

# MATHEMATICS ANXIETY AND COGNITIVE PERFORMANCE IN ADOLESCENT STUDENTS

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## SUMMARY

Several studies highlight that many students feel negative feelings about mathematical learning and that the mathematics anxiety seems to play a central role in mathematical performance. More specifically students with higher level of maths anxiety are less efficient in mathematical tasks. The aim of this study was to investigate the relationship between specific mathematics anxiety as assessed by AMAS, trait and state anxiety as assessed by STAI-Y, and mathematical skills assessed through the ABCA tests in a sample of 83 adolescent students (78.3% males) without diagnosis of dyscalculia and cognitive disorder attending their first year of secondary school. Results showed that 38% of the students referred high level of maths anxiety. Independent T-test revealed that female students referred a higher level of maths anxiety as well as of trait and state anxiety than male ones, while there were no differences in the mathematics performance. The simultaneous multivariate linear regression analysis showed that maths anxiety was influenced by trait anxiety and in its turn has an impact on the high level mathematics performances (i.e. arithmetic facts). Understanding the relationships between maths anxiety and maths learning and performance may have relevant implications in clinical, educational and didactic practice.

**Key words:** mathematics anxiety - cognitive performance - mathematics performance - adolescents

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## INTRODUCTION

In the last years studies have highlighted that high percentages of students, regardless of their culture, experience negative feelings in educational settings, such as anxiety, in particular about mathematics learning (Blazer 2018, Luttenberger et al. 2019). A recent study on 15-16 year-old students, in which 34 Organisation for Economic Co-operation and Development (OECD) countries participated, shows that more than 30% of students of secondary school report tension and nervousness while doing maths homework and maths problems, another 59% refer concern that mathematics will be tricky for them (OECD – The Organisation for Economic Co-operation and Development 2018). These findings underline how the anxiety related to mathematical learning can be considered a widespread problem. What do we mean by maths anxiety (MA)? Fennema and Sherman (1976; p. 326) defined MA as “feelings of anxiety, dread, nervousness, and associated bodily symptoms related to doing mathematics” and it seems to have several implications in learning and using mathematics in educational as well as in daily context (Pechter et al. 2017, Kohn et al. 2013). The MA seems to be consisting of two dimensions, cognitive and affective (Wigfield & Meece 1988): the first dimension refers to the concern about mathematics performance and the possible failure, while the affective dimension refers to the feeling of nervousness in a testing context (Liebert & Morris 1967).

To better understand the antecedents that influence the incidence of MA, several studies have focused on personal aspects like gender and trait anxiety, the tendency to perceive high-stress situations as threatening (Hembree 1990, Pechter et al. 2017). Most studies about gender and MA indicate that female students referred higher levels of MA than male (Else-Quest et al. 2010, Devine et al. 2012, Primi et al. 2013). About the link among trait anxiety and MA the findings of a meta-analysis (Hembree 1990) showed a close relationship between maths and trait anxiety from  $r=0.24$  to  $r=0.54$ , highlighting that they are separate but related constructs (Aschcraft 2002). A more recent research demonstrated how trait anxiety together with gender explained a high percentage of variance in MA (Pechter et al. 2017). In contrast with the aforementioned studies, Grežo and colleagues (2018) didn't find any link between trait anxiety and MA assuming that the latter could be a complex construct better explained through personality traits as well as environmental and contextual variables. Among contextual variables we could consider the setting in which the mathematics performances are measured, the feelings of nervousness, tension and the arousal of the autonomic nervous system related to the particular moment, the so-called state anxiety (Spielberg & Sydeman 1994).

As previously mentioned, MA has an effect on learning and using mathematics. Many studies show that the MA plays a central role in mathematical performance (Baloglu & Koçak 2006, Sad et al. 2016). More

