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Effectiveness of Neuropsychological Intervention on Reading Performance and Executive Functions in Dyslexic Children

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ABSTRACT: The present study aimed to examine the effectiveness of neuropsychological intervention on reading performance and executive functions in dyslexic children. The research method was quasi-experimental. The statistical population of this study included all third grade dyslexic students who referred to the Learning Disabilities Centers in Zahedan in 2021. A total of 28 patients were selected by convenience sampling method and randomly assigned to experimental and control groups (14 people in each group). The neuropsychological intervention was performed in the experimental group for 15 one-hour sessions. Reading and Dyslexia Test (NEMA) (KaramiNouri & Moradi, 2005) and Behavior Rating Inventory of Executive Function (Gioia et al., 2000) was used to collect data. Multivariate analysis of covariance was used to analyze the research hypotheses. The results indicated that the neuropsychological intervention is effective on both reading performance (except for the elimination of sounds and words-fake reading) and executive functions (P <0.01). Furthermore, the results of repeated measures ANOVA showed that the results were significant in the follow-up phase (P <0.01). The findings generally indicated that the intervention can be used as an effective treatment of dyslexia in learning disabilities treatment centers.

Keywords: Neuropsychological intervention, Reading function, Executive functions, Dyslexia.

Introduction

In today's complex world, literacy, which means learning to read, write and calculate, is a must and is one of the most basic human needs and is considered as the basis of his other learning. But on the other hand, despite the importance of learning in human life, there are a lot of children who are seemingly physically normal but have difficulty learning (Toffalini, Giofrè, & Cornoldi, 2017). According to the fifth edition of the Diagnostic and Statistical Manual of Mental Disorders, special learning disorders refer to a group of neurodevelopmental disorders characterized by abnormalities in the cognitive levels associated with behavioral cues, efficient and appropriate processing and processing of verbal and nonverbal information (Association, 2019). One of the disorders in this section is dyslexia (Di Folco, Guez, Peyre, & Ramus, 2020). Although these children have natural intelligence and on the other hand do not have serious sensory-motor problems, but they are not able to read correctly and smoothly according to their age and cognitive abilities (Adlof & Hogan, 2018). Dyslexia is characterized by difficulty in correctly or fluently recognizing the word and poor decoding ability. The prevalence of this disorder has been estimated at 5 to 15% (Petretto & Masala, 2017). Dyslexics are children who are familiar with words and use them in conversation, but are not able to understand and recognize written or typed signs. Some of them, although able to read, do not have a proper understanding of the meaning

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of the word (Snowling, Hulme, & Nation, 2020). Different areas of dyslexia in children are impaired. In this study, reading performance and executive functions were examined.

Acquiring reading skills is one of the most important factors in human development. In addition to improving life skills and knowledge, reading also influences children's imaging process and plays a major role in the development of emotions, ethics and verbal intelligence (Hulme & Snowling, 2016). Reading is a very complex process that has various stages and requires the organization of extensive cognitive activities to decode, understand and learn from the text (Tikdari & Kafi, 2020). Dyslexia impairs reading comprehension fluency or accuracy and can present itself as a problem in phonological awareness, phonological decoding, processing speed, written coding, short-term auditory memory, language skills, and overt oral comprehension (Bjekić, Obradović, Vučetić, & Bojović, 2014). Numerous studies have shown impairment in reading performance in dyslexic individuals (Hemati Almdarloo & Tavakoli, 2020; Johnston, 2019). On the other hand, studies have shown that in dyslexic individuals, executive functions will also be impaired (Barbosa, Rodrigues, Mello, Silva, & Bueno, 2019; MEDINA & GUIMARÃES, 2021). Executive functions are a set of functions that are used when individuals are placed in situations that require cognitive processes to achieve optimal performance (Pasqualotto & Venuti, 2020). The term uses a set of cognitive processes to help a person perform a purposeful, new, challenging adaptive behavior, and these functions are skills that help a person pay attention to important aspects of the task and plan to complete it (Soares, Guerra, Roy, Hazin, & Azoni, 2020). Features such as goal setting, planning, behavioral organization, flexibility, memory and attention systems, problem solving, and observation are required during an executive function (Fischer & Daley, 2007). They are also a set of cognitive yet distinct processes that are responsible for the ability to control cognition and behavior and are located in the cerebral cortex (Ambrosini, Arbula, Rossato, Pacella, & Vallesi, 2019).

