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# Appraisals of previous math experiences play an important role in math anxiety

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## Abstract

Math anxiety affects many people, from young children through to older adults. While there has been debate concerning the developmental trajectory of math anxiety and negative math attitudes, little attention has been given to the role of appraisals of previous math experiences. We surveyed 308 adults (mean age = 27.56 years, SD = 11.25) and assessed self-reported measures of math anxiety, mathematical resilience, math attitudes, and appraisal of previous math experiences. As hypothesized, all variables were found to be interrelated. Math anxiety was significantly negatively related to appraisal of previous math experiences, mathematical resilience, and math attitudes. Moreover, appraisal of previous math experiences was shown to mediate the relations between (1) math anxiety and math attitudes, and (2) mathematical resilience and math attitudes. The findings demonstrate the importance of considering current appraisals of previous math experiences and are consistent with an interpretation account of math anxiety. This may help inform cognitive-based interventions that focus on one's interpretation of past events to support current and future math learning and engagement.

KEYWORDS
appraisal, interpretation account, math anxiety, math attitudes, mathematical resilience

## INTRODUCTION

Mathematics (math) anxiety refers to the feelings of fear and apprehension that many people experience when dealing with math.[1] It is both prevalent and widespread. For example, data from the Organization for Economic Co-operation and Development indicate that 59% of students often worry that it will be difficult for them in math classes.[2] Numerous studies from around the world have found similar results. For example, in a study of over 9000 U.S. students,[3] it was reported that 25.9% had a moderate to high need of help with math anxiety. In line with this, in a study of over 1000 UK undergraduates, researchers found an average of "a fair amount" to "much" self-reported math anxiety.[4] Similarly, in a study of 1000 adults in the U.S. general population, a mean of "some" to "moderate" math anxiety was observed,[5] with math anxiety being normally distributed. Importantly, across the globe, increased math anxiety is associated with decreased achievement in math.[6]

### The relation between math anxiety and math achievement

While there is little to no debate as to whether math anxiety exists, there remains the question of whether math anxiety is an antecedent to, an outcome of, or has reciprocal relations with, variables such as math achievement.[7] The long-accepted explanation for why math anxiety relates to math achievement[8] suggested that math anxiety causes negative thoughts and ruminations which, in turn, cause a transient reduction in the cognitive resources (i.e., working memory) that are needed to succeed in math. As a result, when in an anxious state, people perform at a level below that at which they would otherwise be capable.

It has been previously argued that math anxiety is not simply a proxy for math ability[8] (see also Ref. 9). However, others have presented evidence that poor math achievement can lead to increased math anxiety. Using data from the Longitudinal Study of American Youth, researchers studied 3116 students in grade 7 (age 12–13 years) for a period of 6 years.[10] Results of structural equation modeling indicated that prior low math achievement significantly related to high math anxiety later, but there was little relation between prior high math anxiety and later low math achievement. Such findings support the argument that early math experience is important for the development of math anxiety. Indeed, the authors argue for support of the deficit model of math anxiety, purporting that math anxiety is associated with remembering poor past performance (for a review on the deficit model of math anxiety, see Ref. 11).

More recently, evidence is emerging that suggests that math anxiety and math achievement have a reciprocal relation. Otherwise put, math anxiety may be both the cause of and the consequence of poor math abilities.[7,10,12–15] For example, there is reported evidence of reciprocal relations between math anxiety and math performance in a large-scale longitudinal study with children from grade 1 to grade 2 (mean age of 7.2 years).[14] Children were tested at the beginning of the academic year (Time 1) and again the end of the academic year (Time 2), approximately 6 months apart. Math performance at Time 1 predicted math anxiety at Time 2, and math anxiety at Time 1 predicted math performance at Time 2. Interestingly, the magnitude of the relation between Time 1 math achievement and Time 2 math anxiety ($\beta = -0.20$) was more than three times as large as the effect of Time 1 math anxiety and Time 2 math achievement ($\beta = -0.06$).

## The relation between appraisal and math anxiety

Independent of the directionality of the math anxiety and math achievement relation, not all people on the lower end of the math achievement spectrum go on to develop math anxiety and not all people high in math anxiety demonstrate lower math achievement.[16] Indeed, the correlation between math anxiety and math achievement in adults is typically around $r = -0.30$.[5,17–19] This then prompts the question: why do some people go on to develop math anxiety, while others do not? One possibility is that the answer to this question lies, at least in part, within the ways that people appraise their previous math experiences.

Little research has been conducted into the individual experiences of people concerning math and the exact way in which such experiences relate to current levels of math anxiety and math attitudes. Certainly, at a societal level, attitudes toward math in general are not strongly positive. For example, one study found that 93% of the adults sampled ($n = 157$) reported experiencing some negative math experiences in the classroom between kindergarten through to college.[20] Among these participants, a range of self-reported negative experiences were noted. These often related to teachers, that is, perceived poor instruction, negative attitudes and behavior, unrealistic expectations, and gender bias in favor of boys. This is a worryingly high figure given the importance that is often attached to performing well in math education. There is some (self-reported) evidence to suggest that previous math experiences are associated with current self-reported math anxiety.[21] The researchers interviewed six highly math anxious preservice elementary school teachers in the United States. Analysis revealed several commonalities among the preservice teachers in relation to their negative emotions pertaining to math. For example, participants shared negative experiences of math at school, referring to pressure, poor teaching, and humiliation. Similarly, they shared negative experiences of math within the family, typically referring to unsupportive parents. Shared experiences also extended to magnified anxiety in math test situations, for example, referring to the math component of teaching qualification tests.

