

The influence of prior experience with mathematics and A-Level science subjects on statistics anxiety in undergraduate psychology students

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Abstract

Statistics is a core subject in the psychology undergraduate curriculum and is often associated with increased anxiety among learners. The aim of this study was to identify factors relating to statistics anxiety, and specifically, how prior experiences in mathematics and A-Level science qualifications may influence students' perceptions as they begin their undergraduate course. Four hundred and eighty-seven first year psychology students filled in an online survey with a range of quantitative and qualitative measures. Number of science A-Level subjects studied at school was a significant negative predictor of interpretation anxiety, and a positive predictor of perceived worth of statistics and perceived self-concept. Students without a mathematics qualification felt at a disadvantage in studying statistics in their degree overall and compared to their peers. Findings provide key insights into students' specific concerns and highlight the benefits of studying science subjects in secondary education prior to a psychology undergraduate degree.

Keywords: statistics anxiety, A-Level qualifications, experience in mathematics

The influence of prior experience with mathematics and A-Level science subjects on statistics anxiety in undergraduate psychology students

The British Psychological Society (BPS), which acts as the accrediting body for psychology courses in the United Kingdom (UK), considers research methods and statistics a core subject pertaining to different areas of psychology (BPS, 2019). Knowledge and skills gained in research methods and statistics modules can be applied across the psychology curriculum. Statistical literacy is not only important for degree success but also key for a number of career pathways for psychology graduates (BPS, 2019; Chew & Dillon, 2014; Quality Assurance Agency [QAA], 2018). Students enrolled on psychology courses are often not aware of how much of a role statistics plays in their degree in terms of breadth and weighting (Hulme & Kitching, 2013). In fact, findings suggest that as low as 47% of incoming students are aware of this aspect of their studies (Ruggeri et al., 2008).

Statistics courses are often associated with increased anxiety levels among learners, especially in non-mathematical disciplines such as psychology (Hanna et al., 2008; Macher et al., 2015; Onwuegbuzie & Wilson, 2003; Ruggeri et al., 2008). Statistics anxiety has previously been linked with procrastination around academic work (Onwuegbuzie, 2004; Paechter et al., 2017), the adoption of less effective learning strategies when engaging with the subject in an academic context (Baloglu et al., 2017; Macher et al., 2011), and reduced academic performance (Macher et al., 2013, Paechter et al., 2017). Given these findings, in order to effectively address and target statistics anxiety in our psychology undergraduate population, we need to assess the factors that may influence students' experience of statistics anxiety at the beginning of their student journey, as they transition to their university course. This study explores the nature of attitudes and anxiety towards statistics in undergraduate students at the early stages of their psychology course, and how prior academic qualifications in secondary education influence student perceptions.

Statistics Anxiety

Statistics anxiety has been defined as

a negative state of emotional arousal experienced by individuals as a result of encountering statistics in any form and at any level; this emotional state is preceded by negative attitudes toward statistics and is related to but distinct from mathematics anxiety (Chew & Dillon, 2014, p. 199)

The Statistics Anxiety Rating Scale (STARS; Cruise et al., 1985; Hanna et al., 2008; Bourne, 2018) is perhaps the most widely used measure of the construct. Although originally developed to solely measure statistics anxiety, more recently researchers have argued that STARS includes a measure of attitudes towards statistics in addition to the statistics anxiety measure (Papousek et al., 2012). The first three subscales of the STARS (interpretation anxiety, test and class anxiety, and fear of asking for help) are conceptualised as measuring statistics anxiety, and the last three subscales (worth of statistics, computational self-concept, and fear of statistics teachers) assessing attitudes towards statistics.

Factors Influencing Statistics Anxiety

Antecedents of statistics anxiety have previously been divided into situational, dispositional, and environmental (Onwuegbuzie & Wilson, 2003). Situational antecedents typically include factors that surround the stimulus or situation (e.g., prior knowledge of the subject, learning environment, teaching methods, teaching style, Chew & Dillon, 2014; Neumann et al., 2013); dispositional antecedents include individual characteristics, such as attitudes towards statistics, and motivation; and environmental factors include events that have occurred in the person's past. Cognitive factors, such as attention, strategy execution, and language processing have also been identified as having an influence on statistics anxiety (Cui et al., 2019).

