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Math anxiety affects females' vocational interests

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ABSTRACT

Vocational interest in science, technology, engineering, and math (STEM) fields in middle school can predict life outcomes, including enrollment in STEM courses and pursuing STEM careers. Numerical performance, as well as emotional factors such as math anxiety (MA), may influence vocational interests. The constructs of both vocational interests and MA are sensitive to gender differences. Accordingly, this study explored whether the relations among MA, numerical performance, and math vocational interests among middle-school students vary by gender. A sample of 127 ninth-grade students (68 females) performed a computation task and completed MA and trait anxiety (TA) questionnaires. A math vocational interest questionnaire was composed and assessed with an additional sample of 89 ninth-grade students. For females, MA, but not TA or numerical performance, predicted math vocational interest. Those with low MA levels tended to be interested in careers with higher math proficiency such as STEM careers. For males, high numerical performance and low TA, but not MA, related to interest in careers with high math proficiency. Bayes factors indicated that the data strongly supported the theory. The findings support the assumption that high MA levels affect the career plans of female students, whereas low numerical performance can account for both MA levels and future career plans of male students. It is essential to investigate how career aspirations are shaped in young students to promote the choice of STEM careers, especially among underrepresented populations such as females.

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Introduction

Vocational interests during adolescence can predict later life outcomes such as becoming employed, getting married, and having children (Trautwein et al., 2016). Furthermore, recent longitudinal studies suggest that math performance in high school predicts the later pursuit of a math-intensive career, including in science, technology, engineering, and math (STEM) (Dekhtyar, Weber, Helgertz, & Herlitz, 2018; Lee, Lawson, & McHale, 2015; Wang, Degol, & Ye, 2015). But math aptitude alone is not sufficient to predict the choice of a STEM career (Wang et al., 2015). Motivational–emotional factors can be better predictors than either math aptitude or math course enrollment (Wang & Degol, 2013). For example, one study found that the relations between math performance and STEM careers were partially mediated by "math task value," or the degree to which students enjoyed and were interested in learning math (Dekhtyar et al., 2018). Building on these findings, we investigated the relations between vocational interest in a STEM career and math anxiety (MA), an emotional factor frequently associated with poor math performance (Ashcraft, 2002; Cargnelutti, Tomasetto, & Passolunghi, 2017; Foley et al., 2017; Young, Wu, & Menon, 2012). Another factor influencing the choice of a STEM career is gender (Lazarides & Lauermann, 2019; Su & Rounds, 2015; Yang & Barth, 2015). Because gender also affects MA levels and symptoms, (Goetz, Bieg, Lüdtke, Pekrun, & Hall, 2013; Hill et al., 2016; Ma & Xu, 2004; Rubinsten, Bialik, & Solar, 2012), our study also considered the role of gender.

The study focused on middle school students, extending the research on this population by considering how MA levels affect future career plans. Elevated MA levels are related to poor numerical performance (e.g., Foley et al., 2017; Maloney, Risko, Ansari, & Fugelsang, 2010; Young et al., 2012) and low enrolment in math and science classes (Chipman, Krantz, & Silver, 1992; Hembree, 1990; Huang, Zhang, & Hudson, 2019). Consequently, a causal relationship between MA and avoidance of a career with a high math load seems plausible (Ahmed, 2018). Even though career aspirations are shaped at a relatively young age and remain stable from adolescence to adulthood, most of the research focuses on the vocational interests and choices of college students and adults (Rounds, Low, Yoon, Roberts, & Rounds, 2016). However, it is necessary to investigate how career aspirations are shaped in younger students to promote later enrollment in STEM careers, especially among underrepresented populations such as females (National Science Foundation, 2019). Gender stereotypes of math competence and gendered occupations are probably shaped during middle school (Betz & Sekaquaptewa, 2012), hence the need to focus on this age group. We aimed to fill the gap in the research by measuring gender differences in MA levels and career aspirations among middle school students, looking specifically at ninth graders.

Gender differences in vocational interests

Women have had significant achievements in science, winning Nobel prizes and Fields medals. Although they represent about 50% of the workforce, however, a wealth of research systematically indicates an underrepresentation of females in STEM courses and careers (Lent, Lopez, & Bieschke, 1991; Lent et al., 2018; Wang & Degol, 2017). The gender gap has decreased over the past 20 years, but it still exists (Gati & Perez, 2014). It remains consistent over the life span (Trautwein et al., 2016) and is evident in different cultures (Dekhtyar et al., 2018; Morris, 2016). Female students in middle school and high school are less likely to enroll in math and science courses than male students (Watt, 2016). They are also less interested in pursuing STEM careers regardless of their math aptitude (Lubinski & Benbow, 2006). After high school, they are underrepresented in STEM courses in higher education institutes and STEM careers (National Science Foundation, 2019; Stout, Grunberg, & Ito, 2016; White & Massiha, 2016).

