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The Relationships Between Metacognition, Mathematics Confidence, Mathematics Anxiety and Mathematics Performance

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Abstract

The current study aimed to acquire a better understanding of the relationships between metacognition, mathematics confidence, mathematics anxiety, general anxiety, gender and mathematics performance. The predictor variables investigated in this study were selected and simultaneously assessed as they have been identified in prior research to be related to mathematics performance (Morsanyi et al., 2019). However, previous research has predominantly only looked at these variables in isolation and the interaction between these predictors has only been investigated in a limited number of studies (Descender & Sansanguie, 2022; Lei et al., 2015). Here, 121 UK university students undertook four Likert-scale questionnaires to measure metacognition, mathematics confidence, mathematics anxiety and general anxiety, in addition to undertaking the CRT-Long (Primi et al., 2016) to measure mathematics performance. Results of a hierarchical multiple regression analysis indicated mathematics confidence independently predicted mathematics performance beyond the effect of mathematics anxiety, general anxiety, gender and metacognition for UK University students. Mathematics confidence also mediated the effect of mathematics anxiety on mathematics performance. Moreover, general anxiety was correlated to mathematics anxiety but did not explain additional variance in mathematics performance beyond the effect of the other predictors. A significant negative correlation between mathematics anxiety and mathematics confidence was also observed. The practical implications of these findings are centred around informing teaching practices within the education sector to shape the learning experience of anxious students by optimising learning environments and materials (Morsanyi et al., 2019; Plass et al., 2015). The findings from this investigation suggest that mathematics confidence training should be advocated and emphasised within classroom practice to improve mathematics performance.

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Introduction

Success in life, measured in terms of economic and health outcomes, is positively correlated with mathematical performance (Dougherty, 2003; Jansen et al., 2013; Reyna et al., 2009). The impact of cognitive (Cragg et al., 2017; Mayes et al., 2009; Purpura et al., 2017; Träff, 2013) and emotional (Ahmed et al., 2012; Henschel & Roick, 2017; Jansen et al., 2013; Pipere & Mieriņa, 2017) factors on mathematical performance has garnered a notable extent of academic interest in recent years. This investigation will combine areas of inquiry that had primarily been developed independently to enrich and establish connections in the metacognition literature with research on mathematical decision-making and mathematics anxiety (Morsanyi et al., 2019). We will focus on the interaction between the cognitive factor of metacognition and the affective factors of mathematics confidence, mathematics anxiety and general anxiety, in addition to the influence of gender, upon mathematics performance in this study.

Mathematics Anxiety & Mathematics Performance

Mathematics anxiety is widely recognised as a state of tension, fear or apprehension that impairs an individual's performance on mathematical tasks (Ashcraft, 2002). Despite some individuals with high levels of mathematics anxiety being capable of operating at a normal level of performance (Devine et al., 2018), it has been widely established that mathematics anxiety is associated with relatively low mathematics performance (Aschcraft, 2002; Hembree, 1990; Ho et al., 2000; Miller & Bichsel, 2004). Whilst a strong association between mathematics anxiety and performance has been identified, the direction or causal nature of this relationship is not fully understood (Morsanyi et al., 2019). Research findings in relation to this association have produced conflicting results (Devine et al., 2012), and longitudinal studies are limited in availability (Cargnelutti et al., 2017; Gunderson et al., 2019). The moderate negative relationship between mathematics anxiety and mathematics performance has sought to be understood by numerous explanations (Eysenck et al., 2007; Mammarella et al., 2018). The most plausible explanation is that there is a reciprocal relationship between the two constructs to imply they reinforce one another (Carey et al., 2016; Gunderson et al., 2019).

Mathematics Anxiety, General Anxiety & Mathematics Performance

Mathematics anxiety has been recognised as a distinct form of anxiety (Dew et al.,1984; Hill et al., 2016). After accounting for the effects of test anxiety and general anxiety, mathematics anxiety remains correlated with math performance (Dew & Galassi, 1983; Hembree, 1990). Moreover, from prior research exploring the influence of general anxiety and math anxiety on test performance, the variance explained by these factors can be separated (Szczygiel. 2020). Mathematics anxiety and general anxiety are recognised as distinct influences whereby the debilitating effects of general anxiety are more general, and not math-specific, in contrast to mathematics anxiety's impact on math performance (Hart & Ganley, 2019). Mathematics anxiety has been associated with a decreased capacity for rational decision-making, demonstrated by lower scores on the cognitive reflection test (Primi et al., 2016). Thus, it is also feasible to suggest the metacognitive processes of maths anxious and non-anxious individuals may also differ when undertaking mathematics tasks (Primi et al., 2018).

Mathematics Confidence & Mathematics Performance

Mathematics confidence appears to have a significant influence upon mathematics performance (Dowker et al., 2016; Ganley & Lubienski, 2016). Research findings have demonstrated that mathematics performance is a reliable predictor of mathematics confidence and there is evidence for a reciprocal relationship between mathematics confidence and performance (Ganley & Lubienski, 2016). It has been established there are notable relationships between students' performance and their confidence in their mathematical abilities; however, a causal link has not yet been established (Khasawneh et al., 2021). Increasing students' confidence in their mathematical skills may enhance mathematical performance (Parsons et al., 2009). However, more research is needed to determine the extent of influence that mathematics confidence has on mathematics performance when the influence of other predictors are also present (Morsanyi et al., 2019).

