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Effectiveness of Chess Training for Improving Executive Functions and Mathematics Performance of Students with Mathematics Disorders

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Abstract

The present research aimed to investigate the impact of chess training on executive functions and mathematic performance improvement in students with mathematics disorders. This research was a quasi-experimental one using a pre- and post-test design. The subjects involved were 20 students with and without mathematics disorder in grades four and five in Tehran. They were randomly assigned to a control and an experimental group. The subjects were administered Stroop Test (Stroop, 1935), Continuous Performance test (Rosvold *et al.*, 1965), the computerized version of Tower of London Test (Morris *et al.*, 1993), and Key math test (Connolly, 1988). In the next stage, the experimental group took chess lessons for a year: they were trained for two sessions a week, each lasting one hour. But the control group did not receive any training. Then, with an interval of a month a post-test was administered: in the post-test the executive functions and mathematics performance of both groups (i.e., control and experimental) were tested. The analysis of the data through independent samples t-test showed a significant difference (P= .05) with the experimental group outperforming the control group. Thus, it could be concluded that chess training had a significant impact on the mathematics performance of students with mathematics disorder.

Keywords**:** executive functions, chess training, mathematics disorders

I. INTRODUCTION

Children with mathematics disorder have problems either in the field of mathematical calculation or in their mathematical reasoning ability. Due to disagreements in the definitions of learning disorders and disagreements in educational objectives in teaching these children, the estimated prevalence of the disorder varies from one to thirty. Many causes have been mentioned for dyscalculia based on which different treatment/intervention methods have been offered (Lyon *et al.*, 2003). Several reasons have been put forward by specialists in mathematics to explain the causes of the disorder among which executive functioning problems have been of utmost importance. Executive functioning is a set of cognitive mechanisms which helps a person to achieve the desired behavior, working memory, cognitive flexibility, and self-control (Geary, 2004).

Chess is a classic game with a rule that dates back 1500 years and holds students in enjoyable intellectual competitive activities. The entry of chess in schools links all students of different ages: It provides a strong friendship and promotes social activities. Chess is paradoxically a simple and a complex game. Learning chess skills with the help of its educational principles has beginner chess players involved. Although a person's intellectual abilities are innate, rehearsal is believed to be the most influential factor in developing the innate intellectual abilities. It is suggested that chess players begin playing chess from the age of 10 or 12 so that they are developed firmly and, as a result, their logical reasoning grows better. Chess rehearsal expands the abilities of with mathematics disorders (Root, 2008). New research has emphasized the role of metacognitive skills, mainly the role of the instruction of executive functions, in improving learning. A study done on the executive function of students revealed that students with mathematics disorder have problems in all their executive functions (Fairleigh & Wittlin, 2010).

In the definitions of executive functioning, the various abilities and notions of cognitive flexibility, inhibition, organizing, planning, self-regulation and working memory are included (Roth, 2004). Executive functioning is composed of the complex combination of self-regulatory, planning, organization and problem solving. These skills grow from childhood to adolescence and even through early adulthood. Executive functioning is at the heart of controlling cognitive processes among which working memory is one (Stein & Chowdbury, 2006). The poor performance of students with learning disabilities in tests of executive functioning and working memory has been confirmed by many studies (Reynolds, 1984; Holborow & Berry, 1986; Denckla, 1996; Bohm, Smedler & Forssberg, 2004; and Valera & Seidman, 2006). Studies have revealed that chess training results in improved focusing ability in students with mathematics disorder (Scholz *et al.*, 2008; Mastropieri *et al.*, 2006; Eberhard, 2006; and Ho, 2006).

In a study, cognitive effects of chess training on students at risk for failure in mathematics were assessed. In this study, 38 children aged 8-12 years were measured from 3 elementary schools in South Korea. The results showed a significant difference between the normal group's performance and that of the group with dyscalculia (Hong & Bart, 2007). Chess training also had a positive effect on reading performance (Boruch, 2011). The relationship between math and chess is fundamentally basic: all teachers have come to believe that chess can increase math skills. Successful chess players process and store information much better than other people (Celone, 2001).