Due to the relatively high prevalence of dyslexia and its importance in other aspects of children's lives and due to the fact that this disorder has various causes, different treatment methods have been considered (Davies & Bose, 2020). One of these therapies is neuropsychological treatment (Kappers, 2020). Research suggests that dyslexia is closely related to the neuropsychological domain, which indicates that different parts of the brain are involved in this disorder (Solovieva, Koutsoklenis, & Quintanar, 2021). Research evidence has shown that in the brains of dyslexics, parts of reading and executive functions are impaired (Carioti et al., 2022; Vernet, Bellocchi, Leibnitz, Chaix, & Ducrot, 2021). Neuropsychological intervention examines the structure and functions of the brain that are related to psychological and behavioral processes. Neuropsychological examinations include tests to evaluate brain function in a clinical setting to diagnose disorders. These examinations are an experimental field in psychology that aims to understand how behavior and cognition are affected by the brain and examine the diagnosis and treatment of behavioral and cognitive effects of neurological disorders (Andrewes, 2015). Centanni et al. (2018) indicated that more than half of dyslexic children have significantly higher levels of variability and instability in cortical responses to visual and auditory stimuli.

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The results of Momeni, Malekpour, Abedi, and Faramarzi (2018) indicated that the test scores of the neuropsychological group were significantly more efficient than Davis method. Therefore, neuropsychological interventions can be an effective approach in treating learning disabilities (dyslexia). Also, the results of Bayrami, Movahedi, Esmaili, and Zorahim (2016) showed that neuropsychological rehabilitation caused a significant difference in the status of speed, accuracy and reading comprehension in the subjects of the intervention group compared to the control group. Therefore, neuropsychological rehabilitation interventions are effective in treating dyslexia.

Neuropsychological therapy seeks to understand how children's brains and functions relate to each other. Because improving reading performance and executive functions in dyslexic children is a complex activity, developing these skills can help make progress in other areas of children's lives. Also, since this disorder has a relatively high prevalence, conducting this research can provide useful and practical information to treat this disorder to specialists. Therefore, researchers in this study seek to answer the question of whether therapy based on neuropsychology method is effective in improving reading performance and executive functions of dyslexic children?

Material and Methods

The research method in this study was a quasi-experimental two-group pretest–posttest design. The statistical population of this study included all third grade students with dyslexia who referred to the Learning Disorders Centers in Zahedan, Iran in the fall of the academic year 2021. Since the basis for sample selection in experimental research for each group is 15 people (Delavar, 2017), according to this, 30 people (19 third grade boys and 11 third grade girls) referred to the two centers of Learning disabilities in Zahedan, Iran were selected by convenience sampling method and randomly assigned to an experimental group (neuropsychological method) and a control group, i.e. 15 people in each group. During the study, a number of subjects were excluded from the study, so that a girl from the neuropsychology group left the group (10 boys, 4 girls). After that, a girl was removed from the control group by the researcher (9 boys, 5 girls), finally 28 subjects participated in the study. Criteria for entering the intervention program were: IQ equal to or higher than 85 according to the client's record, healthy eyesight and hearing, third grade student, inability to read based on the diagnostic test of dyslexia. Criteria for leaving the program include: having other neurological disorders such as attention deficit / hyperactivity disorder and autism, having significant sensory-motor problems, taking Ritalin, missing more than 3 sessions in therapeutic interventions, simultaneous participation in therapeutic programs.

The following tools were used to collect data:

1. Reading and dyslexia test (NEMA): NEMA test was developed and designed by Karami Nouri and Moradi (2005) and has been standardized on 1614 students (770 male students and 844 female students) of primary schools in Tabriz, Sanandaj and Tehran. This test consists of 10 subscales that aim to assess the reading ability of elementary school students and diagnose students with reading problems and defects. Given that the cut-off point for this test is 157, students who score 157 or less (154 errors or more) in this test are considered dyslexic students. The correct answers are calculated by referring to the

