Predictors of numeracy performance in undergraduate psychology, nursing and medical students

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Introduction

Numeracy is commonly defined as the ability to understand and use numbers in everyday life (e.g. Rothman, Housam, Weiss, et al, 2006). It is strongly context dependent (FitzSimons, 2002), meaning that what is classed as numeracy might be different for, as an example, a bank clerk compared to a statistician. Many academic degrees contain a substantial numeracy component, even if they themselves are not mathematically-focused. Worryingly, many students strongly dislike this numeracy component, these negative experiences potentially leading on to poor numeracy performance (Phoenix, 1999). Such difficulties with numeracy have been evidenced in a range of academic pathways (e.g. Mulhern & Wylie, 2004; Tariq, 2003).

Psychology, nursing and medicine, in particular, are subjects that require students to be numerate for their degrees. For psychologists, numeracy is necessary for a competent understanding of statistics. The Quality Assurance Agency for Higher Education (QAA) states, as a benchmark, that psychology students in the UK need to have, "A systematic knowledge of a range of research paradigms, research methods and measurement techniques, including statistical analysis," (QAA, 2007). For nurses and medics numeracy is related to tasks that are essential in their future occupational life, such as calculating drug dosages. Again, UK nursing and medical qualifying bodies view numerical ability as a pre-requisite for course completion (e.g. Higher Education Occupational Physicians / Practitioners, 2010; Nursing and Midwifery Council, 2008). The aim of this study was to create statistical models, specific to these three disciplines, that would help to illustrate and explain, at least in part, the combinations of variables (including affective, demographic and educational factors) responsible for causing poor numeracy performance in undergraduate students.

Mathematics Anxiety

Maths anxiety is generally defined in the literature as a feeling of tension, dread or fear that appears when a person is required to undertake some kind of task involving maths performance (Ashcraft, 2002). At university level, it can lead to students purposely avoiding subjects or modules that have a high maths content (e.g. Durrani & Tariq, 2009) and, post-university, taking a less than optimum career path (Durrani & Tariq, 2012). Previous research has suggested that females suffer from maths anxiety more than males (e.g. Maloney, Waechter, Risko & Fugelsang, 2012) although there is no consensus regarding this (e.g. Scafidi & Bui, 2010). Likewise, age appears to impact maths anxiety to some degree (e.g. Baloğlu & Koçak, 2006), with older university students having stronger levels of anxiety about exams and their numeracy-based course than younger students, but having less anxiety regarding the numerical tasks themselves.

A number of studies have illustrated the existence of a relationship between mathematics anxiety and numeracy performance in undergraduate students. Miller & Bichsel (2004) found that maths anxiety significantly predicted performance in both basic and applied maths tests. Literature reviews (e.g. Ashcraft & Moore, 2009) and additional research on different student populations (e.g. Loong, 2012; Núñez-Peña, Suárez-Pellicioni & Bono, 2013) have supported this relationship. In all of these cases, this relationship was a negative one, with anxiety reducing performance. However, it should be noted that some studies (e.g. Macher, Paechter, Papousek, et al., 2012) do show that aspects of anxiety can lead to improvements in numeracy performance.

While this research suggests the existence of a significant relationship between maths anxiety and maths performance, it is currently difficult to empirically infer a causal direction from most of these sources, with many studies basing their conclusions on bivariate correlations (e.g. Bull, 2009). Many researchers argue that fear and anxiety result in poor performance, while others suggest that poor performance leads to an increase in anxiety. Previous literature suggests that the former of the two arguments is the more likely. Hembree (1990), in a meta-analysis of the literature concludes that reductions in maths anxiety result in higher achievement, with treatment raising the performance of individuals with formerly high anxiety to performance levels associated with low maths anxiety. Hembree also points to a lack of relationship between maths anxiety, IQ and general ability, with initiatives designed specifically to improve student maths ability not resulting in any change in maths anxiety levels. Likewise, Ashcraft & Moore (2009) state that maths anxiety results in a level of working memory suppression, which inhibits numeracy performance, thus providing a clear, causal link. However, other research (e.g. Ma & Xu, 2004) suggests that this relationship is inverted (with performance predicting attitudes) or that it is non-existent (e.g. Eldersveld & Baughman, 1986).

Motivation, Usefulness and Confidence

Less research has been undertaken on additional mathematics-based affective variables, and how they might relate to numeracy performance. Fennema & Sherman (1976) suggested that, along with maths anxiety, confidence, motivation and perceptions on the usefulness of maths were important variables in the construct of maths attitudes. Confidence, in particular, has been linked to numeracy performance (e.g. Hoffmann, 2010; Pajares & Miller, 1994). Confidence and self-concept in maths are also related to maths anxiety (Tariq & Durrani, 2012) and seem to be predicted by gender, with males showing stronger levels of confidence than females (Pajares & Miller, 1994) and by age, with mature students being less confident about their maths ability than traditionally-aged students (i.e. students between the ages of 18 and 21) (Tariq & Durrani, 2012).