Perceptions and Abilities in Mathematics as Predictors of Statistics Anxiety

Students taking statistics courses within a non-mathematical discipline often report challenges and worries around the actual and anticipated mathematical component of their course.

Generally, students entering a psychology course are less likely to have a strong background or interest in statistics, which can pose a challenge for both students and educators (Bourne & Nesbit, 2018).

A number of mathematics-related factors have been associated with statistics anxiety. These include students' prior knowledge, experience, and achievements in mathematics courses. Research has shown that students report higher levels of statistics anxiety as a result of the absence of knowledge in mathematics, poor achievement or a negative experience in previous mathematics courses, and having a fear towards mathematics (Lalayants et al., 2012; Mcgrath et al., 2014). Success in mathematics subjects in secondary education is related to more positive attitudes towards statistics and lower reported levels of statistics anxiety (Chiesi & Primi, 2010). Similarly, having background knowledge in mathematics is linked to more positive attitudes towards statistics and lower reported levels of statistics anxiety (Abad et al., 2015; Malik, 2015).

Studies have also sought to explore the link between ability in mathematics and performance in statistics-related components of individuals' degree program. Huws et al. (2005), for example, found no link between students' GCSE (a qualification obtained by individuals in secondary education before moving on to Advanced, or A-Level, qualifications) maths grades and their degree classification. Bourne (2018) developed a test related to the mathematical skills that a psychology undergraduate student would need in their course in order to assess how mathematical ability relates to performance in a range of assessments in research methods across a psychology degree. The test covered interpretation of mathematical information, procedural aspects, such as equations, and semantics of mathematics, such as symbols. Findings showed only one aspect of mathematical ability, namely interpreting graphs, was related to performance of some of the components of year 1 assessments, but not in subsequent years of the course.

These findings suggest that maths understanding may have limited impact on academic performance in research methods and statistics components of an individual's undergraduate

degree. Statistics may require knowledge and application of basic maths concepts, however, in areas such as psychology, the way in which this is applied in practice is mostly in terms of reasoning and drawing conclusions based on available data (Paechter et al., 2017). Given these findings, and previous studies suggesting a link between prior experiences in mathematics and statistics anxiety, further research is needed to explore the influence that prior experience in mathematics may have on statistics anxiety. Given the vast range of experiences and qualifications that students have upon entering a psychology undergraduate degree, in terms of subjects studied at A-Level, it is important to explore this further. A-Levels qualifications focus on academic subjects that pupils study at the later stages of their secondary education in order to gain entry into higher education or the workplace.

Entry requirements to undergraduate psychology courses in the UK often do not include a prerequisite of mathematics qualifications beyond GCSE level (or equivalent). At A-Level, mathematics can be taken as a single subject. In addition, A-Level subjects which are classified as science subjects are also required by the UK Government to incorporate a maths component into the subject's syllabus. Exemplar science subjects include biology, chemistry, and physics (Department for Education, 2014). Emphasis is placed on mathematical knowledge and ability as a learning outcome in science subjects to the extent that examining these skills can constitute between 30-45% of the assessment grade for each respective science A-Level (Department for Education, 2022).

Students studying a psychology degree are not typically required to have studied a set number of science-related subjects in secondary education. Given the link between perceived or actual mathematical ability and statistics anxiety, it is important to try and identify which aspects of this prior experience contributes to students' experience of statistics anxiety. This can provide an evidence-base to help educators develop a learner profile of incoming students and add a further element of support in cohorts where statistics anxiety is often prevalent. This can also inform the design of interventions that will help to lessen this initial source of anxiety and support students'

transition to university, their academic development, and their learning experience. A positive transition experience to university can lead to a stronger sense of belonging at the university, retention, a more positive learning experience, wellbeing and confidence among learners (McPherson et al., 2017).