Further work has illustrated the association between math anxiety and appraisal of specific math experiences at school.[22] In a sample of undergraduate students, the researchers reported a significant negative relation between math anxiety and self-reported support received throughout previous levels of math education. A significant negative relation was further observed between math anxiety and self-reported negative instructional methods experienced in earlier education. However, the quantitative element of the self-report tool that was developed focuses on limited aspects of a person's previous math experiences. Moreover, as the authors point out, there may be a tendency for anxious individuals to recall experiences in a distorted manner. Therefore, presenting statements that are explicitly positive or negative in nature may compromise the reliability of the measure. The findings do, however, highlight the importance of considering the role of retrospective accounts of people's previous math experiences, particularly the relevance of school-based support and instructional methods. Other, qualitative work has found consistent evidence for the association between math anxiety and negative experiences with elementary school teachers.[23–25] Given data that suggest math anxiety exists in very young children,[19,26] it is important that early math experiences are considered when investigating current math attitudes and math anxiety.

A new account of math anxiety was proposed in 2018—the Interpretation Account.[27] This framework emphasizes appraisal processes in understanding math anxiety and may help explain why some people develop high math anxiety when others do not, even though they may have experienced the same educational context (e.g., the same teacher). A key component of the interpretation account is how math experiences and outcomes are appraised at the level of the individual. This is based on existing appraisal theory[28,29] and an attitudes-as-constructions view.[30,31] The argument here is that current attitudes are shaped by one's interpretation of events, including appraisal of physiological cues, personal behavior, and internal states. Because each person is entering into any given situation with their own unique history, it is feasible, for instance, that two children may have the same math teacher, be exposed to the same learning environment, and be awarded the same grade, yet they each interpret the experience very differently. Their interpretation of these events may contribute to their current cognitive-affective state concerning math. There is synthesized evidence in support of this view.[27] For example, in a longitudinal study of elementary school children,[32] it was found that students' *perceptions* of their math ability mediated the effects of past performance on math anxiety. Thus, it is students' interpretations of their achievement outcomes (not the outcomes themselves) that best predict math anxiety. Interestingly, year-1 perceived ability directly predicted year-2 performance expectations and perceived math importance, suggesting perceptions of one's math ability may have a widespread, lasting impact. There is further evidence that early math achievement has a much stronger effect on later anxiety, in contrast to the effect of early anxiety on later achievement.[10,33,34] More recently, a mixed methods approach was used to study math anxiety.[35] They asked participants to complete a series of self-report measures in addition to providing written narratives concerning pivotal moments (i.e., turning points) in their prior history with math. A higher level of math anxiety was associated with negative narratives. Within the narratives, turning points mostly centered on academic performance, relevance, receiving help, and study habits. These findings are consistent with an interpretation account of math anxiety, whereby negative appraisal of previous math experiences is associated with current self-reported math anxiety. It is also possible that appraisals of previous math experiences are relevant during mathematical problem solving. By asking participants to report what thoughts they experienced during a computer-based math task, researchers found that 40.2% of participants reported having thought about previous math experiences.[36] They further showed that math anxiety was significantly higher among those who reported having such thoughts. While care must be taken not to assume causal effects, work has emphasized the complex nature of memories associated with prior math events and it appears that negative appraisals may have an important role to play in the development, maintenance, and/or exacerbation of math anxiety.[35] An interpretation account of math anxiety[27] points toward a cyclical process that perpetuates the development and maintenance of math anxiety. Those who are high in math anxiety may impose maladaptive interpretative narratives toward their math experiences, which in turn impacts math anxiety, self-efficacy, and attitudes. Indeed, such negative appraisals may impact future and ongoing math events, and this may explain why math anxiety is often associated with ruminations.[8] Such an account may further help in understanding different developmental trajectories of math anxiety.[37]

While the interpretation account of the development of math anxiety asserts that appraising math-related situations as negative causes math anxiety, it is important to note that the causal arrow could also go in the opposite direction. Indeed, it could be the case that those who are already anxious about math are more likely to appraise math-related situations as being negative and threatening. Consistent with this, individuals who are generally anxious have a tendency to attend more to negative events than positive events and are prone to perceive situations which are unclear in a negative, threatening manner.[38] Nevertheless, one prediction based on the Interpretation Account of the development of math anxiety is that higher math-anxious individuals are more likely to appraise their previous math experiences as more negative than do their lower math-anxious counterparts.

## Math anxiety and math attitudes

Extant research has demonstrated a consistent, negative relation between math anxiety and math attitudes.[17,39–41] However, it is important to note that math attitudes are multifaceted, and studies vary in whether they create composite math attitude scores from individual scales. A commonly used self-report measure of math attitudes is the Attitudes Towards Mathematics Scale (ATMS).[42] This comprises four subscales: perceived mathematical incompetence, enjoyment of mathematics, perception of utility, and mathematical self-concept. Thus, the ATMS provides a useful, broad assessment of attitudes toward math. Taking the approach of considering math attitudes in relation to one's own math ability, perceived utility/usefulness, and enjoyment is also typical of other studies in the field.[43] While findings with young[39] and very young[44,45] children are somewhat mixed, research with older, primary aged children through to adults has demonstrated a positive relation between math attitudes and several behavioral outcomes, including math achievement,[32,46–49] course selection,[50] and intentions to take more math.[32] Therefore, it is important to fully understand the factors that may contribute to math attitudes, especially as math self-concept has been shown to mediate the relation between achievement and emotions in math,[51] and perceived value of math has been linked to threat appraisals of teachers' communications prior to high-stakes testing.[52]

## Mathematical resilience

In addition to math attitudes, there is a growing body of research investigating mathematical resilience, which relates to the belief that one can overcome adversity and threats to math self-efficacy, persevering in one's math learning.[53,54] This further relates to one's confidence, satisfaction, and sense of value associated with math and math learning, including the endorsement of the belief that mathematical intelligence is malleable, that is, there is the potential for growth.[54] It is argued that mathematical resilience is a unique construct,[53] with evidence that a positive relation exists between mathematical resilience and math achievement.[55] However, research considering both mathematical resilience and math anxiety is scarce. Some studies have investigated the relation between math anxiety and academic buoyancy[56] and ego resiliency,[56,57] but these variables may not be specific enough to math and this may explain the weak correlations that have been reported. Therefore, it is essential that domain-specific measures are used in math education research and applied settings, and mathematical resilience may be a useful construct in furthering our understanding of math attitudes and math outcomes.