Motivation towards doing well in maths has been less thoroughly researched than confidence, but has still been linked to maths-based achievement (e.g. Núñez-Peña, Suárez-Pellicioni & Bono, 2013). Few empirical studies, however, have looked at whether perceptions on the usefulness of maths can predict performance, despite the fact that it is a common factor in numerous measures of maths attitudes and attitudes towards maths-related variables (e.g. Tapia & Marsh, 2004). Armstrong (1985) found there to be a relationship between perceptions of utility and performance, but no causal direction could be ascertained. Conversely, additional research (e.g. Pyzdrowski, Sun, Curtis, et al. 2013) found no links between usefulness (termed ‘subject value’) and numeracy performance.

Demographics

Many studies support the existence of a causal link between gender and numeracy performance, with females performing significantly worse than males (e.g. Martens, Hurks, Meijs et al, 2011; Mulhern & Wylie, 2005). However, such views are not unanimously shared, with other research demonstrating no differences (e.g. Lindberg, Hyde, Linn & Petersen, 2010; Scafidi & Bui, 2010) or, occasionally, stronger numeracy performance in female students (Elmore & Vasu, 1986). Research (e.g. Durrani & Tariq, 2009; Kargar, Tarmizi & Bayat, 2010) also shows that gender has a significant effect on maths-based, affective variables that predict numeracy, particularly anxiety and confidence, with females demonstrating much stronger negative affect compared to males. This suggests the possibility of both direct links between gender and performance, and indirect links via the affective variables.

Only a small number of studies have explored whether student age is a significant predictor of numeracy performance. Durrani & Tariq (2009) found that younger students expressed more confidence and competence in regard to maths than older students. In contrast, Payne & Israel (2010) found exactly the opposite – that older students did significantly better at a statistics course than younger students. Furthermore, a considerable number of studies show that student age has no significant main effect on performance in numeracy-based tasks at all (e.g. Roberts & Saxe, 1982; Zeidner, 1991).

Educational and family background

Considerable previous literature (e.g. Joyce, Hassall, Montaño & Anes, 2006; Tariq & Durrani, 2012) posits that previous mathematics educational background (i.e. highest previous mathematics qualification) has some significant effect on both numeracy-based attitudinal and performance-related variables. Núñez-Peña, Suárez-Pellicioni & Bono (2013) demonstrated that psychology students with a background in humanities were more likely to do worse on the numeracy-based component of their course, compared to those students with more quantitative backgrounds. Huws, Reddy & Talcott (2005) found that GCSE maths grades significantly predicted university grades; A-Level grades, however, did not. (GCSEs are compulsory exams undertaken by UK students at age 16 while A-Levels are non-compulsory exams taken by UK students at age 18, generally used as university admissions criteria.) Grandell-Niemi, Hupli, Puukka & Leimo-Kilpi (2006) and Hilton (1999), studying nursing students, found that those students with higher levels of previous education were more competent with numeracy than those with lower levels. Such findings, however, are not universal with Woodward & Galagdera (2006), for example, uncovering no significant relationship between course performance and previous maths qualification.

A number of studies have looked at factors related to family background (e.g. Ferry, Fouad & Smith, 2000) but never explicitly in the same way as it is defined in the current study. It is possible that a family background in maths could have a positive impact on performance if the student has a parent or sibling who requires some level of numeracy as part of their job, as the student might view numeracy as being more useful and less intimidatingly abstract. The student may, therefore, have more motivation to work harder at maths, as they would see numerical knowledge as being more beneficial and less challenging. It is hoped that the study reported in this article will provide support for this hypothesis.

In conclusion, the relationships between the factors that predict numeracy performance are complex and have not always been the subject of rigorous empirical research. Maths anxiety appears to predict numeracy performance while additional maths affective factors also predict performance directly, as well as indirectly through anxiety. Numeracy and the affective variables are themselves predicted, again both directly and indirectly, by demographic and educational variables. Many of these variables are, however, under-researched and no study has attempted to integrate all of these variables into a single model.

This study

This was an exploratory study with the aim of predicting numeracy performance in a sample of undergraduate psychology, medical and nursing students, as well as determining the relationships between the demographic, educational and affective predictor variables. In particular, anxiety was expected to predict performance, based on the considerable amount of previous research that has suggested this (e.g. Ashcraft & Moore, 2009; Núñez-Peña, Suárez-Pellicioni & Bono, 2013). It was also expected that the additional affective variables, as well as the demographic / educational variables, would significantly predict numeracy performance, either directly or indirectly.

Another aim of this study was to see if the factors that predicted numeracy performance changed between participant disciplines. These three particular groups were chosen because each group is quite different from the others in terms of educational qualifications needed for acceptance into the course. Also, one of the characteristics of numeracy is that it is context dependent (e.g. FitzSimons, 2002), and so what exactly constitutes numeracy differs between groups with psychologists viewing numeracy as statistics competency (Mulhern & Wylie, 2004), and nurses and medics viewing it as the ability to work with numbers in their occupational setting (Hutton, Coben, Hall et al., 2010; McQueen, Begg & Maxwell, 2009). As a result of these differences, it was expected that different patterns of results would be observed for each of the three groups.

