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Evaluating the Effects of Executive Functions and Intervention Based on Cognitive Games on the Neurological Problems in Dyslexic Students

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ABSTRACT

Objective: Reading disorders are one of the neuro-cognitive problems that cause academic and psychological problems for affected students. The aim of the present study was to compare the effectiveness of executive function training and intervention based on cognitive games in reducing neurocognitive problems of elementary school dyslexic students.

Methods: The current research is a semi-experimental type of research. Based on this, 45 elementary dyslexic students were randomly selected from among the students studying at the elementary level in Bandar Abbas city in 2021. They were placed in 3 groups of 15 people (two experimental groups and one control group). Conners' Continuous Performance Test was used to collect data in two stages, pre-test and post-test. The training package of executive functions and intervention based on cognitive games was taught to the participants of the first and second experimental groups, respectively, during 10 sessions of 90 minutes, one session per week; nonetheless, the participants in the control group did not receive any intervention in this regard.

Results: The results of multivariate covariance analysis showed that both the intervention of executive functions and the intervention based on cognitive games have a significant effect on reducing the neurological problems in dyslexic students, but the educational package of cognitive games has a more significant effect in reduction of neurological problems.

Conclusions: The results pertain predominantly to the significance of cognitive games in enhancing the executive functions of students. It is proposed as an efficacious intervention for teachers and parents.

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Introduction

Today, the acquisition of reading proficiency is regarded as a crucial aspect of human development. Reading serves as a fundamental skill that facilitates the reception and comprehension of novel information and concepts, making it the quintessential tool for students' learning (O'Reilly et al., 2014). However, a prevalent form of learning disability, known as reading disorder or dyslexia, poses a significant challenge (Snowling et al., 2020). The International Dyslexia Association recognizes this disorder as a distinct learning disability with a neurological basis, manifesting in impaired accuracy and speed of word recognition, spelling difficulties, and hindered phonetic associations. Approximately 80% of students with learning disabilities encounter difficulties in reading. Although children with reading disorders may possess a substantial vocabulary and employ it in their speech, they struggle to comprehend and identify written symbols. Among the prominent problems experienced by students with reading learning disorders are the inability to differentiate between visually similar words, reliance on the initial and final letters of words to make guesses, reading words in a mirrored fashion, severe spelling difficulties, aversion to learning, and impaired word recognition. These challenges may be attributed to the neurological issues underlying these children's condition (Richlan, 2020).

Multiple studies have demonstrated the efficacy of executive functions in enhancing neurological functioning and, ultimately, improving reading skills (Hoskyn et al., 2017). The term "executive functions" encompasses a broad framework encompassing various skills, including decision-making, planning, inhibition, and organization. These functions rely on higher-order cognitive activities such as attention, working memory, language, perception, and creative thinking. They play a pivotal role in individuals' learning tasks, mental processes, and academic endeavors (Akyurek & Bumin, 2019).

Notably, research shows that preschool children's proficiency in working memory skills can predict their reading performance levels several years later, extending even into adulthood (Schuchardt et al., 2008). In a meta-analysis comprising over 50 studies, Swanson investigated the role of working memory in reading difficulties. The findings indicated that verbal working memory serves as a foundation for other cognitive functions involved in reading, compensating for other deficiencies (Swanson, 2012).

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Executive functions exert a significant influence on academic achievement and social development (Barclay, 2015). Research findings suggest that impaired executive function development can disrupt planning tasks, impede assignment completion, and hinder memory retention. Numerous studies have demonstrated the subpar performance of children with learning disabilities in executive functions. According to Dawson and Guare (2018), executive functions assist in regulating behavior through the utilization of specialized cognitive functions, guiding and directing individuals' actions.

The presence of executive function failure in children with learning disorders indicates that these children have difficulties in attending to important task aspects, inhibiting and controlling unrelated responses, and retaining information from the environment. Consequently, they struggle to delay reinforcement, complete homework, and engage in daily activities in a task-oriented manner. These problems hinder their ability to plan, organize, and integrate different components effectively when providing answers and assignments (Alloway et al., 2014).

Reading is a complex task that requires children to possess optimal neurological abilities in order to perform adequately. There is substantial evidence supporting the notion that students with learning disabilities, particularly reading disorders, exhibit weaknesses in executive functions. Dyslexia, a specific learning disorder with a neuropsychological origin, is characterized by difficulties in accurate and fluent word recognition, poor spelling, and decoding abilities. These problems also impact other cognitive abilities (Arlington, 2013).

While the prevalence and severity of dyslexia are well-known, its underlying causes have not been fully determined. However, it is strongly associated with cognitive factors and deficits. Cognitive and perceptual disorders in dyslexia are evident in impaired phonological knowledge, rapid automatization, verbal short-term memory, visual-spatial perception, and visual-motor coordination. Shaywitz and Shaywitz (2005) argue that cognitive neuroscience and reading learning disorders are closely intertwined. Neurological evidence reveals that reading occurs in the brain and relies on the same brain systems used for spoken language.

