Original Article

IEEPJ Vol. 4, No. 4, 2022, 84-94

http://ieepj.hormozgan.ac.ir/

Iranian Evolutionary and Educational Psychology Journal

IEEPJ

Comparison of the Effectiveness of Executive Function Training and Intervention Based on Cognitive Games on Reading Performance in Elementary Students

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Abstract: One of the most common problems among students is reading problems, which has received considerable research attention. The aim of this study was to compare the effectiveness of executive function training and intervention based on cognitive games on the reading performance in elementary students. The research method is quasi-experimental using a pre-test - post-test design with a control group. Accordingly, among the students studying in the primary school of Bandar Abbas, Iran in 2021, 45 elementary students with learning disabilities were selected and randomly assigned to 3 groups of 15 people (two experimental groups and one control group). The reading performance questionnaire was used to collect data in two stages of pre-test and post-test. Cognitive game-based and executive function interventions was implemented in the first and second experimental groups during seven 90-minutes sessions and ten 50-minutes sessions, one session per week. Control group participants did not receive any intervention during this period. The results of multivariate analysis of covariance showed that both executive function intervention and cognitive game-based intervention had a significant effect on students' reading performance with reading learning disability ($p < .05$). In addition, according to the findings, the executive functions training had a greater effect on reading performance compared to the intervention based on cognitive games ($p < .05$). Considering that the intervention of executive functions is more effective than cognitive games, it can be concluded that the components of executive functions such as working memory, planning, and mental organization are very closely related to reading skills and thus can affect reading performance.

Keywords: Reading performance, executive functions, cognitive games, elementary students

Introduction

Reading is one of the most important methods of acquiring knowledge. Students who are weak in reading show a lot of vulnerability in learning different subjects in all academic years and after that (Maughan et al., 2009). About 80% of students with learning disabilities have difficulty in reading. LD children in reading may know many words and use them in their speech; but they fail to understand and identify written signs. The most important problems that students with reading learning disorders experience include failure to read words that are similar to each other, guessing words by considering their beginning and end letters, reading words upside down, severe problems in spelling, reluctance and disgust to learn and difficulty in distinguishing part from the whole (Richlan, 2020).

Several studies show the effectiveness of executive functions on reading performance (Hoskyn et al., 2017). The term executive functions refers to a general structure that includes various skills such as decision-making, planning, inhibition and organization, and requires higher cognitive activities of the

Article information: Received: 2022/02/24 | Accepted: 2022/04/14 | Published: 2022/12/1. https://doi.org/10.52547/ieepj.4.4.84

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[DOR: 20.1001.1.25884395.2022.4.4.8.4]

[DOI: 10.52547/ieepj.4.4.84]

brain such as attention, working memory, language, perception and creative thinking. These functions help people in learning tasks, mental functions and academic activities (Akyurek & Bumin, 2019). Schuchardt et al. (2008) have shown that preschool children's ability in working memory skills can predict their reading performance level six years later. Smith-Spark and Fisk (2007) reported such a finding in adulthood. Swanson (2012) in a meta-analysis of more than 50 studies in response to the question of why working memory plays a role in reading difficulties concluded that verbal working memory is the basis of other cognitive functions involved in reading and as a compensatory mechanism. It works to cover other deficiencies. Executive functions play a key role in academic success and social growth. According to research results, failure in the development of executive functions can cause disruption in planning for the beginning and end of assignments and memorization of assignments (Barclay, 2015). Numerous studies have shown the low performance of children with learning disabilities in executive functions. According to Dawson and Guare (2018), executive functions help regulate behavior through the use of special cognitive functions and their regulation and guidance.

The existence of failure in the executive function of children with learning disorders indicates that these children have problems in paying attention to the important aspects of the task, inhibiting and controlling responses unrelated to the task, maintaining the information received from the environment, cannot achieve delay reinforcement and engage in task-oriented ways of doing homework and daily activities (Dawson & Guare, 2018). Such problems make children unable to plan and organize and integrate different components well in providing answers and assignments. Butterfuss and Kendeou (2018) suggest that executive functions may help explain the complex interactions between the reader, the text, and the discourse situation, and in existing and future models of reading comprehension, these functions should be considered as important components affecting reading comprehension.