Aims and Objectives of Present Investigation

Previous research has demonstrated a link between prior experiences in mathematics and statistics anxiety at university. However, a question still remains as to the nature of this experience and how it may influence students' perceptions and attitudes. In the present study, prior experience in mathematics was conceptualised as a) having taken mathematics as an individual A-Level subject, and b) having studied science subjects at A-Level. As previously seen, science subjects are expected to incorporate a mathematics component (Department for Education, 2022), therefore, the presence of science subjects studied at A-Level was used as an additional measure of mathematics-related experience in the present investigation.

This study adds to the existing literature by adopting a mixed-methods approach of qualitative and quantitative measures to investigate the nature and predictors of statistics anxiety in incoming undergraduate students at the beginning of their studies. Incorporating a qualitative research aspect in our approach will provide further insights into the nature and sources of worry around statistics and to identify students' expectations and potential misconceptions around the study of research methods and statistics. The qualitative element of our study will enable us to identify specific concerns which may not always be evident from quantitative measures and make recommendations for strategies to support students in the transition to their studies and the student learning experience.

Based on prior research we predict that the more experience students have in mathematics upon entering higher education, the less anxiety they will experience around statistics at the start of their undergraduate studies.

Method

Participants

A convenience sample of 487 participants completed the study; participants were recruited from two first year undergraduate student cohorts enrolled onto a compulsory statistical methods module as part of their undergraduate psychology degree. Their mean age was 18.32 years ($SD = 1.12$). Four hundred and seventeen participants identified as female, 66 as male, and 3 as non-binary. Three hundred and seventy-nine students (77.8%) reported having no maths qualification, 104 (21.4%) reported having an AS or A-Level in mathematics, and four (0.8%) did not specify whether they had studied maths or not. With regards to science qualifications, eight (1.6%) had none, 193 (39.6%) had one, 169 (34.7%) had two, 95 (19.5%) had three, three (0.6%) had four, and 19 (3.9%) did not specify their A-Level subjects. The study received ethical approval from the authors' institution (Ref. F1084) and informed consent was obtained from participants prior to participation.

Measures

A survey was developed and distributed to students using Qualtrics, an online survey platform that stores surveys and data collected from participants. The following measures were included in the survey.

Demographic variables

Participants were asked to report their age and gender.

Prior experience with mathematics

Participants were asked to report whether they studied mathematics at A-Level, or equivalent. We also asked participants which other subjects they had studied at A-Level in

an open-ended question. Including the latter question would enable us to classify responses into science vs non-science subjects.

Statistics Anxiety Rating Scale (STARS)

The STARS scale (Hanna, 2008) is a 51-item scale that measures a person's levels of anxiety (23 items) or their attitudes (28 items) towards statistics. STARS comprises of six subscales, three each for anxiety and attitudes respectively. The three anxiety subscales measured are test anxiety (eight items), interpretation anxiety (11 items), and fear of asking for help (four items). The three attitudes subscales measured are worth of statistics (16 items), fear of statistics teachers (five items), and computational self-concept (seven items). Scores for each item in the survey range from one to five; a score of one indicates that an individual experiences *no anxiety* or *strongly disagrees* with a STARS item, whilst a score of five indicates that an individual either experiences *strong anxiety* or *strongly agrees* with a STARS item. Subscale scores are then calculated by averaging the relevant items, such that subscale scores can then range from 1 to 5. Higher scores on anxiety subscales reflect higher statistics anxiety, whilst higher scores on attitude subscales reflect more negative attitudes towards statistics. Means and standard deviations for subscale scores, as well as Cronbach α scores, can be found in Table 1.

