.49 | 0.32*** | −0.09 | 0.32*** | −0.24** | 0.41*** | −0.30*** | | | | |
| CTAS | 2.45 | 0.57 | 0.28*** | −0.22** | 0.31*** | −0.20* | 0.55*** | −0.31*** | 0.31*** | | | |
| RAVEN | 10.99 | 3.27 | −0.16* | −0.22** | −0.34*** | 0.27** | −0.32*** | 0.42*** | −0.21** | −0.18* | | |
| N-BACK | 0.63 | 0.19 | −0.07 | −0.07 | −0.16* | 0.12 | −0.14 | 0.27*** | −0.07 | −0.12 | 0.31*** | |
| GO/NO-GO | 1.71 | 0.83 | −0.28*** | −0.17* | −0.37*** | 0.33*** | −0.30*** | 0.43*** | −0.20** | −0.17* | 0.37*** | 0.34*** |

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$, $N = 148$–164, MAQA – math anxiety, Gender (coded as 1 – women, 0 – men), Age – in years, MRS – mathematical resilience, IHMS – intellectual helplessness in mathematics, MATH – math performance, STAI – trait anxiety, CTAS – cognitive test anxiety, RAVEN – fluid intelligence, N-BACK – working memory, GO/NO-GO – response inhibition.

**Table 6**
Predictors of MA in Study 3.

| | Model 1 | | | Model 2 | | | Model 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | β | β SE | *p* | β | β SE | *p* | β | β SE | *p* |
| Slope | | | < 0.001 | | | 0.003 | | | 0.003 |
| Gender | 0.09 | 0.06 | 0.166 | 0.07 | 0.07 | 0.299 | 0.06 | 0.07 | 0.38 |
| Age | 0.21 | 0.07 | 0.003 | 0.22 | 0.07 | 0.002 | 0.20 | 0.07 | 0.007 |
| MR | −0.18 | 0.08 | 0.018 | −0.18 | 0.08 | 0.023 | −0.17 | 0.08 | 0.03 |
| IHM | 0.37 | 0.08 | < 0.001 | 0.33 | 0.09 | < 0.001 | 0.32 | 0.09 | 0.001 |
| MATH | −0.23 | 0.07 | 0.003 | −0.22 | 0.08 | 0.005 | −0.10 | 0.08 | 0.02 |
| STAI | | | | 0.07 | 0.07 | 0.303 | 0.07 | 0.07 | 0.34 |
| CTAS | | | | 0.03 | 0.08 | 0.728 | 0.03 | 0.08 | 0.73 |
| RAVEN | | | | | | | −0.04 | 0.07 | 0.60 |
| N-BACK | | | | | | | −0.01 | 0.07 | 0.89 |
| GO/NO-GO | | | | | | | −0.05 | 0.07 | 0.47 |

MAQA – math anxiety (outcome variable), Gender (coded as 1 – women, 0 – men), Age – in years, MR – mathematical resilience, IHM – intellectual helplessness in mathematics, MATH – math performance, STAI – trait anxiety, CTAS – cognitive test anxiety, RAVEN – fluid intelligence, N-BACK – working memory, GO/NO-GO – response inhibition.
Model 1: $N = 148$, $F(5,142) = 26.98$, $p < 0.001$; corrected $R^2 = 0.47$.
Model 2: $N = 148$, $F(7,140) = 19.35$, $p < 0.001$; corrected $R^2 = 0.47$.
Model 3: $N = 148$, $F(10,137) = 13.48$, $p < 0.001$; corrected $R^2 = 0.46$.

included (Model 1), we observed that age, mathematical resilience, intellectual learned helplessness, and math performance significantly predicted MA, while gender did not. We observed the same pattern of results when affective (Model 2) and cognitive variables were added (Model 3). General anxiety, test anxiety, fluid intelligence, working memory, and response inhibition did not predict MA. The results mean that we fully replicated the results from the previous two studies concerning the role of intellectual learned helplessness and mathematical resilience.