In order to make comparisons between the different participant groups it was necessary to use the same set of attitudinal and performance measures on each group. This does not mean that the statistical ability required for the psychologists and the mathematical calculation ability required for the nurses and medics are being treated as the same. Statistics and mathematics are related but different disciplines (e.g. Mulholland & Jones, 1968; Zerbolio, 1989) that are, in this case, both encompassed by the overall definition of numeracy. Pilot work confirmed that the more mathematics-based attitudinal and performance measures used here were valid predictors of statistics performance for the psychology sample.

Four 'stages' of variables were used (see Figure 1). The overall criterion (endogenous) variable (Stage 1) was numeracy performance, Stages two and three consisted of additional endogenous variables that both predicted maths performance and were themselves predicted by the exogenous variables in Stage four. Stage two comprised solely of maths anxiety, which was expected to predict numeracy performance and, itself, to be predicted by the additional affective variables of motivation, usefulness and confidence. Stage three consisted of the additional three affective variables. These are found in the Fennema-Sherman Mathematics Attitude Scale (Fennema & Sherman, 1976), as well as other widely used measures of maths affect (e.g. Aiken, 1974; Tapia & Marsh, 2004).

While part of the same scale, maths anxiety was analysed separately from the additional affective variables as previous research has suggested that it is separate from other aspects of mathematics affect (e.g. Ahmed, Minnaert, Kuyper & van der Werf, 2012; Røykenes & Larsen, 2010). Additionally, pilot work for this study involved the creation of an alternative version of the model, where Stages two and three were combined, this being a much poorer fit for the data than the 4-stage version detailed. Altogether this supports the idea that maths anxiety, while related to additional maths affective variables, should not be correlated with these in a path analysis model.

Stage four comprised the demographics and educational variables. Gender was chosen because of its perceived importance for influencing both affect and performance (e.g. Miller & Bichsel, 2004; Nosek, Banaji & Greenwald, 2002). Likewise, age was included because of the lack of consensus in previous literature as to whether or not it is a significant predictor of affect and performance (e.g. Durrani & Tariq, 2009; Payne & Israel, 2010). It was believed that further exploration of this variable would be valuable.

Highest maths qualification has been demonstrated as being a powerful predictor of affect and performance (Durrani & Tariq, 2009; Huws, Reddy & Talcott, 2005) and so was included here.

Family background was also explored as a variable. As stated above, while little research has been carried out on this variable, it seems likely that family background would have an important effect on affect and, possibly, performance. The proposed initial model is presented in Figure 1.

While research in this area is not, by itself, novel (e.g. Ashcraft & Moore, 2009; Hembree, 1990), what is novel is the scope. Unlike other research which relies on correlations (e.g. Bull, 1999) or regressions (e.g. Miller & Bichsel, 2004) the use of path analyses allows the drawing of theoretical models, so instead of simply saying that there is a significant relationship between, for example, maths anxiety and numeracy performance, the aim of this research is to say that high maths anxiety actually causes poorer numeracy performance. As far as this author is aware, only Pajares & Miller (1994) have attempted to use path analysis techniques with numeracy performance as an endogenous variable, and that study did not include the range of potential exogenous variables explored here.