Table 1

Descriptive and internal consistency data for STARS subscales

Subscale or single item measure	Total subscale mean (SD)	Item Mean(SD)	Cronbach's α	Number of missing cases
Test anxiety	28.77 (5.33)	3.6 (0.65)	0.8	2

Interpretation	30.13 (7.36)	2.75	0.85	2
anxiety		(0.66)		
Fear of asking for	10.3 (3.61)	2.58	0.82	2
help		(0.89)		
Worth of statistics	35.54 (10.54)	2.22	0.92	14
		(0.66)		
Fear of statistics	9.75 (3.33)	1.95	0.73	15
teachers		(0.67)		
Computational self-	19.76 (6.75)	2.83	0.89	13
concept		(0.96)		

Open-ended questions

Participants were asked two open-ended questions where they could type in their responses. The first question asked participants what they were most worried about in relation to the statistics component of their degree. The second question focussed on what participants were most looking forward to in their first year statistics module. These two items were included in the survey to gain insights into students' expectations, prior experiences, and perceived challenges at the beginning of their undergraduate course.

Data analysis

Analysis of quantitative data

For the STARS questionnaire, subscale scores were not calculated where more than one item was missing for that subscale. The number of participants excluded due to missing

subscale scores ranged from 2 to 16 across all scales, with full missing data information available in Table 1. Where only one item was missing for a specific STARS subscale, mean item replacement was used, whereby the subscale mean for each individual participant was rounded to the nearest whole and imputed as missing data. This was so that the scores obtained would accurately reflect the range of possible responses that participant could have given.

To calculate the amount of science subjects a participant had completed at A-Level or equivalent, a list of subjects classified as science subjects were obtained from the websites of the UK's three main exam boards. These are Assessment and Quality Alliance (AQA), Edexcel, and Oxford, Cambridge, and RSA (OCR). Additionally, the admission requirements for the undergraduate psychology course the participants were admitted on to was checked to assess whether any additional subjects could be added to this list. Based on this, participants were deemed to have taken a science subject if they had taken the following subjects: psychology, biology, chemistry, physics, environmental science, geography, or geology. The total amount of science subjects taken was then calculated and added to the remaining data for the purposes of analysis.

Data were analysed using multiple regression analyses in IBM SPSS version 27. For each of these regressions, STARS total subscale scores was an outcome variable, whilst the number of science subjects and whether a participant had a maths qualification acted as predictor variables. Previous experience with Maths was a categorical variable with two levels. Having Maths A-Level or international equivalent was dummy coded and compared to no maths qualification as a reference category.

Analysis of qualitative data

The data from the two open-ended questions were analysed by means of inductive thematic analysis. We made the decision to take a more exploratory approach in the analysis of the qualitative data, despite the growing body of literature in statistics anxiety and the inclusion of the STARS measure in our study. Doing so would provide the opportunity to identify prevalence and sources of anxiety in our sample, without fitting the data into pre-existing categories and, thus, allowing us to gain in-depth insights into attitudes and worries towards statistics. The analysis of qualitative data was performed by the first author; the coding and resulting themes were thoroughly discussed between both authors resulting in the development of the final set of themes.

The data was analysed using the six-step process of thematic analysis developed by Braun and Clarke (2006; 2012) with an essentialist/realist epistemological standpoint, as the focus was on students' experiences and the meanings around those experiences. The analysis began with familiarisation of data by repeatedly reading through the responses to the open-ended questions. This was followed by initial coding, where the first author coded extracts from participants' narratives. Semantic coding was applied, where codes reflected a summary of the ideas presented in the data, rather than the coding reflecting underlying meanings in participants' responses. Initial coding was followed by refining and collating the codes, whereby duplicate codes or instances where more than one code reflected the same idea were removed, resulting in a list of a final set of codes that were then used in the development of themes. Initial themes were developed by grouping codes which reflected similar ideas together into a broader category or theme. Themes were reviewed and evaluated to ensure that the codes within each theme cohere together meaningfully, and that each theme captured distinct ideas from other themes, therefore, ensuring no overlap between the themes conceptually. Names were then developed for the resulting themes

capturing the essence of the theme, followed by a selection of quotations from participants' responses which were used as evidence for the prevalence and content of themes. The themes developed in the analysis are presented below, together with selected quotations from participants' responses.

