

# Comparison Visual-Spatial Working Memory Executive Functions, Tower of London and Computational Errors in Children with Developmental Dyscalculia and Normal Children

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**ABSTRACT:** The developmental dyscalculia is a specific learning disorder affecting the normal acquisition of arithmetic skills in normal children with appropriate education. The present research, first, aims to make a comparison between executive functions of visual- spatial working memory, organizing and planning skills of students with developmental dyscalculia and normal students. The statistical population of research involves male students who enrolled in the first to fifth grade of elementary schools of Mashhad in academic year 2017-2018. Two groups of 16 students were selected randomly among this population as the research sample using quota method. This sampling method is a combination of cluster sampling method and availability method. The first group consists of 16 students with dyscalculia selected among 2383 students of 12 elementary schools in districts 2 and 6 of Mashhad as the selected districts at two levels of prosperous (districts 3,4, and 6) and non-prosperous (districts 1,2,5, and7) within several stages. Then, the ultimate group was selected in terms of Statistical Manual of Mental Disorders, Fourth Edition (DSM-IV), Raven IQ Test and clinical interview. The second group including 16 normal students was selected among the students of similar classes. After that, Shalev's standardized test of mathematics (including three components a. number comprehension, b. number production and c. arithmetic calculation) and Corsi Block Tapping Test and Tower of London test were used to assess the measurement error and visual-spatial executive functions of working memory, respectively. The results were analyzed using descriptive and inferential statistics including Multivariate Analysis of Covariance (MANCOVA) and Multivariate Analysis of Variance (MANOVA). The results demonstrated the visual-spatial working memory of children with developmental dyscalculia is significantly less than normal children. In contrast, there was no significant distinction between planning and organizing functions of children with dyscalculia and normal children. The relationship between several organizing/planning functions and percentage of error was significant. Also, there was a considerable difference between these two groups in terms of arithmetic or math test, number comprehension and number production. In general, executive functions in the new concept of developmental dyscalculia have no influence on math disability. Further, visual-spatial executive function is considered as an influential factor affecting dyscalculia disorder. An improvement of this function can reduce the computational errors of children with dyscalculia.

**KEYWORDS:** Developmental dyscalculia, Executive functions, Visual-spatial working memory, Tower of London test.

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## I. INTRODUCTION

One of the most common types of learning disabilities are math learning problems [1] so that at least half of the elementary students indicate low math performance (Arianpour, Azizi, 2014). Difficulties in understanding numerical relationships begins in some children from early age when other children experience the ability to understand the counting unit, sorting and comparing which can predict lower performance in achievement tests of elementary schools for them than expected [2]. Thus, there is no place for surprise that learning disorder has been repeatedly recognized as one of the significant factors affecting mathematics learning performance [3].

Dyscalculia is one of the specific learning difficulties affecting mathematical skills and concepts and has a negative effect on academic achievement, problem-solving process, attention, personality characters and social behaviors. According to the Diagnostic and Statistical Manual of Mental Disorders, fifth edition (DSM-V), students with a mathematics disorder have problems with their math skills. Their math skills are significantly below normal considering the student's age, intelligence, and education.

