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.

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Abstract

It is well documented that many undergraduate students of psychology experience high levels of anxiety about the statistical components of their degree, and this anxiety is associated with lower academic performance and various negative psychological consequences. Although students are anxious about the use of mathematics within their studies, to date there is little evidence showing a relationship between different aspects of mathematical ability and performance in research methods and statistical analysis modules within a psychology degree. Using a custom designed maths tests to evaluate the specific mathematical skills that are required to complete a psychology degree; this study considered whether mathematical ability could predict performance across various methods of assessment and across all three years of the degree programme in 213 first year undergraduate psychology students. Whilst some significant predictive relationships were found, they were quite specific, quite small and quite short term. Only the interpretation of graphical information was predictive of some components of a first year module, and no aspects of mathematical ability predicted any measure of performance in second or third year modules. These findings have potential implications for curriculum design, particularly in terms of developing interventions to reduce statistics anxiety in psychology students.

Keywords: Statistics anxiety, academic performance, longitudinal study.

Psychology degrees typically contain a great deal of content that focuses on research methodology and statistical analyses. Within the UK the psychology curriculum is greatly guided by the British Psychology Society (BPS), which accredits psychology degrees in the UK. One of the specified core components that must be covered is research methods and statistical analysis, culminating in an independent research project in the final year of study. For some students, it can be unexpected and anxiety provoking to encounter the mathematical requirements that are necessary to understand and conduct statistical analyses. This piece of research examines whether mathematical ability, and which aspects of if, might predict performance on research focused modules throughout a psychology degree.

Up to 45% of students are not aware of the statistical component of a psychology degree (Ruggeri et al., 2008) and many do not understand how statistical analyses are relevant to a psychology degree (Murtonen et al., 2008). This might, at least in part, explain why up to 80% of students report experiencing statistics anxiety (Onwuegbuzie & Wilson, 2003). Statistics anxiety in psychology students has been found to be multifaceted, with one component, "computational self-concept", being specifically about the individual's views of their mathematical abilities and the relevance of mathematics within statistics (Hanna et al., 2008). Given that higher levels of statistics anxiety predict both higher levels of procrastination (Onwuegbuzie, 2004) and lower marks (Macher et al., 2012), it is important to fully understand the relationship between mathematical ability and performance within a psychology degree.

Lalonde and Gardner (1993) suggested that the effective learning of statistics is dependent on three different components: mathematical ability, anxiety about statistics, and motivation to learn. Consequently, it is possible that students with greater mathematical ability may achieve higher levels of academic performance. If lower levels of mathematical ability are predictive of weaker performance, then it may be beneficial to introduce interventions that aim to alleviate anxiety and provide students with the mathematical skills that are necessary to successfully complete the research components of a psychology degree. However, if mathematical ability is not predictive of performance on research focused modules, then it may be that students are unnecessarily experiencing high levels of anxiety. In this case, it may be beneficial to educate students regarding the lack of impact on their academic achievement, and instead target any potential interventions on alleviating the anxiety surrounding statistical analyses and mathematics. Without a full understanding of the relationship between mathematical ability and academic performance, it is difficult to develop effective interventions to alleviate anxiety and improve academic achievement.

Relatively little research has directly examined the relationship between mathematical ability and performance with a psychology degree generally, or the specific research components of a psychology degree. Huws et al. (2005) examined whether GCSE maths grade, a general mathematics qualification taken in the UK at 16 years old, could predict final degree classification on a psychology degree course, but again there were no significant findings. This suggests that mathematical ability plays no role in predicting degree level performance in statistical modules; however this study is limited by using the GCSE maths grade as their measure of mathematical ability. First, it provides a single grade to reflect mathematical ability, and it is possible that only specific elements of maths are relevant to the statistical analyses used within psychological research. Consequently, if mathematical ability cannot predict performance in psychology undergraduate students, it may be necessary to look at more specific aspects of mathematical ability. Second, it is a very general mathematical qualification, covering a wide range of topics, some of which are not relevant to statistics (e.g., trigonometry, geometry).

Mathematics is an incredibly broad discipline that covers a great many skills, and only a relatively small subset of these are actually relevant to, and necessary for, the calculation and interpretation of the basic statistics used to analyse and interpret the data collected in simple psychological research studies. Therefore, the lack of findings by researchers such as Huws et al. (2005) may simply miss more specific relationships between particularly relevant aspects of mathematical ability and performance in a psychology degree. Consequently, research may be more fruitful if examining only the aspects of mathematical ability that a student will actually need within a psychology degree.