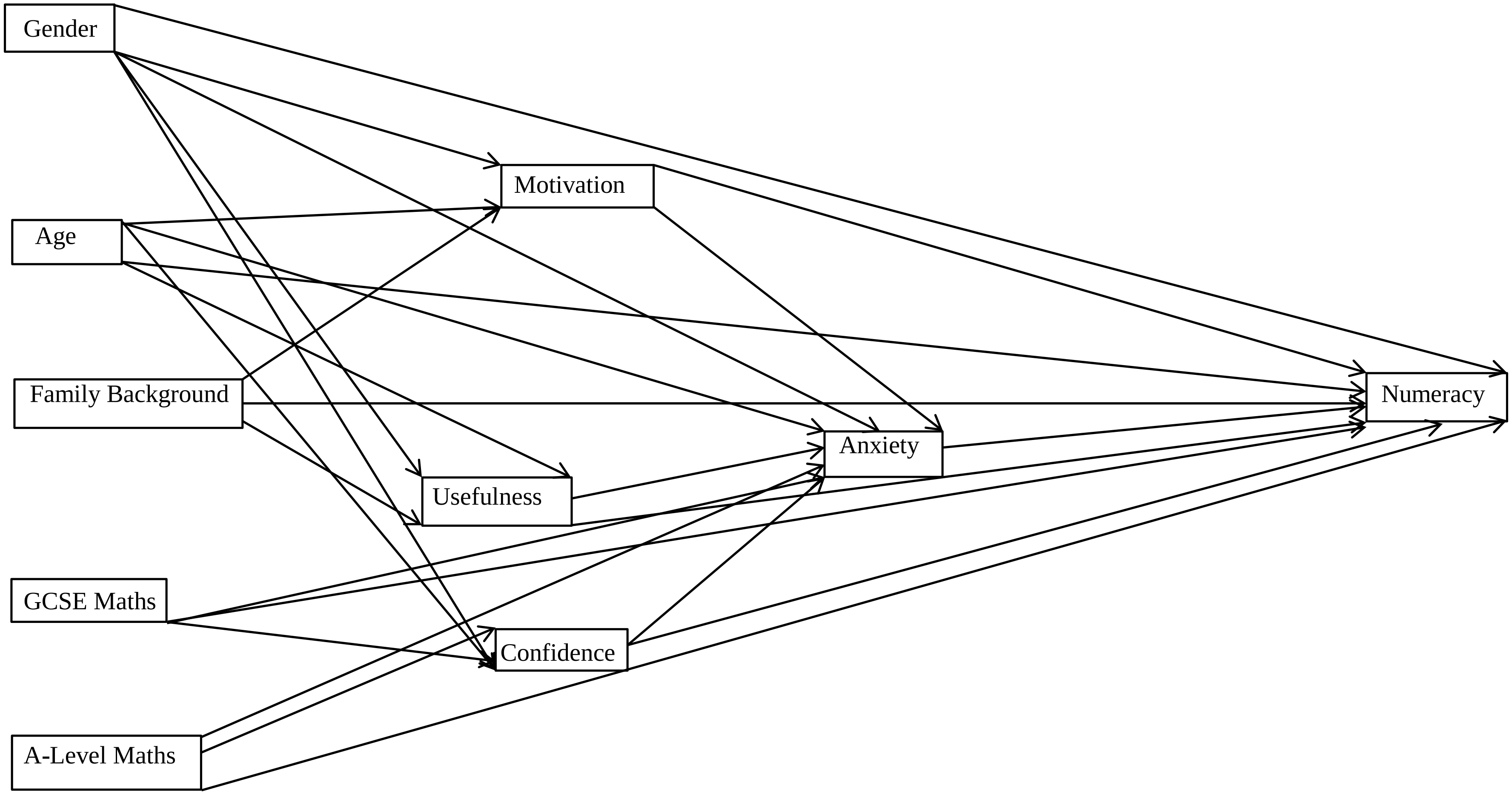

Figure 1. Proposed Initial Path Analysis Model

Methods

Mathematics attitudes

The attitudinal items from this study consisted of four subscales from the Fennema-Sherman Mathematics Attitude Scale (Fennema & Sherman, 1976) - maths anxiety, motivation, usefulness and confidence. Responses were given on a 5-point Likert-type scale with a score of 1 indicating strong agreement with a particular statement and a score of 5 indicating strong disagreement. The four subscales were presented together in a single, 48-item scale. Results were coded so a low score indicated positive attitudes (i.e. low anxiety, high motivation) and a high score indicated negative attitudes. Studies on the internal consistency of this scale have shown favourable results. Mulhern & Rae (1998) reported Cronbach's alpha reliability coefficients ranging from .79 to .96, depending on the subscale.

Demographics and Educational Characteristics

Participants were requested to provide demographics and educational background information in the same measure as the attitudinal questions. Participants were asked their age and gender and if they had a family background in mathematics. Lastly, participants were asked to list all formal maths academic qualifications, specifying the type of qualification and the grade gained. It was decided to split this variable into two parts: GCSE grade and A-Level grade. This was largely to do with the expected differences in highest maths grade that would occur between participant groups, with medics having homogenously high mathematics GCSE scores but quite varied mathematics A-Level scores, and nurses and psychologists having homogenously low mathematics A-Level scores but quite varied mathematics GCSE scores.

Ability Measures

In order to measure numeracy, a performance test (Greer & Semrau, 1984; Mulhern & Wylie, 2004) was used. This consisted of 20 questions. Some questions entailed solving more than one problem, resulting in a total of 32 problems (items) for participants to answer. Each item was worth one point. Between them, these items measured six broad components of numerical knowledge: calculation involving decimals and fractions (9 items), algebraic reasoning (10 items), graphical interpretation (6 items), proportionality and ratio (3 items), probability and sampling (2 items) and estimation (2 items). These questions varied in format. For example, one item asked participants to solve 0.02 x 0.12. Others asked participants to give the answer to complex word problems. Questions also varied in difficulty level, with some being perceived as challenging and others as comparatively simple. This scale has been shown to have an internal consistency of $\alpha = .83$ (Mulhern & Wylie, 2005) confirming the reliability and validity of this scale.

The use of a single numeracy performance measure here was deemed necessary for a number of reasons. Firstly, the three disciplines themselves had no appropriate subject-specific measure that they could have used; the medics had no numeracy test whatsoever. Secondly, a uniform measure was needed to allow comparisons between groups. The numeracy measure was considered appropriate for the sample, as not only were many items similar to those that would appear on a nursing numeracy performance measure, but also pilot work showed that the test scores were significant predictors of scores on the course-set psychology statistics exam.

