ORIGINAL ARTICLE

Profiles of general, test, and mathematics anxiety in 9- and 12-year-olds: relations to gender and mathematics achievement

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Abstract

As international focus increasingly turns to the need to build a future mathematics workforce, research has aimed to better understand the salient individual and contextual factors that influence maths engagement and achievement across development. This study investigates self-reported general anxiety, test anxiety, and maths anxiety in two cohorts of Australian students aged 9–10 years ($n = 158$) and 12–13 years ($n = 115$) and associations with maths achievement and gender. Test and maths anxiety were negatively correlated with maths achievement and there were no gender differences in maths achievement. Cross-sectional latent profile analyses established two anxiety profiles in the older cohort (low and high across all anxiety measures) and a more complex five-profile solution for the younger cohort (various combinations of anxiety). Members of profiles with higher levels of test and mathematics anxiety had lower maths achievement, with girls over-represented in these profiles.

Introduction

Over the last two decades there has been increasing focus in the developed world on education and achievement in the STEM disciplines (science, technology, engineering, mathematics), because of their role in future economic and social prosperity (United Nations Education, Scientific and Cultural Organisation [UNESCO], 2017). UNESCO's goals as part of the Education 2030 Agenda include increasing participation, enhancing the quality of education, increasing achievement, and improving gender diversity in the disciplines (UNESCO, 2017). An increasing body of research work in mathematics in particular, has sought to inform this policy and practice through understanding the individual factors and educational contexts that

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promote or hinder mathematics participation and achievement across the lifespan (Grigg et al., 2018; Luttenberger et al., 2018; Sewasew et al., 2018). Key areas of focus in this work have included mathematics anxiety and its role in achievement (Chang & Beilock, 2016) and a particular focus on gender (Sewasew et al., 2018; Steegh et al., 2019). This study aims to further contribute to this evidence base by documenting profiles of mathematics, test, and general anxiety in two school-aged cohorts and assessing associations among anxiety profile membership, mathematics achievement, and gender. An increased understanding of the complexities that may contribute to achievement in the STEM disciplines will inform future strategies that aim to enhance engagement and achievement over time.

International achievement in mathematics

Singapore, Hong Kong SAR, Korea, Chinese Taipei, and Japan have consistently been the highest achieving countries in mathematics at both the fourth and eighth grades, throughout the 20-year history of the Trends in International Mathematics and Science Study (TIMSS) (Mullis et al., 2020). Notably, the gap between these five high performing countries and other participating countries increases from fourth to eighth grade (26 points in Grade 4, 35 points in Grade 8, 2019 data, Mullis et al., 2020). This widening gap from primary to high school between the top performing countries and all others has implications for school mathematics programs internationally.

Using Australia as an example, the last two releases of the TIMSS in 2015 and 2019 have raised concerns about the quality of Australian mathematics education, particularly in relation to international benchmarks. In TIMSS achieving the international intermediate benchmark indicates that students can apply basic mathematical knowledge in simple situations, not necessarily solve problems (reflective of the high international benchmark). In 2015 and 2019, 30% of Australian Year 4 students (average age 9 years) performed below the intermediate benchmarks for mathematics (Mullis et al., 2016, 2020). For Australian Year 8 students, there is a higher percentage performing below the intermediate benchmarks (2015: 36% and 2019: 32%. Mullis et al., 2016, 2020). The consistency of this performance over time indicates that more work needs to be done to understand and support student learning of mathematics across both primary and high school. This issue of performance is not unique to the Australian context, particularly in Year 8, with countries such as England, New Zealand, and the United States all having 30% or more of Year 8 students not reaching the intermediate international benchmark in mathematics in TIMSS 2015 and 2019 (Mullis et al., 2016, 2020).

Gender and mathematics

A pervasive area of interest and concern are gender differences in mathematics participation and achievement. Previously it was thought that boys have a higher aptitude for mathematics than girls (Leder, 2019), however, this is not consistently demonstrated in empirical data in all contexts (Koch, 2018). Examining the TIMSS 2019 data Thomson et al. (2020) summarised the patterns of achievement based on

gender. In TIMSS 2019 for Year 4 students, 27 of the 58 participating countries (46.55%) had no gender difference in mathematics, whereas 27 countries (46.55%), including Australia, had significant differences favouring males. The remaining four countries (6.90%) had females scoring significantly higher than males in Year 4. Conversely, in Year 8 there was no significant difference between Australian males and females, and this was the case for 26 out of the 39 countries (66.67%) involved in Year 8. There were six countries (15.38%) where females scored significantly higher than males, and seven countries (17.95%) where males scored significantly higher than females.

In Australia, the Office of The Chief Scientist characterises international patterns as indicating no innate difference in mathematics ability across gender (Prinsley et al., 2016a, b). However, attrition is evident with far fewer females participating in STEM disciplines in secondary school, post-secondary education, and the workforce (Prinsley et al., 2016a, b). It has long been known that societal gender constructions lead to boys and girls holding deep-seated beliefs about gender-appropriate behaviour (Skelton et al., 2007), which include conceptions of gendered disciplines (STEM = male; humanities = female; EOC, 2004). This stereotyping is heavily influenced by peer groups and often perpetuated by schools unless they actively address the impact of gender stereotyping (Institute of Physics, 2013). Koch (2018) points to the potential role of mathematics anxiety experienced by students and teachers as a likely contributor to behaviours and attitudes of female students. It is clear that along with addressing gender stereotyping, new understandings of the teaching and learning experiences of students in relation to mathematics, and how these interact with personal characteristics, are needed to inform curriculum and pedagogical design that acts to improve the mathematical achievement of all students (Anthony & Walshaw, 2009; Buckley, 2020; Koch, 2018).