Harvey (2009) attempted such a study by devising a simplified maths test, using questions from GCSE examinations, with four separate components: arithmetic, fractions/decimals/percentages, descriptive statistics and algebra. These four mathematical ability scores were used to predict performance in statistics exams at the end of first and second year. They found that only arithmetic ability was predictive of first year statistics exam performance, but not of second year performance. This suggests that mathematical ability may be predictive of performance on statistics assessments within psychology degrees, but only specific aspects of mathematical ability, and only for more introductory first year assessments. It is also important to note that only examination performance was considered as an indicator of performance, however research and statistical modules are often assessed using a wider range of assignments and examinations.

In a study of undergraduate psychology students in Malaysia, Hamid and Sulaiman (2014) used a very simple 15 item test of basic mathematical ability. They found a positive and significant correlation between performance on the maths test and three different measures of performance on an introductory statistics module, as well as being significantly correlated with three different components of statistics ability. This finding supports the work of Harvey (2009), suggesting that greater mathematical ability may confer a benefit when learning about statistics, and that mathematical ability is also likely to explain some of the variability in a student's experience of statistical anxiety.

Whilst the work of Hamid and Sulaiman (2014) and Harvey (2009) do provide a more specific examination of mathematical ability, the measures of statistical ability still do not fully or specifically encompass the mathematical and numeracy skills needed within a psychology degree. For example, whilst the calculations of descriptive and inferential statistics are clearly covered within the Harvey study, aspects such as the interpretation of information from tables and graphs are not included. Such skills are essential for any psychology student to both clearly present their own research, and for them to accurately understand the information presented in research papers. Consequently, Harvey's study may have been too narrow in its consideration of mathematical ability.

Instead of relying on selecting questions from existing general mathematical examinations, what may be more fruitful is to consider a mathematics test that is designed specifically to cover all of the mathematical and numeracy skills needed within a psychology degree, but without including any superfluous elements. With such an examination, it may be possible to achieve a more accurate understanding of the relationship between mathematical ability and academic performance. A more detailed examination of the relationship between mathematical ability and performance by psychology undergraduates in a first year research methods and statistical analysis module found an intricate pattern of small relationships (Bourne, 2014). A Maths Test, comprising of ten separate components that are specifically relevant to statistical analyses within psychology was given to students soon after starting their psychology degree. The ten components were reduced into three separate variables using factor analysis: the procedural aspects of maths (e.g., equations, rounding off), the interpretation of mathematical information (e.g., interpreting tables and graphs) and the semantics of maths (e.g., understanding symbols such as Σ and $\geq$, using $<$ and $>$ operators). This way of measuring mathematical ability has advantages over previous methods as it more specifically targeted the types of mathematical ability needed to successfully complete statistical analysis calculations and interpret statistical findings within psychological research.

These three aspects of mathematical ability were used to predict performance across all examined components of a first year integrated research methods and statistical analysis module. This included continuing assessment (weekly multiple choice quizzes), four written pieces of coursework (a critical thinking assignment and three lab reports) and a written exam. The procedural and interpretative components predicted higher levels of performance on the continuous assessment, the exam and the overall module mark. Additionally the interpretation factor predicted performance on the critical thinking assignment and the first lab report. This suggests that mathematical ability can predict performance on an undergraduate research module, but only certain aspects of mathematical ability, and only to predict certain elements of performance. It should also be noted that, whilst the predictive relationships were significant, they were relatively small in terms of the amount of variance explained. For each type of assessment, between two and five percent of the variance in performance could be explained by mathematical ability.

When attempting to understand the relationship between mathematical ability and academic performance, the previous research has typically only considered performance early in a student's degree, and has often only considered specific aspects of academic performance. Harvey (2009) found that mathematical ability predicted performance on a first year, but not a second year, statistics exam. This suggests that the negative impact of weak mathematical ability may have a short term influence on exam performance, but not longer term. However, students are typically assessed across a wide range of assessments, not just exams. To what extent might mathematical ability differentially predict performance across different forms of assessment? Bourne (2014) found that specific components of mathematical ability were predictive of performance across all assessment components, looking at lab reports, continuous assessment and exam performance. However, these relationships were only considered within first year students. Therefore, it is unclear whether these consequences of poorer mathematical ability persist beyond first year studies. Consequently, it is necessary to conduct a more longitudinal examination of the relationship between specific and highly relevant aspects of mathematical ability and performance across different modes of assessment through their entire degree.

The existing and limited amount of research linking mathematical ability and performance in psychology undergraduate research modules is inconsistent. Although very general measures of mathematical ability appear to not predict performance (Huws et al., 2006), looking at more relevant and specific aspects of mathematical ability may be able to predict some components of performance. Harvey (2009) found specific relationships with first year, but not second year, exam performance, whereas Bourne (2014) looked only at first year performance, but across a range of assessment pieces, and again found some specific relationships.

