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RESEARCH

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Math anxiety affects career choices during development

Hili Eidlin-Levy[1], Elad Avraham[1], Laurain Fares[1] and Orly Rubinsten[1*]

Abstract

Background Links between math anxiety and the choice of a math-intensive career might change over development and differ by gender. The study included three research populations: primary school ($N=87$, 48 females, mean age = 10.2), high school ($N=107$, 61 females, mean age = 15.7), and university students ($N=100$, 53 females, mean age = 27.4). Students completed a math anxiety questionnaire and reported their desired career choice.

Results Findings suggest that math anxiety directly predicted the career choice math intensity for high school and university students, but not primary school students. Gender had a direct effect on younger students, as female students attending primary and high school preferred careers with a lower math intensity. The effect of gender on career choice math intensity for university students was not direct but mediated by math anxiety.

Conclusions It is crucial to identify young students with math anxiety and provide appropriate math anxiety reduction programs to reduce the cumulative effect of math anxiety on academic achievement and career choice.

Keywords Math anxiety, Career choice, Developmental changes, Gender differences

Introduction

Math knowledge is positively linked with prosperity in our industrial, technological society (Peri et al., 2016). Therefore, there is increasing interest in the pursuit of a math-based career, for example, in the fields of science, technology, engineering, and math (STEM) (Amato, 2021). State-of-the-art research is trying to determine which variables can predict STEM careers (Chan, 2022; National Science Foundation, 2019; Organization for Economic Co-operation and Development [OECD], 2022; Rozek et al., 2019). Concurrent with the assertion that motivational–emotional factors can be better predictors of the pursuit of STEM careers than math aptitude (Dekhtyar et al., 2018; Wang & Degol, 2013), we focused on math anxiety as a predictor of the math intensity of a chosen career.

Math anxiety essentially refers to a spectrum of negative emotional responses to math information or activities (Ashcraft, 2002; Cipora et al., 2022), involving fear or worry (Richardson & Suinn, 1972) related to math stimuli in both educational (Lau et al., 2022) and everyday situations (Guzmán et al., 2023; Skagerlund et al., 2018). Math anxiety is a multidimensional construct involving elevated physiological activity (Eidlin Levy & Rubinsten, 2021; Qu et al., 2020), negative emotional responses (Cohen et al., 2021), and negative attitudes to math (Gunderson et al., 2011). The manifestations of math anxiety can include adverse reactions to math (Ashcraft, 2002), avoidance behavior (Daker et al., 2021; Jenifer et al., 2022), and low math-related self-confidence (Ahmed et al., 2012; Morán-Soto & González-Peña, 2022). Accordingly, math anxiety may be related to an avoidance of math learning and a reluctance to choose STEM courses and careers (Ahmed, 2018; Megreya & Al-Emadi, 2023; Morán-Soto & González-Peña, 2022). Math anxiety is accompanied by low math achievement across cultures

*Correspondence:
Orly Rubinsten
orly.rubinsten@gmail.com
[1] Department of Learning Disabilities, Edmond J. Safra Brain Research Center for the Study of Learning Disabilities, University of Haifa, 199 Aba Khoushy Ave., Mount Carmel, Haifa, Israel

(Barroso et al., 2020; Lau et al., 2022; Zhang et al., 2019) and developmental phases (Hart & Ganley, 2019; Hill et al., 2016; Tomasetto et al., 2021). However, it is important to note that high math anxiety is not automatically accompanied by low math achievement because of certain resilience factors, such as high motivation (Wang et al., 2015) or inhibition of anxiety symptoms (Lyons & Beilock, 2012). We investigated whether math anxiety was associated with the math intensity of career choices at three educational phases: primary school, high school, and university.

Do links between math anxiety and career choice change over time?

Math anxiety seems to increase over the years of schooling. In one study, 11% of elementary and middle school students reported high math anxiety levels (Devine et al., 2018), but this number may double or even triple among older students (Hart & Ganley, 2019; OECD, 2013). We aimed to expand existing knowledge on the association of math anxiety and career choice across gender at different educational phases. We used the social cognitive career theory (Brown & Lent, 2019; Kohen & Nitzan, 2021; Reinhold et al., 2018) to specify three educational phases.

The theory defines the first phase as the wishing phase (primary to junior high school). At this point, students may have an interest in a specific career, with no actual commitment to or decision-making towards career pursuit. To the best of our knowledge, the direct relations between math anxiety and career interests in primary school have not been investigated. However, recent research has found social-emotional factors, such as stereotype endorsement, can influence primary school students' interest in STEM-based subjects regardless of their achievements (Blažev et al., 2017), and students at this educational phase already have occupational gender-biased beliefs (Moè, 2018; Teliousi et al., 2020). Furthermore, positive attitudes towards STEM learning were positively associated with computational thinking (Sun et al., 2021) as well as math achievement (Gulemetova et al., 2022) among primary school students. Researchers have found links between math anxiety and math achievement even in the very first years of primary school (Gunderson et al., 2018; Tomasetto et al., 2021), and math anxiety has been found to interfere with the acquisition of new numerical knowledge (Tomasetto et al., 2021). Hence, as career interests among primary school students are related to their past experiences (Howard et al., 2015), it is plausible to hypothesize that avoidance of math activities will be evident as early as primary school, and children with high math anxiety may already show an interest in non-math-intensive careers.

The second phase is the planning phase (high school). In this phase, students set specific career goals, such as taking advanced math courses. Students who pursue STEM careers may make that choice during middle and high school when they discover a growing interest in mathematics and sciences (Babarović, 2022; Maltese & Tai, 2010). At the same time, math anxiety seem to increase for this age group (OECD, 2013), as does the association between math anxiety and low math achievements (Barroso et al., 2020; Zhang et al., 2019). Relevant to the current research, math anxiety among middle school students has been associated with interest in careers (Eidlin Levy et al., 2021; Huang et al., 2019) and the later pursuit of non-math-intensive careers (Ahmed, 2018). It also seems that high math anxiety can lead to an avoidance of math-intensive activities (Else-Quest et al., 2010; Jenifer et al., 2022). This avoidance has consequences: later on, low math achievements lessen the likelihood of acceptance into STEM studies (Kohen & Nitzan, 2021).

The third phase is the acting phase (higher education). Students make more important career-related decisions, such as choosing a major field of study. Recent research indicates that math anxiety is related to a reluctance to enroll in math courses (Soysal et al., 2022). One study found that math anxiety was a better predictor of STEM course avoidance than math ability among college students (Daker et al., 2021). As discussed earlier, this pattern may be the result of consistent negative links between math anxiety and interest in math-intensive careers, starting in primary school.

We were interested in the possible changing relations between gender, math anxiety, and career choice math intensity throughout the educational journey and thus focused on the wishing (primary school), planning (high school), and acting (university) phases. We also asked if gender might play a role in these decisions in any of the three phases.

Does gender account for the links between math anxiety and career choice?

Female students usually report higher math anxiety (Devine et al., 2012; Hart & Ganley, 2019; Hill et al., 2016; Morán-Soto & González-Peña, 2022), even though gender differences in numerical performance have decreased in the last few decades (Hyde & Mertz, 2009; Lindberg et al., 2010). Starting from primary school, female students are also less likely to be interested in or to enroll in math and science courses than male students (Babarović, 2022; Chan, 2022; Grosch et al., 2022; Watt, 2016). Consequently, regardless of their math competence, females are underrepresented in STEM departments in higher education and in STEM careers (National Science

Foundation, 2019; OECD, 2022). While genetic–biological differences may account for higher math anxiety in females (Júlio-Costa et al., 2019; Wang et al., 2014), social agents, such as parents and teachers, have gender-biased expectations of math competence (Beilock et al., 2010; Gunderson et al., 2011; Lau et al., 2022), and these influence the development of math anxiety.

