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Mathematical Skills in Autism Spectrum Disorder

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ABSTRACT

The aim of this paper is to examine the range of mathematical abilities of children in Autism Spectrum Disorders. Recent neuroimaging and cognitive studies propose that a particular cognitive pattern which seems to be present in people in the autistic spectrum could be beneficial for the emersion and the development of Savant skills or in the cognitive area of mathematics. Nevertheless, no firm conclusions can be drawn if it could represent a mathematical ability of a superior cognitive level. However, it could be certainly supported that this particular cognitive pattern, could give rise to a special and different way of thinking, in comparison with the neurotypical individuals, as a result of differentiated connectivity, organization and function of the brain regions, where the limited interests, motives and persistent practice enhance the development of special skills

Keywords: ASD, Mathematical Skills, Asperger, Mathematical Competence

1. INTRODUCTION

Autism has a long history since the initial clinical definition of classical autism with serious difficulties in interpersonal relationships and communication (Eisenberg, 1956; Kanner, 1943) to the recognition of high – function autism and Asperger's syndrome (Asperger, 1944; Wing, 1981). Autism remains a complex disorder affecting mainly three areas of human behavior: social behavior, communication and imagination (American Psychiatric Association, 2000; World Health Organization, 1992). Long-term basic research in the autism region has highlighted the complex and heterogeneous nature of the disorder, which is more appropriately expressed with the terms "autistic spectrum" or "spectrum of autistic disorders", including all cases of children with behaviors falling within the three areas of development mentioned above, regardless of their degree of mental capacity (Wing, 1996a, 1996b; Wing & Gould, 1979).

The existence of mental retardation in the majority (75%) of children with autism creates additional learning disabilities and educational needs (Howlin, 1998; Jordan, 2001). However, a minority of children with Asperger syndrome or high functioning autism have as their main features the highest cognitive and linguistic level (Attwood, 2007; Frith, 2004).

In the last decade, there has been an impressive increase in the incidence of autism, which is interpreted as a consequence of factors such as the improvement of diagnostic criteria, timely and early detection, acceptance and use of the term "autistic spectrum" (Tager - Flusberg, Joseph & Folstein, 2001). According to an extensive and recent epidemiological survey, the prevalence of the autistic spectrum is estimated at 116.1 per 10,000 of the general population (approximately 1%) (Baird et al., 2006). In addition, autism spectrum disorders occur more frequently in boys than in girls (4:1). However, it is interesting to have a gender distribution in the autistic spectrum, where boys with high functionality are superior to girls (6:1), while girls with low functionality are more than the boys (4:1) (Fombonne, 1999). Also it is characteristic the heterogeneous performance in executive and verbal intelligence, since the executive intelligence of children with autism and mental retardation has been found to be higher compared to verbal intelligence (Lincoln, Allen, & Kilman, 1995).

An interesting manifestation of the behavior of children in the autism spectrum, which is closely linked to recurrent behaviors, is their unusual reactions to sensory stimuli. An interesting manifestation of the behavior of children in the autism spectrum, which is closely linked to recurrent behaviors, is their unusual reactions to sensory stimuli. The sensory experiences of these individuals are characterized by excessive or very low sensitivity to sensory stimuli, poor ability to engage, and over-selection of stimuli (Iarocci & McDonald, 2005; Ozonoff & Rogers, 2005). Although associated sensory peculiarities are not a distinctive feature of the autistic spectrum, they significantly affect social communication and create many learning difficulties in autistic children (Bogdashina, 2003).

Although several studies have so far focused on exploring cognitive factors favoring the emergence of specific numerical / computational skills in some people with low functional autism, the mathematical competence of pupils with high functional autism spectrum disorders has little attracted the research interest of the experts. The neuropsychological approach of Savant syndrome[1] has enabled the detection of non-standard skills of perception, memory and executive control that are subject to the development of specific numerical / computational skills. Also, due to the fact that 70% of children diagnosed with ASD have also Intellectual Disabilities , it is very important to investigate family characteristics on the development of mathematical abilities, since research has shown the significant effect of some parameters such as siblings (Charitaki, Baralis, Polychronopoulou, Lappas, & Soulis, 2014b).

