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Consumers With Math Anxiety, a Financially Vulnerable Group? Unpacking the Negative Relation Between Math Anxiety and Performance on a Price Comparison Task

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Supplementary Materials: Data, Materials [see Index of Supplementary Materials]

Abstract

Comparison shopping is good financial practice, but situations involving numbers and computations are challenging for consumers with math anxiety. We asked North Americans (N = 256) to select the better deal between two products differing in volume and price. As predicted, math anxiety was negatively related to performance on this Price Comparison Task. We then explored the mechanism underlying this relation by testing math competency, price calculation ability, need for cognition, and cognitive reflection as potential mediators. The results from a competing mediator analysis indicated that all factors, apart from need for cognition, served as significant independent mediators between math anxiety and performance on our Price Comparison Task. This study has important implications for how–and why–math anxiety relates to a person's ability to accurately compare product prices. These data suggest that consumers higher in math anxiety may represent a financially vulnerable population, particularly in the context of financial tasks that are inherently mathematical.

Keywords

math anxiety, math competency, price comparison, cognitive reflection, need for cognition

Comparing products while shopping is good financial practice and is measured on several indices of ideal financial behaviour (Dew & Xiao, 2011; OECD, 2018; Shockey, 2002). However, prices offered for similar products are not always directly comparable (e.g., listed offer versus regular price, dollar-off versus percentage-off discounts), leaving the consumer with the responsibility of calculating prices to determine which product provides superior savings (Chen & Volpe, 1998; Cheng & Monroe, 2013; Suri et al., 2013). Such situations involving numbers and computations may be especially challenging for consumers who experience fear, tension, or apprehension about math, a phenomenon known as math anxiety (Ashcraft, 2002; Feng et al., 2014; Suri et al., 2013). In the present study, we test the hypothesis that people higher in math anxiety will perform worse on a price comparison task than those lower in math anxiety (Objective 1). Critically, we felt it prudent to not only determine whether a relation between math anxiety and performance on this task exists, but to characterise the nature of the relation by testing possible mediators (Objective 2). Uncovering that people higher in math anxiety perform worse on a price comparison task would be interesting but understanding *why* they perform worse (if they do indeed perform worse) has important practical implications. Though individual shopping decisions only result in minor differences in savings at any one given time, the additive consequences of these decisions translate to a substantial loss of savings over a lifetime. As such, it is important to understand how math anxiety relates to peoples' daily consumption decisions.

Math Anxiety

Math anxiety is a global phenomenon (Foley et al., 2017) that impacts both children (OECD, 2013) and adults (Hart & Ganley, 2019). It has been estimated that, in the U.S., 25% of four-year college students and 80% of community college students experience math anxiety to a moderate or high degree (Yeager, as cited in Chang & Beilock, 2016). Math anxiety is believed to begin in childhood (Ramirez et al., 2013; Wu et al., 2012). Barring any targeted interventions, math anxiety tends to increase throughout adolescence and remain stable into adulthood (Hembree, 1990). Math anxiety has long attracted the attention of researchers and educators as an obstacle for academic performance (Lau et al., 2022; Lee, 2009; Maloney & Beilock, 2012; Ramirez et al., 2013). However, given its prevalence and persistence, it is important to consider how math anxiety may relate to performance in society more broadly.

Indeed, math anxiety has been linked to difficulty interpreting medical risks, such as deciding between treatments when given outcomes (Rolison et al., 2016), and impaired financial planning (McKenna & Nickols, 1988). In the context of financial decision-making, math anxiety is negatively associated with performance in situations requiring the processing of price information (Andersen, 2015; Diamond, 1992; Suri et al., 2013). Specifically, consumers who are higher in math anxiety prefer easier-to-process price promotions (i.e., dollar-off discount) compared to more complex formats (i.e., percentage-off discount) (Suri et al., 2013) and will avoid shopping decisions that require price computations (Feng et al., 2014), regardless of their math competency (Feng et al., 2014; Suri et al., 2013). This preference for simpler promotion formats remains even when such promotions provide inferior savings compared to a competing offer using a more complex format (Suri et al., 2013). In fact, individuals higher in math anxiety report higher price satisfaction and express greater willingness to buy a product when the discount is presented in a simpler format (Andersen, 2015).

Math Competency

Another factor related to people's abilities to make sound financial decisions is math competency (see Garcia-Retamero et al., 2019 for a review). Math competency is negatively related to math anxiety (Ashcraft & Kirk, 2001; Hembree, 1990; Hill et al., 2016), but this does not mean math anxiety is simply a proxy for poor math competence (Maloney & Beilock, 2012). Math anxiety is theorized to cause poor performance on math-related tasks both in the moment because of anxiety-induced transient reduction in cognitive resources (Ashcraft & Kirk, 2001; Hunt et al., 2014) and long term because of an increased avoidance of math-related activities, leading to fewer opportunities to hone ones' math skills (Choe et al., 2019; Hembree, 1990; Maloney, 2016). Thus, it is reasonable to expect the decision-making of math-anxious consumers to suffer on financial tasks that require mathematical reasoning, such as a price comparison task. Given the negative relation between math anxiety and math competency (Ashcraft & Kirk, 2001; Hembree, 1990), we hypothesize that math anxiety will be negatively related to performance on a price comparison task and that this relation will be mediated by math competency (Hypothesis 2).

