Exploring statistics anxiety: Contrasting mathematical, academic performance and trait psychological predictors

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Statistics anxiety is experienced by a large number of psychology students, and previous research has examined a range of potential correlates, including academic performance, mathematical ability and psychological predictors. These varying predictors are often considered separately, although there may be shared variance between them. In the present study a wide range of predictors were measured in a sample of 112 first year undergraduate psychology students. For statistics anxiety, trait anxiety was the clearest predictor, with students who have higher levels of trait anxiety also having higher levels of statistics anxiety. For attitudes towards statistics, students who have better mathematical ability, and greater enjoyment of and confidence in their maths ability, also having more positive attitudes towards statistics. These findings suggest that models of statistics anxiety need to consider a wide range of predictors, which may in turn necessitate the development of a range of different interventions to alleviate statistics anxiety.
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Introduction

ALTHOUGH statistical analysis forms a fundamental part of the psychology undergraduate curriculum, around 40 per cent of new students are not aware that it will be a topic that they have to study (Ruggeri et al., 2008), and it is often perceived as the most difficult topic (Barry, 2012) with up to 80 per cent of students reporting some level of statistics anxiety (Onwuegbuzie & Wilson, 2003). Whilst statistics anxiety has been frequently explored within the pedagogic literature, there is still a limited understanding of the potential predictors of higher levels of anxiety as individual studies typically explore a rather limited number of possible predictor variables. However, these predictors may be inter-correlated, and therefore it is important to consider a wide range of variables together in order to fully understand the clearest predictors of statistics anxiety.

Within pedagogic research, statistics anxiety is typically measured by means of a questionnaire. The most frequently used is the Statistics Anxiety Rating Scale (STARS; Cruise et al., 1985, adapted by Hanna et al., 2008), which comprises of six subscales. The first three subscales are thought to reflect anxiety about statistics, and these include test and class anxiety, interpretation anxiety and anxiety around asking for help. The second three subscales indicate more general attitudes towards the study of statistics, including understanding the worth of statistics, perceptions (or fear) of statistics teachers, and computational self-concept, which reflects a person's belief in their own ability to complete mathematical computations. Hanna et al. (2008) showed that there are significant correlations between the six STARS scales, but a factor analysis confirmed that there are six statistically distinct scales. Therefore it is important to look at all six variables separately when attempting to understand the predictors of statistics anxiety as there may be different predictors across the six scales.

An obvious start point is to consider the relationship between an individual's mathematical ability and their anxiety about statistics, and particularly the computational self-concept scale. For example, previous

mathematical ability has been found to explain about 17 per cent of variability in statistics anxiety, and particularly in three of the STARS scales: worth of statistics, interpretation anxiety and computational self-concept (Baloglu, 2002). Similarly, the successful acquisition of high school mathematics was significantly associated with both attitudes towards statistics and statistics anxiety (Chiesi & Primi, 2010). Whilst there appears to be some evidence of a relationship between previous mathematical ability and statistics anxiety, the evidence to a relationship between mathematical ability and academic achievement on undergraduate statistics modules is rather more mixed. Whilst some researchers have found no relationship at all (Huws et al., 2006), others have found weak relationships across different aspects of mathematical ability (Bourne, 2014, in press; Harvey, 2009). Therefore, it seems that mathematical ability and previous experiences may predict some aspects of statistics anxiety, even if there is a weaker relationship between mathematical ability and academic performance.

There is strong evidence for students with higher levels of statistics anxiety having weaker academic performance on statistics modules (e.g. Hanna & Dempster, 2009; Macher et al., 2012). However, it is unclear whether this is a direct relationship, or whether another variable may mediate the relationship. For example, Onwuegbuzie (2004) explored the role of procrastination in graduate students from a range of disciplines who were taking research methods courses. He found that academic procrastination resulted from two key factors; task avoidance and fear of failure. In turn, these are associated with all six of the STARS scales, but particularly the more attitudinal scales. Additionally, higher levels of procrastination have been associated with lower academic performance (e.g. Howell & Watson, 2007). Therefore, whilst there may be a relationship between statistics anxiety and academic performance, it is unclear whether it is a direct relationship, or whether there are other mediating variables, such as more general psychological or learning approaches.