Research in the field of developmental disorders is an important source of knowledge regarding cognitive processes that, when not working properly, lead to weaknesses in mathematical thinking (de Smedt et al., 2009). Taking into account the hypothesis that the neurodevelopment course and the functional competence of mental processes define the cognitive profile of abilities and abilities encountered in an individual, and thus influence the development of mathematical skills, a reasonable question is to investigate the mathematical competence of students with a high functioning autism spectrum disorder, in the light of the neuroscientific features of the disorder itself. However, most data on mathematical competence in people with ASD results from the assessment of the cognitive abilities of individuals who have already be developed at non – typical, high levels of mathematical skills due to their obsessive computing. And recent researches in the field show a significant impact of ICT to children with ASD emotional development (Charitaki, 2015). Therefore, the samples that have been selected so far, as well as the limited number of surveys aimed at evaluating mathematical skills in pupils with ASD, do not allow valid conclusions to be drawn. However, we can assume that a particular cognitive phenotype affects the way students with ASD solve mathematical work, but we do not know if this differentiates their performance from peers of typical development.

[1]The term "savant syndrome" is used to describe a rare, unusual situation in which people with mental deficiencies exhibit excellent insights of genius.

2. THE COGNITIVE APPROACH OF MATHEMATICAL ADEQUACY

Mathematical competence is the ability of a person to develop and apply mathematical thinking (logical and spatial) and representations (types, models, constructions, graphs and tables) to solve a range of problems in situations of everyday life. In addition, mathematical competence involves conceptual knowledge and process of knowledge. Problem solving and computations require both understanding of concepts and knowledge of algorithms, as well as processing methods and strategies. Recent research in the field of neurophysiology and developmental neuropsychology suggests that numerical competence has a tangible and complex brain background (Dehaene, Molko, Cohen & Wilson, 2004; Dennis, Berch & Mazzocco, 2009; Zamarian, Ischebeck & Delazer, 2009; Baralis, Soulis, Lappas, & Charitaki, 2012).

Numerous neurophobic findings argue that arithmetic processing and mathematical thinking are the result of the general cognitive function of the individual, achieved through the activation of interacting neural networks and not focused brain structures (Ansari, 2008; Fias, Menon, Szucs, 2013; Sadrini & Rusconi, 2009). Both endogenous (genetic or structural) and extrinsic (social) factors have been associated with specific or generalized difficulties in mathematics. Many researchers (e.g. Mazzocco, 2009; Murphy, 2009) have focused on the phenotypes of mathematical skills in developmental syndromes (eg Williams, Turner, Fragile X).

According to their remarks, it is noted that there is a great deal of variation in the various cognitive profiles (possibilities and weaknesses) in mathematical thinking, both at intra - individual and intra - group level. This heterogeneity, in terms of the cognitive characteristics presented in the population of individuals with Difficulties in Mathematics, as well as the coexistence of mathematical difficulties with other special learning disorders or developmental syndromes, supports the hypothesis that targeted morphological brain deficits cannot lead to both many different phenotypes of mathematical difficulties (Dennis et al., 2009; Rotzer et al., 2007), but it is probably a direct natural consequence of a general cognitive deficits information from the involved brain systems (Geary, 2004). Accordingly, to Dennis et al. (2009), it is possible that any cognitive profile found in an individual or group of individuals indicates the neurodevelopmental course and processes that led to the emergence of mathematical difficulties.

2.1 COGNITIVE PROCESSES THAT CONTRIBUTE TO MATHEMATICAL THINKING

Despite the fact that diametrical differences in abilities and mathematical performance have been observed, the source of these differences has not yet been fully understood (de Smedt, et al., 2009). Several researchers (e.g. Bull & Scerif, 2001; Gathercole, Pickering, Knight & Stegmamm, 2004; Kyttala & Lehto, 2008) link mathematical performance to both numerical and wider cognitive abilities. Studies in the field of mathematical developmental disorders are an important source of knowledge regarding cognitive processes that, when not working adequately, lead to deficits in mathematical thinking (Meyer et al., 2010). According to Geary (1993), mathematical disorders can be classified into three subtypes as follows: a) Semantic memory disorders that reflect difficulties in symbolic representation of numbers, in understanding and producing numbers when presented orally or in writing, b)

Disturbances of spatial relationships, which involve deficits in the visual representation of numerical information and c) Procedural disorders in the numerical calculation, where deficits occur in the recovery of basic mathematical data and the execution of numerical procedures.

However, regardless of the subtype, mathematical disorders reflect deficits in specific cognitive abilities that inhibit the acquisition and development of numerical skills (Geary, 2004)

In the recent bibliography, we find a multitude of cognitive abilities that support arithmetic skills such as declarative / semantic memory (Passolunghi & Siegel, 2001), working memory (Raghubar, Barnes & Hetch, 2010), processing speed (Swanson & (Passolunghi & Mammarella, 2011) and visual / spatial functions (Toll, van der Ven, Kroesbergen & Van Luit, 2010). The role of specific cognitive processes in mathematics is evident both in developmental neuroanatomic and behavioral studies through neuropsychological tests that measure their functional adequacy in individuals with and without mathematical difficulties. However, it is not yet clear how they interact during academic learning (Ayr et al., 2005).