The present study aims to further understand the relationship between the very specific elements of mathematical ability that are relevant to the computation and interpretation of basic statistics, and performance on different types of research assessments, across a three year degree programme. This will be the first study to combine psychology specific mathematical ability, across different types of assessment and the entire degree programme. As such it is hoped that a better understanding of the predictive relationship between mathematical ability and academic achievement will be gained. On the basis of the findings of Harvey (2009) and Bourne (2014) it is predicted that only specific aspects of mathematical ability will successfully predict higher levels of academic achievement. In particular, the understanding of mathematical procedures and the interpretation of mathematical information are likely to be the best predictors of performance. When looking at different elements of assessment, given the findings of Bourne (2014), it is predicted that the relationship may vary across the different assessed pieces of work, but the exact nature of this is unclear. Finally, given that Harvey (2009) found that mathematical ability predicted first year performance, but not second year, it is predicted that the relationships found will be stronger in the first year of study than in subsequent years.

Methods

Participants

The participants were all first year undergraduate students taking a psychology single honours degree at a university in the South East of the UK. Data was complied across 213 students from two consecutive cohorts: 110 students in cohort two and 103 students in cohort two. Demographic data are not available for the individual participants, but the intake is quite representative of psychology students within the UK. Approximately 81% were female, typically around 19 years old with around 7% of the students being mature (21 years or older at initial registration). About 73% of students are from the UK, 15% from elsewhere in the European Union and around 12% being international students (from outside of the EU). The entrance requirement is AAB at A-level.

Programme and module overview

The programme is a three-year BPS accredited single honours psychology BSc, and within each year 25% of the taught content and assessment focuses on research topics. Within the English higher education system, all undergraduate students are considered as honours students, with psychology students often specialising in a single subject from the very beginning of their degree. Marks awarded are percentages, where 40% is the pass mark, and 70% or above is a First Class mark. At first and second year the research teaching occurs within a single module for each year that integrates both methodology and statistical analysis. Passing the research module is compulsory to progress to the following year. In their final year they complete an independent piece of research.

First year module: The course is taught over 20 weeks, integrating research methods and statistical analysis, taught using hand calculations. Each week there was a one-hour lecture, a one-hour computer workshop and a two-hour practical lab class. There were five separate coursework components, all of which were summative and each was worth 10% of the final course grade. The first component comprised multiple choice quizzes, completed in each of the twenty teaching weeks. There was also a Critical Thinking assignment and three separate lab reports that covered different research designs and statistical analyses (chi square, t test, correlation). The remaining 50% of the module assessment was a three hour unseen open book exam, taken at the end of the course. The exam comprised one research design task and three statistical analysis questions.

Second year module: The structure of the course was the same as for first year, with 20 weeks of teaching including lectures, workshops and lab classes each week. The statistical content was all taught using SPSS, with no hand calculations. Weekly multiple choice quizzes again comprised 10% of the module mark. There were then three lab reports, with two contributing 15% and one contributing 20% to the module mark. At the end of the course students sat a three hour unseen (not open book) exam worth 40% of the module. The exam comprised short answer theoretical questions, a research design task and two statistical analysis questions.

Third year module: For this module students complete an independent research project, supervised by a member of staff, which takes place over a whole academic year. For the project students have to devise a research question, develop their design and materials, collect and analyse their own data, and then write up an independent report in the style of a published APA journal article. The module mark comes from a contribution component of 10% and the remaining 90% comes from the project write up of up to 7,000 words.

Maths test

The Maths Test is completed within a lab class in the fourth week of the students first year. It is a formative piece of work with the main aim of highlighting the key aspects of mathematical ability that are needed to complete the statistical component of a psychology degree. Students complete the Maths Test without any time limit and without the use of a calculator. The test comprises ten separate sections: interpreting graphs, interpreting tables, understanding the language of statistics (e.g., Σ, ≥), understanding and using < and > symbols, number sequences, rounding off, decimals and percentages, negative numbers, power and square calculations, solving simple equations.

After completing the Maths Test, the class lab tutor works through each section, explaining the correct answers, why they are the correct answers and why that particular aspect of mathematical ability is relevant to studying psychological research. Students mark their own tests, and end up with a Mathematical Profile across the ten separate components of the Maths Test. With this profile they can be reassured that they have the necessary mathematical skills to successfully complete the psychological research component of the degree, or if there were sections where they performed poorly, they can seek specific and target support to improve their mathematical abilities.

To gain a copy of the Maths Test and associated lab resources, please email the author.

Results

Analysis of the Maths Test components

Performance within each section of the Maths Test was scored as percentages. Descriptive statistics and correlations between each section are shown in Table One. To simplify subsequent analyses, and in line with previous research using this Maths Test (Bourne, 2014), the ten section scores were analysed using factor analysis with Varimax rotation. Three separate factors were extracted.

