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Research Article

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Math Anxiety and Poor Math Competence: A Longitudinal Investigation of Students Failing to Achieve the Math Skills Required by School Curricula

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ABSTRACT
Mathematics anxiety (MA) has emerged as a significant concern in recent years, recognized for its potential to interfere with learning processes. Our study delved into exploring the relationship between the presence and level of MA and the ability to acquire math skills required by the school curriculum. For this purpose, secondary school students were monitored during their first year of study. A questionnaire designed to assess MA and a math skills assessment test were administered on two separate occasions: initially at the end of the first term and subsequently at the conclusion of the second term. The results of the end-of-year tests indicated that students with high levels of MA, assessed at the beginning of the school year, showed a significantly greater risk of failing to achieve the required competence. These findings seem to support the notion that a high level of MA can significantly contribute to hindering the acquisition of educational outcomes.

Keywords: Math Anxiety, Amas, Math Achievement, Educational Psychology, Secondary School Students

Introduction

According to International educational reports, a considerable segment of the student population has been observed to exhibit anxiety when faced with mathematical tasks [1]. Mathematics anxiety (MA) is recognized as a distinct type of anxiety, separate from other forms such as trait, state, or social anxiety, and is supported by specific neurobiological evidence [2-4]. Richardson and Suinn define MA as “feelings of tension and anxiety that interfere with the manipulation of numbers and the solving of mathematical problems in a wide variety of ordinary life and academic situations” [5]. This type of adverse reaction to mathematics manifests itself in several ways [6-8]: emotionally, it can appear as discomfort, apprehension, aversion, worry, frustration, or fear; physically, it may present as general malaise, tachycardia, muscle tension, shortness of breath, sweating, and other neurovegetative responses; and behaviorally, it often leads to avoidance of school-related activities or a reluctance to engage in homework and study. Notably, the intensity of MA can sometimes increase to the level of a phobia, characterized by an irrational and overwhelming fear of real or even imaginary numerical and mathematical contexts [9].

Extensive research has consistently demonstrated a negative correlation between MA and math test performance [10,11]. This correlation not only affects academic outcomes but also extends to influencing future educational and career decisions [12,13].

Further underscoring this point, our research has found that math performance is inversely related to MA, regardless of state and trait anxiety levels [14]. This correlation was first evident in the scores obtained in the math test conducted alongside the MA questionnaire: students with higher anxiety levels tended to achieve lower scores. A similar trend was observed in the math test scores at the end of the year, further affirming this relationship. Moreover, anxiety levels were inversely related to the students' ability to acquire new mathematical skills: in the comparison of scores between the initial and final math tests, students who did not show an improvement in the second test were found to have significantly higher levels of MA than those who exhibited an improvement [15].

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In this further analysis we sought to evaluate the relationship between MA and success in mathematical learning. School curricula typically outline the skills that should be acquired at each stage of a course. Theoretically, by the end of a school year, students are expected to have attained the minimum competencies required by the year's program. Nonetheless, this educational goal is not always realized. The student's learning level can be assessed through a standardized math test so that the score obtained indicates whether the acquisition of the skills required by the program for the current school year has been successful or not. Thus, in this investigation, at the conclusion of the school year, students were divided into two distinct categories based on their performance: those who met the required skills were classified in the High Math Performance (H -MP) subgroup. Conversely, students who did not acquire the minimum required competencies were placed in the Low Math Performance (L-MP) subgroup. Our hypothesis posits that, in the presence of a relationship between MA and mathematics learning, these two subgroups should show notable differences not only in math academic achievement but also in levels of MA. More specifically, the L-MP subgroup is predicted to manifest a considerably higher level of MA than the H-MP subgroup.

Subjects and Methods

Subjects

The study participants were 73 Italian-speaking students (59 male and 14 female) attending the first grade of a secondary school (corresponding to grade 9 in English-speaking educational system). The mean age was 14 years and seven months, with a standard deviation (SD) of 4 months and an age range spanning from 14 to 15.1 years. Students with a diagnosis of dyscalculia or a specific learning disorder, confirmed by certification from a health authority, were excluded from the study.

Procedure

The study received ethical approval from CEAS, the Local Ethics Committee of the Umbria Region in Italy. The participants and their parents were informed about the purposes of the research and gave signed informed consent. Students were assessed on two separate occasions: initially in January at the end of the first term and subsequently in June at the conclusion of the second term. These assessment periods align with the times when formal testing is conducted in Italian schools to evaluate student learning levels. All participants completed a questionnaire designed to assess MA, as well as another questionnaire evaluating both state and trait anxiety; then, they undertook a math test, a widely used tool for evaluating the mathematical skills they had achieved. In an effort to ensure consistency in the assessment and isolate the impact of anxiety from potential variations in task difficulty, the same mathematics test was administered again at the end of the academic year. In the present analysis, particular emphasis was placed on the data obtained from the MA questionnaire, administered at the beginning of the academic year, and the mathematics test, conducted at the end of the year.