According to Lerner (1993), there are factors that can create disturbances in the learning of quantities and numbers and which often characterize infants and young pupils. These factors include disorders in space perception, visual perception, symbol recognition, linguistic competence and communication, memory (Charitaki, Baralis, Polychronopoulou, Lappas, & Soulis, 2015a). and cognitive strategies, and metacognition. However, he points out that each student is unique and that not all students with learning difficulties will have the same characteristics.

The theory of information processing interprets which information is acquired and in what way. In its fundamental elements are included attention, sensation, perception, short-term memory, long-term memory and reaction (response). Students with learning difficulties in mathematics often have problems that contribute to their poor performance, which are related to the processing of information. Such problems are disintegration, perceptual disorders (visual and acoustic processing difficulties), memory problems, kinetic difficulties and other deficits in information processing.

3. FACTORS THAT AFFECT LEARNING MATHEMATICS

As many scholars of learning difficulties in mathematics point out (e.g. J. Lerner 1993), many endogenous factors affect the learning of mathematics. This is also followed directly from the federal definition of learning difficulties, which refers to "disorders in basic psychological functions".

3.1 DIFFICULTY IN UNDERSTANDING THE SHAPE OF A FRAME

The symptoms posed by students with visual difficulties are varied. They may often lose the point of working on a worksheet or not complete their work or seem careless when copying exercises from their book. They also tend to confuse the parts of the exercises and often copy symbols incorrectly. They also find it difficult to distinguish the exercise from its serial number and may include in their calculations and neighboring irrelevant digits. The proximity of the keys of a microcomputer may cause them difficulties in locating and using the desired key, especially with the symbols of operations when they are adjacent. Reading multicast numbers often confuses them as they tend to focus on individual digits and not group them at the same time. Students with acoustic learning difficulties may have problems in listening to the classroom (confuse sounds). They may also give the impression that they are dreaming or not getting focused while they are actually trying to attend, but it's hard for them to hear and learn. Finally, they may have difficulties in numbering digits (every 3 or 5 or 10) due to difficulties in acoustic discrimination.

3.2 PERCEPTUAL DISCRIMINATION ISSUES

Visual distortions of perceptual forms may be the cause of incorrect reading or writing of the numbers and symbols of operations, and this leads to incorrect results in the execution of the algorithms of operations. Students with such difficulties tend to reverse one-digit numbers, such as 2, 3, 5, and 6. Until the ages of 7 to 8, these difficulties are considered to be expected, but students with learning difficulties experience such difficulties at older ages. Perceptual disorders lead to difficulties and mistakes when writing numbers and symbols, copying the exercises from the table, spontaneously writing during dictation and using the microcomputer. So they are slow to write or type the symbols, losing this way the point in their writing or failing to watch what the teacher shows on the board.

Another common perceptual difficulty results in reversals in two-digit or even multi-digit numbers. Students who tend to reverse and mirror the singular digits as mentioned earlier can also reverse the digits of a two-digit number when they read or write it (13 – 31 or 12 – 21 etc.). These students may have problems with the residual (write dozens and keep the units). As pupils are confronted with more and more symbols, perceptual problems become more pronounced and more prominent.

The problems of acoustic perceptual discrimination have the consequence of being unable to perceive the numbers correctly, thus influencing the student's ability to measure correctly. Also, students may misinterpret words' ending or words that resemble in their pronunciation, and this can lead them to a variety of mistakes (e.g. they choose the wrong act, mistakes due to problems in oral-acoustic communication).

They also find it difficult to tell the time because they are slow to realize the size of the clock indicators, which their classmates do automatically. They also have difficulty in recognizing and using currencies because they cannot distinguish differences in their sizes.

3.3 SPACE AND TIME DISORDERS

The performance of pupils with learning difficulties in mathematics can be seriously affected by disturbances in the organization of space and time. Students with time constraints may be able to read and be able to say the time, but the perception of time is significantly reduced with direct implications for general planning and programming ability.

Students with difficulty in the concept of space cannot perceive the concepts of right-left, up-and-down, front-back and find it difficult to locate places in the space, with the result that the task of aligning numbers is particularly difficult. Also, the handling of residual in algorithms becomes even more difficult. From the didactic point of view, it is particularly important for the student to understand the value of the digit location, i.e. why the number transferred is higher than the number of tens, hundreds, etc. As also visual and kinesthetic aids are needed to identify and feel what means "above".