A few studies have investigated the impact of math anxiety on career choice while controlling for gender (Ahmed, 2018; Daker et al., 2021; Eidlin Levy et al., 2021; Huang et al., 2019; John et al., 2020; Megreya & Al-Emadi, 2023; Morán-Soto & González-Peña, 2022). Some have found that students (both boys and girls) who report consistent or increasing negative experiences with math are more likely to avoid math courses (Ahmed, 2018; John et al., 2020), and this, in turn, may result in avoidance of math-intensive careers. Recently, math anxiety was found to predict university students' enrollment in STEM courses over and above math ability for both genders (Daker et al., 2021). Others have found a direct effect of math anxiety on STEM career interests among middle and high school girls but not boys (Eidlin Levy et al., 2021; Huang et al., 2019; Megreya & Al-Emadi, 2023). Thus, it is not clear whether the links between math anxiety and career choice apply only to females. Gender is typically found to be a predictor of career path (Chan, 2022; National Science Foundation, 2019; OECD, 2022) and math anxiety, which is more common among females, may moderate or mediate the relations between gender and career choice.

The study

We aimed to measure whether the links between math anxiety and the math intensity of a chosen career would differ by gender across the three educational phases. Based on the social cognitive career theory (Brown & Lent, 2019; Kohen & Nitzan, 2021; Reinhold et al., 2018), we used a cross-sectional design with three research populations. Our study was set in Israel; thus, the populations reflect the Israeli educational system.

The first population comprised primary school students in the 4th and 5th grades, the wishing step of social cognitive career theory (Brown & Lent, 2019; Kohen & Nitzan, 2021; Reinhold et al., 2018). We hypothesized that the career choices of 4th and 5th grade students are already likely to relate to former experiences (Howard et al., 2015), including math anxiety (Gunderson et al., 2018; Tomasetto et al., 2021). In Israel, 10th grade students, our second research population, enroll in oriented studies, and these choices may indicate their future career plans (Krill et al., 2019). This population represents the pre-action planning phase of social cognitive career theory, a period when students set goals to follow certain career paths. The third research population was university students. At this phase, students have chosen a major field of study, another indicator of career choice and one much closer to the actual career trajectory. This population is in the action phase (Brown & Lent, 2019; Reinhold et al., 2018). The focus on these particular populations enabled us to track trends in the relations between math anxiety and career choices across educational phases, from the wishing phase to the action phase (Brown & Lent, 2019; Reinhold et al., 2018).

Note that the education system in Israel includes universities, academic colleges, and technical institutes; student applications are based on the specific fields of study offered in each, and their acceptance rests on former academic achievements (Ayalon & Yogev, 2005). Although our sample included students in all three higher education systems, in what follows, we simply refer to university students.

We had two research questions. First, we asked if there are gender difference in math anxiety and/or career choice math intensity. Second, we asked what are the contributions of gender and math anxiety to career choice math intensity at different developmental phases? We hypothesized that females would opt for careers with a lower math intensity (Chan, 2022; Grosch et al., 2022; National Science Foundation, 2019; OECD, 2022). We further hypothesized that math anxiety levels would be higher for females than males, especially in later educational phases (Devine et al., 2012; Hart & Ganley, 2019; Hill et al., 2016), and that this math anxiety might, in turn, discourage students from pursuing math-intensive careers (Eidlin Levy et al., 2021; Huang et al., 2019; Megreya & Al-Emadi, 2023; Morán-Soto & González-Peña, 2022). However, some studies have found links between math anxiety and career choices for both genders (Ahmed, 2018; Daker et al., 2021). Thus, in a cross-sectional design, we tested the plausibility of math anxiety as a mediator or a moderator of the association between gender and career choice to get a more precise and consistent description of the links between variables.

Materials and methods

Participants and procedure

A total of 427 Israeli students participated in the study. Of these, 294 belonged to one of the three research groups based on age: 87 primary school, 107 high school, and 100 university students. Additional 133 participants were part of a post-experimental group to determine the load of math knowledge required for different academic fields of study (similar to former methodology (Ganley et al., 2018); we defined this as career choice math intensity; see "Measures" section).

We performed a statistical power analysis to calculate the required sample size for both variance and regression analyses. For an independent T test with alpha = 0.05 and power = 0.80, the calculated sample size for medium effect size ($d = 0.5$) (Cohen, 1992) using G*Power software was approximately $N = 51$ for each group. For regression analysis with two predictors (gender and math anxiety), each moderately correlating with the outcome variable ($r = 0.3$) (Cohen, 1992), with alpha = 0.05 and power = 0.80, the calculated sample size using G*Power software was approximately $N = 50$. As we potentially had six groups (3 developmental phases X 2 genders), the estimated sample size was 300. Therefore, we aimed to recruit approximately 100 participants for each developmental phase.

Research groups

The study included participants from three cross-sectional samples, representing different developmental phases.

The first sample included 87 4th–5th grade students, 48 female (mean age = 10 years and 2 months, SD = 0.9) and 39 male (mean age = 10 years and 2 months, SD = 0.7) students, attending five different classes. They completed a math anxiety questionnaire and reported their desired career choice.

The second sample included 107 9th–10th grade students, 61 females (mean age = 15 years and 7 months, SD = 0.4) and 46 males (mean age = 15 years and 7 months, SD = 0.4), attending four different classes. These students completed a math anxiety questionnaire and reported their major field of oriented study, representing their desired career choice.

For both primary and high school students, after parental contest was obtained, students completed the experimental tasks in small groups at school during the school day.

The third group included 100 undergraduate university students, 53 females (mean age = 26.43, SD = 6.02) and 47 males (mean age 28.67, SD = 5.65), recruited via online advertisements sent by social networks. To ensure variety in areas of study and academic skills, some students attended a university, while others attended an academic college or technical institute, as these have different acceptance thresholds and specialize in different fields of study yet provide equivalent diplomas in the Israeli academic system. To create a diverse and stratified sample (Enarson et al., 2004; Iliyasu & Etikan, 2021), we published information on our study throughout the country and hence were able to recruit participants from different institutions and geographic regions. Note that student age is relatively high in Israeli higher education, as mandatory military service (lasting approximately 3 years) is usually completed prior to enrollment.

All participants had completed both a math matriculation exam and a psychometric entrance test as a prerequisite for acceptance into higher academic studies. For our study, we asked students to complete a math anxiety questionnaire and to report their study department, representing their career choice. The study procedure lasted about 15 min, and participants were paid 5USD for their participation. They completed the tasks individually.

The study was carried out in accordance with the recommendations of the Ethics Committee of the University and the Chief Scientist Office of the Education Ministry, with written informed consent from university students and parental consent for primary and high school students.

Measures

Math anxiety: Abbreviated Math Anxiety Scale

Participants answered a translated version of the Abbreviated Math Anxiety Scale (AMAS) (Hopko et al., 2014), a 9-item questionnaire. The AMAS is frequently used to measure math anxiety levels and has been validated in various cultural populations and age groups, including primary school, secondary school (Martín-Puga et al., 2020), and university students (Cho, 2022; Primi et al., 2014). The questionnaire is designed to reflect the degree of anxiety experienced in a variety of math-related tasks and situations using a 5-point Likert-type scale (1 = low anxiety; 5 = high anxiety). To obtain the total score, we summed the scores for all questions (score range: 9–45, internal consistency reliability $\alpha = 0.85$). See Table 1 for descriptive statistics.

Career choice math intensity

Career choice math intensity—primary school Primary school students reported their desired career choice by answering the question: 'What do you want to be when you grow up?' Then, we calculated how math-demanding each profession was using a 1–10 scale adapted from former research (Eidlin Levy et al., 2021). In the previous study, 9th grade participants ($N = 89$) were asked to classify the degree of math proficiency required for each profession appearing in a list (1 = very low; 10 = very high). An average score represented the math proficiency for each occupation. In the present study, we coded students' answers based on this previously compiled list of occupational math intensity, by allocating the present response to the same or closest occupation on the list. For instance, the profession of dancer was not seen as having high math demands (mean = 1.41), while engineer was seen as having high demands (mean = 9.34).

