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HIGHLY INTELLIGENT CHILDREN WITH DIFFICULTY IN ARITHMETIC: AN EFFECT OF MATH ANXIETY?

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ABSTRACT

Mathematical anxiety (MA) is a set of beliefs, physical and emotional symptoms that some people experience when dealing with mathematical problems. The study aimed to investigate the effect of MA on the arithmetic performance of children with high intelligence. Fifty-two children with lower performance on the STP arithmetic subtest and classification "above average" or "intellectually superior" in the Raven Matrices participated in the study. The results showed a strong correlation between intelligence and arithmetic EDT (r = 0.82; p < 0.000); and moderate correlations between arithmetic DET and MAQ (r = 0.32; p = 0.02) and MAQ-B (r = 0.35; p = 0.01). Multiple linear regression analysis showed an 8% prediction of the MAQ-A subscale and 11% of the MAQ-B as predictors of arithmetic performance. Mathematical anxiety interferes with arithmetic performance, even in children with higher than expected fluid intelligence, suggesting an important effect of emotional mechanisms.

Keywords: fluid intelligence; mathematical anxiety; arithmetic.

Dificultad en Aritmética en niños con alta inteligencia: ¿efecto de la ansiedad matemática?

RESUMEN

Ansiedad matemática (AM) es un conjunto de creencias, síntomas físicos y emocionales que algunas personas experimentan al lidiar con problemas matemáticos. El estudio tuvo por objetivo investigar el efecto de la AM en el rendimiento aritmético de niños con alta inteligencia. Participaron del estudio 52 niños con rendimiento inferior en la subprueba aritmética del STP y clasificación "superior de la media" o "intelectualmente superior" en las Matrices de Raven. Los resultados apuntan fuerte correlación entre inteligencia y STP aritmética (r = 0,82; p < 0,000); y correlaciones moderadas entre STP aritmética y MAQ-A (r = 0,32; p = 0,02) y MAQ-B (r = 0,35; p = 0,01). El análisis de regresión linear múltiple demostró una predicción del 8% de la subescala MAQ-A y del 11 % de la MAQ-B como predictores del rendimiento aritmético. La ansiedad matemática interfiere en el rendimiento en aritmética, incluso en niños con la inteligencia fluida superior al esperado, sugiriendo un importante efecto de los mecanismos emocionales.

Palabras clave: inteligencia fluida; ansiedad matemática; aritmética.

Dificuldade em aritmética em crianças com alta inteligência: efeito da ansiedade matemática?

RESUMO

Ansiedade matemática (AM) é um conjunto de crenças, sintomas físicos e emocionais que algumas pessoas experimentam ao lidar com problemas matemáticos. O estudo objetivou investigar o efeito da AM no desempenho aritmético de crianças com alta inteligência. Participaram do estudo 52 crianças com desempenho inferior no subteste aritmética do STP e classificação "acima da média" ou "intelectualmente superior" nas Matrizes de Raven. Os resultados demonstraram correlação forte entre inteligência e STP aritmética (r = 0,82; p < 0,000); e correlações moderadas entre STP aritmética e MAQ-A (r = 0,32; p = 0,02) e MAQ-B (r = 0,35; p = 0,01). A análise de regressão linear múltipla demonstrou uma predição de 8% da subescala MAQ-A e de 11 % da MAQ-B como preditores do desempenho aritmético. A ansiedade matemática interfere no desempenho em aritmética, mesmo em crianças com a inteligência fluída acima do esperado, sugerindo um importante efeito dos mecanismos emocionais.

Palavras-chave: inteligência fluída; ansiedade matemática; aritmética.

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INTRODUCTION

School performance is the result of the adequate acquisition of educational skills. In its initial acts, the schooling process has ambitious goals related to the acquisition of reading, writing, and arithmetic (Soares, 2004). Studies point out that difficulties in school education can be explained by cognitive alterations such as deficits in fluid intelligence (Porto, 2018), and deficits in operational memory (Peng et al., 2018).

