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Maths anxiety in primary and secondary school students: Gender differences, developmental changes and anxiety specificity

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ABSTRACT

Maths anxiety (MA) is a debilitating negative emotional reaction towards mathematics. However, MA research in primary and early secondary school is surprisingly sparse and inconsistent. Here we tested primary and secondary students' maths and reading performance and their maths and general anxiety (GA). We examined gender differences, developmental changes regarding the MA/maths performance link and investigated whether MA is linked to other academic domains (reading) and/or to other anxiety-types (GA). Results revealed that girls exhibited higher MA than boys at both educational levels. Whilst there was a reliable negative correlation between MA and secondary students' arithmetic performance, no such relationship was revealed in primary students. Finally, MA was moderately correlated with GA and, when GA was partialled out, MA remained significantly correlated with secondary students' arithmetic performance. MA was not related to reading performance when GA was controlled. It was concluded that the negative MA/maths performance link surfaces later in the educational timeline and MA appears to be both exclusively related to maths and independent of GA.

1. Introduction

Maths anxiety (MA) is a negative emotional response to current or prospective situation involving mathematics. The effects of MA are educationally debilitating; MA sufferers have decreased maths self-confidence, enjoy maths less and may even avoid maths altogether (Ashcraft, Kirk, & Hopko, 1998; Hembree, 1990; Maloney & Beilock, 2012). Nevertheless, the majority of studies have investigated MA in university and secondary school samples; MA research employing primary and early secondary school populations remains surprisingly sparse (Jackson & Leffingwell, 1999). Questions remain regarding MA gender differences amongst child and adolescent populations and it is unclear whether the MA/maths performance link seen in older students also presents in the younger age-range. A further question centres on the specificity of MA and whether MA is *only* related to maths or is a manifestation of general anxiety.

In response to these research gaps, here we had three objectives. Firstly, we examined gender differences in MA during primary and early secondary school. Secondly, we mapped developmental changes relating to MA and its link with maths performance in both primary and secondary school. Finally, we investigated whether MA is a maths specific anxiety-type and is independent of general anxiety.

1.1. Gender differences

Studies employing adult populations have consistently revealed women to have higher MA than men (e.g. Chang & Cho, 2013; Ferguson, Maloney, Fugelsang, & Risko, 2015; Miller & Bichsel, 2004; Woodard, 2004). Yet, far less is known about the development of MA gender differences in childhood and adolescence.

More researchers are beginning to investigate the incidence and effects of MA in primary samples (e.g. Galla & Wood, 2012; Vukovic, Kieffer, Bailey, & Harari, 2013; Wu, Barth, Amin, Malcarne, & Menon, 2012). However, such studies rarely report gender-related findings. Of the few which have, the majority found no gender MA differences (e.g. Gierl & Bisanz, 1995; Harari, Vukovic, & Bailey, 2013, Newstead, 1998; Punaro & Reeve, 2012; Ramirez, Gunderson, Levine, & Beilock, 2013; Young, Wu, & Menon, 2012). Nevertheless, the possibility that MA gender differences surface in primary school should not be ruled out. Some studies have reported primary-age girls' to have higher levels of MA than boys (e.g. Griggs, Rimm-Kaufman, Merritt, & Patton, 2013; Yüksel-Şahin, 2008) and Krinzinger, Wood, and Willmes (2012) revealed primary boys to have more positive attitudes towards maths

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than girls. Further, Satake and Amato (1995) revealed that 5th and 6th grade girls reported higher levels of 'maths test anxiety' compared to male peers. Thus, it remains unclear as to whether girls experience higher MA than boys in primary education.

Data at the secondary level are more consistent with those revealed in adult populations. Although some studies have revealed no MA gender differences (e.g. Birgin, Baloğlu, Çatlıoğlu, & Gürbüz, 2010; Dede, 2008; Kyttälä & Björn, 2014), more have revealed higher MA in girls than boys (e.g. Devine, Fawcett, Szűcs, & Dowker, 2012; Frenzel, Pekrun, & Goetz, 2007; Jain & Dowson, 2009; Kvedere, 2012; Luo, Wang, & Luo, 2009; Primi, Busdraghi, Tommasetto, Morsanyi, & Chiesi, 2014).

Collectively, although null findings have been reported in both primary and secondary samples, the literature suggests girls experience more MA than boys at both educational levels. However, the evidence for a MA gender difference is considerably more extensive and conclusive amongst secondary samples. Although this may simply be due to a lack of research at the primary level, it may also indicate that the MA gender difference is more established and visible in secondary samples, and thus more likely to be reported by researchers. However, this is speculative and more research is required to ascertain whether MA gender differences are already present at the primary level or develop later. Hence, here we examined the presence and nature of MA gender differences in primary and early secondary school students.