Metacognition, Mathematics Anxiety, Mathematics Confidence & Mathematics Performance

Metacognition encompasses the various cognitive processes through which learners strategically plan, monitor, evaluate, and adapt their learning behaviours to align with specific tasks (Chauhan & Singh, 2014). Often referred to as "thinking about thinking" (Flavell, 1979), metacognition encompasses a reflective and intentional approach to the learning process. Anxiety may have a beneficial impact on learning behaviour (Birenbaum & Eylath, 1994; Macher et al., 2015). In particular, students who experience high levels of anxiety before an exam may have lower confidence in their ability to succeed and, as a result, may devote more time to studying and practicing (Macher et al., 2015). Despite being an intriguing theory, this has not been empirically tested at present (Morsanyi et al., 2019). According to other theorists, anxious students may be more likely to devote insufficient time to learning and practice because of their low expectations for their final performance and propensity for avoidance behaviour with regard to mathematics (Ackerman & Goldsmith, 2011; Ashcraft, 2002). Individuals may score poorly on tests because of the debilitating effect of their anxiety on cognitive resources (Ashcraft & Faust, 1994), as well as a utilisation of ineffective learning strategies prior to the test (Ackerman & Goldsmith, 2011).

Considering the negative relationship that has been established between mathematics anxiety and test performance (Zhang et al., 2019), it can be anticipated that mathematics anxiety reduces the efficiency of metacognitive regulation processes (Korem et al., 2022). This is supported by Eysenck's attentional control theory (Eysenck et al., 2007) and neuroimaging findings (Pletzer et al., 2015), which suggest anxiety hinders the functioning of the goal-directed attentional system, whilst simultaneously increasing the processing of low-level cues and stimuli. Those who experience mathematics anxiety may exhibit different metacognitive behaviours after providing an answer to problems (Fleming & Lau, 2014). Compared to non-anxious individuals, they may be more inclined to believe that they provided the wrong response because they are less confident in their responses (Hunt & Maloney, 2022).

Gender & Mathematics Performance

It is well established that there are gender disparities in mathematical performance assessments, including simple arithmetic tests and more complex exams such as the cognitive reflection test (Vos et al., 2023). Research findings have repeatedly demonstrated that women's attitudes towards mathematics are more negative and impact their performance in mathematics (Barroso et al., 2021; Else-Quest et al., 2010). Gender differences in mathematics performance appear to be mediated by mathematics anxiety (Vos et al., 2023). Additionally, it has been found that anxiety, confidence, and CRT performance are impacted by gender (Devine et al., 2012; Primi et al., 2018). Further research is necessary to enhance understanding towards the relationship between gender and mathematics performance, which may vary depending on the math task undertaken (Vos et al., 2023).

The Current Study

Within the current body of literature, there is a lack of examination exploring the relationships between metacognition, mathematics confidence, mathematics anxiety, general anxiety, gender and mathematics performance (Morsanyi et al., 2019). The interaction between some of these variables has been investigated in a limited number of studies (Macher et al., 2015). Legg and Locker (2009) measured both mathematics anxiety as well as metacognition and observed that high-metacognitive regulation appears to overcome the negative effects of mathematics anxiety. Similarly, Lai et al. (2015) found that the effect of mathematics anxiety on performance was mediated by metacognition. Furthermore, Desender & Sasanguie (2022) found individuals with high levels of mathematics anxiety demonstrated less accurate metacognitive judgements when undertaking an arithmetic problem, as well as observing a negative relationship between general confidence and mathematics anxiety that is not math specific (Morsanyi et al., 2019).

The purpose of this study is to acquire a better understanding of the interplay between these variables by examining which predictor(s) have a significant relationship with mathematics performance and can independently predict mathematics performance when these variables are simultaneously assessed. The variables investigated in this study were selected as they have been identified in prior research to influence mathematics performance (Morsanyi et al., 2019). However, prior research has predominantly only looked at these variables in isolation and the interaction between some of these predictors has only been investigated in a limited number of studies, as discussed earlier (Descender & Sansanguie, 2022; Legg & Locker, 2009; Lei et al., 2015). Therefore, the aim of the current study is to bridge this gap in the literature through undertaking a quantitative investigation to examine the relationships between metacognition, mathematics confidence, mathematics anxiety, general anxiety, gender and mathematics performance of UK University Students. By enhancing our understanding of the relationships between these predictors and their influence on mathematics performance, this can provide academics in the domains of metacognition and mathematics anxiety with fresh perspectives and real-world implications – in particular for the education sector and to shape the learning experience of anxious students (Morsanyi et al., 2019).

In line with the reviewed literature, we hypothesised that firstly mathematics anxiety, general anxiety, mathematics confidence, gender and metacognition will have a significant relationship with mathematics performance. Additionally, mathematics anxiety will independently predict mathematics performance beyond the effect of general anxiety, gender, mathematics confidence and metacognition. Moreover, general anxiety will be related to mathematics anxiety but will not explain additional variance in mathematics performance beyond the effect of the other predictors. Finally, mathematics anxiety and mathematics confidence will show a significant negative correlation.

Method

Participants

A sample of 121 university students (45 male, 74 female, 1 non-binary and 1 prefer not to say) studying at universities in the United Kingdom enrolled in a range of degree courses and between the ages of 18-28 (M = 21.14 SD = 1.44) were recruited for this investigation. Participants were recruited using convenience sampling by distributing the online questionnaire through social media and within various lectures and seminars at Loughborough University. All students participated on a voluntary basis. To partake in this research, participants had to be over the age of 18, be a UK university student and have the capacity to fully understand and consent to this research. All participants who started the survey finished it. A sample size target was set at 120 participants to provide necessary power for the effect of interest to be observed.

Materials and measures

Demographic information, including age, gender, degree course and level of degree was collected before Likert-scale questionnaires and a numeracy task was administered. Gender differences were analysed in this investigation. The measures utilised were administered in the following order, whereby the anxiety questionnaires appeared after the CRT-Long, so as not to influence performance on the CRT task and prevent participants guessing the aim of the study.

