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The importance of working memory in children with Dyscalculia and Ageometria

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Abstract. This article is a literature review about Dyscalculia and Ageometria which are part of specific learning disabilities (LD) in Mathematics. Initially, some possible causes of LD are presented. Types of dyscalculia are then listed and the article goes on focusing on Working Memory (WM) and Mathematical Anxiety which play an important role in students' performance in Mathematics.
Keywords: dyscalculia, working memory, VisuoSpatial Sketchpad, short- term memory, cen-tral executive, semantic loop, phonological loop, mathematic anxiety

Introduction

In recent years efforts are being made to identify and define the causes of dyscalculia and ageometria. It is wrong to believe that children with learning disabilities have low IQ (Khing , 2016), (Jiménez-Fernández, 2016). Learning disabilities are inherited (Shalev, 2001) and according to Butterworth' s study (2003) some types of dyscalculia are connected to some abnormality on the X- chromosome (Butterworth, 2003). According to studies, another cause of learning disabilities is related to abnormal brain activity. In particular, the causes of developmental dyscalculia and ageometria are identified in the parietal lobe and in the intraparietal sulcus which is extended in both hemispheres of the brain brain (Isaacs, Edmonds, Lucas, & Gadian, 2001), (Molko, 2003).

In 1974 Dr. Ladislav Kosc was the first that wrote a paper and used the term "Developmental Dyscalculia". In his paper he explained that a person with developmental dyscalculia is not "mentally handicapped", but his problem is due to a brain dysfunction (Kosc., 1974). Furthermore, Kosc identified six types of dyscalculia based on the mathematical disabilities a person has, which can probably occur individually or together (Kosc., 1974).

Verbal dyscalculia: Verbal dyscalculia is manifested by disorders in the ability to define verbally mathematical terms, elements and relations. People with verbal dyscalculia cannot name the number of objects or a number, terms, symbols, and operations. They cannot assess the number of things which are shown to them with their amount. In this category, the Motor Verbal Dyscalculia and Sensory -Verbal Dyscalculia, are included.

Practognostic dyscalculia: A person with practognostic dyscalculia has impaired ability to manipulate, add, compare and estimate the quantity of real or pictured objects.

Lexical dyscalculia or numerical dyslexia: Lexical dyscalculia causes difficulties' in reading mathematical symbols such as numbers, digits, fractions, squares, roots, decimals, generally mathematic language. Lexical dyscalculia usually coexists with other types of dyscalculia.

Graphical dyscalculia or Numeral dysgraphia: Graphical dyscalculia is a difficulty with writing mathematical symbols and it usually coexists with dyslexia and dysgraphia.

Numerical and graphical dyscalculia together are named numerical dyssymbolia.

Ideognostical dyscalculia or Asemantic aphasia: A person with ideognostical dyscalculia has difficulty in understanding quantitative concepts or recalling mathematical ideas and relations and he is unable to perform mental calculations.

Operational dyscalculia or Anarithmetia: People with operational dyscalculia can understand numbers and their relations by they have difficulty in learning and applying any kind of calculations.

Students with learning disabilities have deficits in executive functioning (EF) (Janneke, Peijnenborgh, Hurks, Vles, & Hendriksen, J. G, 2009). The executive functions (EFs), include three cores, inhibition (or inhibitory control), working memory (WM), and cognitive flexibility/task (or set shifting) (Dickstein & & Milham, M. P., 2006), (D'Souza, 2018). Children with learning disabilities, such as dyslexia, ADHD (Semrud-Clikeman, 2013), non-verbal learning disabilities (McDonald, 2018), and dyscalculia (McDonald, 2018) have impairments in three cores of EFs.

Working memory

Working memory (WM) is very important for mathematical learning because it is necessary for the acquisition of the knowledge of numbers in early childhood and for solving mathematical problems.

The present research was conducted by Attout and Majerus (2015) in 32 children aged 8-12 years old (16 with DD and 16 TD) matched on gender, age, IQ and reading abilities. They looked into working memory (WM) in DD children especially between memory for items to be retained and memory for the order of the items within a list. Results showed that children with DD performed quite satisfactory in a WM task for item information but underscored in WM task for order information. The DD group did not also differ significantly from TD group in serial position curves and serial position migration gradients. Also, DD group showed reduced efficiency both in WM for serial order and in a numerical ordinal judgment task (Attout & Majerus, 2015), (Raddatz, Kuhn, Holling, Moll, & Dobel, 2017).