Mathematics performance gender differences are also of interest. Meta-analytic studies have demonstrated a male advantage in mathematics amongst secondary-age students (Hedges & Nowell, 1995; Hyde, Fennema, & Lamon, 1990). Nevertheless, this does vary across country (Else-Quest, Hyde, & Linn, 2010) and recent data suggest this gender gap is disappearing (Hyde, Lindberg, Linn, Ellis, & Williams, 2008; Hyde & Mertz, 2009; Lindberg, Hyde, Petersen, & Linn, 2010). Further, Devine and colleagues showed no gender difference in arithmetic performance, despite girls reporting higher MA than boys (Devine et al., 2012). Thus, here we also compared girls' and boys' arithmetic performance to elucidate whether or not there a gender related mathematics attainment gap.

1.2. Developmental changes

Findings relating to the development of the MA/maths performance link are even less clear-cut than those focusing simply on MA incidence. In secondary school, MA has been found to be negatively correlated with mathematics performance, including term/exam grades and mathematics tests (Hembree, 1990; Ma, 1999; Resnick, Viehe, & Segal, 1982; Richardson & Suinn, 1972; Wigfield & Meece, 1988). However, evidence suggests that the MA/maths performance link typically seen in older students is not present in primary school. For instance, Thomas and Dowker (2000) found no association between MA and calculation ability in six- to nine-year-olds, prompting Dowker (2005) to suggest that MA only affects maths performance after fourth grade. Supporting this, Krinzinger, Kaufmann, and Willmes (2009) found no significant correlations between MA and maths ability in early primary school children.

Nevertheless, other researchers have revealed opposing evidence. For instance, Punaro and Reeve (2012) found a significant relation between nine-year-old children's maths worry ratings and their maths problem-solving judgments. Further, they revealed that a high maths-worry subgroup showed poorer maths performance than other subgroups (Punaro & Reeve, 2012). Similarly, Wu et al. (2012) discovered that 2nd and 3rd grade maths achievement was negatively associated with MA scores. Evidently, the findings lack consistency, with some finding an MA/maths performance relationship even in young children, and others suggesting that it develops later. Thus, here we tested both primary and early secondary school students to explore whether this relationship differs by education level.

1.3. Anxiety specificity

By definition, MA is exclusively related to maths (Hembree, 1990). However, an important issue concerning MA's specificity relates to whether MA is only linked to maths performance or whether it also has associations with other academic domains and skills. The vast majority of research on academic anxiety has focused on mathematics, yet research indicates that reading/literacy anxiety may also exist. For instance, children and adolescents with poor literacy have been shown to exhibit more language anxiety than their literate peers (Carroll, Maughan, Goodman, & Meltzer, 2005) and researchers have noted an association between reading difficulties and anxiety symptomology (Carroll & Iles, 2006). Furthermore, Punaro and Reeve (2012) revealed that nine-year-old children reported high levels of worry in a literacy judgement task corroborating the possibility that literacy can elicit anxiety. Consequently, here we measured maths and reading performance to explore whether MA is exclusively related to maths or whether it is also related to performance in literacy.

Nevertheless, Punaro and Reeve (2012) also discovered that, whilst the high maths-worry subgroup only reported a maths task to be worrisome and not a language task, the high language-worry subgroup reported *both* maths and language tasks to be worrisome. It may be that these children were worried about mathematics and about language simply because they were *generally anxious* children, with a disposition towards many forms of anxiety. General anxiety (GA) differs conceptually and in definition from MA in that it does not relate to a specific situation or activity, but rather refers to an individual's general disposition to worry about events, behaviours and personal abilities. However, evidence suggests that GA and MA may not be entirely independent; GA is moderately correlated with MA (Hembree, 1990) and, in a study exploring the genetic variance of MA, genetic and non-shared environmental factors associated with GA were found to influence MA, implicating GA in MA aetiology (Wang et al., 2014).

There is the further possibility that methodological issues are clouding the issue. Researchers have distinguished between trait and state anxiety (Bieg, Goetz, & Lipnevich, 2014; Goetz, Bieg, Lüdtke, Pekrun, & Hall, 2013). Trait anxiety refers to habitual emotions, whereas state anxiety relates to transitory, contextual worries elicited by real-life experiences. Self-report measures of state and trait anxiety can lead to different results (Porter et al., 2000) and findings reveal higher intensities of trait as compared to state emotions (Goetz et al., 2013). Yet, researchers typically employ self-report questionnaires measuring trait, rather than state, MA.

Whereas state MA reflects an individual's momentary anxiety levels in a given maths-based situation, trait MA reflects an individual's *typical* feelings towards maths, therefore making it more akin to general anxiety. Furthermore, unlike state MA, trait MA levels have been found to be influenced by dispositional and temperament-based factors such as subjective beliefs (Robinson & Clore, 2002) and competence beliefs (Goetz et al., 2013). Consequently, it is conceivable that typical self-report (i.e. trait) MA measures are influenced by GA levels. With this is mind, a pertinent (yet often overlooked) question relates to whether, and how, general and maths anxiety are associated. Are typical self-report MA measures simply highlighting *generally* anxious individuals rather than those *specifically* worried about maths? By utilising both a measure of GA and a typical self-report measure of trait MA we aimed to further explore relations between the two anxiety-types and whether controlling for GA would affect the relationship between students' MA and their maths performance.