specifically students with a higher level of MA are less efficient in mathematical tasks that are included in basic arithmetic computation but especially in high-level computing skills (Ashcraft & Kirk 2001, Maloney et al. 2011, Cates & Rhymer 2003). MA seems to have an impact on the resources of working memory (WM), the cognitive functioning involved in specific aspects of high-level mathematical skills as processing and retrieval of arithmetical facts and method (Ashcraft & Kirk 2001, Ashcraft & Krause 2007). About the link between MA and mathematical performance, literature is conflicting. Most of the studies, as previously underlined, prove the theory that MA tends to affect the performance related to maths; further studies, on the contrary, show that the poor maths performance and the repeated failures could be the predictor of higher level of MA (Ma & Xu 2004, Birgin et al. 2010). This variety of data might support the “Reciprocal Theory” suggesting the bidirectional relationship between MA and mathematics ability; becoming aware of one's difficulties could increase the state of anxiety related to maths and in turn, higher level of MA could have an effect in poor maths performances, creating a vicious circle (Carey et al. 2016). This relationship seems to change based on the context in which the maths ability is measured, e.g. in a relaxed evaluation-free situation, students with high MA reach the same performance level of students with lower MA (Ashcraft & Faust, 1994). Longitudinal studies are needed to better explain this relationship. Furthermore, some studies are focused on the difference in this relationship (MA and maths performance) between genders. Hembree in his meta-analysis (1990) displayed that the MA was more predictive of maths performance in male than female participants, in particular of basic maths ability as suggested by Miller & Bichsel (2004). More recent studies have found that MA predicts maths performance more in girls than boys (Devine et al. 2012, Reali et al. 2016), while other studies didn't find any differences between genders, in particular on applied mathematical performance (Miller & Bichsel 2004). These inconsistent data suggest the need for further studies.

Few studies have investigated this link between MA and mathematics achievement in adolescents (Trezise & Reeve 2015, Passolunghi et al. 2016), most have been carried out on children or young adults (Wu et al. 2012, Ramirez et al. 2013).

Starting from the aforementioned data, the aims of our study were: (1) to analyse the prevalence of the MA and the difference in MA level between gender in a group of 14-15 year-old Italian students, the age group which was less considered, in particular in the studies about the link between MA and mathematical performance; (2) to investigate the role of trait and state anxiety, assessed before and after the mathematics tasks, on variance in MA. Considering the complexity of the construct highlighted by previous studies (Hembree 1990, Peachter et al. 2017, Grežo et al. 2018), MA

variance could be explained not only by trait personality (trait anxiety) but also by contextual variables such as the state anxiety assessed both before, i.e. the state of tension one feels prior to starting a test, and after, i.e. the state of tension one feels after the awareness of how the tests were carried out (3). To explore the link between anxiety and different mathematical abilities, more specifically the effects of the maths, trait and state anxiety on mathematics performance. In a performance context the state anxiety could play a role not only as predictor of MA but also to explain the variance in the mathematics performances. Finally (5) to investigate the gender difference in the relationship between MA and maths performance.

## SUBJECTS AND METHOD

### Subjects

The subjects were 101 students attending the first class of secondary school, who were enrolled through convenience sampling. The inclusion criteria were (a) absence of diagnosis of dyscalculia and cognitive disorder, (b) having good knowledge and fluency of the Italian language and (c) all assessment tools needed to be entirely completed. Since they didn't meet the inclusion criteria, 17 students were excluded from the study, therefore the final sample was composed of 84 students (78.6% males and 21.4% females).

### Procedure

The students and their parents have been informed about the research and data has been collected. Before the study, both mothers and fathers signed in the informed consent form to participate. No incentives were given, and all participants could withdraw at any time. The study was approved by the CEAS, the local ethics committee of the Umbria Region (Italy).

All participants completed the self-report questionnaires and the standardised mathematics test individually in the classroom during school hours. In a first moment the students filled in all measures that assessed, in order, trait, maths and state anxiety; later they completed the three different types of mathematical tests (in this order: 1) written calculation A; 2) written calculation B and 3) arithmetical facts); lastly, the state anxiety one was compiled again. The students before starting the tests had been informed that the mathematics performance was evaluation-free.

### Measures

#### *Abbreviated Math Anxiety Scale (AMAS)*

AMAS (Hopko et al. 2003), is a self-report consisting of 9 items that evaluate using a 5-point Likert scale from 1 “strongly agree” to 5 “strongly disagree”) related to two aspects of MA measured by the sub-scales Learning Maths (5 items) and Maths Evaluation An-

xiety (4 items). Final score can range from 9 to 45, higher scores indicate high MA. In this study we used the Italian version (Primi et al. 2014) that showed good internal consistence (Cronbach's alpha 0.85); the mean of the normative sample was 23.6 (Sd=8.1; IC 99% 22.18-25.02).

### **State and Trait Anxiety Inventory (STAI-Y)**

STAI-Y (Spielberg 1989) is a self-report composed of 40 items that measure using a 4-point Likert scale ranging from 1 (Not at all) to 4 (very much so) two types of anxiety in adult people, 20 items assessing state anxiety, anxiety about a specific moment or event and 20 items assessing trait anxiety as a personal characteristic. In previous studies STAI-Y has been also used with adolescents (Castro-Sanchez et al. 2018). The Italian version of the STAI – Y (Pedrabissi & Santinello 1989) was used, showing good internal consistency and adequate test-retest reliability.