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table of correct answers, then by referring to the relevant table, a balanced score is obtained. This word reading test consists of three lists of 40 words, words such as lead and fox with Cronbach's alpha are 0.98, words such as water and jelly with Cronbach's alpha are 0.91 and words like tables and buses with Cronbach's alpha are 0.85, in the NEMA test, Cronbach's alpha for the comprehension of words is 0.73, Cronbach's alpha for the word chain test is 0.65, Cronbach's alpha for the the text comprehension e is 0.75, Cronbach's alpha for the elimination of sounds is 0.78, Cronbach's alpha for the signs of letters is 0.66, Cronbach's alpha for the signs of words is 0.75 and Cronbach's alpha for the test of rhymes is 0.88, which includes three areas of speed of reading, correct reading and reading comprehension of the subjects. The internal consistency of this test is 0.81 and its Cronbach's alpha coefficient is calculated to be 0.83 (Karami Nouri & Moradi, 2005). The content validity of the test was adjusted based on the correct reading of words and sentences and finally their comprehension by learners and its validity was confirmed by professors and experts (Hosseini, Moradi, Kormi Nouri, Hassani, & Parhoon, 2016).

2. Behavior Rating Inventory of Executive Function (Parent Form): The Behavior Rating Inventory of Executive Function has been prepared by Gioia, Isquith, Guy, and Kenworthy (2000). This questionnaire has the form of parents and teachers. The questionnaire consists of 86 questions that are applicable to children aged 6 to 12 years and measures 8 components "inhibition, displacement, emotion control, initiation, working memory, strategic planning, organizing and monitoring." In this study, only questions of two components of working memory (including 11 questions) and planning (including 15 questions) were used. To score the questionnaire in the Likert scale, it is 3 points in such a way that it is awarded (never 0 points, sometimes 1 point and always 2 points). In one study, Cronbach's alpha was used to examine the internal consistency of the questionnaire. The coefficients for inhibition were 0.85, displacement 0.77, emotion control 0.78, initiation 0.68, working memory 0.77, strategic planning (planning) 0.86, organization 0.77, and supervision 0.77 (Abdolmohamadi, Alizadeh, Farhad, Taiebli, & Fathi, 2018). The internal consistency coefficient for this questionnaire in Nodeei, Sarami, and Keramati (2016) research was obtained from 0.87 to 0.94, which indicates the high internal consistency of all components of the questionnaire. In foreign studies, the reliability of the questionnaire through Cronbach's alpha method has been reported between 0.80 to 0.98 and its retest reliability has been 0.82 (Balsamo et al., 2019).

Intervention: In this study, the intervention program of neuropsychological method was used. The neuropsychological intervention was designed and implemented based on a combination of training programs of Kolkman, Hoijtink, Kroesbergen, and Leseman (2013) and Gray et al. (2012) (Table 1). The different stages of this educational method in this study were performed in the form of fifteen 60-minute sessions in groups by two graduates of the Master of Psychology and Exceptional Children after their training by the researcher. After screening, people with dyslexia were randomly assigned to an experimental group and a control group. The intervention period was in the fall of 2021 and the intervention sessions for the experimental group were held in each one-hour session which lasted a total of 15 sessions (although the principle of intervention programs is 10 sessions, but due to the time consuming content and direction training Improving the quality of the intervention was held in 15

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sessions with the same content of sessions). Finally, after the sessions, both groups were assessed by post-test. The groups were re-evaluated for a follow-up period after two months after the post-test. Multivariate analysis of covariance (MANCOVA) was used to analyze the research data.

Table 1. Summary of neuropsychological interventions

Session	Contents	
1-3	Language	In these sessions, the researcher strengthened auditory attention, auditory clarity, auditory sensitivity, phonological awareness, comprehension of sentences and problems, comprehension of auditory content, comprehension of words and concepts.
4-6	Active memory	In these sessions, the researcher strengthened auditory memory, visual memory, auditory and visual memory exercises, playing with pictures, executing commands, showing videos, recognizing memory, reminder memory, learning list, and following instructions.
7-9	Executive Functions	In these sessions, the researcher reinforces planning for a short-term goal, designing cubes, building towers, maintaining and recalling details of a task, and sorting cards by color, shape, and size.
10-12	Attention Enhancement	In these sessions, the researcher enhanced auditory attention, visual attention, rhythmic movements, maintenance and change of attention, playing with dolls and crowded cards.
13-15	Visual-spatial processing	In these sessions the researcher to strengthen the coordination of eye movement, identify geometric shapes, position in space, navigation in mazes, orientation, perception of shape, perception of shape and context, spatial awareness, copying an image from different images.