1.4. The current study

In response to the abovementioned research gaps, here we had three objectives. Firstly, by testing both primary and secondary students, we further explored MA gender differences and investigated whether gender-related patterns are visible in secondary school, primary school or at both educational levels. Secondly, we mapped developmental changes relating to MA and its link with maths performance in both primary and secondary school. Finally, we examined the specificity of MA by exploring relations between MA and reading performance, as well as those between MA and GA.

2. Methods

2.1. Participants

The cohort consisted of 1014 children attending both primary and secondary schools in Italy. We excluded some children due to missing data, so the final sample consisted of 981 students. The primary sample (N = 639) had 322 girls (mean age = 9 years and 5 months; SD = 7 months) and 317 boys (mean age = 9 years and 5 months; SD = 6 months) from grades 3 to 5. The secondary sample (N = 342) had 148 girls (mean age = 12 years and 7 months; SD = 12 months) and 194 boys (mean age = 12 years and 8 months; SD = 9 months) from grades 6 to 8.

For all children, parental consent was obtained before testing. Children referred to as having a very low socioeconomic level or those with an individualised education plan (IEP) were not included in the study.

2.2. Materials

The *Abbreviated Math Anxiety Scale* (AMAS; Hopko, Mahadevan, Bare, & Hunt, 2003) is a self-report MA questionnaire. It is the shortest valid MA scale, but has been shown to be as effective as the longer Maths Anxiety Rating Scale (MARS; Hopko, 2003) (e.g. internal consistency: Cronbach's $\alpha = .90$; two-week test–retest reliability: $r = .85$; convergent validity of AMAS and MARSR, $r = .85$). Using a 5-point Likert scale, participants indicate how anxious (e.g. 1 = low anxiety; 5 = high anxiety) they would feel during certain situations involving maths.

The *Revised Children's Manifest Anxiety Scale: Second Edition* (RCMAS-2; Reynolds & Richmond, 2012) is a self-report questionnaire used to identify the source and level of GA in children from 6 to 19 years old. It consists of 49 items with a simple yes/no response format divided into 5 scales: physiological anxiety, worries, social anxiety, defensiveness and total anxiety (internal consistency: physiological anxiety Cronbach's $\alpha = .68$; worries $\alpha = .80$; social anxiety $\alpha = .78$; defensiveness $\alpha = .70$; total anxiety $\alpha = .89$). Maximum score is 40.

Arithmetic test (derived from Cornoldi & Cazzola, 2004; Cornoldi, Lucangeli, & Bellina, 2012, AC-MT batteries) The AC-MT batteries include a series of sub-tests evaluating different aspects of math achievement. Our research only used one sub-test: '*accuracy on written calculations*'. This requires children to complete a list of calculation problems (addition, subtraction, multiplication and division) and includes items appropriate to the students' age and schooling level (test–retest coefficients — Pearson correlations ranged from .70 to .79 for primary schools and from .72 to .83 for secondary schools).

Reading comprehension test Cornoldi & Colpo, 1998, MT battery). Only secondary school children completed this test.[1] Children were shown reading passages standardised according to their schooling level. While reading silently, they were able to refer back to the passage while answering questions relating to its content and meaning. There were no time constraints. Children's reading comprehension skill was measured from the total number of correct answers in a multiple-choice questionnaire (Cronbach's $\alpha = .77$).

2.3. Procedure

Researchers administered the tests in school. Children were tested in the classroom in group sessions each lasting approximately 1 h. Materials were administered in a fixed order: arithmetic test, reading comprehension test, RCMAS-2 and AMAS. The questionnaires were administered last in order to avoid stereotype threat effects.

2.4. Statistical analyses

Our primary analysis employed robust, distribution independent, bootstrap statistics. According to these, 'significant' differences appear if appropriate 95% bootstrap confidence intervals do not overlap. Hence, the term 'significant' will refer to such differences in confidence intervals. All bootstrap confidence interval estimations used 10,000 permutations with replacement (Chihara & Hesterberg, 2011) and computed bias-corrected and accelerated (BCa) confidence intervals (Efron, 1987). We assessed group differences by computing 95% BCa bootstrap confidence intervals for the main measures. Although bootstrap confidence intervals provide a better statistical solution than simply presenting p-values (see Cumming, 2014 on the importance of presenting confidence intervals), we also ran parametric tests on our data. Parametric tests were 2×2 ANOVAs with Gender (girl vs. boy) and Level of Schooling (primary vs. secondary) as factors. We also report Hedges's G for relevant effect sizes (see Appendix A).

We assessed the relative importance of predictors of arithmetic scores by bootstrapping standardised Beta values in simultaneous regression models. All regression predictors were standardised except the dichotomous variables of Gender (girls vs. boys) and Level of Schooling (primary vs. secondary). All reported Beta values were derived from these standardised models. To assess potential multicollinearity of variables, Variance Inflation Factors (VIF) were computed for all correlation tables and for variable groups in regression models. For all statistical analyses, we converted children's raw scores in the arithmetic and reading tests to standardised values. Analyses were done in Matlab 2014a and in Statistica 11 (StatSoft).

