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(REVIEW ARTICLE)

Low mathematics performance and the role of digital technologies

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Abstract

In the current study, we dealt with Dyscalculia, Mathematics Anxiety and Low Intelligence Quotient as factors that contribute to low performance in Mathematics. We investigated the relative effect of Dyscalculia and Mathematics Anxiety on students' performance. Also, we examined how technology helps the educational intervention in cases of Low Intelligence Quotient. We first present the main characteristics of the three factors and we continue with studies which indicate the way they affect performance in Mathematics. Through the current study we found that Mathematics Anxiety affects more negatively the students' performance than Dyscalculia does, as Mathematics Anxiety is a broader psychosocial factor that is more difficult to locate and handle. With regards to Low Intelligence Quotient, we concluded that those people can best be educated through technology and specifically through applications that support learning basic Mathematic skills.

Keywords: Dyscalculia; Mathematics Anxiety; Low I.Q.; Mental Retardation; Mathematics

1. Introduction

1.1. Goals of the study

Math has always been a subject of contradiction: many students believe it's the most important lesson concerning their career and they try to reach high levels of knowledge. On the other hand, there is a big portion of students who are afraid of Math. Therefore, they fail when it comes to even simple Math problems. Thus, in this study we tried to shed light on the factors contributing to low performance in Math. We focused on Dyscalculia, Mathematics Anxiety and Low I.Q., as from the literature review it was shown that these three factors are the most common concerning difficulties in the Math-learning procedure. Moreover, we investigated how Technology helps students learn, especially the ones with low I.Q.

1.2. Limitations

The inclusion-exclusion criteria set where the following:

- The majority of the articles we studied where experimental studies and not literature reviews.
- We focused on the three factors mentioned above (Dyscalculia, Anxiety, Low I.Q.)
- We examined studies which took place after the year 2000 and only two of them occurred before 2000.

1.3. Dyscalculia

Dyscalculia is a special learning difficulty which affects children acquiring basic Math skills. Necessary condition to examine Dyscalculia is an -at least- average I.Q. and no other learning disorders comorbidity. More specifically, students diagnosed with Dyscalculia have severe difficulties in Math procedures such us numbering, calculating or learning Math

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axioms. Additionally, they barely learn the multiplication table. It is important to mention that they find obstacles in understanding, representing and handling sets' cardinality. As for the relation between Dyscalculia and Math Anxiety, it is important to mention that Dyscalculia can cause Math Anxiety. This is because students with Dyscalculia have deficiencies in Mathematics and so they have bad experiences referring to Math. In addition, when 6-year old children with Dyscalculia symptoms have their first experience in school, usually their peers have already automated some basic Math procedures. It is thus very possible for the children who have difficulties to feel really pressed in order to answer quickly and right. It is also important to mention that even Math-related words cause Anxiety to children with Dyscalculia -who do not experience Anxiety in general. Another negative impact of Dyscalculia is that it can cause dysfunction of the working memory (Kunwar, 2020; Landerl et al., 2003; Rubinstein & Tannock, 2010; Shalev, 2004; Shalev & Gross-Tsur, 2000).

Concerning relevant research, Landerl et al. (2003) investigated whether reading-related learning disabilities affect Math-related procedures. More specifically, they examined procedures such as cardinality handling and number symbols decoding. In addition, they evaluated the ability of children to compare small numbers. Moreover, participants where asked to name colors -not only numbers. This was because the investigators tried to have color-naming as a control procedure.

As it was shown from the results, students with Dyscalculia had problems in all Math-related procedures. Interestingly, students with Dyslexia had problems in naming in general (numbers and colors). On the contrary, children with Dyscalculia had difficulty only in naming numbers.

Closing, this study came in agreement with prior ones, as it was shown that Math-related procedures take place in a specific part of the brain -bregmatic lobe- and thus they are not affected by other skills (Landerl et al., 2003).

In another study, Rubinstein & Tannock (2010) examined what effect have emotions on arithmetic problem solving. Moreover, they hypothesized that children with Dyscalculia would answer faster to questions which caused them negative feelings. Lastly, they assumed that words such as "quantity" would have a bad effect on students with Dyscalculia.