Mathematics anxiety: definition and conceptual understandings

Experiences and achievement in mathematics are dynamic and the result of multiple factors, including personal attributes, intellectual or task demands, and educational environments. Research evidence (see Dowker et al., 2016 for a review) has suggested that individual feelings of anxiety play a role in children's experience of mathematics learning and achievement internationally. Indeed, comparing Programme for International Student Assessment (PISA) data for Finland, Korea, and the United States, Fan et al. (2019) argued the presence of mathematics anxiety among 15-year-olds was independent of cultural context. Australian mathematics education researchers report the interplay between motivation, emotion, and cognitive strategies in mathematics (Gabriel et al., 2020) and suggest the need for transdisciplinary frameworks including education, psychology, and neuroscience when seeking to understand mathematics anxiety in its state and trait forms (Buckley et al., 2016). Anxiety can be experienced in many situations; in this research the concurrent profiles of general, test, and mathematics anxiety are the focus. Anxiety describes apprehension felt in response to a perceived threat and those who experience general anxiety feel physiological anxiety, worry, and/or social anxiety in

response to everyday situations (Reynolds & Richmond, 2008). In contrast to general anxiety, test and mathematics anxiety are both types of performance anxiety. Test anxiety impacts test performance, where a person experiences intense physiological, cognitive, and/or behavioural symptoms before or during test-taking situations (Sawka-Miller, 2011). Mathematics anxiety relates to discomfort or negative affect when performing mathematics tasks and those experiencing mathematics anxiety can have feelings of apprehension, tension, worry, and fear (Devine et al., 2012; Ma & Xu, 2004).

A range of models have attempted to identify the causes and consequences of mathematics anxiety. For example, Ma and Xu (2004) classify the causes to be environmental (e.g. classrooms and teacher characteristics), intellectual (e.g. mathematics task demands and/or abstract nature of tasks), and personal (e.g. self-esteem, confidence, attitude). Luttenberger et al. (2018) extend these ideas and propose a three-part framework for understanding mathematics anxiety: antecedents, interacting variables, and outcomes. Similar to Ma and Xu's (2004) understanding of the causes, the antecedents include aspects such as environment, gender, disposition, and proneness to general anxiety (Luttenberger et al., 2018). The interacting variables include self-efficacy, self-concept, prior knowledge, motivation, and mathematics anxiety. The possible outcomes include performance, learning behaviour (e.g. procrastination), and choices (e.g. subject selection and educational path).

There are three main theories that attempt to explain the relationship between mathematics anxiety and mathematics performance: the deficit theory, the cognitive interference theory, and the reciprocal theory. The *deficit theory* posits that the progressive accumulation of poor mathematics performance and negative experiences in mathematics that build up over time increase the likelihood of mathematics anxiety in the future (Carey et al., 2016; Hembree, 1990). This suggests that primary school-aged students are likely to have fewer negative experiences and have lower mathematics anxiety than high-school aged students. Conversely, the *interference model*, also known as the debilitating anxiety model, argues for mathematics anxiety interfering at different stages of processing, such as pre-processing, processing, and/or information retrieval, with subsequent impacts on mathematics performance (Carey et al., 2016; Namkung et al., 2019). This theory proposes that mathematics anxiety will have a differential impact depending on the type of mathematics tasks and the complexity (e.g. simple arithmetic versus problem solving). The *reciprocal theory* (Ashcraft et al., 2007; Carey et al., 2016; Foley et al., 2017) suggests the potential for bidirectional relations among mathematics anxiety and performance (and other interacting variables), meaning that each influences each other over time in different ways for individuals. For example, some individuals may initially have negative experiences and/or failure in mathematics, which may lead to mathematics specific anxiety which then impacts subsequent performance. Alternatively, for some individuals, negative emotions and anxiety may be the initial catalyst of poor performance, and shape perceptions of mathematics ability and subsequent performance, creating a vicious cycle.

A meta-analysis (Namkung et al., 2019) referenced these three theories in an analysis of mathematics anxiety and mathematics performance among school-aged students. Analyses found similarly strong relations between mathematics anxiety

and mathematics performance for both primary and high school students. While this partially challenges the deficit theory, there were fewer studies that targeted early primary grades (below Grade 5). Similarly, there was limited evidence for the interference theory. Working memory was not significantly related to mathematics anxiety as this theory would suggest, however, only nine studies examined associations between working memory and mathematics anxiety. The authors concluded that there was evidence to date most closely aligned with the reciprocal theory and suggested that the bidirectional relation among mathematics anxiety and performance is likely to be long lasting. There are still many unknowns related to the manifestation of mathematics anxiety, and targeted research across a range of contexts is required to further the evidence base and inform educational interventions. The following section summarises relevant research studies with school aged children.

Mathematics anxiety and school mathematics achievement: empirical evidence

Research studies conducted with school aged children have established the link between different individual characteristics, such as anxiety and cognitive processes, and mathematics performance (Abin et al., 2020; Carey et al., 2017a, b; Cargnelutti et al., 2017; Ching, 2017; Devine et al., 2012; Hill et al., 2016; Justicia-Galiano et al., 2017; Ramirez et al., 2013, 2016; Sorvo et al., 2017; Wu et al., 2012). For example, Abin et al. (2020) reported variable predictive strength of cognitive, emotional, and motivational skills on mathematics achievement based on gender and school year level. The important distinction is what types of anxiety and/or cognitive processes (e.g. working memory) might be impacting or mediating performance in mathematics assessment (e.g. Ching, 2017; Justicia-Galiano et al., 2017; Ramirez et al., 2013, 2016). Ramirez and colleagues (Ramirez et al., 2013, 2016) investigated relations between mathematics anxiety, working memory, and mathematics achievement with children in Years 1 and 2. Findings showed that higher mathematics anxiety was associated with poorer applied problem solving, but this association was moderated by working memory, with effects stronger for those with higher levels of working memory (Ramirez et al., 2013, 2016). A study with Chinese children confirmed this moderation of the math anxiety to performance association by working memory (Ching, 2017). It was argued that the more advanced working memory strategies applied in problem solving tasks were more likely to be disrupted by mathematics anxiety (Ramirez et al., 2016), supporting the interference model.

