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The Effectiveness of Working Memory Training on Planning and Executive Functions in Children with Learning Disabilities

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Abstract: The aim of this study was to investigate the effectiveness of working memory training on the planning and executive functions in children with learning disabilities. The method of the present study was quasi-experimental pretest-posttest with a control group. The statistical population of the present study included all LD children of Bushehr, Iran in 2021. The participants were 30 students who were selected by accessible sampling method and randomly assigned to experimental and control groups. Data were collected using the Tower of London (TOL) scale and Gioia et al. Behavior Rating Inventory of Executive Function (BRIEF). Working memory training using the protocol of Shaykh al-Islami et al. (2017) was presented to children with learning disabilities in the experimental group during 17 sessions. The control group did not receive any intervention during this period. The results showed that the training of working memory significantly increased the planning and components of executive functions (inhibition, working memory, shifting, planning/organizing and emotional control). These results confirmed the practical and theoretical importance of working memory training programs as methods of training planning and executive functions in L.D children.

Keywords: Executive functions, L.D Children, Planning, Working memory training

Introduction

Learning disorders can appear in different ways in children and it accounts for many cases in the clinical examination issues. Learning disabilities include a wide range of abnormalities and problems; these defects may occur in children's verbal and expressive ability, or appear in the form of a deficiency in math performance or even in the form of difficulty in reading and writing and can be exhibited as primary conditions—as difficulties in attaining specific academic skills—or as secondary conditions, comorbid to other developmental disorders such as attention-deficit hyperactivity disorder (Grigorenko et al., 2020). The parents and teachers, who have the most knowledge about the child's behaviors and reactions, should be well familiar with the signs and symptoms of children's learning disabilities and not confuse these problems with the child's playfulness and mischief. Thus, parent participation in treatment enactment is advisable (Matson, Mahan, & LoVullo, 2009). Sometimes it can be very difficult to diagnose learning disorders in children because there is no list of definitive

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criteria for diagnosing these disorders and the symptoms are diverse in different children (Jones, Hanley, & Riby, 2020). Children with learning disabilities usually have good intelligence and develop quite normally. They have balanced behaviors in the home environment, but when learning, they have defects in receiving, processing and storing information due to disruption in the neural pathways and brain communication ability (Pickard, Malloy, Porteous, Blackwood, & Muir, 2005). It is important to carefully examine the cause of learning disorders because these behaviors may have appeared as a sign of metabolic diseases or genetic defects that definitely need follow-up and treatment (Semrud-Clikeman, 2005).

Several interventions have been proposed to treat learning disorders (Lagae, 2008; Reschly, 2005). Working memory training is one of these interventions designed to improve the planning and executive functions of children with learning disabilities (Peijnenborgh, Hurks, Aldenkamp, Vles, & Hendriksen, 2016). Memory plays a key role in the learning process, but with the change in the focus of the educational system from passive memory to working memory, it has become the center of attention of the educational system (Owens, Stevenson, Norgate, & Hadwin, 2008). Working memory is effective in many daily activities such as reading, problem solving and remembering. Some researchers consider the role of active memory in academic success even more than intelligence (Van't Wout, O'Donnell, & Jarrold, 2019). Since working memory is a tool for keeping information that is stored in short-term memory, the strategy to strengthen this memory is a skill that all children should learn (Patchan & Puranik, 2016). Working memory is needed to perform tasks such as following multi-step instructions or mentally solving math problems, and it plays an important role in the process of conscious processing and management of information to perform complex cognitive activities such as learning, reasoning and understanding (Zhao, Li, Zhao, Gaspar, & Weng, 2015).

Executive functions are one of the characters that are affected by working memory training and can play an effective role in the lives of children with learning disabilities (Lima, Azoni, & Ciasca, 2011). Processes such as concentration, attention, planning, controlling thoughts and behavior, and organizing reasoning are among the cognitive functions that enable humans to perform intelligent activities (Pastor-Cerezuela, Fernández-Andrés, Sanz-Cervera, & Marín-Suelves, 2020). Executive functions perform these tasks with the help of a group of important functions including working memory, flexibility, response inhibition, reasoning, planning and attention. Important changes in executive functions occur between 2 and 5 years of age. Then, these functions grow at the same time as the child grows, and at around 12 years of age, the child's function becomes similar to that of adults (Hawco et al., 2020). A child's failure in performing executive functions can be determined based on the complexity and difficulty of the tasks (Casartelli, Riva, Villa, & Borgatti, 2018). Executive functions as a cognitive structure are responsible for tasks such as problem solving, attention, reasoning, organization, planning, memory, inhibitory control, impulse control, maintaining intention, changing intention and inhibiting response; As a result, disruption in these functions disrupts daily functions (Friedman & Miyake, 2017). Baddeley and Hitch (2000) offered a model of working memory that comprised a phonological loop, a visual spatial sketchpad and a central executive responsible for the