There is a clear connection between reading disorders and cognitive deficits, including deficits in phonology, cognitive-perceptual abilities, memory skills, attention, central coherence, processing speed, and executive functions (D'Mello & Gabrieli, 2018). Various methods exist for stimulating neurological functions, and one crucial method for academic success is playing games. Through

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stimulating the sensory-motor cortex, games establish numerous connections between the limbic region and the visual, auditory, and speech-related parts of the brain . These stimulations, by facilitating new learning and the reciprocal influence between the brain, the nervous system, and behavioral responses, enable improvements in the brain and nervous system through repetitive exercises (McCloskey & Perkins, 2012).

Extensive research demonstrates that games not only impact the brain's structure and neural functions related to learning, but also influence biological processes associated with new stimuli and learning skills over time (Akyurek & Bumin, 2019).

Neuroscientists say that the game causes rewiring of the brain, motor development and rapid performance, increased ability and increased learning capacity. The American Psychological Association states that cognitive and neuropsychological games cause changes in brain function about children with learning disabilities (Atadokht et al., 2015). Researchers have shown that most of the problems in dyslexia are neurological problems in students. They state that there is a relationship between reading skills and cognitive constructs. On the one hand, 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 and on the contrary, it enables the recovery of the brain and the nervous system through their successive behaviors and training. Considering the pivotal role of neurological abilities in the act of reading and the various cognitive processes such as working memory, which hold significant importance in the acquisition of reading skills, and taking into account the enduring consequences of reading learning disorders as well as their high prevalence in primary schools, it becomes imperative to strategically plan for remediation and rectify the issues highlighted in this research. Hence, the objective of the current study is to assess and compare the efficacy of executive functions training and intervention through cognitive games in ameliorating the neurological challenges faced by elementary school students with reading learning disorders.

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Materials and Methods

The present study was conducted as an experiment with a design that involved a pre-test and post-test along with a control group. The research encompassed all the students with reading learning disorder in the elementary school in Bandar Abbas city who sought assistance from the learning disorder clinics in 2020. Out of this population, 45 students were randomly selected and diagnosed with reading learning disorder by the experts from the learning disorder centers. These students were then divided into three groups, with each group consisting of 15 individuals (15 in the first experiment group, 15 in the second experiment group, and 15 in the control group). The inclusion criteria comprised of students in the third to fifth grade of primary school, a diagnosis of reading learning disorder, average intelligence, no participation in educational and therapeutic programs, and willingness to take part in the research. The exclusion criteria included a lack of satisfaction with participating in the research, engagement in other educational and therapeutic programs besides the experimental intervention of this study, and missing more than one session in the educational intervention sessions.

Instruments

Connors neuropsychological test :This questionnaire is known by Connors in 2004 to evaluate neuropsychological skills including attention and memory, sensory-motor activities and visual-spatial processing in four ranges (not observed to severe) for children 5-12 years old. Jadidi and Abedi (2011) translated and standardized this questionnaire in Iran. The internal reliability coefficients ranged from 0.75 to 0.90 and the eight-week reliability coefficient was reported to be 0.60 to 0.90. The validity of the constructs of Conner's forms has been obtained using factor analysis methods and their differential validity has been strongly confirmed by the statistical analysis of the ability of the questionnaire to distinguish people with ADHD from normal and other clinical groups. Jadidi and Abedi (2011) evaluated the construct validity of this tool and reported the reliability of this tool to be 0.72 according to Cronbach's method. The teacher-parent form of the Connors questionnaire, the teacher form of this questionnaire is the most common screening and diagnosis tool in most parts of the world. Neuropsychological disorders have been used (Neudecker et al., 2019).

Intervention program and implementation method: According to the purpose of the present study, the intervention program included an intervention based on executive functions and an

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intervention based on a model based on cognitive games training. After compiling both intervention programs, the pre-test in the experimental and control groups were carried out, and then, the training package based on executive functions (Barclay, 2015) and cognitive games (Jadidi & Abedi, 2011) were implemented on the participants of the first and second experimental groups, respectively. During this period, the participants of the control group did not receive any training in this field. 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 required for the research was collected. In addition, after 1 month, a follow-up test was also performed on the groups. The framework of training sessions based on executive functions and cognitive games is summarized in Table 1.