Students with this impairment have difficulties in linguistic, comprehension, mathematical and attention skills related to math. In some children, this disorder is typically apparent as early as 6 years but in others is not apparent until the age of 10. The dyscalculia disorder emerges in approximately 1 percent of school age children and one child in five children suffers from dyscalculia [4]. The research findings carried out in Iran indicated there is a significant relationship between prevalence rate of dyscalculia in the sample and the prevalence rate reported in the Diagnostic and Statistical Manual of Mental Disorders, fourth edition (DSM-IV). The prevalence rate was higher in Qom province compared with standard prevalence. However, there was no significant difference in the prevalence rate in terms of gender [5]. Children with dyscalculia have difficulty in learning and remembering numbers and cannot recall abstract concepts. Besides, they have weak and inexact calculation system and their substantially lower than expected ability prevents them from their later academic achievement or daily activities. Thus, proper and on-time diagnosis of this impairment and quick involvements can reduce its undesirable consequences in the individual and social lives of students. Several recent studies demonstrate counting abilities similar to linguistic abilities are innate in human and even the infants are born with an innate visual ability to differentiate alphabets and numbers from each other and react to the numbers [6]. Although a high percent of children with specific learning disabilities have mathematical learning difficulty, there is little research carried out on behaviours of students with dyscalculia. Hart [7] in a research on retarded students obtained information about students with dyscalculia and those who had mathematical learning difficulties. The research findings revealed that there is a high rate of behavioural problems among students with dyscalculia. One of the most noticeable characteristics of students with dyscalculia is their inability to grasp and remember numerical concepts. Another characteristic of students with mathematics learning disabilities is their calculation problems, inadequate strategies in problem solving, long time to discover solutions and high levels of errors to do mathematical calculations [8]. Various research has demonstrated three factors affecting the formation of children disorders including children's neurological characteristics, family aspects and social environment [9]. These children generally have trouble with spatial perception [10], which can result from the role of parietal lobe in individuals' computational abilities. Current advances in neurological analysis of math related processes indicate that while processing numbers, parietal cortex in the brain is involved and even there is a possibility that the genetically determined structure of brain exist in the horizontal grooves of parietal lobe for identifying numerical concepts. Since the parietal lobe plays a significant function in formation and application of conceptual values, lesions to this area can have destructive influences on the individual mathematical calculation abilities. In addition, the posterior upper part of bilateral parietal lobe which is associated with processing visual-spatial functions will be involved in detecting mental number line [11]. There are numerous psychological researches that indicate brain lesion and lack of standard development in synapses and neurons of individuals with psychological impairments including dyscalculia [10]. One of the methods of studying brain is by studying brain waves. The brain waves are classified into various types including Delta, Theta, Alpha and Beta. Delta waves are the slowest and highest amplitude brain waves which are commonly observed during deep sleep. Theta waves are observed in religious mystic or spiritual experiences and increase

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creativity, enhance learning and memory. Alpha waves are seen in relaxed mental state and when there is not much mental information processing. Theta waves are mostly observed at the time of abstract thinking, awareness, concentration, mathematical calculations and mental functions. Among these factors, tackling child characteristics (intrapersonal characteristics) is of considerable importance since cognitive variables are one of the influential factors affecting learning [12]. Executive functions are considered as one of the individual variables. In recent years, theory of executive deficit and weak central coherence theory for describing and analysing the reasons for dyscalculia have been developed. Evidence indicates that assessment of executive functions as a higher order cognitive mechanism is one of the best approaches to diagnose children with and without dyscalculia [13]. Executive functions are a set of hypothetical cognitive processes which allow the individuals to control their own behaviours and thoughts consciously towards future-directed objectives. This process typically involves cognitive functions such as inhibition, active memory, mental flexibility, planning, mental organizing and concept acquisition [13,14]. Executive function is a broad umbrella which is used to describe cognitive processes such as planning, active memory, attention, inhibition, self-monitoring, self-regulation and initiation [13].

Executive functions develop during the growth process from early childhood to adulthood and consequently have a substantial influence on academic achievement [13]. All groups of children with learning disabilities have difficulties in executive functions specifically planning/organizing, active memory and inhibition [15]. There are numerous research on executive functions in children and adults with learning disabilities indicating that various areas including verbal and logical active memory, visual-spatial active memory [11], planning, inhibition and cognitive control [16], play a function in it. Visual-spatial active memory, planning/organization as well as response inhibition are among the most significant executive functions. It is assumed that the correct performance of executive functions depends on the correct performance of inhibition in the frontal lobe [17]. As Barkley [13] suggests, children and adults normally show deficits in their physical, cognitive and emotional abilities which most of these deficits can be referred to under executive function.