Cognitive Effort

Research indicates that people who are higher in math anxiety tend to be lower in their need for cognition (Maloney & Retanal, 2020). Need for cognition (NFC) refers to a person's "tendency to engage in and enjoy thinking" (Cacioppo & Petty, 1982, p. 116). In terms of decision-making, individuals with higher NFC have a greater tendency to seek and apply more information to form decisions (Boyle et al., 1998). In contrast, individuals with lower NFC have a greater tendency to form their decisions based on cursory examination. This is particularly relevant to our current work as people with lower NFC tend to process price promotions less thoroughly than individuals with higher NFC (Inman et al., 1990). For example, Inman and colleagues (1990) found that consumers with lower NFC will react to the presence of a promotion signal (i.e., any sign or marker indicating a potential price promotion on the brand display), regardless of whether the price of the promoted brand is in fact reduced. Alternatively, people with higher NFC only react to a promotion signal when it is presented with an actual price reduction (Inman et al., 1990). Additionally, when presented with a discount, consumers with lower NFC are more likely to purchase items when the discount is presented as a dollar amount compared to when it is presented as a percentage (Kim & Kramer, 2006). Meanwhile, the presentation of the discount amount does not influence the behaviour of consumers with higher NFC. These findings, coupled with evidence that people higher in math anxiety tend to prefer price promotions that require less cognitive effort to decipher (Andersen, 2015; Suri et al., 2013), led us to generate the hypothesis that math anxiety will be negatively related to performance on a price comparison task and that this relation will be mediated by NFC (Hypothesis 3).

Cognitive Reflection

Evidence suggests there is a negative relation between math anxiety and cognitive reflection both in general and in situations requiring math (Maloney & Retanal, 2020; Morsanyi et al., 2014). One of the most widely used instruments in research on reasoning and decision making, the Cognitive Reflection Test (CRT) (Frederick, 2005) measures a person's tendency to reflect or deliberate to verify intuitive insights (Bago & de Neys, 2019). People higher in math anxiety tend to obtain lower scores on the CRT and the CRT-2 (a modified version of the original test designed to have less mathematical content) (Thomson & Oppenheimer, 2016) than people who are lower in math anxiety, even after controlling for their general math knowledge and math competency (Maloney & Retanal, 2020; Morsanyi et al., 2014). People higher in math anxiety are also less likely to reflect on problems and are more likely to impulsively select an incorrect response compared to those lower in math anxiety (Faust et al., 1996). Specifically, when asked to verify solutions to arithmetic problems, math-anxious people are more likely to make errors (Ashcraft & Faust, 1994) and to accept an incorrect solution even when it is highly implausible (Faust et al., 1996). Given the established link between math anxiety and cognitive reflection, both in general and in math-related contexts (Ashcraft & Faust, 1994; Faust et al., 1996; Maloney & Retanal, 2020; Morsanyi et al., 2014), we hypothesize that math anxiety will be negatively related to performance on a price comparison task and that this negative relation will be mediated by their propensity to engage in cognitive reflection (Hypothesis 4).

The Present Study

The first objective of the current research is to test the hypothesis that adults higher in math anxiety will perform worse on a price comparison task (i.e., a novel “Price Comparison Task”) than those lower in math anxiety (Hypothesis 1). Working under the assumption that a negative relation between math anxiety and task performance does indeed exist, our second objective is to test a series of theoretically driven hypotheses designed to elucidate the mechanism by which this relation occurs. Specifically, we test whether the relation between math anxiety and performance on the Price Comparison Task is mediated by math competency, price calculation ability (Hypothesis 2), NFC (Hypothesis 3), and cognitive reflection (Hypothesis 4).

Method

Participants

We recruited North American participants using two modes: a student research pool at a university in Canada (n = 24) and Prolific (n = 250). Prolific is an online recruitment forum recommended by researchers for the collection of high-quality data (Palan & Schitter, 2018; Peer et al., 2017). We compensated students with course credit and participants from Prolific with £3.50 (approximately $4.80 USD or $6 CAD).

We removed five participants who failed two or more (out of three) directed attention checks in the data (Curran, 2016) and one participant who completed the survey in under 9.8 minutes (i.e., more than two standard deviations below the average completion time; M = 28.63 minutes; SD = 9.42 minutes) (Teitcher et al., 2015). To calculate average completion time, we excluded participants with z-scores greater than three standard deviations from the mean (n = 17) to provide a more accurate representation of the average. We identified and removed three participants flagged as univariate outliers on the Price Comparison Task (i.e., z-scores more than 3 standard deviations from the mean). We used longstring analysis to identify participants who used the same response category, consecutively, throughout measures that required reverse scoring (i.e., the STAI-T and NFC scale) (Yan, 2008). We removed two participants with a string of consistent responses equal to or greater than three quarters of the length of the total scale (i.e., 15 or more items out of 20 on the STAI-T). Finally, we removed eight participants who identified as non-binary, as all analyses control for binary (i.e., male or female) gender identification. The final sample included 256 participants (114 males; 18 to 68 years old, M = 31.05 years, SD = 11.31). Most participants resided in Canada (n = 206), some resided in the United States (n = 44), and some did not disclose their country of residence (n = 6).

