Learning and Individual Differences 55 (2017) 174–182

Contents lists available at ScienceDirect

Learning and Individual Differences

journal homepage: www.elsevier.com/locate/lindif

Psychometric properties of the Abbreviated Math Anxiety Scale (AMAS) in Italian primary school children

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ARTICLE INFO

Article history:
Received 6 August 2016
Received in revised form 15 February 2017
Accepted 7 March 2017
Available online xxxx

Keywords:
Mathematics anxiety
AMAS
Gender invariance
Factor structure
Primary school children

ABSTRACT

Given the widespread prevalence of mathematics anxiety (MA) and its detrimental long-term impact on academic performance and professional development, it is essential to develop standardized tools capable of identifying MA as early as possible. One of the scales most often used to assess MA is the Abbreviated Math Anxiety Scale (AMAS) (Hopko, Mahadevan, Bare, & Hunt, 2003). The first aim of the present study was to validate this tool in a large sample of Italian primary school children, to confirm the factor structure of the AMAS and to develop standardized norms that can be used in the clinical field. Moreover, as the relation between MA and gender has been extensively reported in adult samples, a second goal of the study was to test the invariance of the scale across genders.

Emotional and motivational aspects have always played an important part in the literature on learning and cognition. Within this wide-ranging framework, special attention has been paid to math anxiety (MA) and its impact on mathematical learning: an ever-growing body of research has recognized that anxiety states and feelings of helplessness and worry experienced during math classes or related activities are significant factors with a negative influence on math learning and basic numerical abilities in both adults (Bursal & Paznokas, 2006; Jameson & Fusco, 2014; Maloney & Beilock, 2012; McMullan, Jones, & Lea, 2010; Pozehl, 1996; Swars, Daane, & Giesen, 2006) and children (Hill et al., 2016; Wu, Barth, Amin, Malcarne, & Menon, 2012). Referring to younger people in particular, MA has been identified as a prominent cause of math difficulties (Ashcraft & Krause, 2007): students with more severe MA, generally identified as feeling tense, fearful and apprehensive about mathematics (Richardson & Suinn, 1972; Tobias, 1993; Zeidner & Matthews, 2005), tend to fail in math tasks more frequently than students experiencing little or no MA (Hembree, 1990; Ma, 1999; Mammarella, Hill, Devine, Caviola, & Szűcs, 2015; Tobias, 1985). Students who suffer from MA during their early formal education also generally avoid mathematics courses as part of their higher education or career paths that demand competence in the mathematical domain. MA thus seems to have serious consequences, not only in the short term (on math performance at school), but also in the long term, adversely influencing an individual's choice of career, type of occupation, and professional growth in adulthood (Ashcraft & Ridley, 2005; Beasley, Long, & Natali, 2001; Hembree, 1990; Ho et al., 2000).

The worrying phenomenon of MA has also been investigated in the most famous international comparison of student achievement in mathematics, the Programme for International Student Assessment (PISA), published by the Organization for Economic Co-operation and Development (OECD, 2013), which assessed the competencies of 15-year-olds students from 65 different countries. Across PISA countries in the 2012 survey, around 30% of students have reported feeling helpless or nervous when faced with math problems, and this finding is associated with a 34-point lower school performance (equivalent to a year of academic learning). In Italy, 43% of students reported experiencing high levels of MA, and this was associated with a 31-point lower score in mathematics.

1. Math anxiety in children

As previously stated, MA has become a subject of increasing interest in educational and clinical settings because of its consequences in limiting people's mastery of mathematics. An increasing number of researchers are beginning to investigate the incidence and effects of MA in primary samples (e.g. Galla & Wood, 2012; Karasel, Ayda, & Tezer, 2010; Wu et al., 2012), and its consequent influence on math achievement (Ramirez, Chang, Maloney, Levine, & Beilock, 2016). The majority of this extant research has been built with cross-sectional designs mainly involving students from fourth-fifth grades through the university

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http://dx.doi.org/10.1016/j.lindif.2017.03.006

(e.g., Baloğlu & Koçak, 2006; Birgin, Baloğlu, Çatlıoğlu, & Gürbüz, 2010; Newstead, 1998 and Suinn, Taylor, & Edwards, 1988).

Only few studies focused on younger samples (Harari, Vukovic, & Bailey, 2013; Krinzinger, Kaufmann, & Willmes, 2009; Ramirez, Gunderson, Levine, & Beilock, 2013) highlighting as initial signs of MA may emerge as early as 6 years-old (Aarnos & Perkkilä, 2012). Other studies investigated the developmental trajectory of MA (Vukovic, Kieffer, Bailey, & Harari, 2013) or tried to define a path from high MA to math performance, developmental dyscalculia, cognitive abilities or lower self-efficacy towards math learning. (e.g. Hoffman, 2010; Kesici & Erdogan, 2010; Maloney, Ansari, & Fugelsang, 2011; Rubinsten & Tannock, 2010): the final picture resulted in a complex puzzle in which MA represents a tough source of individual differences in children's mathematical performance in which also negative experiences with parents or teachers might worsen children's negative attitudes towards mathematics (e.g. Bekdemir, 2010).