### **ABCA 14-16**

ABCA 14-16 (Baccaglioni-Franket al. 2013), was used to assess the students' mathematical skills in secondary school. The ABCA is composed of a battery for the assessment of mathematical ability and allows to identify a profile of each student related to mathematical skills comparing the percentile scores to the cut-off criteria of the normative sample: <40<sup>th</sup> percentile: severe difficulties; 40<sup>th</sup>-70<sup>th</sup> percentile: sufficient skills; >70<sup>th</sup> percentile: optimal ability.

The specific paper and pencil mathematics sub-tests used in this study were:

- **Written Calculation A:** to examine the child's application of the procedures needed to complete written computational operations as addition and subtraction.
- **Written Calculation B:** to examine the child's application of the procedures needed to complete written computational operations as multiplication and division.
- **Arithmetical Facts:** to investigate how students have stored combinations of numbers and whether they are able to access them automatically, without purposive calculation procedures. The items include addition, subtraction, and multiplication.

For each sub-subtest responses are scored for correct answers. The raw scores were subsequently transformed into a percentile scores.

### **Statistical Analyses**

First, descriptive statistics were calculated in terms of means and standard deviations for all variables studied and an independent t-test was performed to investigate the differences in maths, trait and state anxiety and in the single mathematics performance between genders; effect size was measured using Cohen's d, in which levels were small ( $d \geq 0.2$ ), medium ( $d \geq 0.5$ ), and large ( $d \geq 0.8$ ) (Cohen 1988).

Second, to understand the role of trait and state anxiety in the MA variance, multivariate linear regression analysis was run in the whole group. Third, simultaneous multivariate linear regression analysis was run to explore the role of the single anxiety scales (maths, trait and state) on the mathematics performance scores, separately, on written calculation A scores, written calculation B scores and arithmetical facts scores. These last analyses have been carried out on the whole group and separately by gender groups. All analyses were performed using SPSS, release 18 (SPSS Inc., Chicago).

## **RESULTS**

Descriptive statistics of the all measures assessed for the whole sample and separated for gender are reported in Table 1. So, 38% of the students indicate that they experience some level of specific anxiety for maths, reporting higher AMAS test scores than the upper endpoint of 99% confidence interval of the Italian normative sample mean (Primi et al. 2013).

The independent t-test highlighted some differences between genders, in particular female students reported higher levels of specific MA ( $t=-3.04$ ;  $p=0.003$ ;  $d=0.8$ ), higher levels of trait anxiety ( $t=-2.46$ ;  $p=0.016$ ;  $d=0.6$ ) and a higher level of state anxiety assessed after the mathematics performances than male students; from a medium to a large effect size; no difference between genders in state anxiety was assessed before the performance. Regarding the single mathematics tasks, the entire group showed several difficulties, in particular the mean percentile scores achieved in written calculation A and B, which were lower than the cut-off criteria of 40<sup>th</sup> percentile. At the arithmetical facts test the group achieved sufficient mean scores (>40<sup>th</sup> percentile). The t-test did not show differences between genders in any task.

Table 2 shows the results of the multivariate regression analysis. Data highlighted that the regression model with MA as dependent variable and trait and state anxiety (Before and After) as independent variables was highly significant ( $R^2=0.26$ ;  $F_{(3,80)}=9.47$ ;  $p<0.001$ ). The model accounted for 26% of the variance ( $R^2$ ) specifically, only trait anxiety ( $\beta=-0.318$ ;  $SE=0.091$ ;  $t=-2.36$ ;  $p=0.02$ ), significantly predicted MA whereas state anxiety, assessed both before and after the performance, did not.

In Table 3 the results of the regression analysis are reported separately for each single mathematics task of the whole group. In Section 1 data showed that the model explained 14% of the variance of scores achieved in the written calculation A task ( $R^2=0.14$ ;  $F_{(2,81)}=6.50$ ;  $p=0.002$ ). In detail, only state anxiety was significantly linked to worse performance in this specific test ( $\beta=-0.264$ ;  $SE=0.308$ ;  $t=-2.35$ ;  $p=0.021$ ), whereas MA was not. The same data resulted from focusing on the male students' group ( $R^2=0.16$ ;  $F_{(2,62)}=4.05$ ;  $p=0.011$ ), while in the girls' group overall model this link was not significant.