Materials

Price Comparison Behaviour

We designed a novel task to assess product comparison behaviour when consumers are presented with identical products that differ only by size (in terms of volume) and price. We simultaneously presented participants with two products with the price and size presented below the image (in dollars and metric units, respectively).[1] See Appendix A, Figure A1 for a sample trial.[2] Products included common household items that are available to consumers in many sizes, such as laundry detergent. We instructed participants to select the product that represented the better deal (i.e., costs less per metric unit). Within the context of this specific task, an optimal decision would be one wherein the participant chooses the item that represents the lower price per unit. Note here we use the word "optimal" to refer to decisions made within this specific task and are not implying that selecting the cheaper item per unit is always the more optimal choice outside the context of this task.

The task included 40 trials, split into two parts. In the first 32 trials, we asked participants to identify which product was the better deal (i.e., cost less per metric unit) between the two products presented. We presented trials one at a time. Scores range from zero to 32, with higher scores indicating better performance on the task. We will herein refer to this first portion of the task as the "Price Comparison Task."

Price Calculation Ability

We then showed participants four of the same product pairs with modified instructions. We chose only four of the original 32 product dyads in the second portion of the task to reduce survey fatigue while still capturing an accurate representation of their calculation abilities. We asked participants to calculate the exact price per metric unit for each product (i.e., eight products total) and report the price to the fourth decimal place. However, we coded all responses that demonstrated the participant understood how to accurately compute the product price (i.e., understood the procedure) as correct. For example, the correct response for Option 1 in Figure A1 is $3.5914 per litre (i.e., product size of 4.43 litres and price of $15.91), but we also accepted $3.6 as correct. Scores range from zero to eight, with higher scores indicating higher price calculation ability. We will refer to this second portion of the task as the "Price Calculation Task."

The purpose of this exercise was to determine if participants could correctly calculate the product's price per unit when prompted. Previous work has linked higher math anxiety with general math competency (Maloney & Beilock, 2012) and, more specifically, arithmetic ability (Ashcraft & Faust, 1994; Faust et al., 1996). As such, we felt it prudent to take into consideration participants' ability to make a relative value assessment based on the price per unit of volume.

Math Anxiety

We measured math anxiety with the nine-item Abbreviated Math Anxiety Scale (AMAS) (Hopko et al., 2003). Participants rated how anxious they would feel in a variety of situations (e.g., "Listening to a lecture in math class") on a five-point Likert scale ranging from *Low anxiety (1)* to *High anxiety (5)*. Scores range from nine to 45, with higher scores indicating higher levels of math anxiety. This measure has previously demonstrated good to excellent internal consistency (α = .83 to .90) and good test-retest reliability (r = .83) (Hopko et al., 2003). Cronbach's alpha for the current sample was .91.

1) We recognize that many Americans are not accustomed to working with the metric system. However, average performance on the Price Comparison Task for participants residing in Canada (M = 79.28) compared to America (M = 78.65) did not differ, suggesting the use of metric units did not impede performance for participants in America.

2) All materials for the Price Comparison and Calculation Tasks are available in the Supplementary Materials.

General Anxiety

We measured trait anxiety using the 20-item State-Trait Anxiety Inventory, Trait subscale (STAI-T) (Spielberger et al., 1982). Participants answered questions on a four-point Likert scale ranging from *Not at all* (1) to *Very much so* (4). The questionnaire included positive (e.g., "I am a steady person") and negative (e.g., "I worry too much over something that really doesn't matter") items, with positive items being reversed scored and combined with the negative items. Scores range from 20 to 80, with higher scores indicating higher levels of trait anxiety. This measure has previously demonstrated good internal consistency (α = .78) and good test-retest reliability (r = 0.85) (Vitasari et al., 2011). Cronbach's alpha for the current sample was .94.

Math Competency

We measured math competency using the Brief Mathematics Assessment 3 (BMA-3) (Steiner & Ashcraft, 2012), which assesses arithmetic (whole numbers and fractions) and algebra computation procedures. For example, one question asks participants to write .025 as a fraction in the lowest terms. Though there are 10 items, one item is a two-part question, making the range of potential scores zero to 11, with higher scores indicating higher math competency. This measure has previously demonstrated good internal consistency (α = .69) and correlates (r = .66) with the commonly used Wide Range Achievement Test 4 (WRAT4) (Steiner & Ashcraft, 2012). Cronbach's alpha for the current sample was .73.