Study 3 showed that intellectual helplessness and mathematical resilience remained significant predictors of MA even after a range of cognitive and affective variables were included in the same model. Intellectual helplessness was consistently the strongest predictor of MA, which suggests that the feeling of being unable to understand mathematical tasks regardless of how much effort is put into math learning is a key factor that explains why MA is durable over time. Failure to master the basics of mathematics is likely to impact understanding of more advanced curricula, and a student's feeling of not understanding math lessons will deepen. It is possible that people develop and maintain MA related to the consequences of not understanding mathematics. Repeated failure to solve math problems may result in a state of cognitive exhaustion, which results in a reduction in the use of cognitive resources. As a result, a long-term lack of success leads to negative emotions and a lack of motivation to learn (Gacek et al., 2017; Sędek & Kofta, 1990). Interestingly, the role of intellectual helplessness does not change significantly when affective and cognitive variables are controlled, which suggests that individual differences in intellectual helplessness act independently in predicting MA.

Another predictor of MA (negative and weak) in Study 3, regardless of controlling for affective and cognitive variables, was mathematical resilience. Comparing this result with those from the previous two studies, we conclude that mathematical resilience is a stable domain-specific predictor of MA in adolescence and adulthood. Intellectual helplessness concerns beliefs that math difficulties encountered are insurmountable because much (ineffective) effort has already been put into learning. Conversely, mathematical resilience includes beliefs that math is worth learning, that everyone encounters difficulties during the learning process, and failures are a normal part of learning. Based on our findings, one suggestion is that mathematical resilience acts as a protective factor against the development of MA. It is also feasible that, if failures are long-term, not overcome, and lead to the feeling that they cannot be overcome, then a feeling of intellectual helplessness develops and goes hand in hand with increasingly higher MA. Overcoming mathematical intellectual helplessness is possible through the development of mathematical resilience, which in consequence may decrease MA (Goodall & Johnston-Wilder, 2015).

We observed that math performance was a stable predictor of MA (negative and weak) in Study 3, regardless of whether the affective and cognitive variables were controlled. This means that the results regarding the role of math performance for MA are the same as in Study 1, conducted with young adults. However, the results of Study 2 showed that math grades significantly predicted MA but only when affective variables were not controlled. Because math performance was measured in adults by mathematical tests and in secondary students by grades, we do not know whether the results are due to the measurement type or the sample age/status. However, based on previous meta-analytic findings that math grades are more weakly related to MA than math performance is (Zhang et al., 2021), we tentatively conclude that MA is firmly rooted in math skills, even when controlling for variables important to math skills (intelligence, working memory, response inhibitory) and MA (general anxiety, test anxiety). Either way, it would be useful to replicate the research conducted in Study 3 with a sample of secondary school students, measuring math achievement with math tasks rather than reported grades.

We observed no gender difference in MA in Study 3, while a gender gap was observed in Study 1 and Study 2. However, in all three studies we observed a significant zero-order correlation between gender and MA, whereby women had higher MA. Thus, this general trend is consistent with the observations of Hart & Ganley (2019) in adults aged 18–74 years, whereby women reported higher levels of MA across different MA measures. However, our findings suggest that these differences may weaken or disappear when other variables are controlled. This conclusion is consistent with previous research showing full or partial mediation of gender differences in MA when other variables such as spatial anxiety, general anxiety, test anxiety, neuroticism, mathematical skills, and spatial skills are included (Delage et al., 2022; Sokolowski et al., 2019; Szczygieł & Hohol, 2024).

We observed that age was significantly positively related to MA in Study 3, regardless of what type of other variables were controlled for. This is notably different to the non-significant effect observed in Study 1 and the very weak effect shown in Study 2. It is also different to the findings of Hart and Ganley (2021) who found no relationship between age and MA in a sample of adults in the U.S. One possibility is that the specific spread of ages is important. In Study 3, our sample had a mean age of 24 years, whereas the mean age of participants in Hart and Ganley's study was 36 years. It is feasible that MA increases in early adult years, possibly due to the demands of applying math in the real-world, i.e. in jobs post-study, household budgeting, and in family life in general. However, whilst the relationship between age and MA was robust in Study 3, it remained fairly weak.