As a result of this study, it was found that children with Dyscalculia responded faster when they had Math word (or a "negative emotion related" word) as a stimulus. Thus, it arose that negative emotions do affect arithmetic problem solving. More specifically, children with Dyscalculia were found experiencing fear. Closing, the working memory of children underfunctioned when they were diagnosed with Dyscalculia. This was because of the Anxiety this disability caused to them (Rubinstein & Tannock, 2010).

Another study which is of high interest concerning the relation between Math Anxiety and Dyscalculia is the one carried by Devine, Hill, Carey & Szucs (2018). Devine et al. (2018) found that students who had a Dyscalculia diagnosis had twice the possibility of experiencing Math Anxiety than their peers who hadn't. Additionally, the comorbidity of Math Anxiety and Dyscalculia was observed more in girls than boys. On the contrast with previous research, Devine et al. (2018) also found that 77% of the children with high levels of Math Anxiety had average -or above- Math performance (Devine et al., 2018).

1.4. Math Anxiety

Math Anxiety is the condition in which someone feels that they cannot cope with any Math exercise and in general with anything that has to do with Math. Math Anxiety can cause lack of memory and self-confidence. In addition to these, the main symptoms of Math Anxiety are:

- panic: the feeling of being helpless (concerning Math)
- paranoia: a feeling that everybody knows the right answer except for them
- passiveness: students feel that there is nothing they can do to improve their Math performance and they remain idle
- lack of self-confidence

Is has been shown that Math Anxiety does affect negatively school performance, especially girls'. Math Anxiety leads to general poor school performance, not only in Math-related classes. In addition to that, it seems that students who experience Math Anxiety have less motivation to learn than students who don't. As a result, they seem to have poorer opportunities. It's also important to emphasize the relation between parents' and children Math Anxiety, especially in

the cases that parents help their children study (Ashcraft, 2013; Orbach et al., 2019; Suren & Kandemir, 2020; Venkatesh Kumar & Karimi, 2010; Yenilmez et al., 2007).

Venkatesh Kumar & Karimi (2010) examined a sample of 424 Indian pupils, equally divided in girls and boys. Venkatesh Kumar & Karimi (2010) examined how Math Anxiety affects Math and generally academic performance of pupils in India. Their hypothesis of strong relation between Math Anxiety and bad academic performance was confirmed. Additionally, girls experienced Math Anxiety more frequently than boys. Lastly, the performance comparing the two sexes was the same (Venkatesh Kumar & Karimi, 2010)

In another study, Suren & Kandemir (2020) compared the impact of Math Anxiety and motive on Math performance of students. The participants where 777 Turkish pupils. In agreement with previously mentioned studies, Suren & Kandemir (2020) found that Math Anxiety does affect negatively Math performance of adolescents. In addition to that, children with low self-confidence were found to be of high risk experiencing Math Anxiety. Suren & Kandemir (2020) also report that many studies indicate girls more Math-Anxious, because of their generally lower self-confidence than boys and because of the general social stereotypes concerning girls and bad Math performance. More interestingly, students who were taking private Math lessons except for the school ones experienced more Math Anxiety than those who weren't. Finally, it was found that Anxiety had a stronger effect than motive (Suren & Kandemir, 2020).

Orbach et al. (2019) also examined the relation between Math Anxiety, Math performance, I.Q. and motivation for learning. More specifically, 1.179 students in Germany participated in this study. Children with learning disabilities where not included.

Except for the positive association between Math Anxiety and bad performance, Orbach et al. (2019) found that students with high working memory capacity were more affected by Math Anxiety. That is because they usually select more complex strategies to solve Math problems. As it comes to I.Q., it arose that Math Anxiety may affect every child, regardless their I.Q. In addition to these, it is of high importance to mention that children with Math Anxiety experiences have less motivation to learn and thus fewer opportunities (Orbach et al., 2019).