control and regulation of cognitive processes (such as planning and organization of information). Planning refers to the ability to identify and organize the steps and elements needed to achieve a goal (Lezak, Howieson, Loring, & Fischer, 2004). Planning is a multifaceted activity that requires complex cognitive demands (Grafman, 1999). In other words, planning includes the ability to decide on setting priorities. According to researches, studying materials in a distributed style provides the time needed to process information; therefore, students who study distributed have better performance compared to students who study intensively (Eskandari, Kakabraee, Amiri, & Hoseini, 2020). Some studies have pointed out the effectiveness of working memory training on the planning and organization skills of students with learning disabilities (Beck, Hanson, Puffenberger, Benninger, & Benninger, 2010; Bigorra, Garolera, Guijarro, & Hervás, 2016; Sabeghi, Mohammadyfar, & Rezaei, 2022). (Nelwan, Vissers, & Kroesbergen, 2018) have shown that working memory training is an effective method in increasing the ability related to school assignments. The results indicated after receiving working memory training, the highly coached group performed better than the group that received less coaching on visual working memory and mathematics, but not on verbal working memory.

In other studies, the effectiveness of working memory training on a number of cognitive outcomes has been investigated. Dahlin (2011) investigated the relationship between working memory and reading achievement in 57 Swedish primary-school children with special needs. The results indicated that working memory can be seen as a important factor in the reading development of literacy among children with special needs, and that interventions to increase working memory may help children becoming more capable in reading comprehension. Furthermore, Hayashi (2019) investigated the effects of working memory training on foreign language development and indicated the possibility of more specialized WMT programs translating into more tangible gains in second or foreign language performance. In a study in developmental dyslexia (DD) children, Yang, Peng, Zhang, Zheng, and Mo (2017) examined the general and specific effects of working memory training on the reading skills of 45 Chinese children with developmental dyslexia, grades 3 to 5. Results showed that WM training enhanced specific reading-related cognitive skills that are highly associated with the specific WM components that were the goal of training. In a study, 176 children with WM deficits, aged 7–15 years performed 5 weeks of working memory training. Results indicated the training group enhanced significantly more than the control group on all three transfer tests, after correction for baseline performance, age and sex. The effect size for mathematics was small and the effect sizes for the WM tasks were moderate to large. Furthermore, the transfer increased linearly with the amount of training time and correlated with the amount of improvement on the trained tasks (Bergman-Nutley & Klingberg, 2014).

Among thinking skills, working memory plays the most important role in academic performance. Verbal memory plays an important role in understanding content, understanding syllables, solving math problems, and unraveling verbal problems. Since children with learning disorders have problems in executive and planning functions, it seems that interventions such as working memory training can help improve these functions in these children. Therefore, the aim of the present study was to

investigate the effectiveness of working memory training on executive functions and planning in children with learning disabilities in Bushehr city (Iran).

Material and Methods

In this research, a semi-experimental method was used with a pre-test-post-test design with a control group. The statistical population of this research included all children with learning disabilities in Bushehr city in 2021. The sample consisted of 30 children with learning disabilities who were selected by accessible sampling method and randomly assigned to the experimental group (15 students) and the control group (15 students). The participants of the experimental group underwent the intervention of working memory training for 17 sessions, but the control group did not receive any intervention. The inclusion criteria included: 1- having a learning disorder 2- having the motivation to attend meetings regularly. Also, the exclusion criteria for leaving the research included: 1- Not attending more than two consecutive sessions, 2- Requesting non-cooperation by the child. The participants were assured that the in responding the questionnaires no need to write the name and surname. They were also assured that participation in the research is voluntary and they can leave the training sessions whenever they want. All participants completed the informed consent form before the study as well.

