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MATH ANXIETY, INTRUSIVE THOUGHTS AND PERFORMANCE

Exploring the relationship between mathematics anxiety and performance: The role of intrusive thoughts

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Abstract -**The current study examined the relationship between math anxiety and arithmetic performance by focusing on intrusive thoughts experienced during problem solving. Participants (N = 122) performed two-digit addition problems on a verification task. Math anxiety significantly predicted response time and error rate. Further, the extent to which intrusive thoughts impeded calculation mediated the relationship between math anxiety and per cent of errors on problems involving a carry operation. Moreover, results indicated that participants experienced a range of intrusive thoughts and these were related to significantly higher levels of math anxiety. The findings lend support to a deficient inhibition account of the math anxiety-to-performance relationship and highlight the importance of considering intrusive thoughts in future work.**

Key Words: arithmetic performance; cognitive intrusions; intrusive thoughts; math anxiety

I. INTRODUCTION

Mathematics anxiety can be described as “a feeling of tension and anxiety that interferes with the manipulation of numbers and the solving of mathematical problems in a wide variety of ordinary life and academic situations” (Richardson & Suinn, 1972, p.551). It is thought to affect a large number of people (Ashcraft & Moore, 2009), is experienced in children (Wu, Barth, Amin, Malcarne & Menon, 2012) and adults (Ashcraft, 2002), and extends to a range of contexts, such as nursing (McMullan, Jones & Lea, 2012) and consumer behaviour (Jones, Childers & Jiang, 2012).

There is now substantial empirical evidence to suggest that math anxiety is negatively correlated with overall math performance (Ashcraft & Moore, 2009; Hembree, 1990; Ma, 1999). Specifically, research has demonstrated that math anxiety is more consistently and negatively related to performance on complex, compared to simple arithmetic (e.g., Ashcraft & Faust, 1994), and particularly when a problem involves a carry operation (Faust, Ashcraft & Fleck, 1996). However, the mechanisms underlying these relationships are poorly understood. One possible mechanism linking math anxiety to performance is intrusive or worrisome thoughts. Tendency to experience intrusive thoughts has been found to correlate with performance on a range of cognitive tasks (Munoz, Sliwinski, Smyth, Almeida & King, 2013) and, according to processing efficiency theory (Eysenck & Calvo, 1992), on which the more recent attentional control theory (Eysenck, Derakshan, Santos & Calvo, 2007) is based, worrisome thoughts interfere with the limited resources available within the working memory system. Ashcraft and Krause (2007) propose that preoccupation with one’s fears and anxieties pertaining to math may act as a ‘secondary task’, resulting in the depletion of resources necessary for arithmetic task completion. Related to this, Hopko, Ashcraft, Gute, Ruggiero & Lewis (1998) argued that high math anxious individuals may have difficulty in inhibiting attention towards intrusive or worrisome thoughts. Inhibition theory (Hasher & Zacks, 1988; Connelly, Hasher & Zacks, 1991) proposes that there is a mechanism for suppressing, or inhibiting, task-irrelevant distracters. If this mechanism is not working adequately then task-irrelevant information may interfere with working memory processes and consequently result in poor performance. Indeed, Hopko et al (1998) demonstrated that high and medium math anxious groups took significantly longer than a low math anxious group to read through text that included irrelevant information, suggesting poor inhibitory control. Similarly, Hopko, McNeil, Gleason and Rabalais (2002) found that response times of high math anxious individuals were longer on a card counting task with numeric stimuli, compared to a card-counting task involving letters, again implicating inhibitory mechanisms related to working memory.

Whilst previous math anxiety research has made reference to worrisome or irrelevant thoughts, surprisingly little research has attempted to examine the influence of worrisome thoughts on arithmetic performance. In an early study, Hunsley (1987) measured math anxiety, test anxiety, performance appraisals, performance attributions and internal dialogue amongst 96 university students before and after midterm statistics examinations. Participants’ negative internal dialogue was measured using the Cognitive Interference Questionnaire (CIQ, Sarason, 1978), which required participants to rate (on a five-point scale) the frequency with which they experienced negative thoughts during the exam. Math and test anxiety accounted for 15% and 10% of the variance in CIQ scores, respectively. Further, Beilock, Kulp, Holt and Carr (2004) found that students performing arithmetic in a high pressure condition (involving carry operations) had significantly increased perceptions of performance pressure and reported thoughts and worries about the high pressure situation and its consequences, compared to students in a low pressure condition. More recently, DeCaro, Rotar, Kendra and Beilock (2010) reported significant negative correlations between task-related thoughts and arithmetic problem solving accuracy. Such findings give support to the idea that poor performance may, in part, be due to insufficient inhibition of intrusive or worrisome thoughts. However, math anxiety was not measured, so its relationship with intrusive thoughts and performance remains unclear.