The Attitudes to Technology in Mathematics Learning Questionnaire (Fogarty et al., 2001) assesses attitudes towards the use of technology for mathematics learning as well as overall confidence in mathematics and technology use. 11 of the 37 questions assessed general mathematics confidence through statements such as "I find mathematics frightening" (negatively scored) and “I have less trouble learning mathematics than other subjects” (positively scored). Likert-style responses were utilised, with 1 denoting "strongly agree" and 5 denoting "strongly disagree." For mathematics confidence, a score of 11 represents low mathematics confidence, whereas a score of 55 suggests high mathematics confidence. The eleven questions used to gauge confidence in mathematics were taken from a scale created by Fogarty and Taylor (1997) as part of their investigation into how learning styles relate to mathematical ability. For this investigation, the mathematics confidence scale was used. Also, the instruction statement was modified to remove the word confidence to prevent participants from establishing the aim of the experiment. The Cronbach's Alpha score for this measure suggests that the internal consistency is good (α = .83).

Math performance was evaluated using the CRT-Long (Primi et al., 2016), an expanded, 6-item version of the CRT (Frederick, 2005). The CRT-Long enables the measurement of cognitive reflection in samples with lower ability who frequently receive a score of zero on the original CRT (Primi et al., 2016). There is no time limit on how long participants have to finish the CRT items. "If three elves can wrap three toys in one hour, how many elves are needed to wrap six toys in two hours?" is an example of a question from the CRT-Long. Participants' responses were categorised as analytic (correct), intuitive (the typical incorrect response) or other. The total number of correct answers is used to calculate a single composite score. Better math performance is indicated by higher correct scores. For this investigation, the currency valuation within the CRT-long was converted from dollars to pounds to make the corresponding question relevant to a UK sample. Additionally, response options were changed from open-ended to multiple choice to enable data to be collected more efficiently. The Cronbach's Alpha score for this measure suggests that the internal consistency is excellent (α = .92).

The State Metacognitive Inventory Questionnaire is a measure of metacognition (O'Neil Jr & Abedi, 1996) and consists of 20 items divided into 4 subscales: awareness, planning, monitoring, and cognitive strategy. The SMIQ utilises a 4-point Likert scale, where 1 represents "not at all", 2 represents "somewhat", 3 represents "moderately" so and 4 represents "very much so". Participants assess their agreement with 20 statements. The lowest score for each question is 1, and the highest score is 4. "I was aware of my own thinking" is an example of one of the scale's questions. To get the overall score and total score for each subscale, responses are added together. The SMIQ has a minimum score of 20 and a maximum score of 80. Better metacognitive ability is indicated by a higher score, whilst lesser metacognitive abilities are indicated by a lower score. For this investigation 2 items were dropped from the awareness subscale, 1 item was dropped from the planning subscale and 1 item were dropped from the monitoring subscale. These questions possessed a lack of relevance to the CRT-long; thus, in the interest of time constraints they were removed. The Cronbach's Alpha score for this measure suggests that the internal consistency is good (α = .84).

The Abbreviated Maths Anxiety Scale (Hopko et al., 2003) is a measure of mathematics anxiety. The nine items in the AMAS ask participants to imagine their feelings in various scenarios relating to mathematics. Examples include "thinking about an upcoming math test one day before" and "watching a teacher work an algebraic equation on the blackboard." A 5-point Likert-type scale, with 1 denoting low anxiety and 5 denoting high anxiety, is used to express responses. Higher scores imply higher levels of mathematical anxiety. The scores are added together and the overall score can range from 9 to 45. The Cronbach's Alpha score for this measure suggests that the internal consistency is good (α = .89).

The Generalised Anxiety Disorder Scale (GAD-7) is a 7-item measure of anxiety and symptoms of generalised anxiety disorder (Spitzer et al., 2006). The GAD-7 utilises a 4-point Likert scale, with 0 representing "not at all" and 4 representing "nearly every day,". Respondents indicate how frequently they had each symptom over the previous two weeks. "Difficulty relaxing" and "feeling afraid as if something awful might happen" are two examples. Anxiety is graded overall, with a range of 0 to 21. Higher scores indicate more severe functional impairments due to anxiety. A proposed cut-off point of 10 points for moderate anxiety and 15 points for severe anxiety was used. The Cronbach's Alpha score for this measure suggests that the internal consistency is good (α = .87).

Procedure

A detailed study protocol that explained the goal and methodology of the study was approved by Loughborough University's Ethics Review Sub-Committee (Appendix A & Appendix B). Participants were approached on a convenience basis through social media and sent a digital link which directed them to an online Qualtrics survey. Upon opening the survey link, participants were presented with a participant information sheet (Appendix C) outlining the study details, a justification of why the study is taking place and the right to withdraw their data (and that all data collected will remain anonymous and confidential, in addition to being stored in accordance with Loughborough University's data protection policy). Participants were also provided with a consent form (Appendix D) prior to commencing with the investigation and were required to provide informed consent via a tick box.

Following completion of the online informed consent, participants were required to complete a demographics questionnaire including age, gender, degree course and level of degree (Appendix E). Participants were then required to complete four questionnaires alongside a numeracy task. Firstly, the Attitudes to Technology in Mathematics Learning Questionnaire (Fogarty et al., 2001) was undertaken to assess mathematics confidence (Appendix F). Next, the Cognitive Reflection Test Long (Primi et al., 2016) was utilised to record mathematics performance (Appendix G). Following this, The State Metacognitive Inventory Questionnaire (O'Neil Jr & Abedi, 1996) was undertaken to assess metacognition (Appendix H). Then, the Abbreviated Maths Anxiety Scale (Hopko et al., 2003) was administered to assess mathematics anxiety (Appendix I). Finally, the GAD-7 Questionnaire (Spitzer et al., 2006) was administered to assess general anxiety (Appendix J). Altogether these measures took approximately 10 - 15 minutes to complete and a debrief page was provided upon participants submitting their responses (Appendix K). All data collected was completed online and participants were not offered any incentives.