Barkley [13] maintains that response inhibition is the main reason for dyscalculia and response inhibition results in impairment to active memory and other executive functions. In contrast, Sant'Angelo [19] believes that this disorder results from the initial deficit in active memory which leads to impairments of executive functions. Although these two approaches view dyscalculia from different perspectives, they both believe that there are active memory deficits in the individuals with dyscalculia. Active memory as one of the memory systems allows the individual to keep information in the mind and involve for a short period of time [20]. Working memory has the ability to store information for a few seconds while performing other related cognitive operations on the data. The characteristic of this function is to review and encode new related information [20]. The results of several microanalyses of working memory deficits in individuals with dyscalculia indicate the presence of these working memory deficits in these individuals [20]. The visual-spatial active memory is responsible for short-term storage of visual-spatial information such as memory for objects and places [21]. Studies state that working memory plays a major function in learning process [20] class performance and development of academic and verbal skills such as encoding, reading comprehension, mathematics and written expression (such as spelling) depend on appropriate performance of active memory [22]. Studies indicate that children with reading learning disorder, mathematics, developmental dyscalculia and written expression have a lower performance compared with other children [20].

Planning/organization ability as one of the most significant executive functions and higher order activities of brain, due to its role in performing daily activities and coordinating other objective-directed functions has been the focus of various researchers [23]. Lezak et al [24] define this executive function as "the ability for identification and organization of steps or elements needed to carry out an intention or achieve a goal". Since planning/organizing ability is one of the higher functions of prefrontal cortex of brain, it is believed that there is a significant relationship between any lesions or impairments of prefrontal regions and some of the brain's sub-cortical regions and a child's ability for organization and planning [24].

One of the most fundamental components of executive functions investigated in this research is planning and problem-solving ability in terms of Tower of London test. Since problem-solving ability as a smart, rational and purposeful activity is seen as the highest point of human ability and its learning is the main reason for carrying out math research,

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successful problem-solving plays a significant function in academic performance and social adaptability. This skill is related to academic achievement, self-regulation, self-efficacy and success at tasks and can prevent from the future learning and social problems [25] Due to the importance of this skill, students and individuals with specific learning disabilities are often faced with problem in problem-solving situations and the need for attention to this can reduce the future problems of these students [26]. Students with developmental dyscalculia have fundamental problems in cases such as mathematical word problem solving and its related strategies, identification of obvious information in problems, use of self-monitoring and self-regulatory strategies in the process of doing their assignment and keeping their attention until the end of task [27]. Due to the significance of problem solving, research has indicated that students with developmental dyscalculia have substantial weaknesses in attaining the required math problem solving skills [28]. Alizede and Zahedi [17] found that students with math problems are weaker than normal students at inhibition, decision-making, planning and organizing components of executive functions. On the other hand, research on meta-cognitive and self-regulatory dimensions of problem-solving has shown that even though a group of these students know the problem-solving operations, due to attention problems, make errors in attention to marks, columns, writing numbers completely and proximity scripting [29] or they can miss or do not calculate a number. Thus, the attention and speed of students with dyscalculia for mathematical problem solving is significantly lower than normal students. Computational errors are classified into three dimensions in terms of Shalev's standardized test of mathematics (including three components a. number comprehension, b. number production and c. arithmetic calculation). In mathematics applications similar to number calculation, active mind is used for retaining necessary accessible information in cognitive system [14] There is evidence for deficits in executive functions and active memory for transferring and adapting visual-spatial region of working memory. These deficits are evident in math problems, telling time and approximation calculus as well as reading disruption, weakness in verbal short-term memory and information processing speed [30]. The recent studies in developmental neuroscience with a new approach to understanding math deficits reiterate that a major deficit in understanding sets, notion of set and the way for considering a class of objects as a set and the number of set members can be the foundation of all the dimensions of school math [14] There are numerous factors affecting math disorders including intelligence, conscious and active adaptation to new situations which an individual is faced with Active memory: responsible for retention of visual-spatial patterns and storage of movements [30] Sustained attention: is the ability to focus on one specific task for a continuous amount of time and inhibition of evoked responses [13]. Cognitive inhibition: refers to the mind's ability to tune out mental stimuli that are irrelevant to the problem-solving process [14] and planning and organization: is the ability to use the most accessible knowledge to find out solution to a problem. Considering developments in the recognition of developmental dyscalculia and the role of neurological functions of brain in explanation of mathematics disorders, the present research aims to investigate and compare executive functions involved in mathematics disorder, that is, visual-spatial component of active memory, planning and organization and various computational errors in children with developmental dyscalculia and in normal children. Given that developmental dyscalculia is considered as a sub-category of mathematics disorder, the question raised is that how much these functions are effective and more importantly, do these executive functions affect on developmental dyscalculia such as mathematics disorder?