According to the cognitive perspective, learning is the result of consolidation of information in memory in the long term. It depends on the availability of environmental stimuli and neurocognitive capabilities by individuals when it comes to handling such information. The process gets started with the gathering of information by means of organs of the senses, which is codified and decodified in a continuous process that involves levels that are increasingly complex (Eysenck & Keane, 2017). This is the mechanism by means of which information is interpreted, organized, integrated, and stored before an answer is produced (Simões & Nogaro, 2018).

Evidence shows that there is an effect of fluid intelligence in performance in mathematical skills (Colom, 2006; Ribeiro & Freitas, 2018), characterizing intelligence as an important predictor of educational performance (Roth et al., 2015). Fluid intelligence is linked to the capacity of individuals to realize tasks that involve reasoning, abstraction, planning, and the management of problems (Neubert, Mainert, Kretzschmar, & Greiff, 2015). The elaboration of new strategies, processing speed, and the resolution of problems are necessary skills for the accomplishment of numerous math tasks (Luculano, Moro, & Butterworth, 2011).

Another factor whose influence on performance in arithmetic has been tested is math anxiety (MA). Studies point at a negative correlation between mathematical development and mathematics anxiety (Cargnelutti, Tomasetto, & Passolunghi, 2017; Monteiro, Peixoto, Mata, & Sanches, 2017; Reali, Jiménez-Leal, Maldonado-Carreño, Devine, & Szücs, 2016; Vukovic, Kieffer, Bailey, & Harari, 2013). MA is a term that is used for denominating a set of beliefs, physical and emotional symptoms that some children and adults experience regarding math problems both in the school environment and in everyday situations (Carey, Hill, Devine, & Szücs, 2016; Dowker, Sarkar, & Looi, 2016). In this sense, the situation generally gets started during the first years of elementary school or even in child education and goes all the way as far as adulthood (Ashcraft, 2002), without any identification by teachers, caretakers, or even by the students themselves, which can be justified by the fact that studies on mathematical anxiety are quite recent.

MA comprehends beliefs of incapacity and failure, negative assessment on the subject and on performance itself; emotional reactions such as fear, anger, tension, and physiological symptoms like tachycardia, sweating, intestinal colic, and shivers. In order to avoid these sensations, people might develop behaviors of escape (skip class, be absent on test days, fail to participate in papers and activities) and of avoidance (doing homework hastily, being late for class). By doing that, she feels relieved, which is something that reinforces the avoidance pattern. On the other hand, when students do not experience doing these activities, they miss out on opportunities to practice and develop mathematical skills, which might lead to poorer educational performance, when compared to peers that do not suffer from math anxiety (Carmo, 2011; Haase et al., 2013).

Reactions to math anxiety can manifest themselves during or before the realization of activities that involve math and in common occasions in everyday life and work (Beilock & Maloney, 2015). The consequences of this problem include school evasion and a limitation in the number of professional choices for areas that do not involve mathematics (Suárez-Pellicioni, Núñez-Peña, & Colomé, 2016). Some research works investigate the relation between gender, the presence and the level of MA. Ashcraft (2002) demonstrated that MA is more frequent among females and added that such fact can be explained by the women's tendency to speak more openly about their feelings. Dowker et al. (2016) discuss the possibility that the increase in the levels of MA among women might be related to lesser exposure of women to mathematics because the social expectation is that females present poorer performance in mathematics when compared to males; exposure might also lead them to adapt to the existing expectations concerning their group. Some studies assess the impact of mathematics anxiety in executive functions, especially in work memory and attention components (Hartwright et al., 2018; Passolunghi, Caviola, Agostini, Perin, & Mammarella, 2016; Soultanlou et al., 2019).

According to studies that have already been realized, it is possible to consider that MA produces effects that still need to be investigated in specific groups. The objective of the study was to investigate the influence of math anxiety among children that present high scores of fluid intelligence and still present poor performance in arithmetic. The central hypotheses is that MA has a predicting effect for arithmetic performance when fluid intelligence is preserved.

METHOD

The employed method was based on a cross-sectional, quantitative, quasi-experimental outline with a sample by convenience.