Data analysis

No data was excluded throughout the data analysis. Preliminary analyses were conducted to ensure no violations of the assumptions for standard multiple regression. The sample size was adequate (N=121), which met the requirement of 82 participants according to Tabachnick and Fidell's (2007) formula of (N>50+8M). Collinearity Tolerance was greater than 0.5 and VIF was below 10 (Appendix L), suggesting there was no issues with multicollinearity. Normality, homoscedasticity and linearity were all met as indicated by the histogram (Appendix M), scatterplot residuals (Appendix N) and P-plot (Appendix O). The data was not transformed. No outliers were identified, standard residuals were within +/-3.3

standard deviations and values for Cook's distance were below 1 (Appendix P). The statistical test of hierarchical multiple regression was conducted through the programme of SPSS. If results from the hierarchical standard regression were found to be significant it would indicate that the variable accounted for a significant variance in mathematics performance.

Results

The descriptive statistics for CRT correct, metacognition, mathematics confidence, mathematics anxiety and general anxiety score are presented in Table 1. Overall, all the measures possessed a good range of scores and the scores across all measures were generally in the middle.

Table 1. *Descriptive statistics for participants CRT correct, metacognition, mathematics confidence, mathematics anxiety and general anxiety scores.*

Variable	**Range**	**Minimum**	**Maximum**	Mean	Standard Deviation
CRT correct	6.00	.00	6.00	3.64	1.83
Metacognition	38.00	22.00	60.00	39.12	8.42
Mathematics confidence	38.00	16.00	54.00	33.89	8.19
Mathematics anxiety	32.00	9.00	41.00	24.96	6.58
General anxiety	21.00	7.00	28.00	14.56	4.50

The relationships between the predictor variables in this investigation are presented in table 2. The relationship with gender was also considered within the following correlation matrix.

Table 2. *Correlations between participants CRT correct, metacognition, mathematics confidence, mathematics anxiety, general anxiety scores and gender.*

Variable	1	2	3	4	5	6
1 CRT correct	-					
2 Metacognition	.14	-				
3 Mathematics confidence	.35***	.44***	-			
4 Mathematics anxiety	-.29***	-.28***	-.65***	-		
5 General anxiety	-.08	.05	-.06	.30***	-	
6 Gender	-.20*	-.07	-.33***	.35***	.27**	-

*p<.05, **p<.01, ***p<.001

Mathematics confidence, mathematics anxiety and gender are significantly correlated with CRT performance. Mathematics confidence is significantly correlated with all the variables except for general anxiety. Mathematics anxiety has a significant negative correlation with CRT performance, metacognition and mathematics confidence whilst having a significant positive correlation with general anxiety and gender. General anxiety is negatively correlated with CRT score and mathematics confidence whilst being positively correlated with metacognition, mathematics anxiety and gender. Gender is significantly correlated with all the variables except metacognition. The other variables are moderately correlated with each other.

A hierarchical multiple regression was used whereby all the variables were entered at the same time into the regression model to assess the ability of metacognition, mathematics confidence, mathematics anxiety and general anxiety to predict mathematics performance. This demonstrated that mathematics confidence is related to CRT performance beyond the effect of all the other variables. The effect of gender was also controlled for in this regression model. Table 3 provides the outputs of the regression model.

Table 3. *Hierarchical Multiple Regression predicting mathematics performance from metacognition, mathematics confidence, mathematics anxiety, general anxiety and gender.*

	Mathematics Performance									
	Model 1		Model 2		Model 3		Model 4		Model 5	
Variable	B	β	B	β	B	β	B	β	B	β
Constant	2.44**		1.07		2.30		2.32		2.69	
Metacognition	.03	.14	-.00	-.01	-.00	-.01	-.00	-.01	-.00	-.00
Mathematics confidence			.08***	.35	.06*	.29	.07*	.29	.06*	.27
Mathematics anxiety					-.03	-.10	-.03	-.09	-.02	-.08
General anxiety							-.01	-.03	-.01	-.02
Gender									-.26	-.08
R^2	.02		.12		.13		.13		.13	
F	2.41		8.17***		5.72		4.29		3.55**	
ΔR^2	.02		.10		.01		.00		.01	
ΔF	2.41		13.68***		.84		.13		.64	

*p<.05, **p<.01, ***p<.001

Preliminary analyses were conducted to ensure no violation of the assumptions of normality, linearity, multicollinearity and homoscedasticity. None of the assumptions were violated.

Model 1, with metacognition as the only predictor, explained 1.2% of the variation (adjusted $R^2 = 0.012$) and was not significant $F(1,119) = 2.410$, $p = 0.123$.

After entry of mathematics confidence in Model 2, the model explained significantly more variance, $F(2,118) = 8.171$, $p<0.01$, (R^2 change = 0.102, $p < 0.001$). The total variation in mathematics performance explained by the model as a whole was 10.7% (adjusted $R^2 = 0.107$). The significant predictor in Model 2 was mathematics confidence ($p< 0.01$). Metacognition was not a significant predictor.

After entry of math anxiety in Model 3, the model explained non-significantly less variance, $F(3,117) = 5.719$, $p = 0.001$, (R^2 change = 0.006, $p = 0.362$). The total variation in mathematics performance explained by the model as a whole was 10.6% (adjusted $R^2 = 0.122$). There were no significant predictors in model 3.

After entry of general anxiety in Model 4, the model explained non-significantly less variance, $F(4,116) = 4.289$, $p = 0.003$ (R^2 change = 0.001, $p = 0.722$). The total variation in mathematics performance explained by the model as a whole was 9.9% (adjusted $R^2 = 0.099$). There were no significant predictors in Model 4.

After entry of gender in Model 5, the model explained non-significantly less variance, $F(5,115) = 3.549$, $p = .005$ (R^2 change = 0.005, $p = 0.425$). The total variation in mathematics performance explained by this model as a whole was 9.6% (adjusted $R^2 = 0.096$). There were no significant predictors in Model 5.

To better understand the mechanism underlying the relationship between mathematics anxiety, mathematics confidence and metacognition, we tested if mathematics confidence mediates the effect of mathematics anxiety on mathematics performance (see Figure 1). Recently, using the bootstrapping procedure over the Sobel test has been recommended when assessing indirect effects of mediation models, since the bootstrapping procedure does not impose the assumption of normality of the sampling distribution on indirect effects (Hayes, 2009). In our study, this mediation hypothesis was tested with SPSS macro (the INDIRECT procedure) for bootstrapping (with 1000 bootstrap samples) to estimate 95% confidence interval (CI; for more details, see Preacher & Hayes, 2008).