Instruments

1) Behavior Rating Inventory of Executive Function: The Executive Functions Behavior Rating Questionnaire (Parent Form) was prepared by Gioia, Isquith, Guy, and Kenworthy (2000). This questionnaire has two forms for parents and teachers and has 86 questions with a three-point Likert scale, which is scored "never", "sometimes" and "always" respectively from 1 to 3 by the parents. Each of the questions is related to one of the subsets of the questionnaire, and these subsets are divided into two main parts: behavior regulation skills and metacognitive skills, which are as follows: a) Behavior regulation skills: inhibition, transfer , emotion control b) Metacognitive skills: planning, organizing materials, monitoring, working memory, initiation. Gioia et al. (2000) have reported the reliability of the questionnaire in their research with the Cronbach's alpha coefficient of 0.86. The reliability of this questionnaire in the present study was obtained by Cronbach's alpha method of 0.86. Gioia et al. (2000) have reported the satisfactory validity of the questionnaire in their research with the factor analysis.

2) Tower of London Test (TOL): The Tower of London test is a scale used in applied clinical neuropsychology for the evaluation of executive functioning specifically to detect deficits in planning. A computerized variant, known as the Stockings of Cambridge test, is available as part of the Cambridge Neuropsychological Test Automated Battery (CANTAB). The computerized variant was used in present study. This test has four stages; each stage becomes progressively more difficult than the previous stage. The scoring method is based on how many attempts a person solves the problem, a total score is given to him (more attempts, lower score and vice versa). Shallice (1982) reported the reliability of the questionnaire in his research with the Cronbach's alpha coefficient of 0.85. The reliability of this questionnaire in the present study was obtained with the help of Cronbach's alpha

coefficient of 0.83. Shallice (1982) has reported the satisfactory validity of the questionnaire with the factor analysis.

WM training protocol: In this research, WM training protocol was presented to children with learning disabilities using the protocol of Sheykholeslami, Bakhshayesh, Barzegar Bafrooei, and Moradi Ajami (2017) during 17 sessions. This protocol includes training to remember and recall a few letters, numbers or simple words after a few seconds, as well as recalling the first or last letter, number and word, training to hide one of the objects, identifying deleted objects, recalling seen objects, training remembering seen objects, remembering faces and repeating patterns, repeating auditory and visual memory exercises, recall training in reverse order, etc.

Results

In Table 1, the mean and standard deviation of planning variable and components of executive functions are presented. Table 2 shows the results of the Kolmogorov-Smirnov test to test the normality of the data. According to Table 2, the significance level for planning and executive functions is more than 0.05, based on this, the data distribution of these variables is normal.

Table 1. The mean and standard deviation of the planning variable and components of executive functions, of the experimental and control groups in the post-test

Variable	Experimental group		Control group	
	Mean	SD	Mean	SD
Planning	18.07	0.41	15.92	0.31
Inhibition	21.57	0.45	19.02	0.45
Attention transfer	15.46	0.34	13.23	0.34
Emotional control	13.13	0.36	10.66	0.36
Initiation	11.07	0.24	9.12	0.24
Working memory	14.87	0.35	12.42	0.35
Executive planning	21.63	0.39	18.96	0.39
Organizing materials	10.48	0.24	7.81	0.24
Control	12	0.21	9.79	0.21

Table 2. Kolmogorov-Smirnov test results

Variable	Group	Statistic	p
Planning	Experimental	0.15	0.2
	Control	0.19	0.12
Executive functions	Experimental	0.17	0.2
	Control	0.23	0.05

The results of the one-way covariance analysis related to the comparison of the planning mean of the two groups in the post-test are presented in Table 3. According to Table 3, the mean of the planning variable of the experimental group in the post-test is significantly higher than the mean of the control group.

Table 3. Results of one-way covariance analysis related to the effect of WM training on planning

Source	SS	DF	MS	F	p	Eta
Pretest	82.26	1	82.26	48.33	0.001	0.74
Group	23.06	1	23.06	13.55	0.002	0.44
Error	28.93	27	1.7	-	-	-
Total	5920	30	-	-	-	-

The results of Table 3 show that after controlling the effect of the pre-test, the calculated F equals 13.55 is significant at the level 0.002. Therefore, WM training has improved planning. According to the of Eta coefficient the impact of the intervention is equal to 0.444, which means that the intervention explains 44.4% of the planning variance. In Table 4, the results of multivariate covariance analysis on post-test scores of executive function components are presented.

Table 4. Results of multivariate covariance analysis on the post-test scores of executive function components

Effect	Test	Value	F	Hypothesis DF	Error DF	p	Eta
Group	Pillai's trace	0.963	9.78	8	3	0.04	0.963
	Wilks' lambda	0.963	9.78	8	3	0.04	0.963
	Hotelling's trace	26.09	9.78	8	3	0.04	0.963
	Roy's largest root	26.09	9.78	8	3	0.04	0.963

According to Table 4, there is a significant difference between the experimental and control groups in at least one of the components of executive functions. In other words, WM training has improved at least one of the components of executive functions in the experimental group compared to the control group. In Table 5, the results of the one-way covariance analysis embedded in MANCOVA related to the components of executive functions are presented.