2. Gender differences

Some studies found similar levels of anxiety in males and females (Birgin et al., 2010; Ma & Xu, 2004), but findings generally suggested that females suffer from MA more than males (see Else-Quest, Hyde, & Linn, 2010; and see Devine, Fawcett, Szucs, & Dowker, 2012, for a short review), and that women are consequently less likely to seek opportunities for math problem solving, and they tend to avoid math-related activities (Baloğlu & Koçak, 2006; Else-Quest et al., 2010; Jain & Dowson, 2009; McGraw, Lubienski, & Strutchens, 2006; Rubinsten, Bialik, & Solar, 2012). Studies on adult populations have consistently found that women have higher levels of MA than men (Ferguson, Maloney, Fugelsang, & Risko, 2015; Miller & Bichsel, 2004), but less is known about the development of gender-related differences in the levels of MA experienced in childhood and adolescence (Beilock, Gunderson, Ramirez, & Levine, 2010; Hill et al., 2016). Erturan and Jansen (2015) found gender differences related to MA and math performance tested on children sample of grades 3–8: only girls performed worse in mathematics due to their perceived math competence. Further research seem confirm this marked gender differences to the detriment of girls in the relation between MA, math achievement and other cognitive abilities, such as reading and fluid intelligence (Schleepen & Van Mier, 2016).

Taking a look at the PISA data assessed in 2012, although Italy is one of the countries showing more significant improvements in performance in both mathematics and science (particularly between 2006 and 2009), the results showed a much greater discrepancy between boys and girls than the average 11-point gap for OECD countries as a whole: Italian adolescent males outperformed females by 18 points in mathematics. Similar results emerged in the latest PISA survey (OECD, 2016) which reports a 20-point discrepancy between gender. Italian girls also tended to report being less confident in their ability to learn mathematics, and more MA than boys (48.5% of the girls reported high levels of MA vs. 37.8% of the boys; OECD, 2013). These data highlighted an important aspect of the issue of MA, i.e., gender-related differences.

3. Measures of math anxiety

The first attempt to develop a tool for measuring MA was made by Dreger and Aiken (1957), who added 3 math-related items to an existing general anxiety scale (the Taylor Manifest Anxiety Scale; Taylor, 1953), but the first really innovative and complete instrument for measuring MA - the Mathematics Anxiety Rating Scale (MARS) - was published in 1972 by Richardson and Suinn. The good psychometric properties of the MARS prompted the development of several shorter versions: the Fennema-Sherman Mathematics Anxiety Scale (MAS; Fennema & Sherman, 1976); the Sandman Anxiety Toward Mathematics Scale (ATMS; Sandman, 1980); the Math Anxiety Rating Scale-Revised (MARS-R; Plake & Parker, 1982); the Abbreviated Math Anxiety Rating Scale (sMARS; Alexander & Martray, 1989); the Abbreviated Math Anxiety Scale (AMAS; Hopko, Mahadevan, Bare & Hunt, 2003); the Mathematics Anxiety Scale-UK (MAS-UK; Hunt, Clark-Carter, & Sheffield, 2011); and the Single Item Math Anxiety Scale (SIMA; Núñez-Peña, Guilera, & Suárez-Pellicioni, 2014). Compared with the original version, all these scales are less time-consuming to administer, and that is why many of them have been translated into different languages (Cipora, Szczygieł, Willmes, & Nuerk, 2015; Núñez-Peña, Suárez-Pellicioni, Guilera, & Mercadé-Carranza, 2013; Primi, Busdraghi, Tomasetto, Morsanyi, & Chiesi, 2014).

Other MA measures tailored to older children and adolescents were subsequently developed, including: the adapted MARS for middle and high school students (Suinn & Edwards, 1982); the MARS-E with items more appropriate for elementary school children in grades 4 to 6 (Suinn et al., 1988); the Mathematics Anxiety Scale for Children (MASC; Chiu & Henry, 1990); the Math Anxiety Questionnaire (MAQ; Thomas & Dowker, 2000) for assessing 6- to 9-year-olds; the Mathematics Anxiety Survey (MAXS; Gierl & Bisanz, 1995); the Scale for Early Mathematics Anxiety (SEMA; Wu et al., 2012); the Child Math Anxiety Questionnaire (CMAQ; Ramirez et al., 2013); and, more recently, the Revised Child Math Anxiety Questionnaire (CMAQ-R; Ramirez et al., 2016).

One of the most often used questionnaires for examining MA is the Abbreviated Math Anxiety Scale (AMAS) developed by Hopko et al., 2003. It consists of nine items scored on a Likert-type scale from 1 to 5 (higher scores indicating more severe math anxiety), and considers two main factors, math *learning* and math *testing* (anxiety). Hopko et al. (2003) identified the methodological limitations of previous studies, such as small sample size, lack of test-retest analyses (e.g. Plake & Parker, 1982), and data validity issues (e.g. Alexander & Martray, 1989), and developed their scale using a large, representative sample. A confirmatory factor analysis showed that the items could be grouped under two meaningful subscales: math learning anxiety, which relates to anxiety about the process of learning (e.g., listening to a lecture in a math class); and math testing anxiety, which relates more to assessment situations (e.g., thinking about a math test scheduled for the next day). Good internal consistency estimates were reported for both subscales (Learning: Cronbach's $\alpha = .78$; Testing: Cronbach's $\alpha = .79$), as well as for the total scale (Cronbach's $\alpha = .83$).