Participants

Complete year-groups of psychology, nursing and medical undergraduates were invited to take part in this study. Participants were approached (with permission from their respective schools) at the end of lectures or lab-classes. Participation was purely voluntary and ethical approval was obtained from each of the three schools involved. From the overall sample, 325 participants, including 118 1^{st} year psychology students, 76 1^{st} and 2^{nd} year nursing students and 131 1^{st} and 2^{nd} year medical students, took part in all aspects of this study. The majority of students from each discipline were female (psychology - 78.8%; nursing - 92.1%; medicine - 51.1%). The majority of students were also under 21 years of age (psychology - 83.1%; nursing - 43.3%; medicine - 61.8%). Nursing was the only discipline with large numbers of students over the age of 30 (20.6%).

Procedure

Participants were given the measures near the beginning of their academic year. Students were allowed thirty minutes to complete the numeracy test, and the use of calculators and conferring were not permitted. No time limit was enforced for the attitudinal measures. Psychology students were tested in their statistics lab classes while data from the nursing and medical students were collected during lectures and classes.

Results

Reliability

Cronbach's alpha reliability coefficients were calculated for each of the Fennema-Sherman scales used in this study and the results were as follows: maths anxiety $\alpha = .942$, motivation $\alpha = .913$, usefulness $\alpha = .914$ and confidence $\alpha = .951$. Additionally, the numeracy test had an overall alpha value of .871. Each of these coefficients is considered acceptable.

Correlations

Pearson product-moment correlations were used to explore the relationships between maths affect and maths performance for all three of the participant disciplines. This was done in order to identify general trends within the data. Table 1 shows both mean scores and correlations between the various factors. The numeracy test scores have been converted into percentages. As the affective scores were coded so that a low score indicated positive affect (i.e. low anxiety, high motivation), the hypothesised positive affect – high performance relationship appears as negative correlations.

Table 1.

Means, Standard Deviations and Correlations of Numeracy Test Scores and Fennema-Sherman Affective Measures by Participant Group

Participant Group	Variable	Mean	SD	Numeracy	Anxiety	Motivation	Use	Confidence
Psychology	Numeracy	46.28%	5.06	-	-.53**	-.40**	-.21*	-.52**
	Anxiety	2.98	0.95		-	.66**	.39**	.88**
	Motivation	3.00	0.77			-	.56**	.73**
	Usefulness	2.52	0.76				-	.53**
	Confidence	2.95	0.89					-
Nursing	Numeracy	45.03%	4.78	-	-.46**	-.39**	.05	-.42**
	Anxiety	2.84	0.87		-	.82**	.32**	.86**
	Motivation	2.93	0.77			-	.39**	.77**
	Usefulness	2.00	0.50				-	.32**
	Confidence	2.94	0.78					-
Medicine	Numeracy	73.03%	4.52	-	-.53**	-.59**	-.08	-.56**
	Anxiety	2.22	0.76		-	.74**	.26**	.86**
	Motivation	2.54	0.72			-	.34**	.78**
	Usefulness	2.18	0.53				-	.33**
	Confidence	2.16	0.77					-

* $p < .05$ ** $p < .01$

Table 1 shows that in each group the numeracy total score is moderately negatively correlated with all of the attitudinal variables except usefulness, with stronger performance being significantly related to more positive affect. Usefulness was related to performance for the psychology students only.

Path analyses

Using SPSS-AMOS, a path analysis model was formed for each of the three participant groups. These illustrated the effect of demographics, educational characteristics and affect / anxiety on numeracy performance. Each of these models was subjected to a range of fit indices to determine whether they fit the data to an adequate degree. These tests primarily included the χ^2 goodness-of-fit statistics and the Root Mean Square Error of Approximation (RMSEA; Browne & Cudeck, 1993). If χ² values are non-significant, this suggests that the model fits the data. Likewise, RMSEA values up to .05 are considered a good fit for the data, with values of 1 or more being considered a poor fit for the data (Byrne, 1998). Additional tests were also used, including the Comparative Fit Index (CFI), Incremental Fit Index (IFI), Goodness of Fit Index (GFI) and Adjusted Goodness of Fit Index (AGFI), due to possible effects of sample size on the χ² and RMSEA. In the case of the CFI and IFI, scores of .95 or over are considered acceptable while, for the GFI and AGFI the closer the scores are to 1.00 the better the model fit is considered to be.