Participants

The databank that was the basis for the sample contained 412 children between the ages of 7 and 10 years (M = 8.41, SD= 1.15), boys (50%) and girls (50%) from public (70.6%) and from private (29.4%) schools in the city of Vitória da Conquista – BA. By means of this databank researchers selected two groups of children who corresponded to the inclusion criteria for this study. The criteria for Group 1 were: a) intelligence as high as or above 75 % (equivalent to classifications that are 'definitely above average" and "intellectually superior"); and b) poor performance in arithmetic, where the only considered children were the ones with a performance in the STP arithmetic subtest that was inferior to what was expected for the school year. Criteria for Group 2 were: a) intelligence as high as or above 75 % (equivalent to classifications "definitely above average" and "intellectually superior"); and b) performance in arithmetic that was above expectancy for the school year in the STP arithmetic subtest. Thus, the number of participants in Group 1 was 52 children, while 31 (59.6%) were male and 21 (40.4%) were female, between the ages of 7 and 10 years (M = 8.65 years, SD= 1.10 years), out of which 41 (78.8%) came from public schools and 11 (21.2%) came from private schools. The number of participants of Group 2 was 28 children, while 16 (57.1%) were male and 12 (42.9%) were female, between the ages of 7 and 10 years (M = 7.61 years, SD= 0.79 years), out of which 10 (35.7%) came from public schools and 18 (64.3%) came from private schools.

Instruments

Arithmetic subtest of the Educational Performance Test (STP) (Stein, 1994): this subtest consists of arithmetic calculations with increasing levels of difficulty, while three questions were oral and 15 were written operations. The subtest makes it possible to assess the educational performance of children from the 1st to the 6th in this area based on school year as well as on age. During the operation, the child is required to solve as many calculations as possible, according to what has already been learned in the classroom, while only calculations that have not been learned should be left unsolved. Finally, each right answer was marked with a punctuation period; then, the children's performance is compared to the normative tables for age and school year and classified as "above"/"within"/"below" the expected result.

Raven's Colored Matrices (Angelini, Alves, Custódio, Duarte, & Duarte, 1999): an instrument that assesses non-verbal fluid intelligence by means of logical reasoning. It is a book that is divided into three series with 12 items each. Items/series follow an increasing order or difficulty. For each item, children are shown a matrix with a missing part and six alternatives for completion. Participants are required to choose the option that they believe follows the same pattern as the matrix in order to complete it correctly. By means of the Raven results, it is possible to identify the intellectual level of children from the age of 4 years and 9 months until 12.

The Math Anxiety Questionnaire (MAQ) (Wood et al., 2012): is an instrument that assesses the level of math anxiety among children during their school education. It is made up of four base questions related to six subscales: general mathematics, easy calculations, difficult calculations, written calculations, mental calculations and math homework, adding up to a total sum of 24 items. The base questions assess the following categories: (MAQ-A) performance self-perception: "how good are you in…"; (MAQ-B) attitudes concerning math: "how do you like…"; (MAQ-C) unhappiness due to math problems: "how happy or unhappy do you feel when you have problems with…"; (MAQ-D) anxiety related to math problems: "how worried do you get when you have difficulties or problems with …". For example, item 1 is "how good are you in general math?". Each item is provided with a *Likert* scale going from 1 to 5 points, five illustrations that symbolize the intensity of the level of anxiety of students regarding the examination. The total sum of scores obtained by the children in the six items of each base question corresponds to the level of anxiety for each one of the categories.

Procedures

The research was approved by the Ethics Committee of the Federal University of Bahia – Multi-disciplinarian Health Institute, under decision no. 3.082.420. The study proposal was presented in meetings realized at the schools. The parents that got interested signed the Free Informed Consent Term (TCLE), authorizing participation by their children. After authorization, the gathering of data was realized with children by means of individual sessions, with a duration between 30 and 50 minutes, with the signing of the Free Informed Consent Term (TALE) by the child.

Data analysis

After being collected, data were sent to a databank for statistical analysis. This analysis was made by means of the *Statistical Package of Social Science (SPSS)* software, version 25. In addition to the descriptive analysis (for the purpose of characterizing the sample), researchers used Student t and Mann-Whitney's U tests for comparison between groups, as well as Pearson's correlation test and the analysis of multiple linear regression (stepwise method).