Table 1 Descriptive statistics

	Math anxiety			Career choice		
	Female M(SD) [Score range]	Male M(SD) [Score range]	All M(SD) [Score range]	Female M(SD) [Score range]	Male M(SD) [Score range]	All M(SD) [Score range]
Primary school (*N* = 87, 48 females)	23.25 (7.13) [9–39]	20.18 (7.99) [9–40]	22.18 (7.58) [9–40]	4.31 (1.85) [1.41–9.34]	5.49 (2.20) [1.64–9.22]	4.84 (2.09) [1.41–9.34]
High school (*N* = 107, 61 females)	27.65 (7.32) [9–40]	26.82 (8.09) [9–45]	27.29 (7.63) [9–45]	6.81 (1.24) [4.50–8.68]	7.34 (1.39) [4.50–8.68]	7.04 (1.33) [4.50–8.68]
University (*N* = 100, 53 females)	26.32 (8.96) [11–43]	21.81 (7.82) [9–37]	24.20 (8.71) [9–43]	5.81 (2.26) [2.70–8.76]	6.27 (2.23) [2.70–8.70]	6.03 (2.24) [2.70–8.86]
All (*N* = 294, 162 females)	25.91 (8.01) [9–43]	23.27 (8.33) [9–45]	24.73 (8.24) [9–45]	5.74 (2.06) [1.41–9.34]	6.41 (2.09) [1.64–9.22]	6.04 (2.10) [1.41–9.34]

Career choice math intensity—high school and university High school students reported their major field of oriented study, and university students reported their study departments by answering the question: 'What is your current oriented study (for high school students) or major study department (for university students)?' As most fields of study were similar across these groups, we created a list with all reported fields of study, distributed it on social media (Facebook), and asked volunteer participants (100 females, mean age 40.33, SD = 11.97) to classify the degree of math intensity required for each field of study (from 1 = very low to 10 = very high). This sample has ecological validity, as it represents conceptions of the math intensity of different occupations by members (non-students) of the society into which students will integrate after graduating. Furthermore, the over-representation of females in the sample matches the fact that as in other countries, female Israeli students are more likely than male students to enroll in higher education (OECD,).

As we expected, the degree of math intensity required for literature studies was low (mean = 2.27) and the degree for engineering was high (mean = 8.67). For the full list of fields of study and their math intensity score, see Additional file 1: Appendix S1. See Table 1 for descriptive statistics.

Statistical plan

Research question 1

Our first objective was to determine whether gender was related to students' math anxiety levels and/or the math intensity of their career choice. We conducted independent *T* tests for each developmental phase separately. Note that we analyzed each developmental phase separately, but did not compare them, as the construct of career choice math intensity is likely to be incomparable between groups, given the restrictions of the structure of the Israeli education system (e.g., primary school students are not sorted into fields of study, but high school and university students are).

To construct models that were as similar as possible across groups, we standardized math anxiety and math intensity of career choice for each developmental phase before performing the main analyses. We transferred raw scores into *T* scores (Weller, 1984). This allowed us to create a mutual score scale across developmental phases and reduce group variance.

Research question 2

The second objective was to determine the associations and predictive links between gender, math anxiety, and career choice math intensity across developmental phases. Specifically, we asked whether math anxiety moderated or mediated the relations between gender and career choice math intensity (Hayes, 2013). To address this question, we conducted linear regressions with gender and math anxiety as predictors of career choice as a first step. Next, we added the interaction between gender and math anxiety to the equation to create a moderation model.

We conducted separate analyses to determine whether gender was a significant predictor of math anxiety. Concurrent with mediation analysis assumptions, we further explored whether math anxiety mediated the relations between gender and career choice math intensity for cases when gender was a significant predictor of math anxiety and math anxiety was a significant predictor of career choice math intensity.

Interpretation of results

Bayes factors were used for all analyses to strengthen the robustness of the results (Vandekerckhove et al., 2018), as Bayes factors express the ratio between the evidence in favor of the research hypothesis and the null hypothesis. Based on the classification recommended

by Wagenmakers et. al. (2018), we interpreted results using the following strategy: a Bayes factor below 1 supports the null hypothesis; a Bayes factor between 1 and 3 is inconclusive; a Bayes factor above 3 supports the research hypothesis.

Results

Research question 1: are there gender difference in the experimental variables (math anxiety, career choice math intensity)?

We conducted *T* tests to assess possible gender differences in math anxiety and career choice math intensity across developmental phases. As described on Table 2, there were no significant differences in math anxiety among female and male students attending primary school or high school. However, female students reported higher math anxiety levels than males at university, and Bayes results supported this finding. As for career choices, female primary and high school students were interested in careers with lower math intensity, although Bayes results were inconclusive for high school students. Interestingly, although female university students had higher math anxiety levels than males, there were no significant gender differences in career choice math intensity.

Research question 2: what are the contributions of gender and math anxiety to career choice math intensity at different developmental phases?

We conducted regression analyses to explore the association and predictive links between math anxiety and career choice math intensity by gender and over time. Specifically, we asked whether math anxiety mediated or moderated the links between gender and career choice math intensity at each developmental phase (primary school, high school, university).

Primary school students

Moderation analysis: linear regression with gender and math anxiety as predictors of career choices indicated that gender ($\beta = 0.276$, $t = 2.60$, $P = 0.011$, BF10 = 3.74) but not math anxiety ($\beta = -0.048$, $t = 0.45$, $P = 0.653$, BF10 = 0.48) significantly predicted career choice math intensity [$F_{(2,\ 84)} = 3.77$, $P = 0.027$, $r^2 = 0.082$]. Moderation analysis revealed that gender remained a significant predictor of career choice ($\beta = 0.276$, $t = 2.59$, $P = 0.011$, BF10 = 2.86), but math anxiety was not significant in the equation ($\beta = -0.106$, $t = -0.71$, $P = 0.481$, BF10 = 0.37), nor was the interaction between gender and math anxiety ($\beta = -0.082$, $t = 0.55$, $P = 0.583$, BF10 = 0.41). The entire model was marginally significant [$F_{(3,\ 83)} = 2.59$, $P = 0.058$, $r^2 = 0.053$]. Therefore, we rejected the moderation model.

Mediation analysis: gender did not significantly predict math anxiety ($\beta = -0.157$, $t = -1.46$, $P = 0.147$, BF10 = 0.57). Therefore, we did not conduct further mediation analysis.

To conclude, for primary school students (see Fig. 1) gender had a direct effect on career choice, such that male students chose careers with higher math intensity than females, without the moderation of math anxiety.

High school students

Moderation analysis: both gender ($\beta = 0.187$, $t = 2.01$, $P = 0.047$, BF10 = 2.35) and math anxiety ($\beta = -0.240$, $t = 2.57$, $P = 0.011$, BF10 = 5.35) significantly predicted career choice math intensity [$F_{(2,\ 104)} = 0.62$, $P = 0.005$, $r^2 = 0.10$]. Moderation analysis [$F_{(3,\ 103)} = 3.72$, $P = 0.014$, $r^2 = 0.10$] revealed a significant effect of gender ($\beta = 0.187$, $t = 1.99$, $P = 0.048$, BF10 = 1.70) and a marginally significant effect of math anxiety ($\beta = -0.253$, $t = 1.95$, $P = 0.053$, BF10 = 2.94), but their interaction was not significant ($\beta = 0.018$, $t = 0.14$, $P = 0.888$, BF10 = 0.61). Accordingly, we rejected the moderation model.

Mediation analysis: gender did not significantly predict math anxiety ($\beta = -0.054$, $t = -0.56$, $P = 0.579$, BF10 = 0.23), and no further mediation analysis was conducted.