Other research studies have aimed to disentangle the different types of anxiety and their relation with mathematics performance, with most including one other measure of anxiety (general or test) alongside mathematics anxiety (Carey et al., 2017a, b; Cargnelutti et al., 2017; Devine et al., 2012; Hill et al., 2016; Justicia-Galiano et al., 2017; Wu et al., 2012). Cargnelutti et al. (2017), Justicia-Galiano et al., (2017) and Wu et al. (2012) investigated mathematics anxiety alongside general anxiety in the primary school years. All three studies reported both types of anxiety were impacting performance, and that mathematics anxiety was distinct from general anxiety. Meanwhile, Devine et al. (2012) investigated mathematics and test anxiety, but not general anxiety, in Years 7, 8, and 10. Overall, they found a

negative correlation between mathematics anxiety and mathematics performance, however, relationships with test anxiety varied based on gender, which will be further discussed in the following section (Devine et al., 2012). It is important to note that in Devine et al. (2012) the measures were mathematics and test anxiety and a custom designed numerical operations test, rather than a standardised mathematics achievement test.

Subsequent studies (Carey et al., 2017a, b; Hill et al., 2016) improved on this design with larger samples encompassing both primary and high school students and measures of general, test, and mathematics anxiety, as well as standardised tests for mathematics and reading. Hill et al. (2016) conducted a correlational study with a sample of Italian students (Primary: Years 3–5, High School: Years 6–8). Interestingly, they found a significant negative correlation between mathematics anxiety and arithmetic performance with high school students, but not primary students. The negative correlation for the secondary students remained significant after controlling for general anxiety. Based on these findings, Hill et al. (2016) concluded that mathematics anxiety is distinct from general anxiety, and supported the deficit theory by hypothesising that the negative relationship between mathematics anxiety and performance emerges over the course of the schooling years. These findings (Carey et al., 2017a, b; Hill et al., 2016) are consistent with the meta-analytic findings of Zhang et al. (2019) who reported a robust negative maths anxiety-performance link, but that the link was stronger in studies with high school students compared to primary school students.

The consideration of gender differences in anxiety offers a useful lens for examining gender differences in mathematics performance, such as those reported in international tests (Thomson et al., 2020). It is well documented that females experience higher levels of general anxiety than males (Mclean & Anderson, 2009), and it also appears girls of school age experience higher levels of mathematics anxiety than boys (Carey et al., 2017a, b; Hill et al., 2016). In their study of British secondary school students, Devine et al. (2012) reported no gender differences in mathematics performance. However in line with other studies, mathematics and test anxiety levels were higher in females than males, with mathematics anxiety a significant predictor of performance in females and not males. Based on this finding, Devine et al. (2012) propose the potential for females to perform higher in mathematics if it were not for the influence of mathematics anxiety.

Variable-centred vs person-centred approaches to understanding anxiety and mathematics achievement

Most of the research to date on general, test, and mathematics anxiety and associations with mathematics achievement have been variable-centred in nature. That is, correlation or regression analyses provide levels of predictability averaged out over a whole population or sample. In contrast, person-centred approaches hypothesise that the population is heterogeneous in respect to the relationships between variables, and the way they cluster together in individuals (Collins & Lanza, 2010). For example, in relation to this study, person-centred approaches offer an opportunity to explore whether

qualitatively different profiles of general, test, and mathematics anxiety can be identified in school-aged children.

Only two known studies in this field have used a person-centred approach with the inclusion of all three anxiety types. Carey et al. (2017a, b) conduced a latent profile analysis and reported distinct anxiety groups for British primary (Year 4) and high school (Year 7/8) students. Year 4 students were described by four profiles (low, slight, moderate and high anxiety), with general, test, and mathematics anxiety clustering to similar levels in each profile (i.e., the high anxiety profile had relatively high levels of general, test, and mathematics anxiety). Year 4 females were more likely to be in the higher anxiety profile, and males in the low anxiety profile, and academic performance in both reading and mathematics declined with membership of higher anxiety profiles. The Year 7/8 students were described by four different groups (low, academic, general, and high anxiety). Different to the Year 4 groups, the Year 7/8 student groups demonstrated differential levels of anxiety in secondary school. The academic anxiety group were characterised by higher test and mathematics anxiety, relative to general anxiety. The general anxiety group were characterised by higher general anxiety relative to test and mathematics anxiety. In terms of gender and Year 7/8 students, females were more likely to be in the general and high anxiety profiles, and males more likely in the low and academic anxiety profiles. The academic anxiety group had the lowest scores on reading and mathematics standardised tests, particularly compared to those with high levels of general anxiety. The authors present a model that aligns with the reciprocal theory in that individual predisposition to anxiety, along with mathematics performance experiences, influence each other over time to create higher or low levels of mathematics anxiety and performance.

A more recent study used latent profile analysis with general, test, and mathematics anxiety to examine protective factors related to anxiety (Mammarella et al., 2018) with Italian students in Years 3–6 (mean age 9.2 years). The authors measured general protective factors (self-concept – competence scale, ego-resiliency scale) and academic protective factors (self-concept – academic scale, academic buoyancy scale). Three anxiety profiles were determined, low (12% of sample), average (66% of sample), and high risk (22% of the sample), however a gender composition was not reported. Interestingly, and in contrast to Carey et al. (2017a, b), the high-risk anxiety profile was characterised by higher levels of general and test anxiety, relative to mathematics anxiety. Overall, the three anxiety risk profiles had significantly different protective factor scores. The higher the anxiety risk profile the lower general and academic protective factor scores. While personal factors, such as low academic self-concept, have been associated with poorer academic performance in prior research (Justicia-Galiano et al., 2017), no academic performance measures were included in this Italian research.

The current study

As the gap between the highest performing and lowest performing countries in mathematics achievement widens, it is important for research to focus on understanding various explanatory factors, thus seeking to identify the most salient constructs on which to intervene, and for whom, if the gap is to be closed. The reviewed

research has provided an evidence base about the role of different anxiety types, and gender for students from several countries internationally, however, there has been very little examination of whether and how these important anxiety types cluster together in Australian students. Given the variable international patterns of gender-based performance in mathematics (Thomson et al., 2020), further investigation of gender differences in achievement, as well as the role of different profiles of anxiety across gender is clearly needed in a wide range of international settings, representing different mathematics curriculum and educational practices.