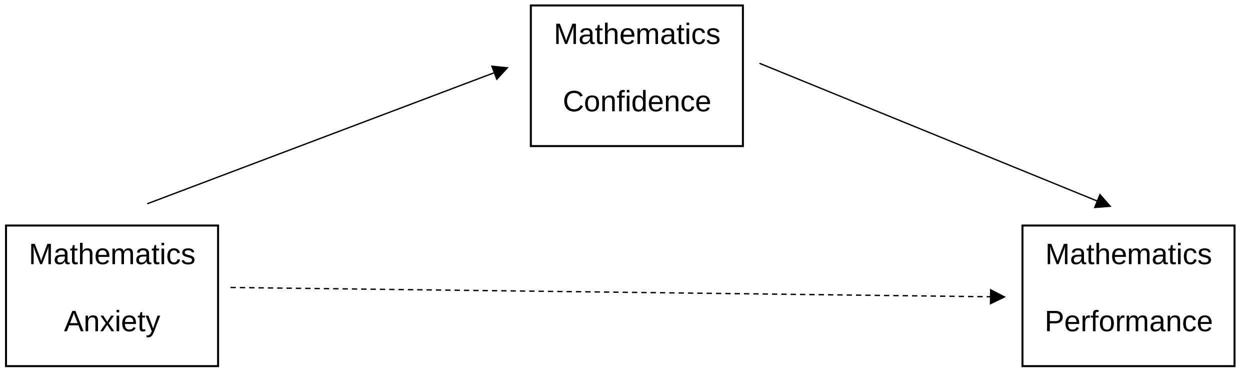

Figure 1. *Path model depicting the relationships between mathematics anxiety, mathematics confidence and mathematics performance. (Dotted line represents non-significant link. Straight line represents significant link).*

The total effect reflects that the regression model is significant (p =.0014). The INDIRECT procedure revealed a significant indirect effect of mathematics anxiety on mathematics performance through mathematics confidence (point estimate - .05, 95% *CI* = - .09 to - .01). The direct effect of mathematics anxiety on cognitive reflection was not significant (p =.359). Overall, the results indicate that the link between mathematics anxiety and mathematics performance was mediated by mathematics confidence.

Discussion

This study aimed to understand the relationships between metacognition, mathematics confidence, mathematics anxiety, general anxiety, gender and mathematics performance of UK University Students. The findings from this investigation highlighted that mathematics confidence was the only variable to have a significant relationship with mathematics performance; thus, our first hypothesis was rejected. Additionally, mathematics confidence independently predicted mathematics performance beyond the effect of mathematics anxiety, general anxiety, gender and metacognition; thus, our second hypothesis was rejected. Furthermore, general anxiety was related to mathematics anxiety but did not explain additional variance in mathematics performance beyond the effect of the other predictors; thus, our third hypothesis was accepted. Moreover, a significant negative correlation between mathematics anxiety and mathematics confidence was observed; thus, our fourth hypothesis was accepted. Mathematics confidence also mediated the effect of mathematics anxiety on mathematics performance.

The significant relationship between mathematics confidence and mathematics performance aligns with the findings of prior studies (Devine et al., 2012; Mammarella et al., 2018; Morsanyi et al., 2019). Moreover, the significant relationship observed between mathematics confidence and mathematics anxiety supports prior research which has suggested that lower mathematics confidence appears to coincide with higher mathematics anxiety (Ashcraft, 2002; Dowker et al., 2016; Hembree, 1990). Mathematics confidence may be a precursor of mathematics anxiety whereby higher confidence can compensate for lower anxiety and improve mathematics performance (Ganley & Lubienski, 2016; Hembree, 1990). Potentially, this explains why mathematics confidence independently predicted mathematics performance beyond the effect of mathematics anxiety, general anxiety, gender and metacognition – as well as offering an explanation for mathematics confidence and mathematics anxiety displaying a significant negative correlation. This can also explain the direct effect of mathematics anxiety on mathematics performance being non-significant whilst the indirect effect mediated by mathematics confidence was significant.

Additionally, this investigation highlights a non-significant relationship between general anxiety and mathematics performance, whereby general anxiety did not explain additional variance in mathematics performance beyond the effect of the other predictors. Prior research has established the debilitating effects of general anxiety are broader in nature, in contrast to predictors such as mathematics anxiety and mathematics confidence, and hence not specifically related to mathematics performance (Szczygield, 2020). This is supported by the correlations assessment highlighting that despite general anxiety being significantly correlated to mathematics anxiety, general anxiety was non-significantly correlated to CRT performance. In contrast, mathematics anxiety was significantly correlated to CRT performance. Conceptually, and by definition, general anxiety is different from mathematics anxiety since it relates to a person's overall tendency to worry about events, actions, and personal skills rather than a particular scenario or activity, such as performing well in mathematics (Hart & Ganley, 2019).

The current body of literature predominantly suggests that mathematics anxiety, general anxiety, gender and metacognition have significant relationships with mathematics performance (Morsanyi et al., 2019). Despite this, the results of this investigation found non-significant relationships for these variables. This discrepancy can potentially be explained as prior studies have typically investigated these variables in isolation or focused upon the influence of one or two of these predictors simultaneously on mathematics performance (Descender & Sansanguie, 2022; Legg & Locker, 2009; Lei et al., 2015). In addition, this study is the first to investigate these relationships specifically for UK university students. Nevertheless, these findings were largely unexpected, suggesting that mathematics anxiety, general anxiety, metacognition and gender are not as directly associated with mathematics performance as previously thought (Descender & Sasanguie, 2022; Legg & Locker, 2009). These predictors may still influence mathematics performance in isolation or have an indirect influence on mathematics performance; however, there is limited research that considers the influence of mediator variables to explain the dynamic nature of such relationships (Morsanyi et al., 2019). Additionally, prior research has investigated similar, but distinct, influences such as self-efficacy (Jameson & Fusco, 2014).