Although zero-order correlations between trait and test anxieties and MA were positive and moderate, in accordance with previous studies (Hart & Ganley, 2019; Luttenberg et al., 2018), we noted that these anxieties did not significantly predict MA if other variables were included in the model. The opposite results were observed in adolescents in Study 2, where both affective variables were significant predictors of MA. Adding trait and test anxieties diminished the role of math grades in students, while in adults math performance still was a significant predictor of MA. Therefore, the question for further studies is whether the role of trait and test anxieties in predicting MA changes according to the type of MA (testing and learning vs. math problem solving) or type of measurement of math achievement (grades vs. test). In Study 2, in comparison to general trait anxiety, test anxiety was a stronger predictor of MA. Combined with the absence of a relationship between other anxieties and MA in Study 3, we suggest that test anxiety is much more relevant to adolescents. Regular testing in education is a common experience for adolescents and it appears that anxiety associated with such testing is associated with MA in that age group. Indeed, mean test anxiety was higher in Study 2 compared to Study 3. We hypothesized that the relationship between MA and math performance would increase in strength as a result of inclusion of time pressure and increased task difficulty. The change in zero-order correlation from −0.42 (Study 1) to −0.53 (Study 3) provides some evidence to support our hypothesis, but we can only make tentative conclusions about the relevance of time pressure given other differences between the two studies.

Finally, although zero-order correlations showed that MA was negatively related to fluid intelligence, working memory, and response inhibition, these variables failed to predict MA when other variables were included in the model. Previous research results have shown a significant negative relationship between MA and fluid intelligence (Schillinger et al., 2018; Szczygieł et al., 2024), working memory (Finell et al., 2022; Pelegrina et al., 2022; Pellizzoni et al., 2022), and executive functions (Núñez-Peña & Campos-Rodríguez, 2024; Pizzie et al., 2020; Van den Bussche et al., 2020; Živković et al., 2022). Indeed, in the current study, the zero-order correlations between MA and fluid intelligence and response inhibition were moderate. This highlights the importance of taking into account other relevant variables when predicting individual differences in MA; in this case intellectual helplessness in mathematics appears to be crucial.

## 11. General discussion

### 11.1. Predictors of MA in adolescence and adulthood

Across three studies, covering different age ranges, we were able to test a wide range of predictors of MA. There have been limited attempts to comprehensively predict MA, and even less research on MA in the general population. Our studies offer some much needed insight into the role of domain-specific and domain-general predictors of MA among adolescents and adults recruited from the general population. Overall, the results suggest the greatest role of domain-specific variables, then affective variables, sociodemographic variables, and the least for general cognitive variables in predicting MA.

The domain-specific variables of intellectual helplessness for mathematics and mathematical resilience were found to be consistent predictors of MA in adolescents and adults. In particular, intellectual helplessness was the strongest predictor of MA in all three studies. These results suggest that in order to break the circle of negative beliefs about one's own mathematical abilities and skills and high MA, it is necessary to take action in both the cognitive and affective spheres of functioning in the classroom. Whilst it is generally agreed that the relation between math achievement and MA is bidirectional, there appears to be a stronger relation between early math achievement and later MA (e.g. Ma & Xu, 2004). This might help explain why we observed such a consistent relationship between intellectual helplessness and MA. It is feasible that math achievement that is poor, whether that is in comparison to standardized thresholds, in comparison to peers, or in relation to one's own or others' expectations, has a lasting impact on one's belief pertaining to a lack of control over outcomes in the context of math learning and performance. Of course, longitudinal research is needed to test this assumption. We should also note here that learned helplessness and self-efficacy are related concepts, and math self-efficacy has been shown to be a correlate of MA (Lee, 2009). Self-efficacy refers to one's belief in one's ability to succeed in specific situations. On the other hand, learned helplessness is based on a person's belief that they have no control over their outcomes and are therefore helpless. Theoretically, high self-efficacy is more likely to result in a belief that one can overcome challenges and achieve desired goals, which in return decreases the chance of experiencing learned helplessness. Conversely, those with low self-efficacy may be more likely to experience learned helplessness because they doubt their abilities to overcome obstacles, thus giving up more easily. Indeed, analysis of longitudinal data has provided support for this suggestion in the context of academic self-efficacy and helplessness (Woo & No, 2023). Therefore, self-efficacy may be seen as playing a crucial role in preventing or mitigating learned helplessness, so future work should explore these relations in the context of math.