Results

Table 2 shows the mean and standard deviation of reading performance (its components) and executive functions (its components) in each group in pre-test, post-test and follow-up.

Table 2. Mean and standard deviation of reading performance (its components) and executive functions (its components) in experimental and control groups

Variables	Phase	Group			
Components		Neuropsychological intervention		Control	
		Mean	SD	Mean	SD
Reading performance	Pretest	124.14	6.37	124.21	7.95
	Post test	140.36	8.25	123.29	5.25
	Follow-up	135	6.49	124.57	6.22
Words reading	Pretest	32.14	2.71	32.14	1.75
	Post test	34.21	2.55	32.79	1.97
	Follow-up	33.07	2.27	33.29	1.64
Words chain	Pretest	9.93	.92	9.64	.93
	Post test	13.14	1.29	10.43	.85
	Follow-up	12.07	1.44	10.57	1.22
Rhymes	Pretest	1.14	.77	4.21	.58
	Post test	5.57	1.09	3.93	.62
	Follow-up	5.07	.92	4.07	.62
Naming the pictures	Pretest	17.36	1.34	16.93	1.59
	Post test	18	1.18	16.36	1.50
	Follow-up	17.64	1.39	15.57	1.74
Understand the text	Pretest	5.43	.94	5.71	.91
	Post test	7.07	1.14	6.07	.62
	Follow-up	6.64	.93	5.29	.47
Understand the words	Pretest	6.36	1.01	6.57	.85
	Post test	6.57	1.02	6.21	1.12
	Follow-up	6	.68	5.57	.76
Delete sounds	Pretest	4.29	.47	4.50	.76

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	Post test	4.86	.77	4.50	.94
	Follow-up	5	.96	4.14	1.10
Words-fake reading	Pretest	12.71	.83	13.07	.62
	Post test	13.43	.76	13.43	1.28
	Follow-up	12.86	.66	13.21	1.37
Letter signs	Pretest	6.14	1.75	5.57	1.09
	Post test	8.50	1.79	5.43	1.28
	Follow-up	7.36	1.74	5.21	1.37
Signs of categories	Pretest	25.64	1.55	25.86	1.35
	Post test	29.71	3	25.79	1.37
	Follow-up	27.93	1.98	24.86	2.48
Executive functions	Pretest	26.21	2.22	25.50	3.63
	Post test	33.57	2.59	25.21	3.47
	Follow-up	32.29	2.79	25.29	3.83
Working memory	Pretest	12.14	1.35	11.86	2.07
	Post test	15.50	1.51	11.71	2.13
	Follow-up	14.50	1.34	11.43	1.45
Planning	Pretest	14.07	1.44	13.86	2.11
	Post test	18.07	1.33	14.36	2.24
	Follow-up	17.79	1.76	14.14	2.18

According to the information in Table 2, the average reading performance and all its components (except fake words reading) in the post-test group of the neuropsychological method is higher than the control group. Also, the average of executive functions and its components in the post-test group of the method Neuropsychology is higher than the control group.

To investigate the effect of the intervention on the dependent variable, the analysis of covariance was used, which requires the establishment of assumptions. One of the assumptions is the normality of the data. To examine it, Kolmogorov-Smirnov test was used, which due to the lack of statistical significance in all components of reading performance and executive functions, the assumption of the normality of the data was confirmed. Levin test was used to evaluate the homogeneity of variances, the results of which indicate the lack of significance and the establishment of this hypothesis. The results of M-box test to examine the homogeneity of the covariance matrix also indicated that this assumption was not significant. Table 3 shows the results of multivariate analysis of covariance to evaluate the effect of neuropsychological method on reading performance. The Wilks' lambda level of this test (F = 48.53, P <0.001) indicates that there is a difference in the post-test and the significance of the intervention.