Statistics anxiety has been associated with a wide range of psychological factors. For example statistics anxiety, measured as a combination of the three anxiety scales of STARS, has been found to be highly correlated with trait anxiety (e.g. Macher et al., 2013). Higher levels of worry are positively correlated with interpretation anxiety, test and class anxiety and computational self-concept, but not with the other three STARS scales (Williams, 2013). Academic locus of control has been explored as a potential correlate of academic anxieties and achievement, with students who have an internal locus of control feeling that they are in control of their academic achievement, whereas those with an external locus of control believe that external factors, such as other people, determine their academic performance. Students with a more internal locus of control have been found to procrastinate less and have higher levels of academic achievement (Carden, Bryant & Moss, 2004).

It is clear that there are a wide range of predictors of statistics anxiety, with potential predictors varying across the different scales of attitudes towards and anxieties about statistics. To date, much of the research in this area explores just one type of predictor, or considered highly correlated predictors within a single study, such as contrasting worry and anxiety (e.g. Macher et al., 2013). In the present study a wider range of predictors are considered within a single sample of first year undergraduate psychology students. According to Lalonde and Gardner (1993), statistics anxiety results from three separate factors; anxiety about statistics, attitudes towards studying and academic ability. Consequently, in the present study a range of variables have been selected to reflect these potential predictors of the six subscales of statistics anxiety.

Mathematical ability was measured using a test designed to specifically assess the components that are necessary for the

computation and interpretation of statistics used within psychological research (see Bourne, 2014), and mathematical attitudes were measured by asking about participants confidence with maths and their enjoyment of maths. Academic performance was quantified for a first year research methods and statistics module in terms of attendance and overall module achievement. Finally, more academically oriented psychological factors were measured through academic locus of control, and non-academically through measuring trait anxiety. By considering such a wide range of factors together it will be possible to contrast intercorrelated variables that may predict differing attitudes towards and anxieties about studying statistics. This is achieved by means of multiple regression analyses to predict each aspect of statistics anxiety, as is typical in this area of research. Given that all of the variables have been found significant in previous explorations of individual predictors of statistics anxiety, it is difficult to develop a specific set of predictions.

Methods

Participants

Participants were 112 undergraduate psychology students in their first year of study. There were 93 females and 19 males, with a mean age of 18.6 years ($SD = 1.8$, range 17–34 years). Eighty-eight of the participants were from the UK, eight from elsewhere in the EU and 15 were international students. All participants were taking a compulsory year-long (20 weeks of teaching) integrated research methods and statistics module. Data were collected in the fourth week of the module. Ethical approval was granted by the College Ethics Board.

Statistics Anxiety Rating Scale (STARS)

The Statistical Anxiety Rating Scale (STARS) was used (Cruise, Cash & Bolton, 1985), adapted for the UK by Hanna et al. (2008). The STARS is a 51-item measure divided into six subscales measuring statistics anxiety and attitudes towards statistics. For the first 23 items, participants indicate how anxious they feel on a five-point Likert scale ranging from 'not at all anxious' to 'extremely anxious'. These items form three subscales: test and class anxiety (eight items; scores range 8–40), interpretation anxiety (11 items; scores range 11–55) and fear of asking for help (4 items; scores range 4–20). For the remaining 28 items participants indicate how strongly they agree on a five-point Likert scale ranging from 'strongly disagree' to 'strongly agree'. These items form a further three subscales: worth of statistics (16 items; scores range 16–80), fear of statistics teachers (five items; scores range 5–25) and computational self-concept (seven items; scores range 7–35). For each scale the items are summed and higher scores indicate higher levels of statistics anxiety or more negative attitudes.

Mathematical ability

All students completed a 'maths test' comprising of 10 sections: interpreting graphs, interpreting tables, understanding the language of statistics (e.g. Σ, $\geq$), understanding and using < and > symbols, number sequences, rounding off, decimals and percentages, negative numbers, power and square calculations, solving simple equations. Students complete the test with no time limit, and no calculators are allowed. The maths test is scored out of 100, with higher scores indicating better performance. Students also completed two items asking how much they 'enjoy' maths and how 'confident' they are with their maths ability. Both were scored from 0–4, with higher scores indicating more enjoyment or greater confidence.