Mathematical resilience was also found to be a consistent predictor of MA across each of the samples in our studies. We should also emphasize that there was a consistent correlation between intellectual helplessness and each of the components of mathematical resilience, suggesting that the perceived importance of struggle in math, a growth mindset, and valuing math are all relevant when considering the development of intellectual helplessness in the specific domain of math. Importantly, mathematical resilience was shown to be an independent predictor of MA once a range of other variables, including intellectual helplessness, were considered. There is some evidence to suggest that a focus on increasing mathematical resilience can help address MA (Johnston-Wilder & Lee, 2024), which contributes to the suggestion that psychological variables pertaining to self-belief and how one thinks about math could be key to the development of MA. We should acknowledge, however, that there is some debate around the concept of mathematical resilience in terms of how narrow or broad the focus should be. That is, whether it focuses on the ability to adapt to mathematical difficulties and challenges or whether it is a broader concept that also incorporates the process of positioning oneself to address such challenges. In the current study, we conceptualised mathematical resilience in terms of growth mindset, the perceived importance of struggle, and the perceived value of math (Kooken et al., 2016), but others have focused on a specific ability to overcome adversity in relation to math, separate to growth mindset (Zeng et al., 2016). Others still have focused on the related construct of maths-specific grit, i.e. long-term interest in math and sustained effort in the face of adversity in math (Yu et al., 2021). Thus, a question remains over how mathematical resilience should be conceptualised.

We observed that math performance was a stable negative predictor of MA in adults, but math grades significantly predicted MA only when affective variables were not controlled in adolescents. Since the results of previous studies indicate that the strength of the correlation between MA and math grades is lower compared to math tests (Zhang et al., 2021), this result could be explained by the type of math measurement. Future research on the predictors of MA in students should take into account the type of mathematical test, controlling for affective and cognitive variables. In light of the results on the importance of intellectual helplessness in math and mathematical resilience in predicting MA, it is possible that students' self-observation of their own mathematical achievements may not be accurate, further shaping beliefs about the possibility of learning mathematics and achieving success in it and, subsequently, leading to the development or exacerbation of MA.

Moving to domain-general variables, we observed a general trend regarding gender, whereby women reported greater MA than men (Devine et al., 2012). However, the predictive value of gender was either weak or non-significant (Study 3) in the final models tested. On the one hand this points to the relevance of gender across different age groups, suggesting a certain degree of consistency. However, the findings also suggest that other variables should be targeted as stronger predictors of MA. Nonetheless, gender should not be ignored as a relevant variable in discussing MA and it is likely there are several complex interactions to consider, especially considering the correlations we observed between gender and other types of anxiety in both adolescents and adults, consistent with previous findings (Delage et al., 2022; Szczygieł & Hohol, 2024).

Considering age and domain-general affective variables, the zero-order correlations between MA and general trait anxiety and test anxiety were stronger in Study 2 (adolescents) compared to Study 3 (adults), and trait anxiety and test anxiety failed to predict MA in Study 3 once other variables were included. This suggests that other anxieties are less important in relation to MA once people move into adulthood. It is also feasible, however, that age itself is not so important, but rather the fact that many adults are not in education and it is the current experience of education that contributes to the association between MA and other anxieties, most notably test anxiety, in adolescents. Nevertheless, in Study 3, which included a wider age range of adults, age was a stable predictor of MA, with an increase in age associated with higher MA. In the absence of a longitudinal design, it is difficult to explain this latter finding, so future work would benefit from tracking adults' MA over time.

Finally, our research has highlighted the lack of importance of domain-general cognitive variables in predicting MA when domain-specific and domain-general affective and sociodemographic variables are taken into account. It is likely that cognitive abilities contribute to MA indirectly (Finell et al., 2022). Indeed, we observed zero-order correlations between cognitive functions and MA, but when we additionally controlled for domain-specific, sociodemographic and affective variables, the significance of cognitive variables did not emerge in the models tested.

To sum up, the obtained results suggest that the key to reducing MA is limiting intellectual helplessness and strengthening mathematical resilience. Solving the problem of intellectual helplessness in mathematics begins with changing the way teachers and students experience challenges and failures in the classroom. Students who internalize repeated failures as something bad often exhibit beliefs about their inability to improve (Eskreis-Winkler & Fishbach, 2022). To counteract this, teachers should show students that mistakes are opportunities for learning, rather than providing punishment for making them (Oszwa, 2022). In addition, feedback focused on progress allows learners to understand mistakes and builds the belief that they are good at something in mathematics, so it is worth trying (Smit et al., 2024). Moreover, addressing learners' difficulty with keeping track and focusing in math class is an aspect of intellectual helplessness that teachers should prioritise. Previous work has demonstrated a negative relation between concentration and MA (Loong, 2012), which is likely to contribute to a learner feeling helpless. Indeed, this highlights the utility of approaches such as the Mathematical Resilience Toolkit, which emphasises a range of techniques such as emotion regulation and the ladder model for supporting learners to progress in math when they feel ready (Apostolidu & Johnston-Wilder, 2023). It is likely that, as helplessness decreases, students are more likely to develop mathematical resilience (Lee & Johnston-Wilder, 2017).