II. Current Study

The current study aimed to test the deficient inhibition explanation of the math anxiety-to-performance relationship, by examining the negative internal dialogue that participants may experience during math performance. Also, we examined whether the perceived severity of intrusive thoughts experienced during a math task, was related to math anxiety. *It was hypothesised that there would be a negative relationship between math anxiety and performance (increased errors and longer response times) on complex addition problems involving a carry operation, but no relationship when a carry operation is not required. Further, it was hypothesised that there would be a negative relationship between self-reported impact of intrusive thoughts (and effort to reduce such thoughts) and performance. In addition, we explored the types of thought that participants indicated they had during the math task, and their relations with math anxiety.*

III. Method

Participants

Participants were 122 (31 men, 91 women) undergraduate psychology students from two Midlands universities in the U.K. The sample included participants from all three years of undergraduate study. Ages ranged from 18 to 51 years (mean = 24.95; SD = 8.76). The mean age is slightly higher than would be expected from a student sample at traditional universities, but is consistent with the slightly higher ages of students in post-1992 universities in the U.K, which make up approximately half of the number of universities in the U.K (Universities Colleges and Admissions Service, 2009). Participants came from an opportunity sample of the general university population gained via advertising at the universities.

Questionnaire measures

The Mathematics Anxiety Scale-U.K. (MAS-U.K., Hunt, Clark-Carter & Sheffield, 2011) was used to measure math anxiety. This is a 23-item scale that uses a five-point Likert-type scale and asks participants to respond how anxious they would feel in a variety of situations involving math. The scale has excellent internal consistency (Cronbach's alpha = .96) and very high test-retest reliability between four and ten weeks (r = .89).

In order to measure intrusive thoughts that may occur during arithmetic items from the Cognitive Intrusions Questionnaire (Freeston et al., 1991, English translation by Freeston, 1994) were selected and modified. The first part of the original questionnaire involves a list of thoughts that participants are required to endorse if they experienced them during a preceding task. This was modified so that the list only contained thoughts related specifically to the math task undertaken: "making mistakes", "time pressure", "method of problem solving", "what people would think", "panicking", "previous math experiences", and "physical changes". Next there was a series of five-point Likert-type scale items, relating to different aspects of the "most worrisome or troubling" thoughts. Wording of the original items was modified so that each one related to the math task and pertained to the following: frequency of the thoughts, difficulty in removing the thoughts, extent to which the thoughts impeded calculation, and the amount of effort used to stop/reduce the thoughts. A final question asked participants to indicate whether they had experienced intrusive thoughts that were non-math-task related, for example relationship problems or health problems.

The study also included a measure of trait anxiety, taken from the State-Trait Anxiety Inventory (Spielberger, Gorsuch, Lushene, Vagg & Jacobs, 1984) but, the zero-order correlations showed no relationship between trait anxiety and error rates and response time, so analyses including trait anxiety are not presented here (these are available from the first author).

Experimental stimuli and procedure

Using the experiment-building software E-prime, 80 two-digit addition problems were presented using a verification task, for example '37 + 18 = 52'. Sixty of these problems had a solution that was true; 20 had an incorrect solution. Of the 60 true problems, 30 involved a carry operation, for example "17 + 18 = 35", and 30 involved no carry, for example "17 + 12 = 29". Addends were randomly taken from a range of 10-89. Problem-size was counterbalanced across addends and carry/no-carry conditions so that performance could be attributed to factors other than the size of the problems. Problems where both addends ending in zeros, for example '20 + 30', or fives, for example '25 + 35', were not included. Incorrect problems were divided approximately equally with splits of +/- 1, +/- 3, and +/- 5, counterbalancing the number of positive and negative splits.

Participants gave informed consent and completed the mathematics anxiety scale. Stimuli were presented in the centre of a VDU, in Times New Roman, size 40, bold font. Following the on-screen instructions and five practice trials, participants were asked to respond 'true' or 'false' to the proposed answers. This was achieved by pressing the 'z' and 'm' keys on a keyboard, for 'true' and 'false', respectively. There was no time limit for participants to respond. After responding, a pause screen, consisting of '+++++' appeared, and this remained until participants pressed one of the keys to proceed to the next trial.

TABLE I. ZERO-ORDER CORRELATIONS BETWEEN MATH ANXIETY, INTRUSIVE THOUGHTS MEASURES AND MATH PERFORMANCE.