Findings

Predictors of anxiety and attitudes

Results from the regression analyses suggested that all models created, apart from fear of asking for help and fear of statistics teachers, were significantly better at predicting anxiety and confidence levels compared to using the mean. The amount of variance in each model explained by maths qualification status and the number of science subjects ranged from 1% (fear of statistics teachers and fear of asking for help) to 16.5% (self-concept). Having a maths-specific qualification acted as a significant negative predictor of statistics anxiety in all significant models, and as a positive predictor of confidence. Additionally, the number of science subjects held by participants acted as a significant negative predictor of interpretation anxiety ($p = .014$), worth of statistics ($p = .011$), and self-concept scores ($p < .001$). This meant that a greater number of science subjects studied at A-Level was associated with lower interpretation anxiety, a greater perceived worth of statistics, and greater computational self-concept. All beta values, along with indicators of statistical significance, can be found in Table 2.

Table 2

Regression models for STARS subscales with maths qualification and number of science subjects at A-Level or international equivalent as predictors

	<i>R</i> ²	<i>b</i>	<i>SE b</i>	<i>t</i>
Test Anxiety	0.06***			
Intercept		30.3	0.56	52.65***
Maths qualification		-2.29	0.64	-3.6***
Number of science subjects		-0.63	0.32	-1.95
Interpretation Anxiety	0.06***			
Intercept		32.62	0.8	41.03***
Maths qualification		-2.85	0.88	-3.24***
Number of science subjects		-1.1	0.44	-2.48*
Fear of asking for help	0.01			
Intercept		10.94	0.4	27.15***
Maths qualification		-0.54	0.45	-1.2
Number of science subjects		-0.28	0.23	-1.23
Worth of statistics	0.07***			
Intercept		39.39	1.16	33.92***
Maths qualification		-4.68	1.3	-3.6***
Number of science subjects		-1.65	0.65	-2.54*

	<i>R</i> ²	<i>b</i>	<i>SE b</i>	<i>t</i>
Fear of Statistics	0.01			
Teachers				
Intercept		10.21	0.38	27***
Maths qualification		-0.19	0.42	-0.45
Number of science subjects		-0.27	0.21	-1.26
Computational self-concept	0.165***			
Intercept		23.44	0.71	33.24***
Maths qualification		-4.83	0.79	-6.13***
Number of science subjects		-1.52	0.4	-3.85***

Note. * $p < .05$; ** $p < .01$; *** $p < .001$

Findings from the thematic analysis

Two themes were developed capturing students' perceptions around the research methods and statistics component of their undergraduate psychology course: a) 'Maths is my weakness', with two subthemes – 'gaps in knowledge and prior challenges' and 'progress and performance'; and b) 'Motivations around engagement'. These are presented below, together with selected quotations from participants' responses.

'Maths is my weakness'

This theme captures the prevalence and nature of anxiety that students face when starting their undergraduate psychology degree.

Gaps in knowledge and prior challenges. A substantial source of worry for students was around the knowledge and skills they brought with them to university, relating to mathematics specifically. Students spoke about gaps in their knowledge in mathematics at the start of their studies. A number of students put this down to not having studied the subject at A-Level. They, therefore, felt that this placed them at a disadvantage, as they did not feel they had sufficient prior or background knowledge in the subject before embarking on the statistics methods component of their course. Others spoke about the large gap in time between studying mathematics at GCSE and studying statistics at university, therefore they felt they were lacking recent experience in the subject.

“Struggling with maths as I have not studied it in a while ...” (Participant B16).

A further source of worry centres around prior challenges experienced when previously studying mathematics. Some students commented that they struggled with mathematics when they studied the subject previously (e.g., at GCSE) in the time it took for them to understand the subject or with their understanding overall. Some mentioned that they struggled with aspects of statistics when this was covered at A-Level.

“[Worry] that I won't be able to keep up and get the right answers to the questions, especially the statistical tests which I struggled with a lot whilst doing A-Level Biology,

Psychology and Geography” (Participant B95).

Progress and performance. This subtheme captures students' perceptions and expectations around their progress and performance in their introductory module of research methods and statistics.