3. Results

3.1. Group differences

Fig. 1 shows group means and 95% bootstrap confidence intervals for total scores on the AMAS and RCMAS-2 according to Gender (Fig. 1a), Level of Schooling (Fig. 1b) and Gender × Level of Schooling (Figs. 1c and 1d). Fig. 1a demonstrates that girls scored significantly higher than boys on both the AMAS (1.9 points higher) and the RCMAS-2 (2.4 points higher). Fig. 1b demonstrates that secondary school children scored higher than primary school children on the AMAS (0.9 points higher), whereas primary school children scored higher than secondary school children on the RCMAS-2 (0.8 points higher). However, primary vs. secondary school differences were not significant. Effect sizes are reported in Table A1 in Appendix A.

When girls and boys were split according to Level of Schooling the previously-found gender difference remained. Fig. 1c demonstrates that primary girls had higher AMAS (1.7 points higher) and RCMAS-2 scores (2.1 points higher) compared to primary boys and likewise, Fig. 1d demonstrates that secondary girls had higher AMAS (2.5 points higher) and RCMAS-2 scores (3.0 points higher) compared to secondary boys. ANOVAs produced consistent results with bootstrap statistics.

As can be seen in Fig. 2, there were no significant differences in girls' and boys' arithmetic scores. This was the case in primary school, secondary school and across both schooling levels.

[1] We did not receive the consent from parents to administer the reading comprehension task on primary school children.

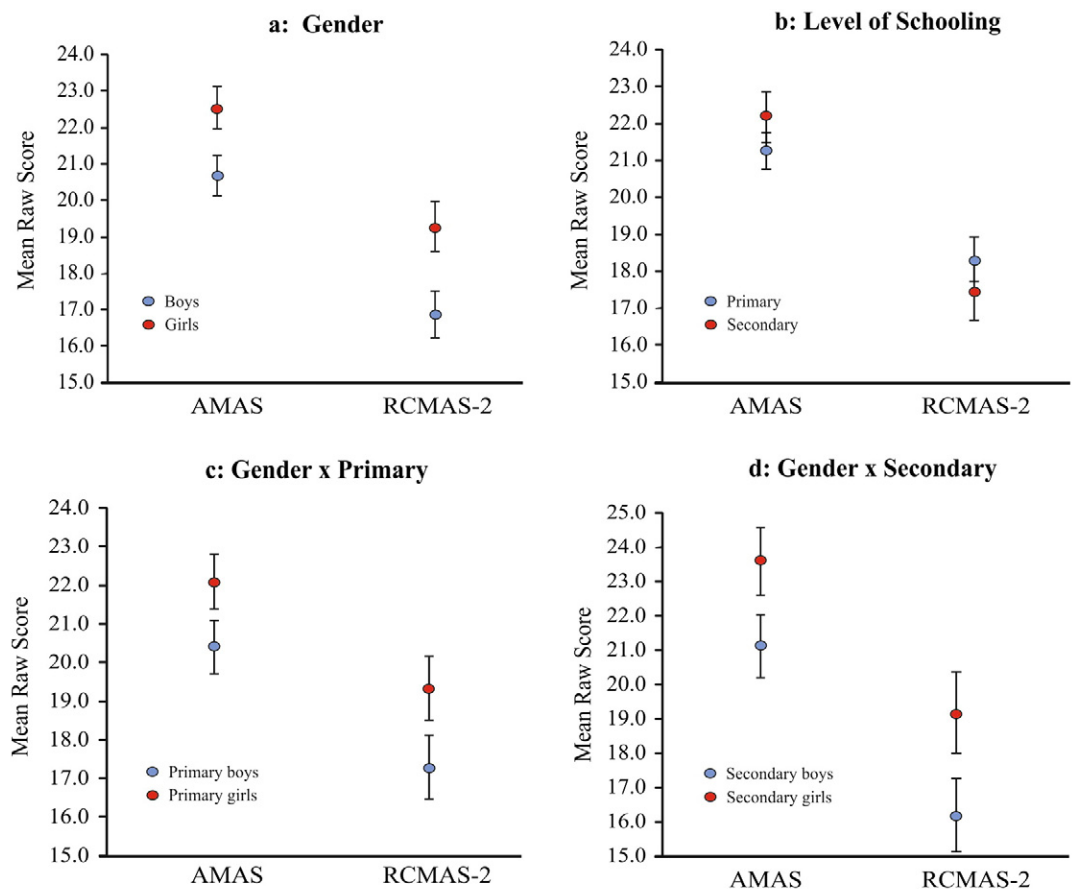

Fig. 1. Group means and 95% bootstrap confidence intervals for total scores on the AMAS and RCMAS-2.

