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The gender gap in math anxiety (and in the link between math anxiety and math achievement) is not so salient when other anxieties are controlled for

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Abstract

Background and objectives Math anxiety (MA) is considered to affect math achievement and the choice of math-related educational paths, thus contributing to the gender gap in STEM careers. However, despite decades of research, the mechanisms underlying the relationships between gender, MA, and math achievement remain largely unclear. One of the reasons is that different types of anxiety and math achievement levels are rarely controlled for.

Design and methods We tested the associations between gender, MA, spatial anxiety, test anxiety, neuroticism, and math achievement in a sample of 269 adults.

Results We replicated previous findings that spatial anxiety in areas of navigation and mental manipulation, but not imagery, mediates the relationship between gender and MA. Importantly, in light of previous contradictory findings, we found that math achievement significantly mediated this relationship. Crucially, we found that gender, spatial anxiety, test anxiety, neuroticism, and math achievement together accounted for 66% of the variance in MA, with gender uniquely accounting for only 5%.

Conclusions The commonly reported gender gap in MA is less pronounced when other anxieties are controlled for, especially given that we did not observe gender differences in the strength of the relationship between MA and math achievement.

Keywords: gender, math anxiety, spatial anxiety, test anxiety, neuroticism, math achievement

Introduction

Numeracy proficiency and participation in Science, Technology, Engineering, and Mathematics (STEM) are widely recognized as important predictors of higher earnings and better financial and health decisions (Black et al., 2021; OECD, 2016, 2024). For this reason, numerous initiatives have been undertaken worldwide to strengthen students' math achievement at all stages of education. However, the effectiveness of these efforts may depend not only on interventions aimed at improving math achievement, but also on efforts addressing the determinants of these skills. Among the predictors of math achievement, both individual factors (sociodemographic, cognitive, affective, motivational) and environmental factors (family-, school-, peer-related) have been identified (Lau et al., 2022; Luttenberger et al., 2018; Meece et al., 1990; Retanal & Maloney, 2026).

Math anxiety (MA) is one of the most extensively studied and well-established correlates of math achievement (Pelegrina et al., 2025). MA is defined as “a feeling of tension and anxiety that interferes with the manipulation of numbers and the solving of mathematical problems in a wide variety of ordinary life and academic situations” (Richardson & Suinn, 1972, p. 551). In line with this definition, MA is a multidimensional construct encompassing anxiety related to learning, testing, and problem solving, with these dimensions strongly interrelated and also reflected in general feelings toward mathematics (Dowker et al., 2016; Hart & Ganley, 2019; Hopko et al., 2003). MA is typically understood and assessed as a trait (Orbach et al., 2019), and this is the approach we adopt in the present study. MA develops gradually from childhood, peaks in adolescence, and persists into adulthood, even after the end of formal education (Hart & Ganley, 2019; Hembree, 1990). This persistence may be important for the transfer of MA to subsequent generations, as previous research indicates that parental and teachers' MA is associated with children's MA and their mathematics achievement (Beilock et al., 2010; Maloney et al., 2015; Ramirez et al., 2018b). MA has attracted considerable attention because most studies involving children, adolescents, and adults suggest that girls and women report higher levels of this anxiety (Eidlin-Levy et al., 2023), which may be linked to lower female participation in STEM fields (Lunardon et al., 2022; Megreya et al., 2025).

Previous research suggests that reducing MA may enhance math achievement and participation in STEM, particularly among women (Ramirez et al., 2018a). However, planning effective interventions requires a deeper understanding of the factors associated with gender differences in MA. The present study aims to investigate the factors that mediate the relationship between gender and MA and to examine whether gender differences exist in the

association between MA and math achievement. To address these aims, we additionally analyze the correlates of MA and gender differences in these correlates.

Correlates of math anxiety

To better understand the mechanisms underlying gender differences in MA, it is essential to examine the correlates of MA, which have themselves been widely investigated with regard to gender differences. Research on the specificity of MA has been extensive, and findings indicate that it is a distinct form of anxiety that is related to, but not reducible to, neuroticism (Lunardon et al., 2022), general (Malanchini et al., 2017), test (Caviola et al., 2022), or spatial anxiety (Delage et al., 2022; Sokolowski et al., 2019). Although all types of anxiety can be analyzed both as stable traits and as situational states, here we focus on trait-level constructs. Math achievement is another key correlate of MA that is conceptually distinct from anxiety and has been extensively investigated (Barroso et al., 2021; Zhang et al., 2019).

Neuroticism Neuroticism (the inverse of *emotional stability*) is a broad personality trait reflecting a stable tendency to experience negative affect, emotional reactivity, and difficulty regulating distress across situations (Gosling et al., 2003). Individuals low in emotional stability tend to be more sensitive to stressors and more prone to experiencing worry, tension, and mood fluctuations. Previous studies indicate that neuroticism is positively and weakly-to-moderately related to MA (e.g., $r = .32$, Lunardon et al., 2022), likely acting as its precursor by increasing the likelihood that mathematics-related situations are appraised as threatening and by amplifying worry and emotional reactivity during mathematical problem solving. Women tend to report higher levels of neuroticism than men (Chapman et al., 2007; Lunardon et al., 2022), which may partially explain gender differences in MA, as greater emotional reactivity and worry in women may increase vulnerability to anxiety in mathematics-related contexts.

General anxiety General anxiety is conceptualized as a stable disposition to experience worry and tension across a wide range of situations (Spielberger, 1983). Individuals high in general anxiety tend to perceive ambiguous or demanding situations as more threatening and to respond with elevated and persistent worry. Although general anxiety and neuroticism originate from different theoretical traditions, they are conceptually similar in that both capture relatively stable individual differences in emotional vulnerability that may predispose individuals to higher levels of MA. Consistent with this view, previous research indicates substantial statistical overlap between general anxiety and neuroticism (e.g., $r > .70$; Jylhä & Isometsä, 2006). Therefore, in the present paper, we treat both constructs as manifestations of trait anxiety vulnerability. Similarly to neuroticism, general anxiety is positively and weakly-to-moderately associated with MA (e.g., $r = .30$, Malanchini et al., 2017; $r_s = .11-.29$, Szczygieł, 2022), likely

because individuals prone to excessive worry are more likely to appraise mathematics-related situations as stressful. Women also tend to report higher levels of general anxiety than men (McLean & Anderson, 2009), which may contribute to gender differences in MA by increasing women's vulnerability to anxiety in mathematics-related contexts.

Test anxiety Test anxiety is conceptualized at the trait level as a relatively stable tendency to experience negative affective, cognitive, and physiological reactions in evaluative situations such as exams (Cassady, 2023; Caviola et al., 2022). Individuals high in test anxiety tend to anticipate failure, worry about negative evaluation, and exhibit heightened emotional arousal across testing contexts. Previous research indicates that test anxiety is positively and moderately related to neuroticism (e.g., $r = .45$, Chamorro-Premuzic et al., 2008), general anxiety (e.g., $r = .45$, Liu et al., 2025), and MA (e.g., $r_s = .45-.51$, Kazelskis et al., 2000; $r = .46$, Caviola et al., 2022). A high level of test anxiety may contribute to MA, as solving math problems often involves fears of making mistakes, receiving poor grades, or being judged negatively by teachers or peers (Szczygieł & Pieronkiewicz, 2022). Women tend to report higher levels of test anxiety than men (von der Embse et al., 2018), which may further contribute to observed gender differences in MA. Elevated test-related worry and evaluative sensitivity among females may increase the likelihood that mathematics, often learned in evaluative contexts, is experienced as particularly threatening, thereby reinforcing math-specific anxiety.