A great majority of students commented that the anticipated mathematics element of their introductory statistics course was a substantial source of worry. The presence, complexity, or volume of equations and formulas they would encounter on the course was also a concern to some students. Other students mentioned anxiety around statistical testing, such as choosing the appropriate statistical test in a given context, running the test using statistical software, and interpreting findings. Some also commented that they anticipated understanding the theory behind the statistical tests to be challenging, and falling into the habit of simply memorising the method associated with running the tests . The objectivity associated with statistics and having a right or wrong answer was also worrying to some students, as was the possibility of getting it wrong.

“The fact that I'm unsure how much maths is actually involved in the component and whether we will need to be naturally really strong and confident at maths” (Participant A106)

“Hypotheses and statistical testing. Finding it difficult to identify which statistical test to use and apply to my data, and remember all of their names” (Participant A154)

“Understanding the meaning behind how processes like hypothesis testing work, as opposed to just memorising the method of what to do” (Participant A103)

Students also wrote about their perceptions and expectations around the learning of the subject in their responses. Perceived difficulty of the subject was identified in responses, with the vast majority commenting that they would find it hard to study statistics. Some students also expressed their worries around not being able to understand the content despite the level of efforts that they would put in this. Concerns around the anticipated

workload and effort required in the subject was a further source of worry for students; some felt that it would take them a significant amount of time to understand the content.

“Appears to not only be a high mathematical understanding of interpreting and manipulating data, but seems as though I will be expected to put a lot of time and work into understanding it also” (Participant A104)

“I worry that I won't understand an aspect of the course and will have to spend a lot of time trying to comprehend it. I think I will be able to understand it eventually, I'm worried it'll take a long time” (Participant A107)

Not being able to properly understand and learn the content of the module would lead to feeling overwhelmed and anxious about their progress in the module and how this may impact on their overall course grades. With regards the assessment students expressed concerns around answering maths-related questions, interpreting assessment questions correctly, and their ability to remember equations and other content, as some students anticipate that they would not understand and learn this content to a sufficient level to be able to perform well in the exam. Students also commented that not being able to understand the content would then put them in a position where they would need to seek support from teaching staff on a regular basis.

“[Worried] that I just don't get it and end up failing the module as maths has never been my strong suit at school or since leaving school” (Participant A124)

“I'm worried I will get lots of the statistics muddled up and not be able to complete the exams accurately and correctly” (Participant B159)

“... I am nervous this module will pull my overall year percentage down. I am also worried about having to constantly ask for help and assistance which will frustrate lecturers and

peers - particularly within the first few weeks while I am getting used to numbers again"

(Participant B184)

In addition to worrying about being able to keep up with the content covered in the statistics course, students also worried about their progress and performance in comparison to their peers. Some students felt that they would not learn the content at the same pace as everyone else, therefore, they would fall behind their peers. Others also commented that they felt that the majority of their peers would have substantially more experience around mathematics or statistics compared to them and feared that they would be the only person not understanding the content. This may also reflect students' perceptions around the different levels of prior experiences between themselves and others on the course.

"getting stuck, not understanding while everyone else does which would then make me embarrassed to ask for help as I would feel as I'm moving at a slower pace compared to my peers" (Participant B149)

"A-Level maths students having an advantage and I end up falling behind" (Participant B60)

"A-Level... this will all be very new to me whereas for other students they may have been taught it first so would be familiar with this content so I would automatically be behind"

(Participant B198)

Motivations around engagement

This second theme captures students' motivations and expectations around studying research methods and statistics in their first year of their undergraduate studies. Developing the ability to analyse, interpret, and report data, and draw conclusions based on data, as well as the ability to successfully and accurately apply the knowledge they gain were some of the more commonly reported motivators of engagement for students. The vast number

of participants in our sample spoke about statistics, and mathematics in particular, in more negative terms, in terms of generally not enjoying the subject or the fact that this was not their strongest subject. However, responses suggest that some students in our undergraduate sample expressed a liking towards or feeling comfortable with the subject. Students also commented that engaging with the content of the module would help them develop confidence in this subject area. Some students also commented that a motivating factor in engaging with the module was to overcome their anxiety associated with statistics, to develop a liking for the subject but also potentially having a feeling of accomplishment when they have successfully learnt and understood the content and performed well in the module.