The practical implications of these findings are centred around informing teaching practices within the education sector to shape the learning experience of anxious students by optimising learning environments and materials (Morsanyi et al., 2019). Mathematics confidence independently predicted mathematics performance beyond the effect of mathematics anxiety, general anxiety, gender and metacognition. Mathematics confidence also mediated the effect of mathematics anxiety on mathematics performance. Therefore, it appears strategies to promote mathematics confidence through mathematics confidence training should be advocated and emphasised within classroom practice to improve mathematics performance. Game-based learning (GBL) has gained attention recently as a possible strategy for raising students' confidence (Plass et al., 2015; Tobias et al., 2014). According to research by Veggel & Amory (2016) this approach produced superior results than paper-based learning in terms of students' performance and confidence. Further investigation has revealed that small group tutorials are also an effective method of mathematics support to enhance student mathematics confidence and performance (Ku et al., 2014). Additional support through e-learning has the potential to benefit students who prefer online learning (Ku et al., 2014).

This study is the first to investigate the relationships between metacognition, mathematics confidence, mathematics anxiety, general anxiety, gender and mathematics performance. Additionally, this investigation utilised a sample of UK university students in contrast to prior research which has predominantly utilised samples from different populations (Descender & Sasanguie. 2022; Muncer et al., 2022). However, in terms of limitations, within this study there was limited assessment into the presence of potential mediator variables. Furthermore, no analysis was undertaken with regards to the differences between age and degree qualification. Moreover, the assessment tools used to evaluate mathematics anxiety, general anxiety, metacognition and mathematics confidence were all self-report questionnaires – hence prone to social desirability bias.

Future research should aim to address these areas by firstly exploring the influence of mediator variables further. A deeper comprehension of the potential role of mediator variables can assist in answering questions such as what metacognitive decisions mediate maths anxious participants' tendency to give up on problems too early? (Morsanyi et al., 2019.) Further analysis into the influence of mediator variables may also provide a more adequate explanation for the non-significant results observed in this study (Legg & Locker, 2009). Future research may also analyse if differences are present between participant demographics such as age and degree qualification.

Moreover, future research should aim to experimentally manipulate metacognition, mathematics anxiety, general anxiety and mathematics confidence in order to make more robust claims regarding possible causal relationships among these variables. Metacognition can experimentally be manipulated by providing some participants with metacognitive training prior to the task (Myers & Wells, 2013). Another potential method to enhance control over metacognition might involve posing metacognitive analysis questions to individuals during a problem-solving exercise (Parker et al., 2020). The methodology developed by Beilock and Carr (2005), in which participants are videotaped, told they have a partner who is depending on them and informed that professors will be evaluating their videotapes, may be one way to manipulate mathematics anxiety, general anxiety, and mathematics confidence in future research.

In conclusion, mathematics confidence independently predicted mathematics performance beyond the effect of mathematics anxiety, general anxiety, gender and metacognition for UK University students. Mathematics confidence also mediated the effect of mathematics anxiety on mathematics performance. Moreover, general anxiety was related to mathematics anxiety but did not explain additional variance in mathematics performance beyond the effect of the other predictors. Furthermore, a significant negative correlation between mathematics anxiety and mathematics confidence was observed. The implication of these findings can shape the learning experience of anxious students by optimising learning environments and materials through emphasising mathematics confidence training, such as GBL, within classroom practice to improve mathematics performance (Morsanyi et al., 2019; Plass et al., 2015). Although a direct significant relationship between mathematics performance and mathematics anxiety, general anxiety, gender or metacognition had not been observed in this study, the potential presence of further indirect relationships influenced by mediator variables may still be apparent (Henschel & Roick, 2017).

Therefore, future research needs to experimentally manipulate these predictor variables to enhance our understanding of such relationships with mathematics performance.

References

Ackerman, R., & Goldsmith, M. (2011). Metacognitive regulation of text learning: on screen versus on paper. *Journal of experimental psychology: Applied*, *17*(1), 18.

Ahmed, W., Minnaert, A., Kuyper, H., & Van der Werf, G. (2012). Reciprocal relationships between math self-concept and math anxiety. *Learning and individual differences*, *22*(3), 385-389.

Ashcraft, M. H., & Faust, M. W. (1994). Mathematics anxiety and mental arithmetic performance: An exploratory investigation. *Cognition & Emotion*, *8*(2), 97-125.

Ashcraft, M. H. (2002). Math anxiety: Personal, educational, and cognitive consequences. *Current directions in psychological science*, *11*(5), 181-185.

Barroso, C., Ganley, C. M., McGraw, A. L., Geer, E. A., Hart, S. A., & Daucourt, M. C. (2021). A meta-analysis of the relation between math anxiety and math achievement. *Psychological bulletin*, *147*(2), 134.

Beilock, S. L., & Carr, T. H. (2005). When high-powered people fail: Working memory and “choking under pressure” in math. *Psychological science*, *16*(2), 101-105.

Birenbaum, M., & Eylath, S. (1994). Who is afraid of statistics? Correlates of statistics anxiety among students of educational sciences. *Educational Research*, *36*(1), 93-98.

Carey, E., Hill, F., Devine, A., & Szücs, D. (2016). The chicken or the egg? The direction of the relationship between mathematics anxiety and mathematics performance. *Frontiers in psychology*, *6*, 162813.

Cargnelutti, E., Tomasetto, C., & Passolunghi, M. C. (2017). The interplay between affective and cognitive factors in shaping early proficiency in mathematics. *Trends in neuroscience and education*, *8*, 28-36.

Chauhan, A., & Singh, N. (2014). Metacognition: A conceptual framework. *International Journal of Education and Psychological Research (IJEPR)*, *3*(3), 21-22.