[Insert Table One about here]

The first factor had an eigenvalue of 2.71 and explained 27.13% of the variability in the Maths Test scores. This factor contained six of the ten Maths Test components (in order of importance: decimals and percentages, rounding off, power and square calculations, solving simple equations, number sequences, interpreting tables). The first factor appears to represent general mathematical ability.

The second factor had an eigenvalue of 1.69, explaining 16.94% of the variability. This factor contained three of the Maths Test components (in order of importance: understanding and using < and > symbols, understanding the language of statistics (e.g., Σ, ≥), negative numbers). This factor seems to reflect the "language" of maths. The third factor had an eigenvalue of 1.21, and explained 12.1% of the variability in scores in the overall test. This factor contained just one item, interpreting graphs, and has been named accordingly.

For the purposes of subsequent analyses mean percentage scores were calculated for each factor. The two cohorts did not differ in mathematical ability across the three factors (Factor 1: $t\ (211) = 0.98$, $p = .328$; Factor 2: $t\ (211) = 0.48$, $p = .634$; Factor 3: $t\ (211) = 1.06$, $p = .289$). Consequently the two cohorts were combined and treated as one for all subsequent analyses.

Analysis of the relationship between mathematical ability and performance in research modules

Descriptive statistics for all performance measures, and the correlations between performance and mathematical ability measures are presented in Table Two. Zero order correlations between all of the performance measures, and partial correlations between the performance measures whilst controlling for mathematical ability, are shown in Table Three. Almost all of the performance measures were significantly positively correlated, even after controlling for mathematical ability.

Multiple regression analyses were used to predict performance on research focused modules, predicting individual components and overall module marks separately. The three mathematical ability factors were entered as predictors of performance. All of the variables were measured on percentage scales.

[Insert Tables Two and Three about here]

The regression analyses are summarised in Table Four. Looking at the first year marks, the overall model was significant when predicting marks on the first lab report, the written exam and the final module mark. For each of these, on the third factor, "Interpretation of Graphical Information" was a significant predictor. All three showed a positive relationship, with better ability to interpret graphical information predicting higher marks.

[Insert Table Four about here]

No aspect of mathematical ability was able to predict performance in any component of the marks for second and third year research modules.

Discussion

The aim of this study was to examine whether very specific aspects of mathematical ability that are necessary to calculate the basic statistics used in psychology research was able to predict performance in research modules across an entire psychology degree. Only one aspect of mathematical ability, the ability to interpret graphs, was predictive of performance, and this was only for some components of the first year course: the first lab report, the exam and the overall module mark. There were no significant relationships when considering performance in the second or third year. It therefore seems that one very specific aspect of mathematical ability, the interpretation of graphs, maybe be predictive of better performance, but only for some parts of a research methods and statistics module, and only within the first year of a degree. Consequently, the possible impact of weaker mathematical understanding appears to have a rather limited and short term impact on academic performance.

This study found some limited evidence for marks on a research module being predicted by mathematical ability. The previous research in this area has been quite contradictory, and as such it can been seen as consistent with the present findings. For example, Huws et al. (2006) found no relationship between general mathematical ability and performance in first year modules and final degree classification. As the measure of mathematical ability was general (GCSE) and included many different components, it is possible that any more specific effects were diluted and therefore the overall finding was not significant. This therefore suggests that a very general measure of mathematical ability may not be suitable to identify the specific components of mathematical ability that are relevant to a student's academic attainment in a psychology degree.

Harvey (2009) examined more specific components of mathematical ability and found that arithmetic ability, but no other components, were predictive of performance in first and second year statistics exams. Whilst Harvey and the present findings both show some specific relationships between mathematical ability and performance measures, the findings are quite different. First, Harvey found that arithmetic ability was the only predictor of performance, whereas the arithmetic component (factor one) of the present analysis was not a significant predictor of any performance measure. Second, Harvey's study used two statistics exams as the performance measure. In the present study, the performance measures were taken from a course that combines methodology and statistical analysis, which assesses a wider range of skills than just statistical analysis. As such, although the two studies both find some relationships between specific mathematical abilities and performance measures, the findings are not directly comparable.

The present study found that the ability to interpret graphical information could significantly predict performance for a first year combined methodology and statistics module (overall module mark), but looking at the separate components within the module, it only predicted performance in the first lab report and in the exam. The first lab report requires interpreting and clearly reporting the findings of others, and the analysis and presentation of their own data. As such, the ability to understand graphical information may have provided an advantage in either or both of these components. The exam combines designing studies, critiquing designs and calculating and reporting statistical analyses. The ability to interpret graphical information is likely to play into some of these skills. Given that the module, and the assessments, were all based on students demonstrating their knowledge of both statistics and research methods, it is perhaps not too surprising that the variance in performance explained by mathematical ability was quite small, with around 4% being accounted for in the significant models. If it were possible to isolate only the statistical components of the assessment it is possible that the strength of the relationships found would increase. However, as the “interpretation” of graphical information is the only significant predictor of performance, and interpretation is not purely a statistical skill, perhaps the relationship is quite a small, albeit statistically significant one. Clearly further research is warranted to clarify whether mathematical ability is predictive of performance in statistical assessments only, or whether mathematical ability is predictive of more general academic performance.