Spatial anxiety Spatial anxiety refers to fear and apprehension related to spatial processing (Lyons et al., 2018). Following Lyons et al. (2018), spatial anxiety comprises three main components: (a) *mental manipulation anxiety*, referring to anxiety experienced during tasks that involve mentally transforming or rotating objects; (b) *spatial imagery anxiety*, referring to anxiety associated with forming and maintaining detailed mental images of objects or spatial layouts; and (c) *navigation anxiety*, referring to anxiety related to wayfinding and orienting oneself in large-scale environments. These components capture individual differences in affective responses to three out of the four core spatial domains most relevant to spatial anxiety (Uttal et al., 2013). Research on the nature of spatial anxiety remains relatively limited compared to other anxiety constructs (Geer et al., 2024). Previous findings indicate that spatial anxiety is positively and weakly-to-moderately related to general anxiety, suggesting partial overlap driven by shared emotional vulnerability (e.g., $r_s = .19-.32$ in Sokolowski et al., 2019; $r_s = .29-.35$ in Delage et al., 2022; $r_s = .24-.44$ in Malanchini et al., 2017). Indeed, similar results were observed when analyzing the relationship between spatial anxiety and emotion control ($r = -.37$; Pazzaglia et al., 2018) and between self-assessed visuo-spatial inclinations (defined as a combination of the attitudes toward orientation and spatial anxiety) and emotion

control ($r = .41$; Carbone et al., 2019). To our knowledge, prior research has not systematically examined the associations between spatial anxiety and test anxiety.

Spatial anxiety shows positive but weak-to-moderate associations with MA (e.g., $r_s = .09$ – $.50$ in Sokolowski et al., 2019; $r_s = .23$ – $.48$ in Delage et al., 2022; $r_s = .32$ – $.41$ in Malanchini et al., 2017). Spatial anxiety and MA are similar in that both are domain-specific constructs, however, spatial anxiety may represent a proximal precursor of MA, as negative affect experienced during spatial processing can generalize to mathematics. To our knowledge no longitudinal studies have directly examined the nature of the relationship between MA and spatial anxiety. However, although the available evidence remains primarily correlational, prior research has often conceptualized spatial anxiety as a predictor of MA rather than vice versa (Delage et al., 2022; Sokolowski et al., 2019). Evidence on gender differences in spatial anxiety suggests a differentiated pattern across its components. Women consistently report higher levels of navigation anxiety and mental manipulation anxiety (Delage et al., 2022; Lyons et al., 2018; Malanchini et al., 2017). In contrast, findings for spatial imagery anxiety are less consistent, with some studies reporting no gender differences (Lyons et al., 2018) and others indicating small female elevations (Delage et al., 2022).

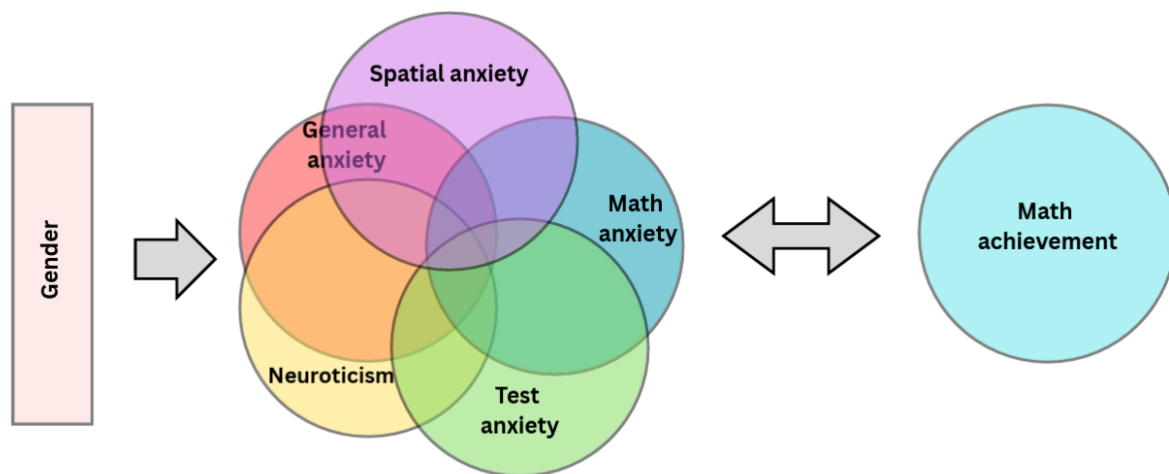
Math achievement A small-to-moderate negative cross-sectional relationship between MA and math achievement is well established (e.g., $r = -.28$ in Barroso et al., 2021; $r = -.32$ in Zhang et al., 2019). Moreover, meta-analytic longitudinal evidence indicates a reciprocal relationship, with prior MA predicting later math achievement ($b = -.11$) and prior achievement predicting later MA ($b = -.12$; Pelegrina et al., 2025). These findings align with the view that MA may stem from repeated mathematical difficulties (Deficit Theory) and, in turn, impair performance through cognitive interference and avoidance (Debilitating Anxiety Theory), ultimately forming a reciprocal cycle (Reciprocal Theory; Carey et al., 2016). Evidence regarding gender differences in math achievement is mixed, with most meta-analyses indicating small or negligible average differences.

Earlier syntheses reported a slight male advantage, particularly in adolescence and among high performers (Hyde et al., 1990, 2008). More recent meta-analyses have generally found very small overall gender differences, with results varying depending on the sample, mathematical domain, and outcome measure; some studies reported near-zero differences or small female advantages (Else-Quest et al., 2010; Leyva, 2017; Lu et al., 2023; Voyer & Voyer, 2014). However, an updated large-scale meta-analysis covering studies published between 2010 and 2022 identified a small but significant overall male advantage, especially in later grades and in spatially intensive domains such as geometry (Caviola et al., 2026). Cross-national

assessments further show substantial variability in the gender gap across countries, highlighting the role of sociocultural factors (OECD, 2016, 2024).

In summary, Figure 1 presents the conceptual overlap among anxiety types and their relations to gender and math achievement, integrating previous empirical findings on the associations among the studied variables.

Figure 1. *Conceptual Overlap Among Anxiety Types and Relations to Gender and Math Achievement.*



Mediators of the relationship between gender and math anxiety

Previous research (Barlow, 2000) suggests a hierarchical organization of anxiety constructs, ranging from broad dispositional vulnerability to domain-specific manifestations. Neuroticism and general anxiety reflect the most general level of emotional vulnerability, with test anxiety often conceptualized as a situationally focused expression of general anxiety (Zeidner, 1998). In turn, MA has been described as a more domain-specific form of anxiety nested within test anxiety (Chamorro-Premuzic et al., 2008). Consistent with this framework, spatial anxiety occupies an intermediate but partly distinct position: although related to broader emotional vulnerability, individual differences in spatial anxiety are not fully explained by general anxiety and it should therefore be treated as a domain-specific construct (Alvarez-Vargas et al., 2020; Oliver et al., 2023). Overall, these findings suggest that more specific anxieties (e.g., spatial anxiety and MA) may develop on the basis of broader dispositional risk factors while retaining meaningful domain specificity within the hierarchy of anxieties.

Importantly, previous research indicates that all types of anxiety (though findings on spatial imagery anxiety are less consistent) are higher in women than in men (Caviola et al., 2022; Delage et al., 2022; Eidlin-Levy et al., 2023; Lunardon et al., 2022; Lyons et al., 2018; Sokolowski et al., 2019; Xie et al., 2024). Therefore, if MA and other anxieties share a common

core of negative valence, and if women, on average, report higher levels of all these anxieties than men, then it is likely that they all contribute to gender differences in MA. In other words, a general tendency to experience negative emotions may be associated with higher levels of specific types of anxiety. Therefore, gender differences in MA may be explained, at least in part, by other types of anxiety. Although gender differences in math achievement are generally small and inconsistent across developmental stages (Caviola et al., 2026; Else-Quest et al., 2010; Hyde et al., 1990; Lu et al., 2023; Voyer & Voyer, 2014), it may still function as a mediator of the gender-MA relationship. Even modest gender differences in math achievement can contribute to differential experiences of success and failure in mathematics, which are known to shape MA (Pelegrina et al., 2025). Therefore, the math achievement pathway remains a theoretically plausible mechanism underlying gender differences in MA.