Reading is one of the most difficult tasks in which children must have the optimal level of cognitive abilities to perform properly. In general, there are supporting evidences regarding the weakness of executive functions in students with learning disabilities, especially students with reading disabilities (Alloway et al., 2014). Dyslexia is defined as a specific learning disorder that has a neuropsychological origin and is characterized by problems in correct and fluent recognition of words, poor spelling and decoding ability. These problems lead to deficits related to other cognitive abilities (Adlof & Hogan, 2018).

Unlike the prevalence and severity of dyslexia, its fundamental reasons have not been fully determined, but it is seriously related to cognitive factors and defects. Regarding the nature of cognitive and perceptual disorders of dyslexia, they point out that these people have defects in phonological knowledge, fast automatic naming, verbal short-term memory, visual-spatial perception, and visual-motor matching (Richlan, 2020). Shaywitz and Shaywitz (2005) believe that cognitive neuroscience and reading learning disorder are closely related. Neurological evidence shows that reading is done in the brain and is dependent on the brain systems used in spoken language. There is a

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[DOI: 10.52547/ieepj.4.4.84]

correlation between reading disorder and cognitive deficits. These comorbidities include phonological deficits, cognitive-perceptual deficits, deficits in memory skills, deficits in attention, deficits in central coherence, deficits in processing speed, and deficits in executive functions. (D'Mello & Gabrieli, 2018). There are several methods to stimulate the neurological functions. One of these methods, which are essential for success in academic matters, is play (Brewer & Jalongo, 2018).

While stimulating the sensory-motor cortex, the game establishes many connections between the limbic region and the parts of vision, hearing and speech, and the repetition and continuation of such stimulations creates new learning, the mutual effect of the brain and the nervous system on the quantity and quality of behavioral responses. It enables the improvement of the brain and nervous system through successive exercises (Reynolds & Voress, 2009). Several researches show that the game not only affects the structure of the brain and the neural functions of learning, but also affects the brain over time through the biological processes involved with new stimuli and learning skills (Reynolds & Voress, 2009). Neuroscientists say that the game causes rewiring of the brain, motor development and rapid performance, increasing ability and increasing learning capacity.

On the other hand, some researches have shown that one of the cognitive deficits in children with reading learning disorder is a deficit in executive functions (Butterfuss & Kendeou, 2018). This group of researches seeks to find differences between people with learning disorders and normal children have been in executive functions. They have shown that students with learning disorders are inferior compared to students without disorders in different areas of executive functions such as working memory, planning and organization, performance. Therefore, a large amount of research findings have confirmed the weakness in the executive functions of students with reading disorders. Considering the basic and fundamental role of various executive functions such as active memory in learning reading skills, it is assumed that the reading performance of this group of students can be improved by strengthening and developing executive functions. Since, the long-term consequences of learning disorders in reading and its high prevalence in primary schools, proper planning in the matter of rehabilitation and correction of problems becomes necessary. Therefore, the present study aimed to compare the effectiveness of executive function training and intervention based on cognitive games on the reading performance in elementary school students with reading learning disorders.

Material and Methods

The present research method was semi-experimental and its design was pretest - posttest with control group. The statistical population included all the students with reading learning disorder in the elementary school in Bandar Abbas city who visited the learning disorder clinics in 2020. Participants were diagnosed with reading learning disorder by the experts of learning disorder centers, were randomly assigned to three groups (15 people in the first experiment group, 15 people in the second experiment group, and 15 people in the control group). The inclusion criteria included studying in the third to fifth grade of elementary school, receiving a diagnosis of reading learning disorder, normal

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intelligence, not participating in educational and therapeutic programs, and consenting to participate in the research. The exclusion criteria included not being satisfied with participating in the research, entering other educational and therapeutic programs other than the experimental intervention of the present study, and absenting more than one session in the educational intervention sessions. For the purpose of training, help was taken from experts. The research tools included the Wechsler test and the reading performance questionnaire, whose psychometric characteristics are described below.

Revised Wechsler Intelligence Scale for Children (WISC-R): This scale, developed in 1945 to measure children's intelligence and revised in 1974, consists of two subscales of Verbal IQ (VIQ) and Performance IQ (PIQ). Each subscale has 6 sub-tests (12 sub-tests in total), of which 5 are main sub-tests and one sub-test is used as a supplementary or reserve sub-test. The main sub-tests of the verbal scale include general information, similarities, calculation, vocabulary, and comprehension, and in the performance scale, completing pictures, arranging pictures, designing cubes, connecting parts, and deciphering or numerical symbols. Digit Span and mazes subtests are considered as supplementary or reserve sub-tests. This scale was standardized by Shahim (1992) on a sample of 1400 children aged 6 to 13 in Shiraz, and its test-retest reliability was reported as 0.44 to 0.94 and its alpha was reported as 0.42 to 0.98. The concurrent validity of this scale using the correlation of the scores with the scores of the performance part of the Wechsler scale for preschool children was 0.74. Correlation coefficients of verbal, performance and total intelligence have been reported as 0.84, 0.76 and 0.80 respectively.