*$p \leq .05$ **$p \leq .01$ **$p \leq .001$

Variable	Carry errors %	No-carry errors %	Carry RT	No-carry RT	Math anxiety total	Freq. Most troublesome/ worrisome thought	Difficulty removing thought	Impeding calculation	Effort to reduce thought
Carry errors %	1								
No-carry errors %	.28**	1							
Carry RT	.06	.02	1						
No-carry RT	.25**	.17	.83***	1					
Math anxiety total	.25**	-.00	.30***	.30***	1				
Freq. of most troublesome / worrisome thought	.19*	.03	.23*	.26**	.59***	1			
Difficulty removing	.20*	.10	.11	.16	.56***	.62***	1		
Impeding calculation	.35***	.04	.25**	.28**	.52***	.57***	.55***	1	
Effort to reduce thought	.21*	.05	.22*	.24**	.61***	.69***	.74***	.65***	1

Immediately after completion of the arithmetic task, participants completed the cognitive intrusions questionnaire. Finally, they were debriefed and thanked.

GENERAL DATA SCREENING AND DIAGNOSTIC CHECKS

Initially participants were asked to select from a list which non-task related intrusive thoughts they had experienced. However, the results demonstrated a bi-modal distribution. Therefore the decision was made to dichotomise the variable into the levels "yes" (at least one non-task related thought) and "no" (no non-task related thoughts), to represent experience of non-task related thoughts.

Visual inspection of histograms of the data showed the data to be sufficiently univariately normally distributed. For each regression, normality of standardised residuals was tested by visual inspection of histograms; these were found to be normal. Standardised residuals and standardised predicted values were also plotted against each and no obvious curvilinear relationships were apparent, with the display also indicating the presence of homoscedasticity. Checks for bivariate outliers were also made using scattergraphs and no outliers were identified. In order to test for multivariate outliers Cook's distance and leverage values were plotted against each other; no cases appeared to obviously deviate from the main cluster of cases. In addition, checks of tolerance values and variance proportions indicated that there were no problems with multicollinearity among the data.

Reliability analyses for the MAS-U.K demonstrated a Cronbach's alpha of .94, indicating excellent internal consistency.

IV. RESULTS

PROBLEM TYPE ANALYSIS

A within-subjects t-test was used to compare the difference in per cent of errors between problems with a carry term (mean = 5.13%; SD = 5.72) and problems without (mean = 2.39%; SD = 3.32). Significantly more errors were made in response to problems that included a carry term, $t(121) = 5.24$, $p < .001$, two-tailed test, 95% CIs [1.70, 3.77], $d = 0.58$, indicating a medium effect (Cohen, 1988). A within-subjects t-test revealed that participants took significantly longer to respond to problems including a carry term (mean = 5730.97ms; SD = 1696.32) than to problems not including a carry term (mean = 3835.15ms; SD = 1052.82), $t(121) = 20.60$, $p < .001$, two-tailed test, 95% CIs [1713.60, 2078.04], $d = 1.34$.

ZERO-ORDER CORRELATIONS

The zero-order correlations between all variables can be seen in Table I. Math anxiety was significantly positively correlated with percentage of errors on problems involving a carry operation but was not correlated with percentage of errors to no-carry problems. Math anxiety was also significantly positively correlated with response time to problems with and without a carry operation.

Math anxiety was very strongly and highly significantly positively correlated with perceived frequency of the most troublesome/worrisome thoughts, effort to reduce thoughts and perceived impedance of thoughts on calculation. Frequency of the most troublesome/worrisome thoughts, difficulty removing the thoughts, effort to reduce the thoughts, and perceived impediment to calculation were significantly positively related to percentage of errors to carry-problems. Perceived frequency of the most troublesome/worrisome thoughts, effort to reduce thoughts and perceived impedance of thoughts on calculation were significantly positively correlated with response time to both carry-problems and no-carry problems. Perceived frequency of the most troublesome/worrisome thoughts was strongly and significantly correlated with perceived difficulty in removing thoughts, effort to reduce the impact of thoughts and perceived impedance on calculation.

Regression Analyses

A series of hierarchical multiple regressions were then conducted. In all models tested, math anxiety was included in the first step, followed by variables related to the self-reporting impact of the most troublesome/worrisome thoughts, including frequency of the thoughts, difficulty in removing the thoughts, and impact of the thoughts on the calculation process. Step three included self-reported effort in reducing the impact of the thoughts.