RESULTS

The math anxiety of the children from Group 1 (high intelligence and poor arithmetic performance) was above average when compared to the standard norm, but this difference was not significant. Only category B (attitudes regarding math), the experimental group presented a level of anxiety below the general average (Table 1).

When we compare the children from Group 1 to the children from Group 2 (high intelligence and high arithmetic performance), it was possible to observe that Group 1 presented less MA in the B categories (attitudes regarding math) and C (unhappiness due to math problems) of the MAQ, whereas group 2 presented less MA in the A categories (performance self-perception)

Table 1 *Comparison of the level of math anxiety between standard norm children and children with poor performances in arithmetic.*

	Standard Norm	Poor performance in arithmetic		
	M (SD)	M (SD)	t	P
MAQ-A	12.72 (4.21)	13.00 (3.52)	-.460	.646
MAQ-B	13.32 (5.42)	12.96 (4.81)	.450	.653
MAQ-C	16.19 (5.38)	16.44 (5.17)	-.320	.749
MAQ-D	17.64 (5.24)	18.38 (4.66)	-.971	.332

Note. MAQ – Math Anxiety Questionnaire; M = media; SD= standard deviation; t = student t; p = significance. *p<0,05. **p<0,01.

and D (anxiety related to math problems). However, differences were not statistically significant (Table 2).

Regarding the gender difference, Table 3 shows that the girls from Group 1 presented higher levels of anxiety in all categories when compared to boys. The result for test 1 indicated that there are significant differences between boys and girls in category D (anxiety related to math problems) of the MAQ.

The type of choice was also assessed with a comparison of the anxiety scores among children from public and private schools in Group 1. Table 3, the obtained results demonstrated that the children from private schools presented higher scores of math anxiety than the children from public schools, except for category D of the MAQ. No significant differences were found between the types of school.

A strong, significant correlation between intelligence and performance in arithmetic. Also, moderate correlations were found between the STP arithmetic subtest and the MAQ-A categories (performance self-perception) and MAQ-B (attitudes regarding math), according to Table 4.

It is also possible to observe the A and B categories of the MAQ as predictors of arithmetic performance. The first model presents the MAQ-A (performance self-perception) predicting 8% of the arithmetic performance (Table 5).

The second model shows that the MAQ-B (attitude

Table 2 *Comparison of the level of math anxiety between children with low performance in arithmetic and children with high performance in arithmetic.*

	Low performance in arithmetic	High performance in arithmetic		
	M (SD)	M (SD)	U	p
MAQ-A	13.00 (3.52)	11.71 (4.21)	536.500	.052
MAQ-B	12.96 (4.81)	13.93 (6.91)	717.500	.915
MAQ-C	16.44 (5.17)	17.39 (3.85)	647.500	.415
MAQ-D	18.38 (4.66)	17.00 (4.16)	585.500	149

Note. MAQ – Math Anxiety Questionnaire; M = average; SD= standard deviation; U = Mann-Whitney's U; p = significance. *p<0,05. **p<0,01.

Table 3 *Comparison of the level of math anxiety by gender and type of school.*

	Male	Female		
	M (SD)	M (SD)	T	P
MAQ-A	12.23 (3,33)	14.14 (3.54)	1.985	.053
MAQ-B	12.06 (4.24)	14.29 (5.38)	1.662	.103
MAQ-C	15.32 (5.16)	18.10 (4.3)	1.951	.057
MAQ-D	16.97 (4.86)	20.48 (3.50)	2.842	.006**
	Public	Private		
	M (SD)	M (SD)	T	P
MAQ-A	12.66 (3.62)	14.27 (2.87)	1.364	.179
MAQ-B	12.63 (4.87)	14.18 (4.58)	.947	.348
MAQ-C	16.02 (5.18)	18.00 (5.04)	1.129	.264
MAQ-D	18.41 (4.83)	18.27 (4.20)	-.089	.930

Note. MAQ – Math Anxiety Questionnaire; M = average; SD= standard deviation; t = Student t; p = significance. *p<0,05. **p<0.01.