Due to a programming error, responses to Item Two of the BMA-3 did not record for participants recruited through the university student pool (n = 24). As such, BMA-3 averages for the student sample are scored out of 10.[3] Note that one participant from the student sample did not complete the BMA-3 and have thus been excluded from analyses including math competency.

Need for Cognition

We measured participants' motivation to engage in effortful cognitive activities using the 18-item Need for Cognition scale (NFC) (Cacioppo & Petty, 1982). Participants rated their agreement with items (e.g., "I prefer complex to simple problems") on a five-point Likert scale ranging from *Not at all characteristic of me (1)* to *Extremely characteristic of me (5)*, with some items requiring reverse scoring (e.g., "Thinking is not my idea of fun"). Scores range from 18 to 90, with higher scores indicating higher levels of motivation to engage in complex thought. This measure has previously demonstrated excellent internal consistency (α = .91) and good test-retest reliability (r = .88) (Sadowski & Gulgoz, 1992). Cronbach's alpha for the current sample was .91.

Cognitive Reflection

We measured participants' tendency to reflect or deliberate to verify intuitive insights using the four-item Cognitive Reflection Test 2 (Thomson & Oppenheimer, 2016). The CRT-2 was created to increase the pool of available questions, as the original three-item CRT (Frederick, 2005) is a commonly used measure and is often discussed in Introductory Psychology classes. The CRT-2 further addresses numeracy confounds that exist within the CRT, as it is less strongly related to numeracy than the original CRT (Thomson & Oppenheimer, 2016). Participants answered four questions (e.g., "If you're running a race and you pass the person in second place, what place are you in?") and received one point for each correct answer. Scores range from zero to four, with higher scores indicating that an individual is more likely to engage in further reflection or deliberation to arrive at a correct response. Cronbach's alpha for the current sample was .58, which is considered an acceptable alpha for a scale with fewer than 10 items (Pallant, 2016).

Demographic Information

We asked participants demographic questions including age, gender, occupation, and education. We did not ask participants to disclose their ethnic background.

3) A series of t-tests revealed no significant differences between BMA-3 averages for participants recruited through the student pool (i.e., omitted Item 2 with a total score out of 10) and participants recruited through Prolific (i.e., included Item 2 with a total score out of 11). See Appendix B for these analyses.

Procedure

We programed our study using the Experiment Builder function on Gorilla.sc. We allowed participants to compete the study using a computer or tablet, but not a mobile device, as the small screen distorted our product images and textbox placements. We allowed participants to use a calculator during the study.

After providing informed consent, participants completed demographic questions followed by the measures of anxiety and cognition. We randomized presentation of the AMAS, STAI-T, NFC, and CRT-2. Participants then completed the Price Comparison Task (i.e., select the product that represents the "better deal") followed by the Price Calculation Task (i.e., calculate the price per unit for each product). We did not impose a time restriction for these measures. Lastly, participants had 10 minutes to complete the BMA-3 before the survey timed out and directed participants to the debriefing form. We obtained ethical approval for this study from the Office of Research Ethics and Integrity at the University of Ottawa (file number H-11-19-4999).

Results

Preliminary Analyses

We performed analyses using SPSS version 28. All analyses control for recruitment method (i.e., student pool or Prolific), gender, and general anxiety. We included gender as a covariate within our analyses as it is well-documented that women tend to report higher levels of math anxiety compared to men (Ashcraft, 2002; Delage et al., 2022; Hembree, 1990; Maloney et al., 2012). Further, although math anxiety is a distinct construct from general anxiety (Dowker et al., 2016; Hembree, 1990), these two constructs are moderately correlated (r = 0.44) (Hart & Ganley, 2019). As such, we also included general anxiety as a covariate to ensure that any relation observed between math anxiety and task performance is not the result of general anxiety (O'Leary et al., 2017). See Table 1 for descriptive information for each variable and the zero-order correlations between all variables.

Table 1

Correlations and Descriptive Statistics for All Measures

Variable	1	2	3	4	5	6	7	8
1. Gender[a]	–	.16*	.07	-.08	-.02	-.06	-.02	.09
2. Math Anxiety[b]		–	.32***	-.31***	-.21**	-.23***	-.12*	-.20**
3. General Anxiety[b]			–	-.22***	.01	.02	.15*	.09
4. Need for Cognition[b]				–	.05	.10	.08	.11
5. Cognitive Reflection[b]					–	.37***	.38***	.18**
6. Math Competency[b]						–	.35***	.29***
7. Price Comparison Task[b]							–	.33***
8. Price Calculation Task[b]								–
N per measure	–	256	256	256	256	233	256	256
M	–	21.77	47.32	59.65	2.38	7.78	25.80	5.71
SD	–	8.06	11.10	12.54	1.16	2.16	4.71	3.12
Minimum Score	–	9	20	21	0	2	13	0
Maximum Score	–	44	76	85	4	11	32	8
Possible Range	–	9 – 45	20 – 80	18 – 90	0 – 4	0 – 11	0 – 32	0 – 8

Note. Descriptive statistics reported for math competency derive from the Prolific sample (n = 233). Descriptives of math competency for the student sample (n = 22) are as follows: Min = 2, Max = 10, M = 6.64, SD = 2.24, possible range = 0 – 10. Correlations with math competency include the entire sample (N = 255).