Taken together, it can be assumed that various forms of anxiety and math achievement may function as important mediators of the gender-MA relationship. At the same time, it should be noted that this represents only one of several plausible theoretical models. Given the substantial intercorrelations among these variables, they may also mutually influence one another over time (e.g., spatial anxiety $\rightarrow$ MA, MA $\rightarrow$ spatial anxiety, math achievement $\rightarrow$ MA, MA $\rightarrow$ math achievement; Pelegrina et al., 2025). However, although empirical evidence for mediation remains limited, findings from the previous studies across different age groups support the assumption that the gender gap in MA can be accounted for, at least in part, by less domain-specific forms of anxiety and by math achievement.

The research findings on this topic are as follows. Lunardon et al. (2022) showed that neuroticism partially mediated gender differences in numeracy among STEM students and was positively related to MA. As the study did not directly test neuroticism as a mediator of the gender-MA relationship, this specification appears theoretically weak, given that neuroticism is typically conceptualized as a broad, relatively stable dispositional trait that precedes, rather than results from, domain-specific anxiety such as MA. No other variables were included as mediators or statistically controlled for in that study.

Szczygieł (2020) tested first- and second-grade primary school children longitudinally, concluding that general anxiety fully mediates gender differences in MA. She did not include any other mediators in the analysis. Girls reported higher levels of general anxiety, which in turn predicted higher MA, indicating that broad emotional vulnerability may contribute to domain-specific math-related anxiety early in education. These findings are theoretically consistent with models positing that more specific anxieties emerge from broader dispositional tendencies (Barlow, 2000). At the same time, there is likely no evidence from adult samples,

leaving it unclear whether the mediating role of general anxiety persists across development or is partly replaced by more domain-specific mechanisms such as test or spatial anxiety.

To our knowledge, the mediating role of test anxiety in the gender-MA relationship has not yet been directly examined. However, such a pathway appears theoretically plausible, as test anxiety is higher in women than in men (von der Embse et al., 2018) and is moderately related to MA (Caviola et al., 2022; Kazelskis et al., 2000). In the opinion of some researchers, MA represents a domain-specific form of test anxiety (Chamorro-Premuzic et al., 2008; Caviola et al., 2022). Moreover, learning mathematics typically occurs in evaluative educational contexts that may heighten test-related worries about performance. Consistent with this view, some authors have argued that MA largely reflects a specific manifestation of test-related evaluative anxiety (Hembree, 1990; Zeidner, 1998).

Delage et al. (2022) and Sokolowski et al. (2019) showed that gender differences in MA among adults are mediated by spatial anxiety in the areas of manipulation and navigation, but not in the area of imagery. These results were observed regardless of whether general anxiety was controlled for (Sokolowski et al., 2019) or not (Delage et al., 2022), suggesting that spatial anxiety contributes to gender differences in MA beyond general emotional vulnerability and reflects a more domain-specific mechanism. Many mathematical tasks rely on spatial representations and transformations, making anxiety experienced during spatial processing particularly likely to generalize to mathematics.

Despite sharing a common negative valence, neuroticism, general anxiety, test anxiety, and spatial anxiety differ in their degree of conceptual overlap: neuroticism and general anxiety show the greatest overlap, whereas test anxiety and spatial anxiety are more domain-specific and overlap to a lesser extent. Accordingly, each construct is expected to account for a unique proportion of the variance in gender differences in MA, with the exception that, due to their substantial overlap, neuroticism and general anxiety should not be included simultaneously in the same analyses. Taking into account the prominent positive associations between spatial ability and math achievement (Mix et al., 2016), and findings that women tend to perform worse on spatial tasks and report higher spatial anxiety than men (Geer et al., 2024), it can be expected that, among various types of anxiety, spatial anxiety particularly contributes to the relationship between gender and MA. Next, test anxiety can be expected to emerge as a significant mediator, given that MA is often emphasized as being closely related to situations involving testing and evaluation. By contrast, a general propensity to experience negative emotions, conceptualized as neuroticism or general anxiety, may play a smaller role. However, it is important to control for this factor in order to account for the specificity of the remaining constructs.

Although studies examining math achievement as a factor linking gender and MA are relatively scarce, their findings remain inconsistent. Some evidence suggests that math achievement may act as a mediator of the gender-MA relationship. For example, Delage et al. (2022) found that gender differences in math achievement were associated with differences in MA. In contrast, Sokolowski et al. (2019) did not observe a significant mediating role of math achievement. These mixed results may reflect differences in samples, analytic strategies, or the extent to which other relevant affective factors were controlled. Given the well-established reciprocal relationship between MA and math achievement, further clarification of the role of math achievement in explaining gender differences in MA is warranted. Therefore, the present study aimed to revisit these contradictory findings and to examine whether math achievement contributes to the gender gap in MA.

Gender differences in the relationship between MA and math achievement

Previous meta-analyses have confirmed that MA is weakly to moderately and negatively related to math achievement in children, adolescents, and adults (Barroso et al., 2021; Zhang et al., 2019). However, inconsistent results have been observed regarding the gender differences in significance and strength of the relationship between MA and math achievement (Yu et al., 2024). While many studies suggest a stronger link between MA and math achievement in girls than in boys (Erturan & Jansen, 2015; Geary et al., 2019; Van Mier et al., 2019; Yu et al., 2024), others have found no statistically significant gender differences in this relationship (Hill et al., 2016; Reali et al., 2016) or have found a stronger link for boys than for girls (Szczygieł, 2020). Although Szczygieł (2020) concluded that MA affects boys' math achievement more than that of girls, she did not compare the strength of the correlation by using a statistical test. Therefore, to make the results comparable, we conducted an additional analysis on Szczygieł's (2020) dataset and found that, regardless of whether general anxiety was controlled for, boys showed a significantly stronger negative relationship between MA and math achievement than girls in first grade ($Z = -1.76, p = .04$; controlled for general anxiety: $Z = -2.31, p = .01$) but not in second grade ($Z = -.69, p = .25$; controlled for general anxiety: $Z = -.86, p = .19$).

Importantly, Szczygieł's (2020) study was conducted in children, while other research suggests that MA in childhood largely depends on general anxiety (Szczygieł et al., 2024). Moreover, boys and girls are exposed to stereotypes regarding mathematics learning and emotional expression, which may reinforce boys' belief that they should possess high mathematical competence, as well as their reluctance to admit experiencing MA (Justicia-Galiano et al., 2023). In adulthood, such tendencies may be particularly evident, as MA is shaped over the course of the entire education. Note that Szczygieł (2020) controlled only for

general anxiety, whereas gender differences in the MA-math achievement relationship may also be influenced by test anxiety and spatial anxiety. Therefore, the contribution of various types of anxiety should be controlled for when testing gender differences in the relationship between MA and math achievement to clarify the unique contribution of MA. To our knowledge, previous studies have not controlled for the above-mentioned types of anxiety when examining the relationship between MA and math achievement in women and men. A notable exception is the study by Lunardon et al. (2022), which identified neuroticism as a significant mediator linking MA and math achievement in women only, highlighting the potential role of broader emotional vulnerability in shaping gender-specific performance outcomes.

The inconsistent findings regarding gender differences in the MA-math achievement relationship may partly stem from insufficient control of broader emotional vulnerability factors. Many studies examining gender moderation have not simultaneously accounted for neuroticism, general anxiety, test anxiety, or spatial anxiety, despite strong theoretical and empirical links between these constructs and MA. Because girls and women typically report higher levels of several anxiety forms, the observed gender moderation effects may partly reflect shared emotional vulnerability rather than MA-specific mechanisms. Therefore, simultaneously controlling for multiple anxiety-related constructs appears crucial for clarifying whether gender differences in the MA-math achievement relationship reflect domain-specific MA effects or broader affective dispositions. This integrative approach may help reconcile inconsistent findings in the literature and provide a more precise estimate of gender-specific MA effects.