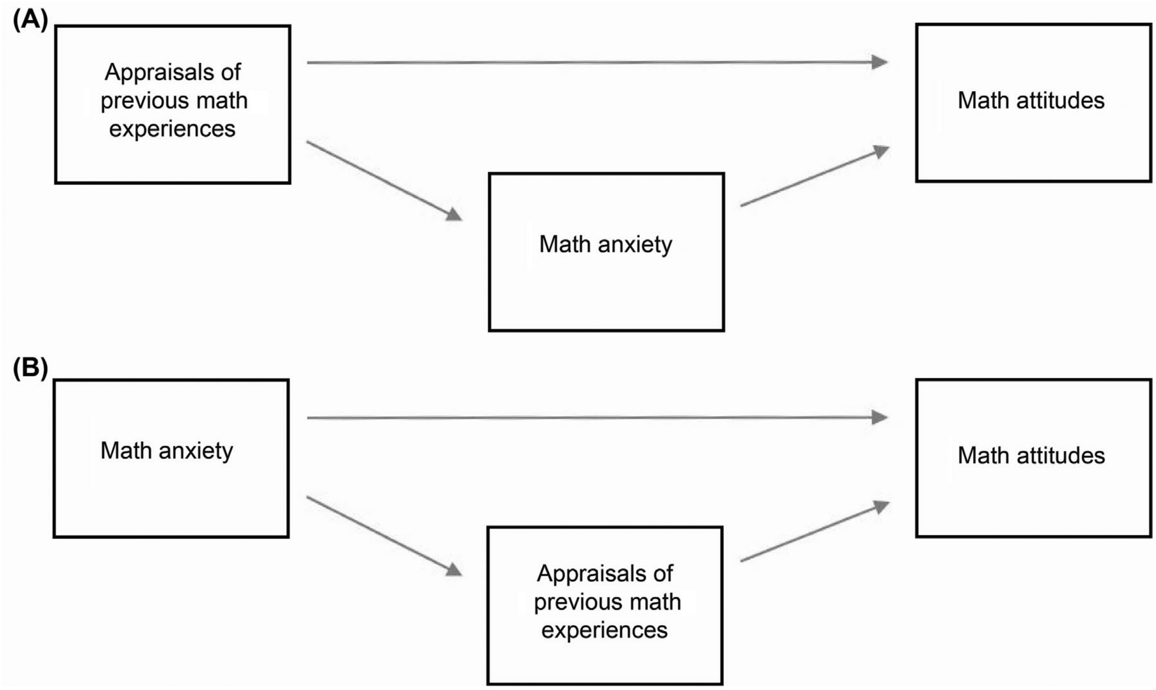


**FIGURE 1** Two theoretical models: predicting math attitudes from appraisals of previous math experiences and math anxiety

## The present study

Based on the theory that an individual's own appraisal of a math-related situation contributes to the development of, or persistence of, math anxiety,[27] we tested the hypothesis that appraisals of previous math experiences, mathematical resilience, math anxiety, and math attitudes would all be interrelated. Specifically, we tested the hypothesis (1a) that positive appraisals of previous math experiences are positively related to mathematical resilience, such that those who report more positive appraisals of their past math experiences will also score higher on a measure of mathematical resilience; (1b) that positive appraisals of past math experiences are negatively related to math anxiety, such that those with less positive appraisals of past experiences will also report higher levels of math anxiety; and (1c) positive appraisals of previous math experiences are positively related to math attitudes, such that those with more positive appraisals of past experiences will also report more positive attitudes about mathematics overall. Furthermore, we tested two additional hypotheses: (2a) that the relation between math anxiety and math attitudes is mediated by appraisals of previous math experiences, and (2b) the relation between mathematical resilience and math attitudes is mediated by appraisals of previous math experiences. The theoretical mediation models that were tested are depicted in Figures 1 and 2. Importantly, to assess people's appraisals of previous math experiences, we first created an in-house measure, the Appraisals of Previous Mathematics Experiences Scale (APMES). Because this is a newly created measure, we report not only the psychometric properties of the measure but also relations between sex and response to the APMES.

# METHOD

## Participants

Using opportunity sampling through advertising via social media and the online research participation system at a UK Midlands university, 308 adult participants voluntarily took part in an online survey (mean age = 27.56 years, SD = 11.25). Most participants were based in the UK (92.88%), with 3.88% of participants based elsewhere in Europe and 3.24% located outside of Europe. Most participants were white British. The sample comprised 229 females, 76 males, one who preferred not to say, and two who preferred to self-describe. Most of the sample (71.43%) were studying, or had previously studied, to at least undergraduate level. People with dyscalculia were not eligible to participate.

