The Effect of Working Memory Training on Executive Function of Children with Attention Deficit/Hyperactivity Disorder

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Abstract

Attention Deficit/Hyperactivity Disorder (ADHD) is among developmental disorders that has taken the attention psychologists and psychiatrics from a long time ago. The present study aims to investigate the effect of attention and working memory improvement training on executive function of children with ADHD. The present study was a quasi-experimental study and the sample included 44 children with ADHD who referred to psychiatric clinics of Babol and had the characteristics of interest and they were divided into test and control groups, each group contained 22 subjects. Their performance was evaluated using Tower of London Test at the pretest stage. Then, each group member exposed to training with attention and working memory improvement application for 20 sessions of 30 minutes (7 weeks, 3 times a week, 30 minutes). After the training period, posttest was administered with the same application for both groups. The results of analysis of covariance showed that despite increased executive function in both groups at the presets, the executive function in test group was higher and for this reason, attention and working memory improvement training has influenced the executive function of children with ADHD. Attention and working memory training and similar programs can be used as a complementary treatment method or an alternative for medical therapies.

Keywords: Attention Deficit/Hyperactivity Disorder; Executive Function; The Tower Of London Test; Working Memory.

1. Introduction

Attention Deficit/Hyperactivity Disorder (ADHD) is a developmental and neurological disorder among children that is characterized by disorders in attention and hyperactivity (Marcelle, Ho, Kaplan, Adler, Castellanos & Milham, 2018). This disorder is prevalent for 10% of children and continues until adolescence and adulthood (Rajeh, Amanullah, Shivakumar & Cole, 2017). Diagnostic criteria according to the Fifth Diagnostic and Statistical Manual of Psychiatric Disorders for ADHD address two points: the presence of disorders related to attention deficit and hyperactivity prior to 12 years old at least in two different environments (Criterion C), in home and school, home and workplace, home and school and workplace (Weiss, Wasdell, Bomben, Rea & Freeman, 2006).

Studies indicated that children with ADHD show overlapping disorders. In this regard, 27% have anxiety, 7% have behavioral disorder, 38% have CD, and 13% suffer from depression (Singh, Yeh, Verma & Das, 2015). Also, these children are at high risk of suicide compared with other children (Bauer, Gustafsson, Nigg & Karalunas, 2018). Moreover, they show that some relationships exist between ADHD and Tourette syndrome (Termine et. al., 2016). Among children with ADHD, 45 to 75% suffer from motor skills problems and this can negatively influence social competence of relationships with others and academic skills (Tseng, Henderson, Chow & Yao, 2004).

Morphological, cognitive and functional neurobiological biochemistry studies according to the neuropsychological basis of ADHD point to the involvement of specific nervous areas such as frontal lobe, laryngeal lobe, hippocampus, and cerebellum (León-Domínguez, Martín-Rodríguez & León-Carrión, 2015). Studies that examined the effects of disorders in executive function on ADHD pathology, show disorders in working memory and inhibitory control as the result of malfunctioning in

the prefrontal cortex (Duff & Sulla, 2015). These nervous areas have close relationships with executive function, so that researchers have concluded that the existing defects in executive functions are the main core of this disorder and they consider these defects as justification for problems in failure to pay attention to the impulsiveness and hyperactivity of these people (Benzing, Chang & Schmidt, 2018).

ADHD is related to low executive function and motor problems. Executive functions are defined as cognitive and high-level functions and regulate fundamental cognitive processes; therefore, they are essential for flexible and purposeful behavior. Executive functions are composed of three major processes: 1. Prevention that includes preventing dominant reactions and controlling the senses; 2. Change that includes change in affairs or mental set; 3. Working memory that includes maintenance and process of information (Hasani, Samimi, Parooi & Tamini, 2017).

The terms "function" or "executive function" refer to a set of regulatory processes that are required to select, implement, and monitor thinking, emotions, and certain aspects of sensory-motor functions. This aspect is composed of areas such as prevention, start, sustained attention, changes in working memory, emotional regulation, planning, identification, and monitoring (Qian, Chen, Shuai, Cao, Yang & Wang, 2017).

Among executive functions, working memory is an important aspect that functions as an essential component in most of cognitive tasks such as attention control and problem solving (Thorell, Lindqvist, Bergman Nutley, Bohlin & Klingberg, 2009). In the following, considering the topic, we concentrate on working memory.