“Seeing what data shows and whether it supports the claims, also seeing how important statistics is in empirical research” (Participant A18)

“If I am able to successfully understand the statistical module, I will feel confident in my own abilities as personally I find maths and knowing what tests to apply in what situations a tricky task. Hopefully these skills will then aid me in the future” (Participant A147)

“Actually learning how to do statistics properly and enjoy maths again” (Participant B274)

A number of participants also spoke about the value of statistics, and the relevance and application of this knowledge beyond their statistics module. Learning about statistics would enable students to apply this knowledge to real life experiments and to be able to draw conclusions based on data obtained in their own research studies and those seen in the literature, such as enhancing their ability to understand and evaluate statistics-related information seen in journal articles. Some students also commented that knowledge of statistics would be useful for their future career.

“Being able to confidently assess experimental data after completing the module as being able to understand statistical data is paramount for all areas of psychology” (Participant B258)

“I am looking forward to understanding more about statistics and also be able to link to other areas of my course” (Participant B291)

“Developing a better understanding of how to read the numerical results of psychological studies online” (Participant A59)

Discussion

The current study aimed to explore the prevalence and nature of statistics anxiety in a sample of undergraduate psychology students, and additionally, the ways in which previous experience may impact the feelings students have when transitioning to research methods and statistics modules as part of their undergraduate psychology course. Analysis of quantitative data suggested that whilst a maths qualification significantly reduces statistics anxiety, a larger number of science subjects studied at A-Level was associated with reduced levels of interpretation anxiety, increased perceived worth of statistics, and increased levels of computational self-concept. Additionally, findings from the qualitative data in our survey highlighted the ways in which students without a maths qualification felt themselves to be at a disadvantage compared to their peers. These findings not only provide more insight into the specific concerns of students beginning an undergraduate statistics module, but also highlights the benefits of studying science subjects prior to commencing an undergraduate psychology degree and undertaking university level statistics courses.

The findings that having a maths qualification at A-Level was a negative predictor of statistics anxiety supports previous literature on the relationships between maths qualifications, statistics anxiety, and performance on statistics modules (Chiesi & Primi, 2010; Nasser, 2004; Paechter et al., 2017; Tremblay et al., 2000). The qualitative findings expand on the literature by highlighting the consequences this may have for those without a maths qualification. The theme of 'maths is my weakness' suggests that those without a maths A-Level perceive themselves to be at a disadvantage compared to their peers. This indicates that upward comparisons are being made in this context (Wheeler, 1966), which can be a beneficial or detrimental process depending on the context. Whilst literature into student populations suggests that upward comparisons can lead to lower levels of confidence and self-concept (Muller-Karhoff & Moller, 2017; Pulford et al., 2018), other findings suggest these comparisons can inspire students to perform better in assessments (Blanton et al., 1999). Our findings therefore contribute to the literature on the detrimental consequences of making upward comparisons.

From a practical perspective, it may be useful for those teaching statistics to inform students about how maths qualifications may affect performance on statistics modules. Previous research shows a link between mathematical ability and performance in statistics; however this relationship can heavily depend on context. Research on the relationship between mathematical ability and statistics performance suggests that this link exists within an examination context as opposed to other methods of assessment such as laboratory reports. Furthermore, this effect is not present at later, arguably more important stages of the degree (Bourne, 2018). Making students aware of this and research into upward comparisons when they begin statistics modules could help to demystify some of the self-perceptions that students make when making these upward comparisons, and potentially

reduce statistics anxiety. However, it is also worth noting that the current study's effect sizes indicate that for some subscales, having a maths qualification may only reduce anxiety by a small amount. For example, an intercept of 30.3 for test and class anxiety indicates that no maths qualification predicts an individual item rating of 3.79, whilst a coefficient of -2.29 indicates that having a maths A-Level only reduces individual item averages to 3.5. Thus, reminders of the relationship between statistics anxiety and performance may still be helpful in reducing statistics anxiety for students with a maths A-Level, even if they may not be making the same upward comparisons.