## II. METHODOLOGY

The research method of present study is of a causal-comparative type in terms of the nature of subject and objectives.

**Population, Sample, and Sampling Method:** The research sample consists of all the students with developmental dyscalculia aged between 8-12 years old who enrolled in learning disability centers of Mashhad in academic year 2017-2018 going through assessment, diagnosis and treatment process. Also, all the normal children aged 8-12 years old who were studying in the first to fifth grade of elementary schools of Mashhad in academic year 2017-2018 participated in this study. The statistical population of students with developmental dyscalculia was considered as the target group and the normal children population as the comparison group. It is to note that children with developmental dyscalculia and normal children paired with each other in terms of age (each group aged between 12-18 years old) and average IQ level (normal IQ range) variables. The sample involved 16 students with developmental dyscalculia who were selected

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randomly using quota method from learning disability centers and 16 normal students who were chosen using a multi-stage cluster sampling method among the boys' elementary schools of Mashhad.

## Instruments

**Corsi Blocks Tapping Test:** The Corsi Block Tapping Test was used to assess visual-spatial component of working memory with the help of computers. The process of the Corsi block tapping task requires the subject to observe the sequence of blocks "tapped" (or lit up in the computer version), and then repeat the sequence back in order. Although Corsi block tapping test is widely used to assess spatial component of working memory in psychological research, there is little information confirming the validity and reliability of this test (Kazlez, 2004).

**Tower of London Test:** this test is one of the most important instruments for assessing executive functions of planning and organization (Lezak et al. 2004). Since the computerized execution of this test can have numerous advantages such as precision at the time of execution, accurate measurement of results including both true and false responses, exact scheduling of steps, the cognitive-behavioral research institute, Sina, developed a computerized version of this test using Delphi programming language. The purpose of this test is that subjects make use of their maximum abilities to achieve the best function quickly. It is necessary to ensure that the individual has the skill for using a computer's mouse before administrating the test. After entering demographic information of each subject, the examiner uses the beads and the boards to present the examinee with problem-solving tasks. The participants was told to move only one of the colorful beads (green, blue and red) at a time and that he or she should try to form the sample picture with the fewest movements possible. Then, the sample example is shown to the subject. At this stage, the individual is allowed three trials to solve the problem and he or she should solve the problem with the fewest movements. Afterwards, the subjects are told that they are given 12 problems similar to the example. At each stage, after each successful trial, the next problem is given to the subject. The scoring method of the test is as follows; if the examinee solves the problem in the first trial, he or she receives 9 points, in the second trial, 2 points and in the third trial 1 point. When the examinees all the three trials fail, he or she will be given a zero score. The maximum score in this test is 91 ( $12 \times 9 = 91$ ). Also, the number of solved problems, number of trials, delay time or planning time, number of errors and total score are exactly estimated by computer.

**Raven's Progressive Metrics:** Rave's progressive metrics was originally developed in the U.K. in 1938 for measuring the Spearman's  $g$  (general intelligence). To answer raven's test requires the subject to discover the relationship between geometrical shapes. It is the most common and popular test administered to groups with different abilities ranging from 5-year-olds to the elderly. This test is made of 91 colourful pictures with a blank space. There are 6 alternatives under each picture which can be placed in the empty space to complete the picture (Karini, Fathi Azar, 2007). The reliability of this test was 0/80 and above 0/90 %. The correlation coefficient of Raven's test has been reported with correlation coefficient of Stanford - Binet test (0/60), Wechsler Scale (0/70) and Wechsler Verbal test (0/60).