To conclude, both gender and math anxiety showed a direct effect on career choice math intensity for high school students. Female students tended to choose

Table 2 Gender differences in math anxiety and career choice math intensity by group

Group	Task	Females M(SD)	Males M(SD)	Independent *T* test	*P* value	Effect size Cohen's *d*	BF10
Primary school	Math anxiety	51.41 (9.41)	48.26 (10.55)	1.46	0.147	0.31	0.53
	Career choice	**47.46 (8.88)**	**53.12 (10.51)**	**−2.72**	**0.008**	**0.58**	**5.35**
High school	Math anxiety	50.46 (9.59)	49.37 (10.59)	0.56	0.579	0.11	0.33
	Career choice	**48.27 (9.34)**	**52.29 (10.47)**	**−2.10**	**0.039**	**0.41**	**2.78**
University	**Math anxiety**	**52.43 (10.31)**	**47.25 (8.98)**	**2.66**	**0.009**	**0.53**	**4.65**
	Career choice	49.05 (10.04)	51.07 (9.48)	−1.01	0.316	0.21	0.33

Both math anxiety and math intensity of career choice are presented by *T* scores for each group

Bold values represent significant group difference

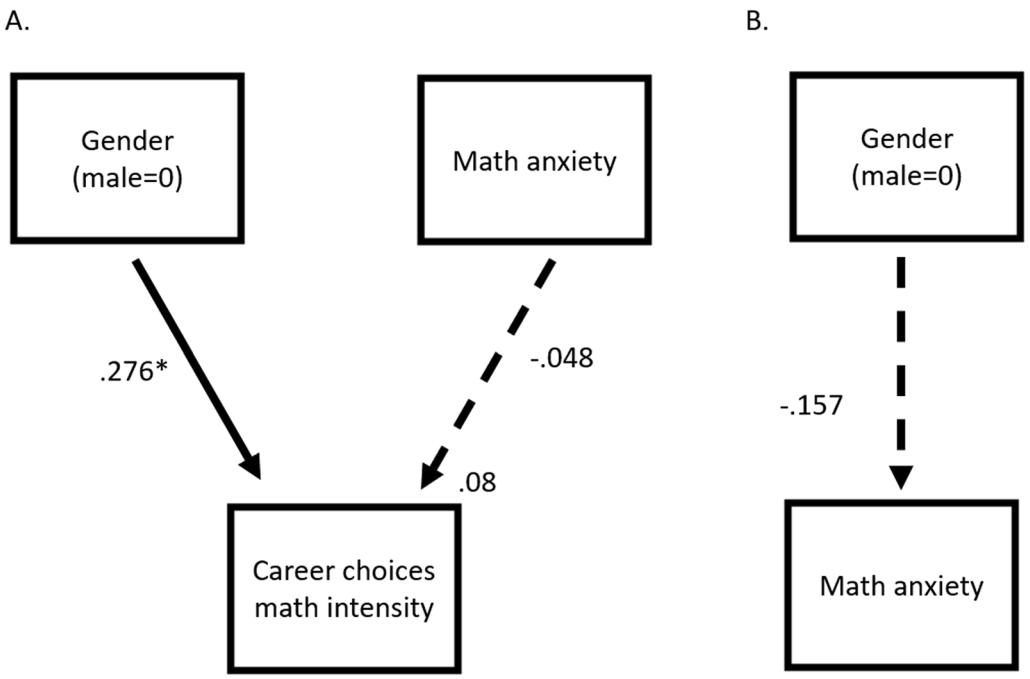

Fig. 1 Links between gender, math anxiety and math intensity of career choice for primary school students. Illustration of gender and math anxiety as predictors of career choice math intensity for primary school students. **A** Gender ($\beta = 0.276$, $t = 2.60$, $P = 0.011$, BF10 = 3.74), but not math anxiety ($\beta = -0.048$, $t = -0.451$, $P = 0.653$, BF10 = 0.48), significantly predicted career choice [$F_{(2, 84)} = 3.77$, $P = 0.027$, $r^2 = 0.082$]. **B** Gender did not significantly predict math anxiety ($\beta = -0.157$, $t = -1.46$, $P = 0.147$, BF10 = 0.57)

careers with lower math intensity, and both male and female students with high math anxiety tended to choose careers with lower math intensity. Importantly, no moderating or mediating effects were evident (see Fig. 2).

University students

Moderation analysis: math anxiety ($\beta = -0.235$, $t = 2.31$, $P = 0.023$, BF10 = 3.26), but not gender ($\beta = 0.040$, $t = 0.39$, $P = 0.693$, BF10 = 0.42), significantly predicted career choice math intensity [$F_{(2, 97)} = 3.19$, $P = 0.046$, $r^2 = 0.062$]. The main effect of math anxiety on career choice ($\beta = 0.306$, $t = 2.32$, $P = 0.022$, BF10 = 1.00) remained significant in moderation analysis, with non-significant main effects of gender ($\beta = 0.046$, $t = 0.45$, $P = 0.652$, BF10 = 0.34) and gender and math anxiety interaction ($\beta = 0.112$, $t = 0.85$, $P = 0.395$, BF10 = 0.87). The moderation model was non-significant [$F_{(3, 96)} = 2.63$, $P = 0.076$, $r^2 = 0.069$] and thus was rejected.

Mediation analysis: gender was a significant predictor of math anxiety ($\beta = -0.260$, $t = -2.67$, $P = 0.009$, BF10 = 4.65), so we conducted mediation analysis. Gender did not predict career choice math intensity ($\beta = 0.101$, $t = 1.01$, $P = 0.316$, BF10 = 3.26), but math anxiety did ($\beta = -0.245$, $t = -2.50$, $P = 0.014$, BF10 = 3.26). Mediation analysis (see Fig. 3 for illustration) indicated the existence of a significant indirect effect of gender on career choice math intensity via math anxiety (95% CI 0.011 to 0.146; $P = 0.012$, as tested by a bias-corrected bootstrap procedure). Note that a direct effect of the independent variable on the dependent variable is not mandatory for mediation analysis (Hayes, 2013).

We conclude that for university students, gender had an indirect effect on career choice math intensity via math anxiety. Females reported higher math anxiety levels, and these were related to a choice of a career with a lower math intensity.

Discussion

This study investigated the links between gender, math anxiety, and math intensity of career choice at different educational phases. We found that gender, but not math anxiety, predicted career choice math intensity for primary school students; female students were more interested in careers with lower math intensity than male students. High school students showed different trends, as both gender and math anxiety directly predicted career choice math intensity, without interactions between them. In high school, female students and students with high math anxiety (both genders) were more interested in careers with a lower math intensity. For university students, the association of gender on career choice math intensity was indirect and mediated by math