The purpose of this study is to establish the extent to which different profiles of general, test, and mathematics anxiety exist in two cohorts of Australian children aged 9–10 years and 12–13 years. The research questions are:

1. *What are the profiles of general, test, and mathematics anxiety in children aged 9–10 years and 12–13 years?*
2. *How do the profiles differ in mathematics achievement and gender composition?*

Methods

Participants

Two cohorts of children were recruited: 158 in Year 4 / 5 (9 -10-years-old, named the younger cohort) and 115 in Year 7 / 8 (12–13-years-old, named the older cohort). Data collection was conducted towards the end of one school year with children in Years 4 and 7 (November in Australia) and the beginning of the following year (February – March) with children in Years 5 and 8. We took this approach to ensure that the approximate years of formal schooling completed was equal within each of the younger and older cohorts.

Children were recruited from eight co-educational non-government schools within a capital city region. The participating schools had Index of Community Socio-Economic Advantage (ICSEA) values above the national mean of 1000 (± 100), ranging from 1053–1170 (mean 1094 ± 45). ICSEA values are calculated from community (remoteness and percent Indigenous enrolment) and child-level (parent occupation and education) data. All children in the relevant year levels were invited to participate through information and consent forms sent home to parents, response was voluntary. In both cohorts girls were overrepresented with 58% girls in the younger cohort and 62% in the older cohort. Ethics approval was provided by the authors' University Human Research Ethics Committee.

Procedure

Children completed four survey instruments in one group session held at each school lead by the research team. Instructions were delivered consistently through the use of a slide presentation and the same two members of the research team facilitating all data collection sessions. Mathematics achievement data were collected from

existing databases held by each school where standardised mathematics achievement testing had been conducted with students within a six-month period of our anxiety data being collected.

Measures

General anxiety

General anxiety was measured through the *Revised Children's Manifest Anxiety Scale – Second Edition (RCMAS-2)—Short Form* (Reynolds & Richmond, 2008). This is a 10-item short form instrument, derived from the 40-item Total Anxiety RCMAS-2. The short form comprises three items from the Psychological Anxiety scale (e.g. 'often I feel sick in my stomach'), four items from the Worry scale (e.g. 'I worry about what is going to happen'), and three items from the Social Anxiety scale (e.g. 'I am afraid to give a talk to my class'). For each item, children responded to the statements with either 'yes' or 'no', and raw scores were calculated as the total number of 'yes' responses. While there are no validity scores for the RCMAS-2 Short Form, it is closely related to the 40-item Total Anxiety RCMAS-2 (Reynolds & Richmond, 2008). Reliability (Cronbach's alpha) in total sample = 0.79; younger cohort = 0.82, older cohort = 0.70.

Test anxiety

Text anxiety was measured through the *Children's Test Anxiety Scale* (CTAS, Wren & Benson, 2004). This is a 30-item instrument comprising eight-item Off-Task Behaviour subscale, nine-item Autonomic Reactions subscale, and 13-item Thoughts subscale. Example items include 'when I take tests I play with my pencil or pen', 'when I take tests my heart beats fast' and 'when I take tests I worry about failing'. For each item, children respond using a 4-point scale from almost never (1) to almost always (4). Raw scores were calculated by adding responses for each item to form a total. Internal consistency for the CTAS is 0.92. This test anxiety measure has been used widely, including Carey et al. (2017a, b), as well as other anxiety research with school-based samples (e.g. Hadwin & Richards, 2016). Reliability (Cronbach's alpha) in total sample = 0.93; younger cohort = 0.95, older cohort = 0.91.

Mathematics anxiety

Mathematics anxiety was measured through the *Modified Abbreviated Mathematics Anxiety Scale* (mAMAS), based on the Abbreviated Mathematics Anxiety Scale (AMAS, Hopko et al., 2003). Internal consistency for the AMAS is 0.90 and test–retest reliability is 0.85 (Hopko et al., 2003). The modifications evident in the mAMAS are to make the AMAS applicable to children and adolescents. The AMAS included reference to 'lectures', 'chapters' and 'algebraic equations', which have been removed in the mAMAS to make it appropriate to a wider range of participants. The mAMAS is

a nine-item instrument in which students respond on a 5-point scale from low anxiety (1) to high anxiety (5) in relation to a series of mathematics scenarios (e.g. watching the teacher work out a mathematics problem on the board; starting a new topic in mathematics). Raw scores were calculated by adding responses for each item to form a total. Modified forms of the AMAS have been used in multiple prior studies investigating mathematics anxiety in primary and secondary school children (Carey et al. 2017a, b; Devine et al., 2012; Hill et al., 2016; Justicia-Galiano, et al., 2017) and statistical analyses have found the mAMAS to be a valid and reliable scale (Carey et al. 2017a, b). Reliability (Cronbach's alpha) in total sample=0.89; younger cohort=0.90, older cohort=0.87.

Mathematics achievement

Mathematics achievement was measured through the *Progressive Achievement Tests in Mathematics* (PAT-M; Stephanou & Lindsey, 2013) or the Numeracy Assessment from the *Middle Years Ability Tests* (MYAT; Withers et al., 2012), depending on each participating schools' existing testing protocol. As in Hill et al. (2016) reading comprehension scores (*Progressive Achievement Tests in Reading* PAT-R; Stephanou et al., 2015) were used as a covariate in analyses to control for any reading difficulties that might impact mathematics achievement. Tests included 25–40 multiple-choice items, aligned with Australian National Curriculum content areas and general capabilities. For example, the PAT-M includes test items that link to the Number and Algebra, Measurement and Geometry, Statistics and Probability Strands of the Australian Curriculum: Mathematics. The tests for the younger and older cohorts encompassed similar content areas, including number and place value, patterns and algebra, using units of measurement, data representation, and interpretation and chance. All tests were published by the Australian Council for Educational Research and are widely used by teachers in Australian schools to monitor student progress against curriculum expectations.

The normative samples for the PAT-M, MYAT, and PAT-R tests were Australian representative samples of primary and high school students, representing all school sectors (government and non-government). The PAT-M sample included 12,296 students from 134 schools. The PAT-R sample included 9,482 students from 117 schools. The MYAT sample included 2032 students from all Australian states and territories. The PAT-M and PAT-R tests delivered in Years 4 and 5 and Years 7 and 8 have good reliability, with Cronbach's Alpha close to 0.9 (PAT-M α range=0.89—0.91; PAT-R α range=0.87—0.88). Following the respective administrative guidelines, the tests were completed in class groups under examination conditions. Raw scores were converted to scale scores and percentiles, based on the Australian normative samples.