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

Session	Content		Duration
	Executive functions intervention	**Cognitive games intervention**	
1	Getting to know the members and stating the logic and objectives of the meetings, performing the initial assessment and stating the work framework	Getting to know the members and stating the logic and objectives of the meetings, performing the initial assessment and stating the work framework	90 Min.
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	Teaching the dot-to-dot-target game: strengthening the visual sequence, increasing selective attention Look carefully game training. Goal: increase visual accuracy and visual memory, increase concentration and attention threshold, strengthen visual perception	90 Min.
3	Teaching mental imagery techniques, use of mediums and location methods, note taking, summarizing and retelling the material	Teaching the hidden picture recall game. Purpose: to strengthen visual memory, to strengthen active memory Teaching the game to memorize. Purpose: to strengthen visual attention and accuracy, to strengthen visual memory, to understand the details of an image, to strengthen active memory.	90 Min.
4	Teaching discipline and self-regulation strategies	Learning the picture recall game. Purpose: strengthening visual attention and accuracy, strengthening visual memory, understanding the details of an image, strengthening active memory Teaching domino game. Goal: hand-eye coordination, increasing accuracy and attention, visual order and sequence,	90 Min.

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		improving action speed, strengthening motor skills.	
5	Dealing with executive functions ‌active planning and(...	Learning the hidden shape search game. Goal: Perception and recognition of text and context. Increased accuracy and attention, visual clarity Teaching the game of visual contrasts. Goal: increasing accuracy and concentration, strengthening the concentration threshold, strengthening movement skills	90 Min.
6	Dealing with executive functions 2	Frostig game training. The goal is to increase visual perception, increase spatial memory. Strengthening central nervous system	90 Min.
7	Overview of techniques	Teaching incomplete images. Goal: increasing accuracy and attention, increasing recognition of spatial relationships, increasing visual completion, central coherence Training to play with cache (strengthening spatial memory-increasing recognition-strengthening fine motor skills-strengthening visual attention)	90 Min.
8	Overview of techniques		90 Min.
9	Post-test implementation	Teaching the game 50 photos and sharp. Purpose: to strengthen spatial memory - to increase recognition - to strengthen fine motor skills - Teaching the game of jumbled yarns. Goal: increasing visual sequence, selective attention, hand-eye coordination	90 Min.
10	Follow up implementation	Post-test implementation and follow-up after one month	

Results

Descriptive information including mean and standard deviation in experimental and control groups is given in table 2.

Table 2. Mean and standard deviation of neurological problems in experimental and control groups

Group	Pretest		Posttest		Follow up	
	Mean	SD	Mean	SD	Mean	SD
Executive functions	161.34	31.73	120.33	24.24	138.45	26.83
Cognitive games	163.80	35.04	87.23	31.46	114.60	31.09
Control	158.74	23.62	140.66	17.80	156.25	22.24

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According to Table 2, the average of the groups in the pre-test stage does not show much difference and all three groups are in the same range in terms of neurological problems. The average of neurological problems in executive actions group in pre-test, post-test and follow-up period is 161.34, 120.33 and 138.45 respectively. In the group of cognitive games, pre-test, post-test and follow-up period were 163.8, 87.23 and 114.6, respectively and in the control group, the average of pre-test, post-test and follow-up neurological problems is 158.74, 140.66 and 156.25, respectively. The mentioned values show that the scores of neuropsychological problems of two test groups (executive actions and cognitive play) decreased from pre-test to post-test. But it has not changed much in the control group. The average of the neuropsychological problems of the two test groups in the follow-up phase compared to the pre-test phase also shows a decrease. According to the average decrease in the group of psychological games is more evident.

Table 3. Results of normality Shapiro-Wilk test

Variable	Group	Statistic	Shapiro-Wilk test	
			N	P
Neuropsychological problems	Executive functions	0.86	15	0.19
	Cognitive games	0.89	15	0.065
	Control	0.88	15	0.21

According to Table 3, considering that the significance level of the Shapiro-Wilk test in neurocognitive skills in all three groups is greater than 0.05, it can be concluded that the scores related to all the dependent variables in different time stages have a normal distribution.

Research hypothesis: There is a significant difference between the effectiveness of training based on executive functions and intervention based on cognitive games on the neurological problems of dyslexic elementary school students.

Considering that the assumptions have been met, therefore, it is possible to use the results of the multivariate test. In Table 4, the results of the multivariate variance test on the average score of neuropsychological problems in the executive function, cognitive games and the control group in the pre-test, post-test and follow-up phases are given.