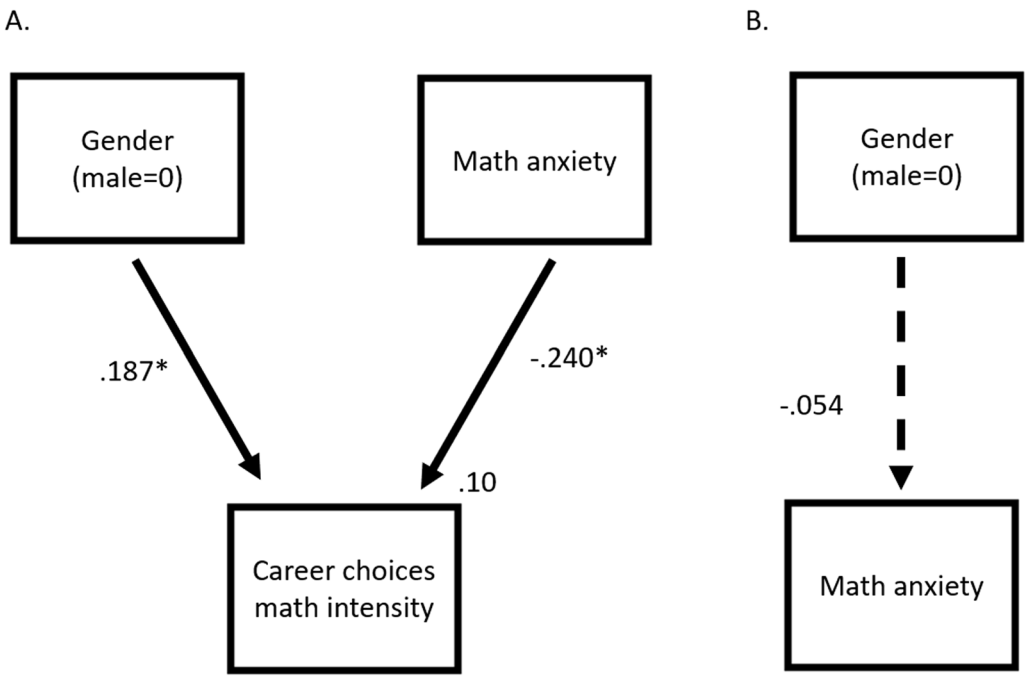

Fig. 2 Links between gender, math anxiety, and math intensity of career choice for high school students. Illustration of gender and math anxiety as predictors of career choice math intensity for high school students. **A** Both gender ($\beta = 0.187$, $t = 2.00$, $P = 0.047$, BF10 = 2.35) and math anxiety ($\beta = -0.240$, $t = -2.58$, $P = 0.011$, BF10 = 5.35) significantly predicted career choice [$F_{(2, 104)} = 5.63$, $P = 0.005$, $r^2 = 0.098$]. **B** Gender did not significantly predict math anxiety ($\beta = -0.054$, $t = -0.56$, $P = 0.579$, BF10 = 0.23)

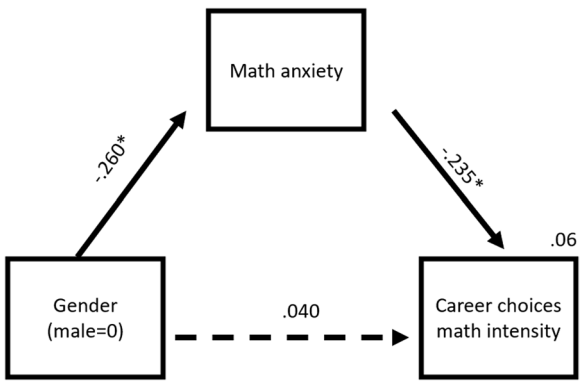

Fig. 3 Links between gender, math anxiety, and math intensity of career choice for university students. Among university students, gender was a significant predictor of math anxiety ($\beta = -0.260$, $t = -2.67$, $P = 0.009$, BF10 = 4.65), but did not predict career choice math intensity ($\beta = 101$, $t = 1.01$, $P = 0.316$, BF10 = 3.26), while math anxiety did ($\beta = -0.245$, $t = -2.50$, $P = 0.014$, BF10 = 3.26). Mediation analysis indicated a significant indirect effect of gender on career choice math intensity via math anxiety (95% CI 0.011 to 0.146; $P = 0.012$, as tested by a bias-corrected bootstrap procedure) [$F_{(2, 97)} = 3.19$, $P = 0.046$, $r^2 = 0.062$]

anxiety. Unlike the preceding educational phases, female university students reported higher math anxiety levels than males, and this predicted the choice of a career with a lower math intensity. Therefore, our preliminary results suggest that the influence of math anxiety on career choice may emerge in secondary school (Eidlin Levy et al., 2021; Huang et al., 2019; Megreya & Al-Emadi, 2023) and persists into higher education (Ahmed, 2018; Daker et al., 2021; Morán-Soto & González-Peña, 2022).

Gender differences in associations between math anxiety and math intensity of a selected career

Our findings suggest that the interplay between gender and math anxiety as predictors of variance in career choice seems to change across development. For primary school students, gender but not math anxiety predicted preferences for a math-intensive career. Very young students can experience math anxiety (Gunderson et al., 2018; Primi et al., 2020; Tomasetto et al., 2021). However, the influence of math anxiety on later outcomes, such as career choice, may be insignificant at this educational phase, as students do not need to set career goals (Kohen & Nitzan, 2021; Reinhold et al., 2018). Even so, primary school students seemed to have already internalized gender-biased stereotypes, which influenced their career plans (Moè, 2018; Teliousi et al., 2020).

Both gender and math anxiety made unique contributions to career choice for high school students, with no interaction between them. Consistent with the

assumption that math anxiety increases over school years (Devine et al., 2018; Hart & Ganley, 2019; OECD, 2013) and becomes differentiated from other anxieties (Carey et al., 2017), we found that the link between math anxiety and possible outcomes, such as career choice, appeared among high school students. High anxiety has been associated with avoidance behavior (Dymond & Roche, 2009) and hence possible low academic achievement, and as indicated in our results, enrollment in orientation studies with lower math intensity. Career goal setting in high school, such as enrollment in math-intensive orientation studies and advanced math courses, can impact later career paths. Avoidance behavior is related to lower math competence in the long term (Daker et al., 2021), and this may be a predictor of Delaney and Devereux (2019), Tandrayen-Ragoobur and Gokulsing (2022) or even a prerequisite (Ayalon & Yogev, 2005) for acceptance into math-intensive studies in higher education. Past research suggests that math anxiety levels may be higher for high school students (OECD, 2013) than for university students (Hart & Ganley, 2019), suggesting that extreme math anxiety levels may even prevent students from attending higher education.

Interestingly, the association of math anxiety and career choice was independent from gender, and gender did not predict math anxiety for high school students. The findings suggest that math anxiety has a negative link with students' aspirations for a career with a high math intensity, regardless of gender (as in Ahmed, 2018; Daker et al., 2021). Continuous negative math experiences resulting in avoidance patterns (Choe et al., 2019; John et al., 2020) may account for these findings, challenging gender segregation theories (Else-Quest et al., 2010; Stoet et al., 2016).

For university students, the effect of gender on career choice math intensity was not direct, but mediated by math anxiety. Female students reported higher math anxiety levels, and these were associated with preferences for careers with a lower math intensity. The findings also indicated a negative association between math anxiety and career choice math intensity among university students. However, the characteristics of the university sample may account for the differences between high school and university samples, as not all high school graduates continue on to higher education. Furthermore, as in other countries, female Israeli students are more likely than male students to enroll in higher education, but are less likely to enter scientific fields (OECD,). Social–behavioral aspects, such as ethnicity or behavioral disorders, can affect drop out (Peguero et al., 2019, 2021). Personal–social resilience factors, such as social support (Tandrayen-Ragoobur & Gokulsing, 2022), positive contact with instructors and peers (Meyer & Strauß, 2019), or personal traits (Isphording & Qendrai, 2019) can account for choosing and persisting in math-intensive studies, especially among females. Therefore, we can speculate that females entering higher education and specifically taking STEM courses may have had social–personal resilience factors and thus enrolled in math-intensive studies despite high math anxiety levels.

Associations between math anxiety and math intensity of a chosen career: a developmental perspective

Although we did not directly compare different educational phases, the preliminary findings suggest some interesting trends in the associations between math anxiety and math intensity of a chosen career across development. The link between math anxiety and career choice was evident for older but not younger students. This pattern may result from the more restrictive structure of the Israeli educational system for older students, who are requested to choose a field of study and set more specific career goals and plans (Brown & Lent, 2019; Kohen & Nitzan, 2021). Students' career aspirations are also adjusted by their personal experiences along the educational trajectory (Reinhold et al., 2018). Accordingly, the findings could represent the cumulative effect of math anxiety on the choice of a career. Students with high math anxiety may avoid participating in math activities, such as doing homework, on the micro level; this, in turn, can harm their math grades and decrease their interest in math-intensive careers on the macro level (Daker et al., 2021; Soysal et al., 2022).