**Table 1.** Descriptive statistics and independent T test for gender with means and standard deviations for anxiety measures and mathematic performance task percentile scores

	Totale Sample Mn ± Sd	Gender		t	p	d
		Male; Mn ± Sd	Famale; Mn ± Sd			
<b>Anxiety Measures</b>						
AMAS Tot	21.67±6.33	20.62±5.87	25.5±6.63	-3.040	0.003	0.8
STAI Trait	39.95±9.33	38.68±8.67	44.61±10.39	-2.460	0.016	0.6
STAI State (Before)	36.38±9.90	35.39±10.06	40.0±8.59	-1.770	0.080	-
STAI State (After)	39.31±11.05	37.63±10.26	45.44±11.96	-2.760	0.007	0.7
<b>Math Performance</b>						
Written Calculation A	37.05±27.05	37.77±26.62	34.39±29.19	0.468	0.641	-
Written Calculation B	25.38±29.78	25.39±30.10	25.33±29.42	0.008	0.994	-
Arithmetical Facts	41.26±30.57	43.23±30.41	34.06±30.96	1.130	0.262	-

p: <0.05 significant difference; d: ≥0.2 small effect size; ≥0.5 medium effect size; ≥0.8 large effect size; AMAS = Abbreviate Math Anxiety Scale; STAI = State and Trait Anxiety Inventory

**Table 2.** Results of regression analysis with MA as depend variable and Trait and State Anxiety as predictors

AMAS Tot	F	gdl	R	R <sup>2</sup>	β	SE	t
Section 1	9.47**	3.80	0.512	0.26			
STAI Trait					0.318	0.091	2.36**
STAI State (Before)					0.085	0.087	0.626
STAI State (After)					0.190	0.068	1.60

\* p<0.05; \*\* p<0.01; AMAS = Abbreviate Math Anxiety Scale; STAI = State and Trait Anxiety Inventory

**Table 3.** Results of regression analysis separately for individual mathematics performance scores as depend variables: (1) Written calculation A; (2) Written calculation B and (3) Arithmetical facts

	F	gdl	R	R <sup>2</sup>	β	SE	t
<b>(1) Written Calculation A</b>							
Section 1	4.43**	3.80	0.378	0.14			
AMAS Tot					-0.199	0.507	-1.680
STAI Trait					0.092	0.424	0.631
STAI State					-0.317	0.384	-2.25*
<b>(2) Written Calculation B</b>							
Section 2	2.21	3.80	0.277	0.08			
AMAS Tot					-0.237	0.579	1.920
STAI Trait					-0.087	0.485	-0.572
STAI State					0.025	0.173	0.863
<b>(3) Arithmetical Facts</b>							
Section 3	5.28**	3.80	0.407	0.17			
AMAS Tot					-0.332	0.565	-2.83**
STAI Trait					0.000	0.473	-0.002
STAI State					-0.137	0.428	-0.989

\* p<0.05; \*\* p<0.01; AMAS = Abbreviate Math Anxiety Scale; STAI = State and Trait Anxiety Inventory

Section 2 highlighted that the overall model was not significant ( $R^2=0.08$ ;  $F_{(1,82)}=2.21$ ;  $p=0.094$ ). The same results have been found both in male and female participants. The anxiety scales did not link with the written calculation B scores variance.

Finally, regarding the arithmetical facts (Section 3), the last test that was performed, the results of the regression analysis showed that the overall model explained 17% of the variance ( $R^2=0.17$ ;  $F_{(3,80)}=5.28$ ;  $p=0.002$ ), more specifically, MA was the only variable that was significantly linked to the arithmetical performance ( $\beta=-0.332$ ;  $SE=0.565$ ;  $t=-2.83$ ;  $p=0.006$ ) whereas trait and state anxiety were not. The same was true for the male students' group ( $R^2=0.135$ ;  $F_{(3,62)}=3.23$ ;  $p=0.028$ ) but not for the female's group.

## DISCUSSION

The main aims of this study were the understanding of the antecedents of MA and its relationship with the basic and high-level mathematics performances in a sample of adolescent students of a technical-professional Italian secondary school. Until today, literature has been mostly focused on children and young adults (Wu et al. 2012, Ramirez et al. 2013), less in adolescents. This is a transitional age also on an educational level, during which the stabilization of the knowledge occurs as well as the one of the beliefs, the emotions and also the behaviours for learning and studying in general and towards specific learning subjects in particular (i.e. mathematics). About mathematics, adoles-

cence is a period of life in which the experiences one has made that are related to maths learning during primary school could have an influence on the feelings one experiences and on the approach to the study of this specific subject. In turn, the negative feeling towards mathematics may have an influence in the cognitive performance related to mathematics skills, so as to give consistency to the assumptions of the “reciprocal theory” (Carey et al. 2016); in this sense it has been important for us to investigate this issue in this specific age group.