Table 4 *Correlation between intelligence, performance in arithmetic and math anxiety.*

	Raven	STP	MAQ-A	MAQ-B	MAQ-C	MAQ-D
Raven	1					
STP	.82**	1				
MAQ-A	.29*	.32*	1			
MAQ-B	.22	.35*	.62**	1		
MAQ-C	.19	.22	.42**	.37**	1	
MAQ-D	.12	.13	.22	.183	.54**	1

Note. Raven – Raven's Colored Progressive Matrices Test; STP – performance scores in the arithmetic subtest of the School Performance Test; MAQ – Math Anxiety Questionnaire. *p<0.05. **p<0.01.

Table 5 *Regression analysis by the stepwise method for verifying the prediction of math anxiety (MAQ-A) on arithmetic performance.*

Variable criterion	Independent Variable	R	R^2 adjusted	β	t	p
MAQ-A	Arithmetic STP	.318	.083	.318	2.374	.021

Note. MAQ – Subscale A of the Math Anxiety Questionnaire (performance self-perception); arithmetic subtest of the STP; R^2 = regression coefficient; β = beta coefficient; t = student t; p = significance.

Table 6 *Regression analysis by the stepwise method in order to verify the prediction of math anxiety (MAQ-B) on arithmetic performance.*

Variable criterion	Independent Variable	R	R^2 adjusted	β	t	p
MAQ-B	STP arithmetic	.350	.105	.350	2.640	.011

Note. MAQ – Subscale B of the Math Anxiety Questionnaire (attitude regarding math); arithmetic subtest of the STP; R^2 = regression coefficient; β = beta coefficient; t = Student's t-test; p = significance.

regarding math) predicts 11% (Table 6). No results were presented for categories C (unhappiness due to math problems) and D (anxiety related to math problems) of the MAQ.

DISCUSSION

The effects of MA have been considered for a better understanding of the difficulties for learning by children with low arithmetic performance. The negative emotions triggered by the fear might hinder cognitive processes and interfere in performance even for children that do not present cognitive deficits. However, Fassis, Mendes and Carmo (2014) suggest that it is not possible to say that high levels of math anxiety are linked to low performance in the subject. In a research developed by these authors with students from elementary school, the students with higher levels of MA were the ones who presented better performance in the discipline. In this study, the objective was to verify the influence of MA in children that present high scores in fluid intelligence in combination with low arithmetic performance.

The results of this study provided evidence for the presence of MA in children who present lower-than-expected performance in math but present high scores in fluid intelligence. However, the levels of MA were not significatively different from the results of the more comprehensive sample. On its turn, fluid intelligence proved a strong predictor of performance in arithmetic skills.

The correlation analysis evidenced two categories related to arithmetic performance, the MAQ-A (performance self-perception) and the MAQ-B (attitude regarding math). No moderate or strong correlations were found between arithmetic performance and the categories that assess the MAQ-C (unhappiness due to math problems) and the MAQ-D (anxiety due to math problems). These results demonstrate the bidimensional nature of MA, with a more cognitive dimension (MAQ-A and MAQ-B) and a more emotional dimension (MAQ-C and MAQ-D) (Haase et al., 2013). These results also provide evidence that the way children assess their own performance and their own attitude regarding math produce a deeper effect in their performance than the unhappiness or anxiety they face when they have to handle discipline problems.

Multiple Linear Regression Analysis confirmed these results by providing evidence that the MAQ-A category is a predictor of 10 % of performance and category MAQ-B as a predictor of 12%. Such result suggests that performance self-perception explains a variation of 10 % of arithmetic performance, and that attitude regarding math explains 12 % of performance.

These results are in accordance with the findings of Silva, Paixão, Machado and Miguel (2017), which demonstrate that the belief in self-efficacy for learning math (a person's confidence in their own capacity to accomplish math tasks successfully), they are inversely related to MA. This suggests that students with low expectations regarding their own performance in the discipline present higher levels of MA, which have a negative impact on performance. Núñez-Peña and Suárez-Pellicioni (2015) verify that people with higher levels of MA tend to make more mistakes, provide less accurate answers, and need more time to solve the same math problem proposed to individuals with lower levels of MA. Individuals with high levels of math anxiety also tend to overload their work memory by concentrating on negative emotions and expectations regarding their own performance in the task they have to accomplish.