Suggestions for future research

This study, along with other recent studies (Ahmed, 2018; Daker et al., 2021; Eidlin Levy et al., 2021; Huang et al., 2019; Megreya & Al-Emadi, 2023; Morán-Soto & González-Peña, 2022), indicates math anxiety may affect students' decisions to enroll in math-intensive courses and follow math-intensive careers. However, further research is required to address some important issues. It is not clear whether the association between math anxiety and avoidance of math-intensive studies is exclusive to females (Eidlin Levy et al., 2021; Huang et al., 2019; Megreya & Al-Emadi, 2023; Morán-Soto & González-Peña, 2022) or evident across genders, as we and others have found (Ahmed, 2018; Daker et al., 2021). Replication studies controlling for possible covariates such as trait or test anxieties (Carey et al., 2017; Devine et al., 2012; Hill et al., 2016) and including measures of math competence would address this question. Furthermore, qualitative research, as well as investigation of the relations between parents' and teachers' math anxiety and students' career plans, may reveal interesting aspects regarding the social influences of career choice. As our research was cross-sectional, further longitudinal research is essential to probe the early

influences of math anxiety on academic achievements and career choices. Studies should also compare students with different academic experiences, such as freshmen vs. upperclassmen. Finally, future research may assess both enrollment in math-intensive studies and grades in these studies to capture the influence of math anxiety on academic and career behavior on both macro- and micro-levels, as suggested by Daker et. al. (2021).

Conclusion

In our study, math anxiety directly predicted career choices for high school and university but not primary school students. Gender had a direct effect for younger students, as female students attending primary and high school preferred careers with a lower math intensity. The effect of gender on career choice for university students was not direct but mediated by math anxiety. Thus, it is crucial to identify young students with math anxiety and provide appropriate math anxiety reduction programs (Furner & Duffy, 2022; as suggested by Rozek et al., 2019) to reduce the possible cumulative effect of math anxiety on academic achievement and career choice.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s40594-023-00441-8.

Additional file 1: Appendix S1. Math intensity scores for different academic departments as determined by an online survey ($N=133$). Scores range from 1 (low math intensity) to 10 (high math intensity).

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Author contributions
HEL contributed to the conception, study design, and data acquisition, analysis, and interpretation and was a major contributor in writing the manuscript. EA and LF contributed to the conception and to data acquisition. OR contributed to the conception, data analysis, writing and revision of the manuscript and provided the study funding.

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Data availability
The data sets generated and/or analyzed during the study are available at: https://docs.google.com/spreadsheets/d/1IsmQWUeS__QK8LF6oTFlMambxXF2txTH/edit?usp=sharing&ouid=107130947137250234792&rtpof=true&sd=true.

Declarations

Competing interests
The authors declare that they have no competing interests.

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References

Ahmed, W. (2018). Developmental trajectories of math anxiety during adolescence: Associations with STEM career choice. *Journal of Adolescence, 67*(August), 158–166. https://doi.org/10.1016/j.adolescence.2018.06.010

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. https://doi.org/10.1016/j.lindif.2011.12.004

Amato, L. M. (2021). Barriers to a stem career: Math anxiety and the adult female. *Research anthology on adult education and the development of lifelong learners* (pp. 1469–1495). IGI Global. https://doi.org/10.4018/978-1-5225-9108-5.ch004

Ashcraft, M. H. (2002). Math anxiety: Personal, educational, and cognitive consequences. *Current Directions in Psychological Science, 11*(5), 181–185. https://doi.org/10.1111/1467-8721.00196

Ayalon, H., & Yogev, A. (2005). Field of study and students' stratification in an expanded system of higher education: The case of Israel. *European Sociological Review, 21*(3), 227–241. https://doi.org/10.1093/esr/jci014

Babarović, T. (2022). Development of stem vocational interests during elementary and middle school: A cohort-sequential longitudinal study. *Journal of Career Development, 49*(6), 1230–1250. https://doi.org/10.1177/08948453211036986

Barroso, C., Ganley, C. M., McGraw, A. L., Geer, E. A., Hart, S. A., & Daucourt, M. C. (2020). A meta-analysis of the relation between math anxiety and math achievement. *Psychological Bulletin*. https://doi.org/10.1037/bul0000307

Beilock, S. L., Gunderson, E. A., Ramirez, G., & Levine, S. C. (2010). Female teachers' math anxiety affects girls' math achievement. *Proceedings of the National Academy of Sciences, 107*(5), 1860–1863. https://doi.org/10.1073/pnas.0910967107

Blažev, M., Karabegović, M., Burušić, J., & Selimbegović, L. (2017). Predicting gender-STEM stereotyped beliefs among boys and girls from prior school achievement and interest in STEM school subjects. *Social Psychology of Education, 20*(4), 831–847. https://doi.org/10.1007/s11218-017-9397-7

Brown, S. D., & Lent, R. W. (2019). Social cognitive career theory at 25: Progress in studying the domain satisfaction and career self-management models. *Journal of Career Assessment, 27*(4), 563–578. https://doi.org/10.1177/1069072719852736

Carey, E., Devine, A., & Hill, F. (2017). Differentiating anxiety forms and their role in academic performance from primary to secondary school. *PLoS ONE, 12*(3), 1–20.

Chan, R. C. H. (2022). A social cognitive perspective on gender disparities in self-efficacy, interest, and aspirations in science, technology, engineering, and mathematics (STEM): The influence of cultural and gender norms. *International Journal of STEM Education, 9*(1), 1–13. https://doi.org/10.1186/s40594-022-00352-0

Cho, K. W. (2022). Measuring math anxiety among predominantly underrepresented minority undergraduates using the abbreviated math anxiety scale. *Journal of Psychoeducational Assessment, 40*(3), 416–429. https://doi.org/10.1177/07342829211063286

Choe, K. W., Jenifer, J. B., Rozek, C. S., Berman, M. G., & Beilock, S. L. (2019). Calculated avoidance: Math anxiety predicts math avoidance in effort-based decision-making. *Science Advances, 5*(11), 1–10. https://doi.org/10.1126/sciadv.aay1062

Cipora, K., Santos, F. H., Kucian, K., & Dowker, A. (2022). Mathematics anxiety—Where are we and where shall we go? *Annals of the New York Academy of Sciences, 1513*(1), 10–20. https://doi.org/10.1111/nyas.14770

Cohen, J. (1992). Statistical power analysis. *Current Directions in Psychological Science, 1*(3), 98–101.

Cohen, L. D., Yavin, L. L., & Rubinsten, O. (2021). Females' negative affective valence to math-related words. *Acta Psychologica, 217*, 103313. https://doi.org/10.1016/j.actpsy.2021.103313

Daker, R. J., Gattas, S. U., Sokolowski, H. M., Green, A. E., & Lyons, I. M. (2021). First-year students' math anxiety predicts STEM avoidance

and underperformance throughout university, independently of math ability. *Npj Science of Learning, 6*(1), 17. https://doi.org/10.1038/s41539-021-00095-7

Dekhtyar, S., Weber, D., Helgertz, J., & Herlitz, A. (2018). Sex differences in academic strengths contribute to gender segregation in education and occupation: A longitudinal examination of 167,776 individuals. *Intelligence, 67*(November), 84–92. https://doi.org/10.1016/j.intell.2017.11.007

Delaney, J. M., & Devereux, P. J. (2019). Understanding gender differences in STEM: Evidence from college applications. *Economics of Education Review, 72*(June), 219–238. https://doi.org/10.1016/j.econedurev.2019.06.002

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), 33. https://doi.org/10.1186/1744-9081-8-33

Devine, A., Hill, F., Carey, E., & Szu, D. (2018). Cognitive and emotional math problems largely dissociate: Prevalence of developmental dyscalculia and mathematics anxiety. *Journal of Educational Psychology, 110*(3), 431–444.