[a]Dichotomous variable; Gender 1 = male, 2 = female. [b]Mean scores.

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

We inferred missing data was missing at random as Little's MCAR test was statistically significant, $\chi^2(1683) = 1851.41$, $p = .002$, but missingness was not predictable from our dependent variable as indicated by the Separate Variance t-tests (Tabachnick & Fidell, 2007). There were no variables with 2% or more missing data. To address missing data, we conducted multiple imputation with a maximum of 50 iterations.

Main Analyses

Relation Between Math Anxiety and Performance on the Price Comparison Task

In line with our first objective (i.e., to test the hypothesis that people higher in math anxiety will make more errors on the Price Comparison Task compared to people lower in math anxiety), we conducted a multiple regression analysis. Our dependent variable is performance on the Price Comparison Task. Consistent with our prediction, those who were higher in math anxiety were less likely to select the product that represented the better deal ($\beta = -.20$, $p = .004$) after controlling for recruitment method, gender, and general anxiety (see Table 2).

Table 2

Multiple Regression Results for Performance on the Price Comparison Task

	Average Score on Price Comparison Task					
					95% CI for B	
Variable	**B**	SE_B	**β**	p	*LL*	*UL*
Constant	0.78	0.09		< .001	0.60	0.95
Recruitment Method	-0.01	0.03	-0.02	0.739	-0.08	0.05
Gender	-0.00	0.02	-0.01	0.851	-0.04	0.03
General Anxiety	0.23	0.07	0.21	0.001	0.09	0.36
Math Anxiety	-0.16	0.06	-0.20	0.004	-0.27	-0.05
R^2	0.06					
$\triangle R^2$	0.04					
F	3.73			0.006		

Note. $N = 255$. Model = "Enter" Method in SPSS Statistics; B = unstandardized regression coefficient; SE_B = standard error of the coefficient; β = standardized coefficients; CI = confidence interval for standardized coefficients; *LL* = lower limit; *UL* = upper limit; R^2 = coefficient of determination; $\triangle R^2$ = adjusted R^2; gender 1 = male, 2 = female.

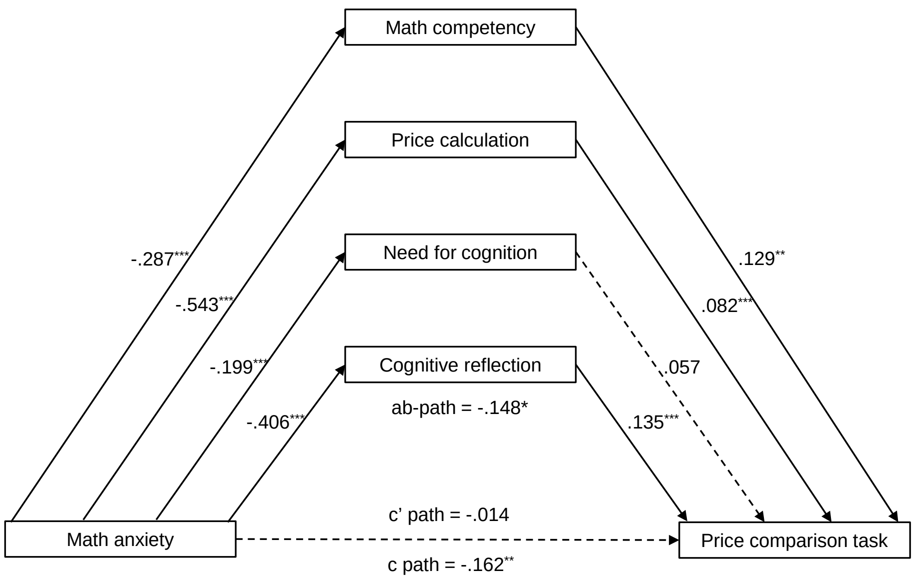
Cognitive Factors as Mediators of the Relation Between Math Anxiety and Task Performance

In line with our second objective (i.e., to understand the mechanism by which the relation between math anxiety and performance on the Price Comparison Task occurs), we conducted a competing mediator analysis. With this analysis we assessed whether various cognitive factors (i.e., math competency, price calculation ability, NFC, or cognitive reflection) uniquely explain the relation between math anxiety and performance on the Price Comparison Task. We used the PROCESS macro version 4.1, model number four in SPSS (Hayes, 2018) and tested significance using a bootstrapping method with 5,000 iterations.