The AMAS was adapted successfully to different cultures: the Iranian (Vahedi & Farrokhi, 2011), Italian (Primi et al., 2014), and Polish (Cipora et al., 2015) adaptations of the AMAS provided further evidence of the tool's construct validity and reliability, confirming its suitability for testing MA in various linguistic settings. The factor structure of the AMAS also remained unchanged and showed no gender-related differences. A modified version of the AMAS, with the addition of two more items, was applied to Australian students (Gyuris, Everingham, & Sexton, 2012), producing a similar pattern of results (though they cannot be compared directly with the findings of other studies because of the modifications introduced by the authors).

4. The present study

All the above-mentioned findings are difficult to compare because studies (especially those on younger populations) used different MA assessment tools and different mathematical tasks. Some researchers developed non-standardized ad-hoc questionnaires (Thomas & Dowker, 2000; Wren & Benson, 2004; Wu et al., 2012). Others assessed MA in children using tools adapted from scales applied to adults, with inadequate psychometric properties. Some studies have methodological weaknesses, such as small sample sizes, no test-retest analyses or confirmatory procedures to assess the reliability and dimensionality of the scales adopted, and an overall lack of normative data (Eden, Heine, & Jacobs, 2013; Harari et al., 2013). A measure of MA to be considered suitable for children, should not only have acceptable psychometric proprieties, but also be in line with educational expectations, which depend on the school curriculum. There are many English versions of tools for measuring MA in children, but an Italian self-report measure for primary school children has yet to be developed. Hence the present study was designed to address this issue by adapting the AMAS self-report to make it appropriate for Italian third- to fifth-graders. The main purpose of our study was thus to test the suitability of the AMAS in measuring primary school children's MA by testing the psychometric properties (validity and reliability) of the adapted version for use in Italian children.

The AMAS was chosen as our starting point because it has been considered a parsimonious, reliable, and valid scale for assessing MA, and it is one of the tools most often used to measure MA in college and high school students (for a review, see Eden et al., 2013; for an Italian adaptation applied to high school students, see Primi et al., 2014). Although the scale has already been used with children aged 8 to 11 years (Hill et al., 2016), and adolescents aged 11 to 15 years (Devine et al., 2012; Mammarella et al., 2015), to date no published studies have confirmed its psychometric properties in a so young age group of primary school children (across three grades). The only exception is represented by a recent work in which a wide sample of 4th (and also 7th and 8th) British graders have been tested (Carey, Hill, Devine, & Szűcs, 2017).

5. Data analysis

Firstly, the conversion from raw scores to normative data of the adapted AMAS was made by reporting means, standard deviations and percentiles distinguished for gender and age group for the two subscales and the total score. Then, a confirmatory factor analysis (CFA) was used to test whether the two dimensions (i.e., *math learning anxiety* and *math testing anxiety*) describe MA adequately in this age group. Based on previous research, we expected a congruent pattern of results for both convergent and discriminant validity (i.e., Ashcraft & Ridley, 2005). The latter, discriminant validity, is important for determining the construct validity of a measure, but it is also important to demonstrate substantial relations with other claimed measures of the target construct (i.e., convergent validity). We therefore aimed to check aspects of discriminant validity, examining whether the AMAS scores simply reflect a generally poor school performance, and we also controlled for convergent validity by assessing the respondents' level of general anxiety.

Previous studies on MA (see Hembree, 1990, for instance, and Ma, 1999, for a review) have examined its relationships with other affective constructs (e.g., generalized or test anxiety, and attitudes to mathematics), and with academic outcomes (e.g., school grades). Consistently with previous research on the correlations between MA and other anxiety measures, we expected a moderate positive correlation between AMAS self-report measures and general anxiety assessed by using the Revised Children's Manifest Anxiety Scale - 2nd Edition (RCMAS-2, Reynolds & Richmond, 2012), supporting that MA and general anxiety are different constructs (Ashcraft, 2002; Zettle & Raines, 2000). We also expected a negative correlation between MA and mathematics achievement tested by using two standardized tests, measuring respectively calculation abilities (the AC-MT 6–11; Cornoldi, Lucangeli, & Bellina, 2012) and math fluency (Caviola, Gerotto, Lucangeli, & Mammarella, 2016).

Finally, the invariance across genders was also tested using a multigroup confirmatory factor analysis (MGCFA). Evidence of meaningfulness and appropriateness across different groups is an essential element for any measurement tool. Conclusions drawn from comparative analyses may be biased or invalid if the measures used do not have the same meaning across groups. In other words, a lack of measurement equivalence makes group comparisons ambiguous because it becomes hard to say whether any differences are a function of the trait being measured, or artefacts of the measurement process (Vandenberg & Lance, 2000). To be more specific, starting from a key psychometric assumption (using most assessment tools, the sum of the scores for a number of items serves as an approximation of an individual's trait score), differences in total scores should reflect true differences in the latent variable that the scale intends to measure. When interpreting group differences in total scores, the tool should measure the same underlying trait across groups, which means that it has to be metrically invariant (e.g., Slof-Op 't Landt et al., 2009). That is why we planned to test the equivalence of the AMAS across boys and girls from third to fifth grade: the invariance of the AMAS was assessed to establish whether there was a conceptual equivalence of the underlying latent variable(s) across gender groups, reflected in the use of identical indicators to measure the same trait(s) with the same measurement error (Vandenberg & Lance, 2000).