Cragg, L., Keeble, S., Richardson, S., Roome, H. E., & Gilmore, C. (2017). Direct and indirect influences of executive functions on mathematics achievement. *Cognition*, *162*, 12-26.

Desender, K., & Sasanguie, D. (2022). Math anxiety relates positively to metacognitive insight into mathematical decision making. *Psychological Research*, *86*(3), 1001-1013.

Devine, A., Fawcett, K., Szűcs, D., & Dowker, A. (2012). Gender differences in mathematics anxiety and the relation to mathematics performance while controlling for test anxiety. *Behavioral and brain functions*, *8*, 1-9.

Devine, A., Hill, F., Carey, E., & Szűcs, D. (2018). Cognitive and emotional math problems largely dissociate: Prevalence of developmental dyscalculia and mathematics anxiety. *Journal of Educational Psychology*, *110*(3), 431.

Dew, K. H., & Galassi, J. P. (1983). Mathematics anxiety: Some basic issues. *Journal of Counseling Psychology*, *30*(3), 443.

Dew, K. H., Galassi, J. P., & Galassi, M. D. (1984). Math anxiety: relation with situational test anxiety, performance, physiological arousal, and math avoidance behavior. *Journal of counseling Psychology*, *31*(4), 580.

Dougherty, C. (2003). Numeracy, literacy and earnings: Evidence from the National Longitudinal Survey of Youth. *Economics of education review*, *22*(5), 511-521.

Dowker, A., Sarkar, A., & Looi, C. Y. (2016). Mathematics anxiety: What have we learned in 60 years?. *Frontiers in psychology*, *7*, 164557.

Else-Quest, N. M., Hyde, J. S., & Linn, M. C. (2010). Cross-national patterns of gender differences in mathematics: a meta-analysis. *Psychological bulletin*, *136*(1), 103.

Eysenck, M. W., Derakshan, N., Santos, R., & Calvo, M. G. (2007). Anxiety and cognitive performance: attentional control theory. *Emotion*, *7*(2), 336.

Flavell, J. H. (1979). Metacognition and cognitive monitoring: A new area of cognitive–developmental inquiry. *American psychologist*, *34*(10), 906.

Fleming, S. M., & Lau, H. C. (2014). How to measure metacognition. *Frontiers in human neuroscience*, *8*, 443.

Fogarty, G. J., & Taylor, J. A. (1997). Learning Styles Among Mature-Age Students: Some Comments on the Approaches to Studying Inventory (ASI-S). *Higher Education Research & Development*, *16*(3), 321-330.

Fogarty, G., Cretchley, P., Harman, C., Ellerton, N., & Konki, N. (2001). Validation of a questionnaire to measure mathematics confidence, computer confidence, and attitudes towards the use of technology for learning mathematics. *Mathematics Education Research Journal*, *13*, 154-160.

Frederick, S. (2005). Cognitive reflection and decision making. *Journal of Economic perspectives*, *19*(4), 25-42.

Ganley, C. M., & Lubienski, S. T. (2016). Mathematics confidence, interest, and performance: Examining gender patterns and reciprocal relations. *Learning and Individual Differences*, *47*, 182-193.

Gunderson, E. A., Hamdan, N., Hildebrand, L., & Bartek, V. (2019). Number line unidimensionality is a critical feature for promoting fraction magnitude concepts. *Journal of Experimental Child Psychology*, *187*, 104657.

Hart, S. A., & Ganley, C. M. (2019). The nature of math anxiety in adults: Prevalence and correlates. *Journal of numerical cognition*, *5*(2), 122.

Hayes, A. F. (2009). Beyond Baron and Kenny: Statistical mediation analysis in the new millennium. *Communication monographs*, *76*(4), 408-420.

Hembree, R. (1990). The nature, effects, and relief of mathematics anxiety. *Journal for research in mathematics education*, *21*(1), 33-46.

Henschel, S., & Roick, T. (2017). Relationships of mathematics performance, control and value beliefs with cognitive and affective math anxiety. *Learning and Individual Differences*, *55*, 97-107.

Hill, F., Mammarella, I. C., Devine, A., Caviola, S., Passolunghi, M. C., & Szűcs, D. (2016). m anxiety in primary and secondary school students: Gender differences, developmental changes and anxiety specificity. *Learning and individual differences*, *48*, 45-53.

Ho, H. Z., Senturk, D., Lam, A. G., Zimmer, J. M., Hong, S., Okamoto, Y., ... & Wang, C. P. (2000). The affective and cognitive dimensions of math anxiety: A cross-national study. *Journal for research in Mathematics Education*, *31*(3), 362-379.

Hopko, D. R., Mahadevan, R., Bare, R. L., & Hunt, M. K. (2003). The abbreviated math anxiety scale (AMAS) construction, validity, and reliability. *Assessment*, *10*(2), 178-182.

Hunt, T. E., & Maloney, E. A. (2022). Appraisals of previous math experiences play an important role in math anxiety. *Annals of the New York Academy of Sciences*, *1515*(1), 143-154.

Jameson, M. M., & Fusco, B. R. (2014). Math anxiety, math self-concept, and math self-efficacy in adult learners compared to traditional undergraduate students. *Adult Education Quarterly*, *64*(4), 306-322.

Jansen, B. R., Louwerse, J., Straatemeier, M., Van der Ven, S. H., Klinkenberg, S., & Van der Maas, H. L. (2013). The influence of experiencing success in math on math anxiety, perceived math competence, and math performance. *Learning and individual differences*, *24*, 190-197.

Khasawneh, E., Gosling, C., & Williams, B. (2021). What impact does maths anxiety have on university students?. *BMC psychology*, *9*, 1-9.

Korem, N., Cohen, L. D., & Rubinsten, O. (2022). The link between math anxiety and performance does not depend on working memory: A network analysis study. *Consciousness and Cognition*, *100*, 103298.