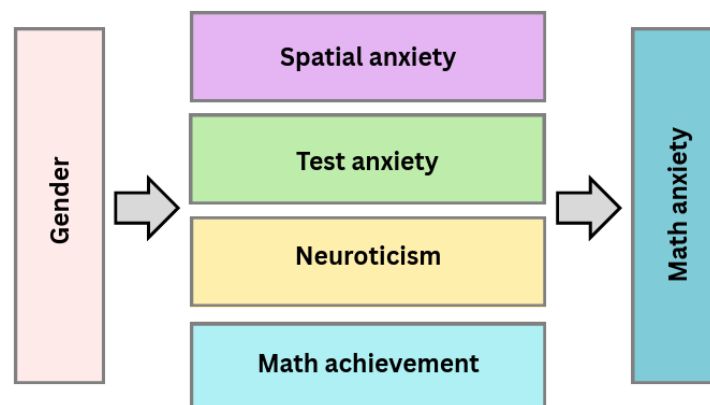
Current study

Although a substantial body of research has examined MA (Dowker et al., 2016; Hart & Ganley, 2019), important gaps remain regarding the relative contribution of different affective and math achievement-related factors to gender differences in MA in adulthood and to gender differences in the relationship between MA and math achievement. In particular, prior studies have rarely considered multiple anxiety constructs simultaneously, despite their partial conceptual overlap and their connections with both gender and MA. As a result, it remains unclear which factors uniquely contribute to gender differences in MA and in the MA-math achievement relationship, and how much variance in MA can be explained when these constructs are examined jointly.

The present study addresses this gap by adopting an integrative approach that situates anxiety constructs along a hierarchical continuum, from more domain-specific forms of anxiety (spatial and test anxiety), to broader emotional vulnerability (neuroticism and general anxiety),

while also including math achievement within a single analytic approach. This approach is grounded in hierarchical models of anxiety, which posit that more specific anxieties may emerge from broader dispositional vulnerabilities while retaining their domain specificity. Given the substantial conceptual and empirical overlap between neuroticism and general anxiety, only neuroticism was retained in the joint analyses to avoid redundancy and to more precisely estimate the unique contribution of the remaining predictors. The study applied a correlational cross-sectional design and examined the proposed mediation mechanism and the covariation between variables. Although both models are theoretically plausible, they do not constitute evidence of causal effects, allowing alternative explanations. First, we examine the mediating effects of spatial anxiety in the relationship between gender and MA and then assess the proportion of MA variance explained by gender and spatial anxiety to replicate the most robust prior findings (Delage et al., 2022; Sokolowski et al., 2019). Next, we extend the model by adding neuroticism and test anxiety to evaluate their incremental mediation effects and assess the additional variance explained beyond spatial anxiety. Finally, we include math achievement to determine whether it serves as an additional mediator and accounts for further variance in MA not captured by the affective factors. Our stepwise strategy allows us to assess both the incremental mediation effects and the cumulative variance explained by the proposed predictors (see Figure 2).

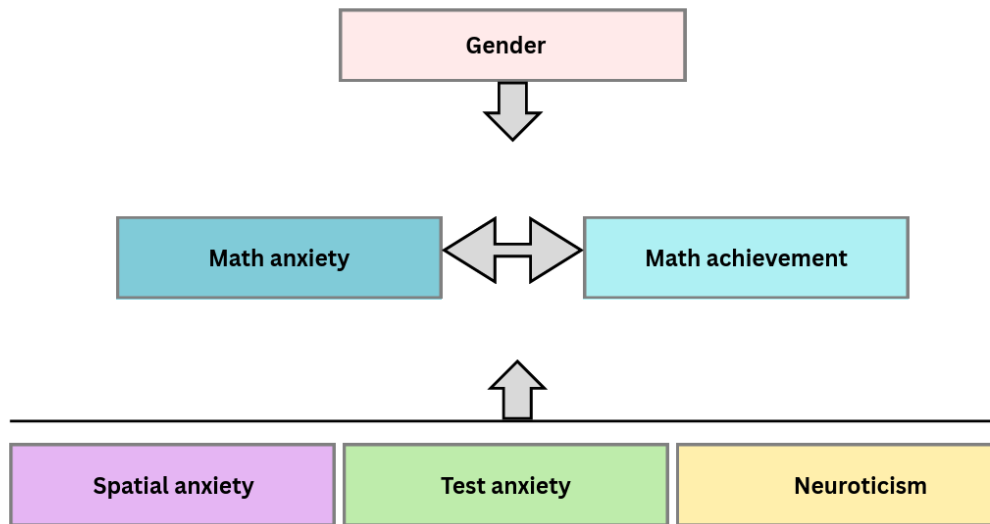
Figure 2. *Tested Theoretical Model of Mediation between Gender and Math Anxiety*



Then, we examine whether the strength of the relationship between MA and math achievement differs by gender, both before and after controlling for multiple anxiety-related constructs (spatial anxiety, test anxiety, neuroticism). This analysis is important because previous findings on gender differences have been inconsistent and may reflect insufficient control for broader emotional vulnerability. Accordingly, we include spatial anxiety, test

anxiety, and neuroticism as covariates, given their conceptual and empirical overlap with MA (see Figure 3).

Figure 3. *Tested Theoretical Model of Gender Differences between Math Anxiety-Math Achievement Relationship with Covariates*



Taken together, the study aims to answer three research questions: Do various types of anxiety and math achievement mediate the relationship between gender and MA? What percentage of the variance in MA can be accounted for by gender, various types of anxiety, and math achievement? Does the relationship between MA and math achievement differ significantly in women and men when various types of anxiety are controlled for?

Regarding the first research question, we expected to replicate the findings of Delage et al. (2022) and Sokolowski et al. (2019), namely that spatial anxiety, particularly in the domains of navigation and manipulation, mediates the relationship between gender and MA. We further expect test anxiety to function as an additional significant mediator, given that MA is closely linked to evaluative contexts. Finally, neuroticism, as a broader disposition reflecting negative emotionality, is expected to play a comparatively less prominent role. Regarding math achievement, we did not pose a hypothesis due to the contradictory findings of previous studies. As for the second research question, we expected that models of increasing complexity would account for progressively more variance. Finally, regarding the third research question, given the inconsistent findings regarding gender differences in the MA-math achievement relationship and the limited number of studies that have simultaneously controlled for multiple anxiety-related constructs, the present study treats this issue as an open empirical question.

Accordingly, we do not formulate a directional hypothesis regarding gender differences in the strength of the association between MA and math achievement. Instead, we examine whether such differences emerge before and after controlling for broader emotional vulnerability and domain-specific anxieties.

Method

Participants

In total, 273 adults residing in the UK with fluent English participated in the online study. Four participants were excluded from the analysis because they failed at least two out of five attention checks. Data from 269 participants were analyzed (157 women, 112 men; $M_{\text{age}} = 41.1$ years, $SD_{\text{age}} = 12.9$, range = 20–75).

Materials

Math anxiety

Three scales were used to capture the multidimensional nature of MA. The first was the *Abbreviated Math Anxiety Scale* (Hopko et al., 2003), consisting of nine items with two subscales: testing MA ($\alpha = .88$) and learning MA ($\alpha = .90$), comprising four and five items, respectively. An example item from the former subscale is “Taking an examination in a math course”, and from the latter, “Starting a new chapter in a math book”. Participants indicated their level of anxiety in a given situation using a five-point Likert scale (1 – “low anxiety”, 5 – “high anxiety”). The second scale was the *Math Anxiety Questionnaire for Adults* (Szczygieł, 2022), consisting of 19 items ($\alpha = .95$) and measuring MA related to math problem-solving (e.g., “Calculation of the surface area of a sphere”). Participants were asked to imagine that they were in a situation in which it was necessary to solve a math problem and to indicate whether they felt anxious in such situations (a four-point Likert scale; 1 – “I definitely do not feel anxiety”, 2 – “I rather do not feel anxiety”, 3 – “I rather feel anxiety”, 4 – “I definitely feel anxiety”). The third scale was the *Single-Item Math Anxiety Scale* (Núñez-Peña et al., 2014), consisting of the question: “On a scale from 1 to 10, how math anxious are you?” (1 – “not anxious”, 10 – “very anxious”). In all cases, higher scores indicate higher levels of MA. To capture the multidimensional nature of MA, we created a composite MA score based on all the scales (see Appendix). Its McDonald’s ω for the second-order latent factor was .94.