3.2. Relations between maths anxiety, general anxiety and arithmetic performance

Correlations between scores on the AMAS, RCMAS-2 and arithmetic test were explored. Table 1 shows 95% bootstrap BCa confidence intervals for appropriate zero-order and partial correlations. First, AMAS scores were significantly and positively correlated with RCMAS-2 scores. This was the case across all Gender × Level of Schooling groups. However, as can be seen in Fig. 3, correlations between AMAS and RCMAS-2 scores were only moderate.

Second, there were significant, negative and moderate correlations between AMAS and arithmetic scores amongst both secondary boys and girls. Further, a significant negative correlation between AMAS

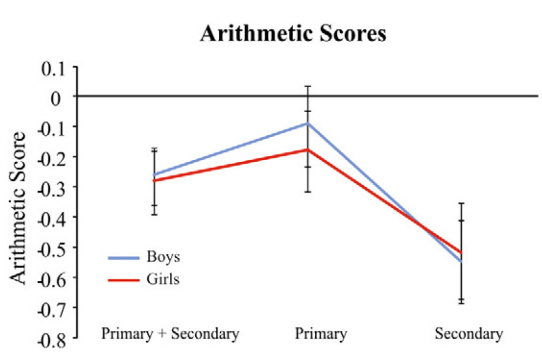

Fig. 2. Standardised means and 95% bootstrap confidence intervals for total scores on arithmetic test according to Level of Schooling. Note that values are negative because this particular sample attained lower scores than the standardisation means.

and arithmetic scores was revealed amongst primary girls, although the effect size was very small. The correlation between primary boys' AMAS and arithmetic scores was both very small and non-significant. However, when the effect of RCMAS-2 scores were partialled out from the AMAS vs. arithmetic test correlations, AMAS scores remained significantly correlated with arithmetic performance in secondary school *only*. The strength of these correlations decreased only slightly and remained in the moderate range. In contrast, the weaker relationship between AMAS and arithmetic scores in primary school girls became non-significant and remained small.

Adding further support to the above findings, when partialling out AMAS scores, RCMAS-2 was only correlated with maths performance in secondary school boys. In all other cases, the correlations were non-significant.

Hierarchical regression analyses were also run for all four groups (prim/sec girls/boys). Table 2 shows that AMAS scores contributed additional information to the models on top of RCMAS-2 scores. In secondary students, the results were in line with the partial correlations; when AMAS scores were added into the model, this significantly improved the model fit for both secondary boys and girls. However, differing from the partial correlational data, the addition of AMAS scores significantly improved the model fit for primary girls also. Once again, a non-significant result was revealed for primary boys.

3.3. Relations between maths anxiety, general anxiety and reading performance

Further analyses explored whether AMAS scores were correlated with arithmetic performance only or whether they were also correlated with reading performance. Relations between reading performance and

Table 1
Zero-order and partial correlations. Zero-order correlations: between AMAS, and RCMAS-2 scores and between AMAS and arithmetic test scores. Partial correlations: between AMAS and arithmetic test scores whilst partialling out RCMAS-2 scores. Significant correlations are in bold. R^2 values are also presented for partial correlations between AMAS and arithmetic scores. VIF values for the correlation matrix ranged between 1.12 and 1.23. The parametric results were consistent with the non-parametric results.

Group (N = sample size)	Mean age ± SE	Zero-order correlations (95% bootstrapped confidence intervals)		Partial correlations (95% bootstrapped confidence intervals)	
		RCMAS-2	Arithmetic	Arithmetic	R^2
Primary girls (N = 322)	114 ± 0.7	**.36 (.26/.45)**	**−.13 (−.23/−.02)**	−.11 (−.22/−.01)	.01 (.05/.00)
Secondary girls (N = 148)	152 ± 1	**.41 (.24/.56)**	**−.34 (−.46/−.19)**	**−.28 (−.41/−.13)**	**.08 (.02/.17)**
Primary boys (N = 317)	114 ± 0.6	**.47 (.37/.55)**	−.07 (−.19/.05)	−.04 (−.15/.08)	.00 (.01/.02)
Secondary boys (N = 194)	154 ± 0.9	**.37 (.21/.50)**	**−.28 (−.41/−.15)**	**−.22 (−.34/−.08)**	**.05 (.01/.12)**

MA were tested in the secondary sample only since reading scores were only obtained for this education level.

Table 3 shows 95% bootstrap BCa confidence intervals for zero-order and partial correlations between AMAS, RCMAS-2 and reading scores in secondary school. For the zero-order correlations, there was a significant negative correlation between reading and AMAS scores for boys, although the effect size was fairly small. The correlation between girls' reading and AMAS scores was also negative, but it was smaller and non-significant. However, when RCMAS-2 scores were partialled out, the correlation between AMAS scores and reading performance in boys became both weaker and non-significant. Table 3 also shows that, when RCMAS-2 scores were correlated with reading performance while AMAS scores were partialled out, a significant, negative and moderate to low correlation between RCMAS-2 and reading was revealed in boys only. This suggests that, whilst RCMAS-2 scores had a slight negative correlation with reading, AMAS scores *on their own* displayed no such correlation with reading performance.