Academic performance

Two separate measures of academic performance were recorded on the basis of the first year module in research methods and statistics, which runs across the entire first year. Attendance was recorded as a percentage, covering a one hour lecture, a one-hour workshop and a two-hour lab class each week for 20 weeks of teaching. Achievement was recorded as the percentage gained for

Table 1: Means and standard deviations for all predictor and outcome variables, and zero order correlations between the variables

	Descriptive statistics				Zero order correlations											
	Min.	Max.	Mean	SD	1	2	3	4	5	6	7	8	9	10	11	12
1: Maths ability	72	100	95.0	4.8	-											
2: Maths confidence	0	4	2.7	.8	.36***	-										
3: Maths enjoyment	0	4	2.2	1.1	.23**	.60***	-									
4: Attendance	0	100	86.2	14.8	-.02	-.03	-.05	-								
5: Module mark	12	76	61.2	8.8	.13	-.02	-.07	.50***	-							
6: Trait anxiety	22	78	46.7	10.5	.09	-.24**	-.03	.13	.09	-						
7: Academic locus of control	2	23	10.0	4.5	.11	-.07	-.06	-.09	-.26**	.50***	-					
8: SA: Test and class anxiety	8	40	22.1	7.3	-.22*	-.47***	-.35***	.15	.09	.42***	.15	-				
9: SA: Interpretation anxiety	11	44	25.2	7.6	-.26**	-.29**	-.26**	.09	-.02	.39***	.18	.66***	-			
10: SA: Asking for help	3	20	8.0	3.7	-.07	-.12	-.06	.14	.04	.60***	.32**	.61***	.53***	-		
11: SA: Worth of statistics	16	54	31.4	9.8	-.18	-.36***	-.46***	.02	-.02	.19*	.23**	.49***	.43***	.35***	-	
12: SA: Fear of statistics teachers	5	24	9.3	3.4	-.12	-.18	-.18	-.08	-.04	.22**	.23**	.31**	.31**	.28**	.59***	-
13: SA: computational self-concept	7	31	16.0	6.5	-.33***	-.63***	-.62***	.09	.02	.26**	.20*	.59***	.46***	.33***	.71***	.48***

the entire module, including one critical thinking essay, three lab reports, ongoing assessment (weekly online multiple choice quizzes) and an open book, unseen exam.

Psychological predictors

Trait anxiety was measured using the State-Trait Anxiety Inventory (Spielberger et al., 1983), a 20-item measure where participants are asked to rate their feelings and emotions 'generally in life' on a four-point Likert scale from 'almost never' to 'almost always'. Items are scored from one to four and a total score is calculated by summing item scores. Higher scores indicate higher levels of trait anxiety.

Academic Locus of Control was measured using the 28-item scale developed by Trice (1985), where participants are asked to respond 'true' or 'false' to items describing how they may feel about studying. For seventeen items, responding 'true' indicates an external academic locus of control and responding 'false' indicates an internal academic locus of control. For the remaining eleven items the opposite pattern is true. Responses are summed across all items so that scores range from 0–28, with higher scores indicating a more external locus of control and lower scores indicating a more internal locus of control.

Design and analysis

Multiple regression analyses were used to predict each of the six statistics anxiety scale scores. There were seven predictors in total: three mathematical predictors (maths ability test score, confidence in maths ability and enjoyment of maths) two academic predictors (attendance and module percentage) and the psychological predictors (trait anxiety and academic locus of control).

Results

The descriptive statistics and zero order correlations between all variables are shown in Table 1. Whilst a number of the variables, none were more strongly correlated than $r = .60$, suggesting that there was no evidence of multicolinearity between the predictor variables. Additionally, the tolerance values ranged from .52 to .80, all being greater than the recommended level of .10, and the VIF values ranged from 1.25 to 1.92, all being below the recommended level of 10. Consequently there is no evidence of multicolinearity amongst the predictors, and all can be considered to be separate predictors of statistics anxiety.