Spatial anxiety

We quantified spatial anxiety using the *Spatial Anxiety Questionnaire* (Lyons et al., 2018), consisting of three subscales with eight items each (24 in total): spatial imagery anxiety (SA-I, $\alpha = .88$), navigation anxiety (SA-N, $\alpha = .92$), and mental manipulation anxiety (SA-M, $\alpha = .96$). Participants were asked how anxious they would feel in response to the situation

described in each item, and the possible responses were as follows: “not at all”, “a little”, “a fair amount”, “much”, and “very much”. Example items are as follows: “Asked to give a detailed description of a person’s face whom you’ve only met once” (SA-I), “Memorizing routes and landmarks on a map for an upcoming exam” (SA-N), and “Asked to imagine and mentally rotate a 3-dimensional figure” (SA-M). Higher scores indicate greater spatial anxiety.

Neuroticism

Neuroticism was measured using the *Ten-Item Personality Inventory* (Gosling et al., 2003). Although other personality traits were measured, only the neuroticism subscale consisting of two items, i.e., “Anxious, easily upset” and “Calm, emotionally stable” ($\alpha = .72$), was analyzed. Participants responded using a seven-point slider (1 – “disagree strongly”, 2 – “disagree moderately”, 3 – “disagree a little”, 4 – “neither agree nor disagree”, 5 – “agree a little”, 6 – “agree moderately”, 7 – “agree strongly”). For interpretative consistency with other anxiety measures, the scale was reverse-scored so that higher scores indicated higher neuroticism.

Test anxiety

To measure test anxiety, we used the second edition of the *Cognitive Test Anxiety Scale* (Cassady, 2023; $\alpha = .97$), consisting of 24 items (e.g., “I lose sleep over worrying about examinations”). Participants indicated how typical the situations described in each item were for them (“not at all typical of me”, “somewhat typical of me”, “quite typical of me”, “very typical of me”). Higher scores indicate higher levels of test anxiety.

Math achievement

Because mathematics comprises partially distinct domains, we assessed participants’ achievement across core content areas (i.e., arithmetic, algebra, and geometry) to obtain a broad and representative estimate of mathematical competence. Math achievement was assessed with 20 single-choice math problems, each with five response options ($\alpha = .77$). They targeted arithmetic (“600 g of cake costs £8.40. How much does 1 kg of this cake cost?”) and algebra (“Which number belongs to the solution set of the inequality $(x-2)(x+3) < 0$?”), as well as geometry (“A regular hexagonal pyramid has...”). The problems were developed based on materials for primary students (Karpińska & Radtke, 2019), students preparing for final high school exams (matemaks.pl), and for testing adults (Szczygieł & Sari, 2024). The same set was used in Obidziński et al.’s (2025) study, which yielded moderate positive correlations between performance on these problems and both objective and subjective measures of math skills. Task difficulty was averaged by dividing the total number of points obtained by all participants by the maximum number of points possible for them. It ranged from easy (.78) to very difficult

(.15), with an average of .55, indicating a moderate level. Higher accuracy indicated better math achievement. There was no time pressure.

Procedure

The study was approved by the Ethics Committee for Research at the Faculty of Philosophy, Jagiellonian University and run online in Qualtrics XM, lasting approximately 30 minutes. Participants were recruited via Prolific and received £6. They were informed during recruitment that they would complete questionnaires and solve mathematical tasks. Each questionnaire was displayed on one screen. Because all questions were mandatory, there were no missing data. The participants completed the questionnaires in the following order: Cognitive Test Anxiety Scale, Spatial Anxiety Questionnaire, Ten-Item Personality Inventory, Abbreviated Math Anxiety Scale, Math Anxiety Questionnaire for Adults, Single-Item Math Anxiety Scale, State-Trait Anxiety Inventory, and Math achievement problems. Finally, participants answered demographic questions and could share their opinions about the study. We did not analyze the results from the State-Trait Anxiety Inventory due to an excessively high level of overlap between the anxiety-related variables.

Plan of analysis

All analyses were conducted in R, and the script is available on the Open Science Framework at <https://osf.io/rgcy5/>. Prior to testing hypotheses, we examined the relevant test assumptions and found no evidence of serious violations.

In the first step, we conducted zero-order Pearson correlation analyses and independent-samples *t*-tests to examine gender differences in MA, other forms of anxiety, and math achievement.

Then, we addressed the three research questions in two analytic steps. To address the first and second research questions, we tested three multiple-mediation models in *lavaan* (Rosseel, 2012), with gender (women = 1, men = 0) as the predictor and the MA composite score as the outcome. Model 1 included the three dimensions of spatial anxiety (imagery, navigation, mental manipulation) as mediators. Model 2 added neuroticism and test anxiety. Model 3 additionally included math achievement. The ordering of models allowed us to evaluate both the incremental mediation effects and the additional variance in MA explained by progressively broader sets of predictors. In all models, the mediators were allowed to covary, enabling estimation of the unique indirect effect associated with each mediator while accounting for shared variance among mediators. All three models were just-identified ($df = 0$); therefore, global SEM fit indices and likelihood-ratio tests of model fit were not informative and are not reported. The incremental contribution of added mediators is indexed by changes in the variance in MA

explained (R^2), reported alongside the R^2 of each mediator. Indirect effects are reported as unstandardized coefficients (B) with their corresponding BCa confidence intervals; effects whose CIs excluded zero were considered significant.

To address the third research question, which concerns whether the strength of the MA-math achievement relationship differs between women and men, we computed Pearson zero-order and partial correlations between MA and math achievement separately for women and men. The partial correlations controlled for spatial imagery anxiety, navigation anxiety, mental manipulation anxiety, neuroticism, and test anxiety. Gender differences in the magnitude of these correlations were tested using Fisher's z test for two independent correlations. This analysis treats gender as a moderator of the MA-math achievement association and is conceptually complementary to, but distinct from, the mediation analyses, in which gender is treated as a predictor of MA.

The two strategies address different questions: whereas the mediation models examined whether gender differences in MA could be statistically accounted for by the proposed mediators, the separate correlation analyses for women and men tested whether the association between MA and math achievement differed by gender after controlling for shared variance with the affective variables. Both analytic approaches were included because the study aimed to examine complementary hypothetical models within a correlational framework.

Results

Descriptive statistics and zero-order correlations

Descriptive statistics and Pearson's zero-order correlation matrix are presented in Table 1.

Two-sided t -tests for independent samples yielded significant gender differences in MA, navigation anxiety, mental manipulation anxiety, and neuroticism, but not in spatial imagery anxiety and test anxiety. Women showed higher MA ($t_{267} = -3.88, p < .001, d = -0.48$), navigation anxiety ($t_{267} = -2.56, p = .011, d = -0.32$), mental manipulation anxiety ($t_{267} = -3.73, p < .001, d = -0.46$), and neuroticism ($t_{267} = -3.58, p < .001, d = -0.44$) than men. Gender differences were most pronounced in MA, mental manipulation anxiety and neuroticism (the effect sizes at the upper bound of the small range, approaching medium). Gender differences in math achievement were significant ($t_{267} = 2.37, p = .019, d = 0.29$), with men slightly outperforming women.

All correlations between the variables are presented in Table 1. Among the most important findings, MA was at least moderately and positively correlated with all types of spatial anxiety, test anxiety, and neuroticism, and negatively correlated with math achievement.