Another study realized by Dowker et al. (2016) with the objective to discuss research works realized in the last 60 years on MA suggests that people who recurrently present low performance in math tasks tend to avoid them, which diminishes the possibility to learn the subject in the short and in the long term, wears out cognitive resources that should be employed in the solution of math problems, and compromises performance. According to the authors, there is also the possibility that math anxiety interferes in operational memory, with a negative impact on arithmetic performance, especially in operations with several digits and transport operations. It is an important construct to be studied.

Concerning the gender comparison, significant differences were found between boys and girls only in category MAQ-D, which assesses the anxiety related to math problems. This result suggests that girls with high intelligence and low arithmetic performance are not different from boys when it comes to performance self-perception, attitude regarding the discipline, 0and unhappiness due to math problems, but present higher levels of anxiety regarding these problems. Some studies found different results when comparing the attitude and performance self-perception for math by gender. Pinxten, Marsh, De Fraine, Van Den Noortgate and Van Damme (2014), in a longitudinal study realized with students from the 4th to the 7th school year, verified that boys report that they like the subject more than girls and they also tend to assess their own math performance more positively. Besides that, a study realized by Loos-Sant'ana and Brito (2017) indicated that boys tend to believe that girls present an inferior performance in the discipline and girls do not commonly believe their own performance in the discipline might be better than the one by boys, even in situations in which they actually perform better than the boys.

Concerning the comparison of the level of MA of the children in the sample by type of school, the children from the private education system presented higher levels of math anxiety for three of the four categories of the Math Anxiety Questionnaire. However no statistically significant differences were found. This result is in accordance with the results found by Fassis et al. (2014), in which the average level of MA of the students from public schools was lower than the level presented by the students from private schools. This difference also failed to show any significance in the statistical assessments though.

Concerning the relation between intelligence and arithmetic performance, a strong correlation between the two variables was found, which suggests that students with higher scores in intelligence tend to present better performance in arithmetic. A study realized by Ribeiro and Freitas (2018) chose intelligence as a variable to explain 40 % of the variation in school performance. Another study developed by Mecca, Dias, Seabra, Jana and Macedo (2016) indicated that children with higher scores in reasoning tend to present better performance in arithmetic tasks.

Fluid intelligence is a more general component of intelligence and is linked to our capacity for problem solution, planning and the production of strategies (Carrol, 1993). The assessed children presented capacities that were above average for these functions, but they presented a performance that was below average in math. Math anxiety proved a factor for explaining this variation. However, it is not the only one. We must remember that empty spaces in education might lead to MA, as well as specific difficulties stemming from low arithmetic performance.

The study provides a representative sample with over 400 children assessed and, based on this group, 12.6% of the children were identified as part of a specific group that presents difficulty in learning math. This percentage is compatible with studies of prevalence that indicate that approximately 10 % of the Brazilian population during the school phase present difficulty in reading and calculus tasks (Garcia, 2003; Giacheti, 2002). As a limitation to this study, we can highlight the fact that there was no investigation of math skills in a comprehensive way in order to define whether such children present dyscalculia or not. Besides that, there was no investigation of possible environmental causes, such as educational blanks. These limitations can be explored in future studies, including methodological refinement by means of longitudinal studies.

Despite the aforementioned limitations, the realization of this study is important for the comprehension of factors that interfere in the arithmetic performance of children and also in order to amplify the discussion on math anxiety.

Scientific literature has presented an increasing number of research works in the area of number cognition. In this context, the present study collaborates with the results that reflect direct and indirectly in the realm of education, while using scientific foundations in order to point at factors that influence the school performance of children.

The obtained results denotte the impact of emotional variations on arithmetic behavior, promoting a discussion on possible interventions for these problems. Thus, it is important that studies continue to be done in order to investigate arithmetic performance from different perspectives.

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