Table 5. Results of one-way covariance analysis embedded in MANCOVA of the components of executive functions

Source	Variable	SS	DF	MS	F	p	Eta
Group	Inhibition	29.85	1	29.85	15.15	0.003	0.60
	Attention transfer	22.78	1	22.78	19.88	0.001	0.66
	Emotional control	27.92	1	27.92	22.03	0.001	0.69
	Initiation	17.48	1	17.48	30.75	0.001	0.75
	Working memory	27.39	1	27.39	22.97	0.001	0.69
	Planning	32.79	1	32.79	22.11	0.001	0.68
	Material organization	32.80	1	32.80	58.41	0.001	0.85
	Control	22.51	1	22.51	51.21	0.001	0.83

According to Table 5, there is a significant difference between the experimental and control groups in terms of each of the components of executive functions, i.e. inhibition (F=15.15, P=0.003), attention transfer (F=19.88, P=0.001), emotional control (F=22.03, P=0.001), initiation (F=30.75, P=0.0001), working memory (F=22.97, P=0.001), planning (F=22.11, P=0.001), organization of materials (F=58.41, P=0.0001) and control (F=51.21, P=0.0001). In other words, WM training improved all components of executive functions in the experimental group compared to the control group.

Discussion

The aim of this study was to investigate the effectiveness of WM training on improving planning and executive functions of children with learning disabilities. The results of the research indicated that WM training improved the planning of the experimental group compared to the control group. Also, the intervention improved each of the components of executive functions, i.e., inhibition, attention transfer, emotional control, initiation, working memory, planning, material organization, and control in the experimental group. The findings of the present research are in line with the findings of Pastor-Cerezuela et al. (2020), Peijnenborgh et al. (2016), Bergman-Nutley and Klingberg (2014).

WM training is one of the appropriate methods to improve reading and writing disorders and academic self-esteem of children with learning disorders. Working memory is effective in many daily activities such as reading and problem solving. WM is a cognitive structure providing temporary access to symbols needed for complex cognition in the current moment. The individual capability limit of this essential ability is supposed to be a largely stable trait, and previous research revealed a strong association between WM capacity and multiple other cognitive abilities (Barrett, Tugade, & Engle, 2004). WM training is one of the suitable methods to improve the reading disorder of children with learning disabilities. Working memory refers to the storage of information that is stored in short-term memory. Active memory plays an important role in the process of conscious processing and management of information to perform complex cognitive activities such as learning, reasoning and understanding (Shipstead, Hicks, & Engle, 2012). Defects in working memory cause disruption in the efficiency and learning of calculations and solving complex problems. Hudson, Shapiro, and Sosa (1995) stated that children as young as three are able to build different types of verbal plans, such as planning for familiar events. This primary type of planning is different to that found in children of 7 to 11 years who display strategic behavior and reasoning capabilities leading to more organized and competent planning. WM training can improve planning from the point of view that many of the skills required for planning are obtained through memory and its strengthening. During planning, the working memory capability plays an vital role for keeping and organizing the sub-goal sequences (Goela, Pullara, & Grafman, 2001). Working memory defines the ability to temporally keep information in mind and is related not only to planning and problem solving but to comprehension, reasoning, and learning as well.

The findings showed that WM training also improves executive functions. Executive functions permit people to change their mind set rapidly and adapt to various situations while at the same time preventing unsuitable behaviors. They allow people to create a plan, initiate its execution, and persevere on the task at hand until its completion. Executive abilities mediate the capability to organize our thoughts in a goal-directed way and are therefore crucial for success in school and work situations, as well as everyday living (Barker et al., 2014). WM training can expand executive functions in the sense that memory is at the center of executive functions. In other words, executive functions process information with the help of memory and create cognitive outputs.

In addition to the obtained findings, the present study also has limitations that should be taken into consideration in the generalization of the findings. One of these limitations is the use of self-report questionnaires, which are based on the participants' verbal reports. Parents' assessment of children's behavior may be biased. It is suggested to use other methods of data collection such as observation in future studies. Also, the length of the training sessions made the children tired, which may affect their performance. Therefore, it is suggested to design the WM training program in the form of short-term interventions and use it to improve the executive functions of children with learning disabilities. It is also suggested that in future studies, the effect of WM training on the executive functions of other samples should be investigated.

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