On the other hand, Vanbinst, Bellon & Dowker (2020) examined how Math Anxiety is inherited from one generation to the next. As it was shown from previous research, Math Anxiety of parents has an effect on their children only in case they do their homework together. As it was anticipated, Math Anxiety was found to have a bad effect on students' performance. Moreover, although girls were found to be more Math-anxious, they didn't have worse performance than boys. It is important to mention that mothers with better education had less possibility to experience Math Anxiety. However, in general mothers tend to be more frequently Math-anxious than fathers do (Vanbinst et al., 2020).

1.5. Low I.Q.

As for people with low I.Q., their functionality differs in relation to the degree of their disability. More specifically, people with low mental disability ($50 \leq$ I.Q. ≤ 70) have slow pace in understanding and using new information, but they can usually internalize basic everyday skills. Morin & Miller (1998) mention that students with mental disability find it hard to separate the necessary from the unneeded information when dealing with a Math problem.

As reported by the relevant research, it is found that teaching students with low I.Q. through ICTs can be importantly effective. Characteristically, Mastropieri, Scruggs & Shiah (1997) examined how guidance through computer can help these students solve Math problems via animated images, using the right strategies. The participants were 4 children, with an I.Q. average of 70,7. All of them were getting an education by special education teachers. Except for observation of the participants, interviewing was also included in the research procedure. In the end of the study it was shown that students had definitely improved their performance, as they had increased the number of correct answers, in comparison with the ones before the study. According to the interviews taken from the participants, it arose that children really enjoyed the use of calculator and that they felt supported. However, from the observation it was shown that every child needed the help of the educators (Daily et al., 2000; Mastropieri et al., 1997; Morin & Miller, 1998).

Jansen, De Lange & Van der Molen (2013) examined how executive functions such as cognitive flexibility, working memory, planning and problem solving are related to basic Math skills. They also investigated how effective learning through computer can be, concerning executive functions as far as basic Math skills. They used the application Math Garden, in which vocal feedback plays a significant role. This happens through adding (or subtracting) coins to the user. The participants were trained on addition, subtraction, multiplication and division for 5 weeks before the main part of the study. As it was shown after the study, the majority of the children improved their Math performance. Closing, the executive functions were improved in all of the participants (Jansen et al., 2013).

In another study, Dekker et al. (2016) investigated the relation between intelligence and Math skills, as long as how poor working memory and lack of adaptability relate to these skills. More specifically, in this study there were participants with mild mental disorder (50<I.Q.<85). It arose that children with less behavioral problems -such as inhibition problems- related to working memory, as long as those who had higher I.Q. had more developed Math skills. On the other hand, inhibition or adaptivity problems were shown to be in positive relation to not developed Math skills (Dekker et al., 2016).

Another study that is of great interest is the one that was conducted by Singh & Agarwal (2013). Singh & Agarwal (2013) were based on previous research, due to which the use of appropriate multimedia helps decisively people with low I.Q. get their education (not only regarding Math). Singh & Agarwal (2013) mention that with the use of computer students with low I.Q. can focus on one stimulus at a time more easily. Moreover, they can activate their imagination and interact with other children. Thus, Singh & Agarwal (2013) examined the effectiveness of computer games, in connection with developing Math skills. After the experimental procedure, it arose that all of the participants improved their Math skills in comparison with the control group. Singh & Agarwal (2013) also mention that the feedback given to the participants played a crucial role in their performance (Singh & Agarwal, 2013).

Root, Saunders, Spooner & Brosh (2017) focused on the impact of the use of organizing sketches and calculators on educating people with moderate mental disability. The participants of the study were 3 boys at the age of 14. They had been diagnosed with Down Syndrome and had moderate mental disability (40<I.Q.<55). The participants dealt with everyday, realistic financial problems. There were included problems related to tips (addition) and discount (subtraction). Root et al. (2017) found that the participants improved their performance. In addition, all of them claimed that they would like to keep on solving such problems, that they felt more secure regarding addition and subtraction and that they would like to get educated in dealing with more financial problems. In conclusion, Root et al. (2017) underline the role of organizing sketches and calculators in helping these people become more independent, regarding financial problems. They also mention that the participants managed to generalize on iPhone/iPad the strategies they learned (Root et al., 2017).