Percentage of errors on carry problems

The final regression model was significant, $F(5, 116) = 3.57$, $p = .005$, accounting for 13.3% (Adj $R^2 = .096$) of the variance. As shown in Table II, whilst math anxiety was a significant predictor at step 1, it became non-significant at step 2, remaining non-significant in the final stage. All other predictor variables were non-significant, with the exception of the variable impeding calculation, representing the level of which the most troublesome/worrisome thoughts impeded the participant's calculation of the math problems. Impeding calculation was significantly positively related to percentage of errors to carry problems and remained so in the final step, suggesting a mediation effect. The criteria for mediation, suggested by Baron and Kenny (1986), were met. As such, the indirect path between math anxiety, impeding calculation and percentage of errors was tested using a Sobel test, which demonstrated a significant indirect path, $p = .006$.

Percentage of errors on no-carry problems

The final regression model was not significant, $F(5, 116) = 0.34$, $p = .89$, accounting for <1% (Adj R^2 <.01) of the variance in percentage of errors to no-carry problems. As shown in Table 2, no individual variable was a significant predictor.

Response time to carry problems

The final regression model was significant, $F(5, 116) = 3.35$, $p = .007$, accounting for 12.6% (Adj $R^2 = .088$) of the variance in response time to problems involving a carry operation. As shown in Table III, math anxiety had a high level of predictive power, being significantly positively related to response time to carry problems and explaining 9.0% of the variance. Inclusion of intrusive thoughts measures did not add significantly to the model. Math anxiety remained significant through steps two and three.

Response time to no-carry problems

The final regression model was significant, $F(5, 116) = 3.31$, $p = .008$, accounting for 12.5% (Adj $R^2 = .087$) of the variance in response time to problems that did not involve a carry operation. Math anxiety was a significant predictor at step one but no variables were significant in the remaining steps.

Types of intrusive thoughts

As shown in Table IV, the most frequent intrusive thought experienced by participants related to making mistakes. Approximately half of all participants experienced thoughts about time pressure or method of problem solving. 41.8% of participants reported having thoughts that were non-task related, with similar numbers experiencing thoughts about previous math experiences or what people might think. Almost a third of all participants reported thoughts relating to physical changes and just over one fifth of participants reported having thoughts about panic. A comparison of math anxiety levels between those with and those without specific intrusive thoughts revealed several significant differences. With the exception of thoughts about method of problem solving, endorsement of each of the other intrusive thoughts was associated with significantly higher math anxiety.

TABLE II. RESULTS OF HIERARCHICAL REGRESSION WITH PERCENTAGE OF ERRORS AS THE OUTCOME VARIABLE

*$p \leq .05$ **$p \leq .01$

Step	Variables Entered	Carry problems Beta	Carry problems R^2 change	Carry problems Model R^2	No-carry problems Beta	No-carry problems R^2 change	No-carry problems Model R^2
1	Math anxiety	**.251****		**.063****	-.004		<.001
2	Math anxiety	.131	**.069***	**.132****	-.078	.014	.014
	Frequency	-.069			-.028		
	Difficulty in removing	-.018			.147		
	Impeding calculation	**.331****			.016		
3	Math anxiety	.141	.002	**1.33****	-.078	<.001	.014
	Frequency	-.052			-.028		
	Difficulty in removing	.012			.147		
	Impeding calculation	**.347****			.016		
	Effort to reduce thoughts	-.074			.002		

TABLE III. RESULTS OF HIERARCHICAL REGRESSION WITH RESPONSE TIME AS THE OUTCOME VARIABLE

*P ≤.05 **P ≤.01 **P ≤.001

		Carry problems			No-carry problems		
Step	Variables Entered	Beta	R^2 change	Model R^2	Beta	R^2 change	Model R^2
1	Math anxiety	**.299*** **		**.090*** **	**.302*** **		**.091*** **
2	Math anxiety	**.262***	.034	**.124** **	.213	.033	**.124** **
	Frequency	.105			.114		
	Difficulty in removing	-.198			-.127		
	Impeding calculation	.166			.179		
3	Math anxiety	**.249***	.002	**1.26** **	.207	.001	**.125** **
	Frequency	.085			.104		
	Difficulty in removing	-.234			-.144		
	Impeding calculation	.146			.170		
	Effort to reduce thoughts	.089			.042		