Approach to analysis and missing data

These analyses take a person-centred analytic approach. First we use latent profile analysis (LPA) in MPlus Version 7 (Muthen & Muthen, 2008–2012) to establish profiles of general, test, and math anxiety separately for each of the younger and older cohorts. LPA is a semi-parametric group based approach that

allows for estimation of qualitatively different groups when membership cannot be observed a priori (Collins & Lanza, 2010).

Selection of the optimal number of profiles for each cohort was based on four measures of relative model fit (compared to the same model with one less profile): the Bayesian Information Criterion (BIC; Schwarz, 1978); Consistent Akaike's Information Criterion (CAIC; Bozdogan, 1987); the Lo-Mendell-Rubin (LMR) test (Lo et al., 2001); and the bootstrapped likelihood ratio test (BLRT; McLachlan & Peel, 2000). As a second step, we exported class membership probabilities to the Statistical Package for Social Sciences program Version 21 (SPSS; IBM Corp, 2012) where gender composition of the profiles was examined with reference to the sample composition (approximately 60% females), and ANOVAs were used to test significant differences among the profiles on mathematics achievement.

Missing data on the anxiety measures was negligible and at the item level only for one or two cases for each of 8 unique survey items (out of a potential 49 items) resulting in a total of 12 missing data points (out of 1347; 0.01%). We imputed the sample modal value in each case for each item. Maths achievement data was missing for 8 cases (3%). Analyses comparing profile groups for maths achievement used available maths achievement data for 97% of cases. A total of 40 cases were missing data on reading achievement used as a covariate in final models.

Results

Descriptive statistics

Bivariate correlations and descriptive statistics for the younger cohort are shown in Table 1, and for the older cohort in Table 2. Across both cohorts, general anxiety had a small positive correlation with test and maths anxiety while test and maths anxiety were highly (younger cohort) or moderately (older cohort) correlated. Mathematics achievement was negatively correlated (to a small degree)

Table 1 Bivariate correlations and descriptive statistics for anxiety and achievement for the younger cohort

	1	2	3	4	5
1 Mathematics anxiety	1				
2 Test anxiety	.84*	1			
3 General anxiety	.36*	.36*	1		
4 Mathematics achievement	-.30*	-.23*	-.11	1	
5 Reading achievement	-.12	-.11	-.05	.55*	1
Range	9—45	30 – 120	0 – 10	1 – 99	4 – 98
Mean	19.51	58.71	4.15	46.54	57.20
SE	.69	1.45	.24	2.12	2.21
Reliability (Cronbach's alpha)	.91	.94	.82	NA	NA

*$p < .05$

Table 2 Bivariate correlations and descriptive statistics for anxiety and achievement for the older cohort

	1	2	3	4	5
1 Mathematics anxiety	1				
2 Test anxiety	.54*	1			
3 General anxiety	.30*	.37*	1		
4 Mathematics achievement	-.41*	-.20*	-.10	1	
5 Reading achievement	-.22*	-.11	-.07	.60*	1
Range	9 – 43	30 – 107	0 – 9	3 – 99	4—99
Mean	19.90	62.03	2.89	52.12	58.59
SE	.76	1.35	.21	2.46	2.46
Reliability (Cronbach's alpha)	.87	.91	.70	NA	NA

$*p < .05$

with maths and test anxiety, but not general anxiety. Reading achievement was moderately correlated with maths achievement and had small negative correlations with mathematics anxiety.

Gender differences in each of the measures for the whole sample and each of the age cohorts were also examined (Table 3). These show that girls had statistically significant higher general anxiety than boys in the older cohort, with a similar though non-significant trend in the younger cohort. Girls also had higher test anxiety and mathematics anxiety in the younger cohort with a similar non-significant trend found in the older cohort. In comparing the age cohorts there was only one significant difference with the younger cohort reporting higher general anxiety. There were no gender differences for maths or reading achievement in either cohort.

Table 3 Mean comparisons for gender and across the age cohorts

	Younger cohort			Older cohort			Comparing age cohorts		
	Female $n=91$	Male $n=67$	p	Female $n=71$	Male $n=44$	p	Young cohort $n=158$	Older cohort $n=115$	p
Mathematics anxiety	21.21	17.21	<.01	21.10	17.95	.05	19.52	19.90	.71
Test anxiety	62.23	53.93	<.01	63.69	59.36	.12	58.71	62.03	.11
General anxiety	4.54	3.63	.06	3.35	2.14	.01	4.15	2.89	<.01
Maths achievement	43.22	50.82	.08	52.50	51.52	.85	46.54	52.12	.09
Reading achievement	57.94	56.14	.69	60.21	55.88	.40	57.20	58.59	.67

Identification and description of the anxiety profiles

Latent profile models with one through to six profiles were fitted separately for each age cohort to determine the most parsimonious number of profiles to describe profiles of anxiety (see Table 4 for fit indices). The optimal solution for the younger cohort was selected as the five profile model. This solution had the lowest BIC value, relatively high entropy, and the PBLRT value suggests it was a significant improvement on the four-profile solution. It also had an acceptable number of members per profile with the smallest profile representing 6% of the sample ($n = 10$). Posterior probabilities in these analyses ranged from 0.85 to 0.98, allowing a high degree of confidence in profile assignment.

The optimal solution for the older cohort was selected as the two profile model. Estimation was ceased at the four-profile solution which was unidentified. Both the two and three profile solutions had low BIC values and relatively high entropy. The LMR and VLRT values suggested that the three profile solution did not significantly improve on the two profile solution. Posterior probabilities for the two profile solutions ranged from 0.85 to 0.97, allowing a high degree of confidence in profile assignment. The highest chance of misclassification was found in Profile 1 where up to 15% of cases (or 4 cases) had the chance of being misclassified into Profile 2.

Description of the anxiety profiles and gender composition

Profile probabilities were saved in MPlus and then exported to SPSS where simple data screening and diagnostics were conducted. Anxiety scores were standardised to enable the production of Figs. 1 and 2 which depict the anxiety scores for the identified profiles in the younger and older cohorts respectively.