Signs of categories 96.30 1 96.30 19.60 .001 .55

Table 3. Multivariate analysis of covariance test The effectiveness of neuropsychological method on reading performance

Dependent variable	SS	DF	MS	F	*p*	Eta
Read the words	13.27	1	13.27	12.33	.003	.43
Chain of words	28.46	1	28.46	50.12	.001	.75
Rhymes	18.06	1	18.06	102.96	.001	.86
Naming the pictures	7.30	1	7.30	38.55	.001	.70
Understand the text	4.75	1	4.75	9.29	.008	.36
Understand the words	2.20	1	2.20	4.81	.04	.23
Delete sounds	.71	1	.71	2.35	.14	.12
Fake words	.96	1	.96	2.16	.16	.11
Signs of letters	32.81	1	32.81	127.90	.001	.88
Signs of categories	96.30	1	96.30	19.60	.001	.55

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Table 3 shows the results of the multivariate analysis of covariance. The obtained F values were significant for all dependent variables except the components of sound elimination and reading of fake words at the level of P <0.05. Therefore, it can be said that the neuropsychological method has also had a significant effect on the components of word reading (except for the elimination of sounds and reading fake-words).

Table 4 shows the results of multivariate analysis of covariance to evaluate the effect of neuropsychological method on executive functions. The Wilks' lambda level of this test (F = 105.28, P <0.001) indicates that there is a difference in the post-test and the significance of the intervention.

Table 4. Multivariate analysis of covariance test related to effectiveness of neuropsychological method on executive functions

Dependent variable	SS	DF	MS	F	*p*	Eta
Working memory	85.57	1	85.57	123.80	.001	.83
Planning	82.41	1	82.41	189.29	.001	.88

Table 4 shows the results of the multivariate analysis of covariance. The obtained F values were significant for both dependent variables of working memory and planning at the level .05.

To assess of the follow-up effect, repeated measures analysis of variance was used. The results are presented in the following table.

Table 5. Analysis of repeated measure analysis of variance for reading performance and executive functions

Dependent variable	Source		SS	DF	MS	F	*p*	Eta
Reading performance	Within groups	Factor	.90	184.88	2	38	.001	.43
		Interaction	1.05	21.95	4	78	.001	.53
	Between groups	Group	204.33	2	102.16	7.40	.002	.27
Executive functions	Within groups	Factor	.54	22.60	2	38	.001	.54
		Interaction	.69	10.37	4	78	.001	.34
	Between groups	Group	15.49	2	7.74	6.38	.004	.24

The results of Table 5 show that with the significance of the factor and the interactive effect within the group, there is a significant difference between the three measurements of pre-test, post-test and follow-up on the dependent variable of reading performance and executive functions and the interaction of three measurement steps with the two experimental and control groups are confirmed at the level 0.01. Therefore, the effectiveness of neuropsychological method on improving reading performance and executive functions of dyslexic children in the follow-up period has been lasting.

Discussion

Findings showed that neuropsychological method has a significant effect on reading performance and its components, word chain, text comprehension, rhymes, naming images, word comprehension, letter signs and category signs and it has no significant effect on the components of eliminating sounds and

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reading fake words. This effectiveness was also significant in the follow-up phase. This finding is in line with previous findings in this field (Babapour, Porsharifi, & Hamedi, 2015; Bayrami et al., 2016; Hosseinkhanzadeh, Latif, & Taher, 2018; Momeni et al., 2018). The results of Momeni et al. (2018) showed that the test scores of the neuropsychological group were significantly more efficient than Davis method. Also, Bayrami et al. (2016) in their research concluded that neuropsychological rehabilitation caused a significant difference in the status of speed, accuracy and reading comprehension in the subjects of the intervention group compared to the control group.

Explaining this finding from the present study, it can be acknowledged that children must have mastered a set of skills to master reading. These skills have aspects of the psychological nerve and are acquired through experience, teaching and learning. Most children learn these skills automatically, but children with dyslexia have difficulty learning these skills and need to be taught. In other words, identifying the problems that dyslexic students have in neuropsychological skills can help the training set to understand how the problem is or to design appropriate training programs. Psychological variables can also be considered as predictors of reading progress, because even if they cannot specify IQ scores alone, they will have accurate predictions when added to IQ scores. In other words, identifying the problems that dyslexic students have in terms of neuropsychology can help to understand the type of problem by designing and developing educational programs tailored to the educational set. A very important point in developing neuropsychological interventions is that a child's inability to read can be related to several aspects of his or her neuropsychological skills, such as attention, executive functions, visual-spatial processing of language, and memory.