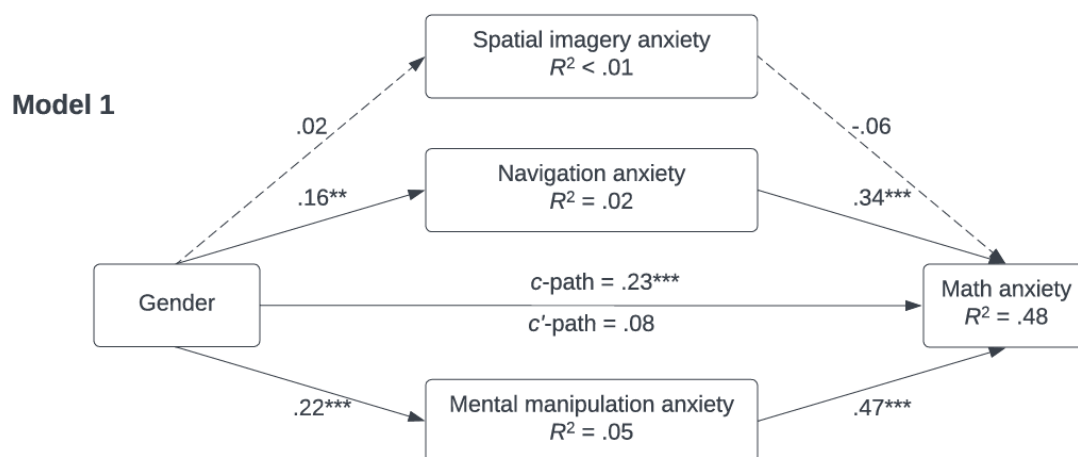
Table 1. *Descriptive Statistics and Pearson's Zero-Order Correlation*

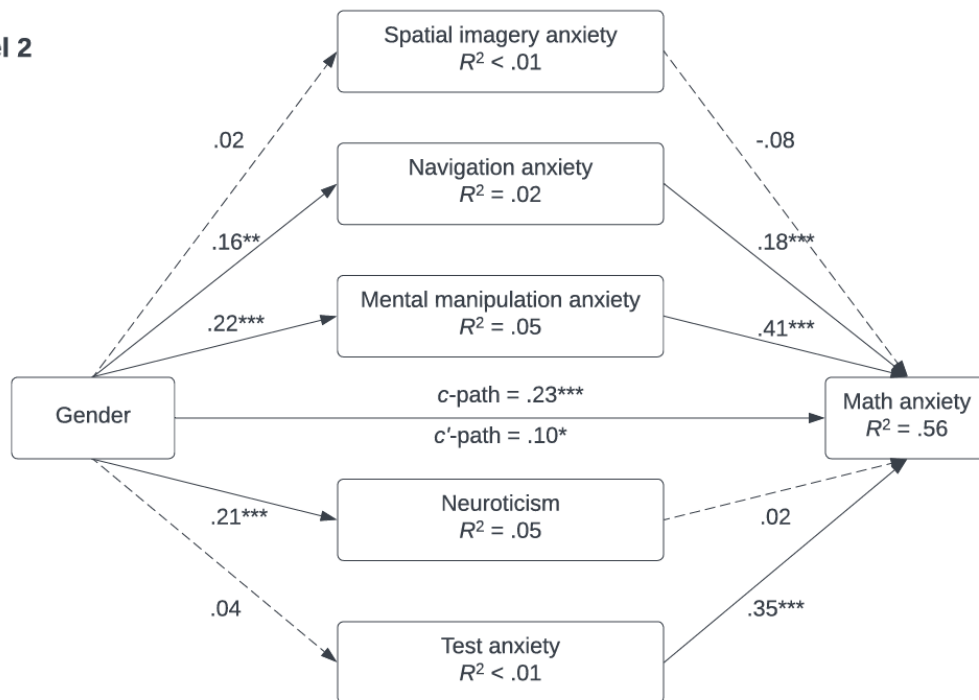
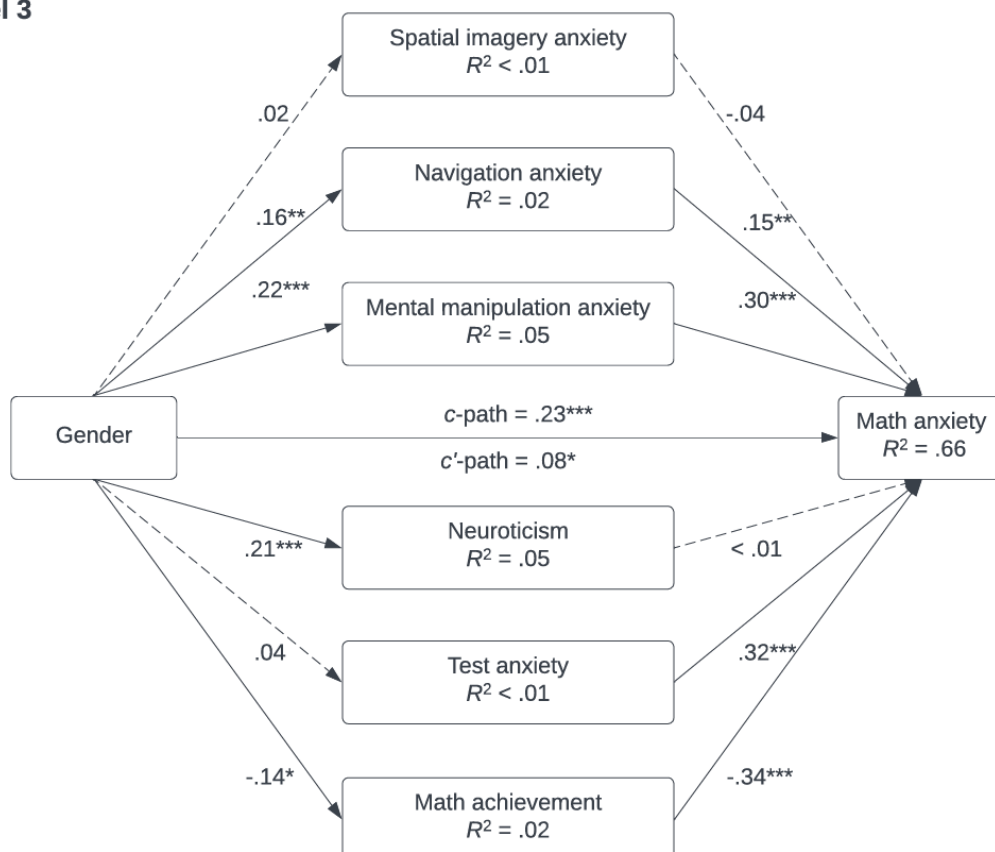
	<i>M</i>	<i>SD</i>	Range	<i>Sk.</i>	<i>K.</i>	Gender	MA	SA-I	SA-N	SA-M	NEUR	TA
MA	77.20	23.82	29-127	-.13	-.90	.23***						
SA-I	19.46	7.02	8-38	.58	-.28	.01	.37***					
SA-N	22.26	7.75	8-40	.23	-.62	.15*	.56***	.48***				
SA-M	23.38	9.26	8-40	.21	-.98	.22***	.62***	.58***	.51***			
NEUR	7.17	3.16	2-14	.28	-.78	.21***	.37***	.17**	.43***	.23***		
TA	51.49	18.07	24-93	.40	-.95	.04	.59***	.36***	.54***	.40***	.49***	
MATH	11.08	4.02	1-20	-.04	-.70	-.14*	-.57***	-.16*	-.27***	-.37***	-.18**	-.24***

Note: * $p < .05$, ** $p < .01$, *** $p < .001$; Gender – women are coded as 1 and men as 0, MA – math anxiety, SA-I – spatial imagery anxiety, SA-N – navigation anxiety, SA-M – mental manipulation anxiety, NEUR – neuroticism, TA – test anxiety, MATH – math achievement.

Multiple-mediation analyses

We tested three multiple-mediation models with gender as the predictor and MA as the outcome (see Plan of Analyses). The results of the multiple-mediation analyses are presented in Figure 4.

Figure 4. *Multiple-Mediation Models*

Model 2**Model 3**

Note: * $p < .05$, ** $p < .01$, *** $p < .001$, $N = 269$; Gender – women are coded as 1 and men as 0; c – standardized total effect; c' – standardized direct effect. Dashed lines indicate non-significant paths.

In Model 1, we observed full mediation. The indirect effects via navigation anxiety, $B = 2.52$, 95% CI [0.61, 4.88], and mental manipulation anxiety, $B = 5.02$, 95% CI [2.37, 8.42], were significant, whereas the indirect effect via spatial imagery anxiety was not, $B = -0.04$, 95% CI [-0.82, 0.31]. Gender and spatial anxieties together accounted for 48% of the variance in MA.