TABLE IV. FREQUENCY OF INTRUSIVE THOUGHTS AND MATH ANXIETY LEVEL AS A FUNCTION OF SPECIFIC THOUGHTS

*BASED ON A POOLED STANDARD DEVIATION

		Thought occurrence					
		Yes		No			
		Frequency	Math anxiety	Frequency	Math anxiety	*T* (& *p*) value	Effect size (*d*)*
Nature of thought	Making mistakes	109 (89.3%)	52.72 (16.51)	13 (10.7%)	43.00 (11.11)	2.06 (.04)	0.61
	Time pressure	60 (49.2%)	56.03 (16.67)	62 (50.8%)	47.47 (14.82)	3.00 (.003)	0.54
	Method of problem solving	58 (47.5%)	53.29 (17.08)	64 (52.5%)	50.22 (15.48)	1.04 (.30)	0.19
	What people might think	48 (39.3%)	59.58 (16.53)	74 (60.7%)	46.55 (13.96)	4.68 (<.001)	0.87
	Panicking	26 (21.3%)	65.08 (19.01)	96 (78.7%)	48.05 (13.40)	5.22 (<.001)	1.15
	Previous math experiences	49 (40.2%)	55.67 (16.97)	73 (59.8%)	49.00 (15.32)	2.26 (.03)	0.42
	Physical changes	36 (29.5%)	60.97 (17.84)	86 (70.5%)	47.79 (13.92)	4.38 (<.001)	0.87
	Non task-related	51 (41.8%)	56.43 (15.25)	71 (58.2%)	48.27 (16.22)	2.81 (.006)	0.52

V. DISCUSSION

Consistent with previous findings (e.g., Ashcraft & Faust, 1994) overall response time was significantly longer to problems involving a carry operation, and significantly more errors were made on problems involving a carry operation. Math anxiety was related to poor performance, but once intrusive thoughts data, namely frequency, difficulty in removing and impeding calculation, were accounted for, math anxiety did not predict percentage of errors to either carry or no-carry problems. However, math anxiety was a significant predictor of response time for carry problems. In contrast, intrusive thoughts measures were unrelated to responses times for carry and no-carry problems. Contrary to expectations, self-reported frequency of intrusive thoughts did not predict error rates to either carry problems or no-carry problems. Similarly, self-reported difficulty in removing intrusive thoughts did not predict error rates. However, there was a significant positive relationship between the self-reported extent to which intrusive thoughts impeded calculation and percentage of errors on problems involving a carry operation, partially supporting the hypothesis that the self-reported impact of intrusive thoughts would be related to performance. Therefore, perceived impact of intrusive thoughts was a predictor of performance whereas self-reported frequency of thoughts was not. This is consistent with other recent findings that showed frequency of thoughts to be unrelated to working memory performance (Nixon et al., 2008).

Moreover, the extent to which intrusive thoughts impeded calculation mediated the relationship between math anxiety and error rates on problems involving a carry operation; there were no relationships between math anxiety or intrusive thoughts measures, on the one hand, and error rates on problems involving no carry operation, on the other. These findings lend support to inhibition theory (Hasher & Zacks, 1988; Connelly, Hasher & Zacks, 1991) and provide the first data to suggest that failure to inhibit intrusive thoughts is responsible for the math anxiety-to-performance relationship, particularly on problems involving the transitory maintenance of a carry term (e.g. Faust et al., 1996).

In addition to assessing participants' perceived impact of intrusive thoughts, the CIQ (Freeston et al., 1991) permitted identification of specific intrusive thoughts. Participants reported a range of intrusive thoughts, with almost 90% having thoughts about making mistakes and nearly half reporting thoughts about time pressure and method of problem solving. Further, participants with higher math anxiety scores were more likely to endorse intrusive thoughts, particularly relating to what people might think, panicking and physical changes.

The current study represents the first occasion in which intrusive thoughts related to completing a math task have been have examined using the CIQ (Freeston et al., 1991). However, the precise nature of the relationships observed remains unclear, in part due to the self-report approach taken. For example, it is unclear whether thoughts about time pressure were an antecedent to response time or whether they occurred following response time. The present study is limited by the extent to which math anxiety is manipulated. However, experimental designs could be used to examine the importance of particular thoughts in math anxious individuals by manipulating them; for example regular reminders of a time limit (c.f. Kellogg, Hopko & Ashcraft, 1999) or the use of a flashing camera light to increase awareness that performance is being observed. It would also be interesting to investigate the relationship between math anxiety and arithmetic performance, and the importance of intrusive thoughts about previous math experiences, as previous research has emphasised the importance of negative math experiences as antecedents to math anxiety (Trujillo & Hadfield, 1999).

In conclusion, math anxiety was shown to be a significant predictor of response time to both carry and no-carry problems. In addition, math anxiety was related to a higher error rate on problems involving a carry operation. Importantly, the extent to which intrusive thoughts impeded calculation mediated this relationship. These findings provide support for an inhibition theory account of math anxiety effects on performance. Intrusive thoughts should be the focus of future research that investigates the relationship between math anxiety and performance.

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