Reading Performance Questionnaire: This questionnaire was designed by Azizian and Abedi (2006) with the aim of diagnosing the reading performance of students based on the components introduced for reading learning disorder based on the Diagnostic and Statistical Manual of Mental Disorders. This questionnaire has 12 questions that evaluate different dimensions of reading skills in terms of accuracy in word reading, rhythm and reading fluency and reading comprehension. The reliability of this test was evaluated by Yousefi et al. (2019) after implementing it on a group of 30 elementary school students and its Cronbach's alpha coefficient was 0.81.

Intervention program and implementation method: according to the purpose of the current research, the intervention program included an intervention based on executive functions and an intervention based on a model based on cognitive games. After compiling intervention programs, a pre-test was done in three groups. The training package based on executive functions and cognitive games was implemented on the participants of the first and second experimental groups. During this period, the participants of the control group did not receive any training. Finally, one week after the last session of the intervention, the post-test was conducted on the participants of all three groups and the data was collected. The summary of training sessions based on executive functions and cognitive games is provided in Table 1.

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Table 1. The Summary of intervention sessions of executive functions and intervention based on cognitive games

Session	Contents		Duration
	Intervention based on executive functions	Intervention based on cognitive games	
1	Getting to know the members and stating the logic and objectives of the meetings, conducting an initial assessment and stating the work framework	Getting to know the members and stating the logic and objectives of the meetings, conducting an initial assessment and stating the work framework	90 minutes
2	The issue of reading performance (determining the purpose of the text, suitable reading environment, concentration and attention while reading, reviewing and re-inspecting the text and correcting mistakes	Training to look carefully and remember (goal: strengthening visual attention and accuracy, strengthening visual memory, understanding the details of an image, strengthening active memory)	90 minutes
3	Teaching mental imagery techniques, use of mediums and location methods, note taking, summarizing and retelling the material	Adjusting and recalling images (understanding the relationship between whole and part, coherence of details, creativity of the mind, ability to combine images)	90 minutes
4	Teaching discipline and self-regulation strategies	Ambiguous box (increasing recognition of spatial relationships, increasing accuracy and concentration, increasing divided attention	90 minutes
5	Dealing with executive functions and academic performance	Management of the child's educational and academic situation (teacher selection, recommendations about the curriculum, etc.	90 minutes
6	Review of techniques	Ambiguous box (increasing recognition of spatial relationships, increasing accuracy and concentration, increasing division attention	90 minutes
7	Overview of techniques	Incomplete images (increasing accuracy and attention, increasing recognition of spatial relationships, increasing visual completion, central coherence)	90 minutes
8	Post-test	Playing with rubber band (strengthening spatial memory-increasing recognition-strengthening fine motor skills-strengthening visual attention)	90 minutes
9	-	50 photos and acuity game (strengthening spatial memory-increasing recognition-strengthening fine motor skills-strengthening visual attention)	90 minutes
10	-	Review sessions and post-test implementation	

Results

Descriptive information including the mean and standard deviation of the reading performance variable and their subscales in the two experimental groups and the control group in the pre-test and post-test phases along with the summary of the Shapiro-Wilks test to determine the normality of the distribution are presented in Table 2. One-way analysis of covariance was used to investigate the effect of executive function training and cognitive games on the overall score of reading performance in elementary school students with poor reading ability. The results of the pre-test and post-test regression slope homogeneity test of reading performance in the experimental and control groups showed that the regression slope of these variables was equal in the groups ($F=1.98$, $p > 0.05$). The results of Levene's test to check the homogeneity of the variance of reading performance in the groups showed that the variance of these variables is equal in the groups ($F=3.18$, $p > 0.05$). The F-statistic of the covariance analysis of the difference between the groups in the post-test of reading performance

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was found to be significant (F=59.73, p <0.001). These findings show that there is a significant difference between the groups in these variables. The effect size for reading performance was obtained 0.74.