In math classes, students with mathematics disorder do not have the required math problem-solving skills and, thus, the right incentives should be provided for them to encourage them take a more active role in overcoming the disorder. Using a variety of methods, learning math can be made more enjoyable. Executive functions cannot be separated from problem-solving activities. Thus, studying this process and discussing the possible ways to improve it can lead to strengthening the mathematical skills. Considering that the executive functioning is a cognitive activity, one can propose some possible improving strategies so that the emergence of a negative cycle of frustration can be avoided (Latzman *et al.*, 2010). On the other hand, studies have shown that instruction and development of executive functions have a major role in the development of social competencies and academic abilities (Blair, Zelazo & Greenberg, 2005). Chess is a game with rules and complex structures that lead to growth and excellence of thought and creativity. Executive functions and cognitive abilities play an important role in playing and succeeding in chess (Elkies & Stanley, 2003). Playing chess has lasting effects on concentration, visualization, analytical thinking skills, abstract thinking, creativity, critical thinking skills, cultural enrichment, and early intellectual maturity (Berkman, 2004).

In a study, two groups of students with dyscalculia were studies. The control group received one hour of chess training lessons per week, and the other group received mathematics instruction. The students' math scores were measured before and after the training, and the scores were compared. The results showed that in the counting skills, problem solving and computational tasks, the students who received chess training had higher math scores (Markus *et al.*, 2008).

The ddevelopment of executive functions based on complexity theory and cognitive control in the form of age-related increase and the maximum operation of complex rules that children can do and use to solve problems have been investigated. (Zaobuo *et al.*, 1998). It seems that children develop and use a variety of met-cognitive skills. These skills include understanding and the control of cognitive processes. Such cognitive processes involved in the pursuit of cognitive tasks include prototype monitoring and modifying (Sternberg, 2006).

Playing chess is dramatically effective in improving analytical thinking skills, problem solving techniques, self-confidence, organizational habits, logical and reasoning skills, patience and persistence, decision-making skills and the ability to think logically (Bankauskas, 2000). Moreover, playing chess enhances cognitive skills (Bulgren *et al*., 2007). Playing chess has positive effects and improves children's communication skills and ability to recognize mental models (Deshler *et al.*, 2004). Studies shave confirmed that playing chess affects higher-graders more, especially in their English and mathematics (Hall, 1983). Thus, studying this process and discussing the ways to improve it can lead to developing math skills. Considering that the executive functioning is a cognitive activity, some strategies can be taken into consideration so as to prevent the emergence of a negative cycle of frustration (Latzman *et al.*, 2010). On the other hand, studies have already shown the training and development of executive functions play a major role in the development of social competencies and academic ability (Blair, Zelazo & Greenberg, 2005).

II. METHODOLOGY

A. Procedure

The study is a semi-experimental one for which 20 children with math disorder in the fourth and fifth grades with the age of 9-12 years were sampled from the Center of Learning Disorders in Tehran, Iran. Then they were randomly divided into a control and an experimental group. The students' IQ, based on Raven's colored progressive matrices, was on top 90 and, thus, they did not have any psychological problem. All subjects were evaluated through the test of executive functioning and Key Math Test. Then, the experimental group participated in training chess course for a year. The training program was offered twice a week for one-hour. After this step all subjects (both the experimental and the control group) were evaluated again in terms of their executive functioning and math performance. It should be reminded that the control group did not receive any intervention and both groups received their usual school education. After one month, the post-test was administered.

B. Instrumentation

Raven's Progressive Matrices: The colored version of the Raven's Progressive Matrices was used to assess the intelligence of participants.