Various theories have attempted to explain why females are less interested in STEM. Some assume that females and males have different academic strengths and that this leads them to make different vocational choices (e.g., Dekhtyar et al., 2018). Specifically, females are relatively better in verbal skills than in math skills, whereas males are better in math than in verbal skills (Stoet, Bailey, Moore, & Geary, 2016; Stoet & Geary, 2018). The personal strength hypothesis assumes that an individual will choose a career path matching his or her strengths. Thus, females will prefer occupations requiring high verbal skills (e.g., teaching), and males will prefer careers with a high math load (e.g., engineering). Yet in some cases, females with higher math abilities (compared with their verbal skills) do not necessarily prefer occupations with a high math load (Dekhtyar et al., 2018). In addition, among students with both STEM- and non-STEM-related vocational interests, females are less likely than males to choose STEM-related majors in college (Cardador, Damian, & Wiegand, 2021).

The roots of the gender differences in career choices emerge at school (Dietrich & Lazarides, 2019), but recent research suggests that different factors affect the desire to pursue STEM careers (Lent et al., 2018). For males, intrinsic factors, such as math achievements and mastery experiences (Zeldin, Britner, & Pajares, 2008) and economic goals (Wolter, Ehrtmann, Seidel, & Drechsel, 2019), play a crucial role in their preference for a STEM career. Females are more sensitive to environmental influences such as social influences and conceptions of women in STEM (Tellhed, 2017; Zeldin & Pajares, 2000). They tend to enroll in specific STEM occupations that involve intensive interaction with people such as healthcare work (Su & Rounds, 2015). Few choose to study STEM occupations that mostly feature interactions with objects and calculations (Ertl & Hartmann, 2019). Because math-intensive STEM fields require massive interactions with objects (Webb, Lubinski, & Benbow, 2002), females are underrepresented in these fields (National Science Foundation, 2019).

Accordingly, social motivational factors may be as important as math aptitude for STEM career attainment (Wang & Degol, 2013), at least for females. Previous research has focused on the relations between vocational interest and motivational–emotional factors, such as mathematics self-concept (Lazarides & Lauermann, 2019) and values attributed to math learning (Watt, Bucich, & Dacosta, 2019; Wille et al., 2020), as predictors of career choices. We focused on a different emotional construct, math anxiety, which is strongly related to both numerical performance (Foley et al., 2017; Zhang, Zhao, & Kong, 2019) and gender differences (Devine, Fawcett, Szűcs, & Dowker, 2012; Stoet et al., 2016). Specifically, we explored whether differences in levels of MA could shed light on the origins of the gender gap in vocational interests.

Math anxiety and gender differences

Some people find it challenging to learn arithmetic or mathematics because they suffer from math anxiety, a persistent adverse reaction to math ranging from mild discomfort to extreme avoidance (Ashcraft, 2002; Ashcraft, 2019; Hembree, 1990). The symptoms of MA are heterogeneous and expressed on various spectra, including physiological (e.g., Pizzie & Kraemer, 2017; Qu et al., 2020), emotional (e.g., Justicia-Galiano, Martín-Puga, Linares, & Pelegrina, 2017; Organization for Economic Cooperation and Development [OECD], 2013), educational (Lukowski et al., 2019; Zhang et al., 2019), and attitudinal ones (e.g., Furner, 2019; Gunderson, Ramirez, Levine, & Beilock, 2011b; for a review, see Rubinsten, Marciano, Levy, & Cohen, 2018). MA manifestations include, for example, adverse reactions to math (Ashcraft, 2002), avoidance behavior (Choe, Jenifer, Rozek, Berman, & Beilock, 2019), and low math-related self-confidence (e.g., Ahmed, Minnaert, Kuyper, & van der Werf, 2012). Individuals with high MA levels often report physical discomfort when engaged in math-related tasks, including fast heartbeats, sickness, and headache or stomach ache (Harari, Vukovic, & Bailey, 2013; Maloney, Schaeffer, & Beilock, 2013). MA is quite prevalent (OECD, 2013), and accumulating evidence suggests that MA levels increase over the years of schooling (Cargnelutti et al., 2017; Gunderson, Park, Maloney, Beilock, & Levine, 2018). In a recent study, 11% of elementary school and middle school students reported high MA levels (Devine, Hill, Carey, & Szu, 2018), but this number may double or even triple among older students (Hart & Ganley, 2019; Perry, 2004).

Some existing data show a gender gap for MA, with females reporting higher levels than males (Devine et al., 2018; Hill et al., 2016; Stoet et al., 2016), although the gender differences in numerical performance have decreased during the past few decades (Hyde, Lindberg, Linn, Ellis, & Williams, 2008; Hyde & Mertz, 2009; Lindberg, Hyde, Petersen, & Linn, 2010). However, other research has discovered similar MA levels across genders, at least for some research populations (Cooper & Robinson, 1991; Madjar, Zalsman, Weizman, Lev-Ran, & Shoval, 2018; OECD, 2013; Rubinsten, Eidlin, Wohl, &

Akibli, 2015), thereby questioning both the universality and the causes of gender differences in MA. Relevant to the current study, gender differences in MA may increase along developmental phases. They are less pronounced or even absent among primary school students (Dowker, Bennett, & Smith, 2012; Ramirez, Gunderson, Levine, & Beilock, 2012; Wu, Barth, Amin, Malcarne, & Menon, 2012) but see also Hill et al., 2016) or even middle school students (Madjar et al., 2018), but they become prominent during late adolescence (e.g., Primi, Busdraghi, Tomasetto, Morsanyi, & Chiesi, 2014; Xie, Xin, Chen, & Zhang, 2019). It is necessary to understand why some female students exhibit high MA levels in order to promote their math performance and encourage their choice of math and science courses and careers.