## Materials

### Appraisals of Previous Mathematics Experiences Scale

Pilot work demonstrated that it is possible to measure people's appraisals of their previous math experiences in a reliable way.[58] Given this, in the current study, we designed a novel tool to assess individuals' appraisals of their previous mathematics experiences (i.e., APMES). Specifically, a 24-item scale was devised, including items relating to a range of situations involving math. Items were devised from items on previously validated scales of math anxiety (e.g., the Mathematics Anxiety Scale-UK)[4] and responses from individuals on social media

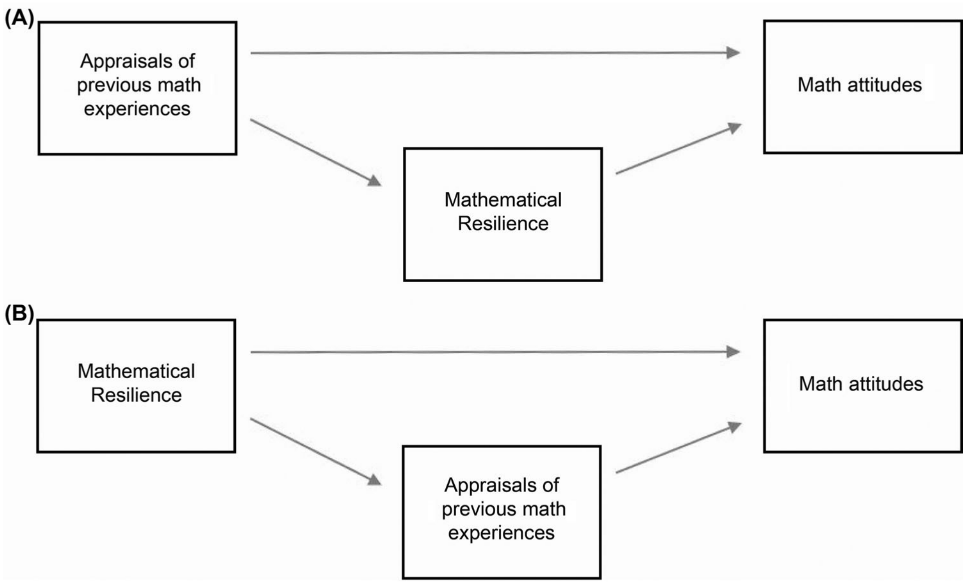


**FIGURE 2** Two theoretical models: predicting math attitudes from appraisals of previous math experiences and mathematical resilience

when asked about their previous math experiences. Example items include "Learning math at school," "Playing cards or a board game where you have to add up or keep track of the score," and "Doing a presentation that involves numbers." The items were purposely designed to indicate specific math experiences, without alluding to whether each experience was negative or positive. Participants were required to appraise their previous experience of that situation, ranging from very negative to very positive, with a central response point indicating a neutral experience or nonapplicability. For each situation listed, participants were instructed to respond based on their overall experience of each situation, considering all their experiences pertaining to that situation. Furthermore, informal discussion on social media concerning people's previous experiences of math led to the generation of an additional eight items, thus ensuring a wide range of contexts could be represented. A final item was included that enabled the respondent to consider another math situation they could recall that may be pertinent to them. Scoring of each item on the scale ranged from −2 to 2, such that the total score represented an overall negative (<0), neutral (0), or positive (>0) appraisal of previous experiences of math. The scale used in the current study, therefore, included a total of 32 items.

## Mathematics Anxiety Scale–UK

This 23-item self-report instrument uses a 5-point Likert-type scale ranging from 1 (not at all) to 5 (very much) to assess how anxious participants would feel in a variety of situations relating to math, for example, "Taking a math exam" and "Working out how much time you have left before you set off to work or place of study." Total scores can range from 23 to 115, with higher scores representing higher levels of math anxiety.[4] The scale possesses excellent internal consistency and high test-retest reliability.[36,59,60]

## Attitudes Towards Mathematics Scale

This 32-item self-report measure uses a 5-point Likert-type scale ranging from 0 (strongly disagree) to 4 (strongly agree) to assess respondents' attitudes toward math.[42] The original authors reported a four-factor solution, comprising factors of perceived mathematical incompetence, enjoyment of mathematics, perception of utility, and mathematical self-concept.[42] A high ordinal Cronbach's alpha level (0.93) was reported. For the current study, the wording of three items was modified slightly. Two items referred to "in math," so this was changed to "when it comes to math." The wording of a further item was changed from "in math" to "in math classes." It was felt this increased the clarity of the items. Reversal of some scores meant a higher score reflects a more positive attitude toward math.

## Mathematical Resilience Scale

This self-report instrument uses a 7-point Likert-type scale ranging from 1 (strongly agree) to 7 (strongly disagree) to measure participant's resilience in the face of struggles with mathematics, including a growth mindset.[61] A three-factor structure has been reported, comprising value, struggle, and growth, with Cronbach's alpha >0.70 for each subscale.[61] The value (Mathematical Resilience Scale [MRS]) and perception of utility (ATMS) subscales were significantly moderately correlated, $r(306) = 0.48$, $p < 0.001$. While related, they are sufficiently independent to justify their inclusion given the focus on the broader constructs of mathematical resilience and math attitudes in this study. The original MRS scale included 24 items. However, three items on the "struggle" subscale were reported to load poorly onto the corresponding factor.[61] These were, therefore, removed for the