In the younger cohort, the largest profile with 39% of the sample we called mean level anxiety (see Table 5). This profile had consistently average or just above average scores on all three anxiety measures (Fig. 1) and was representative of the gender composition of this cohort. The second largest profile with 31% of the sample we called the low anxiety profile, which was characterised by the lowest scores across all of the anxiety measures with boys overrepresented in this group. The third largest profile with 13% of the sample we called the moderate academic anxiety profile which was characterised by approximately mean level general anxiety but moderately high test and mathematics anxiety with girls overrepresented in this group. The fourth largest profile with 11% of the sample was the high general anxiety group characterised by the highest general anxiety among the profiles but low test and mathematics anxiety with boys overrepresented in this group. The smallest and final profile with 6% of the sample was the high academic anxiety group characterised by the highest scores on test and maths anxiety and moderately high general anxiety scores with girls overrepresented in this group.

For the older cohort in which two profiles was the best solution, the largest profile with 77% of the sample we called low anxiety as these participants were characterised by below mean level scores on each of the three anxiety measures (Fig. 2). This profile was approximately representative of the gender composition of this

Table 4 Model fit information for the latent profile analyses

	Number of profiles	Log-likelihood	Number of parameters	Entropy	BIC	AIC	LMR p-value	VLRT p-value	PBLRT p-value
Younger cohort	1	-1644.182	6		3318.739	3300.363	-	-	
	2	-1572.742	10	.933	3196.110	3165.484	.135	.126	.00
	3	-1527.635	14	.864	3126.145	3083.269	.0371	.0335	.00
	4	-1502.016	18	.863	3095.159	3040.032	.306	.291	.00
	5	**-1487.670**	**22**	**.873**	**3086.717**	**3019.340**	**.009**	**.011**	**.00**
	6	-1479.979	26	.883	3091.586	3011.958	.577	.564	.012
Older cohort	1		6		2333.869	2317.295	-	-	
	2	**-1152.648**	**10**	**.779**	**2306.852**	**2279.231**	**.0584**	**.00514**	**.00**
	3	-118.471	14	.840	2303.613	2264.942	.333	.3188	.00
	4	UNIDENTIFIED							
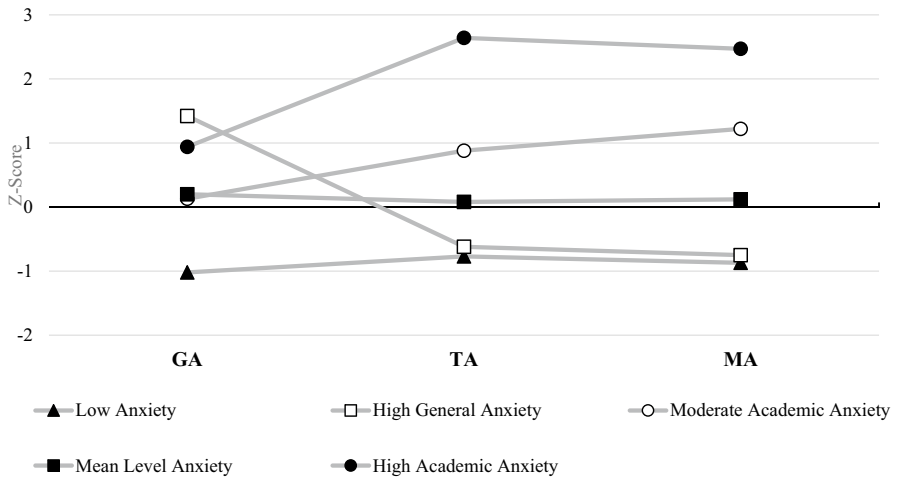
Fig. 1 Transformed standardised anxiety scores for five profiles of general, test, and mathematics anxiety in younger cohort

cohort. The other profile for this cohort with 23% of the sample we called the high anxiety profile as they were characterised by significantly higher scores on all three anxiety measures. This profile was over-representative of girls in this cohort.

Anxiety profile membership and maths achievement

ANOVAs with post hoc Bonferroni multiple comparisons were used to test for mean level differences in maths achievement for each of the profiles for the younger and older cohorts. The assumption of homogeneity of variance across profiles in both
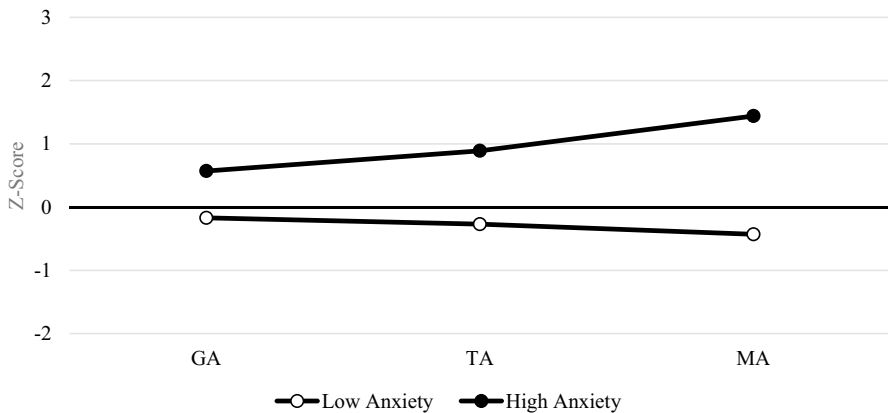
Fig. 2 Transformed standardised anxiety scores for two profiles of general, test, and mathematics anxiety in older cohort