Measures

Battery for the Assessment of Calculation Ability

The "Battery for the Assessment of Calculation Ability" (ABCA 14-16) is a battery of paper-pencil tests for the assessment of math skills in individuals aged 14- to 16 [16]. This assessment tool is widely implemented in Italy to establish whether students have successfully acquired the mathematical skills outlined for their current academic year. The different subtests in the battery measure varying levels of mathematical proficiency through tasks of differing complexity. The subtests used in this study specifically consist of advanced math skills that investigate how students have stored combinations of numbers within the calculation system and whether they are able to access them automatically (for example, "2+3 × 4 ="). The items provide a specific individual profile comparing the percentile scores to the cut-off criteria of the normative sample. In other words, the math test score indicates whether the performance corresponds to the expected one in terms of age and education and make it possible to identify students who, showing underperformances, require educational support. Scoring is based on the number of correct answers and ranges from zero, denoting the lowest level of performance, to a maximum of 28. In accordance with these test norms, students who met or surpassed the required competencies, as demonstrated by scoring above the cut-off, were classified in the successful acquisition of math competence (H-MP, High Math Performance) subgroup; conversely, those by scoring below the cut-off who did not meet the minimum required competencies, as demonstrated by scoring below the cut-off, were classified in the failure of acquisition of math competence (L-MP, Low Math Performance) subgroup.

Abbreviated Math Anxiety Scale

The "Abbreviated Math Anxiety Scale" (AMAS), one of the most widely employed scales to measure math anxiety, is a questionnaire comprising nine items, each rated on a 5-point Likert scale, resulting in a total score ranging from 9 (the lowest level of MA) to 45 (the highest level of MA) [17]. Five items explore anxiety related to learning math (for example, "Carefully listening to the math lesson" or "Starting a new topic in mathematics"), while the other four explore anxiety related to being tested in math (for example, "Doing a written math examination/test"). In this study, we employed the Italian version validated by Primi et al. [18]. The Italian adaptation of AMAS exhibits psychometric properties similar to those of the original test and its transcultural validity has allowed collaborative studies between Italian and English researchers [10]. Based on the AMAS scores, students were divided into two groups: those scoring above the mean by one SD were categorized as having high levels of anxiety (H-MA), and those scoring below the mean by one SD were identified as having low levels of anxiety (L-MA).

Statistical Analysis

For data analysis, we utilized the Jamovi program [19]. Descriptive statistics, including mean and SD, were applied to describe the scores obtained from the AMAS questionnaire and ABCA 14-16 test. A Levene test was performed to assess the equality of variances. Student's t-test for unpaired samples was used for homogeneous variances, otherwise Welch's t-test was employed to compare the scores of the subgroups in both the math test and the anxiety questionnaire. Additionally, a Fisher exact test was employed to examine the distribution patterns of students with high and low MA within the subgroups characterized by sufficient and insufficient math performance. We considered a P-value <0.05 (2-sided) as statistically significant.

Results

The average score obtained on the math test was 16.37 (SD=6.3). Subgroup analysis at the conclusion of the academic year revealed that 52 students (71.23%) were categorized into the H-MP subgroup, demonstrating adequate math skills, with a mean score of 19.62, (SD=3.73). Conversely, 21 students (28.77%) were classified into the L-MP subgroup, which is indicative of insufficient math abilities, with a mean score of 8.33 (SD=3.77). A significant difference was noted in the math test scores between these subgroups (p<0.001). Furthermore, students in the H-MP group exhibited a significantly (p<0.001) lower MA level, with a mean score of 20.46 (SD=5.69), compared to those in the L-MP subgroup, who had a mean MA score of 25.10 (SD=6.03), as shown in Table 1.

Table 1: Comparison of Math Anxiety and Math Performance Scores Between Subgroups with High and Low Math Performance

	H-MP	L-MP	P
Number	52	21	
MA	20.46 ± 5.69	25.10 ± 6.03	0.001
MP	19.62 ± 3.73	8.33 ± 3.77	0.001

Note: In this comparison, the Low Math Performance (L-MP) subgroup displayed significantly higher levels of mathematics anxiety (MA) compared to the High Math Performance (H-MP) subgroup. The "Number" row denotes the count of students in each subgroup. “MA” reflects the level of math anxiety, with higher scores indicating higher levels. “MP” assesses performance in mathematics, with higher scores denoting better performance. The p-values represent the statistical significance of the differences between the H-MP and L-MP subgroups in both MA and MP.