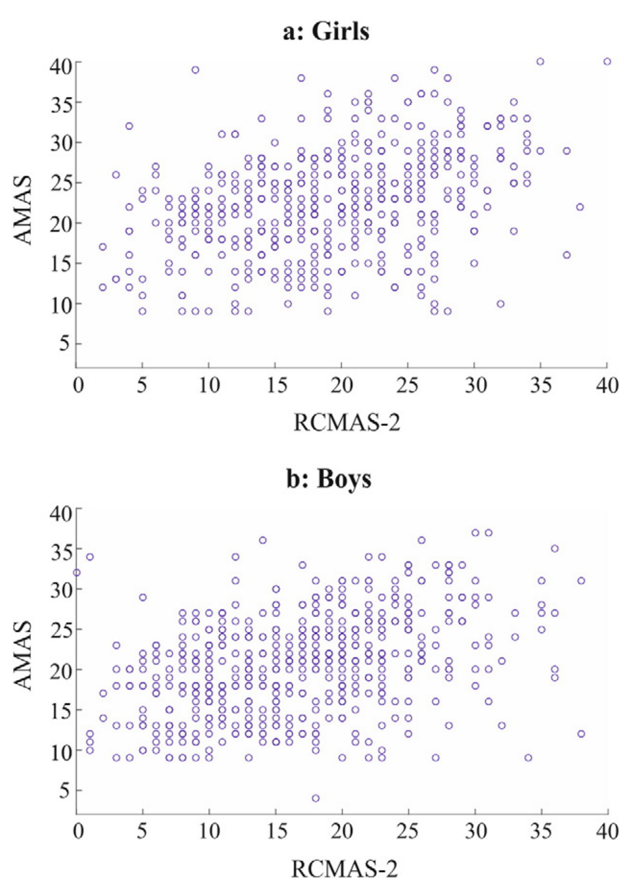

Fig. 3. Scatterplots to demonstrate the correlation between scores on the AMAS and RCMAS-2 in males and females.

4. Discussion

The current study had three objectives. Firstly, we examined gender differences in MA in primary and early secondary school students and investigated at what point in the educational timeline these differences might emerge. Secondly, we explored possible developmental changes relating to the association between MA and maths performance. Finally, we investigated whether MA is specifically related to maths and independent of GA.

4.1. Gender differences

Results revealed that girls had higher MA scores than boys. This corroborates the findings in adult studies cited in the introduction. Importantly, when girls and boys were split according to schooling level the same gender patterns were observed at secondary and primary levels. Our data agree with studies using secondary (Devine et al., 2012; Frenzel et al., 2007; Goetz et al., 2013; Jain & Dowson, 2009; Kvedere, 2012; Luo et al., 2009; Primi et al., 2014) and primary samples (Griggs et al., 2013; Krinzinger et al., 2012; Satake & Amato, 1995; Yüksel-Şahin, 2008). They also suggest that the MA gender patterns typically seen in older students can surface in primary school, in contrast to studies which found no gender differences in primary samples (Gierl & Bisanz, 1995; Harari et al., 2013; Newstead, 1998; Punaro & Reeve, 2012; Ramirez et al., 2013; Young et al., 2012).

Several explanations have been proposed as to why females exhibit higher MA levels. Although research indicates that genetic factors contribute to individual differences in MA (Wang et al., 2014), environment and socialisation may also play a part. Since mathematics is traditionally viewed as a male domain, females may believe that they are less mathematically able which may engender higher anxiety (Bander & Betz, 1981). Indeed, research indicates that maths gender-stereotypes can

Table 2
Results from the hierarchical regression analyses. For each group, a first model predicted math scores from RCMAS scores and a second model also added AMAS as a predictor. We examined whether the second model demonstrated a significantly better fit on top of the first model (i.e. whether there was a significant r^2 increase from model 1 to model 2). Significant results are in bold.

	R^2 increase from model 1 to 2	p-Value
Primary girls (N = 322)	**.0130**	**.0400**
Secondary girls (N = 148)	**.0754**	**.0005**
Primary boys (N = 317)	.0010	.5000
Secondary boys (N = 194)	**.0442**	**.0023**

Table 3
Zero-order and partial correlations. Zero-order correlations: between AMAS, and reading test scores. Partial correlations: between AMAS and reading test scores whilst partialling out RCMAS-2 scores and between RCMAS-2 and reading test scores whilst partialling out AMAS scores. Significant correlations are in bold. VIF values for the correlation matrix ranged between 1.06 and 1.11. The parametric results were consistent with the non-parametric results.

Group (N = sample size)		Correlations (95% bootstrapped confidence intervals)		
	Reading correlated with	AMAS	AMAS	RCMAS-2
	Covariate	None	RCMAS-2	AMAS
Secondary girls (N = 148)		−.10 (−.24/.05)	−.06 (−.22/.10)	−.08 (−.23/.09)
Secondary boys (N = 194)		**−.18 (−.31/−.02)**	−.08 (−.24/.09)	**−.24 (−.37/.07)**

impair females' maths performance and learning (Appel, Kronberger, & Aronson, 2011; Flore & Wicherts, 2014; Spencer, Steele, & Quinn, 1999).