5.1. Methods

5.1.1. Participants

The study involved 1013 primary school students (51% males) recruited from three different cohorts, based on year of schooling. The children were between 8 and 11 years old ($M = 9.45$; $SD = 0.9$): 366 were in grade 3 (52% males; $M = 8.69$; $SD = 0.66$); 279 in grade 4 (46% males; $M = 9.49$; $SD = 0.58$); and 366 in grade 5 (55% males; $M = 10.18$; $SD = 0.78$). The children were attending Italian urban State-run schools in different Italian regions (in northern and central Italy). The average class size was 19.74 (SD = 3.79), range 15–25.

The study has been approved by the ethics committee of the University and parental consent was obtained for all the children before they took part in the study. The participants' parents/guardians were contacted via the school administrator to explain the purpose of the study and the procedures involved, and to ask them to sign a consent form. The procedures adopted to obtain the informed written consent of parents/guardians and the children's verbal assent were consistent with the APA guidelines. An eligibility criterion was that the children were not being considered for, or already the object of any individualized education plan for demonstrated special needs at the time of our study.

5.1.2. Materials

5.1.2.1. Emotional assessment. The *Abbreviated Math Anxiety Scale* (AMAS; Hopko et al., 2003) involves nine Likert-type items in a 5-point scale ranging from “strongly agree” to “strongly disagree” and is divided in two subscales measuring *Math Learning Anxiety* (5 items) and *Math Testing Anxiety* (4 items). Higher scores on the scale indicate higher levels of MA. The Italian version of the AMAS for primary school children was derived from the English version using a complete *forward and back-translation* method. The present study began with the translation of the AMAS into Italian (see Appendix 1), choosing the wording and content of each item to make them suitable for children. This preliminary Italian version of the scale was then back-translated into English by a native English-speaker, and finally another native English-speaker checked the two English versions of the test against the Italian one (both the native English-speakers were teachers of English with a good command of the Italian language). The discrepancies between the original English version of the test and the English back-translation were solved by consensus and the Italian version was fine-tuned where necessary.

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 general anxiety (GA) in children and adolescents from 6 to 19 years old. It consists of 49 items with a simple yes/no response format, and is divided into 5 different 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 $\alpha = .89$).

Table 1
Means, standard deviations and percentiles distinguished for gender and age group for the two subscales and the AMAS total score.

Grade		N	M	SD	Percentile										
					5	10	20	30	40	50	60	70	80	90	95
Male students															
3	AMAS	189	20.47	6.49	9	11	14	17	18	20	22	24	26	29	31
	MLA		9.94	3.55	5	5	6	7	8	9	10	11	12	14	16
	MTA		10.71	4.11	4	5	7	8	9	10	11	12	14	16	18
4	AMAS	129	22.73	6.82	11	13	16	18	20	22	25	26	28	31	33
	MLA		10.53	3.75	5	6	7	8	9	10	11	12	13	16	18
	MTA		12.25	3.92	5	7	8	9	11	12	13	14	15	17	18
5	AMAS	202	21.49	5.87	11	13	16	18	20	21	23	24	26	29	31
	MLA		9.49	3.10	5	5	6	7	8	9	10	11	12	13	15
	MTA		12.06	3.90	5	6	8	10	11	12	13	14	16	17	18
Female students															
3	AMAS	176	23.04	6.72	10	13	16	19	22	23	25	27	28	31	32
	MLA		10.71	3.52	5	6	7	8	9	10	11	12	13	15	17
	MTA		12.43	4.14	4	6	8	10	11	12	14	15	16	17	18
4	AMAS	149	23.46	6.23	13	14	17	19	22	23	25	27	29	30	32
	MLA		10.22	3.44	5	5	6	7	9	10	11	12	13	14	16
	MTA		13.36	3.72	6	7	9	11	12	14	15	15	16	17	18
5	AMAS	166	22.58	6.63	10	13	17	19	21	22	24	25	27	30	33
	MLA		9.85	3.89	5	5	6	7	8	9	10	11	12	15	16
	MTA		12.79	3.99	4	6	9	11	12	13	14	15	16	17	18

Note. MLA = math learning anxiety subscale, which consists of item 1, 3, 6, 7, and 9; MTA = math testing anxiety subscale, which consists of item 2, 4, 5, and 8.

5.1.2.2. Mathematics achievement. Mathematical abilities were assessed using the AC-MT 6–11 standardized mathematics test (Cornoldi et al., 2012) designed for first- to fifth-graders. This test assesses calculation procedures and number comprehension by means of a set of paper-and-pencil tasks that can be grouped into two areas: "written calculation" and "number knowledge." In the former, participants have to solve eight written multi-digit calculations (two additions, two subtractions, two multiplications and two divisions). The latter contains tasks that involve number magnitude judgments, place-value (i.e., syntax) comprehension and number ordering. The test re-test reliability is $r = .83$. Z-scores were calculated on the basis of normative samples by school grade.

Math fluency in additions, subtractions and multiplications: this measure of math fluency (Caviola et al., 2016) consists of three printed pages with 24 multi-digit problems on each page. The children were given 2 min to complete each page and were asked to solve the problems as quickly and accurately as possible. The number of additions, subtractions and multiplications correctly solved was recorded. Cronbach's α was >0.83 for each subtest (page).