Key Math Diagnostic Arithmetic Test: This test was introduced by Connolly, Nachtmann, & Prichett (Connolly, 1988). It was validated for preK-8 students in in the fall of 1984. Key Math validity Cranach's alpha level of 5 grades was ranged from 0.80 to 0.84 (Hamad Ismail, 2000). This test is applicable from kindergarten to eighth grade. The test measures three general mathematics content areas: basic concepts, operations, and applications. The scoring is done through calculating the mean of the sum of all subtest scores. The test is administered individually and is suitable for the ages of pre-school to 11 years.

Computerized version of Tower of London Test: Tower of London test was first designed by Shallice (1982) to measure planning ability in patients with damage to their frontal lobes. This test is a computer program designed to form a loop in which the pieces are on display with a three-dimensional structure (Morris *et al.*, 1993). The current version of the TOL task involved computerized presentation and responses made using a light-pen. The subjects are given a double row pattern and are asked to arrange the rows. Participants were told that there were two parts to each trial: first mentally planning the moves to make the bottom set of disks match those of the goal set in the fewest possible moves, and second using the light-pen to move the disks on the bottom set of pegs as quickly as possible. In each trial, the top row shows remains constant and the subjects are required to move and rearrange the bottom row disks to match with the upper-tier arrangement. The target for the rings varies, but the starting position is kept constant. The students were required to solve the problems with minimum number of moves (Morris *et al.*, 1995). Tower of London test is thus used to assess the ability of planning and organization, which is sensitive to frontal lobe function (Owen*et al.*, 1990).

The Continuous Performance Test: The continuous Performance Test was devised by Rosvold *et al.* (1965). It is a go/no-go challenge test, or what is known as a choice reaction time test. This test is used to measure *inhibition* and *attention*. There are several forms of the continuous performance test. The main method is that the target stimulus is randomly displayed on the screen and among different stimuli and the subjects are taught to press a button on the emergence of the target stimulus. The continuous performance test has been devised to yield a reliable pre-post measure on attentional variables. These variables include: A) commission errors which are an indicator of impulsivity are the subjects' responses to non-target stimuli. B) Omission error occurs when subjects do not respond to target stimulus and it implies that subjects had problems in inferring target stimulus. C) Reaction time which is the time between the presentations of target stimulus and the subjects' reply.

The Stroop Test: The Stroop Test was devised by Stroop (1935). This test can be used for the assessment of attention, mobility and inhibition. In the Stroop test, the subjects are given three cards – Card A: the "color card" on which there are 100 patches from three to five different colors, and the subjects' task on card A is simply to utter the names of the colored patches as rapidly as possible, scanning the rows from left to right. Card B: the "word card" on which are printed the names of the colors in black and white, and the subjects read aloud the color names as rapidly as possible. Card C: the "color-word card" on which are printed the names of the colors, but printed in an ink of a conflicting color (e.g. the word RED might be printed in green, yellow, or blue, but never in red). Each card has 100 items to be named. On card C the subjects are required to name the colors of the inks while ignoring the conflicting printed color names. The subjects' basic score on each card is the total time (in seconds) he takes to utter the 100 names. All these tests have been validated at the Institute of Cognitive Sciences (Tehranifriend *et al.*, 1995).

III. RESULTS

A Descriptive Statistics was run to display the characteristics of the experimental and control groups (Table 1).

Table 1: Characteristics of the experimental and control groups

	The control group (n = 10)		The experimental group (n= 10)	
	Average	Standard deviation	Average	Standard deviation
Age	10.14	1.9	9.11	1.6
IQ	6.95	0.12	94.2	1.5

In order to determine whether the experimental and the control group are homogeneous at the beginning of the study, a pre-test was given to them the results of which are shown in table 1. The t-test analysis of the results did not show any significant differences between the experimental and control groups.