As pointed out, ADHD is a common developmental and neural disorder among about 5% of children. Self-regulatory problems with this disorder include problems in both cognitive and emotional functions. Common problems include decreased performance in tasks related to working memory that investigate the monitoring capacity and regulation of input information (Jensen et. al., 2018).Working memory, as defined by Bedly (2012), is a brain-based system that provides the possibility to maintain stimulus and change information (Nelwan, Vissers & Kroesbergen, 2018).

The functions of working memory include:

- Maintenance of information in mind and working on them;
- Fundamental role in prediction and imitation of new behavior;
- Relationship with time and patience;
- Internal mental operation where any inconsistency makes the person dependent on external feedback; on the other hand, due to the problem in mental review, task reviews will be accompanied by problem.

Researchers believe that most of children with ADHD suffer from problems in executive functions and working memory, especially in inhibition of response and working memory where the main signs are resulted from failure in these two components (Holmes, Gathercole, Place, Dunning, Hilton & Elliott, 2010). Different medical and non-medical therapies are used to treat ADHD (Klingberg, Forssberg & Westerberg, 2002). Since medical therapies cannot be sufficient to compensate problems related to ADHD, development of more medical methods is necessary to target the main neuropsychological problems (Qian et. al., 2017).

A study by Greenberg et. al., showed that working memory improvement can lead to improved executive functions such as working memory, inhibition of response, and arguments in children with ADHD (Schreiber, Possin, Girard & Rey-Casserly, 2014). Computer-based working memory training for children with ADHD indicates advancers in working memory, inhibition of reaction, and complex reasoning tests as well as a significant decrease in the number of ADHD signs (Schreiber et. al., 2014). Recent studies show that computer-based cognitive training can provide reliable and sufficient improvement in attention, impulse control, social function, educational function, and complex skills (Rapport, Alderson, Kofler, Sarver, Bolden & Sims, 2008). Egland et. al. in their studies showed that working memory training influences motor functions and improves reading and mathematics (Egeland, Aarlien & Saunes, 2013). In both qualitative and meta-analysis studies, it has been indicated that working memory training can improve working memory functions related to trained working memory

affairs and has a close relationship in children, adolescents, and adults with different types of ADHD (Marcelle et. al., 2018). According to the above mentioned, the purpose of the present study is to investigate the effect of working memory on executive function of children with ADHD.

2. Materials and Methods

The present study is a quasi-experimental study and the study was conducted at pediatric psychiatric clinics in Babol and each clinic was managed by a psychiatric and at least a psychologist. All patients who referred to these units had medical file and were revisited at least every two months. The population included all children referring to psychiatric clinics in Babol who were diagnosed with DSMIV and ADHD according to the diagnostic criteria and the psychologist and were under medical therapies at least for 30 days and their parents consented to participate in this study. In this regard, 44 subjects were selected as the sample based on purpose sampling and divided into two groups of test and control, each containing 22 subjects. The research units had the following characteristics: 1. According to the evidences and the doctor's opinion, they were suffering from ADHD; 2. Their medical therapy was started at least 30 days ago; 3. They were between 7 and 12 years old; 4. Their parents were willing to participate in the study; 5. They could read and write and were familiar with computer; 6. They did not have any other problems such as mood disorders, anxiety, and conduct and coping disregard; 7. They had average IQ according to Wechsler's Intelligence Scale. Exclusion criteria included: 1. Failure to understand the educational materials for the test; 2. Suffering from a certain disease where they did not have the necessary conditions to continue the procedure both physically and mentally; 3. They migrated from their place of residence for any reason. Subjects, according to these conditions were assigned into test and control groups based on purpose sampling. The measurement instrument in this study was the Tower of London Test. This test is one of the most popular instruments to measure executive function (Baughman & Cooper, 2007; Zook, Davalos, DeLosh & Davis, 2004). This test is designed by Shalis (Shallice, 1982) and different researchers such as Krikoorian, Battok, Gi (Krikorian, Bartok & Gay, 1994) and Kalberson and Zilmer (Culbertson & Zillmer, 1998) used it with modifications and standardization. Brain imagining study using PET, MRI, and FMRI indicates that the Tower of London Test is more susceptible to prefrontal cortex (Boghi et. al., 2006; Rasser et. al., 2005). This test is one of the important instruments to measure executive function (Baron, 2003; Lezak, Howieson, Loring & Fischer, 2004; Qian et. al., 2017). This test has high construct validity in measuring executive function of people. Between the results of this test and Porteus Maze Test, correlation of $r = 0.41$ is reported (Culbertson et. al., 1998; Krikorian et. al., 1994). The validity of this test is reported as 0.79 and it is acceptable (Lezak et. al., 2004). This test is designed to assess at least two aspects of executive function that are strategic planning and problem-solving. After entering personal information of the subject in personal information section, the experimenter shows the screen to the subject and says: this is a problem-solving test; you should move the colored pages (i.e. green, blue, red) and place them in suitable places and create the sample with the minimal movement required. Note that you only can move the upper pages and place 3 pages in the long column, 2 pages in the middle column, and 1 page in the short column. Then, the subjects are asked to solve the example. In this stage, the person has three chances and should solve the problem according to the guidelines with minimum movements. Then, the subject is called: you will have 12 problems and you should create the sample (like the example) with minimal movements. Also, we remind people they have three chances for each problem and in each stage, after success (if after three attempts, the problem is not solved yet), the next problem will be given. When the subject understands the guidelines, the experimenter says: if you are ready, we start the test. When the subject confirmed, the test stars.