Another possibility is that maths competency beliefs (e.g. maths self-concept, maths self-efficacy) account for MA gender differences. Studies have reported negative associations between competency beliefs and MA (Ahmed, Minnaert, Kuyper, & van der Werf, 2012; Frenzel et al., 2007; Goetz, Cronjaeger, Frenzel, Lüdtke, & Hall, 2010; Griggs et al., 2013; Hoffman, 2010; Jain & Dowson, 2009). Since boys have greater confidence in maths, higher maths self-perceptions, higher ratings of maths' value and stronger self-identification with maths (Cvencek, Meltzoff, & Kapur, 2014; Fennema & Sherman, 1977; Fredricks & Eccles, 2002; Marsh & Yeung, 1998; Pajares, 2005; Sherman & Fennema, 1977; Wigfield, Eccles, Mac Iver, Reuman, & Midgley, 1991), competency beliefs may indeed play a role in MA gender differences.

We cannot discount the possibility that these gender differences were due to methodological issues; not only is it more likely for women to report anxieties (Hunsley & Flessati, 1988), but self-report measures may be biased by personal-competence beliefs (Goetz et al., 2013). Nonetheless, even if these gender differences result from subjective reporting bias, the subjective perception of higher anxiety may not be irrelevant. For instance, research indicates that females experiencing higher subjective levels of MA are less likely to pursue careers requiring quantitative skills (Chipman, Krantz, & Silver, 1992). Thus, although females' higher MA may be partly driven by subjective biases, these subjective impressions can still have substantial, long-lasting effects on behaviour. In addition, as suggested by Flore and Wicherts (2014), caution is required when interpreting gender differences in children and adolescents. It is worth noting that we did not consider some variables, such as the students' classroom teacher, which may be crucial in inducing MA gender differences (Beilock, Gunderson, Ramirez, & Levine, 2010).

However, despite finding a gender difference in MA, girls and boys scored comparably on the arithmetic test. This corroborates recent data indicating that gender differences in maths performance are disappearing (Hyde et al., 2008; Hyde & Mertz, 2009; Lindberg et al., 2010). Further, and in support of Devine et al.'s (2012) findings, the fact that girls performed similarly to boys in mathematics, despite reporting greater emotional stress towards the subject, may suggest that they actually have greater mathematics *potential* than boys.

4.2. Developmental changes

To map developmental changes relating to the MA/maths performance link, we tested correlations between MA, GA and arithmetic scores and compared these in primary and secondary students. Consistent with previous research (Hembree, 1990; Ma, 1999; Resnick et al., 1982; Richardson & Suinn, 1972; Wigfield & Meece, 1988), we revealed moderate negative correlations between MA and arithmetic scores in secondary students. These correlations were observed in both girls and boys and remained significant even when controlling for GA. Further, hierarchical regression analyses indicated that GA did not explain away MA's importance in predicting secondary students' arithmetic scores. Thus, MA is robustly and reliably negatively associated with secondary students' maths performance.

Conversely, we found no stable MA/maths performance relationship in the primary cohort. A significant, but very weak negative correlation was revealed between MA and arithmetic scores in primary girls, and the corresponding correlation in primary boys was non-significant. Additionally, when GA was controlled, the weak MA/maths performance relationship in primary girls became non-significant. Our results support previous studies revealing no association between MA and maths ability/performance in younger students (Thomas & Dowker, 2000; Krinzinger et al., 2009).

Our results would suggest that the negative MA/maths performance link surfaces later in the educational timeline. Indeed, it is conceivable that MA might be associated with more academic problems in secondary education, where the maths curriculum becomes more cognitively demanding, and students are increasingly exposed to 'high-stakes' testing. Additionally, secondary schooling sees the onset of adolescence; a period of significant social and emotional development. These changes will undoubtedly influence how students engage with maths which, in turn, is likely to affect their emotional reaction towards the subject.

4.3. Anxiety specificity

To investigate MA specificity, we explored the association between MA and GA. Findings revealed positive, but moderate, correlations between MA and GA across all Gender x Level of Schooling groups. Furthermore, hierarchical regression analyses showed that MA scores contributed additional information to the models on top of GA scores. These findings corroborate previous research showing a modest association between MA and GA (Hembree, 1990) but suggest that, despite their overlap, they are distinct constructs.

When controlling for GA in the correlation between MA and arithmetic scores, the negative association between secondary students' MA and maths performance remained significant. This suggests that, in secondary school at least, MA is independent of GA. However, in primary students, when GA was partialled out, the previously significant relationship between primary girls' MA and arithmetic scores became non-significant. As, the original correlation between primary girls' MA and arithmetic scores was very weak, perhaps these girls were actually experiencing general anxieties on top of maths-specific anxiety. Consequently, rather than casting doubt over MA's exclusivity, this finding may instead provide further evidence for the lack of a robust MA/maths performance link in primary school.