Table 5 Gender composition and mathematics achievement for the profiles

	Total N (%)	Female n (%)	Mathematics achievement M (SD)	General anxiety M (SD)	Test anxiety M (SD)	Mathematics anxiety M (SD)
Younger cohort	158 (100)	91 (58)	46.54 (26.08)	4.15 (3.02)	58.71 (19.19)	19.51 (8.62)
Mean level anxiety	61 (39)	37 (61)	41.85 (26.12)	4.75* (2.05)	60.13* (9.32)	20.52* (2.96)
Low anxiety	49 (31)	24 (49)	54.30 (26.54)	1.08 (1.19)	44.76 (7.74)	11.98 (2.50)
Moderate academic anxiety	20 (13)	16 (80)^	40.58 (19.04)	4.55* (2.10)	74.75* (9.46)	30.05* (3.03)
High general anxiety	18 (11)	6 (33)	56 (26.10)	8.44* (1.33)	47.39 (5.75)	13.06 (3.24)
High academic anxiety	10 (6)	8 (80)^	34.90 (25.40)	7* (3.23)	106.70* (10.70)	40.80* (3.99)
Older cohort	115 (100)	71 (62)	52.12 (26.31)	2.89 (2.29)	62.03 (14.49)	19.90 (8.19)
Low anxiety	89 (77)	52 (58)	56.56 (25.19)	2.46 (.21)	58.26 (12.38)	16.43 (4.97)
High anxiety	26 (23)	19 (73)^	37.12* (24.85)	4.34^ (2.64)	74.96* (13.93)	31.77* (4.96)

^ girls overrepresented in the profile

* significantly different from the low anxiety profile at *p* < .05

age cohorts was checked (Levene's test) and met. The most common profiles were used as the reference group for each cohort, to which all other profiles were compared. The reference group for the younger cohort was the mean level anxiety profile and for the older cohort the reference group was the low anxiety profile.

For the younger cohort, while the overall ANOVA model was significant ($F = 2.94$, $p = 0.02$), multiple comparisons using the Bonferroni statistic showed that there were no significant differences in achievement for each of the profile groups compared to the mean level anxiety profile. However, a trend can be noted with the lowest mean maths achievement in the high academic anxiety profile, and the highest maths achievement in the low anxiety, and high general anxiety groups (Fig. 3). With larger sample sizes within each profile it is likely these differences might have reached statistical significance.

For the older cohort, the high anxiety profile had significantly poorer maths achievement than the low anxiety profile ($F = 12.02$, $p < 0.01$). The difference equated to a 0.7 standard deviation reduction in mathematics achievement for the high anxiety group. We repeated the analyses including reading achievement as a covariate in the model and the results did not significantly alter.

Discussion

As global policies aim to increase participation and achievement in STEM disciplines in order to build the future workforce, it is more important than ever to understand the individual factors that may be influential in this regard. This study is one of the few known studies internationally to examine profiles of general, test, and mathematics anxiety in students aged 9 to 13 years, and the first with Australian students. Our findings are unique in establishing five anxiety profiles in our younger cohort (low anxiety, high general anxiety, mean anxiety, moderate academic anxiety,
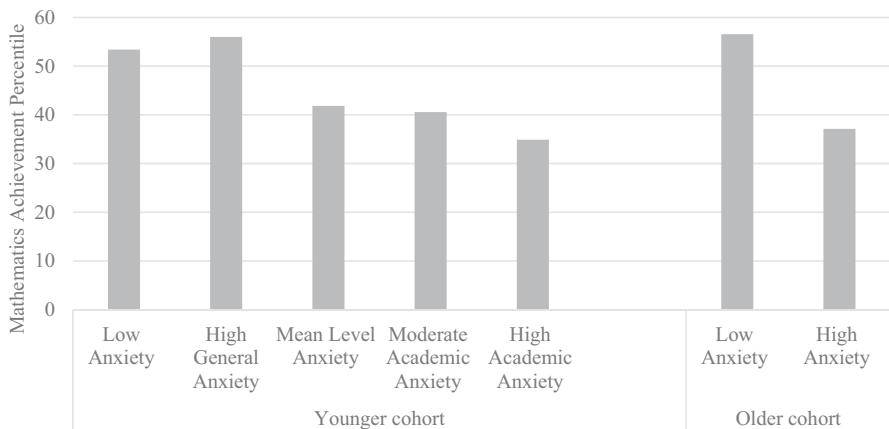

Fig. 3 Mathematics achievement for anxiety profiles in younger and older cohorts

high academic anxiety) and a more consolidated two anxiety profiles (low anxiety and high anxiety) in our older cohort.

The clustering and prevalence of general, test, and mathematics anxiety

Compared to the two previous studies that have reported profiles of general, test, and mathematics anxiety in school aged students, the way the anxiety types clustered together differed in the current study. Specifically, both Carey et al. (2017a, b) and Mammarella et al. (2018) reported profiles in young students in which the three anxiety types clustered together as either all low, moderate, or high within each of three (Mammarella et al., 2018) or four (Carey et al., 2017a, b) profiles. In the current study a similar solution was ascertained in our older cohort of students but with only a two-profile solution of low (77%) and high anxiety (23%). The solution for our younger students was more complex and more in line with Carey's profile solution for their older students. That is, in our younger students we found distinct profiles of academic anxiety, in which although test and mathematics anxiety were moderate to high, general anxiety was low.

In both cohorts, the majority of students were characterised as having low or mean level anxiety, aligning with the prior profile studies from Britain and Italy (Carey et al., 2017a, b; Mammarella et al., 2018) with a smaller proportion classified as having various manifestations of higher anxiety. In the younger cohort a total of 30% of students were classified as high in various forms of anxiety including high general anxiety (11%), moderate academic anxiety (13%) or high academic anxiety (6%). This aligns relatively well with the 24% of younger cohort students of the same age being in moderate or high anxiety groups in the British profile study (Carey et al., 2017a, b), and 22% in the high anxiety profile in the Italian profile study (Mammarella et al., 2018) although the profile compositions in terms of clustering of anxiety types differed as described above. Interestingly the academic anxiety prevalence rate in our younger cohort represented by two profiles and totalling 20% aligns with the 20% of older cohort students with an academic anxiety profile in the British study (Carey et al., 2017a, b). In the older cohort in the current study 23% of students were classified with high anxiety that included higher than average levels of all anxiety types, aligning well with the prevalence rates of higher anxiety previously published (Carey et al., 2017a, b; Mammarella et al., 2018).