Difficulties with space can be an obstacle for a student to even form the numbers (he reverses or converts them), though he or she perceives them visually. In this case it is necessary to practice even on a daily basis, which will include motor activities, color codes and verbal descriptions.

At older ages students with space-perceived problems have difficulty in decimals, fractions and solving verbal problems. Even when there is complete conceptual understanding, they may have difficulty. They get confused where they will make a decimal point, they find it difficult to determine the sequence of steps in algorithms and solve verbal problems, and they have a problem with fractions and mixed numbers (they confuse the position of numbers).

4. MATHEMATICAL COMPETENCE IN AUTISTIC SPECTRUM DISORDERS

The mathematical adequacy of students with ASD is a field that has so far been scrutinized so empirical findings are very limited. The review of the existing literature shows that the majority of investigations are limited to the study of Savant syndrome in cases of individuals, usually adults, who develop particular numerical and computational skills within a context of generally lower mental functioning (Chia, 2012).

Despite their scarcity, the special mathematical and computational skills developed in Savant Syndrome have been studied in the field of psychology and neuroscience in order to identify those factors that favor the emergence of this phenomenon, but also to understand the cognitive phenotype of the ASD (Heaton & Wallace, 2004; Treffert, 2009). However, these studies of specific mathematical skills are neither sufficient nor reliable as a source of information as they relate to a minority of the autistic population and their findings are difficult to generalize.

In other studies, the research interest focuses on identifying the specific cognitive characteristics of pupils with ASDs that may affect their learning and their performance in various subject areas. In other studies, the research interest focuses on identifying the specific cognitive characteristics of pupils with ASDs that may affect their learning and their performance in various subject areas. In recent years, what is considered important by some researchers is to recognize the psycho-educational profiles encountered in the pupil population with ASD, in order to appropriately support their specific learning needs (Jones et al., 2009; Wei et al., 2014). Nonetheless, the academic performance of students with AAS is most commonly approached, with researchers mainly trying to identify those children who have a particularly high performance in a cognitive field such as mathematics or reading (Estes et al., 2011; Jones et al., 2009).

Weighted tests and neuroimaging techniques have been used to investigate the academic strengths and weaknesses of students with DAP, as well as the neurobiological factors that may be responsible for the emergence of highly developed skills or mathematical deficits. In the field of empirical studies, the autistic population has been compared with individuals with learning difficulties or formal development, with or without particular mathematical skills (e.g. Griswold et al., 2002; Mayes & Calhoon, 2003; Snyder et al., 2003) (e.g. Fehr, Weber, Willmes, Hermann, 2010; Pesenti et al., 2001), which have a high performance in the field of mathematics and numerical computations (e.g. mathematicians). However, limited researches have focused exclusively on the mathematical capability of high-functionality ASD students (e.g. Kennedy & Squire, 2007; Church et al., 2000).

5. THE PERFORMANCE OF STUDENTS WITH ASD IN MATHEMATICS

From the existing empirical findings on the mathematical performance of autistic students, although most researchers recognize that the autistic population's heterogeneity in potentials and weaknesses is a problem for safe conclusions, it appears that autistic students have typical Mathematical skills (Churchet al., 2000; Griswold et al., 2002; Mayes & Calhoun, 2003; Minshew et al., 1994; Wei et al., 2014). However, in the review of Chiang & Lin (2007) it is reported that other studies have identified difficulties in solving mathematical problems, other typical performance and other charisma. These researchers have concluded that people with high-functionality ASD have a typical mathematical ability or a clinically insignificant mathematical weakness, while few can show mathematical charisma.

In the study of Jones & al., (2009), 100 adolescents in the autism spectrum were examined and 7 out of 10 had at least one area (reading, spelling, reading comprehension, arithmetic, wider mathematical skills) with deficits or high performance. 14.1% of the sample (14 individuals) showed high reading performance and 10.1% below standard. These individuals were characterized by typical intelligence and superior numerical competence and much better performance than their verbal skills. Finally, 6.1% of the sample showed low numerical capacity, while their general mental level was typical.

By comparing their research results, the researchers concluded that arithmetic is a developed area for people with autism, which may arise from the inherent cognitive profile of autism (Baron - Cohen, 2006).