5.1.3. Procedure

Children were tested in two different classroom sessions lasting approximately 30 min each. They were tested with the AC-MT 6–11 (Cornoldi et al., 2012) and the Math Fluency task (Caviola et al., 2016) during the first session, and with the AMAS and RCMAS-2 questionnaire during the second. All tests were paper and pencil administered.

5.2. Results

5.2.1. Normative data

Table 1 reported means, standard deviations and percentiles distinguished for gender and age group for the two subscales and the AMAS total score. In Table 2 are reported item distributions and descriptive statistics of the nine items. Checking item distribution for normality, skewness and kurtosis indices of some items showed that the departures from normality were unacceptable (Marcoulides & Hershberger, 1997).

5.2.2. Factor structure and reliability

In line with the original version of the AMAS, we tested a two-correlated factor model, by using a confirmatory factor analysis (CFA). The Mean-Adjusted Maximum Likelihood (MLM) estimator (Mplus 6.1software; Muthén & Muthén, 2010), which provides the Satorra-Bentler scaled chi-square (SBχ2; Satorra & Bentler, 2010) was used, in order to provide an adjusted and robust measure of fit for non-normal sample data, that is more accurate than the ordinary chi-square statistic (Bentler & Dudgeon, 1996).

To assess the overall model fit practical fit measures were used. Since the χ^2 statistic depends on sample size, we considered two relative fit indices - the Comparative Fit Index (CFI; Bentler, 1990) and the Tucker-Lewis Index (TLI; Tucker & Lewis, 1973) - and two residual indices - the Root Mean Square Error of Approximation with the relative confidence interval (RMSEA; Steiger & Lind, 1980) and Root Mean Square Residual (RMSR; Jöreskog & Sörbom, 1996). Findings from a Monte Carlo simulation study revealed that CFI and TLI values ≥0.95, RMSR values equal to or below 0.09 (Hu & Bentler, 1999) and RMSEA values ≤0.06 indicate a good representation of the data (Hu & Bentler, 1999). However CFI and TLI values ≥0.90 (Bentler, 2005; Byrne, 1994) and RMSEA values ≤0.08 (Browne & Cudeck, 1993) can be considered adequate.

Our results revealed that the goodness of fit indices for the two-factor model (i.e., Math Learning Anxiety and Math Testing Anxiety) were all adequate ($SB\chi^2 = 153.26$, $df = 26$, $p < 0.001$, CFI = 0.93; TLI = 0.90, RMSR = 0.07; RMSEA = 0.07 [CI: 0.06–0.08]). Standardized factor loadings ranged from 0.35 to 0.75, (all significant at the 0.001 level), and the correlation between the two factors was significant (0.64) (Fig. 1).

As concerns reliability, in terms of internal consistency, Cronbach's alpha was: 0.77 (CI 0.74–0.79) for the AMAS; 0.64 (CI 0.60–0.68) for the Math Learning Anxiety subscale; and 0.74 (CI 0.70–0.77) for the Math Testing Anxiety subscale. These values did not increase if any of the items were deleted, and all item-corrected total correlations[1] were above 0.31 (Table 1).

5.2.3. Validity

In order to investigate the relationship between MA and GA, we calculated the correlations between the AMAS and its subscales (AMAS correlated 0.83 with Math Learning Anxiety score and 0.88 with Math Testing Anxiety score), and the RCMAS-2 and its subscales (correlations between RCMAS-2 and subscales were all positive and above 0.70 with the exception of defensiveness subscale equal to −0.17). Since some children did not entirely fill the RCMAS-2 and AC-MT 6–11, there

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[1] This analysis refers to correlation between an item and the rest of the questionnaire, without that item considered in the total score of the questionnaire itself.

Table 2
Descriptive and corrected item-total correlations of the nine items in the Abbreviated Math Anxiety Scale (AMAS) administered to Italian primary school students.

	M	*SD*	Skewness	Kurtosis	Corrected item-AMAS total correlations	Corrected item-MLA subtotal correlations	Corrected item-MTA subtotal correlations
Item 1 MLA	1.83	1.00	1.27	1.21	.31	.26	–
Item 2 MTA	3.00	1.29	−0.04	−1.10	.55	–	.60
Item 3 MLA	2.24	1.18	0.68	−0.45	.42	.43	–
Item 4 MTA	2.85	1.35	0.11	−1.20	.51	–	.57
Item 5 MTA	2.78	1.34	0.20	−1.12	.43	–	.38
Item 6 MLA	1.77	1.03	1.33	1.12	.38	.42	–
Item 7 MLA	1.88	1.14	1.26	0.74	.34	.37	–
Item 8 MTA	3.58	1.42	−0.57	−1.03	.56	–	.59
Item 9 MLA	2.37	1.27	0.56	−0.79	.46	.46	–

Note. MLA = math learning anxiety subscale; MTA = math testing anxiety subscale.

were some few missing cases (ranging from 1 to 8 across the different scales and subscales) in the correlational analyses. Results are reported in Table 3. Our findings revealed a moderate positive correlation between the AMAS and the RCMAS-2 total score ($r = 0.40$), demonstrating that the two measures shared the same construct. The RCMAS-2 also correlated positively with the Math Learning Anxiety ($r = 0.32$) and Math Testing Anxiety ($r = 0.37$) subscales. The difference between the two correlations was not significant ($z = 1.67$, $p = 0.09$). When we considered the RCMAS-2 subscales and the correlation with the AMAS, the subscales for physiological anxiety, worries, and social anxiety revealed moderate positive correlations ($r = 0.32$, $r = 0.40$, and $r = 0.38$, respectively).