After controlling for recruitment method, gender, and general anxiety, the total indirect effect was significant as the 95% confidence interval did not include zero (effect = -.15., 95% CI [-.22, -.08]). The total indirect effect accounted for 91% of the total effect (%C = .91). The indirect effect of NFC was not significant (effect = -.01, 95% CI [-.04, .01]), suggesting that NFC does not mediate the relation between math anxiety and performance on the Price Comparison Task. Math competency (indirect effect = -.04, 95% CI [-.08, -.01]), price calculation ability (indirect effect = -.04, 95% CI [-.08, -.02]), and cognitive reflection (indirect effect = -.06, 95% CI [-.10, -.02]) served as significant independent mediators. The indirect effect of math competency accounted for 23% of the total effect (%C = .23), the indirect effect of price calculation ability accounted for 27% (%C = .27), and the indirect effect of cognitive reflection accounted for 34% (%C = .34). The direct effect between math anxiety and performance on the Price Comparison Task was no longer significant after including the mediators (effect = -.01, 95% CI [-.12, .09]). See Table 3 for a summary of the analysis and Figure 1 for a visual representation.

Figure 1

Visual Representation of Math Competency, Price Calculation Ability, Need for Cognition, and Cognitive Reflection as Mediators of the Relation Between Math Anxiety and Performance on the Price Comparison Task



*Indicates a significant 95% confidence interval. ** $p < .01$. *** $p < .001$.

Table 3

Competing Mediation Analysis of the Cognitive Factors as Mediators of the Relation Between Math Anxiety and Performance on the Price Comparison Task

						95% CI for B	
Model	**B**	***SE*/*SE*†**	**β**	***p***	**%C**	***LL***	***UL***
Model without mediators							
AMAS ⟶ Price Comp (c)	-.16	.06	-.20	.004		-.27	-.05
R^2 AMAS ⟶ Price Comp	.06			.006			
Model with BMA-3, Price Calc, NFC, CRT-2 as mediators							
AMAS ⟶ BMA-3 (a)	-.29	.07	-.26	< .001		-.43	-.14
AMAS ⟶ Price Calc (a)	-.54	.14	-.25	< .001		-.83	-.26
AMAS ⟶ NFC (a)	-.20	.05	-.26	< .001		-.30	-.10
AMAS ⟶ CRT-2 (a)	-.41	.11	-.25	< .001		-.62	-.19
BMA-3 ⟶ Price Comp (b)	.13	.05	.18	.005		.04	.22
Price Calc ⟶ Price Comp (b)	.08	.02	.22	< .001		.04	.13
NFC ⟶ Price Comp (b)	.06	.06	.05	.355		-.06	.18
CRT2 ⟶ Price Comp (b)	.14	.03	.27	< .001		.08	.12
AMAS ⟶ Price Comp (c’)	-.01	.05	-.02	.792		-.12	.09

Model	B	SE/SE†	β	p	%C	95% CI for B	
						LL	UL
Indirect effects (a*b)							
AMAS ⟶ BMA-3 ⟶ Price Comp	-.04	.02†	-.05		.23	-.08	-.01
AMAS ⟶ Price Calc ⟶ Price Comp	-.04	.02†	-.05		.27	-.08	-.02
AMAS ⟶ NFC ⟶ Price Comp	-.01	.01†	-.01		.07	-.04	.01
AMAS ⟶ CRT-2 ⟶ Price Comp	-.06	.02†	-.07		.34	-.10	-.02
AMAS ⟶ Total ⟶ Price Comp	-.15	.04†	-.18		.91	-.22	-.08
R^2 AMAS ⟶ BMA-3, Price Calc, NFC, CRT2 ⟶ Price Comp	.26			< .001			

Note. N = 255. Model controlling for recruitment method, gender, and general anxiety. AMAS = Abbreviated Math Anxiety Scale; Price Comp = Performance on the Price Comparison Task; BMA-3 = Brief Math Assessment 3; Price Calc = Performance on the Price Calculation Task; NFC = Need for Cognition Scale; CRT-2 = Cognitive Reflection Test 2; *SE* = standard error; *SE*† = bootstrap standard error; %C = the percent of the total effect (c) that is accounted for by the indirect effect (a*b). The data in this table are depicted in Figure 1.

Discussion

Math anxiety is a widespread phenomenon and, recently, researchers have begun to explore relations between math anxiety and performance on math-related tasks that goes beyond what happens in a math classroom or on a standardized test. The results from the current study add to the growing body of literature indicating that math anxiety is relevant in a host of everyday situations involving math. In support of our first hypothesis, we demonstrated a novel finding that consumers who experience higher levels of math anxiety made worse decisions on our Price Comparison Task compared to people lower in math anxiety. That is, when asked to determine which product represented the better deal (i.e., cost less per metric unit) between two products, consumers higher in math anxiety were less likely to correctly select the product that provided superior savings. Importantly, we went beyond simply demonstrating that math anxiety relates to performance on this task. We also tested a series of theoretically driven hypotheses geared at understanding the mechanism underlying this negative relation. We found that math competency, price calculation ability, and cognitive reflection–but not NFC–each significantly mediated the relation between math anxiety and performance on the Price Comparison Task. After considering all mediators, there was no longer a significant direct effect between math anxiety and task performance.