The findings also demonstrate the influence of science subject at A-level on students' attitudes towards statistics. Not only was there reduced anxiety associated with interpreting data, but those with more science subjects also reported greater levels of self-concept and greater worth of statistics as a subject. This may be due to the requirements for science subjects to contain a mathematical component to them as outlined by the Department for Education (Department for Education, 2014). Whilst this requirement exists for science education in the UK, the content and level of assessment of mathematical components differs across A-Level subjects. For example, AQA state that at least 10% of assessment marks measure mathematical competency and that students could be asked to choose and conduct relevant inferential tests (AQA, 2021), whilst chemistry A-Level assessments allocate at least 20% of marks to mathematical competency, without testing the ability to choose or conduct inferential tests (AQA, 2015). Nonetheless, if a student covers science subjects without also studying maths, then may well have some exposure to mathematics and the use of data within the context of drawing real-world conclusions. Therefore, this may contribute towards feeling more reassured at the prospect of studying statistics at a higher level. To our knowledge, this possibility has not been discussed in

previous research and could lead to practical recommendations from an admissions perspective. If at the application stage students are made aware of the advantages of having science A-Levels for the statistics components of their degree, then this may help increase confidence and positive attitudes in future cohorts as they begin such modules.

However, these recommendations do not help those who do not have science-related experience at A-Level, prior to attending university. The question is then, for students who fit into this category, how do we support them at the beginning of a statistics and research methods module in terms of perceptions around the subject and in tackling levels of statistics-related anxiety? The answer to this may lie in the motivational theme captured in our qualitative analysis. Within this theme, students noted that taking part in the module would not only develop their knowledge, but also allow them to feel accomplished if they were able to overcome their anxieties and increase their confidence. Literature on motivation consistently demonstrates a negative correlation between confidence and statistics anxiety (Macher et al., 2012; Nasser, 2004; Tremblay et al., 2000); moreover, it is also known that increased intrinsic motivators, such as those highlighted in our results, is positively associated with levels of statistics engagement and achievement (Gonzalez et al., 2016). Thus, using strategies to increase student motivation may help to subsequently reduce anxiety and potentially increase levels of achievement. Such strategies could include highlighting the extrinsic and intrinsic benefits of making it through a statistics module, or use self-assessment toolkits throughout the semester as part of the module's summative assessment (Ferland et al., 2022).

These findings provide important insight into the ways in which we could support students transitioning from secondary school to statistics-related components of their

psychology course in Higher Education. However, there are some limitations that should be addressed. Firstly, in a similar fashion to Hanna et al.'s (2008) research, the current study's sample is limited to UK undergraduate psychology students. Since then, it has been noted that cross-cultural differences exist on the STARS subscales (Baloğlu et al., 2011). Whilst this research was limited to comparing Turkish and American samples, it is possible that further differences may exist in UK students. Thus, some of the recommendations made in this paper may not be as effective for all institutions. Additionally, it would be useful for further research to assess how qualifications affect statistics anxiety over the course of the degree, as well as whether these factors affect statistics performance during this same period. Due to the lack of relationship between maths qualification and statistics performance in later stages of a degree (Bourne, 2018), it is possible that similar relationships may exist in relation to the number of science qualifications or statistics anxiety.

In conclusion, the current study found that whilst having a maths A-Level may influence levels of statistics anxiety, the number of science subjects studied at A-Level was also associated with lower levels of aspects of statistics anxiety and more positive attitudes towards statistics. Furthermore, qualitative findings highlighted how students may be particularly anxious about perceived gaps in knowledge but may also recognise the motivational benefits to studying statistics. Taken together, these findings provide theoretical implications on how upwards comparisons function in statistics modules. They also enable us to make some practical recommendations on ways in which statistics anxiety could be addressed when students are applying for degrees with statistics, as well as ways in which we could support students as they begin their research methods and statistics modules.

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