To analyze the relationship between MA and math achievement, correlations were calculated between the AMAS and its subscales, and the mathematics achievement tasks. Small negative correlations were found between all the math tasks and the AMAS (Table 2): the sign of the correlation indicates that higher levels of MA were associated with a weaker performance in math tasks, though the strength of the association reveals only weak correlations between these measures.

5.2.3.1. Invariance across genders. A multi-group analysis was run to investigate the gender invariance of the AMAS in our sample of primary school children. First, we tested separately the baseline model for males and females. The goodness of fit indexes of the two-factor model for boys, were the following: $SB\chi^2 = 104.22$, $df = 26$, $p < 0.001$; $CFI = 0.91$; $TLI = 0.90$; $RMSR = 0.08$; $RMSEA = 0.08$ [CI: 0.06–0.09]. Standardized factor loadings ranged from 0.34 to 0.74, all significant at the 0.001 level, as was the correlation between the two factors (0.60). The goodness of fit indexes of the two-factor model for girls, were: $SB\chi^2 = 72.69$, $df = 26$, $p < 0.001$; $CFI = 0.94$; $TLI = 0.92$; $RMSR = 0.07$; $RMSEA = 0.06$ [CI: 0.04–0.08]. Standardized factor loadings ranged from 0.35 to 0.74, all significant at the 0.001 level, and so was the correlation between the two factors (0.67).

In addition, a hierarchically nested series of confirmatory factor analyses were conducted (Meredith, 1993), starting from an unconstrained model, used as a baseline (Baseline model), in order to test three more restrictive models. Specifically, in Model 1 the factor loadings were constrained to make them the same across boys and girls; in Model 2 the factor loadings, and also the factor variances and covariances,

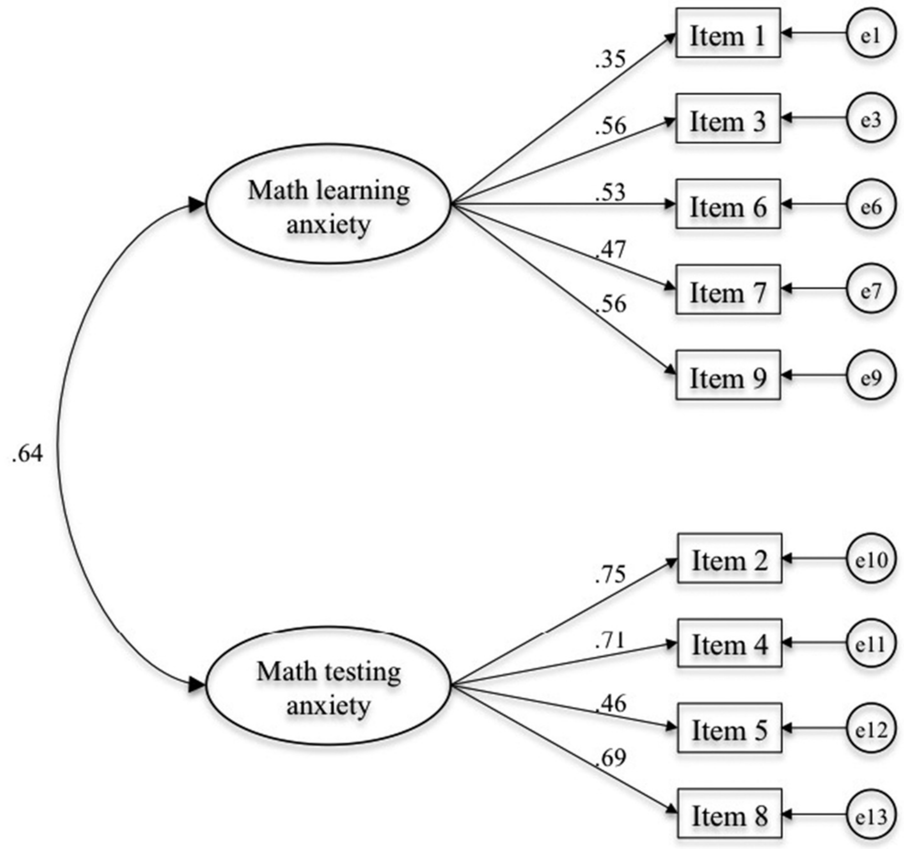

Fig. 1. Standardized estimates (significant at $p < 0.001$) of the two-factor model of the Abbreviated Math Anxiety Scale (AMAS) for Italian primary school children.

Table 3
Correlations between AMAS total, math learning and math testing scores, and all other variables in the study.