We then observed partial mediation in Model 2. The indirect effects via navigation anxiety, $B = 1.32$, 95% CI [0.30, 3.00], and mental manipulation anxiety, $B = 4.45$, 95% CI [2.11, 7.56], remained significant when neuroticism and test anxiety were controlled for. The remaining indirect effects were not significant: spatial imagery anxiety, $B = -0.06$, 95% CI [-0.90, 0.40]; neuroticism, $B = 0.18$, 95% CI [-0.85, 1.35]; and test anxiety, $B = 0.59$, 95% CI [-1.44, 2.74]. All variables together accounted for 56% of the variance in MA.

Finally, we observed partial mediation in Model 3. The indirect effects via navigation anxiety, $B = 1.12$, 95% CI [0.21, 2.66], mental manipulation anxiety, $B = 3.20$, 95% CI [1.46, 5.54], and math achievement, $B = 2.35$, 95% CI [0.43, 4.54], were significant. The remaining indirect effects were not: spatial imagery anxiety, $B = -0.03$, 95% CI [-0.66, 0.21]; neuroticism, $B = 0.06$, 95% CI [-0.95, 1.08]; and test anxiety, $B = 0.54$, 95% CI [-1.34, 2.50]. All variables together accounted for 66% of the variance in MA.

The total standardized effect of gender was modest ($\beta = .23$), corresponding to approximately 5% of accounted variance in MA.

Zero-order and partial correlations by gender

We tested Pearson's correlation between MA and math achievement separately for women and men without (zero-order correlation) and with controlling for (partial correlation) navigation anxiety, mental manipulation anxiety, spatial imagery anxiety, neuroticism, and test anxiety. The results for women are: zero-order correlation $r = -.52$, $p < .001$, partial correlation $r = -.42$, $p < .001$. For men: zero-order correlation $r = -.62$, $p < .001$; partial correlation $r = -.55$, $p < .001$. Gender differences in the strength of the association between MA and math achievement were not significant either before ($Z = 1.19$, $p = .235$) or after ($Z = 1.33$, $p = .181$) controlling for different types of anxiety.

Discussion

Our study addressed three research questions in a sample of adults with a wide age range. First, we found that gender differences in MA are significantly weaker when spatial anxiety, test anxiety, neuroticism, and math achievement are considered as mediators. Second, we demonstrated that gender, all the aforementioned anxieties, and math achievement together account for 66% of the variance in MA levels. Third, we found that the strength of the

relationship between MA and math achievement in women and men is weaker when other anxieties are controlled for. Moreover, there are no significant differences between women and men in the strength of the relationship between MA and math achievement, regardless of whether other anxieties are controlled for.

Mediators of the Relationship between Gender and MA

Given the inclusion of multiple affective mediators and math achievement across models, we discuss their mediating roles in the gender-MA relationship sequentially (spatial anxiety, neuroticism and test anxiety, and math achievement).

First, we examined mediation using the domain-specific affective mediators, namely the different dimensions of spatial anxiety. Previous research (Delage et al., 2022; Sokolowski et al., 2019) has found spatial anxiety to be a robust mediator of gender differences in MA in young adults in the areas of mental manipulation and navigation. Notably, contrary to Delage et al. (2022), but consistent with Sokolowski et al. (2019), we did not find significant gender differences in spatial imagery anxiety. Therefore, we fully replicated the findings on spatial anxiety reported by Sokolowski et al. (2019) and partially replicated those reported by Delage et al. (2022), extending their generalizability to an adult population spanning a wider age range. The results indicating that mental manipulation and navigation, but not imagery, mediate gender differences in MA are convincing given that the corresponding Spatial Anxiety Scale subscales primarily tap dynamic spatial transformations and route-planning processes that overlap with mathematical reasoning demands, whereas the imagery subscale focuses mainly on static visual memory and descriptive detail, which are less directly related to mathematics. Importantly, this pattern is consistent with meta-analyses showing that gender differences are largest in mental rotation, moderate in spatial perception, and small or inconsistent in spatial visualization (Linn & Petersen, 1985; Voyer et al., 1995). Research by Lawton (1994) suggests that gender differences in spatial abilities and spatial anxiety may stem from differential reliance on navigation strategies, unequal spatial experience, and sociocultural constraints on environmental exploration among girls, which may help explain inconsistencies across studies regarding gender differences in various dimensions of spatial anxiety.

Beyond spatial anxiety, high neuroticism may increase the risk of developing MA by heightening threat perception and weakening emotional regulation in math-related situations. Correspondingly, high level of test anxiety may be associated with MA, as math tasks often evoke fears of failure and negative evaluation. As studies generally show that these types of anxiety are higher in girls and women than in boys and men (Caviola et al., 2022; Lunardon et al., 2022; Lyons et al., 2018), each can be considered a potential mediator of the relationship

between gender and MA. Indeed, Szczygieł (2020) found that general anxiety fully mediated gender differences in MA in children. Given MA's persistence in adulthood (Hart & Ganley, 2019; Hembree, 1990), a similar pattern could be expected in adults. However, our results do not support the mediating role of neuroticism or test anxiety in the relationship between gender and MA, when spatial anxiety (and math achievement) are controlled for, or not. Although gender predicted neuroticism, its indirect effect on MA was weak and non-significant. Test anxiety significantly predicted MA but was not significantly related to gender, ruling it out as a mediator. Thus, while affective factors are associated with MA overall, they are not so important in accounting for gender differences in adults when different types of spatial anxiety (and math achievement) are controlled for. Therefore, gender differences in MA in adults are more strongly related to differences between women and men in emotions associated with spatial navigation and mental manipulation than to gender differences in neuroticism and test anxiety. This pattern suggests that, whereas in childhood general anxiety may account for much of the gender differences in MA (Szczygieł, 2020), in adulthood more domain-specific anxieties, likely shaped through educational experience, appear to be more closely linked to MA.

Next, we revisited the potential association of math achievement with the relationship between gender and MA. While Sokolowski et al. (2019) did not find a mediating effect of math achievement between gender and MA, Delage et al. (2022) reported a positive result. We found that math achievement significantly mediates the relationship between gender and MA, thus supporting the latter result. Sokolowski et al. (2019) quantified math achievement using a time-pressured arithmetic test. In contrast, Delage et al. (2022) used a set of questions tapping into several branches of mathematics without time pressure. Although we used a different set of problems to assess participants' math achievement, our approach more closely resembles the latter one. Previous research findings on the gender gap in math achievement are inconclusive (Kaiser & Zhu, 2022), however, if such gender differences are observed, they may contribute to higher levels of MA in women than in men.

Finally, we investigated what percentage of the variance in MA can be accounted for by gender, various types of anxiety, and math achievement. We found that gender and spatial anxiety accounted for 48% of the variance in MA, which increased to 56% with the addition of neuroticism and test anxiety. When math achievement was added, the total explained variance in MA rose to 66%. These results are consistent with Sokolowski et al. (2019), who found that gender, spatial anxiety, and perceived and observed spatial manipulation abilities accounted for 65% of MA variance. Although the full model explained a substantial proportion of variance in MA (66%), the unique contribution of gender was relatively modest (5%). This suggests that

gender is best conceptualized as a distal correlate whose association with MA is largely accounted for by correlated affective traits and math achievement. Accordingly, the conclusions regarding gender effects should be interpreted as relatively small in magnitude. We conclude that gender, spatial anxiety, more general types of anxiety, and math achievement are key factors determining the level of MA in adults. However, we refrain from concluding that spatial anxiety is uniquely central (accounting for nearly 50% of variance in MA in our models), as we did not test alternative model specifications (e.g., models progressing from more general to more domain-specific forms of anxiety), and given the substantial intercorrelations among the examined variables. The remaining variance is likely explained by cognitive and environmental factors (Justicia-Galiano et al., 2023; Lau et al., 2022; Retanal & Maloney, 2026; Szczygieł et al., 2024, 2025).