Several theories have tried to explain why females tend to exhibit higher MA levels than males. Genetic–biological differences can account for females' proneness to high MA levels (Júlio-Costa et al., 2019; Wang et al., 2014). Júlio-Costa et al. (2019) found significant sex- and anxiety-related genotype interactions; homozygous girls had higher MA levels than homozygous boys. In this study, genetic factors accounted for approximately 40% of the variance in MA. However, social–environmental factors also play a crucial role in MA development, especially for females. According to the gender stratification hypothesis (Baker & Jones, 1993), for example, females have fewer social opportunities to engage in math and science activities (e.g., Else-Quest, Hyde, & Linn, 2010; Guiso, Monte, Sapienza, & Zingales, 2008). Accordingly, more intensive engagement in such activities may help to decrease females' high MA levels (Stoet et al., 2016). In addition, social agents' (e.g., parents, teachers) expectancies of math competence are often gender biased, and this affects students' MA levels and their numerical performance (Beilock, Gunderson, Ramirez, & Levine, 2010; Cohen & Rubinsten, 2017; Gunderson, Ramirez, Levine, & Beilock, 2011a). In one study, students and their parents perceived math education as more critical for sons than for daughters (Stoet et al., 2016). It is important to note, however, that environmental pressure to achieve in math can induce high anxiety levels (Foley et al., 2017; Zhang et al., 2019), with an impact on math performance for both genders.

Math anxiety–math performance link: Gender differences?

Poor numerical performance can lead to lower attainment of STEM-related careers (Lee et al., 2015; Wang et al., 2015). Nevertheless, despite the apparent gender bias in MA levels, there are inconsistent findings on the relations between MA and numerical performance by gender. Some evidence suggests high MA levels relate to low numerical performance among males (e.g., Hembree, 1990; Ma & Xu, 2004). Other evidence suggests that MA hinders math achievements among females (Devine et al., 2012). Still other work points to similar patterns across genders (Hill et al., 2016; Wu et al., 2012), including some recent meta-analyses (Barroso et al., 2021; Zhang et al., 2019). Females tend to report higher levels of other anxiety types, such as trait and test anxieties (Costa, Terracciano, & McCrae, 2001; Egloff & Schmukle, 2004; Schnell, Tibubos, Rohrmann, & Hodapp, 2013; Vianello, Schnabel, Sriram, & Nosek, 2013), making it important to control for other anxiety constructs to get a better understanding of MA and numerical performance associations across genders. For example, Devine et al. (2012) investigated middle school students and found that after controlling for test anxiety, MA was related to numerical performance for females but not for males. However, both genders showed negative relations between MA and numerical performance when general anxiety was controlled (Hill et al., 2016). Accordingly, we explored whether the relations between anxiety (general or math specific) and numerical performance vary by gender and, if so, how these variations affect the vocational interests of middle school students.

Math anxiety and career choice: Why middle school is important

Surprisingly, the relations between MA and vocational interests do not attract widespread scientific attention. Only a few studies have investigated the vocational interests of adolescents with high MA levels (Ahmed, 2018; Huang et al., 2019) even though vocational interests during adolescence can predict later career choices. For instance, Maltese and Tai (2010) found that most students who pursued STEM careers made that choice during high school because of a growing interest in math and science. Longitudinal studies have established the relations between MA levels and career choices. A recent longitudinal study (Ahmed, 2018) followed a group of students for 7 years, starting in the seventh grade. Participants who reported consistently high or increasing levels of MA were less likely to pursue STEM careers than participants with consistently low or decreasing MA levels. Interestingly, the study did not find gender differences. In contrast, Huang et al. (2019) found a direct effect of MA on math and science career interests among middle school girls but not among middle school boys.

We sought to replicate previous findings on the influence of gender and MA on vocational interest. By including trait anxiety (TA) and numerical performance as covariants of MA, we hoped to generate a more sensitive understanding of the sources of the expected gender differences.

The current study

Most studies have measured vocational interests and choices dichotomously (STEM vs. non-STEM careers). We measured the effect of MA on vocational interests on a broader spectrum, creating a scale to measure occupations' math demands (for other continuous measurements of occupational math demands, see (Ganley, George, Cimpian, & Makowski, 2018; Lazarides & Lauermann, 2019). This method enabled the inclusion of non-STEM career fields that are math intensive such as math teachers and economists. For additional information on STEM and non-STEM careers, see the Classification of Instructional Programs (CIP) list on the website of the National Center for Educational Statistics (https://nces.ed.gov/ipeds/cipcode/Default.aspx?y=56). Our research design was intended to promote understanding of the relations among MA, gender, and vocational interests from a broader perspective than a design using a dichotomous STEM or non-STEM classification.