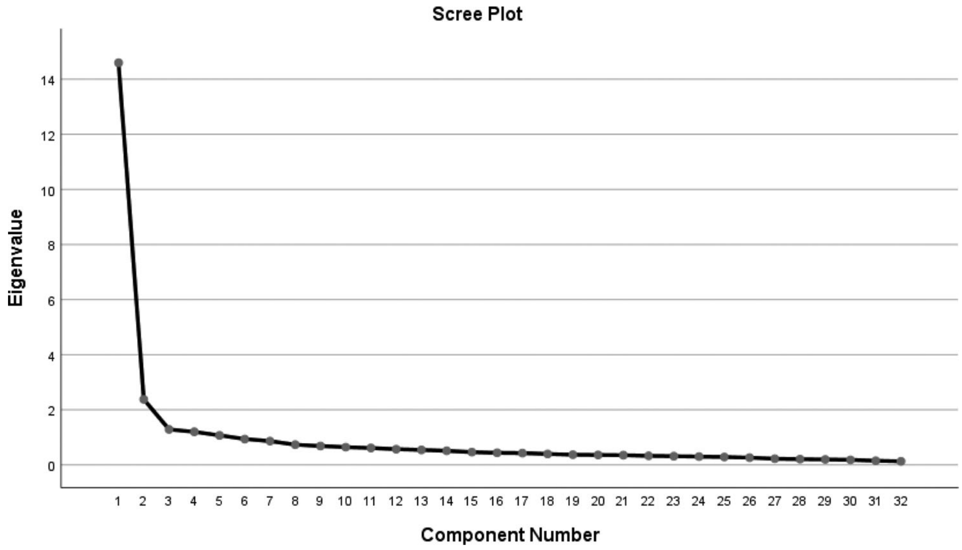


**FIGURE 3** Scree plot indicating the existence of two factors prior to the point of inflection

current study, leaving 21 items. A higher score represents greater mathematical resilience.

## Procedure

The survey was administered in Qualtrics. Participants were reminded of their right to withdraw and were debriefed upon completion of the survey. Demographic questions appeared first and the psychometric scales followed in random order.

## RESULTS

For clarity, the Results section is divided into two sections. In the first section, we discuss the psychometric properties associated with the newly created APMES. In the second section, we then test the hypotheses that were outlined in the Introduction section.

## Psychometric properties of the APMES

### Internal consistency

We first tested the internal consistency of the scale. Cronbach's alpha for the overall scale was 0.96 and the mean item–total correlation ($r$ = 0.67, min. = 0.55), suggesting that the scale has high internal consistency and removal of items was not necessary.

### Exploratory factor analysis

Next, we conducted exploratory analyses to assess the factor structure of the measure. An initial exploratory factor analysis was conducted using principal axis factoring. The maximum iteration for convergence was set at 100. A high Kaiser–Meyer–Olkin measure (KMO = 0.96) indicated that sampling adequacy was met and low values in the diagonal of the antiimage correlation matrix provided further evidence that the data were suitable for factor analysis.[62] Using eigenvalues above 1 as criteria for factor extraction, five factors were extracted, explaining a total of 64.15% of the variance. However, the scree plot revealed two clear factors (Figure 3). A two-factor structure was confirmed via parallel analysis in which only the first two eigenvalues exceeded the criterion values based on 100 random datasets.[63] Therefore, the analysis was rerun, specifying a two-factor structure and applying a direct oblimin rotation. Using a cutoff of 0.40 for factor loadings, four items loaded onto multiple factors and a further four items failed to meet the 0.40 threshold. Following removal of these items, the analysis was rerun, resulting in a 24-item scale. The two factors accounted for a total of 55.80% of the variance, with the first factor accounting for 46.03%. The final scale and factor loadings can be seen in Table 1.

### Descriptive statistics and factor labeling

Total scores were normally distributed, with no issues with skew ($z$ = −0.16) or kurtosis ($z$ = 0.68). The overall scale mean was 0.32 (SD = 0.75). Factor 1 mean was 0.55 (SD = 0.72) and factor 2 mean was −0.14 (SD = 1.01). Cronbach's alpha for the final scale was 0.95. For both subscales, Cronbach's alpha was 0.93. Regarding the labeling of the factors, the 16 items that comprise the first factor represent experiences of math activities in everyday contexts. These make no reference to academic or evaluative settings. As such, we labeled this factor everyday math experiences. Concerning the eight items that comprise the second factor, these represent math experiences that involve real or perceived evaluation, often involving evaluation in the presence of others. Therefore, we labeled this factor math evaluation experiences.

**TABLE 1** Factor loadings for retained items on the Appraisals of Previous Mathematics Experiences Scale

| Item | Everyday math experiences | Math evaluation experiences |
|---|---|---|
| Working out how much change you should receive when paying for something | 0.83 | |
| Working out how much money you need to pay at a shop checkout | 0.80 | |
| Calculating your share of the cost of something you have bought with someone else | 0.78 | |
| Working out a concessional rate of payment, for example, student or OAP charges | 0.74 | |
| Working out the cost of a sale item | 0.69 | |
| Computing numbers with the aid of technology, for example, a calculator | 0.69 | |
| Playing cards or a board game where you have to add up or keep track of the score | 0.67 | |
| Dealing with money with a customer at work | 0.64 | |
| Calculating a budget for the month | 0.64 | |
| Calculating measurements for DIY or work purposes | 0.60 | |
| Understanding figures within the media, for example, during a news broadcast | 0.60 | |
| Converting foreign currency/exchange rates | 0.56 | |
| Any other situation involving math that is personally salient to you | 0.55 | |
| Performing calculations as part of a video game | 0.49 | |
| Discussing revenue targets with a colleague | 0.47 | |
| Calculating how much interest you need to pay on a loan or credit card | 0.47 | |
| Being asked a number problem/question in front of others | | 0.92 |
| Being asked a question in math class in front of the class | | 0.91 |
| Taking a math exam | | 0.86 |
| Unexpectedly being given a number task/test in a math class | | 0.85 |
| Being asked a question in math class on a one-to-one basis | | 0.62 |
| Being asked a math/numerical question in a job interview | | 0.61 |
| Learning math at school | | 0.60 |
| Doing a presentation that involves numbers | | 0.50 |

Given the reported relations between math performance and sex, as well as math anxiety and sex,[17] we felt it prudent to assess whether any relations exist between sex and responses to the APMES. An independent samples *t*-test revealed that, compared to females, males reported significantly more positive appraisals of previous math experiences, $t(303) = 2.29$, $p = 0.023$, two-tailed test, $d = 0.30$.