To implement this design, the subjects are matched in terms of demographic characteristics (e.g. gender and age) and assigned into test and control groups. Then, the performance of groups was assessed using the Tower of London Test at pretest. In the next stage, each member of the test group received instruction for 20 sessions of 30 minutes (7 weeks, 3 times a week, 30 minutes) individually using attention and working memory improvement application. After the training period, posttest was administered for both groups using the same application. This application includes three sections of

auditory memory, visual memory, and stabilization. Auditory memory and visual memory have forward and reverse memory training capabilities. Each section of forward and reverse training includes three subsections of letters and figures. Each section such as numbers, letters, and figures is divided in terms of difficulty level from 1 to 9. After selecting the difficulty level, what the subject hears or sees is indicated in difficulty levels of 1-9 in three rows. Also, in letters' section, 9 letters with similar pronunciations and in figures' section, 9 figures are indicated. The subject should answer what he is heard or saw with the computer mouse; for this purpose, inserts in the forward section and answers in the reverse section. For each correct answer, the subject receives 20 points and for each false answer, 10 points are deducted. After 5 correct answers, the subject goes to the next stage. The stabilization section divides into auditory and visual sections, so that each section divides into numbers, letters, and figures. After selecting each section, 9 cells are indicated. By selecting the difficulty level, numbers or letters or figures are heard or saw in these cells. Then, the subject should answer what is heard or saw that is randomly asked by the application. Again, the subject receives 20 points for each correct answer and for each false answer, 10 points are deducted.

3. Results

In order to analyze data, descriptive statistics indices and covariance test were used and the results are presented in the following. Frequency distribution of demographic characteristics is presented in Table 1. According to Table 1, the percentages of males and females are equal in research groups, so that in each group, 19 males and 3 females exist. Average age in test group is 8.95±1.56 and in control group is 9.36±1.47 and average IG in test group is 110.86±11.67 and in control group is 110.45±9.87.

Table 1. Frequency distribution of demographic characteristics

Demographic characteristics	Test group		Control group	
	Frequency	Percentage	Frequency	Percentage
Gender				
Male	19	86/4	3	13/6
Female	19	86/4	3	13/6
Age (year)				
7-9	16	72/7	6	27/3
10-12	14	63/6	8	36/4
IQ				
90-100	5	22/7	4	18/2
101-110	7	31/8	9	40/9
111-120	5	22/7	5	22/7
Above 120	5	22/7	4	18/2

Table 2 shows the results of executive functions for test and control groups at pretest, posttest, and posttest after removing pretest's effect. The resulted mean indicates increased posttest executive function compared with pretest in both test and control groups where the highest increase was observed in test group.