In another recent study (Haas, 2010), the goal was to investigate the strategies applied by 3 students with high functionality (5 – 7 years) in solving problems, comparing them with 13 typical students. The performance of students with ASD was as good as their peers with a typical development, while both teams performed a logarithmic representation of the arithmetic sequence. The difference between them, however, lies in the strategies they used. Autistic pupils applied a 100% recall to respond, while neurotypical applied a 30% recall, but also strategies such as counting minds, loud or fingers, in a completely different way than typically developing children and children with Down syndrome (Charitaki, Baralis, Polychronopoulou, Lappas, & Soulis, 2015, 2014a).

The findings have led to the conclusion that autistic students may as well achieve in mathematics with their typical classmates as simple problems, while those requiring many steps are expected to take longer and use less flexible strategies without necessarily means they respond with less accuracy and accuracy.

Despite the bibliographic references that highlight particular mathematical capacities or even speak of the talent of individuals in the autism spectrum, research findings suggest that autistic individuals have difficulty with mathematics and problem solving (Myles & Simpson, 2003). The study by Griswold et al. (2002) aimed to assess the academic performance of Asperger Syndrome students through the Wechsler Individual Achievement Test (WIAT) Mathematical Practice sub-scale. Their findings conclude that students with Asperger's Syndrome fall short of mathematical ability. It has, however, been argued that speech-based intelligence measurements (e.g. WISC – R) may not be appropriate to assess cognitive development, mathematical knowledge, schizophrenia, and the specific skills of people with autism given their deficits in communication and their disintegration (Mottron et al., 2009).

Another important research finding regarding the mathematical skills of pupils in the autism spectrum is the differences between mathematical performance and the general cognitive level of a child (Estes et al., 2011). According to the latter, many students with a high functioning autistic disorder exhibit discrepancies between performance in mathematical work and the expectations that arise from their high mental level.

Consequently, we can conclude that although the pupil's general cognitive effect affects mathematical performance, it is still considered an insufficient indicator of the cognitive abilities of individuals with ASD, as the cognitive phenotype exists regardless of the level of intelligence and the deficits in the executive functions do not always affect their general mental function (Pooragha et al., 2013; Watanabe et al., 2005). The differentiated function of individual cognitive processes plays an important role in the acquisition and development of mathematical skills in pupils with autism.

Existing research on the mathematical skills of people with ASD is scarce, limited to small samples and usually focuses on the low performance of individuals with specific numerical and computational skills, and sometimes aimed at detecting academic standards, or focusing on the performance of language and mathematics. Although it has been argued that mathematics is probably a cognitive field in which autistic people have a typical performance, the findings are currently not considered representative of the autistic population.

However, from the literature review, we conclude that student performance with ASD in mathematics is likely to be influenced by the tool used and the content of the specific project they are called upon to cope with.

Finally, the higher the level of general cognitive ability and functionality of the individual, the more capable it is in exercising executive control and organizing its action, which affects mathematical reasoning, selection and implementation of complex and flexible resolution strategies mathematical works (Haas, 2010; Happe, 1999).

REFERENCES

1. Ansari, D. (2008). Effects of development and encultulation on number representation in the brain. Nature Reviews Neuroscience, 9, 278 – 291.
2. American Psychiatric Association (2000). Diagnostic and statistical manual of mental disorders (4th ed. text rev.). Washington, DC: Author.
3. Asperger, H. (1944). Die "autistichen Psychopathen" im Kindersalter. Archiv für Psychiatrie und Nervenkrankheiten, 117, 76 – 136. [Translated by U. Frith in U. Frith (Ed.) (1991). Autism and Asperger Syndrome (pp. 36 – 92). Cambridge: Cambridge University Press].
4. Attwood, T. (2007). The complete guide to Asperger's syndrome. London: Jessica Kingsley Publishers.
5. Ayr, L. K., Yeates, K. O., Enrile, G. B. (2005). Arithmetic skills and their cognitive correlates in children with acquired and congenital brain disorder. Journal of International Neuropsychological Society, 11, 249 – 262.
6. Baird, G., Simonoff, E., Pickles, A., Chandler, S., Loucas, T., Meldrum, D., & Charman, T. (2006). Prevalence of disorders of the autistic spectrum in a population cohort of children in South Thames: the Special Needs and Autism Project (SNAP). Lancet, 368, 210 – 215.
7. Baralis, G., Soulis, S-G., Lappas, D., & Charitaki, G. (2012). Providing students with mild mental retardation the opportunity to solve Division Problems related to real life. CIEAEM 64 Rhodes, Greece, 23-27 July 2012 Mathematics Education and Democracy: learning and teaching practices, HMS International Journal for Mathematics in Education, 195-206.
8. Baron-Cohen, S. (2006). The hyper-systemizing, assortative mating theory of autism. Progress in Neuropsychopharmacology and Biological Psychiatry, 30, 865 – 872.
9. Bogdashina, O. (2003). Sensory perceptual issues in autism and Asperger Syndrome. London: Jessica Kingsley Publishers.
10. Bull, R., Scerif, G. (2001) Executive functioning as a predictor of children's mathematics ability: Inhibition, switching, and working memory. Developmental Neuropsychology, 19, 273-293.
11. Charitaki, G., Baralis, G., Polychronopoulou, S., Lappas, D., & Soulis, G. S. (2015a). Difficulty in Learning to Count or Effect of Short-term Memory Deficiency in Mathematical Abilities?. International Journal of Innovation and Research in Educational Sciences, 2(2), 60-62.
http://www.ijires.org/index.php/issues?view=publication&task=show&id=56