The reason for our study finding profiles characterised by academic anxiety in our younger cohort but not our older cohort, the opposite to the British study, is unclear. It may be that our findings are evidence of the reciprocal theory (Ashcraft et al., 2007; Carey et al., 2016) and the complex interplay of contributing variables (environment, intellectual, and personal; Ma & Xu, 2004), which have not been measured in either study. It could be that the different geographical and curricular contexts bring about different antecedents for academic anxiety. However, our findings should be interpreted with caution given our small, non-representative, and relatively small sample size with unequal representation by gender, and the cross-sectional nature of the design.

Associations among anxiety and mathematics achievement

Small-moderate negative correlations were evident between anxiety measures and mathematics achievement, in both the younger and older cohorts. This is mostly aligned with the British findings of Carey et al. (2017a, b), but not the Italian findings of Hill et al. (2016) who reported significant correlations with high school students and not primary students. In our results, the negative correlations were significant for academic anxiety measures (mathematics and test anxiety), but not general anxiety. While not all research (e.g. Cargnelutti et al., 2017; Devine et al., 2012; Justicia-Galiano et al., 2017; Wu et al., 2012) has combined general, test, and mathematics anxiety in correlational analyses, there does appear to be agreement that mathematics anxiety is a distinct type of anxiety and that it negatively impacts mathematics performance.

Gender, anxiety, and mathematics achievement

The relations between anxiety and achievement become even more complex when also considering differences based on gender. Similar to the findings of Devine et al. (2012), Hill et al. (2016), and numerous countries in the 2019 TIMSS (Thomson et al., 2020) our investigation identified no gender differences in mathematics achievement. Our results (Table 3) do indicate significant gender differences on selected anxiety measures, with females typically experiencing higher levels of anxiety than males in both cohorts, with overrepresentation of females in the high anxiety profiles. We interpret this finding as further evidence of what Devine et al. (2012) and Koch (2018) proposed as the role of mathematics anxiety in attenuating performance. That is, although females tend to experience higher levels of anxiety, there are no significant gender differences on performance, suggesting that females appear to be able to maintain an achievement level comparable to males even when they are experiencing high levels of anxiety. Thus, females have the potential to outperform males if the effects of anxiety can be lessened or appropriately managed. This view may explain the inconsistent findings related to gender differences in mathematics achievement across prior studies in which the impact of anxiety on performance has not been explored (e.g. Thomson et al., 2020). An important consideration as girls move through primary and in to secondary school is to understand the potential impact of mathematics anxiety, if not on achievement, then on mathematics subject and career choices, and motivation for such.

Limitations and future directions

While this study has provided unique information, it is not without limitations. The sample is non-representative in terms of both socio-economic characteristics and gender, with a higher percentage of families with girls consenting to the research, and a relatively advantaged sample. The cross-sectional, correlational nature of the design does not allow for any causal inferences to be made. Future studies should take a longitudinal approach to understanding the developmental nature of general, test,

and maths anxiety, how these interact over time, and their influence on mathematics engagement and achievement. Future research should also address the fact that studies in this field to date have largely been conducted only in relatively middle-low performing countries in terms of international benchmarks. Replication studies in high performing countries would allow for comparisons to be made and could illuminate some of the key individual and contextual factors that support high performance.

Mathematics anxiety and achievement are the result of the complex interplay of different factors including individual antecedents, as well as interacting variables that are specific to the context and the individual (Luttenberger et al., 2018; Ma & Xu, 2004). Given findings about the role of other constructs including maths self-efficacy, self-concept, and motivational beliefs (Grigg et al., 2018; Sewasew et al., 2018) it is important that future programs of research include a wider variety of measures so that a complex and dynamic model of mathematics development can be built over time. Further, research has identified specific components of mathematics anxiety including anxiety related to calculations, the maths classroom, and maths tests (e.g. Lukowski et al., 2019), and future studies could further explore this multi-dimensional nature of maths anxiety. Longitudinal mixed methods research across a range of educational contexts will support these goals. As well as individual factors, this might include further understanding of regional and contextual factors such as the home and school environment, parental and teacher anxieties and expectations related to mathematics, as well as the design and implementation of mathematics learning and assessment.

Implications

With 20 – 30% of students in this and other similar studies experiencing mathematics or other academic anxiety profiles which are likely to influence their achievement, there is a clear imperative for the field of education to establish interventions to manage anxiety and uncertainty in mathematics. A range of intervention approaches including mathematics pedagogy and approaches that aim to alter student appraisal and mind-set in relation to mathematics have been suggested but rarely evaluated when implemented with school-aged children (Buckley & Sullivan, 2023; Ramirez et al., 2018). Holistic approaches that consider the early home learning environment, parental mathematics anxiety and approaches, and teacher and educational psychologists' capacities to support student reappraisal are needed (Maloney & Beilock, 2012). Given ongoing concern about female participation in STEM disciplines, special attention to disrupting gender stereotypes from the earliest years of education is also needed. Our findings suggest that for younger children in our study, clustering of anxiety types has not yet bedded down in to overall high and low profiles and so primary school may provide a window of opportunity to address early signs of academic and mathematics anxiety. However, much more rigorous and longitudinal research that identifies the most effective ways to do this is required.

Conclusion

This paper has characterised the general, test, and mathematics anxiety profiles of primary and high school cohorts with a sample of students in Australian schools. While both cohorts of students had significant negative correlations between test and mathematics anxiety measures and mathematics achievement, there were no significant differences between males and females in mathematics achievement. However, females in each cohort had significantly higher mathematics anxiety scores than their male peers. There were a greater number of distinct anxiety profiles identified in the primary students (9–10 years of age), and fewer more consolidated anxiety profiles identified in the high school students (12–13 years of age). Membership of profiles with higher test or mathematics anxiety were generally associated with poorer maths achievement. These individual factors are clearly an important issue for teaching and learning in schools. However, there is need for further systematic investigation to create a more detailed picture of the environmental, intellectual and personal factors that impact maths engagement and achievement trajectories.

Declarations

Ethical approval Ethics approval was provided by the Queensland University of Technology Human Research Ethics Committee, approval number 1400000695.

Informed consent Parents/carers of the students involved in the study provided informed consent for their children to participate. Assent to participation was also collected from children. Principals of the schools through which children were recruited provided informed written consent.

Conflicts of interests There are no conflicts of interests to declare.

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