If mathematical ability were found to be predictive of general academic performance, an interesting possibility might be considered: does mathematical ability, as a specific skill, predict academic achievement, or is mathematical ability a proxy measure for general cognitive ability, or IQ? In children, non-verbal IQ has been found to be significantly correlated with mathematical ability (Kyttälä & Lehto, 2008). It is therefore possible that the correlations found in the present study result from a relationship between general cognitive ability and academic performance, rather than between mathematical ability more specifically. In future research, it would be interesting to measure non-verbal cognitive ability, as well as mathematical ability, and then contrast which is the better predictor of academic performance in a research methods and statistics module.

Importantly, whilst interpreting graphical information was a significant predictor of two component module marks, there were no significant predictors of the other four component marks. This means that the use of mathematical ability as a predictor of performance within first year is quite limited. There were no significant predictors of the weekly multiple choice quizzes, and this may be because the questions asked about the theoretical content from lectures and the calculations conducted within workshops. Though graphical interpretation was a significant predictor of performance on the first lab report, it did not predict performance on the subsequent two reports. It is possible that the first lab report allowed students to develop the relevant skills needed to complete further reports, and therefore, once those skills had been acquired, there was no longer any relationship between performance and the ability to interpret graphical information. This possibility is supported by performance on the first lab report in first year being positively and significantly correlated with all other performance measures across all three years of study, both with and without controlling for mathematical ability.

Marks on the critical thinking assignment were not predicted by graphical interpretation, or any other component of mathematical ability. This is possibly surprising as much of this assignment relies on the ability to accurately interpret and report on the findings in published research. However, not all papers use graphs to present information. Many use tables, and even if graphs are used, the findings can additionally be understood through reading the text of the Results and Discussion. Therefore it is possible that students who had lower scores for the interpretation of graphical information used alternative ways of understanding the findings of the papers they reviewed.

Significant findings within the present study were only found for some assignments within first year, and there were no significant predictive relationships for second or third year component or module marks. This suggests that the possible impact of graphical interpretation ability only has a relatively short term effect, only being relevant during first year. It is important to consider why this might be the case. One major difference between the courses in first and second year is that statistics are calculated by hand in first year, but SPSS is used in second year. It is possible that the mathematical skills identified are more relevant to, and therefore more predictive of performance when doing manual calculations than the use of computer programmes. As such, it may be that mathematical skills are more relevant in first year than second year, and therefore on predictive of performance in first year. An alternative interpretation is that students acquire the skills they need during first year, and therefore progress into second year with sufficient skills to eradicate any significant influence on performance. One way to examine these possibilities could be to compare results across two different programmes or institutions, one where SPSS is introduced at the beginning of the degree in first year and the other not introducing SPSS until second year.

There are some limitations of this study, which need to be considered when interpreting these findings. First, the sample is slightly limited in that data were only included if the students attended on the day that the maths test lab class ran and if they progressed through to the end of their degree. As such, it is possible that the sample did not included students with weaker academic performance. However, if this were the case, it is likely that including a sample with a wider range of abilities may reveal stronger relationships. As such, the present findings may be an underestimate of the actual relationships between mathematical ability and performance. Second, the performance on the maths test was generally quite high, with performance being around 85% to 97% correct. It is possible that these limited scores are one reason why the findings from the present study were so limited. If the test had provided a wider range of scores, then it is possible that this increased variance in the dataset could have led to more significant findings. However, although the percentage correct tended to be high, there was a wide range of scores, with the total score on the test ranging from 53% to 100% correct, and scores ranging from 0% to 100% on four of the ten subsections. Therefore, whilst these results do not necessarily represent a strict ceiling effect, it is possible that the high scores limit the variability in the dataset and could make it more difficult to detect significant effects. Again, if this were the case, the present results may be an underestimate of the relationship between mathematical ability and performance.

Although some correlations and predictive relationships were identified in this study, it must be acknowledged that they were all relatively small with all r values less than .2, indicating a moderate effect size. Additionally, many of the correlations were not significant.