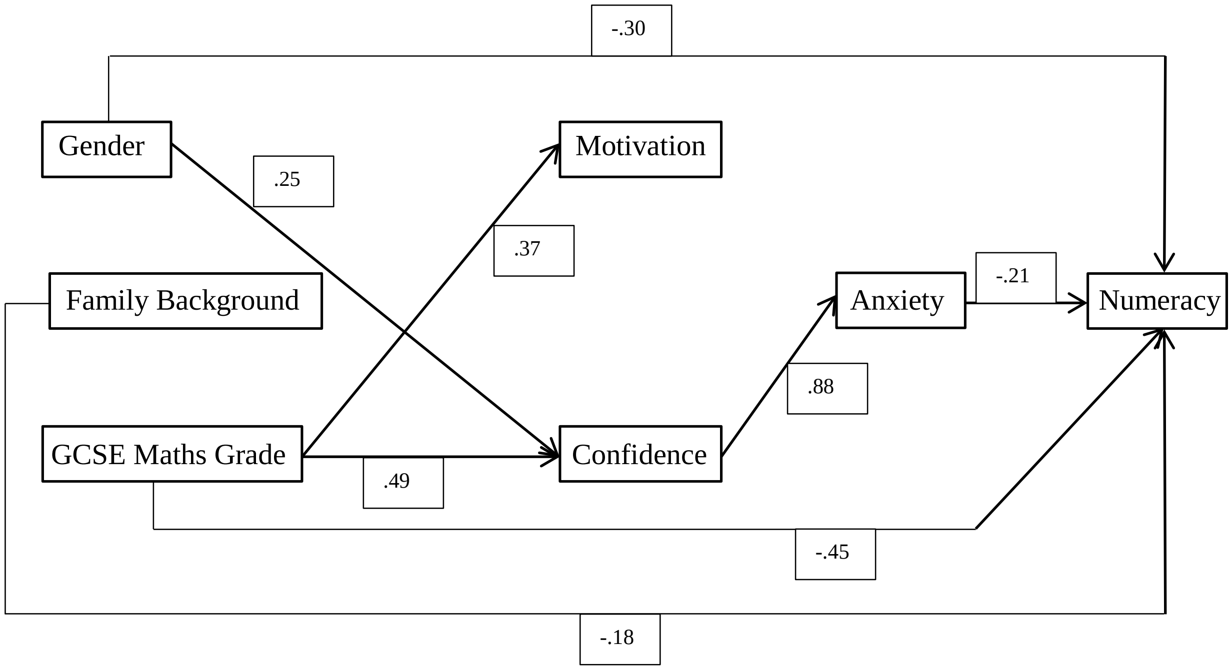

Figure 2. Final Psychology Path Analysis Model with Standardised Direct Effects

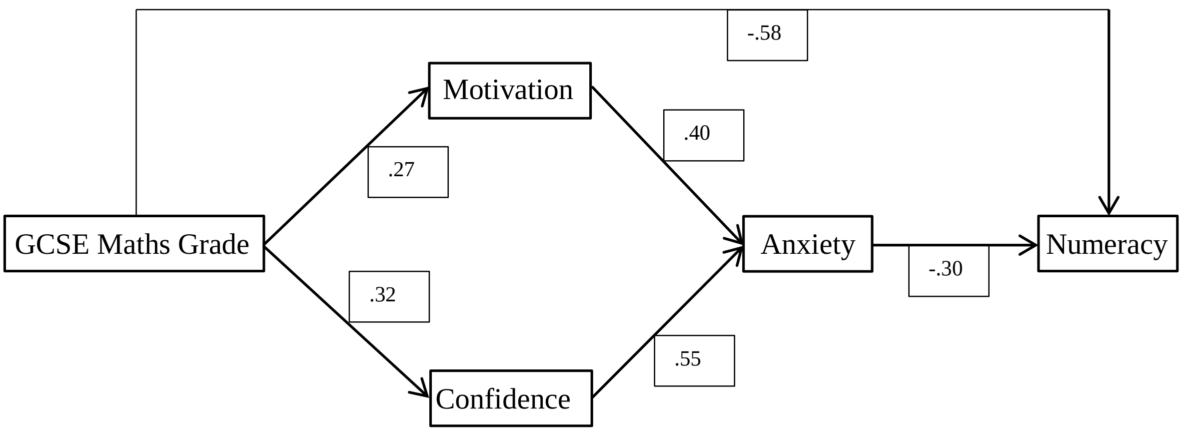

Figure 3. Final Nursing Path Analysis Model with Standardised Direct Effects

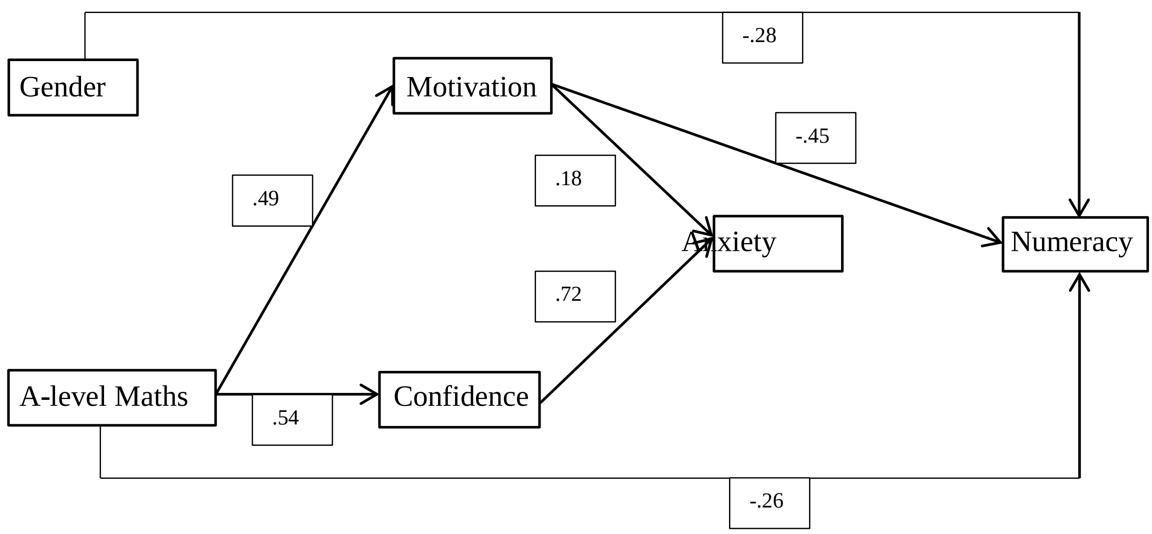

Figure 4. Final Medicine Path Analysis Model with Standardised Direct Effects

Psychology

All non-significant paths and variables were removed from the model (see Figure 2) As they are both part of the same scale, the motivation and confidence were correlated (r= .694, p < .001). The various predictors of numeracy total score explained 47.1% of its variance. Additionally, 77.6% of the variance within anxiety was explained by the model, as was 14% of the variance within motivation and 30.1% of the variance within confidence. Table 2 shows how the various goodness-of-fit indices all suggest that the model developed for the psychology students is a good fit for the data.

Nursing

As with the psychology model, a number of changes had to be made to the model to make it more applicable to the nursing sample (see Figure 3). Motivation and confidence, being part of the same scale, were again correlated (motivation – confidence: r = .755, p < .001). The various endogenous predictors of total score explained 52.1% of its variance. Also, 79.6% of the variance within anxiety was explained by the model, as was 7.1% of the variance within motivation and 10.5% of the variance within confidence. The goodness of fit indices in Table 2 suggest that the model developed for the nursing students is an appropriate explanation for the data.

Medicine

Once more, a number of variables were removed from this model (see Figure 4). As the variables of motivation and confidence were measured as part of the same scale, these were once more correlated (motivation – confidence: r = .702, p < .001). The various predictors of total numeracy score explained 46.3% of its variance. Additionally, 75.1% of the variance within anxiety was explained by the model, along with 23.9% of the variance within motivation and 29.1% of the variance within confidence. The goodness of fit indices in Table 2 suggest that the model developed for the medical students was a good fit for the data.

Table 3 summarises the standardised total effects (as opposed to direct effects) of each significant relationship in the model.

Table 2.

Goodness-of-Fit Indices for the Psychology, Nursing and Medicine Path Analysis Models