Because TA (Owens, Stevenson, Norgate, & Hadwin, 2008) and MA (Carey, Hill, Devine, & Szücs, 2015; Hembree, 1990; Ma & Xu, 2004) are associated with low math achievements, we measured both specific (math) and general (trait) anxiety types and used them as control variables. Hill et al. (2016) found significant correlations between MA and math but not reading performance among secondary school students after controlling for general anxiety. MA, but not TA, predicted performance in both fundamental (calculation) and more complex (math problems) math-related tasks (Miller & Bichsel, 2004). Relevant to our research, previous research has established the relations between TA and vocational interests, with high anxiety levels often related with career indecision (Fuqua, Seaworth, & Newman, 1987). However, to the best of our knowledge, no research has measured the complex associations between math and trait anxieties and vocational interests.

We aimed to fill the scientific gap and determine whether there are gender differences in young students' vocational interests because of differences in their MA levels and math performance when TA is controlled. Fig. 1 presents the theoretical framework of the relations among MA, TA, and numerical performance as predictors of math vocational interest. We hypothesized that high MA levels would correlate with an interest in careers with lower math demands for females, who typically internalize gender stereotypes at this age (Betz & Sekaquaptewa, 2012). Because there is a direct path between personal strengths and vocational choices for males (Dekhtyar et al., 2018), we hypothesized

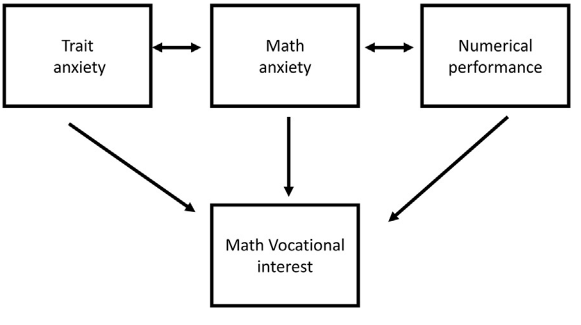

Fig. 1. Theoretical framework of the relations among math anxiety, trait anxiety, and numerical performance as predictors of math vocational interest.

that math performance, and not MA, would predict an interest in careers with math demands for male students. The hypotheses follow previous research findings (Wang et al., 2015) that math achievements mediate the relations between gender and STEM careers; specifically, females have lower math achievements and are less interested in STEM careers.

In general, we expected female students' vocational interests to be influenced by emotional–social factors and male students' vocational interests to be associated with actual performance. These findings would suggest the need to consider separating the analysis of females and males in research on the consequences of MA as well as the need to develop gender-specific remediation programs.

Method

Participants

A sample of 135 ninth-grade students participated in the experiment and completed a series of tasks. Participants attended four different classes in two private schools. Six participants were excluded because of missing data; two others were excluded because their score in the vocational interest task deviated 2.5 standard deviations or more from the mean score. The final sample consisted of 127 students: 68 females (M_{age} = 14.68 years, *SD* = 0.51) and 59 males (M_{age} = 14.76 years, *SD* = 0.49). Another sample of 89 ninth-grade students (40 females) completed an occupational math proficiency ranking form to create a continuous scale representing how math-demanding different professions are.

We obtained parental consent for all students, the experimental and prior data collection study samples, before testing. The study was carried out following the recommendations of the ethics committee of the University of Haifa. The ethics committee approved the protocol of the study.

Experimental tasks

Math anxiety

Participants answered a translated and computerized version of the Abbreviated Math Anxiety Scale (AMAS; Hopko, Mahadevan, Bare, & Hunt, 2003), a 9-item questionnaire. The AMAS is frequently used to measure MA levels and has been validated in different cultural populations (e.g., Cipora, Szczygieł, Willmes, & Nuerk, 2015; Primi et al., 2014; Vahedi & Farrokhi, 2011). The AMAS has previously been used to assess MA among middle school students (e.g., Hill et al., 2016). The questionnaire is designed to reflect the degree of anxiety experienced in a variety of math-related tasks and situations based on a 5-point Likert-type scale (from 1 = *low anxiety* to 5 = *high anxiety*). To obtain the total score, we summed the scores for all questions (score range = 9–45; Cronbach's alpha internal consistency reliability, α = .85).

Trait anxiety

Participants answered a translated version (Teichman, 1979) and computerized version of the State–Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983). A total of 20 items measuring TA were chosen from the full STAI, which contains 40 items (the remaining 20 items measure state anxiety). The questionnaire is designed to measure how an individual generally feels and to detect proneness to anxiety based on a 4-point Likert-type scale (from 1 = *not at all* to 4 = *very much*). To obtain the total score, we reversed the scale of 10 questions that were phrased positively (e.g., "I usually feel content") and summed the scores for all items (score range = 20–80; internal consistency reliability, α = .83).