Regression analyses are summarised in Table 2. When predicting 'test and class anxiety' the overall model was significant, with the predictors explaining around 36 per cent of the variance in that aspect of statistics anxiety. There were two significant individual predictors. Higher levels of confidence in maths ability and lower levels of trait anxiety predicted lower levels of test and class anxiety. For 'interpretation anxiety' the significant model explained about 27 per cent of the variance, and this came from two predictors; higher levels of mathematical ability and lower levels of trait anxiety predicted lower levels of interpretation anxiety. For 'fear of asking for help' the overall model was significant, explaining 40 per cent of the variance, but with only high levels of trait anxiety predicting higher levels of fear of asking for help. When predicting 'worth of statistics', the significant overall model explained about 27 per cent of the variance, coming from just one significant predictor; higher levels of enjoying maths predicted lower scores that indicate the participant believes statistics are worthwhile. For 'fear of statistics teachers' the overall model was not significant, nor were the individual predictors. Finally, the 'computational self-concept' model was significant, with 54 per cent of the variance explained, coming from all three of the mathematical predictors. Lower levels of mathematical ability, confidence in mathematical ability and enjoyment of maths all predicted higher scores on the computational self concept measure, which indicates that participants have little confidence in their mathematical ability.

Table 2: Summary of the regression analyses, exploring mathematical, academic and psychological predictors of statistics anxiety

	STARS: Test and Class Anxiety			STARS: Interpretation Anxiety			STARS: Fear of Asking for Help			STARS: Worth of Statistics			STARS: Fear of Statistics Teachers			STARS: Computational Self Concept		
Model statistics	R2	F	p	R2	F	p	R2	F	p	R2	F	p	R2	F	p	R2	F	p
Final Model	.36	8.4	< .001	.27	5.6	< .001	.40	9.7	< .001	.27	5.5	< .001	.12	2.0	.059	.54	17.2	< .001
Predictor statistics	β	t	p	β	t	p	β	t	p	β	t	p	β	t	p	β	t	p
Maths ability	-.2	-1.4	.154	-.4	-2.5	.013	-.1	-1.7	.083	-.2	-1.1	.282	-.1	-1.2	.230	-.2	-2.1	.043
Maths confidence	-2.1	-2.2	.032	.1	.1	.888	.6	1.2	.222	-.6	-.4	.663	.0	.0	.987	-2.3	-3.2	.002
Maths enjoyment	-1.1	-1.7	.101	-1.4	-1.9	.059	-.3	-.8	.428	-3.5	-3.7	< .001	-.4	-1.2	.247	-2.3	-4.6	< .001
Attendance	.0	.9	.395	.0	.6	.542	.0	.9	.381	.0	.0	1.0	.0	-1.2	.249	.0	.6	.542
Module mark	.0	.1	.931	-.1	-.8	.436	.0	-.3	.776	.0	.0	.991	.0	.4	.660	.0	.0	.988
Trait anxiety	.3	3.8	< .001	.3	4.0	< .001	.2	6.4	< .001	.1	.9	.395	.1	1.4	.159	.1	1.6	.116
Academic locus of control	-.1	-.4	.715	-.1	-.3	.766	.0	.3	.732	.4	1.6	.113	.1	1.3	.183	.2	1.3	.182

Discussion

In this study mathematical, academic and psychological variables were used in combination to predict different aspects of statistics anxiety in first year undergraduate psychology students. Different patterns of predictors were found across the different subscales of statistics anxiety. The first three subscales, test and class anxiety, interpretation anxiety and fear of asking for help, were all mainly predicted by trait anxiety, with higher levels of trait anxiety predicting higher levels of statistics anxiety, a finding that is consistent with the previous research (e.g. Macher et al., 2013). Additionally, higher levels of mathematical confidence predicted lower levels of test and class anxiety, whereas higher levels of mathematical ability predicted lower levels of interpretation anxiety.

A rather different pattern was found for the final three statistics anxiety scales, as only mathematical predictors were significant. For worth of statistics, greater enjoyment of maths was predictive of lower levels of the perceived worth of statistics, whereas there were no significant predictors for the fear of statistics teachers scales. In terms of computational self concept, all three mathematical predictors were significant, showing that greater mathematical ability, enjoyment of maths and confidence in maths are all predictive of lower levels of self-belief in successfully completing mathematical computations. These findings are consistent with the previous research that has shown a relationship between mathematical ability and a number of the STARS scales (Baloglu, 2002; Chiesi & Primi, 2010).