**Shalev's Standardized Mathematical Tests/Academic achievement Test and Diagnostic Math Test:** This test was originally developed by Shalev (1985) in terms of MacCloskey et al. (2006) numerical processing model and has been widely used for diagnosing math learning difficulties. It consists of three components: (a) Numerical understanding which includes 8 sub-tests for number counting, understanding, matching, reading, writing numbers using letters and digits, comparing numbers, symbol use and sequencing; (b) Numerical production involving sub-tests for assessing skills related to addition, subtraction, multiplication and simple division; and (C) Numerical calculation is composed of five questions. The total score of this test is 100 and it is one of the reference group tests. The reliability of this test on a sample of 703 students was 0/92 (Shalev et al. 1993). This test was translated in Iran by Berahmand, Narimani and Emami (1981) in a study titled "The outbreak of dyscalculia in elementary students of Ardebil". The reliability coefficient of this test was reported to be 0/95 using Cronbach's alpha coefficient.

## III. FINDING

This section, first, summarizes the descriptive statistics measures such as mean and standard deviation of executive functions of subjects with dyscalculia and normal subjects in neurological tests for assessing visual spatial, planning



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/organization, sustained attention components of working memory. Then, the Multivariate Analysis of Covariance (MANCOVA) was used for testing research hypotheses.

**Table 1. Frequency Percentage of subjects in impaired math group in terms of their level**

Level	Frequency	Percentage
Second grade	5	32/2
Third Grade	4	25
Fourth Grade	4	25
Fifth Grade	1	6/3
Sixth Grade	2	12/5
Total	16	100

Table 1 represents the frequency and percentage of subjects in impaired math abilities group in terms of their level. The normal group was also selected likewise. According to the above table, the second grade has the highest frequency and the fifth grade the lowest frequency.

**Table 2. Mean age of subjects in terms of their level**

Level	Impaired math group	Normal group
Second grade	85/6	88/9
Third grade	99/4	99/2
Fourth grade	110/5	110/5
Fifth grade	121	121

Now, the descriptive statistics such as mean and standard deviation of subjects with developmental math disabilities and normal subjects in the IQ test are represented.

**Table 3. Descriptive statistics of subjects' performance in IQ test for impaired math group and normal group**

Intelligence quotient	Mean	Standard deviation
Impaired math group	90/1	8/7
Normal group	95/4	10

Table 3 shows the intelligence quotient of subjects in the impaired math group and normal group obtained using Raven's colored progressive matrices. Given that intelligence quotient was not raised as an indicator in this research, to avoid the unnecessary effect of this indicator, it was analysed as a covariance.

**Table 4. Mean and Standard deviation of Subjects performance in visual spatial component of working memory in terms of Corsi Block Tapping Test**

Visual spatial component of working memory	Impaired math group		Normal group	
	Mean	Standard deviation	Mean	Standard deviation
Memory span	3	1/1	3/7	0/19
Memory score	18/1	14/3	24/5	

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Table 4 indicates the mean and standard deviation of Subjects performance in visual spatial component of working memory in both math impaired group and normal group. According to this table, normal students had better performance in both functions of visual spatial testing of working memory.

*Multivariate Analysis of Covariance (MANCOVA)* was used for testing the first research hypothesis assuming that the visual spatial component of working memory in children with developmental math disabilities is significantly lower than normal group. The visual spatial components of working memory were entered into model as dependent variables, the groups as independent variable and intelligence and level as the control variable. Table 5 illustrates the results of *Multivariate Analysis of Covariance (MANCOVA)* for comparing two groups using *Corsi Blocks Tapping Test*.

**Table 5. Multivariate Analysis of Covariance (MANCOVA) results for comparing two groups performance in Corsi Blocks Tapping Test**

Test	Value	Df Impact	DF error	F	Eta-Squared
<i>Wilks' Lambda</i>	0/75	2	27	4/48	0/27

As it can be seen in table 5, there is a substantial distinction between impaired math group and normal group in a new variable resulting from a combination of dependent variables  $f_{2,27}$ . Further, the Eta-squared obtained indicates that 24% of math impairment variations result from visual spatial component of working memory. The general rule is: if Eta-squared is less than 0/2, it is considered 'weak', less than 0/5, "average" and more than this value, "strong" (Cohen, 1988). Table 6 represents the results of impact tests for between subjects comparing two groups in dependent variables.