Numerical performance

To assess numerical performance, we used the calculation subtest of the Woodcock–Johnson Tests of Achievement (Woodcock, Johnson, & Mather, 1990). The calculation test is a standardized pen-and-pencil test commonly used for math achievement testing (e.g., Rubinsten & Tannock, 2010). It is applicable for use with individuals from 2 to 90 years of age. It requires the calculation of problems ranging from simple addition to complex calculus (as trigonometry and algorithms). The test is stopped after test completion or after a sequence of six wrong answers. Then, each item is scored as 1 or 0 based on accuracy, and the summation of all correct items serves as the raw subtest score. Raw scores are converted into standard scores using a computerized program, with an average of 100 points and a standard deviation of 15.

Math vocational interest

Recall that we divided our sample randomly into two groups. In the first group, to determine the math demands of different occupations, we asked participants (n = 89) to classify the degree of math proficiency required for each profession appearing in a list from 1 (*very low*) to 10 (*very high*). An average score represented the math proficiency for each occupation. For instance, the profession of dancer was not seen as having high math demands (mean score = 1.41), whereas engineer was ranked as a high math-demanding profession (mean score = 9.34). For the full list of occupations and their math proficiency scores by gender, see the Appendix.

In the second group (the main experiment), we used a questionnaire to measure whether students thought they were capable of succeeding in occupations with different levels of math demands. We created a list of 30 occupations based on Roe (1954) and Holland (1996) occupational classification theories. The list included occupations from different categories (e.g., scientific, artistic, social, physical, humanities). Students were asked to report whether they thought they could succeed in each occupation appearing in the list. For each occupation, students needed to choose the most suitable answer out of three options: (1) "I will succeed in this occupation"; (2) "I will not succeed in this occupation"; (3) "I may succeed in this occupation." Then, we calculated a math vocational interest score for each student, represented by a mean score of math proficiency levels of professions in which students reported they would or might succeed. The scores ranged from 1 (interested in professions with low math proficiency) to 10 (interested in professions with high math proficiency). Descriptive statistics of participants' performance and the intercorrelation of variables appear in Table 1.

Procedure

Tests were administered in school during the second term of the ninth grade (in April). Because all tests were computerized, students were tested in a computer classroom in group sessions, each lasting approximately 45 min. To avoid biased responses, anxiety tasks were administered after the completion of other experimental tasks. Occupational math proficiency ranking forms were administered separately to other students, who were also tested in the classroom in group sessions.

Data analysis

Based on our research hypotheses, trait and math anxieties, as well as numerical performance, were independent variables, and math vocational interest was the dependent variable. Because gender differences were our main interest, we started by conducting independent t tests to detect gender differences across variables. All other analyses to explore relationships between variables (Pearson correlations and path analysis) were done for female and male participants separately.

Table 1
Participants in the main experiment: Descriptive statistics and correlations (N = 135).

		Descriptive statistics					Intercorrelations			
		Min	Max	M	SD	Skewness	1	2	3	4
1.	Math anxiety	9	45	27.04	8.352	−.34		.175*	−.365**	−.208*
2.	Trait anxiety	24	68	43.19	7.867	−.08			−.095	−.300**
3.	Numerical performance	53	131	99.19	16.057	−.58				.298**
4.	Math vocational interest	4.34	7.15	5.53	0.550	.27				

Note. Min, minimum; Max, maximum.
* $p < .05$.
** $p < .01$.

To address recent requests to combine several statistical methods to calculate the probability with which the findings favor the research hypothesis (H_1) over the null hypothesis (Vandekerckhove, Rouder, & Kruschke, 2018; Wasserstein & Lazar, 2016), we calculated Bayes factors for t tests and correlation tests. To interpret the Bayes factors, we adopted the classification recommended by Wagenmakers, Love, et al. (2018), in which Bayes factor values smaller than 1 support the null hypothesis, values between 1 and 3 suggest anecdotal support of the research hypothesis, and values greater than 3 suggest moderate to strong support (for values up to 10) of the research hypothesis.

For a description of causal relations between variables and, more specifically, to identify the predictors of math vocational interest, we conducted path analysis, a method suitable to measure a set of relations between variables, including causal ones (Ullman & Bentler, 2013). Recent simulation studies have found that relatively small sample sizes have sufficient power in structural equation modeling (SEM) analyses (Sideridis, Simos, Papanicolaou, & Fletcher, 2014; Wolf, Harrington, Clark, & Miller, 2013). According to Wolf et al. (2013), a sample size of 30 participants ensures sufficient power analysis (.80) for a model with four indicators. Because our sample sizes exceeded this number, and based on our research hypotheses, we built separate path analysis models for female (n = 68) and male (n = 59) participants.

Following the literature, we considered model fit values, including those for the comparative fit index (CFI) and normed fit index (NFI), higher than .95 to indicate acceptable model fit (Hu & Bentler, 1999). For the root mean square error of approximation (RMSEA), we considered values lower than .50 to indicate acceptable model fit (Browne & Cudeck, 1993).