Table 2: Test results of the Tower of London in both experimental and control groups

Control group						Experimental group.					
Significant level	error	deviation	follow	Post	pre	error	deviation	follow	Post	pre	number of moves
0.05	0.54	0.48	1.47	1.89	2.19	1.18	2	1.09	98	2.76	level 2
0.05	0.91	0.72	4.11	4.14	4.64	1.43	1.11	1.19	39.3	4.82	level 3
0.05	1.53	9.18	9.98	10.15	7.25	1.33	0.91	3.53	4.45	10.52	level 4
0.05	0.65	1.17	11.02	11.11	12.71	1.19	1.35	7.16	37.6	12.34	level 5
											Next time think
0.05	1.51	1.59	11.91	11.97	12.90	0.56	1.45	5.49	67.5	16.75	level 2
0.05	0.45	27.56	27.11	29.43	16.41	0.91	1.72	18.91	52.19	30.12	level 3
0.05	1.27	50.34	52.21	56.32	37.35	1.10	2.54	41.62	55.32	51.14	level 4
0.05	2.02	2.39	57.41	58.51	59.90	1.33	2.34	41.11	51.42	59.69	level 5
											Scheduled time
0.05	1.20	1.31	5.41	5.81	5.31	21.7	1.76	3.37	11.3	5.82	level 2
0.05	2.59	2.27	5.72	6.31	6.49	21.0	1.91	5.43	23.5	7.09	level 3
0.05	1.61	1.27	4.62	4.21	4.62	81.2	1.65	3.78	76.5	5.72	level 4
0.05	0.890	0.33	4.05	4.23	5.21	81.1	1.42	4.10	12.2	7.53	Level 5

As can be seen in Table 2, which shows the pre-test and post-test results of the Tower of London test in both the experimental and control group, the number of movements in the experimental group is more than that in the control group. This difference is statistically significant both at level 2 ($t(20) = 3.19$, $P < 0.05$), and level 3 ($t(20) = 3.11$, $P < 0.05$).

Table 3: Characteristics of the two groups on the Stroop test

Significance level.	Control group					Experimental group.					
	error	deviation	follow	post	pre	error	deviation	follow	post	pre	
0.01	3.32	4.09	17.92	18.91	19.80	2.43	3.54	17.87	16.03	19.71	Time points card.
0.01	0.36	0.41	0.32	0.39	0.43	0.50	0.64	0.77	0.14	1.20	Faults on the card.
0.01	2.28	8.29	22.51	27.03	29.51	1.69	2.56	23.91	23.45	33.05	Time cards words
0.01	0.17	0.29	1.01	1.19	1.34	0.38	0.64	1.54	1.12	2.11	Faults on the card words
0.01	1.51	8.75	21.02	16.21	29.09	1.91	3.25	35.02	34.45	53.51	Times the color card
0.01	0.05	0.32	0.47	0.56	0.71	2.61	1.33	1.47	1.32	3.42	Errors in the color card.

As can be seen in Table 2, which shows the pre-test and post-test results of errors of the Stroop test in both the experimental and control group, the reaction time for naming the colors of the card with patches compared to the word cards and color-word cards in the two groups based on t-test is meaningful.

Table4: details the control and experimental groups in a continuous performance test.

Significance level	control group					experimental group					
	error	deviation	follow	post	pre	error	deviation	follow	post	pre	
0.01	0.32	0.56	1.56	1.61	1.81	0.43	0.54	1.91	1.16	2.69	Count of commission error
0.01	0.41	0.17	0.25	0.26	0.43	0.50	0.73	0.43	0.31	1.23	Number of omission error
0.01	0.29	0.86	1.61	7.91	8.28	0.79	0.41	9.02	8.65	11.45	Reaction time

In the continuous performance test, the number of commission errors in the experimental group (with disorder) is more than that in the control group in the post-test. The results of the pre-test and post-test scores of both groups show the effectiveness of the training program. As can be seen in table 4, the number of commission errors in the students with mathematics disorder is higher than that in the control group. Also there is a significant difference between the experimental and the control group regarding the omission error ($t(20) = 2.31$, $P < 0.05$). Further, as seen in table 4, reaction time was significantly different between the two groups.