It is therefore very clear that a wide range of unmeasured variables must account for the unexplained variance in these analyses, and individual differences are likely to be amongst these. Lalonde and Gardner (1993) suggested that effective statistics learning is dependent on three different things: mathematical ability, anxiety about (and attitudes towards) statistics, and an individual's own motivations to learn. As such, attainment in a research methods and statistics module is likely to be explained by numerous variables. For example, previous mathematics experience has been shown to explain around 17% of the variance in statistics anxiety (Baloğlu (2003) and a recent meta-analysis has shown that males perform better than females in mathematics (Reilly et al., 2015). Unfortunately these demographic and background educational variables were not collected in the present study, but it is very likely that their inclusion would improve the predictive model greatly

This research has shown some limited and short term relationships between mathematical ability and performance in research methods and statistics modules within a psychology degree. Given that up to 80% of students experience statistics anxiety (Onwuegbuzie & Wilson, 2003), and one component of this is a student's views regarding their own mathematical ability, it is possible that students are experiencing unnecessary anxiety. If weaker mathematical skills are not a major impediment to successful academic studies, then the promotion of these findings to students may well alleviate some of the anxieties experienced by students. As such, it is important to consider the need for further research to explore how these findings might be translated into pedagogic strategies to improve the learning experience and learning outcome of students.

Some of the existing interventions are based around improving student's mathematical and statistical abilities. For example, Lloyd and Robertson (2012) used recorded screencast tutorials, and found that students who used the screencasts performed better on a statistics exercise, in comparison to a control group who used a textbook only. Other forms of intervention have taken a different approach, and instead attempt to alleviate statistical anxiety in order to improve performance. Huang and Mayer (2016) asked students to complete an online statistics exercise, and students were either given an anxiety reducing message about how to cope with statistics anxiety, or no message was given. They found that students who received the coping message performed better than those who did not. Chiou et al. (2014) used a simple writing task, asking students to write down the most important concept learned and any remaining unanswered questions at the end of each class. They found that, in comparison to a control group, students who completed the writing task had both improved performance and reduced anxiety. It therefore seems that both interventions tackling mathematical ability and interventions tackling statistical anxiety may be effective in improving academic performance. It therefore seems that the development of an intervention that were able to encompass both mathematical ability and statistics (or mathematical) anxiety would be most effective for supporting and improving academic achievement.

Although the findings of the present study find quite small effects of mathematical ability on performance, there is quite well documented evidence for higher levels of statistics anxiety predicting lower levels of academic performance, as well as other negative psychological consequences within psychology students (for a review, see Onwuegbuzie & Wilson, 2003). There is also more general evidence for individuals who have higher levels of mathematical anxiety performing more poorly on a large number of mathematical tasks, from straightforward counting (Maloney et al., 2010) through to solving mathematical computations that require multiple steps (Mattarelle-Micke et al., 2011). It is therefore possible that students are anxious about their mathematical ability having a negative impact on their academic performance. As such, statistical anxiety may be a mediating or moderating variable that contributes to the student’s perception of a relationship between mathematical ability and academic performance. Cleary, to truly understand the relationship between mathematical ability, statistics/mathematical anxiety and academic performance, future research needs to consider all three variables within the same study.

It is also possible that interventions could be developed that targeted more general cognitive processes than mathematical ability and anxiety, but that would still have a positive impact on both. For example, Maloney et al. (2013) suggested that stereotype threat, which occurs when an individual underperforms on a task to match a negative stereotype of a group they belong to, may be an important factor when considering the relationship between mathematical ability and anxiety. One clear example of this is gender stereotypes of females being less proficient at maths than males, and indeed, when this stereotype is made salient to women participants before completing a maths task, their performance drops considerably (e.g., Beilock et al., 2007). Maloney et al. therefore suggest that interventions around maths ability and anxiety do not necessarily need to directly address either, but instead through techniques such as cognitive reappraisal of their anxiety or expressive writing about their emotions regarding an imminent test or exam. This raises the interesting possibility that effective interventions need not necessarily involve numbers at all.

If it were possible to reduce student's levels of anxiety around the statistical and mathematical components of a psychology degree, then there could be a range of academic and psychological benefits for students. Such interventions deserve attention in future studies. First, if students are anxious about their mathematical ability, then it may be possible to either reassure students regarding their mathematical ability, or to provide further support and training within the aspects of mathematics that they are less proficient with. The maths test used in the present study could be used to help facilitate this level of understanding and self-concept, and may be particularly effective in allowing the student to identify very specific aspects of mathematics skill that require revision. As such, it may be possible to pre-screen students to develop a profile of their abilities across the various components, and then deliver targeted interventions to improve their skills where needed. Additionally, whilst many students feel that maths is irrelevant to a psychology degree (Murtonen et al., 2008), giving them a maths test that is custom designed to meet the mathematical needs of psychology students, such as the one used in this study, may further facilitate their engagement in the intervention. Second, it may be helpful to inform students about the weak predictive relationship between mathematical skills and academic performance, and to address wider cognitive concepts, such as stereotype threat. This may provide a second way in which students could be reassured that the mathematical skills that they have are unlikely to have a major impact on their academic achievement. Taken in combination, an intervention that clearly demonstrates to students which aspects of maths are relevant within a psychology degree, their level of competence within each aspect, and educates student about the weak association between mathematical ability and performance in research modules, may prove to be an effective intervention.