While novel, the current findings are nonetheless in line with previous research on math anxiety and its relation to math competency, NFC, cognitive reflection, and consumer behaviour. We replicated the well-established finding that math anxiety is negatively related to math competency (Ashcraft, 2002; Hembree, 1990). Our results are also consistent with the broader finding that lower math competency is associated with the tendency to make less optimal decisions in general (Peters, 2012; Peters et al., 2006). More specifically, our findings support the notion that consumers higher in math anxiety are more likely to make errors (Ashcraft & Faust, 1994) that result in reduced savings (Suri et al., 2013). When attempting to explain the poor performance of individuals higher in math anxiety, researchers often present the idea that math anxiety ties up valuable working memory resources that are required to successfully carry-out a mathematical task (Beilock & Carr, 2005). Indeed, complex computations increase cognitive load (Hecht, 2002), which may in turn increase the negative impact of math anxiety on performance. However, the Price Comparison Task is not particularly complex, requiring only one calculation to arrive at the correct response (i.e., dividing the price by the units). Given the simplicity of the task, and the ability to off-load cognitively demanding information by using a calculator, the findings from the present study present an alternative hypothesis. This points to the possibility that consumers higher in math anxiety are less likely to use the resources available to them (i.e., a calculator) or that they lack the procedural or conceptual knowledge required to carry out the calculation properly.

Consistent with this theory, and in support of our second hypothesis, both price calculation ability (as measured by the Price Calculation Task) and math competency (as measured by the Brief Math Assessment 3) were significant independent mediators of the relation between math anxiety and performance on the Price Comparison Task. Indeed, math competency and price calculation ability were not as highly correlated as we expected (r = .29), further suggesting that these factors each capture unique variance in performance on the Price Comparison Task. Evidently, it would not be enough to simply train people with math anxiety on how to perform the computations necessary to determine the product's price per unit. These data suggest that mathematical reasoning more broadly plays a role in performance on a task that requires only arithmetic knowledge.

Further, when looking at the distribution of scores on the Price Calculation Task, 49 participants (19.1% of the sample) obtained an accuracy score of 15% or lower whereas 179 participants (69.9% of the sample) obtained an accuracy score of 75% or higher. We interpret this to mean that the people in the low-scoring group either do not know which procedure to apply or have extremely poor calculation abilities. People in the high-scoring group, on the other hand, know the procedure but occasionally made calculation errors. It is likely that calculation ability is detecting variability between people who know the correct procedure versus those who do not, whereas math competency is detecting variability between participants who know which procedure to apply but differ with respect to their other mathematical abilities (e.g., conceptual understanding). An important next step would be to understand the procedure participants apply when deciding which product to select.

While we did not find support for our third hypothesis (i.e., that NFC would mediate the relation between math anxiety and performance on the Price Comparison Task), we did replicate the finding that math anxiety is negatively related to NFC as reported by Maloney and Retanal (Maloney & Retanal, 2020). Thus, while those who are higher in math anxiety do report having a lower NFC than people lower in math anxiety, this lower NFC does not explain why consumers with higher levels of math anxiety perform worse on the Price Comparison Task. It is possible that this lack of relation is a result of the simplicity of the present task. Recall that NFC refers to an individual's tendency to seek and apply more information to form decisions (Boyle et al., 1998). This tendency may only become relevant for tasks that require the consideration of multiple factors. Indeed, the only factors to consider in our Price Comparison Task is price and volume. People who are higher in their NFC may prefer to deliberate on a multitude of factors when comparing products. Thus, NFC may be more related to a multifaceted price comparison task.

We further replicated the finding that people higher in math anxiety are less reflective in their thinking (Maloney & Retanal, 2020; Morsanyi et al., 2014). In support of our fourth hypothesis, our results also indicated that cognitive reflection (as measured by the CRT-2) mediated the relation between math anxiety and performance on the Price Comparison Task. Notably, this mediation persisted even after considering the effects of math competency and price calculation ability. That is, when we asked consumers higher in math anxiety to pick the more price-optimal product, they were less likely to re-evaluate their initial assessment of the price comparison (recall that the CRT-2 measures a person's propensity to reflect or deliberate to verify intuitive insights) (Bago & de Neys, 2019). This finding is consistent with previous research demonstrating that people higher in math anxiety are more likely to impulsively select an incorrect response to an arithmetic problem compared to those lower in math anxiety (Faust et al., 1996). Accordingly, the performance of math-anxious consumers may be improved by an intervention designed to challenge them to reflect on their intuitive responses to math-based problems. For example, providing a prompt that encourages them to reconsider their response before committing to an answer may yield improvements in product selection.