2. Discussion

It is a fact that number related procedures do not depend on reading procedures. Thus, Dyscalculia is a developmental disorder which is detected at a specific part of the brain. It is also found that, although children diagnosed with Dyscalculia have severe educational difficulties, they can solve complicated Math problems, provided more time (Kunwar, 2020).

Concerning Math Anxiety, we found that it constitutes a major obstacle to the whole academic life of the child, as long as the career of an adult. It is also important to point out that Math Anxiety is not related to I.Q. More specifically, Math Anxiety can lead to panic and therefore low attention, during problem solving. Moreover, Dyscalculia can be a factor contributing to Math Anxiety, as Dyscalculia can be a source of bad experiences for the student (Rubinstein & Tannock, 2010; Venkatesh Kumar & Karimi, 2010; Yenilmez et al., 2007).

On the other hand, low I.Q. affects every aspect of the educational processes. Most of the students with low I.Q. complete school studies without having mastered important everyday Math skills. Therefore, it is very important to find ways to improve the educational procedure concerning these students. We found that the use of ICTs can help decisively in getting the most important everyday Math skills. More specifically, ICTs help students with low I.Q. focus on one stimulus at a time. Moreover, direct feedback (awarding or disapproving) to children is easy and more effective through computers. Furthermore, learning through stories makes Math more tangible and creating stories is easier using computer. Finally, the positive effect of the use of computers on the psychology and self-confidence of students is of great importance and should not be disregarded.

Last but not least, we emphasize the significance of digital technologies in the educational domain and math comprehension, which are very productive and successful, and how they facilitate and improve assessment, intervention, and educational procedures via mobile devices that bring educational activities everywhere [37-40], various ICTs applications that are the main supporters of education [41-56], and AI, STEM, Games and ROBOTICS that raise educational procedures to new performance levers [57-64]. Additionally, ICTs are being improved and combined with theories and models for cultivating emotional intelligence, mindfulness, and metacognition [65-93], accelerates and improves more the educational practices and results, especially in children with Math problems, treating domain and its practices like assessment and intervention.

3. Conclusion

Concluding, it is very important to understand how each of these three factors affects differently the Math performance of the students. We underline that, although developmental Dyscalculia and low I.Q. are inherent disorders, Math Anxiety is not. More specifically, Math Anxiety is related to bad experiences such us inefficient educational methods, insecure feelings in the family or parents who experience Math Anxiety. Moreover, low self-confidence can lead to Math Anxiety and this can make it very hard to deal with this disorder. On the contrary, students diagnosed with Dyscalculia can improve their Math performance provided the right learning strategies.

Therefore, we underline the importance of dealing with Math Anxiety. Motivating children to learn instead of being successful can substantially help them handle Math Anxiety. It is essential to improve the way the students feel into the classroom, but also into their families. Except for focusing on proper educational planning, motivating parents get a main role in changing the way their children feel about Mathematics is also of high importance.

Additionally, the use of new technologies is necessary when it comes to children with low I.Q. Hand calculators and specific ICTs applications, focusing on helping them get independent, can be very efficient in making these children more secure in their everyday life.

In conclusion, it is suggested that future research should be focused on longitudinal studies and on real conditions. Moreover, it would be of great interest investigating what happens especially when it comes to Geometry. This is because in the current study we mainly took younger children into consideration and in the lower grades usually there is no separation between Algebra and Geometry. Moreover, focusing on Geometry would be of great interest, since Geometry is directly related to the sense of Space. In addition, research about how students with high I.Q. improve their performance in Math, as long as how distant learning affects the learning experience, would lead us to clearer results concerning dealing problems which block the well-tempered Math learning procedure. Finally, we stress the importance of all digital technologies in the field of education and in mathematics training. These technologies are highly effective and productive, as they facilitate and improve assessment, intervention, and educational procedures, as they can motivate children to learn through interaction.

Compliance with ethical standards

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Disclosure of conflict of interest

The Authors proclaim no conflict of interest.

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