Dymond, S., & Roche, B. (2009). A contemporary behavior analysis of anxiety and avoidance. *Behavior Analyst, 32*(1), 7–27. https://doi.org/10.1007/BF03392173

Eidlin Levy, H., Fares, L., & Rubinsten, O. (2021). Math anxiety affects females' vocational interests. *Journal of Experimental Child Psychology, 210*, 105214. https://doi.org/10.1016/j.jecp.2021.105214

Eidlin Levy, H., & Rubinsten, O. (2021). Numbers (but not words) make math anxious individuals sweat: Physiological evidence. *Biological Psychology, 165*(September), 108187. https://doi.org/10.1016/j.biopsycho.2021.108187

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), 103–127. https://doi.org/10.1037/a0018053

Enarson, D. A., Kennedy, S. M., & Miller, D. L. (2004). Choosing a research study design and selecting a population to study [Research Methods]. *The International Journal of Tuberculosis and Lung Disease, 8*(9), 1151–1156.

Furner, J. M., & Duffy, M. L. (2022). Addressing math anxiety in a STEM world: Preventative, supportive, and corrective strategies for the inclusive classroom. *European Journal of STEM Education, 7*(1), 1–10. https://doi.org/10.20897/ejsteme/12645

Ganley, C. M., George, C. E., Cimpian, J. R., & Makowski, M. B. (2018). Gender equity in college majors: Looking beyond the STEM/Non-STEM dichotomy for answers regarding female participation. *American Educational Research Journal, 55*(3), 453–487. https://doi.org/10.3102/0002831217740221

Grosch, K., Haeckl, S., & Kocher, M. G. (2022). Closing the gender STEM gap—A large-scale randomized-controlled trial in elementary schools. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.4212071

Gulemetova, M., Beesley, A. D., Fancsali, C., & Balakrishnan, U. (2022). Elementary students' mathematics identity: Findings from a longitudinal study in an out-of-school setting. *Journal for STEM Education Research, 5*(2), 187–213. https://doi.org/10.1007/s41979-022-00067-5

Gunderson, E. A., Park, D., Maloney, E. A., Beilock, S. L., & Levine, S. C. (2018). Reciprocal relations among motivational frameworks, math anxiety, and math achievement in early elementary school. *Journal of Cognition and Development, 19*(1), 21–46. https://doi.org/10.1080/15248372.2017.1421538

Gunderson, E. A., Ramirez, G., Levine, S. C., & Beilock, S. L. (2011). The role of parents and teachers in the development of gender-related math attitudes. *Sex Roles, 66*(3–4), 153–166. https://doi.org/10.1007/s11199-011-9996-2

Guzmán, B., Rodríguez, C., & Ferreira, R. A. (2023). Effect of parents' mathematics anxiety and home numeracy activities on young children's math performance-anxiety relationship. *Contemporary Educational Psychology, 72*(December), 102140. https://doi.org/10.1016/j.cedpsych.2022.102140

Hart, S. A., & Ganley, C. M. (2019). The nature of math anxiety in adults: Prevalence and correlates. *Journal of Numerical Cognition, 5*(2), 122–139. https://doi.org/10.5964/jnc.v5i2.195

Hayes, A. F. (2013). *Introduction to mediation, moderation, and conditional process analysis: A regression-based approach*. Guilford.

Hill, F., Mammarella, I. C., Devine, A., Caviola, S., Passolunghi, M. C., & Szucs, D. (2016). Maths anxiety in primary and secondary school students: Gender differences, developmental changes and anxiety specificity. *Learning and Individual Differences, 48*, 45–53. https://doi.org/10.1016/j.lindif.2016.02.006

Hopko, D. R., Mahadevan, R., Bare, R. L., & Hunt, M. K. (2014). The abbreviated math anxiety scale (AMAS) construction, validity, and reliability. *Assessment, 10*(2), 178–182. https://doi.org/10.1177/1073191103252351

Howard, K. A. S., Flanagan, S., Castine, E., & Walsh, M. E. (2015). Perceived influences on the career choices of children and youth: An exploratory study. *International Journal for Educational and Vocational Guidance, 15*(2), 99–111. https://doi.org/10.1007/s10775-015-9298-2

Huang, X., Zhang, J., & Hudson, L. (2019). Impact of math self-efficacy, math anxiety, and growth mindset on math and science career interest for middle school students: The gender moderating effect. *European Journal of Psychology of Education, 34*, 621–640.

Hyde, J. S., & Mertz, J. E. (2009). Gender, culture, and mathematics performance. *Proceedings of the National Academy of Sciences, 106*(22), 8801–8807.

Iliyasu, R., & Etikan, I. (2021). Comparison of quota sampling and stratified random sampling. *Biometrics & Biostatistics International Journal*. https://doi.org/10.15406/bbij.2021.10.00326

Isphording, I. E., & Qendrai, P. (2019). Gender differences in student dropout in STEM. *IZA Discussion Paper, 3*(82), 126–134. https://doi.org/10.5157/NEPS

Jenifer, J. B., Rozek, C. S., Levine, S. C., & Beilock, S. L. (2022). Effort(less) exam preparation: Math anxiety predicts the avoidance of effortful study strategies. *Journal of Experimental Psychology: General, 151*(10), 2534–2541. https://doi.org/10.1037/xge0001202

John, J. E., Nelson, P. A., Klenczar, B., & Robnett, R. D. (2020). Memories of math: Narrative predictors of math affect, math motivation, and future math plans. *Contemporary Educational Psychology, 60*(January), 101838. https://doi.org/10.1016/j.cedpsych.2020.101838

Júlio-Costa, A., Martins, A. A. S., Wood, G., de Almeida, M. P., de Miranda, M., Haase, V. G., & Carvalho, M. R. S. (2019). Heterosis in COMT Val158Met polymorphism contributes to sex-differences in children's math anxiety. *Frontiers in Psychology, 10*(MAY), 1–17. https://doi.org/10.3389/fpsyg.2019.01013

Kohen, Z., & Nitzan, O. (2021). Excellence in mathematics in secondary school and choosing and excelling in STEM professions over significant periods in life. *International Journal of Science and Mathematics Education*. https://doi.org/10.1007/s10763-020-10138-x

Krill, Z., Geva, A., & Aloni, T. (2019). The effect of the field of study on the higher education wage premium—Evidence from Israel. *Labour, 33*(3), 388–423. https://doi.org/10.1111/labr.12150

Lau, N. T. T., Hawes, Z., Tremblay, P., & Ansari, D. (2022). Disentangling the individual and contextual effects of math anxiety: A global perspective. *Proceedings of the National Academy of Sciences of the United States of America, 119*(7), 1–11. https://doi.org/10.1073/pnas.2115855119

Lindberg, S. M., Hyde, J. S., Petersen, J. L., & Linn, M. C. (2010). New trends in gender and mathematics performance: A meta-analysis. *Psychological Bulletin, 136*(6), 1123–1135. https://doi.org/10.1037/a0021276

Lyons, I. M., & Beilock, S. L. (2012). Mathematics anxiety: Separating the math from the anxiety. *Cerebral Cortex, 22*(9), 2102–2110. https://doi.org/10.1093/cercor/bhr289

Maltese, A. V., & Tai, R. H. (2010). Eyeballs in the fridge: Sources of early interest in science. *International Journal of Science Education, 32*(5), 669–685. https://doi.org/10.1080/09500690902792385

Martín-Puga, M. E., Justicia-Galiano, M. J., Gómez-Pérez, M. M., & Pelegrina, S. (2020). Psychometric properties, factor structure, and gender and educational level invariance of the Abbreviated Math Anxiety Scale (AMAS) in Spanish children and adolescents. *Assessment*. https://doi.org/10.1177/1073191120980064

Megreya, A. M., & Al-Emadi, A. A. (2023). The impacts of math anxiety, science anxiety, and gender on arts versus sciences choices in Qatari secondary schools. *PeerJ, 11*, e14510. https://doi.org/10.7717/peerj.14510

Meyer, J., & Strauß, S. (2019). The influence of gender composition in a field of study on students' drop-out of higher education. *European Journal of Education, 54*(3), 443–456. https://doi.org/10.1111/ejed.12357

Moè, A. (2018). Mental rotation and mathematics: Gender-stereotyped beliefs and relationships in primary school children. *Learning and Individual Differences, 61*(November), 172–180. https://doi.org/10.1016/j.lindif.2017.12.002

Morán-Soto, G., & González-Peña, O. I. (2022). Mathematics anxiety and self-efficacy of mexican engineering students: Is there gender gap? *Education Sciences, 12*(6), 391. https://doi.org/10.3390/educsci12060391

National Center for Science and Engineering Statistics. (2019). Women, minorities, and persons with disabilities in Science and Engineering: 2019. In *Science* (Issue March). https://www.nsf.gov/statistics/wmpd

Organization for Economic Co-operation and Development (OECD). (2013). *PISA 2012 results: Ready to learn: Students' engagement, drive and self-beliefs* (Vol. III). OECD.