**Table 6. Impact tests between subjects results in components of Corsi Blocks Tapping Test**

Statistical results	Sum of squares	Df	Df error	Mean squares	F	Eta-Squared
Variable						
Memory span	3/36	1	30	3/36	3/58	0/11
Test Scores	283/15	1	30	302/23	11/87	0/06

According to table 6, there is no significant difference between two groups in memory span variables and memory final scores ( $P > 0/05$ ). However, the results of Multivariate Analysis of Covariance (MANCOVA) (Table 5) reveal that the general impact of group is significant. This confirms the first hypothesis indicating that the visual spatial component of working memory in children with impaired math ability was lower than normal children.

**Table 7. Mean and standard deviation of two groups' subjects in Tower of London test**

Organization and planning	Impaired math group		Normal group	
	Mean	Standard deviation	Mean	Standard deviation
Total time	965/5	315/17	721/2	208/9
Delay time	88/9	77	46/4	23/2
Testing time	867/5	311/2	674/8	198/8
Number of error	52/8	22/1	36/7	17/5
Number of solved problem	9/1	2/1	10/5	1/5
Total score	23/7	5/1	27/5	4

Table 7 represents the mean and standard deviation of impaired math group and normal group in the planning and organization component of working memory using Tower of London Test. As it can be seen, the performance of subjects in normal group was better compared with math impaired group in all components of Tower of London Test. The Multivariate Analysis of Covariance (MANCOVA) was used to test the second hypothesis indicating that there is a considerable distinction between children with developmental math learning disabilities and normal children in

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planning and organizing ability. The components of Tower of London Test as dependent variables, groups as independent variable, subjects' level and intelligence as control variables were entered into the model. Table 8 illustrates the results of Multivariate Analysis of Covariance for comparing two groups in Tower of London Test.

**Table 8. Multivariate Analysis of Covariance (MANCOVA) results for comparing performance of two groups in Tower of London Test.**

Test	Value	df Impact	Df error	F	Eta-Squared
Wilks' Lambda	0/72	5	24	1/85	0/27

The results of Multivariate Analysis of Covariance (MANCOVA) shown in Table 8 indicate that there is no significant difference between children with developmental math learning disabilities and normal children in the new variable resulting from a combination of dependent variables ( $P > 0/05$ ). Table 9 illustrates the results of impacts between subjects' tests.

**Table 9. The results of Impacts between subject tests in components of Tower of London Test**

Statistical results	Sum of Squares	Df	Df error	Mean square	F	Eta-Squared
Variable						
Total time	31046/54	1	30	31046/54	4/23	0/13
Delay time	9849/31	1	30	9849/31	2/96	0/09
Testing time	209716/32	1	30	209716/32	2/96	0/90
Number of errors	1845/57	1	30	1845/57	6/30	0/18
Number of solved problem	94/51	1	30	94/51	6/11	0/17

As the above table indicates, there is a considerable difference between two groups in terms of total time ( $F_{(30,11)}=4/23$ ,  $P < 0/05$ ), number of errors  $0/18 = \text{Eta-Squared}$ ,  $P < 0/05$ ,  $F_{(30,11)}$ , , number of solved problems =  $0/15 = \text{Eta-Squared}$ ,  $F_{(30,11)}=5/09$ ,  $P < 0/05$  and total score =  $0/17 = \text{Eta-Squared}$   $P < 0/05$   $F_{(30,11)}$ ) variables. However, the results of Multivariate Analysis of Covariance (MANCOVA) indicating the total impact of group did not confirm the second hypothesis.