Gender differences in the strength of MA-math achievement relationship

Gender differences in the strength of the relationship between MA and math achievement were not significant, regardless of whether other anxieties were controlled for. This pattern is consistent with several prior studies reporting comparable MA-achievement associations in women and men (e.g., Hill et al., 2016; Reali et al., 2016), although it contrasts with research suggesting stronger links in women (e.g., Yu et al., 2024) or in first-grade primary school boys (Szczygieł, 2020). The present findings contribute to the mixed literature by suggesting that previously reported gender moderation effects may partly reflect insufficient control for broader affective factors. Because girls and women tend to report higher levels of several forms of anxiety, gender differences in the MA-math achievement relationship observed in some studies may, in part, capture shared emotional vulnerability rather than MA-specific processes.

At the same time, the broader literature suggests that the magnitude of gender differences in the MA-math achievement relationship may depend on developmental stage and sociocultural context. For example, some evidence from younger samples indicates stronger associations in boys (Szczygieł, 2020), whereas cross-cultural work has reported stronger links in girls in certain educational contexts (Yu et al., 2024). These inconsistencies may reflect differences in stereotype exposure, evaluative pressure, or educational experiences across age groups and cultures. Future longitudinal and cross-cultural research is therefore needed to clarify when and under what conditions gender differences in the MA-math achievement relationship emerge.

Study limitations and future research directions

The study's limitations are as follows. The design was correlational and cross-sectional; therefore, the mediation models should not be interpreted as evidence of causal mechanisms or temporal ordering. Although we focused on traits, that is, relatively stable individual differences, alternative model specifications remain theoretically plausible. Future research should use longitudinal designs (and, where feasible, intervention paradigms) to establish temporal precedence and to better distinguish between competing directional accounts.

Because the mediation models were just-identified/saturated and differed in the set of observed variables included, they could not be formally compared using global SEM fit indices or likelihood-ratio tests for nested models. Therefore, conclusions about the incremental contribution of added mediators are based on changes in explained variance rather than on formal SEM model-fit comparisons.

In our study, the task order was fixed. As we used a correlational design and measured traits, this should not have confounded the results. Nevertheless, future studies should counterbalance the task order. We should also note that the sample included more women than men. This imbalance likely reflects typical self-selection patterns in voluntary psychological research, but it may also indicate differential willingness to participate in a study involving mathematics. As participants were informed during recruitment that they would complete questionnaires and solve mathematical tasks, self-selection related to attitudes toward mathematics, anxiety, or competence cannot be ruled out.

Importantly, anxiety-related constructs in our models are conceptually and statistically overlapping. To reduce redundancy, we did not include state anxiety in the analyses. Nevertheless, future work could explicitly model a higher-order negative affectivity factor and examine whether domain-specific pathways persist after accounting for this shared variance.

Whereas Sokolowski et al. (2019) and Delage et al. (2022) tested both spatial abilities and spatial anxiety, we focused only on the latter. Given established links between spatial processing and mathematics, future research should include both spatial performance measures and spatial anxiety to clarify their relative and joint contributions to MA and math achievement. Additionally, these studies and ours differed in the method used to measure math achievement. Future studies should employ both time-pressured arithmetic tasks and broader sets of math problems to be solved without time pressure, to investigate potential task dependence underlying inconsistent findings.

The questionnaire we used to assess spatial anxiety does not include anxiety related to the extrinsic-static spatial processing, which encompasses skills potentially math-relevant, such

as integrating continuous and categorical information (Uttal et al., 2013). Future research is needed to investigate the contribution of extrinsic-static spatial anxiety to the gender gap in MA, particularly because it has been found that men outperform women in tasks tapping into that dimension (Uttal et al., 2013).

Finally, it should be noted that gender differences in self-reported anxiety that we found may partly reflect differences in the social acceptability of emotional expression. Women may be more willing to acknowledge and report anxiety symptoms, whereas men may be less likely to disclose such experiences due to gender-related social expectations (McLean & Anderson, 2009).

Conclusions

Our study supports previous findings regarding the gender gap in MA, but these differences appear to be weaker when spatial anxiety, test anxiety, neuroticism, and math achievement are accounted for. We conclude that gender differences in MA are largely statistically indirect and can be substantially accounted for by associated affective factors and math achievement. We suggest that interventions aimed at reducing spatial anxiety in the domains of mental manipulation and navigation in women could help reduce the gender gap in MA. The remaining indirect paths, including test anxiety and neuroticism, were nonsignificant, suggesting that spatial anxiety in navigation and manipulation plays a key role in accounting for gender differences in MA, likely because both types are related to mathematics. Finally, the relationship between MA and math achievement, tested separately in women and men, is weaker when controlling for various types of anxiety, and the gender difference in the strength of this relationship is not statistically significant. The absence of gender differences in the MA-achievement link suggests that interventions targeting anxiety may yield similar benefits for women and men in terms of math achievement.

Declarations

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Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.]

Data availability statement: The data and analysis script that support the findings of this study are openly available in Open Science Framework at <https://osf.io/rgcy5/> [DOI 10.17605/OSF.IO/RGCY5]. The mathematical tasks can be made available by the authors upon reasonable request via email.

Ethics approval statement: The study was conducted in accordance with the principles of the Declaration of Helsinki, and its protocol was approved by the Research Ethics Committee at the Faculty of Philosophy, Jagiellonian University (approval number: 221.0042.44_2023).

Participant consent statement: All participants were informed about the purpose and procedures of the study and gave their informed consent to participate.

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Appendix A

Confirmatory Factor Analysis of MA

First, we checked whether the scores of math anxiety scales are highly related to each other (see Table A1). The results indicated that AMAS-L, AMAS-T, MASA, and SIMA are significantly, positively, and strongly related to each other.

Table A1

Descriptive statistics and Pearson's correlations between math anxiety scales

	<i>M</i>	<i>SD</i>	Range	<i>Sk.</i>	<i>K.</i>	AMAS-L	AMAS-T	MASA
AMAS-L	23.81	9.21	9-45	.22	-.83			
AMAS-T	12.64	4.59	4-20	-.21	-.93	.74***		
MASA	47.39	14.02	19-76	-.17	-.79	.67***	.65***	
SIMA	5.99	2.62	1-10	-.26	-1.05	.68***	.73***	.80***

*** $p < .001$. AMAS-L – learning math anxiety, AMAS-T – testing math anxiety, MASA – math problem-solving anxiety, SIMA – general anxiety.

Then, we tested the hierarchical CFA model in which AMAS-L, AMAS-T, MASA, and SIMA were first-order latent factors loaded by scales' items, and MA was a second-order latent factor loaded by first-order factors. All regression paths λ were significant $p < .001$ and ranged from .55 to .90 for first-order level factors and from .84 to .93 for second-order level factor (see Table A2). The data were fitted to the model well: $\chi^2_{374} = 364.57$, $p = .63$, CFI = 1, TLI = 1, RSMEA [95% CI] = 0 [0, .02], SRMR = .056. The results indicate that all types of math anxiety (learning, testing, math problem-solving anxiety, general math anxiety) create higher-order math anxiety factor. Therefore, we could treat the sum of scores in various math anxiety measures as an indicator of MA.

Table A2

CFA results

AMAS Learning	λ
AMAS1	.73
AMAS3	.90
AMAS6	.79
AMAS7	.78
AMAS9	.82
AMAS Testing	
AMAS2	.82
AMAS4	.89
AMAS5	.87
AMAS8	.68

MASA	
MASA1	.68
MASA2	.55
MASA3	.77
MASA4	.72
MASA5	.66
MASA6	.71
MASA7	.73
MASA8	.58
MASA9	.60
MASA10	.75
MASA11	.69
MASA12	.77
MASA13	.72
MASA14	.76
MASA15	.66
MASA16	.74
MASA17	.55
MASA18	.72
MASA19	.70
MA	
AMAS Learning	.88
AMAS Testing	.88
MASA	.84
SIMA	.93

All paths were significant at level $p < .001$