Table 2. The results of Tower of London Test for test and control groups in pretest and posttest

Variable	Stages	Test		Control	
		Mean	SD	Mean	SD
Tower of London Test	Pretest	24/86	3/907	26/73	5/479
	Posttest	31/86	2/933	28/59	3/775
	Posttest after removing pretest's effect	32/16	–	28/30	–

Table 3 shows the analysis of covariance test. To administer this test, first, homogeneity of slopes (F = 0.494 and p = 0.486) and homogeneity of error variances (F = 0.436 and p = 0.513) were investigated. The results of this test indicate that controlling the pretest score percentage, the result of Tower of London Test ($p<0.01$), and according to the estimated F, a significant difference exists between estimated mean of posttest scores and the final result of Tower of London Test between test group and control group. The differences show that 29% of the observed dispersion is the result of attention and working memory improvement training.

Table 3. The results of covariance test for posttest mean of scores in test and control groups in Tower of London Test controlling pretest.

Variable	Source of changes	Sum of squares	Degree of freedom	Mean of squares	F	Significance level	Eta square	Statistical power
Tower of London Test	Pretest	94/728	1	94/728	10/083	0/003	0/197	0/873
	Group	157/641	1	157/641	16/780	0/000	0/290	0/979
	Error	385/181	41	9/395				
	Total	40800/000	44					

4. Discussion

This study aimed to investigate the effect of working memory training on executive function of children with ADHD. Executive function refers to a set of processes that include planning, cognitive flexibility, working memory, organization, inhibition, and problem-solving. A significant number of studies show that disorders in behavioral manifestations of executive function are the key features of ADHD and treatments that target executive function disorders are important options for children with ADHD (Payne, Arnold, Pride & North, 2012). Executive function is an important brain activity dependent on prefrontal cortex and is measured by Tower of London Test. Findings confirmed significant changes in average executive function at the posttest in research groups.

Data showed that the executive function of the test group after receiving working memory training improved compared with the control group. The results of this study reemphasize the positive effect of working memory training on executive function of children with ADHD. In a study by Wang et. al. (2018), it was indicated that cognitive capacity increased by working memory training in both ASB and ADHD groups that is consistent with the present study (Wang et. al., 2018). Also, the present study is consistent with the following studies. A study by Nelvan et. al. (2018) showed that working memory training can influence mathematics and visual memory (Nelwan et. al., 2018). Shuai et. al. (2017) conducted a study on executive function training for children with ADHD and the results showed that the intervention leads to improved inhibition, working memory, planning, and decreased ADHD and daily life aspects (Shuai et. al., 2017).

Qian et. al. (2017) conducted a study that showed training improves executive skill (Qian et. al., 2017). A review study by Kwan et. al. (2015) on 695 articles to investigate the effects of cognitive training on ADHD symptoms, neuropsychological disorders and academic skills in children and adolescents with ADHD showed that in addition to improving the working memory functioning, those approaches that target different neuropsychological processes can optimize the transfer of effects from cognitive problems to clinical symptoms (Qian et. al., 2017). A study by Mahvash et. al. (2016) showed that working memory training influences cognitive problems and attention in children with ADHD (Wernoosfaderani, Mahaki & Ebrahimi, 2016).

Also, Samimi et. al. (2017) investigated the effect of emotional working memory training on executive functions of children with ADHD and the results showed that emotional executive function decreases response rate and improves reverse memory in these people (Wernoosfaderani et. al., 2016).

The most important limitation of the present study is the use of purpose sampling method and it is suggested to use other sampling methods with lower error rate for the future studies (Willcutt, Doyle,

Nigg, Faraone & Pennington, 2005). Also, it is recommended to investigate the effect of working memory on other disorders that hyperactive children suffer from, such as anxiety, depression, suicide, etc. Since most of disorders accompanied by ADHD continue until adulthood, similar studies on adults with ADHD and comparing the results with children suffering from ADHD can provide interesting and useful results (Hummer et. al., 2011).

According to the findings, it can be said that working memory training can be used in medical centers. Psychiatrics and clinical psychologists can use working memory training method beside other therapies such as drug therapy and neurofeedback to improve executive functions of people with ADHD. For this reason, children with ADHD show different neuropsychological symptoms and they may be influenced by more than one disorder. Multi-component training can be used to target a series of neuropsychological domains (Cortese et. al., 2015).

Moreover, it is useful to train teachers and parents of children with ADHD and normal children to use this strategy to decrease children's impulsive behavior and increase their social skills.

5. Conclusion

Finally, working memory training can significantly and positively influence ADHD improvement in children who suffer from it.

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