Table 2. Descriptive analysis of variables in three groups

Variable	Group	Pretest		Posttest			
		M	**SD**	**M**	**SD**	**S-W**	**P**
Reading performance (Total score)	Cognitive games	29	1.64	18.13	4.32	0.97	0.92
	Executive function	28.87	1.50	14.13	4.40	0.89	0.07
	Control	28.83	3.82	29.33	2.92	0.93	0.37
Accuracy in word-reading	Cognitive games	9.47	0.83	6.27	1.22	0.91	0.16
	Executive function	9.47	0.64	4.93	1.43	0.89	0.10
	Control	9.67	1.24	9.47	1.18	0.91	0.17
Fluency	Cognitive games	7.20	1.47	4.53	1.68	0.90	0.12
	Executive function	7	1.41	3.87	1.72	0.93	0.34
	Control	7.33	1.44	7.40	1.59	0.88	0.06
Comprehension	Cognitive games	12.23	1.17	7.23	2.82	0.96	0.77
	Executive function	12.40	1.05	5.33	2.19	0.95	0.63
	Control	11.93	1.83	12.47	1.18	0.89	0.10

In Table 3, the results of the multiple comparisons of the groups in reading performance are reported.

Table 3. Comparison of mean groups in reading performance

Variable	**Reference group**	**Comparison group**	**Mean difference**	**Std. Error**	**p**
Reading performance	Cognitive games	Executive function	3.97	1.44	0.03
	Cognitive games	Control	-11.21	1.44	0.001
	Executive function	Control	-15.18	1.44	0.001

According to Table 3, in reading performance, the mean of the executive function group is significantly lower than the mean of the cognitive games group (p<0.05). The average of the cognitive games and executive functions group is also significantly lower than the average of the control group (p <0.001). According to these findings, it can be said that the training of executive functions and cognitive games has a positive effect on the reading performance of dyslexic students. But the effectiveness of the executive functions method is higher than the method of cognitive games.

Furthermore, multivariate covariance analysis was used to investigate the effect of executive function training and cognitive games on reading performance components in dyslexic students. The results of the pre-test and post-test regression slope homogeneity test of reading performance components, i.e. accuracy in word reading (F = 2.13, p > 0.05), reading fluency (F = 3.10, p > 0.05) and reading comprehension (F=2.41, p > 0.05) in the experimental and control groups, showed that the regression slope of these components is equal in the groups. The results of Levene's test to check the homogeneity of the variance of reading performance components, i.e., accuracy in word reading (F = 0.96, p > 0.05), reading fluency (F = 1.31, p > 0.05) and reading comprehension (F=2.18, p > 0.05) in the groups showed that the variance of these variables is equal in the groups. The results of the Box's

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M test to check the equality of the covariance matrix of the dependent variables between the experimental and control groups also showed that the covariance matrix of the reading performance components is equal in the groups (F=1.81, 0.001). The results of the Bartlett test statistic to test for equality of variances across groups in reading performance components (x^2=35.82, p <0.001) showed that the relationship between these components is significant. The results of multivariate covariance analysis showed that there is a significant difference between the groups in reading performance components (F=13.62, p<0.001, Lambda Wickels = 0.23). To check which of the experimental and control groups differ from each other in which of the components of reading performance, the results of univariate analysis of variance are reported in Table 4.

Table 4. The results of one-way analysis of variance of reading performance components

Variable	Component	F	p	Eta
Reading performance	Accuracy	48.68	0.001	0.71
	Fluency	17.13	0.001	0.46
	Comprehension	43.85	0.001	0.69

According to Table 4, the F statistic for the components of accuracy (48.68), fluency (17.13) and comprehension (43.85) is significant. This finding shows that there is a significant difference between the groups in these components. In Table 5, the results of the multiple comparisons of the groups in reading performance components are reported.

Table 5. The analysis results of comparing groups in reading performance components

Component	Reference group	Comparison group	Mean difference	Std. Error	p
Accuracy	Cognitive games	Executive function	2.35	0.45	0.005
	Cognitive games	Control	-4.16	0.46	0.001
	Executive function	Control	-4.52	0.47	0.001
Fluency	Cognitive games	Executive function	0.60	0.60	0.32
	Cognitive games	Control	-3.80	0.61	0.001
	Executive function	Control	-3.40	0.61	0.001
Comprehension	Cognitive games	Executive function	2.01	0.79	0.01
	Cognitive games	Control	-5.60	0.80	0.001
	Executive function	Control	-7.36	0.81	0.001

According to Table 5, in the components of accuracy and comprehension, the average of the executive function group is significantly lower than the average of the cognitive games group (p<0.01). However, there is no significant difference between the two groups in the fluency component (p >0.05). In the components of accuracy, fluency and comprehension, the average of the cognitive games group and executive function is significantly lower than the average of the control group (p <0.001). According to these findings, it can be said that the training of executive functions and cognitive games has a positive effect on the reading performance components of dyslexic students. But the effectiveness of the executive functioning method on the components of accuracy and comprehension is higher than the method of cognitive games.