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Table 1: *Descriptive Statistics and Correlations Between the Individual Components of the Maths Test and the Mean Factor Scores.*

	Descriptive statistics				Zero order correlations												
	Min	Max	Mean	SD	2	3	4	5	6	7	8	9	10	11	12	13	14
1: Graphs	60.0	100.0	97.4	6.3	.17*	.13	.22**	.11	.14*	.11	.15*	-.04	.07	.31**	.17*	.21**	1.00**
2: Tables	20.0	100.0	87.8	14.6		.23**	.09	.20**	.21**	.31**	.19**	.26**	.30**	.55**	.61**	.20**	.17*
3: Language of statistics	0.0	100.0	85.2	18.4			.29**	.13	.06	.10	.24**	.16*	.27**	.48**	.29**	.85**	.13
4: < > than symbols	0.0	100.0	92.6	14.7				.08	.10	.07	.20**	.05	.23**	.47**	.19**	.75**	.22**
5: Number sequences	40.0	100.0	91.9	12.7					.18**	.33**	.21**	.22**	.37**	.44**	.59**	.13	.11
6: Rounding off	50.0	100.0	98.9	4.8						.55**	.01	.47**	.43**	.42**	.52**	.10	.14*
7: Decimals and percent	0.0	100.0	96.1	10.4							.15*	.47**	.42**	.55**	.67**	.11	.11
8: Negative numbers	25.0	100.0	92.0	13.7								.25**	.37**	.70**	.55**	.28**	.15*
9: Power and square	10.0	100.0	96.0	9.6									.60**	.58**	.69**	.13	-.04
10: Equations	0.0	100.0	93.5	12.5										.73**	.78**	.31**	.07
11: Total	53.0	100.0	93.5	6.6											.92**	.59**	.31**
12: Factor 1	33.6	100.0	93.7	7.1												.31**	.17*
13: Factor 2	20.0	100.0	88.9	13.3													.21**
14: Factor 3	60.0	100.0	97.4	6.3													

* $p < .050$, ** $p < .010$

Table 2: *Descriptive Statistics for the Component and Module Marks, and their Correlations with the Three Mathematical Factor Scores. All Marks are Percentages.*

		Descriptive statistics		Correlations		
		Mean	SD	Basic mathematical ability	Understanding the language of maths	Interpretation of graphical information
Year One	Weekly quizzes	83.16	11.96	.100	.014	.093
	Critical thinking assignment	59.56	7.58	.078	.110	.095
	Lab report 1 (chi square)	59.72	8.40	.110	.106	.168*
	Lab report 2 (t test)	58.46	10.01	-.005	.010	.048
	Lab report 3 (correlation)	58.10	9.63	.019	.000	-.012
	Exam	62.59	6.52	.058	.086	.199**
	Module mark	63.20	5.52	.086	.087	.183**
Year Two	Weekly quizzes	70.73	14.93	-.009	.034	.022
	Lab report 1 (ANCOVA)	60.65	8.08	.071	.071	.109
	Lab report 2 (ANOVA)	61.42	8.33	.060	.061	.032
	Lab report 3 (Regression)	61.58	9.70	.056	.023	.023
	Exam	60.46	9.54	.035	.082	.100
	Module mark	62.73	7.31	.051	.079	.088
Year Three	Contribution	78.13	14.01	-.046	-.097	.056
	Write up	66.87	7.69	.114	.038	.086
	Module mark	68.08	7.61	.090	.015	.090

* $p < .050$, ** $p < .010$

Table 3: *Zero Order Correlations Between the Different Types of Assessment Above the Diagonal, and Partial Correlations Controlling for Mathematical Ability Below the Diagonal.*