## Testing the hypotheses

A series of Pearson's bivariate correlations were performed on all variables (Table 2). In line with our first hypothesis (a), appraisals of previous math experiences are positively related to mathematical resilience, $r(306) = 0.53$, $p < 0.001$, such that those who reported more positive appraisals of their past math experiences also scored higher on a measure of mathematical resilience. A significant, partial correlation remained after math anxiety was controlled for, $r(305) = 0.23$, $p < 0.001$. Next, in line with our second hypothesis (b), appraisals of past math experiences were negatively related to math anxiety, $r(306) = -0.78$, $p < 0.001$, such that those with more positive appraisals of past experiences will also report lower math anxiety, and (c) appraisals of previous math experiences are positively related to math attitudes, $r(306) = 0.46$, $p < 0.001$, such that those with more positive appraisals of past experiences also report more positive attitudes about mathematics overall. A significant, partial correlation remained after math anxiety was controlled for, $r(305) = 0.28$, $p < 0.001$. Furthermore, math anxiety was significantly, moderately negatively related to mathematical resilience $r(306) = -0.52$, $p < 0.001$, and math attitudes, $r(306) = -0.38$, $p < 0.001$.

## Mediation analyses

All mediation analyses reported below were computed using the PROCESS macro v. 3.4 in SPSS. Significance was tested using a bootstrapping method with 5000 iterations. Indirect effects were calculated for each of the 5000 bootstrapped iterations and the 95% confidence interval was determined by computing the indirect effect at the 2.5th and 97.5th percentiles. All mediation analyses also include age as a covariate.

First, appraisals of previous math experiences significantly predicted math attitudes even after controlling for age, $B = 0.380$,

**TABLE 2** Pearson correlations between appraisals of previous math experiences, math anxiety, mathematical resilience, attitudes toward math, and age

| | APMES | APMES F1 | APMES F2 | MASUK | MRS | ATMS | Age |
|---|---|---|---|---|---|---|---|
| APMES | 1 | | | | | | |
| APMES F1 | 0.94*** | 1 | | | | | |
| APMES F2 | 0.88*** | 0.66*** | 1 | | | | |
| MASUK | −0.78*** | −0.69*** | −0.74*** | 1 | | | |
| MRS | 0.53*** | 0.50*** | 0.45*** | −0.52*** | 1 | | |
| ATMS | 0.46*** | 0.36*** | 0.50*** | −0.38*** | −0.26*** | 1 | |
| Age | 0.03 | 0.09 | −0.07 | −0.10 | 0.07 | 0.07 | 1 |

***$p < 0.001$.

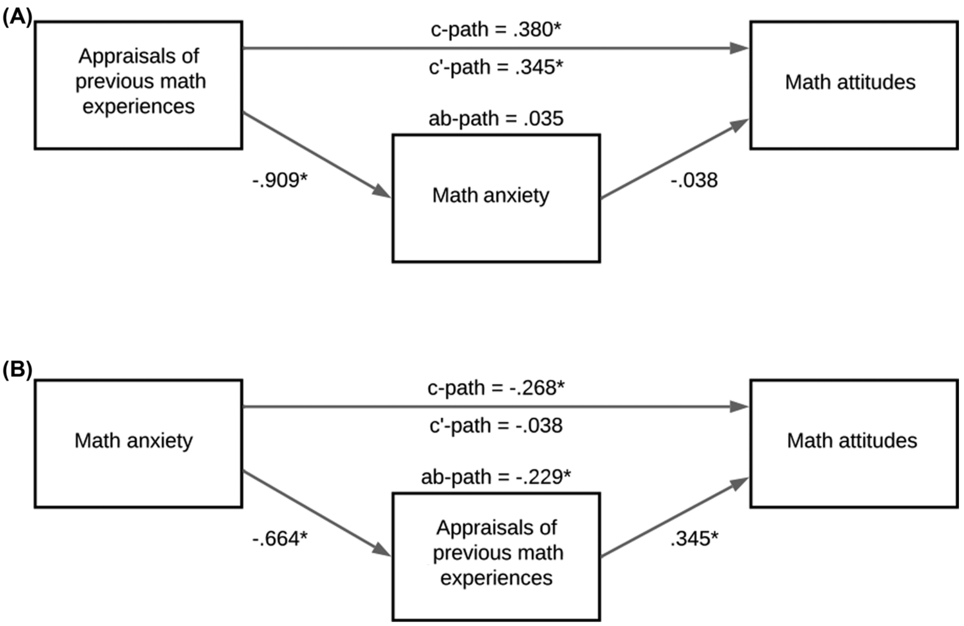


**FIGURE 4** Two models predicting math attitudes from appraisals of previous math experiences and math anxiety

$p < 0.001$, and after controlling for math anxiety, B = 0.345, $p < 0.001$. The mediation analysis illustrated that the indirect effect from appraisals of previous math experiences—math anxiety—math attitudes was not significant, as the 95% confidence interval did include zero (95% CI = −0.074 to 0.138; see Figure 4A).