In the following, the descriptive statistics such as mean, standard deviation of subjects' performance on Shalev's mathematical test in impaired math group and normal children are represented. Also, Pearson Correlation Coefficient, Multivariate Analysis of Covariance and Hierarchical Multiple Regression Analysis were used to answer research question. The results of these analyses are represented in the following.

**Table 10. Mean and standard deviation of subjects of two groups performance on Shalev's mathematical test**

Types of mathematical error	Impaired math group		Normal group	
	Mean	Standard deviation	Mean	Standard deviation
Number understanding	15	8/4	2/3	2/8
Number production	3/6	3/8	0/6	0/9
Number calculation	4/8	8/4	1/1	2/2
Total score	23/5	12/8	4/1	4/4

The above table demonstrates the mean and standard deviation of subjects of impaired math group and normal group performance on Shalev's mathematical test. As we can see in the table, the performance of normal group subjects on all components of Shalev's mathematical test was better than impaired math group. The impaired group in all three components and total score was about two standard deviations different from normal group. The Pearson Correlation



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coefficient was used to answer research first question stating that there is a correlation between performance of children with developmental math learning disabilities on executive functions of visual spatial working memory and the total score of computational errors.

**Table 11. Correlation coefficients between executive functions of visual spatial working memory and London of Tower Test with the total score of computational errors in children with math learning disabilities**

Executive functions	Executive sub-functions	Total score of computational errors on mathematics test
Visual spatial memory	Memory span	-0/29
Planning and organization	Memory Final score	-0/32
	Total time	0/75
	Delay time	-0/24
	Testing time	0/82
Number of errors		0/15
Number of solved problems		-0/26
Final score		-0/12

The results of this analysis indicate that there is no significant correlation between executive functions of visual spatial working memory and total score of computational errors in children with math learning disabilities ( $P > 0/05$ ). There is a positive correlation between total time of test (one-tailed test  $R = 0/75$ ,  $N = 16$ ,  $P < 0/01$ ) and total time of test (one-tailed test  $R = 0/82$ ,  $N = 16$ ,  $P < 0/01$ ) of executive functions of planning and organization with total score of computational errors.

The Multivariate Analysis of Variance (MANOVA) was used to answer the second research question: “Is there any significant correlation between types of computational errors of children with developmental math learning disabilities and normal children”? The components of Shalev’s mathematics test and group were entered into model as the dependent variable and independent variable, respectively. Table 12 represents the results of Multivariate Analysis of Variance for comparing the math ability of two groups on Shalev’s mathematics test.

**Table 1.2 the Results of Multivariate Analysis of Variance for comparing the performance of two groups on Shalev’s mathematics test**

Test	Value	df Impact	Df error	F	Eta-Squared
Wilks’ Lambda	0/42	3	28	12/90	0/58

The results of Multivariate Analysis of Variance indicate that there is a significant distinction between children with impaired math ability and normal children on new variable resulting from dependent variables ( $f_{3,8} = 12/90$ ,  $< P/001$ , Wilks’ Lambda = 0/42). Also, the Eta-squared obtained (0/58) indicates that 58 percent of Shalev’s mathematics test variations between two groups relates to the calculation component. Table 13 depicts results of impact tests between subjects.

**Table 13. The Results of Multivariate Analysis of Variance for comparing the performance of two groups on Shalev’s mathematics test**

Statistical results Variable	Sum of squares	Df	Df error	Mean squares	F	Eta-squared
Number understanding	1287/7	1	30	1287/7	32/4	0/52
Number production	72	1	30	72	9/1	0/23
Number calculation	108/7	1	30	108/7	2/8	0/80

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The results of above table indicates that there is a significant difference between two groups in terms of number understanding ( $f_{30,1} = 32/4, P < 0/001, Eta\ squared = 0/52$ ) and number production ( $f_{30,1} = 9/1, P < 0/001, Eta\ squared = 0/23$ ). However, there is no substantial difference between impaired math group and normal group with respect to number calculation ( $P > 0/05$ ).

## IV. DISCUSSION AND CONCLUSION

The assessment of executive functions in children with learning disabilities including developmental math learning disabilities has recently dedicated a considerable number of researches to itself. There are numerous researches on these executive functions and their role in development of the afore-mentioned learning disorders.