Our findings, according to previous studies (Luttenberger et al. 2019, OECD 2018), confirm the high percentage of the presence of the specific MA also in the adolescent students and higher level of MA as well as of trait anxiety in females compared to males. Furthermore, in line with Peachter and colleagues (2017), our results highlights the close relationship between MA and trait anxiety; The MA variance of 26% is explained by the presence of trait anxiety while it does not seem to be influential by context-related anxiety, or rather the state anxiety that was assessed before and after the maths performance, in this case probably because the students knew that their performance would not have been evaluated by their teachers.

As of the mathematics performances our sample proves to be in shortfall. In almost all the tasks, the students have proved insufficient without showing differences between females and males, perhaps due the difference in the number of components of the two groups. This difference in the number, one of the main limits of this study, makes the results referring to males more consistent than the ones referring to females.

Many studies focused on the relationship between MA and mathematical performance, particularly in the high-level computing performance (Ashcraft & Ridley 2005, Devine et al. 2012, Ma 1999). Our findings show that MA is linked only to arithmetical facts while it is not linked with basic maths performance (written calculation A and B). In the first task completed by the students, written calculation A, 14% of the maths performance variance is explained only by state anxiety; perhaps the physiological anxiety related to the particular moment may have affected this specific performance, because it was the first, but not the subsequent ones, since state anxiety tends to modulate over time. With reference to the written calculation B test, no link may have emerged between the performance and MA probably because there is not a great variability in the obtained results, in fact the whole group has obtained rather low scores in a homogeneous way.

The specific MA is linked to the arithmetical facts task that assessed the students’ stored combinations of numbers and their ability to access them automatically. This task assessed more advanced maths competence involving higher levels of cognitive functioning and working memory processes that seem to be affected by MA, in particular the retrieval of the automatism process. Moreover, some information required by this task may be recently acquired and, as suggested Raghobar

and colleagues (2010), the acquisition of new maths skills may depend on visual-spatial WM, therefore it is more exposed to the interference of anxiety in its retrieval and processing, causing many computing mistakes. This specific relationship is present in the male’s group but not in the female’s group; in our sample the MA is only linked to the male group’s maths performance; even if the female students show higher level of MA than male ones, it does not seem to interfere with the mathematics performance, differently from most of the previous studies (Devine et al. 2012, Reali et al. 2016) that found a stronger relationship between MA and maths performance in girls than boys, but most likely we did not find the same results due to the low number of females.

This study has some limits, i.e. the already mentioned difference between the number of males and females, which makes the males’ results more consistent than those of the females. A second one is that the sample comes from a single educational institute therefore, in order to generalise the results, a more representative cohort of students coming from other kinds of educational institutes is needed. Finally, this study has been conducted only in a relaxing evaluation-free setting, thus, since the link between MA and maths performance seems to change according to the assessment context, a school-evaluation setting will be needed for a greater generalisation of the results and to study this link. Moreover, an assessment in school-evaluation context may also better explain the role of the contextual variable on the MA variance.

## CONCLUSION

The present study confirms that also in Italy adolescent students, like in other countries (OECD 2018), have some levels of specific MA and importantly this one is closely related to the mathematics performances that do not seem to be affected by other anxiety forms. Few studies have focused on this link in the Italian context, therefore this study tries to fill this gap. Understanding the link between MA and mathematics performances may have relevant implications in clinical, but above all in educational and didactical practice, giving teachers food for thought to implement new teaching strategies to try reducing anxiety in the school context.

In order to better understand this relevant issue, longitudinal studies are in progress, in particular future studies will focus on the assessment of MA and maths performance also in a school-evaluation situation.

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### Contribution of individual authors:

Livia Buratta: substantial contribution to the conception of the study, to its design and to data collection, statistical contribution and interpretation of data, writing of the manuscript.

Massimo Piccirilli: contribution to the conception of the study, interpretation of data and manuscript revision.

Gianni Alberto Lanfaloni: contribution to the conception and preparation of the study, to data collection and data interpretation.

Silvia Ilicini: contribution to the preparation of the study and data collection.

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