On the other hand, math anxiety significantly predicted math attitudes even after controlling for age, B = −0.268, $p < 0.001$, but not after controlling for appraisals of previous math experiences, B = −0.038, $p = 0.506$. Indeed, a mediation analysis illustrated that the indirect effect from math anxiety—appraisals of previous math experiences—math attitudes was significant, as the 95% confidence interval did not include zero (95% CI = −0.336 to −0.137; see Figure 4B).

Second, appraisals of previous math experiences significantly predicted math attitudes even after controlling for age, B = 0.380, $p < 0.001$, and after controlling for mathematical resilience, B = 0.363, $p < 0.001$. The mediation analysis illustrated that the indirect effect from appraisals of previous math experiences—mathematical resilience—math attitudes was not significant as the 95% confidence interval did include zero (95% CI = −0.058 to 0.086; see Figure 5A).

On the other hand, mathematical resilience significantly predicted math attitudes even after controlling for age, B = 0.203, $p < 0.001$, but not after controlling for appraisals of previous math experiences, B = 0.029, $p = 0.522$. Indeed, a mediation analysis illustrated that the indirect effect from mathematical resilience—appraisals of previous math experiences—math attitudes was significant, as the 95% confidence interval did not include zero (95% CI = 0.115–0.243; see Figure 5B). A summary of all mediation analyses can be found in Table 3.[1]

Mediation results are similar when considering the two *APMES* factors separately (see Supplementary Material).

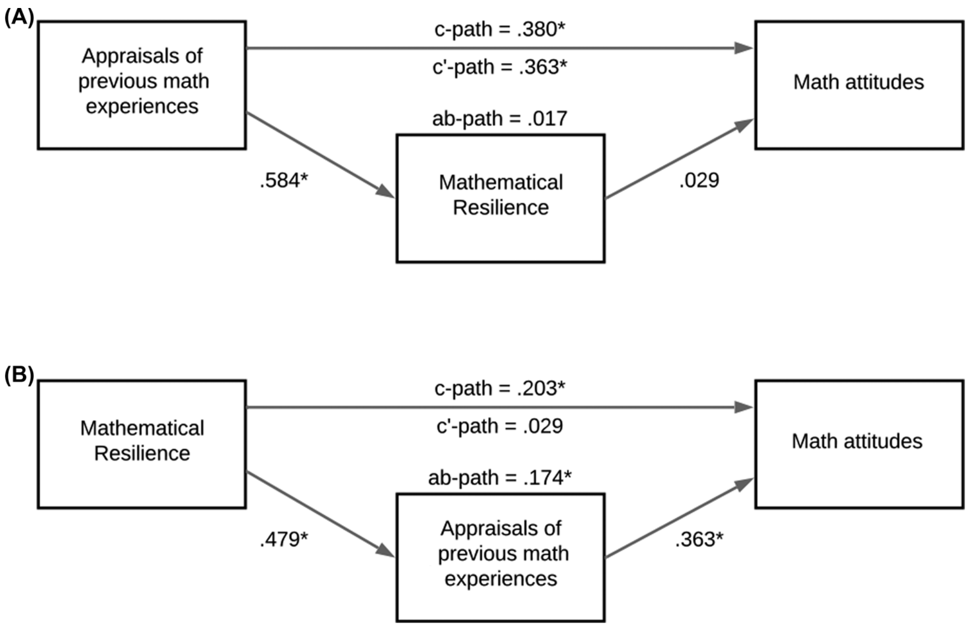


**FIGURE 5** Two models predicting math attitudes from appraisals of previous math experiences and mathematical resilience

## DISCUSSION

Why is it that math anxiety and mathematical resilience are related to overall math attitudes? The current study suggests that appraisals of previous math experiences play an important role. Using a newly created self-report instrument, the APMES, we present evidence that appraisals of previous math experiences explain, at least in part, the relation between math anxiety and math attitudes, as well as the relation between mathematical resilience and math attitudes. Our findings are consistent with an interpretation account of math anxiety[27] and offer new insight into cognitive-affective research in math.

As predicted, math anxiety was moderately, negatively related to math attitudes, which was comprised of perceived math incompetence, enjoyment of math, perception of utility, and math self-concept. This is consistent with previous findings.[17,39–41] Furthermore, a moderate, negative relation was observed between mathematical resilience and math anxiety. In addition, a weak-to-moderate relation was found between mathematical resilience and math attitudes, which highlights the importance of incorporating a domain-specific measure of resilience. Appraisals of previous math experiences were found to be moderately, positively related to both math attitudes and mathematical resilience. Moreover, a strong negative relation was observed with math anxiety.

Also as hypothesized, the relation between math anxiety and math attitudes, and mathematical resilience and math attitudes, was shown to be mediated by appraisals of previous math experiences. These findings are consistent with an interpretation account of math anxiety.[27] More specifically, an individual's appraisal of their own prior math experiences shapes their current attitudes toward math. In the current study, we have extended this to mathematical resilience, whereby an indirect path was observed from math anxiety to appraisal of previous math experiences to math attitudes, as well as an indirect path from mathematical resilience to appraisal of previous math experiences to math attitudes. It is, indeed, important to note here that these data were all collected during one time point and, as such, causal inferences cannot be drawn. While we cannot conclude whether those with math anxiety are more likely to negatively appraise their math-related situations or whether a tendency to negatively appraise situations leads one to develop math anxiety, what we can conclude from these data is that the relations between math anxiety and math attitudes and between math anxiety and math resilience can be explained, at least in part, by appraisals of previous math experiences.