12. Charitaki, G., Baralis, G., Polychronopoulou, S., Lappas, D., & Soulis, G. S. (2015b). Common Difficulties which face children with Down's syndrome in acquiring basic counting skills. British Journal of Education, Society & Behavioural Science, 7(2), 121-128. http://dx.doi.org/10.9734/BJESBS/2015/15323

13. Charitaki, G., Baralis, G., Polychronopoulou, S., Lappas, D., & Soulis, G. S. (2014a). Early Numeracy in Children with Down's Syndrome in Greece. Psychology, 5, 1426-1432. http://dx.doi.org/10.4236/psych.2014.512153

14. Charitaki, G., Baralis, G., Polychronopoulou, S., Lappas, D., & Soulis, S.-G. (2014b). Factors Related to Numerical Ability of Children with Down's syndrome. The International Journal of Early Childhood Learning, 21, 1-17. http://ijlecl.cgpublisher.com/product/pub.256/prod.48

15. Charitaki, G. (2015). The effect of ICT on emotional education and development in young children with Autism Spectrum Disorder. International Conference on Communication, Management and Information Technology (ICCMIT 2015), Procedia Computer Science, 65, 285-293. http://www.sciencedirect.com/science/article/pii/S1877050915029117

16. Chia, N. K. H. (2012). The need to include savant and crypto – savant in the current definition. Academic research international, 2 (2). 234 – 240.

17. Chiang, H. M., Lin, Y – H. (2007). Mathematical ability of students with Asperger Syndrome and high functioning autism. SAGE publications and The National Autistic Society, 11:6., 547 – 556.

18. Church, C., Alisanski, S., Amanullah, S. (2000). The social behavioral and academic experiences of children with Asperger Syndrome. Focus Autism Other Dev. Disabl., 15 (12), 12 – 20.

19. Dehaene, S., Molko, N., Cohen, L., Wilson, A. (2004). Arithmetic and the Brain. Current Opinion in Neurobiology, 14, 218 – 224.

20. Dennis, M., Berch, D., Mazzocco, M., (2009). Mathematical learning disabilities in special populations: phenotypic variation and cross-dosorder comparisons. Developmental Disabilities Research Reviews, 15, 80 – 89.

21. De Smedt, B., Janssen, R., Bouwens, K., Verschaffel, L., Boets, B., Ghesquière, P. (2009). Working memory and individual differences in mathematics achievement: a longitudinal study from first grade to second grade. Journal of Experimental Child Psychology, 103(2), 186 – 201.

22. Eisenberg, L. (1956). The autistic child in adolescence. American Journal of Psychiatry, 112, 607 – 612.

23. Estes, A., Rivera, V., Bryan, M., Cali., P., Dawson, G. (2011). Discrepancies Between Academic Achievement and Intellectual Ability in Higher – Functioning School – Aged Children with Autism Spectrum Disorder. J Autism Dev Disord., 41, 1044 – 1052.

24. Fehr, Th., Weber, I., Willmes, K., Hermann, M. (2010). Neural correlates in exceptional mental arithmetic About the neural architecture of prodigious skills. Neuropsychologia, 48, 1407 – 1416.

25. Fias, W., Menon, V., Szucs, D. (2013). Multiple components of developmental dyscalculia. Trends in Neuroscience and education, 2, 43 – 47.

26. Fombonne, E. (1999). The epidemiology of autism: A review. Psychological Medicine, 29, 769-787.

27. Frith, U. (2004). Emanuel Miller lecture: Confusions and controversies about Asperger syndrome. Journal of Child Psychology and Psychiatry, 45, 672 – 686.