Results

Gender differences in anxiety, numerical performance, and math vocational interest

As Table 2 shows, female and male participants reported similar levels of MA, but females reported higher levels of TA. Females also performed more poorly on the calculation test and were more interested in occupations with lower math proficiency than males. Because we wanted to know whether the links between variables varied by gender, we analyzed the data for females and males separately.

Analysis of females

The correlation matrix for female participants appears in Table 3. Our goal was to identify whether anxiety levels or numerical performance would predict their vocational interest in math-related fields.

Correlations with vocational interest

MA was negatively correlated with math vocational interest among female participants (r = −.293, p = .015, BF_{10} = 5.444), suggesting moderate to strong support of H_1, and the correlations between TA and vocational interest were not significant (r = −.114, p = .355; BF_{10} = 0.971). The correlations

Table 2
Gender differences.

Test	Females (n = 68)	Males (n = 59)	Independent t test	p Value	Effect size (Cohen's d)	BF_{10}
Math anxiety	27.74 (7.78)	26.23 (8.96)	1.019	.310	.17	0.285
Trait anxiety	44.51 (7.97)	41.66 (7.51)	2.061	.041	.37[a]	1.309
Numerical performance	96.42 (15.31)	102.38 (16.42)	−2.116	.036	.37[a]	1.764
Vocational interest math load	5.33 (0.50)	5.76 (0.51)	−4.768	<.001	.85[b]	1357.631

Note. Standard deviations are in parentheses.
[a] Moderate effect size (Cohen, 1988).
[b] Strong effect size (Cohen, 1988).

Table 3
Correlation matrix for females.

		1	2	3	4
1.	Math anxiety		.147	−.258*	−.293*
2.	Trait anxiety			−.114	−.194
3.	Numerical performance (calculation)				.214
4.	Vocational interest math load				

* $p < .05$.

between numerical performance and vocational interest were marginally significant but did not reach an acceptable Bayes factor value (r = .214, p = .080, BF_{10} = 1.272).

Correlations with math anxiety

MA showed significant negative correlations with numerical performance (r = −.258, p = .033, BF_{10} = 2.728) but not with TA (r = .147, p = .233, BF_{10} = 0.073). There were no correlations between TA and numerical performance (r = −.114, p = .355, BF_{10} = 0.377).

Predictors of math vocational interest

We used path analysis to unidirectionally examine causal associations of the predictors, MA, TA, and numerical performance, with math vocational interest. A strength of this method is the possibility to account for the confounding of the predictors. Based on our findings and those of previous literature, we tested TA and numerical performance as covariants of MA.

The model, illustrated in Fig. 2, showed good fit to the data, $\chi^2(1)$ = 0.874, p = .350, NFI = .944, CFI = 1.000, $RMSEA$ = .000. The model explained 12% of the variance in interest in a career with a high math load. MA level significantly predicted interest (β = −.24, p = .046), but TA level was not a significant predictor (β = −.145, p = .210), nor was numerical performance (β = .137, p = .248). Numerical performance was a significant covariant of MA (β = −.246, p = .049), but TA was not (β = .119, p = .318).

Analysis of males

Correlations with vocational interest

For males (see Table 4), the correlations between MA and math vocational interest were not significant (r = −.086, p = .258, BF_{10} = 0.200), but the correlations between TA and math vocational interest reached significance (r = −.322, p = .006, BF_{10} = 6.65), suggesting moderate to strong support of H_1. The

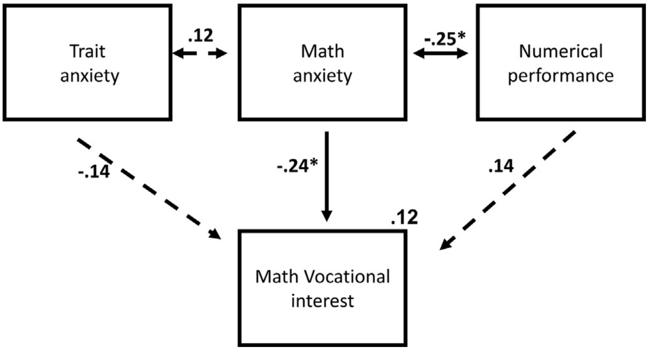

Fig. 2. Illustration of predictors of females' vocational interest in math-related fields. Solid lines represent significant associations; dashed lines are nonsignificant associations. *$p < .05$. Model fit indices: $\chi^2(1)$ = 0.874, p = .350, normed fit index = .944, comparative fit index = 1.000, root mean square error of approximation = .000.

Table 4
Correlation matrix for males.

		1	2	3	4
1.	Math anxiety		.180	−.447**	−.087
2.	Trait anxiety			−.006	−.322*
3.	Numerical performance (calculation)				.285*
4.	Vocational interest math load				

* $p < .05$.
** $p < .01$.

association between numerical performance and vocational interest also reached significance ($r = .285$, $p = .014$, $BF_{10} = 3.29$), indicating moderate support of H_1.