Implications

The current research has important implications for our understanding of the financial vulnerability of consumers with math anxiety. We demonstrate a novel finding that, when prompted, consumers higher in math anxiety are less likely to correctly select a product that costs less per unit compared to those lower in math anxiety. While the current results are based on a Price Comparison Task completed in the lab, this task was designed to parallel decisions about price comparisons that consumers encounter on a regular basis. Thus, assuming that consumers higher in math anxiety are also making errors when engaging in price comparisons in the aisles of their local grocery stores, then this research suggests that math anxiety may be associated with financial consequences above and beyond those already demonstrated in the literature (e.g., Feng et al., 2017; Lipsman, 2004; Skagerlund et al., 2018). Further, the fact that we observe this sub-optimal performance in a simple price comparison task contrived in the lab is cause for concern. In our Price Comparison Task, we only ever presented participants with two options at a time and these options varied on only two dimensions (i.e., price and volume). Given that increasing task complexity leads math-anxious people to commit more errors (Ashcraft & Moore, 2009), it is reasonable to expect this performance deficit to transfer to a more complex product comparison situation. For example, tasks such as comparing mortgages or insurance policies may be especially challenging for people higher in math anxiety, as many options are available at a given time and each option varies on multiple dimensions.

Limitations

The present study had limitations. First, we are unable to draw causal links from our mediation analysis given the correlational design of our research. For example, the current data does not allow us to determine whether participants' lower math competency and their inability to accurately compute the price was caused by a math anxiety induced transient reduction in working memory resources (Ashcraft & Kirk, 2001), or whether their decreased competency is the result of years of math anxiety induced avoidance of math and opportunities to hone their math skills (Maloney, 2016). Nonetheless, the results of the present study indicate that those who are higher in math anxiety are at an increased risk of poor performance when engaging in tasks involving price comparisons. Any interventions aimed at remedying this problem may be best served by bolstering math competencies in addition to reducing anxieties. Second, in the design of the Price Comparison Task, we did not consider how price framing heuristics may impact participant's perception of which product represented the better deal. Such heuristics may include the left-digit anchoring heuristic, whereby consumers sometimes perceive nine-ending prices to be lower than a price one cent higher (e.g., $3.99 to $4.00) (Thomas & Morwitz, 2005) as well as the ease-of-computation heuristic, which posits that "consumers' judgments of the magnitude of numerical differences are influenced by the ease of mental computations" (Thomas & Morwitz, 2009, p. 81). In the context of our Price Comparison Task, it is possible participants relied on these heuristics (as opposed to performing the calculation) to arrive at a decision. This may have, in turn, influenced their perception of which product represented the better deal.

Conclusion

In the present study we established a negative relation between math anxiety and performance on a novel Price Comparison Task and investigated possible mediators of this relation. The negative relation between math anxiety and task performance can be partially explained by the evidence suggesting that people higher in math anxiety are less capable of performing the necessary computations to discern the most cost-effective deal, are lower in math competency in general, and are less likely to engage in reflective thinking (i.e., verify that their calculation is correct). Considering the prevalence of math anxiety, future research should continue to investigate how math anxiety impacts consumers' daily decisions. Potential means of mitigating these negative impacts include bolstering calculation and math competencies as well as a willingness to override intuitive responses.

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Data Availability: For this article, a data set is freely available (Storozuk, Retanal, & Maloney, 2023a).

Supplementary Materials

The Supplementary Materials contain the following items (for access see Index of Supplementary Materials below):

- all materials for the Price Comparison and Calculation Tasks
- the research data for this study

Index of Supplementary Materials

Storozuk, A., Retanal, F., & Maloney, E. A. (2023a). *Supplementary materials to "Consumers with math anxiety, a financially vulnerable group? Unpacking the negative relation between math anxiety and performance on a price comparison task"* [Research data]. PsychOpen GOLD. https://doi.org/10.23668/psycharchives.12572

Storozuk, A., Retanal, F., & Maloney, E. A. (2023b). *Supplementary materials to "Consumers with math anxiety, a financially vulnerable group? Unpacking the negative relation between math anxiety and performance on a price comparison task"* [Task materials]. PsychOpen GOLD. https://doi.org/10.23668/psycharchives.12573

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Appendices

Appendix A

Figure A1

Sample Trial From the Price Comparison Task

Note. We instructed participants to select the product that represented the better deal.

Appendix B

Due to a programming error, responses to Item Two of the BMA-3 did not record for participants recruited through the university student pool (n = 24). We considered omitting Item 2 from the total scores of participants recruited through Prolific, but a paired samples t-test revealed a significant difference between averages on the Brief Math Assessment-3 (BMA-3) with Item 2 included in the total score (M = .70; SD = .20) compared to BMA-3 averages with Item 2 removed from the total score (M = .68; SD = .21), t(250) = -9.60, p = <.001. We then conducted an independent samples t-test to determine if there were significant differences between BMA-3 averages for participants recruited through the student pool (i.e., omitted Item 2 with a total score out of 10) and participants recruited through Prolific (i.e., included Item 2 with a total score out of 11). There were no significant differences in BMA-3 averages between the student sample (M = .66; SD = .22) and the Prolific sample (M = .71; SD = .20), t(249) = -.95, p = .343. As such, we elected to retain the student pool participants in the sample with BMA-3 averages scored out of 10.

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