	AC-MT	F-Add	F-Sub	F-Mult	R-Def	R-Phy	R-Wor	R-Soc	RCMAS-2
AMAS	−0.12***	−0.22***	−0.24***	−0.19***	−0.15**	0.32**	0.40**	0.38**	0.40**
	($N = 1011$)	($N = 1008$)	($N = 1009$)	($N = 1009$)	($N = 1005$)	($N = 1005$)	($N = 1005$)	($N = 1005$)	($N = 1005$)
Math learning anxiety	−0.11**	−0.19***	−0.22***	−0.16***	−0.07*	0.26**	0.27**	0.29**	0.32**
	($N = 1012$)	($N = 1009$)	($N = 1010$)	($N = 1010$)	($N = 1006$)	($N = 1006$)	($N = 1006$)	($N = 1006$)	($N = 1006$)
Math testing anxiety	−0.11**	−0.20***	−0.21***	−0.17***	−0.17**	0.28**	0.38**	0.35**	0.37**
	($N = 1012$)	($N = 1009$)	($N = 1010$)	($N = 1010$)	($N = 1006$)	($N = 1006$)	($N = 1006$)	($N = 1006$)	($N = 1006$)

Note. AMAS = abbreviated math anxiety scale, AC-MT = standardized mathematics battery, F-Additions = Math fluency in additions; F-Subtractions = Math fluency in subtractions; F-Multiplications = Math fluency in multiplications; R-Def = RCMAS-2 defensiveness subscale; R-Phy = RCMAS-2 physiological anxiety subscale; R-Wor = RCMAS-2 worries subscale; R-Soc = RCMAS-2 social anxiety subscale; RCMAS-2 = general anxiety total score.

** $p < 0.01$.

*** $p < 0.001$.

were constrained to make them the same across genders; and in Model 3 the factor loadings, factor variances and covariances, and also the error variances were all constrained to make them the same across genders. The criteria for assessing the differences between the competing models were based on the scaled difference chi-square test (Satorra & Bentler, 2010), and on the difference in the CFIs of the nested models, as proposed by Cheung and Rensvold (2002). A difference in CFI values lower than 0.01 was assumed to support the more constrained of the competing models.

The overall and comparative fit statistics of the invariance models are presented in Table 4. Our findings revealed an adequate fit for the data in the baseline model, showing that the same pattern of fixed and free parameters was shared across gender groups. $SB\Delta\chi^2$ was not significant when the unconstrained model was compared with Model 1, indicating a factor loading invariance between boys and girls in our sample. Model 1 was consequently compared with Model 2 to test the hypothesized invariance of variances and covariance; the scaled difference chi-square test results supported this invariance hypothesis. Considering Model 2 for reference, the error variance hypothesis was tested by including constraints on the error variances (Model 3). Results showed that when the two models were compared $SB\Delta\chi^2$ was not significant, meaning equality of measurement errors across genders. All the differences in CFI values between the nested models were lower than 0.01.

5.3. Discussion

As emerges clearly from the international literature, one of the difficulties of conducting research on MA in children concerns how to quantify this construct. In the main, self-report questionnaires for children have been adapted from materials developed for adults or developed for the purpose of particular studies on samples with a limited age range such as MARS-E (Suinn et al., 1988), MAXS (Gierl & Bisanz, 1995). Overall, the psychometric properties of most of these tools are generally inadequate due to several methodological shortcomings (Eden et al., 2013; Harari et al., 2013).

The first aim of project was to standardize and consequently develop the normative data of our Italian primary school version of the AMAS. The innovative aspect of the present study thus lies in the young and broad age-range (covering three school years) of our sample and, for the first time, the conversion from raw scores to normative data of the adapted questionnaire, useful for evaluation settings.

The second objective of our study was to confirm the two-factor structure of the adapted questionnaire, since the psychometric properties of the AMAS have mainly been investigated in young adults and adolescents. Confirmatory factor analysis generated further evidence of the underlying two-factor structure of the Italian version of the AMAS proposed by Hopko et al. (2003), with adequate fit indices and items highly loaded on the expected factors. As concerns reliability, our findings showed a good internal consistency for the total scale and the Math Testing Anxiety, whereas the value was slightly under.70 for the Math Learning Anxiety scale. As for validity, a moderate positive correlation emerged between MA and GA, confirming that the two are similar but separate constructs (Ashcraft, 2002; Zettle & Raines, 2000). In particular, the shared components seem to relate to worries, and to the physiological and social aspects of anxiety. We also confirmed that students with more severe MA performed less well in math tasks (Devine et al., 2012; Hill et al., 2016). Importantly, our findings showed slightly "stronger" correlations between MA and math fluency than between MA and mathematical achievement, although the overall strength of the relation between MA and math performance is to be considered as moderate. The majority of studies whom assessed this connection in children populations reported quite low negative correlations compared to adult studies, and the reported values are similar to ours (the r_s tend to slightly vary if considered divided by gender; e.g., Ramirez et al., 2016; Schleepen & Van Mier, 2016). This is not surprising considering the fact that math anxiety develops gradually across age, following a series of failures and negative experiences related to this subject: increasing ages means also an increasing of MA negative influences on mathematical performance, which translates into a growth of correlation values. Thus, from one hand, our results confirmed the early presence of MA since the first stage of primary school; from the other, they confirmed the importance of having adapted and standardized a

Table 4
Fit statistics of the Abbreviated Math Anxiety Scale (AMAS) gender-invariant models.