The AMAS questionnaire yielded an average anxiety level of 21.79 (SD=6.12). Within this framework, 15 students (20, 55%) were identified as the H-MA subgroup, characterized by elevated anxiety levels (M=30.33, SD=1.95). In contrast, 14 students (19, 18%) fell into the L-MA subgroup, marked lower anxiety levels (M=14, SD=1.11). The disparity in AMAS scores between these two subgroups was statistically significant (p<0.001). Notably, students in the H-MA subgroup showed significantly (p<0.001) poorer math performance (M=12.67, SD=7.54) than those in the L-MA subgroup (M=20.71, SD=3.87), as illustrated in Table 2.

Table 2: Comparison of Math Anxiety and Math Performance Between Subgroups with High and Low Math Anxiety

	H-MA	L-MA	P
Number	15	14	
MA	30.33 ± 1.95	14 ± 1.11	0.001
MP	12.67 ± 7.54	20.71 ± 3.87	0.001

Note: In this comparison, the High Math Anxiety (H-MA) subgroup exhibited significantly lower mathematics performance than the Low Math Anxiety (L-MA) subgroup. The "Number" row reflects the count of students in each category. “MA” reflects the level of math anxiety, with higher scores indicating higher levels. “MP” assesses performance in mathematics, with higher scores denoting better performance. The p-values underscore the statistical significance of the disparities in MA and MP scores between these subgroups.

Further analysis with Fisher exact test indicated a significant distribution of H-MA and L-MA students across the H-MP and L-MP subgroups (p=0.006). Particularly, it was observed that none of the L-MA students were present in the L-MP subgroup; conversely, students who showed high levels of MA at the beginning of the year have a significantly greater risk of not achieving the math skills required by the educational curriculum (Table 3).

Table 3: Student Distribution According to Math Performance and Math Anxiety levels

	H-MA	L-MA
H-MP	8	14
L-MP	7	0

Note: This table highlight a significant disparity (p = 0.006 by Fisher exact test) in the distribution of students showing High Math Anxiety (H-MA) and Low Math Anxiety (L-MA) between the High Math Performance (H-MP) and Low Math Performance (L-MP) subgroups. The numbers indicate the count of students in each specified category.

Discussion

Our study aimed to explore the potential relationship between MA and successful learning of mathematics, focusing on students in their first year of secondary school. We consider this stage critical for identifying the risk of mathematical difficulties, as it represents a transitional phase in the mathematics curriculum, serving as a bridge between students' past experiences with math and the development of future learning strategies [20]. Furthermore, this period coincides with adolescence, a pivotal time in students' lives characterized by notable emotional and behavioral changes.

The main result of our investigation suggests that students who show high MA levels at the beginning of the school year were significantly more likely to fail to achieve the math skills required by the educational curriculum. Notably, none of the students with low anxiety levels were among those who failed the math test. Conversely, students who, at the end of the school year, did not acquire the minimum required math skills predominantly belonged to the subgroup of those who had very high levels of MA at the beginning of the year.

These findings seem to support the notion that MA could be a contributing factor to learning barriers. However, it is important to note that these results do not establish a causal relationship between MA and difficulties in mathematics [21]. In other words, it remains unclear whether anxiety leads to challenges in mathematical comprehension or, conversely, if encountering difficulties in mathematics gives rise to increased levels of anxiety [22-24]. According to the “reciprocal theory”, it is plausible that anxiety and performance mutually reinforce each other, creating a cyclical pattern at some point in the student's educational trajectory [25,26]. Nevertheless, our research indicates that the onset of anxiety has a substantial impact on mathematical learning, regardless of its initial cause [15].

The recognition of MA as a factor in learning difficulties necessitates that educators develop strategies for detecting its presence and varying impact on individual students [27]. The role of teachers is vital in this context, as numerous studies indicate that the origin of MA is not inherently linked to mathematics itself but rather to the manner in which it is taught [28,29]. From this perspective, instructional approaches should be designed to address not only the cognitive but also the emotional challenges associated with studying mathematics [30-32]. Certainly, much more research is needed on this issue, but measuring and trying to eliminate MA from the school context should be a primary goal of good educational practice.

Finally, it would be appropriate to consider the alarm raised by the international educational institutions about the progressive decline in the number of students who achieve sufficient mathematics skills to address with the problems of daily life [33]. It is likely that MA contributes to this phenomenon as a very relevant factor. In this regard, if this relationship was confirmed, as our data also seems to suggest, it might then be time to propose MA as a distinct diagnostic category in the classification systems of mental disorders.

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Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Regulation (EU) 2016/679 of the European Parliament and of the Council of April 27, 2016 on the protection of natural persons with regard to the processing of personal data was followed at all times.

Informed Consent Statement: An informed consent was obtained from all individual participants in-cluded in the study.

Data Availability Statement: The data and materials are available from the corresponding author upon a reasonable request.

Conflicts of Interest: Nothing to declare.

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