The novelty and attractiveness of this treatment method for students and the competitive and playful aspect of the exercises provided by the computer, has attracted the attention and maintenance and continuity of this function during the presentation of computer exercises and the result of this process. There has been a relative improvement in the ability of children with dyslexia to function. Papastergiou (2009) argues that computers have a greater capacity for motivation than traditional education. Computers also provide instant feedback on a child's performance, preventing the child from repeating a mistake for a long time, as repeating the mistake fixes the mistake and makes it harder to change. In addition, in relation to the effectiveness of the neuropsychological method through software on attention and attention maintenance, it can be said that according to Piaget theory, play is basically the main factor in the child's cognitive development. Children achieve balance in the form of play by understanding the facts and controlling personal skills. Children acquire new mental concepts during play, and especially educational games, and acquire more and better skills. Therefore, attention is no exception to this rule, and educational games that provide such methods to students cause the area of constant attention to be stimulated and strengthened in these students. In addition, the tools and games that are commonly used in computer programs of the neuropsychological method, each time used, are different from the previous exercises, and this issue does not create the effect of repetition and practice consumption in students and will not be monotonous and repetitive for them. Therefore, the novelty and attractiveness of this method will be effective in improving reading performance in dyslexic children.

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The findings also showed that the neuropsychological method has an effect on executive functions and its components: working memory and planning. This finding is consistent with previous findings in this field (Arghavani, Mosavi Nasab, & Khezri Moghadam, 2017; Babapour et al., 2015; Gray et al., 2012; Hosseinkhanzadeh et al., 2018). The results of Arghavani et al. (2017) showed that students' cognitive empowerment training leads to the strengthening and improvement of executive functions. They concluded that cognitive empowerment could be used to improve the executive functions of students with learning disabilities.

Explaining this finding from the present study, it can be acknowledged that the performance of students with reading disorders in executive function tests (problem solving, planning, organizing), attention (selective attention), sustained attention, team attention, attention capacity, memory, accuracy, perceptual-motor skills, and language skills are significantly poorer than in normal children, and this deficiency in neuropsychological skills can predict children's reading disabilities. Executive function is a complex process that refers to a wide range of processes, skills, and states of cognition, attention, and memory. It can be said that today attention is increasingly considered as a bias in the neural processing of information. Stimuli compete for representation and presence in the field of sensory-winning neurons, and attention by creating bias in this representation causes only certain stimuli to be considered and stored in memory. The concept of attention has traditionally been associated with resource theory and its main idea, which is the limited capacity of living beings to process information. Thus, information is selected and processed to be considered, while inputs that are not considered are removed from the realm of consciousness and will not be stored. It is also clear that poor working memory function is a characteristic of children with reading disabilities, and that memory system processes and mental storage seem to be impaired. In the crucial years of elementary school, working memory dynamics are a prerequisite for learning everything, including reading, writing, and math. Therefore, although the executive function includes various modalities, it can be said that the neuropsychological method promotes this function.

Because neuropsychological skills are a set of prerequisite skills that a child needs to learn subjects in school, including reading, and because these skills are taught through experience, and learning is achieved; Therefore, it can be said that the method of neuropsychology improves visual and auditory memory by improving dyslexic children in recalling or repeating auditory information chains in a regular process, which promotes reading development.

On the other hand, with the development of executive functions in dyslexic students, we can help improve problem solving, concept building, and association in them, which in turn allows children to distinguish between words and things around them. On the other hand, to create a bridge between text and print and its meaning, the student must activate a set of processes, especially the ability to perceive vision and other cognitive abilities such as attention, memory and organization that this will be achieved by improving neuropsychological skills. In sum, children need to master a set of skills that are aspects of neuropsychology, such as attention, executive functions, language, visual-spatial processing, and memory, in order to complete reading assignments. These skills are the result of experience, training

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and learning. Most children develop these skills automatically, while children with dyslexia have difficulty learning to use these skills and need to be trained. Therefore, reading performance in these people can be improved by using neuropsychological methods.

Therefore, in general, it can be said that neuropsychological treatment is effective in improving reading performance and executive functions in dyslexic children. Also, because the available sampling method is used in this study, caution should be exercised in generalizing the results. It is suggested that the effectiveness of this treatment on other areas related to dyslexia be evaluated and compared with other treatments. Finally, this treatment can be used as an intervention and treatment of dyslexic disorders

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