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Year One	1: Weekly quizzes	-	.22**	.41***	.44***	.35***	.34***	.65***	.42***	.39***	.42***	.39***	.33***	.55***	.24***	.36***	.37***
	2: Critical thinking assignment	.21**	-	.27***	.32***	.26***	.21**	.45***	.12	.36***	.31***	.27***	.20**	.36***	.16*	.33***	.33***
	3: Lab report 1 (chi square)	.40***	.25***	-	.39***	.31***	.26***	.56***	.27***	.42***	.28***	.35***	.35***	.45***	.16*	.34***	.34***
	4: Lab report 2 (t test)	.44***	.32***	.39***	-	.53***	.29***	.64***	.23**	.35***	.38***	.34***	.34***	.46***	.25***	.44***	.45***
	5: Lab report 3 (correlation)	.36***	.26***	.32***	.54***	-	.29***	.60***	.30***	.42***	.42***	.39***	.29***	.48***	.23**	.39***	.40***
	6: Exam	.33***	.19**	.23**	.28***	.30***	-	.83***	.31***	.38***	.34***	.28***	.41***	.47***	.12	.30***	.30***
	7: Module mark	.67***	.44***	.54***	.65***	.61***	.83***	-	.42***	.56***	.52***	.47***	.51***	.68***	.26***	.50***	.50***
Year Two	8: Weekly quizzes	.42***	.12	.27***	.23**	.30***	.31***	.43***	-	.44***	.46***	.38***	.31***	.57***	.22**	.22**	.25***
	9: Lab report 1 (ANCOVA)	.38***	.35***	.41***	.35***	.42***	.37***	.55***	.44***	-	.53***	.45***	.41***	.69***	.19**	.39***	.40***
	10: Lab report 2 (ANOVA)	.42***	.30***	.27***	.38***	.42***	.34***	.52***	.46***	.53***	-	.52***	.34***	.66***	.14*	.40***	.39***
	11: Lab report 3 (Regression)	.39***	.26***	.35***	.34***	.39***	.28***	.47***	.38***	.45***	.52***	-	.43***	.74***	.19**	.34***	.34***
	12: Exam	.33***	.18**	.34***	.34***	.30***	.40***	.50***	.31***	.40***	.34***	.43***	-	.83***	.15*	.39***	.38***
	13: Module mark	.54***	.31***	.44***	.46***	.48***	.47***	.67***	.57***	.68***	.66***	.74***	.83***	-	.24***	.49***	.49***
Year Three	14: Contribution	.24**	.17*	.16*	.25***	.24**	.12	.26***	.22**	.20**	.15*	.19**	.15*	.25***	-	.39***	.55***
	15: Write up	.35***	.32***	.32***	.44***	.40***	.29***	.49***	.22**	.38***	.40***	.39***	.39***	.49***	.40***	-	.98***
	16: Module mark	.36***	.33***	.32***	.45***	.41***	.29***	.50***	.25***	.39***	.39***	.34***	.38***	.49***	.55***	.99***	-

* p < .050, ** p < .010, *** p < .001

Table 4: *Summary of the Regression Analyses, Using Mathematical Ability to Predict Performance in Research Assignments and Modules.*

		Overall model			Basic mathematical ability			Understanding the language of maths			Interpretation of graphical information		
		R^2	*F*	*p*	B	*t*	*p*	B	*t*	*p*	B	*t*	*p*
Year One	Weekly quizzes	.017	1.20	.309	0.16	1.33	.186	-0.03	-0.45	.651	0.16	1.19	.235
	Critical thinking assignment	.019	1.36	.257	0.04	0.56	.576	0.05	1.14	.257	0.09	1.02	.310
	Lab report 1 (chi square)	.038	2.75	.044	0.08	0.96	.340	0.04	0.77	.444	0.19	2.09	.038
	Lab report 2 (t test)	.003	0.18	.913	-0.02	-0.20	.846	0.01	0.06	.951	0.08	0.70	.484
	Lab report 3 (correlation)	.001	0.04	.989	0.03	0.31	.760	-0.01	-0.05	.958	-0.02	-0.21	.837
	Exam	.042	3.03	.030	0.01	0.19	.847	0.02	0.59	.555	0.19	2.69	.008
	Module mark	.038	2.74	.044	0.04	0.65	.519	0.02	0.53	.600	0.15	2.40	.017
Year Two	Weekly quizzes	.002	0.13	.943	-0.05	-0.32	.752	0.04	0.50	.615	0.04	0.25	.800
	Lab report 1 (ANCOVA)	.002	1.13	.336	0.05	0.60	.549	0.02	0.53	.599	0.12	1.33	.186
	Lab report 2 (ANOVA)	.006	0.41	.745	0.05	0.60	.551	0.03	0.61	.544	0.02	0.23	.821
	Lab report 3 (Regression)	.003	0.23	.874	0.07	0.72	.476	0.01	0.05	.957	0.02	0.20	.844
	Exam	.014	1.00	.401	0.01	0.01	.990	0.05	0.87	.386	0.13	1.23	.219
	Module mark	.012	0.85	.467	0.02	0.29	.774	0.03	0.79	.430	0.08	1.03	.304
Year Three	Contribution	.002	1.14	.333	-0.05	-0.37	.711	-0.11	-1.45	.150	0.18	1.17	.243
	Write up	.018	1.26	.289	0.11	1.46	.147	-0.01	-0.12	.902	0.09	1.00	.302
	Module mark	.015	1.04	.377	0.09	1.17	.242	-0.02	-0.38	.703	0.10	1.16	.247