We tested relations between secondary students' MA and reading to elucidate whether MA was correlated with arithmetic performance only or also with reading performance Results revealed a slight negative correlation between boys' GA and reading, but no evidence to suggest that MA scores *on their own* were related to reading performance. MA appears to be specifically related to mathematics.

Furthermore, given that boys' GA and reading scores were correlated but that this relationship was independent of maths-specific anxiety, it is possible that reading was uniquely eliciting anxiety. Interestingly, this finding was only revealed amongst boys. This gender pattern contrasts with that typically observed in MA. Since gender differences in MA have consistently been linked to maths gender-stereotypes, there is the possibility that language gender-stereotypes could elicit contrasting gender patterns relating to reading anxiety. This requires further research.

However, with no reading anxiety measure, we cannot be certain whether it was operating here. The reading test may have elicited general academic anxiety in boys, rather than exclusive reading anxiety. Indeed, Punaro and Reeve (2012) noted that a high language-worry subgroup reported *both* maths and language tasks to be worrisome suggesting that they were experiencing broader academic worries. More empirical research is needed to explore the existence of reading anxiety.

One limitation of our study is the lack of measurement or control for test anxiety (TA). TA is defined as worrying about situations involving performance evaluation (Brown et al., 2011). Research indicates that TA is moderately correlated with MA (Dew & Galassi, 1983; Hembree, 1990). Further, Devine et al. (2012) revealed that, after controlling for TA, whilst the negative relation between girls' MA and maths performance remained, the negative relationship between boys' MA and maths performance became only marginal. Thus, although our results indicate that MA appears distinct from GA and specifically related to maths, without controlling for TA, we cannot be sure that students' MA was not independent from their anxiety about simply being *tested*. The relation between secondary boys' GA and reading may have been similarly engendered. Future research into MA should therefore measure TA concurrently.

4.4. Implications

Although our results suggest that the negative relationship between MA and maths performance may not develop in primary school, MA was still *present* at this age and primary students may not possess the coping strategies or cognitive maturity to deal effectively with their maths-related worries. Additionally, our findings suggest that a negative link between MA and maths performance is likely to develop as students are faced with increasing educational demands in secondary school. Our findings thus highlight the need to: 1) provide more emotional support to primary students suffering from MA and; 2) develop preventative, protective measures aimed at halting the emergence of MA in primary school in order to reduce effects on performance in secondary education.

4.5. Conclusions

Firstly, our results indicate that girls have greater MA than boys, corroborating findings from studies on adult, secondary and primary samples. Importantly, this gender difference was found in both our primary and secondary cohorts. Our data demonstrate that differences in boys' and girls' MA can emerge early in primary school. We found no gender difference in maths performance.

Secondly, whilst we found a stable negative relationship between MA and secondary students' maths performance in secondary students, this relationship was not reliable in primary students. The negative MA/maths performance link thus appears to surface later in the educational timeline, perhaps as a result of the greater demands associated with the secondary maths curriculum. This signals the need for the development of measures aimed at halting MA's emergence in primary school.

Finally, although MA and GA were moderately related, the negative relationship between secondary students' MA and maths performance remained after controlling for GA. Furthermore, when GA was controlled, MA was not related to secondary boys' reading performance. Whilst our results suggest that MA is specifically related to maths, and independent from GA, further research is required to determine whether MA can be considered separate from TA.

Appendix A

Effect size computation

Effect sizes were computed as defined by Hedges (1981):

$$G = \frac{m_1 - m_1}{SD}$$

where m_1 stands for the mean performance score of girls, m_2 stands for the mean performance score of boys and SD stands for the pooled standard deviation of both groups computed as:

$$SD = \sqrt{\frac{(n_1-1)sd_1^2 + (n_2-1)sd_2^2}{n_1 + n_2 - 2}}$$

where sd_1 and sd_2 stands for the standard deviations measured in the groups and n_1 and n_2 denote the sample sizes in groups.

Effect sizes in the study

Table A1
Means, SDs and effect sizes.

A. Means and standard deviations

Group	Measure	AMAS	RCMAS	Arithmetic
Girls primary	Mean	22.1	19.3	−0.2
N = 322	SD	6.5	7.7	1.2
girls secondary	Mean	23.6	19.2	−0.5
N = 148	SD	6.2	7.4	1.0
boy primary	Mean	20.4	17.3	−0.1
N = 317	SD	6.2	7.6	1.2
boy secondary	Mean	21.1	16.2	−0.5
N = 194	SD	6.4	7.7	1.0
Full sample	Mean	21.6	18.0	−0.3
Full sample	SD	6.4	7.7	1.2

B. Standardised effect sizes (Hedges's G)

Contrast	AMAS	RCMAS	Arithmetic
Primary girls–boys	0.26	0.27	−0.07
Secondary girls–boys	0.28	0.29	0.02

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