The results shown in tables 2, 3, and 4 confirm that the functioning-memory training program could improve executive functioning and mathematics performance of students with mathematics disorders.

The results of the second post-test of executive functioning and mathematics performance that was administered with an interval of one month after the study also confirmed the improvement of executive functioning in students with mathematics disorder.

Table 5: Performance of both the experimental and control groups of children with Mathematics disorder in Key Math test

Operation	concepts	rational numbers)	approximations	calculate	interpreting	solving	money and time	division	Multiplication	geometry	measurements	Subtraction	collected	counting		Grade
4.11	5.29	0.67	1.23	2.14	2.46	5.18	4.23	9.32	4.23		25.2	41.4	120.6	152.8	pre	third
9.42	6.31	1.43	2.12	4.02	7.03	7.92	9.04	13.11	9.45		98.4	67.5	409.8	301.10	post	
5.41	6.431	1.11	2.45	3.15	3.38	3.13	5.12	5.43	7.45		11.9	21.7	151.8	43.11	pre	Fourth
6.11	8.12	2.10	3.04	4.32	5.34	4.27	6.12	7.15	9.31		23.11	45.8	10.11	25.12	post	
4.61	5.23	4.23	3.12	4.26	3.33	4.15	8.21	6.13	9.41	51.	43.11	151.9	131.9	351.11	pre	Fifth
7.31	7.04	6.32	5.19	6.31	5.48	7.65	11.11	8.05	11.16			89.12	111.10	65.13	post	

Table 5 displays the results of the pre-test and the post-test of the experimental and the control groups of students with mathematics disorders on the key math test. The results show significant differences between the two groups ($t(20) = 3.09$, $p < 0.05$ is) with the experimental group outperforming the control group.

IV. DISCUSSION

The results of the study is in agreement of the result of Butterworth's study (2005) in that both support that chess training improves the mathematics performance of students. Chess is a model of cognitive processing which improves the capabilities of perception, information management, memory, attention, logical thinking, and problem solving (Gobet & Simon, 1996; Grossen, 1991; and Horgan, 1987). These capabilities have also been measured in other studies of chess and they have shown increased performance through training (Chase & Simon, 1973; Charness, 1992; Frank &D'Hondt, 1979; Horgan, 1987, Margulies, 1991; and Bottge *et al.*, 2009).

Problem-solving tasks are too difficult for students with dyscalculia (Markus *et al.*, 2008). There have been differing views on how to improve mathematics performance. Yet, in all these differing views there is a consensus that attention is the most basic of all determining factors. In playing chess, this attention can be enhanced (Kaufmann, Handl & Thony, 2003). Chess playing can enhance frontal lobe functioning which is seen in the MRI scans taken from people who are playing chess (Hong & Bart, 2007). Cognitive inhibition deficits reduce the mathematics performance of students. Limited capacity of working memory is also one of factors which result in mathematics disorder. The high correlation of Mathematics Disorder and Attention Deficit-Hyperactivity also explain for these findings in children with mathematics disorder (Passolunghi *et al*., 2001; Friedenberg & Silverman, 2007). Also, in the comparison done in the study, the Stroop test results, which are indicators of the cognitive functions of selective attention, attention shifting and response control, showed that students with mathematics disorder spend more time to read color cards that require both the performance on reading inhibition and its de-contextualization (Barrett & Fish, 2011).

A 30-week chess training program improved the math performance of sixth, seventh and eighth grade students in the United States (Horgan, 1992). Chess training results in the improvement of spatial visualization. Story (2000) showed that chess training leads to an enhancement of concentration capabilities.

Other results show that children with dyscalculia have much poorer visual-spatial working memory and executive working memory and that there is a correlation between the mathematics and the amount of working memory usage (Fairleigh & Wittlin, 2010, Monette, Bigras & Guay, 2011). Chess training improves visual-spatial memory and working memory (Smith, 1998; Smith & Cage, 2000). Therefore, chess training can be very promising to improve executive functioning and mathematics performance of students with dyscalculia.

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