The research results revealed that the working memory of children with developmental math learning disabilities is significantly less than normal children. These findings are in agreement with various research findings such as Robinson and Heng, [30]; Dahlin [14]. Numerical calculation involves using the active memory (retaining accessible and appropriate information in the cognitive system) Robinson and Heng [30]. state that lower level visual-spatial mechanisms create restrictions on quantity retrievals which are used in calculation process especially in subtraction. Further, the working memory deficits can cause confusion in retrieving mathematics actions and lead to impediment in multiplication and addition operations Kauffmann et al [30]. Several studies indicate that memory improvement has a positive effect on learning and subsequently academic achievement since memory supports learning. In other words, memory results in concentration on the task, irrelevant information inhibition and relevant information integration which together facilitate learning process [30].

One of the significant executive functions which can be impaired in individuals is planning and organization executive function which a major supra-brain activity related to prefrontal cortex performance which can be assessed using Tower of London Test, Tower of Hanoi Test and Mazes Test. The results of present research indicated that there is no significant difference between children with math difficulties and normal children in their organization and planning sequence. According to Butterworth [31] it seems that developmental math difficulties are not the consequence of cognitive abilities. The developmental math disabilities or dyscalculia is a numerical central disability while math difficulties results from cognitive impairment [31]. Most of domestic research has been carried out on math disabilities related to executive functions such as planning and organization (1). However, the present research findings demonstrated that children with developmental math disabilities had a weaker performance on planning and organization functions compared with normal children. These findings are in agreement with research literature indicating that children with math disabilities similar to children with Attention Deficit Hyperactivity Disorder (ADHD) and math disorders are weak at executive functions specifically planning and organization and actions which require coordination [2] This indicates overlapping between math disabilities and developmental math learning disabilities disorder and consequently the effect of relevant executive functions on developmental math learning disabilities. However, in general, this correlation is not statistically significant.

Also, research findings revealed that none of the components of executive functions have significant relationship with score percentage of computational errors which is in agreement with research hypotheses. In addition, there was a negative correlation between components of visual spatial active memory and computational error score. Research results indicated that there is a significant correlation between total time and testing time components of planning and organization executive functions with total score of computational error score. Planning/organization ability as one of the most significant executive functions and higher order activities of brain, due to its role in performing daily activities and coordinating other objective-directed functions has been the focus of various researchers. This executive function is defined as "the ability for identification and organization of steps or elements needed to carry out an intention or achieve a goal and has numerous applications in Shalev's mathematics test [31].

Further, research results demonstrated there is a considerable distinction between two groups in three components of math disability, number understanding, and number production. Children with developmental math learning disabilities suffer from disorders in the groove of their parietal lobe which is responsible for counting, comparison, addition and subtraction. In Shalev's mathematics test, the sub-components of number understanding and number production involve these concepts. According to Shalev's findings, children with developmental math learning disabilities have

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dysfunctions in these concepts. As Butterworth et al. [31] state, the groove inside the parietal lobe in the brain is mostly related to developmental math learning disabilities. This region is responsible for internal processing of numbers such as simple counting, estimation and calculation. The most significant indicator for identification of developmental math learning disabilities, according to Butterworth et al. [31] is the child's disability in understanding the concept of set and number of set members which is one of the fundamental variables in number understanding component. These children are likely to have problems with numbers, number processing speed, counting, representation of one-digit numbers and their computational procedure.

The effect of lack of nerve growth in children with learning difficulties can be investigated for clarifying these findings. Studies indicate widespread or little brain lesions can result in various learning disabilities. These findings are also useful for explaining most of these children's behavioural disorders such as time adjusting, appropriate usage of paper in writing academic performance and performing every day activities. In fact, it can be said that the child's disability in organizing new and challenging tasks is likely due to these children's planning and organization function deficits. These findings contribute researchers to understand the reason for children's weak academic performance and learning disabilities. The organization function and central coherence allows these children to perform their assignments and every day activities combining information they receive.

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