Correlations with math anxiety

Numerical performance was negatively correlated with MA ($r = -.447$, $p < .001$, $BF_{10} = 76.69$), indicating very strong support of H_1, but was not negatively correlated with TA ($r = .006$, $p = .483$, $BF_{10} = 0.16$). Interestingly, the correlations between MA and TA tended to be significant but did not meet acceptable Bayes factor values ($r = .180$, $p = .087$, $BF_{10} = 0.73$).

Predictors of math vocational interest

The structural model, illustrated in Fig. 3, showed excellent fit to the data, $\chi^2(1) = 0.002$, $p = .966$, $NFI = 1.000$, $CFI = 1.000$, $RMSEA = .000$. The model explained 20% of the variance in interest in vocations with a high math load. MA level did not predict interest in vocational math load ($\beta = .127$, $p = .342$), but TA level was a significant predictor ($\beta = -.344$, $p = .004$), as was numerical performance ($\beta = .340$, $p = .010$). Numerical performance was a covariant of MA ($\beta = -.447$, $p = .002$) but not of TA ($\beta = .139$, $p = .340$).

Discussion

We investigated whether gender differences affected the relations among MA, numerical performance, and vocational interests among middle school students. Female and male participants reported similar MA levels, but the relations among MA, numerical performance, and vocational interests varied by gender. MA, but not TA or numerical performance, predicted math vocational interest among female participants. Those with low MA levels tended to be interested in careers with higher math proficiency such as STEM careers. For male participants, high numerical performance and low TA

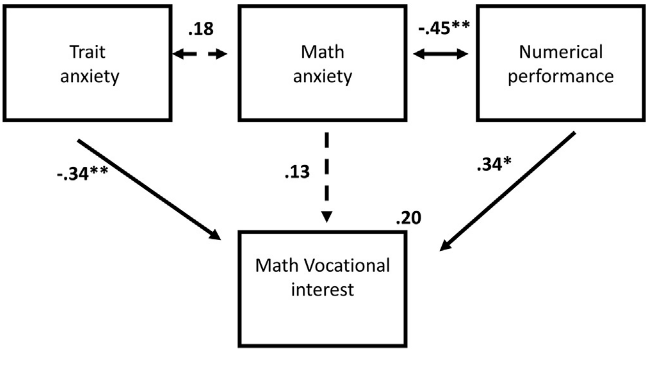

Fig. 3. Illustration of predictors of males' math vocational interests. Solid lines represent significant associations; dashed lines are nonsignificant associations. *$p < .05$; **$p < .01$. Model fit indices: $\chi^2(1) = 0.002$, $p = .966$, normed fit index = 1.000, comparative fit index = 1.000, root mean square error of approximation = .000.

levels were related to interest in careers with high math proficiency. Interestingly, there were no significant correlations between MA levels and vocational interests for males.

Because both deductive analysis and Bayesian statistics yielded consistent and robust patterns (Vandekerckhove et al., 2018; Wasserstein & Lazar, 2016), our results reliably imply that the constructs shaping math vocational interests in middle school students vary by gender. This has implications for both theory and education.

Math anxiety, vocational interests, and gender differences

In our study, female and male students reported similar levels of MA. Like our study, a number of other studies have not found a gender difference (Cooper & Robinson, 1991; Madjar et al., 2018; Rubinsten et al., 2015). Furthermore, a PISA (Programme for International Student Assessment) study (OECD, 2013) found no gender gap in MA in some countries (9 of 64). In some cases, there was even a reverse gap, with males reporting higher MA levels than females (3 countries). Our results corroborate these findings and suggest that the gender gap in MA is not universal.

Environmental and cultural influences can account for the heterogeneity of findings (Foley et al., 2017; Rubinsten, Levy, & Cohen, 2019). Specifically, a careful examination of the results reveals that the male students in our study rated themselves as having relatively high MA levels (M = 26.23, SD = 8.96) compared with participants in other studies with a similar population (Hill et al., 2016; Primi et al., 2014). Because our participants were enrolled in high-achieving private schools, high expectations of achievement may account for their high MA levels (Radišić, Videnović, & Baucal, 2015).

Yet interestingly, and relevant to our research hypotheses, the relations between MA and vocational interests varied by gender. The female participants with high MA levels were less interested in careers with high math proficiency, regardless of their numerical performance, and were more interested in careers with a lower math load than male participants. Importantly, both deductive and Bayes analyses yielded consistent findings, indicating moderate to strong support of the theory (Cohen, 1988; Funder & Ozer, 2019; Wagenmakers, Marsman, et al., 2018a, 2018b). Specifically, these findings support theories of gender stratification in numerical performance (Baker & Jones, 1993), whereby males are seen as better in math and STEM careers are masculine (Steele, 2003). As a consequence of gender stratification, females with high MA levels are less likely to enroll in scientific classes than those with low MA levels (e.g., Chipman et al., 1992). Our research population merits careful attention because female middle school students internalize both feminine and math-related stereotypes (Betz & Sekaquaptewa, 2012; Huguet & Régner, 2007; Sengupta, 2006). Betz and Sekaquaptewa (2012) found that female middle school students who did not like math could not identify with a feminine STEM role model (e.g., a female STEM student wearing pink clothes). In fact, exposure to such a feminine role model further depressed their future plans to study math. In our study, MA predicted our female participants' interest in STEM-related careers, something also found for other emotional factors (Lent et al., 2018; Tellhed, 2017; Zeldin et al., 2008; Zeldin & Pajares, 2000).