Academic performance, both in terms of attendance and achievement, was not significant in predicting any facet of statistics anxiety. This is an important finding as it suggests that students with higher levels of statistics anxiety do not necessarily perform more poorly on modules with statistical content. This finding is at odds with the previous research, which has typically shown that students with statistics anxiety tend to have poorer academic achievement (e.g. Hanna & Dempster, 2009; Macher et al., 2012). It is possible that this is the result of considering a range of different factors within the same study. By considering multiple predictors within the same study, it is possible to determine which explains the most unique variance in the statistics anxiety, so if academic performance were considered without the addition of mathematical and psychological predictors, stronger relationships may have been found. However, examination of the zero order correlations shows that the two academic predictors are not correlated with any of the STARS scales, and the only correlation with non-academic predictors is between academic achievement (module mark) and academic locus of control. The negative correlation shows that students who achiever a higher module mark have lower scores on the locus of control scale, indicating a more internal locus of control, a finding that is consistent with the previous research (Carden, Bryant & Moss, 2004).

It is also interesting that academic locus of control was not a significant predictor of any aspect of statistics anxiety, however it was significantly correlated with a number of variables. Academic locus of control was negatively correlated with performance on the research methods and statistics module, showing that students with a more internal locus of control (lower scores) achieve higher marks in the module. Academic locus of control was also significantly correlated with four of the six STARS scales. However, all of these correlations were weak in strength in comparison to the correlation between academic locus of control and trait anxiety, where there was a moderate to strong positive correlation. Given this strong correlation and the finding that academic locus of control was not a significant predictor in any of the regression models, but instead trait anxiety was, it seems that any possible relationship between academic locus of control and statistics anxiety is actually mediated by trait anxiety. Consequently, adding trait

anxiety into the model eradicates the relationship between academic locus of control and statistics anxiety.

Very different patterns of significant predictors were found across the two halves of the statistics anxiety questionnaire. The first three scales were primarily predicted by the trait anxiety predictor, whereas the second three were only predicted by the mathematical variables. Whilst the STARS measure has six distinct scales, they do divide into two separate aspects. The first three scales (test and class anxiety, interpretation anxiety and fear of asking for help) are all measures of anxiety, whereas the other three scales are attitudinal in nature (worth of statistics, fear of statistics teachers and computational self concept). It therefore seems that trait anxiety is the best predictor of statistical anxiety, whereas mathematical variables are the best predictors of attitudes towards learning statistics.

Identifying two separate effects, one more mathematical and one more generally relating to trait anxiety, when attempting to understand individual differences in statistics anxiety may be of benefit when designing and implementing interventions that aim to alleviate statistics anxiety. Existing interventions tend to focus on just one aspect of statistics anxiety. For example, some have focused more on reducing anxiety through improving coping skills (Huang & Mayer, 2016), whereas others have aimed to improve mathematical skills linked with calculating statistical analyses (Lloyd & Robertson, 2012). Whilst both types of intervention were found to be effective, it is possible that different types of students may benefit from different types of intervention. As such, some form of pre-screening to establish the most appropriate intervention, targeting either mathematical skills or trait anxiety reduction, may be more effective. Future research could focus on identifying students with different underlying patterns of attitudes towards and anxieties about statistics, and then implement the type of intervention that is likely to be the most effective. Alternatively, an intervention with two distinct components may be more effective, with one feature addressing the anxiety and the other addressing the mathematical competency and confidence.

The finding of the present research suggests two distinct clusters of relationships between the STARS scales and a range of predictors. The more anxiety based scales (test and class anxiety, interpretation anxiety, and fear of asking for help) are primarily predicted by trait anxiety, with some small role for the mathematical predictors. In contrast, the more attitudinal scales (worth of statistics, fear of statistics teachers and computational self concept) are predicted by the mathematical variables, including mathematical ability, confidence and enjoyment. These findings show how gaining a full understanding of who experiences statistics anxiety is likely to take a multifaceted approach, and in turn, that developing singular interventions is unlikely to be an effective strategy in reducing levels of statistics anxiety. Instead, future research may be more fruitful if it considers a wider range of possible predictors and interventions, particularly distinguishing between anxiety and attitudes towards statistics. The development of cohort wide approaches to supporting the learning of research methods and statistics are likely to be fruitful, with a view to alleviating anxiety and improving attitudes towards statistics. In addition to reducing the negative emotional consequences of studying statistics for some students, this approach is likely to improve engagement and performance across the entire cohort.