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Discussion

The aim of the present study was to compare the effectiveness of executive functions training and model based on cognitive games on reading performance in students with reading learning disorder. The results showed that the intervention of executive functions and the intervention based on cognitive games have a significant effect on the reading performance in students with reading learning disorders, and the executive functions training package had a greater effect on the dependent variables.

The effectiveness of executive functions training on the reading performance of students with learning disabilities in the present study is consistent with the results of previous studies, including McCloskey et al. (2014). In their research, McCloskey et al. (2014) showed that brain function related to executive functions (working memory) improves in children after training. In this regard, some researches such as Karimi and Askari (2013) have shown that the reading performance of students with learning disabilities improves through the teaching of active memory strategies, which is an important part of executive functions.

In the explanation of this result, in line with the research literature in the field of reading disorder, we can point to the inadequacies of students with reading disorder in executive functions. A large amount of research has shown the poor performance of students with reading disorders in various components of executive functions and the relationship between these deficiencies and poor reading performance (Cutting et al., 2009; Engel de Abreu et al., 2014). Also, researchers have emphasized the key role of executive functions in learning academic skills, especially reading skills (Watson et al., 2016).

On the other hand, neuropsychological studies in the field of reading emphasize that children must be skilled in executive functions in order to master reading skills. In fact, the various abilities of executive functions, including active memory, response inhibition, and mental planning and organization provide the possibility of decoding, reading and understanding content (Kirk et al., 2014). Therefore, considering the importance of executive functions and its key role in learning reading skills, it can be expected that effective interventions on executive functions will have an impact on the development of reading skills.

In the present study, the intervention process based on executive functions was designed in such a way that the most effective components of executive functions that are involved in reading skills were taught to the children of the experimental group during different sessions. Teaching effective executive functions in reading skills to the students participating in the experimental group has helped them to show progress in reading skills by improving these skills.

The effectiveness of the intervention of executive functions in comparison with the model based on cognitive games in students with reading disorders can be explained as follows. According to previous researches, the intervention components of executive functions such as active memory, mental planning and organization are closely related to reading skills. In the intervention of executive functions, the techniques of mental imagery, note-taking, summarizing, retelling of contents, and strategies of order and self-regulation were used. Considering the very close relationship of these strategies with learning reading skills and their predictive role in predicting reading skills, which has

been confirmed in previous studies (Dias & Seabra, 2017), it can be expected that using of these techniques and strategies can have a significant impact on learning reading skills and consequently on students' self-concept.

From a practical point of view, regarding the effectiveness of the intervention of executive functions and the model based on cognitive games on improving the progress of reading skills in students with reading disorders, the results of this research can be used for special learning disorder therapists. In this context, therapists and clinical specialists in working with students with special learning disorders can use the intervention of executive functions and model-based intervention based on cognitive games as effective and research-oriented interventions in rehabilitation and treatment activities.

Considering that the participants of this study were students with reading disorders, the generalization of its results to students with other disorders or students without disorders is limited. Also, due to the limited number of participants, the generalization of the research results to other grades and levels of education should be done with caution. In this regard, researchers are suggested to test the effectiveness of intervention of executive functions and cognitive games in students suffering from other disorders as well as other grades and levels of education. It is also suggested that researchers use single-subject designs in future studies to determine the effectiveness of interventions based on cognitive games and intervention of executive functions in order to identify the individual differences of the participants.

Conflict of interest: The authors state no conflict of interest in the study.

Financial sponsor: The authors acknowledge that they have not received any financial support for all stages of the study, writing and publication of the paper.

Acknowledgements: This research is taken from the doctoral dissertation of the first author in the field of educational psychology of Islamic Azad University, Qeshm branch. We hereby thank and appreciate all the people who participated in the implementation of this research, as well as the supervisor and advisor of this work.

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[DOR: 20.1001.1.25884395.2022.4.4.8.4]

[DOI: 10.52547/ieepj.4.4.84]