In contrast, TA, but not MA, predicted interest in vocational math load for male participants. Furthermore, math and trait anxieties were marginally correlated for males but not for females. The relatively small sample size may account for this marginal result, but according to the findings gender may explain the heterogeneity in MA (Rubinsten et al., 2018). More specifically, we argue that males' MA development and their avoidance of STEM-related careers are related to intrinsic factors such as proneness to anxiety (Rubinsten et al., 2019) and less sensitivity to environmental influences. Further research is crucial to validate this assumption given that recent data have shown significant correlations between MA and general anxiety for both genders (Hill et al., 2016). Either way, our research stresses the need to assess different anxiety constructs to measure gender differences in MA levels as well as their consequences, here represented by math vocational interest.

Associations among math anxiety, numerical performance, and math vocational interest

In our study sample, the associations between MA and numerical performance varied by gender, a fact that may account for the observed gender differences in vocational interests. Specifically, numerical performance predicted math vocational interest among male participants but not among their female counterparts. Although there was a negative association between MA and numerical performance for both genders, Bayesian statistics suggested that the pattern was more pronounced among males. Some recent meta-analyses found that the impact of MA on math achievements was similar across genders (Barroso et al., 2021; Zhang et al., 2019). Accordingly, although our findings might not clearly show a gender difference in the relations between MA and numerical performance, we suggest that the antecedents of the negative relations between MA and numerical performance may vary by gender. Specifically, like previous research, our findings demonstrate that male students' feelings about math learning are tied up with their actual math performance (Ma & Xu, 2004).

Similarly, intrinsic factors, such as math achievements and mastery experiences, play a crucial role in males' desire to pursue STEM careers (Lent et al., 2018; Tellhed, 2017; Zeldin et al., 2008; Zeldin & Pajares, 2000). Both students (Butler, 2014) and teachers (Robinson-Cimpian, Lubienski, & Ganley, 2014) think male students succeed in math because of their ability, whereas female students succeed because of hard work and good behavior. It was not surprising, however, to find higher MA levels among males with low numerical performance. High MA levels relate to low numerical performance among females as well (e.g., Stoet et al., 2016; Zhang et al., 2019), but their MA levels are also influenced by socialization agents such as parents and teachers (Beilock et al., 2010; Gunderson et al., 2011a). Devine et al. (2018) found that low math aptitude was not automatically accompanied by high MA levels and suggested that cognitive and emotional math difficulties should be treated differently. We extend this argument and suggest that intervention programs should take gender into account. Important for younger populations such as middle school students, recent research found that students who reported consistent negative experiences with math tended to avoid math-related situations more than students with mixed positive and negative experiences (John, Nelson, Klenczar, & Robnett, 2020). Thus, educators may consider investing effort in changing the narratives of young students with high MA levels to decrease avoidant patterns and increase the choice of courses and careers with a higher math load.

Suggestions for future research

One strength of the study is the observation of students' behavior in a real-life context, an experimental paradigm with greater ecological validity than a laboratory experiment (Nastase, Goldstein, & Hasson, 2020; Shamay-Tsoory & Mendelsohn, 2019).

However, our study included a specific population of ninth-grade students, and the sample was relatively small. Further research including other populations and ages is needed to fully establish the relations among MA, numerical performance, and vocational interests and choices. Manipulation experiments, such as intervention studies, may also enhance scientific knowledge of the effect of MA on adolescents' vocational interests.

Furthermore, our findings, as well as those of other recent studies (Barroso et al., 2021; Rubinsten et al., 2015; Zhang et al., 2019), question whether female students experience higher MA levels than male students, and this debilitates their numerical performance. Large-scale studies and meta-analyses should address which developmental and environmental factors contribute to gender differences in MA.

Conclusions

Our findings corroborate those of previous research and indicate that high MA levels affect the career plans of female middle school students. Specifically, our female participants with high MA were already interested in occupations requiring relatively low math proficiency. However, MA levels had no direct effect on the vocational interests of our male participants. In contrast to the findings for females, the findings for males suggest that a tendency to general (trait) anxiety, as well as low numerical performance, can account for both MA levels and future career plans. The findings support the assumption of heterogeneity in MA development (Rubinsten et al., 2018).

Based on the results, we recommend the inclusion of gender as a covariant when assessing MA levels or evaluating the effectiveness of intervention programs.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jecp.2021.105214.

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