Organization for Economic Co-operation and Development (OECD). (2017). Key findings from education at a glance 2017. In *Education at a glance 2017*. https://doi.org/10.1787/eag-2017-en

Organization for Economic Co-operation and Development (OECD). (2022). *Education at a glance 2022*. OECD indicators. https://doi.org/10.5860/choice.41-5419

Peguero, A. A., Merrin, G. J., Hong, J. S., & Johnson, K. R. (2019). School disorder and dropping out: The intersection of gender, race, and ethnicity. *Youth and Society, 51*(2), 193–218. https://doi.org/10.1177/0044118X16668059

Peguero, A. A., Zavala, E., Shekarkhar, Z., & Walker-Pickett, M. (2021). School victimization, immigration, dropping out, and gender disparities. *Journal of Interpersonal Violence, 36*(5–6), 2703–2731. https://doi.org/10.1177/0886260518760004

Peri, G., Shih, K., & Sparber, C. (2016). STEM workers, H-1B Visas, and productivity in US cities. *The Economics of International Migration, 49*(3), 277–307. https://doi.org/10.1142/9781

Primi, C., Busdraghi, C., Tomasetto, C., Morsanyi, K., & Chiesi, F. (2014). Measuring math anxiety in Italian college and high school students: Validity, reliability and gender invariance of the Abbreviated Math Anxiety Scale (AMAS). *Learning and Individual Differences, 34*, 51–56. https://doi.org/10.1016/j.lindif.2014.05.012

Primi, C., Donati, M. A., Izzo, V. A., Guardabassi, V., Connor, P. A. O., Tomasetto, C., & Morsanyi, K. (2020). The early elementary school Abbreviated Math Anxiety Scale (the EES-AMAS): A new adapted version of the AMAS to Measure math anxiety in young children. *Frontiers in Psychology, 11*, 1014. https://doi.org/10.3389/fpsyg.2020.01014

Qu, Z., Chen, J., Li, B., Tan, J., Zhang, D., & Zhang, Y. (2020). Measurement of high-school students' trait math anxiety using neurophysiological recordings during math exam. *IEEE Access, 8*, 57460–57471. https://doi.org/10.1109/ACCESS.2020.2982198

Reinhold, S., Holzberger, D., & Seidel, T. (2018). Encouraging a career in science: A research review of secondary schools' effects on students' STEM orientation. *Studies in Science Education, 54*(1), 69–103. https://doi.org/10.1080/03057267.2018.1442900

Rozek, C. S., Ramirez, G., Fine, R. D., & Beilock, S. L. (2019). Reducing socioeconomic disparities in the STEM pipeline through student emotion regulation. *Proceedings of the National Academy of Sciences of the United States of America, 116*(5), 1553–1558. https://doi.org/10.1073/pnas.1808589116

Skagerlund, K., Lind, T., Strömbäck, C., Tinghög, G., & Västfjäll, D. (2018). Financial literacy and the role of numeracy—How individuals' attitude and affinity with numbers influence financial literacy. *Journal of Behavioral and Experimental Economics, 74*(August), 18–25. https://doi.org/10.1016/j.socec.2018.03.004

Soysal, D., Bani-Yaghoub, M., & Riggers-Piehl, T. A. (2022). A machine learning approach to evaluate variables of math anxiety in STEM students. *Pedagogical Research, 7*(2), em0125. https://doi.org/10.29333/pr/11978

Stoet, G., Bailey, D. H., Moore, A. M., & Geary, D. C. (2016). Countries with higher levels of gender equality show larger national sex differences in mathematics anxiety and relatively lower parental mathematics valuation for girls. *PLoS ONE, 11*(4), 1–24. https://doi.org/10.1371/journal.pone.0153857

Sun, L., Hu, L., Yang, W., Zhou, D., & Wang, X. (2021). STEM learning attitude predicts computational thinking skills among primary school students. *Journal of Computer Assisted Learning, 37*(2), 346–358. https://doi.org/10.1111/jcal.12493

Tandrayen-Ragoobur, V., & Gokulsing, D. (2022). Gender gap in STEM education and career choices: What matters? *Journal of Applied Research in Higher Education, 14*(3), 1021–1040. https://doi.org/10.1108/JARHE-09-2019-0235

Teliousi, V., Zafiri, M., & Pliogou, V. (2020). Occupation and gender stereotypes in primary school: The case of the english language coursebooks in Greek primary schools. *Universal Journal of Educational Research, 8*(4), 1135–1148. https://doi.org/10.13189/ujer.2020.080403

Tomasetto, C., Morsanyi, K., Guardabassi, V., & O'Connor, P. A. (2021). Math anxiety interferes with learning novel mathematics contents in early elementary school. *Journal of Educational Psychology, 113*(2), 315–329. https://doi.org/10.1037/edu0000602

Vandekerckhove, J., Rouder, J. N., & Kruschke, J. K. (2018). Editorial: Bayesian methods for advancing psychological science. *Psychonomic Bulletin and Review, 25*(1), 1–4. https://doi.org/10.3758/s13423-018-1443-8

Wagenmakers, E. J., Marsman, M., Jamil, T., Ly, A., Verhagen, J., Love, J., Selker, R., Gronau, Q. F., Šmíra, M., Epskamp, S., Matzke, D., Rouder, J. N., & Morey, R. D. (2018). Bayesian inference for psychology. Part I: Theoretical advantages and practical ramifications. *Psychonomic Bulletin and Review, 25*(1), 35–57. https://doi.org/10.3758/s13423-017-1343-3

Wang, M., & Degol, J. (2013). Motivational pathways to STEM career choices: Using expectancy-value perspective to understand individual and gender differences in STEM fields. *Developmental Review, 33*(4), 304–340. https://doi.org/10.1016/j.dr.2013.08.001

Wang, Z., Hart, S. A., Kovas, Y., Lukowski, S., Soden, B., Thompson, L. A., Plomin, R., McLoughlin, G., Bartlett, C. W., Lyons, I. M., & Petrill, S. A. (2014). Who is afraid of math? Two sources of genetic variance for mathematical anxiety. *Journal of Child Psychology and Psychiatry, and Allied Disciplines, 55*, 1–9. https://doi.org/10.1111/jcpp.12224

Wang, Z., Lukowski, S. L., Hart, S. A., Lyons, I. M., Thompson, L. A., Kovas, Y., Mazzocco, M. M. M., Plomin, R., & Petrill, S. A. (2015). Is math anxiety always bad for math learning? The role of math motivation. *Psychological Science, 26*(12), 1863–1876. https://doi.org/10.1177/0956797615602471

Watt, H. M. G. (2016). Promoting girls' and boys' engagement and participation in senior secondary STEM fields and occupational aspirations. In *Australian council of educational research conference*, 11. http://research.acer.edu.au/cgi/viewcontent.cgi?article=1285&context=research_conference

Weller, C. (1984). Comparison of diagnostic test scores through use of a T-score table. *Psychological Reports, 54*(2), 519–522.

Zhang, J., Zhao, N., & Kong, Q. P. (2019). The relationship between math anxiety and math performance: A meta-analytic investigation. *Frontiers in Psychology, 10*(AUG), 1–17. https://doi.org/10.3389/fpsyg.2019.01613

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