28. Gathercole, S. E., Pickering, S. J., Knight, C., Stegmann, Z. (2004). Working memory skills and educational attainment: Evidence from national curriculum assessments at 7 and 14 years of age. Applied Cognitive Psychology, 18(1), 1 – 16.

29. Geary D. C., (1993). Mathematical disabilities: cognitive, neuropsychological and genetic components. Psychological Bulletin, 114, 345 – 62.

30. Geary D. C., (2004). Mathematics and learning disabilities. Journal of Learning Disabilities, 37 (1), 4 – 15.

31. Griswold, D. E., Barnhill, G. P., Smith Myles, B., Hagiwara, T., Simpson, R. L. (2002). Asperger syndrome and academic achievement. Focus on autism and other developmental disabilities, 17 (2), 94 – 102.

32. Haas, S. (2110). Differences in Estimation and Mathematical Problem Solving Between Autistic Children and Neurotypical Children. In partial fulfillment of the requirements for the School of Humanities & Social Sciences Honors Thesis.

33. Happe, F. (1999). Autism: cognitive deficit or cognitive style? Trends in cognitive sciences, 3:6, 216 – 222.

34. Heaton, P., Wallace, G. L. (2004). Annotation: The savant syndrome. Journal of Child Psychology, 45:5, 899 – 991.

35. Howlin, P. (1998). Children with autism and Asperger syndrome. A guide for practioners and carers. Chichester: Wiley.

36. Iarocci, G., & McDonald, J. (2005). Sensory integration and the perceptual experience of persons with autism. Journal of Autism and Developmental Disorders, 36, 77-90.

37. Jones, C. R. G., Golden, H., Simonoff, E., Baird, G., Happe, F., Marsden, A., Tregay, J., Pickles, A., Charman, T. (2009). Reading & Arithmetic in Adolescents With Autism Spectrum Disorders: Peaks and Dips in Attainment Neuropsychology, 23:6, 718 – 728.

38. Jordan, R. (2001). Autism with severe learning difficulties: a guide for parents and professionals. London: Souvenir Press.

39. Kanner, L. (1943). Affective disturbances of affective contact. Nervous Child, 2, 217 – 250.

40. Kennedy, D. P., Squire, L. B. (2007). An analysis of calendar performance in two autistic calendar savants. Learning and Memory, 14, 533 – 538.

41. Kyttala, M., & Lehto, J. E. (2008). Some factors underlying mathematical performance: The role of visuo-spatial working memory and non-verbal intelligence. European Journal of Psychology of Education, 23 (1), 77 – 94.

42. Lerner J., (1993), Learning disabilities: Theories, Diagnosis & Teaching Strategies, Boston, Ed. Houghton Mifflin Company, sixth Ed.

43. Lincoln, A. J., Allen, M. H., & Kilman, A. (1995). The assessment and interpretation of intellectual abilities in people with autism. In E. Schopler & G. B. Mesibov (Eds.), Learning and Cognition (pp. 89 – 117). New Yolk: Plenum Press.

44. Mayes, S. D., Calhoon, S. L. (2003). Ability profiles in children with autism: influence of age and IQ. Autism, 7 (1), 65 – 80.

45. Mazzocco, M. M. M. (2009) Mathematical learning disability in girls with Turner syndrome: a challenge to defining MLD and its subtypes. Dev Disabil Res Rev., 15, 35 – 44.

46. Meyer, M. L., Salimpoor, V. N., Wu, S. S., Geary, D. C., Menon, V. (2010). Differential contribution of specific working memory components to mathematics achievement in 2nd and 3rd graders. Learning and Individual Differences, 20, 101 − 109.

47. Minshew, N., Goldstein, G., Taylor, G., Siegel, D. (1994). Academic Achievement in high functioning autistic individuals. Journal of Clinical & Experimental Neuropsychology, 16(2), 261 – 270.

48. Mottron, L., Dawson, M., Soulieres, I. (2009). Enhanced perception in savant syndrome: patterns, structure and creativity. Phil. Trans. R. B., 364, 1385 – 1391.

49. Murphy MM. (2009). A review of mathematical learning disabilities in children with fragile X syndrome. Dev Disabil Res Rev., 15, 21 – 27.

50. Myles, B. S., Simpson, R. L. (2002). Asperger Syndrome: An Overview Of Characteristics. Focus on Autism & other Developmental Disorders, 17:3, 132 – 137.

51. Ozonoff, S., & Rogers, S. (2005). Annotation: What do we know about sensory dysfunction in autism? A critical review of the empirical evidence. Journal of Child Psychology and Psychiatry, 46, 1255 – 1268.