Fit Indices	χ^2	RMSEA (with confidence intervals)	CFI	IFI	GFI	AGFI
Psychology	16.65 df = 12, p = .163	.06 (0.00 – 0.12)	.99	.99	.96	.91
Nursing	.28 df = 3, p = .96	.00 (0.00 – 0.00)	1.00	1.00	1.00	.99
Medicine	8.18 df = 7, p = .32	.04 (0.00 – 0.12)	1.00	1.00	.98	.94

Table 3.

Path Coefficients (Standardised Total Effects) by Participant Group

PATH	PATH COEFFICIENT (PSYCH)	PATH COEFFICIENT (NURSING)	PATH COEFFICIENT (MEDICS)
Gender › Confidence	.25**	-	-
Gender › Numeracy	-.34**	-	-.28**
FB › Numeracy	-.18*	-	-
GCSE Maths › Moti	.37**	.27*	-
GCSE Maths › Conf	.49**	.32*	-
GCSE Maths › Num	-.54**	-.66**	-
A-Level Maths › Moti	-	-	.49**
A-Level Maths › Conf	-	-	54**
A-Level Maths › Num	-	-	-.48**
Motivation › Anxiety	-	.40**	.18*
Motivation › Num	-	-	-.45**
Confidence › Anxiety	.88**	.55**	.72**
Anxiety › Numeracy	-.21*	-.30**	-

* p < .05 ** p < .01

Discussion

The aims of this study were to explore what factors predict numeracy performance in undergraduates, and to see if these factors differed across the three disciplines. Path analyses showed that previous educational factors, along with student affect, are both direct and indirect significant predictors of numeracy performance for all three participant groups. Maths GCSE score was the only significant educational predictor for the psychologists and nurses whereas Maths A-Level was the only significant educational predictor for the medics. Also, while low maths anxiety is central for strong numeracy performance in the psychologists and nurses, motivation is more important for the medics.

In common with some previous research (e.g. Martens, Hurks, Meijs et al., 2011) gender significantly impacted performance for all but the nursing students. Potential gender effects in the nurses may have been concealed by the overwhelming disparity between the male and female gender ratio (only 8% of the sample were male). However, the expected gender – affect link was, for the most part, not observed. Age, likewise, failed to predict any of the endogenous variables across the three participant groups, supporting the work of, for example, Zeidner (1991) who also found no significant effect of age on performance. Unequal age groups in this current study's sample (80-100% of participants being under 30) may have masked significant findings. Baloğlu & Koçak (2006), who included much larger percentages of >30 participants, did find significant effects of age on performance.