Baddeley (1986) developed a model of WM, based on which WM consists of:

- VisuoSpatial sketchpad
- Central executive
- Phonological loop
- Short-term memory
- Semantic loop

VisuoSpatial sketchpad

It is suggested that children with mathematic learning disabilities have poor visual-spatial WM which plays an important role in cognitive, neurobiological, and developmental models of typical and atypical mathematical skill acquisition. It is found through neuroimaging that problems in WM are connected to dyscalculia. In particular problems in visual-spatial WM may have an effect on numerical magnitude judgment and arithmetic problem-solving deficits in children with dyscalculia (Menon, 2016).

As we already know WM is linked to mathematical performance. Mathematical learning disability (MLD) children have deficits in WM. However, the exact way VSWM affects MLD children is controversial. Mammarella et al. (2017) made research in three groups of children aged 9-10 years. In the first group there were 24 children with MLD, in the second group there were 24 children with low mathematics achievement (LMA) and the third group consisted of 24 TD children. They examined visual, spatial-sequential, and spatial-simultaneous working memory in the above three groups. Results showed that MLD and LMA groups had low visuospatial WM (in tests of spatial-sequential and spatial-simultaneous). However, MLD children had bigger problems in WM than LMA. This was the originality of the present research compared to others (Maehler & Schuchard, 2016), (Raddatz, Kuhn, Holling, Moll, & Dobel, 2017).

Layes and his colleagues (2017) conducted an experiment to identify if a WM training program improves only WM or it has a positive effect on mathematical skills too. In their research 28 fourth - grade students (16 males and 12 females) with dyscalculia participated. The experiment involved two groups, the control and the experimental. The first group consisted of 14 persons (mean group age = 115.29 months), and the second consisted of 14 persons (mean group age 116.00). All groups were pre and post tested for nonverbal intellectual ability (Raven), mathematical and WM tasks. The experimental group received a WM training program for 8 weeks. At the conclusion of the experiment, the group that received the intervention had better scores in WM and mathematical tasks than the control group [19]. The results were consistent with other researches (Bergman-Nutley S, 2014), (Söderqvist, 2015). Furthermore, a WM training program appears to expand the capacity of working memory (Appelgren, 2016).

Short-term memory

Mammarella et al. (2015) made research in 24 DD children, 22 MA children, and 23 TD children (matched for age, schooling, and gender), ages between 6th and 8th grade. They looked into working memory (WM) performance and verbal and visual-spatial short-term memory (STM) in children with MA and DD. As far as the forward or backward verbal tasks TD and DD children had similar performance. On the contrary, in the visual-spatial WM task, DD children underscored. In addition, MA children depicted low scores in the verbal WM task.

Central executive

Maehler and Schuchard (2016) conducted a research in 31 children with dyslexia, 18 with dyscalculia, 34 with ADHD, 37 with dyslexia and dyslexia and ADHD, 21 with dyscalculia and ADHD and 32 children with TD. They wanted to examine 3 aspects of WM (central executive, visual-spatial phonological) through 16 tests. Results showed that children with dyslexia had problems in the phonological loop. Children with dyscalculia had problems in the visual-spatial sketchpad. ADHD children showed deficits in the central executive. However, their data analyses reviled that children with DD and children with dyslexia have some tendencies of central executive problems. Another finding was that children with comorbidity (two deficits at the same time) had bigger WM deficits.

Semantic loop

Van Luit and Toll (2018) carried out research in 84 students aged 8-18 old in The Netherlands. They looked into planning skills, naming speed, short-term and/or working memory, and attention as the main factors associated with math problems in children with DD. It is worth mentioning that for the measurement of the naming speed cards, depicting pictures, digits, letters, and colors were used and children would tell as quickly as they could what they were watching. Naming speed (naming numbers) problems were most common in mathematical deficits in children with DD. Short-term /working memory and planning skills were found in less frequency. And last were the findings in poor attention. At this point, it is worth mentioning that poor attention in children with DD was always accompanied by at least two of the other main factors. In the end, we must bear in mind as other researchers have shown (Van Luit et al., 2014; Träff et al., 2017) that there are more than these primary associative factors that came with DD.