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References

Baloglu, M. (2002). Psychometric properties of the statistics anxiety rating scale. *Psychological Reports, 90*(1), 315–325.

Barry, J.A. (2012). Do students who get low grades only in research methods need the same help as students who get low grades in all topics in psychology? *Psychology Teaching Review, 18*(2), 116–125.

Bourne, V.J. (2014). To what extent is mathematical ability predictive of performance in a methodology and statistics course? Can an action research approach be used to understand the relevance of mathematical ability in psychology undergraduates. *Psychology Teaching Review. 20*(2), 14–27.

Bourne, V.J. (in press). Does mathematical ability predict performance in the research components of an undergraduate psychology degree? Only a little bit, for a little while, and in specific ways. *Scholarship of Teaching and Learning in Psychology.*

Carden, R., Bryant, C. & Moss, R. (2004). Locus of control, test anxiety, academic procrastination, and achievement among college students. *Psychological Reports, 95*(2), 581–582.

Chiesi, F. & Primi, C. (2010). Cognitive and non-cognitive factors related to students' statistics achievement. *Statistics Education Research Journal, 9*(1), 6–26.

Cruise, R., Cash, R. & Bolton, D. (1985). *Development and validation of an instrument to measure statistical anxiety.* Paper presented at the annual meeting of the Statistical Education Section, Chicago.

Hanna, D. & Dempster, M. (2009). The effect of statistics anxiety on students' predicted and actual test scores. *The Irish Journal of Psychology, 30*(3–4), 201–209.

Hanna, D., Shevlin, M. & Dempster, M. (2008). The structure of the statistics anxiety rating scale: A confirmatory factor analysis using UK psychology students. *Personality and Individual Differences, 45*(1), 68–74.

Harvey, A., J. (2009). The merits of a general numeracy test as a predictor of undergraduate statistics performance. *Psychology Learning & Teaching, 8*(2), 16–22.

Howell, A. J. & Watson, D. C. (2007). Procrastination: Associations with achievement goal orientation and learning strategies. *Personality and Individual Differences, 43*(1), 167–178.

Huang, X. & Mayer, R.E. (2016). Benefits of adding anxiety-reducing features to a computer-based multimedia lesson on statistics. *Computers in Human Behavior, 63,* 293–303.

Huws, N., Reddy, P. & Talcott, J. (2005). Predicting university success in psychology: are subject-specific skills important? *Psychology Learning & Teaching, 5*(2), 133–140.

Lalonde, R.N. & Gardner, R.C. (1993). Statistics as a second language? A model for predicting performance in psychology students. *Canadian Journal of Behavioural Science, 25*(1), 108–125.

Lloyd, S.A. & Robertson, C.L. (2012). Screencast tutorials enhance student learning of statistics. *Teaching of Psychology, 39*(1), 67–71.

Macher, D., Paechter, M., Papousek, I. & Ruggeri, K. (2012). Statistics anxiety, trait anxiety, learning behavior, and academic performance. *European Journal of Psychology of Education, 27*(4), 483–498.

Onwuegbuzie, A.J. (2004). Academic procrastination and statistics anxiety. *Assessment & Evaluation in Higher Education, 29*(1), 3–19.

Onwuegbuzie, A. J. & Wilson, V. A. (2003). Statistics Anxiety: Nature, etiology, antecedents, effects, and treatments – -a comprehensive review of the literature. *Teaching in Higher Education, 8*(2), 195–209.

Ruggeri, K., Dempster, M., Hanna, D. & Cleary, C. (2008). Experiences and expectations: The real reason nobody likes stats. *Psychology Teaching Review, 14*(2), 75–83.

Spielberger, C.D., Gorsuch, R.L., Lushene, R. et al. (1983). *Manual for the State-Trait Anxiety Inventory.* Palo Alto, CA: Consulting Psychologists Press.

Trice, A.D. (1985). An academic locus of control scale for college students. *Perceptual and Motor Skills, 61*(3), 1043–1046.

Williams, A.S. (2013). Worry, intolerance of uncertainty, and statistics anxiety. *Statistics Education Research Journal, 12*(1), 48–59.