Whether or not students had a family background in mathematics was weakly but significantly predictive of numeracy performance for the psychologists only, with those students with family backgrounds scoring higher on the numeracy test than those students without. This suggests that family background may not be as important a variable as was originally hypothesised in this study. Also, different participant groups may have had different definitions of what constitutes a 'family background' in numeracy, suggesting that this variable needs to be defined more clearly in future surveys.

One possible explanation for GCSE grades being significant performance predictors for the psychologists and nurses but not for the medics, and vice versa for A-Level grades, is that very few of the psychologists and nurses studied maths up to A-Level (12.7% and 9.2% respectively). Similarly, because of the extremely high entry requirements for their course, 96.1% of medical students had either A or A* grades at GCSE maths. In both cases this resulted in a lack of variability in the data. Surprisingly, previous mathematics qualifications were not related to anxiety, despite considerable research that suggests the contrary (e.g. Durrani & Tariq, 2009). There does appear, however, to be an indirect effect of qualifications on anxiety via the affective variables, particularly confidence. It is possible that studies in the past that have been purporting to measure maths anxiety have, in fact, failed to control for the effect of maths confidence, as was done in the path analysis models here. Consequently they may not have been measuring maths anxiety as a pure construct. In the Tapia & Marsh (2002) scale, for example, many of the items measuring self-confidence (e.g. "Studying mathematics makes me feel nervous,") could be argued as measuring maths anxiety instead.

In terms of the affective variables, maths anxiety and motivation appear to be the strongest direct predictors of numeracy performance, depending on discipline. This is possibly because levels of maths anxiety for the medical students are lower than they were for the other two groups, indicating that they are not afraid of numeracy-based tasks, their performance dictated instead by their motivation and enjoyment of the topic. In contrast, for the psychologists and nurses, motivation is 'over-ridden' by their maths anxiety. Previous research has demonstrated the contribution of maths anxiety to performance in psychologists and nurses (e.g. e.g. Bull, 2009; Núñez-Peña, Suárez-Pellicioni & Bono, 2013) but no research has investigated the effect of anxiety or motivation on medical students.

Confidence, meanwhile, appears to be only an indirect predictor of numeracy performance. For the psychologists and nurses, confidence predicted (either moderately or strongly) anxiety which then went on to predict numeracy performance. Likewise, for the medics, not only did confidence predict anxiety, but it is possible that it has some effect on motivation which then predicts numeracy performance. Such results were not expected, considering the research that has shown direct links between confidence and performance. Pajares & Miller (2004), for example, through the use of path analyses, found a causal confidence – performance link. Anxiety, however, was not a factor in the Pajares & Miller study and, as has been shown before, it seems necessary to control for one of these constructs when looking at the effect of the other. Usefulness, meanwhile, was not a significant predictor in any of the participant groups. This suggests that, no matter how useful a student perceives numeracy to be, this will have no effect on their actual performance, or their anxiety, supporting the results of e.g. Pyzdrowski, Sun, Curtis, et al (2013).

Conclusion

Overall, in the cases of all three models, approximately 50% of the variance within numeracy performance was explained. It is clear that unmeasured supplementary variables are at work, influencing performance. Additional research has looked at the effect of a potential genetic disposition to engage or disengage with numeracy (e.g. Wang, Hart, Kovas et al., 2014) or the effect of individual differences in working memory across participants (e.g. Hoffman, 2010). It should also be noted that it does not appear to be possible to generalise the results of one model across more than one discipline. This should not be surprising, as each course utilises student numeracy for different ends (e.g. statistics for psychologists, dosage calculations for nurses, etc.), and so students will have different expectations and opinions of the numeracy-based aspect of what they are studying. Future studies examining this area may need to be course-specific, not attempting to generalise their results across different subject areas.

Potential shortcomings of the study could include the subjectivity of participant responses to the affective measures. Such issues are, however, unavoidable due to the impracticality of adopting more objective physiological measures (e.g. heart rate and skin conductance – Hopko, McNeil, Lejeuz, et al. 2003). Also, as this study recruited on a volunteer basis, there is the issue that students with particularly strong negative affect towards numbers may have declined to take part, thus making the sample appear to have more positive affect and show stronger performance than is really accurate for the student populations investigated here.

A major strength of this research was the use of path analyses instead of correlations and regression analysis. Also, the wide range of variables explored and the examination and comparison of three different subject areas (two of which are greatly under-researched regarding studies of this sort) make this research especially relevant and valuable. From the results of this study, educators working in university subject areas that, while not numerically-based, still have some numerical component within them, should be able to predict that those students with lower previous mathematics qualifications and higher anxiety will be most at risk of performing poorly in these components. From these results, interventions aiming to correct such issues could potentially be formalised. Nevertheless, it should be noted that these findings are exploratory, coming only from three departments of a single university, and that repetition of the results obtained from different subjects (e.g. business studies or bioscience) in different institutions is necessary.

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