52. Passolunghi, M. C., Mammarella, I. C. (2011). Selective spatial working memory impairment in a group of children with mathematics learning disabilities and poor problem-solving skills. J. Learn. Dis.,45 (4), 341 – 350

53. Passolunghi, M. C., Siegel, L. S. (2001). Short-term memory, working memory, and inhibitory control in children with difficulties in arithmetic problem solving. Journal of Experimental Child Psychology, 80, 44 – 57.

54. Pesenti M., Zago L., Crivello F., Mellet E., Samson D., Duroux B., Seron X., Mazoyer B., Tzourio – Mazoyer, N. (2001). Mental Calculation in aprodigy is sustained by right prefrontal and medial temporal area. Nature Neuroscience, 4, 103 – 107.

55. Pooragha, F., Kafi, S. M., Sotodel, S. O. (2013). Comparing Response Inhibition and Flexibility for Two Components of Executive Functioning in Children with Autism Spectrum Disorder and Normal Children. Iran J. Pediatr, 23 (3), 309 – 314.

56. Raghubar, K. P., Barnes, M. A., Hetch, A. S. (2010). Working Memory and Mathematics: a review of individual difference and cognitive approaches. Learning and Individual Differences, 20, 110 – 122.

57. Rotzer, S., Kucian, K., Martin, E., Von Aster, M., Klaver, P., Leonneker, T. (2007). Optimized – Voxel – based morfhometry in children with developmental dyscalculia. NeuroImage, 39, 417 – 422.

58. Sadrini, M., Rusconi, E. (2009). A brain for numbers. Cortex, 796 – 803.

59. Snyder, A. W. Mulchay, E., Taylor, J., Mitcell, J., Sachdev, P., Gandevia, S., (2003). Savant-like skills exposed in normal people by suppressing the left fronto-temporal lobe. Journal of Integrative Neuroscience, 2 (2), 149 – 158.

60. Swanson, H. L, Kim K., (2007). Working memory, short – term memory, and naming speed as predictors of children’s mathematical performance. Intelligence, 35, 151 – 168.

61. Tager-Flusberg, H., Joseph, R., & Folstein, S. (2001). Current directions in research in autism. Mental Retardation and Developmental Disabilities Research Reviews, 7, 21 – 29.

62. Treffert, D. A. (2009). The savant syndrome: an extraordinary condition. A synopsis: past, present, future. Phil. Trans. R. Soc. B., 364, 1351 – 1357.

63. Toll, W. T. S., Van der Ven, H. G. S., Kroesbergen, H. E., Van Luit, E. H. T. (2010). Executive Functions as Predictor of Math learning disabilities. Journal of learning disabilities, 44 (6), 521 – 533.

64. Watanabe, K., Origino, T., Nakano, K., Hattori, J., Kado, Y., Sadana, S., Ohtsuka, Y. (2005). The Rey – Osterrieth Complex Figure as a measure of executive function in childhood. Brain and development, 27, 564 – 569.

65. Wei, X., Christiano, E. RA., Yu, J. W., Wagner, M., Spiker, D. (2014). Reading and math achievement profiles and longitudinal growth trajectories of children with an autism spectrum disorder. Autism, 18 (3), 1 – 11.

66. Wing, L. (1981). Asperger's syndrome: A clinical account. Psychological Medicine, 11, 115 – 130.

67. Wing, L. (1996a). The autistic spectrum. A guide for parents and professionals. London: Constable.

68. Wing, L. (1996b). Autistic spectrum disorders. British Medical Journal, 312, 327 – 328.

69. Wing, L., & Gould, J. (1979). Severe impairments of social interaction and associated abnormalities in children: epidemiology and classification. Journal of Autism and Developmental Disorders, 9, 11 – 29.

70. World Health Organization (1992). International Classification of Mental and Behavioral Disorders: Clinical descriptions and diagnostic guidelines. Geneva: WHO

71. Zamarian, L., F, A., & Delazer, M. (2009). Neuroscience of learning arithmetic—Evidence from brain imaging studies. Neuroscience and Biobehavioral Reviews, 33, 909 – 925.

72. Ηλιάδου Ν., Κιάκη Κ. & Τσιαούση Ε – Χ., (2013), Δημιουργία Βάσης Δεδομένων: Διαγνωστικά Εργαλεία στις Ειδικές Μαθησιακές Δυσκολίες, [Πτυχιακή Εργασία], Τεχνολογικό Εκπαιδευτικό Ίδρυμα Ηπείρου, Τμήμα Λογοθεραπείας, Ιωάννινα.