Model	$^{*}\chi^2$ (df)	*CFI	*RMSEA	Model comparison	$\Delta\chi^2$	Δdf	p	ΔCFI
Baseline	176.91 (52)	0.926	0.05	–	–	–	–	–
Model 1	181.09 (59)	0.927	0.05	*Model 1* - Baseline	4.18	7	0.76	0.001
Model 2	183.24 (62)	0.928	0.04	*Model 2 - Model 1*	2.15	3	0.54	0.001
Model 3	187.10 (71)	0.931	0.04	*Model 3 -Model 2*	3.86	9	0.92	0.003

Note. $^{*}\chi^2$ = Satorra-Bentler χ^2; df = degrees of freedom; *CFI = robust comparative fit index; *RMSEA = robust root mean square error of approximation; $\Delta\chi^2$ = Satorra-Bentler scaled difference; Δdf = difference in degrees of freedom between nested models; p = probability value of the $\Delta\chi^2$ test; ΔCFI = difference between robust CFIs for the nested models. *Model 1* = equality of factor loadings; *Model 2* = *Model 1* + equality of factor variances and covariance between factors; *Model 3* = *Model 2* + equality of error variances.

valid tool that is able to identify these negative feelings in primary school children.

Another aim of our study was to test the invariance of the AMAS across genders. Our results confirmed the equivalence of the scale when administered to boys and girls attending primary school; i.e., the same underlying construct was measured across the two gender groups. This means that the AMAS can be administered to compare MA in males and females, and that any differences can be interpreted in terms of the underlying construct, math anxiety, not gender. The strength of the present work is based on the unicity of our young sample and the same reason ensures no overlap with previous works. Indeed, in the study of Primi et al. (2014), the two-factor structure and the gender invariance across the subscales (evidence already present in the literature, see Eden et al., 2013) have been evaluated in high school and university students. However, the validity of the AMAS was assessed using different tests and, importantly, correlations between math skills and MA across age could not be tested since mathematical achievement had not been tested. In addition, in the present study, means and standard deviation of MA scores have been reported.

More interesting, from this point of view, is the comparison between the Italian and the English sample (Carey et al., 2017), possible only for the fourth grade. Looking at the AMAS total score of the two samples, even if girls reported higher scores than boys in both studies, it can be noted as Italian children reported higher scores, of about 3–4 points for both genders, compared to their English peers. These outcomes are partially corroborated by PISA survey in 15 years-old students which report that 24.4% of the girls reported high levels of MA vs. the only 15% of the boys, that can be explained by a smaller difference in terms of mathematical performance between gender (only 11/12-point gap in both surveys; Organization for Economic Cooperation and Development, OECD, 2013, 2016).

In summary, the results of the present study provided support both for validity and reliability of the AMAS, administered to Italian primary school children, though further studies are needed to strengthen our findings. In particular, further research should consider the validity aspects in more depth: the structure of MA questionnaires tends to be based on an implicit assumption that MA is persistent (like a trait), rather than a state experienced at certain times, such as while solving particular problems (Trezise & Reeve, 2014). To reinforce the interpretability of this type of overall, retrospective self-report tool, it would be interesting to develop an on-line measure of MA that would enable the anxiety experienced while solving math problems to be assessed.

Considering larger samples and broader age ranges might prove interesting, both to obtain normative data and to test the invariance of the scale across school years by including students in first and second grade, for instance. The recent literature has also shown that signs of MA may emerge as early as in the first and second years of primary school (Aarnos & Perkkilä, 2012; Hill et al., 2016), so the AMAS could become a valid, reliable tool for investigating the onset of MA from early childhood.

In conclusion, this study led to the development of a valid tool in the Italian language for measuring MA in young children. Our adaptation of the AMAS may be useful not only for researchers interested in emotional aspects related to mathematics achievement, but also for clinicians and psychologists concerned with identifying male and female children suffering from MA. In addition, the scale could be usefully applied to assessing the utility and efficacy of specific intervention designed to reduce MA, and to improve mathematics performances as a result.

Appendix A. Adapted AMAS scale for children

Name: ______________________________ Grade: __________
Date: _____________

Imagine yourself in the situations described below. Evaluate each situation in terms of how much fear you feel during the specified activities, putting a tick in the column that corresponds to your level of fear: please rate your feelings on a scale from one (no bad or negative feelings) to five (the worst feelings: the most fear, worry, or nervousness).

1 = No bad feelings; 2 = Somewhat bad; 3 = Moderate fearful, tense or nervous; 4 = Bad feelings; 5 = Very bad feelings.

	1	2	3	4	5
1. Having to use the diagrams and multiplication tables in the back of a math textbook. *Usare gli schemi e le tabelline riportate in fondo al libro di matematica.*					
2. Thinking about the upcoming written math test you have tomorrow. *Pensare alla verifica scritta di matematica che dovrai fare domani.*					
3. Watching the teacher break down a complex problem on the blackboard. *Seguire l'insegnante che risolve alla lavagna una difficile operazione di matematica.*					
4. Doing a written math examination/test. *Fare una verifica scritta di matematica.*					
5. Having to solve many difficult math problems for homework due the next class lesson. *Svolgere per casa molti esercizi difficili di matematica per la prossima lezione.*					
6. Carefully listening to the math lesson. *Seguire con attenzione la lezione di matematica.*					
7. Watching another student solve a math problem. *Seguire un altro studente che risolve un esercizio di matematica.*					
8. Having an oral test on math without knowing in advance. *Essere interrogato "a sorpresa" in matematica.*					
9. Starting a new topic in mathematics. *Affrontare un nuovo argomento di matematica.*					

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