The APMES was found to be internally consistent and a two-factor structure was observed, including factors relating to everyday math activities and contexts involving math evaluation. The sample mean for appraisal was positive. However, closer inspection showed that mean appraisal for math learning experiences was negative. This aligns with previous findings, whereby negative math experiences form a major theme in the narratives of individuals high in math anxiety.[21,25,35] Given the evidence that many people think about previous math experiences during mathematical problem solving,[36] the current findings suggest that appraisals of such experiences should be given consideration in the context of math learning and testing. This may be pertinent in the case of addressing current math attitudes, particularly as math attitudes are associated with several behavioral outcomes, for example, achievement,[46–49] course selection,[50] and intentions to take more math.[32]

The APMES provides researchers and educators with a way to identify differences in how individuals appraise their previous math experiences. This may help inform cognitive-based interventions that focus on one's interpretation of past events. In particular, math outcomes can be objectively compared against subjective interpretation, for example, actual (good) performance on math tests compared to

**TABLE 3** Summary of mediation analyses with appraisals of previous math experiences

| | Coefficient | SE/SE[a] | *p* | 95% CI |
|---|---|---|---|---|
| Model 1a (PME → MASUK → ATMS) | | | | |
| APMES → ATMS (c) | 0.380 | 0.043 | <0.001 | [0.297, 0.464] |
| APMES → MASUK (a) | −0.909 | 0.042 | <0.001 | [−0.992, −0.826] |
| MASUK → ATMS (b) | −0.038 | 0.058 | 0.506 | [−0.152, 0.075] |
| Direct effect (c’) | 0.345 | 0.068 | <0.001 | [0.212, 0.478] |
| Indirect effect (a*b) | 0.213 | 0.053[a] | | [−0.074, 0.138] |
| $R^2$ | | | | |
| Model 1b (MASUK → PME → ATMS) | | | | |
| MASUK → ATMS (c) | −0.268 | 0.038 | <0.001 | [−0.342, −0.193] |
| MASUK → APMES (a) | −0.664 | 0.031 | <0.001 | [−0.725, −0.604] |
| APMES → ATMS (b) | 0.345 | 0.068 | <0.001 | [0.212, 0.478] |
| Direct effect (c’) | −0.038 | 0.058 | 0.506 | [−0.152, 0.075] |
| Indirect effect (a*b) | −0.229 | 0.051[a] | | [−0.336, −0.137] |
| $R^2$ | 0.213 | | | |
| Model 2a (PME → MRS → ATMS) | | | | |
| APMES → ATMS (c) | 0.380 | 0.043 | <0.001 | [0.297, 0.464] |
| APMES → MRS (a) | 0.584 | 0.054 | <0.001 | [0.478, 0.689] |
| MRS → ATMS (b) | 0.029 | 0.045 | 0.522 | [−0.060, 0.118] |
| Direct effect (c’) | 0.363 | 0.050 | <0.001 | 0.265, 0.462] |
| Indirect effect (a*b) | 0.017 | 0.037[a] | | [−0.058, 0.086] |
| $R^2$ | 0.213 | | | |
| Model 2b (MRS → APMES → ATMS) | | | | |
| MRS → ATMS (c) | 0.203 | 0.042 | <0.001 | [0.121, 0.285] |
| MRS → APMES (a) | 0.479 | 0.044 | <0.001 | [0.393, 0.566] |
| APMES → ATMS (b) | 0.363 | 0.050 | <0.001 | [0.265, 0.462] |
| Direct effect (c’) | 0.029 | 0.045 | 0.522 | [−0.060, 0.118] |
| Indirect effect (a*b) | 0.174 | 0.033[a] | | [0.115, 0.243] |
| $R^2$ | 0.213 | | | |

*Note*: The data in this table are depicted in Figures 4 and 5.
Abbreviations: APMES, Appraisals of Previous Mathematics Experiences Scale; ATMS, Attitudes Towards Mathematics Scale; MASUK, Mathematics Anxiety Scale UK; MRS, Mathematical Resilience Scale; SE, standard error.
[a]SE, Bootstrap standard error.

an individual’s (negative) appraisal of taking the tests. A conversation could take place in which such incongruency could be explored to modify a student’s cognitions regarding their math learning. Relatedly, future research could assess individual appraisals following the same math experience, for example, teaching and math outcomes. This would enable a more refined assessment of individual differences in appraisal. Furthermore, while unequal groups prohibited a fuller analysis, compared to females, males reported significantly more positive appraisals of previous math experiences. While the effect was only small, this may provide an interesting line of investigation when researching sex differences in math anxiety.

The current study has some limitations that should be considered. Despite the high internal consistency of the APMES, the measure relies on participants focusing on previous experiences and not current or hypothetical future experiences. Furthermore, because the data were all collected at one time point, it is impossible to discern whether those who are higher in math anxiety are more likely to negatively appraise math-related situations or whether those who are more likely to negatively appraise math-related situations go on to develop math anxiety. It is also not possible to know whether those who recall their past math-related situations as negative today would also have appraised those same situations as negative at the time of their happening. Fortunately, these are important questions that can be assessed in future research using the newly developed APMES. Also, recent work has highlighted the importance of academic motivation in the context of math anxiety.[64–66] Thus, it is conceivable that appraisals of previous math experiences may impact current motivation to study math; future work should test this.

In sum, the findings from the current study emphasize the need to consider appraisals of previous math experiences when researching math anxiety and math attitudes, and when considering treatment options for math anxiety more specifically. The current work also provides a tool that can be useful in the investigation of appraisals of previous math-related experiences, the APMES.

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## COMPETING INTERESTS

The authors declare no competing interests.

## AUTHOR CONTRIBUTIONS

T.E.H. led the data collection. T.E.H. and E.A.M. contributed equally to the data analysis and writing of the manuscript.

## PEER REVIEW

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## SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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