At this point, it is safe to conclude that problems in naming speed are associated with deficits in the semantic loop of WM.

Phonological loop

Maehler and Schuchardt (2016) investigated the relation between WM and school achievement. In particular, they checked if normal functioning of WM plays an important role in school achievement regardless of intelligence. In this study, 3rd grade students of primary schools from three different parts of Germany participated. Four groups were selected after a long process. The first group consisted of 30 students with arithmetical and reading disabilities (mean IQ score 99, mean group age 8- 9 years, low school achievement), the second group consisted of 25 students with comparable LD (mean IQ score 77, mean group age 8- 10 years, low school achievement), the third consisted of 13 students who perform well or close to average at school (mean IQ score 78, mean group age 8- 10 years, normal school achievement) and the control group with TD students (mean IQ score 98, mean group age 8- 9 years, regular school achievement). They looked into phonological loop, visual spatial sketchpad, and central executive via 14 tasks. According to the results of the analysis, school achievement does not depend exclusively on the level of intelligence, while WM (visuoSpatial sketchpad, central executive, phonological loop) influences school achievement significantly. In addition, they found that children's low school achievement was true both due to low intelligence or higher intelligence but impaired WM. On the contrary children with low intelligence may depict higher school achievement than expected due to good functioning WM. These results agree with previous researches (Preßler, 2014), (Alloway, 2010).

Mathematic anxiety

Mathematical skills are considered important in many areas of modern society. Research has been made to find out why some people lag in these skills. One of the things that have been blamed for this is math anxiety (MA) (Tuncer & Yilmaz, 2020). Some of the ways that MA affects math performance are; First indirectly through WM. Indirectly through symbolic number processing and thirdly through a direct effect on math performance (Skagerlund, Östergren, Västfjäll, & Träff, 2019).

In 2017, Kiss and Vukovic suggested that students with LD are more likely to develop MA as 1) they show greater sensitivity to anxiety in general (McQuarrie, Siegel, Perry, & Weinberg, 2014), 2) their WM has a limited capacity (Geary, 2004) and 3) they have negative mathematical experiences (Kiss & Vukovic, 2017).

Cheng et al (2018) conducted research in Beijing between primary school students 39 of which had Dyslexia, 48 had dyscalculia, 18 comorbidities and 48 TD that were the control group. They investigated cognitive visual perception deficits in children with dyslexia and dyscalculia. All three disorders investigated groups depicted deficits in numerosity processing and visual perception. Another finding was that visual perception performance could be the cause of numerosity processing deficits.

A study carried out in Switzerland and Germany among 172 students aged 7–11 by Kucian et al (2018). The control group included 96 children with TD and 76 children with DD were the sample. They wanted to found out whether there was a link between negative emotions and arithmetical performance in children with TD and DD through affective priming task, mathematical performance, domain- general abilities and math anxiety. They did not find out a negative math priming effect in group children with DD. Another finding was that both male and female children had the same levels of math anxiety which had a negative effect on performance. They suggested that it is better to detect math anxiety and how it affects mathematical performance by questionnaires than by an affective math priming task.

Justicia-Galiano et al. (2017) researched the way MA and math performance are linked through WM and math self-concept. Their sample consisted of 167 children (aged 8-12 years). Through multiple mediation analyses, they found that WM and math self-concept could help in the understanding of the way MA and math achievement interact. They proposed that WM and self-concept should be taken into account when planning how children with MA will be helped. These findings are consistent with previous research done by Passolunghi.

Conclusion

Final conclusions or considerations should be aligned with the objective of the paper. Must be in Arial 10, double column, justified alignment According to our research, it is obvious that some types of dyscalculia are related to other learning disorders such as dyslexia, dysgraphia. Many research has proven that dyscalculia coexists with dyslexia (Peters, 2018), (Moreau, 2018), ADHD (Moll, 2014), (Haberstroh, 2019), and with other specific learning disabilities (Willcutt, 2019). In addition, children with specific learning disorders show deficits in WM (Peng, 2016) and its subsystems (VisuoSpatial sketchpad, short-term memory, central executive, semantic loop and phonological loop). Low achievement in mathematics appeared in students with DD and ageometria is further deteriorated due to mathematic anxiety.

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