Ku, O., Chen, S. Y., Wu, D. H., Lao, A. C., & Chan, T. W. (2014). The effects of game-based learning on mathematical confidence and performance: High ability vs. low ability. *Journal of Educational Technology & Society*, *17*(3), 65-78.

Lai, Y., Zhu, X., Chen, Y., & Li, Y. (2015). Effects of mathematics anxiety and mathematical metacognition on word problem solving in children with and without mathematical learning difficulties. *PloS one*, *10*(6), e0130570.

Legg, A. M., & Locker Jr, L. (2009). Math performance and its relationship to math anxiety and metacognition. *North American Journal of Psychology*, *11*(3).

Macher, D., Papousek, I., Ruggeri, K., & Paechter, M. (2015). Statistics anxiety and performance: blessings in disguise. *Frontiers in psychology*, *6*, 154176.

Mammarella, I. C., Caviola, S., Giofrè, D., & Borella, E. (2018). Separating math from anxiety: The role of inhibitory mechanisms. *Applied Neuropsychology: Child*, *7*(4), 342-353.

Mayes, S. D., Calhoun, S. L., Bixler, E. O., & Zimmerman, D. N. (2009). IQ and neuropsychological predictors of academic achievement. *Learning and Individual Differences*, *19*(2), 238-241.

Miller, H., & Bichsel, J. (2004). Anxiety, working memory, gender, and math performance. *Personality and individual differences*, *37*(3), 591-606.

Morsanyi, K., Cheallaigh, N. N., & Ackerman, R. (2019). Mathematics anxiety and metacognitive processes: Proposal for a new line of inquiry. *Psihologijske teme*, *28*(1), 147-169.

Muncer, G., Higham, P. A., Gosling, C. J., Cortese, S., Wood-Downie, H., & Hadwin, J. A. (2022). A meta-analysis investigating the association between metacognition and math performance in adolescence. *Educational Psychology Review*, *34*(1), 301-334.

Myers, S. G., & Wells, A. (2013). An experimental manipulation of metacognition: a test of the metacognitive model of obsessive-compulsive symptoms. *Behaviour research and therapy*, *51*(4-5), 177-184.

O'Neil Jr, H. F., & Abedi, J. (1996). Reliability and validity of a state metacognitive inventory: Potential for alternative assessment. *The journal of educational research*, *89*(4), 234-245.

Parker, S. K., Mulligan, L. D., Milner, P., Bowe, S., & Palmier-Claus, J. E. (2020). Metacognitive therapy for individuals at high risk of developing psychosis: A pilot study. *Frontiers in Psychology*, *10*, 2741.

Parsons, S., Croft, T., & Harrison, M. (2009). Does students' confidence in their ability in mathematics matter?. *Teaching Mathematics and its Applications: An International Journal of the IMA*, *28*(2), 53-68.

Pipere, A., & Mieriņa, I. (2017). Exploring non-cognitive predictors of mathematics achievement among 9th grade students. *Learning and Individual Differences*, *59*, 65-77.

Plass, J. L., Homer, B. D., & Kinzer, C. K. (2015). Foundations of game-based learning. *Educational psychologist*, *50*(4), 258-283.

Pletzer, B., Kronbichler, M., Nuerk, H. C., & Kerschbaum, H. H. (2015). Mathematics anxiety reduces default mode network deactivation in response to numerical tasks. *Frontiers in human neuroscience*, *9*, 202.

Preacher, K. J., & Hayes, A. F. (2008). Asymptotic and resampling strategies for assessing and comparing indirect effects in multiple mediator models. *Behavior research methods*, *40*(3), 879-891.

Primi, C., Morsanyi, K., Chiesi, F., Donati, M. A., & Hamilton, J. (2016). The development and testing of a new version of the cognitive reflection test applying item response theory (IRT). *Journal of Behavioral Decision Making*, *29*(5), 453-469.

Primi, C., Donati, M. A., Chiesi, F., & Morsanyi, K. (2018). Are there gender differences in cognitive reflection? Invariance and differences related to mathematics. *Thinking & Reasoning*, *24*(2), 258-279.

Purpura, D. J., Logan, J. A., Hassinger-Das, B., & Napoli, A. R. (2017). Why do early mathematics skills predict later reading? The role of mathematical language. *Developmental Psychology*, *53*(9), 1633.

Reyna, V. F., Nelson, W. L., Han, P. K., & Dieckmann, N. F. (2009). How numeracy influences risk comprehension and medical decision making. *Psychological bulletin*, *135*(6), 943.

Spitzer, R. L., Kroenke, K., Williams, J. B., & Löwe, B. (2006). A brief measure for assessing generalized anxiety disorder: the GAD-7. *Archives of internal medicine*, *166*(10), 1092-1097.

Szczygiel, M. (2020). Gender, general anxiety, math anxiety and math achievement in early school-age children. *Issues in Educational Research*, *30*(3), 1126-1142.

Tabachnick, B. G., & Fidell, L. S. (2007). *Experimental designs using ANOVA* (Vol. 724). Belmont, CA: Thomson/Brooks/Cole.

Tobias, S., Fletcher, J. D., & Wind, A. P. (2014). Game-based learning. *Handbook of research on educational communications and technology*, 485-503.

Träff, U. (2013). The contribution of general cognitive abilities and number abilities to different aspects of mathematics in children. *Journal of experimental child psychology*, *116*(2), 139-156.

Van Veggel, N., & Amory, J. (2014). The impact of maths support tutorials on mathematics confidence and academic performance in a cohort of HE Animal Science students. *PeerJ*, *2*, e463.

Vos, H., Marinova, M., De Léon, S. C., Sasanguie, D., & Reynvoet, B. (2023). Gender differences in young adults' mathematical performance: Examining the contribution of working memory, math anxiety and gender-related stereotypes. *Learning and Individual Differences*, *102*, 102255.

Zhang, J., Zhao, N., & Kong, Q. P. (2019). The relationship between math anxiety and math performance: A meta-analytic investigation. *Frontiers in psychology*, *10*, 1613.