### 11.2. Limitations and future directions

All predictors explained between 46 and 59 % of the variance in MA, suggesting that there are other important variables that we did not consider. These may include individual (e.g., math self-efficacy; Lee, 2009) and environmental (e.g., stereotype threat; Bedyńska et al., 2018; teaching methods; Sędek & MacIntosh, 1998; parental and teachers' MA; Sarı & Hunt, 2020) variables. In particular, future work would benefit from understanding the extent to which intellectual helplessness and self-efficacy independently predict MA. As mentioned, longitudinal work is necessary to fully understand the nature of the relations between MA and other psychological variables, including intellectual helplessness and mathematical resilience, over time; the cross-sectional nature of the current research means that causal inferences cannot be made. The key role of teachers and parents is often mentioned among the reasons for MA (Aldrup et al., 2020; Beilock et al., 2010; Guderson et al., 2012), whereas our study focused on individual differences as predictors of MA.

We also found a lack of standardized tools for measuring math performance in adults and adolescents, which made comparisons difficult. The absence of a uniform grading system across schools led us to adopt an approach involving converting percentages to grades in some instances, which may have impacted reliability. Whilst Study 2 included a much larger sample than studies 1 and 3 and benefited from high statistical power, this made comparisons of statistical models across studies challenging. Despite recognising these limitations, the current research represents an original and methodologically rigorous approach to exploring predictors of MA in multiple samples of the Polish population. Future work should focus on longitudinal measurements to assess the potential bidirectional nature of the relationships we have reported. We also recommend ensuring a valid approach is taken to measure MA across age groups. Existing scales for measuring MA have largely been developed in the context of education, and there is a need to consider the suitability of these for a general adult population. In our studies involving adults, we adopted the Math Anxiety Questionnaire for Adults (MAQA; Szczygieł, 2022), while using the Abbreviated Math Anxiety Scale (AMAS; Hopko et al., 2003) when testing adolescents. Whilst this means that different scales were used for adolescents and adults, the approach offers a more valid way of measuring MA and we urge researchers to carefully consider the measurement tool when assessing MA among those in a non-education context. Finally, because the study involved volunteers who responded to an advertisement for the study, it should be considered that those with very high MA may not have volunteered to participate in the study. However, it is difficult to solve this problem, which continues to pose a challenge for researchers of MA.

## 12. Conclusion

In tackling MA, our findings point towards a need to focus on both addressing intellectual helplessness and increasing mathematical resilience. It is important that people, irrespective of age, are supported in feeling that their math achievement can change and that practical strategies are employed to develop mathematical resilience. This might include, but is not limited to, adapting material to the student's competencies, praising and highlighting progress, having the opportunity to understand and correct mistakes, connecting mathematics with everyday life, and facilitating connection with others in a compassionate and empathetic math learning environment. In particular, our findings highlight intellectual helplessness as a factor that increases MA. Thus, MA is likely, in part, to be due to an individual's belief that they cannot control the consequences of their actions after difficulty focusing or repeated failures in math, thus developing a sense of helplessness. Helping people overcome this perceived lack of control could be vital for tackling MA. For adolescents this would typically apply to a formal school context, although the role of parents should not be dismissed. Our findings demonstrate the need to also remain cognisant of the psychological barriers that adults might face, with adults in or out of education experiencing MA. Therefore, strategies to support adults in education or potentially re-entering education in math or STEM more generally should include a focus on overcoming intellectual helplessness and improving mathematical resilience when addressing MA.

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The authors report there are no competing interests to declare.

**Declaration**



## CRediT authorship contribution statement

**Monika Szczygieł:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing. **Thomas E. Hunt:** Writing – original draft, Writing – review & editing. **Mehmet Hayri Sarı:** Writing – original draft, Writing – review & editing. Thomas E. Hunt and Mehmet Hayri Sari contributed equally.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cedpsych.2025.102400.

## Data availability

The data that support the findings are openly available in Open Science Framework at https://osf.io/tgsvp/ [DOI https://doi.org/10.17605/OSF.IO/TGSVP].

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