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Table 4. MANOVA results

Effect		Value	F	DF1	DF2	P	Effect size	Power
Treatment	Pillai's trace	0.826	16.083	4	84	0.001	0.416	1
	Wilks' lambda	0.176	28.848	4	82	0.001	0.591	1
	Hotelling's trace	5.121	51.210	4	80	0.001	0.725	1
	Roy's largest root	5.119	101.395	2	42	0.001	0.834	1
Group * Treatment	Pillai's trace	0.949	391.049	2	41	0.001	0.948	1
	Wilks' lambda	0.049	391.049	2	41	0.001	0.950	1
	Hotelling's trace	19.123	391.049	2	41	0.001	0.950	1
	Roy's largest root	19.124	391.049	2	41	0.001	0.950	1

Considering the significance of Wilks's lambda test result (P<0.01), regarding the within-subjects' effects (time), it can be concluded that at least between two time steps and the changes related to the investigated variables in different time stages have been different. Also, considering the significance of Wilks's lambda test result (P<0.01), regarding the interaction between time and group, it can be concluded that the behavior of the group effect on at least one of the dependent variables in at least two different time stages. This means that in terms of at least one of the dependent variables, the groups have a behavior in the pre-test that may be different in the post-test or follow-up. If the groups are the same in the pre-test in terms of that dependent variable, this actually indicates the significant effectiveness of at least one of the educational interventions.

According to table 4 and significance of the effect of the independent variable between the subjects (group), there is a difference between at least two groups of the studied groups and at least in one of the studied variables. To determine this difference is related to which dependent variable, the repeated measurement ANOVA for each of the dependent variables was carried out and presented in table 5.

Table 5. The effects of between-subjects (group) results from two-way analysis of variance

Source	SS	DF	MS	F	P	Effect size	Power
Group	18123.20	2	9061.60	4.27	0.02	0.169	1
Error	89063.01	42	2120.54				

According to Table 5, there is a significant difference between the investigated groups for all the investigated variables (P<0.01) .Considering the significance of the effect of the independent variable within the group, and that at least one of the dependent variables is different during one of the different time periods (pre-test, post-test and follow-up), to check that this difference

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regarding which variable is dependent, the result of ANOVA test (single variable) was used (Table 6) .

Table 6. Results of the one-way analysis of variance test

Effect	SS	DF	MS	F	P	Effect size	Power
Variable	46535.32	2	34857.91	530.72	0.001	0.913	1
Variable * group	14478.23	2.67	5422.57	82.56	0.001	0.81	0.80
Error	3683.45	56.08	65.68				

According to Table 6, it can be concluded that the average scores of all dependent variables investigated during at least two time periods (pre-test-post-test-follow-up) had a significant difference ($F = 530.723$, $p < 0.01$). Also, according to the obtained results, it can be concluded that the contrast of the group in time is also confirmed and significant ($F = 82.56$, $P<0.01$). In the following, to investigate the difference in the effectiveness of the investigated intervention groups on the investigated dependent variables compared to the control group, the L.S.D. post hoc test was used to compare groups. The results of this test are given in Table 7.

Table 7. The results of the L.S.D. post-hoc test

Group (I)	Group (J)	Mean difference	SD	P
Executive functions	Cognitive games	21.11	8.21	0.03
	Control	9.20	8.21	0.04
Cognitive games	Control	29.13	9.81	0.001

By examining table (7), it can be seen that the variable of neuropsychological problems in the group of cognitive games has a significant difference compared to each group of executive and functions and control ($P<0.01$). The findings also show that there is a significant difference in the scores of neuropsychological problems between the two groups of executive functions and cognitive games. This means that the training of cognitive games compared to executive functions has had a greater effect in reducing neurological problems and increasing the neuropsychological skills ($P<0.01$).

Discussion

The aim of the present study was to compare the effectiveness of executive functions training and the model based on cognitive games training on reducing neurocognitive problems in students with reading learning disorders. The results showed that both the intervention based on executive

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functions and the intervention based on cognitive games training have a significant effect on the neurological problems of students with reading learning disorders in elementary school students, and of these two training methods, cognitive games training plays a more significant role and it has been more effective in reducing the neurological problems of students with dyslexia.

The effectiveness of teaching executive functions on neurocognitive skills and the effect on the reading performance of students with reading learning disorder has been shown in the research of Akyurek and Bumin (2019). Akyurek and Bumin (2019) showed that there were statistically significant differences in BRIEF teacher and parents form scores between the children with dyslexia and the controls (typical developed children). On the other hand, neuropsychological researches 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 (Dias & Seabra, 2017).

The effectiveness of the intervention based on cognitive learning compared to executive functions in students with reading disorders can be explained in this way has provided the ground for scientific awareness about the necessity of understanding the nature of reading and reading problems, and has convinced researchers that neuropsychological layers are the source of learning disorders, including dyslexia. These researchers have made significant progress in diagnosing the nervous systems of reading, detecting the defects of these systems in dyslexics and understanding the mechanism related to the development of fluent reading.

Research on students showed that the use of toys such as Lego and nested shapes helps students in expanding their mental models of mathematical concepts. Intensive remedial training can lead to the normalization of the activity profile in the part involved in reading (the posterior part of the left upper temporal gyrus) (Vanbecelaere et al., 2020).

In order to create a bridge between text or printed letters and its meaning, the reader must activate a set of processes, especially cognitive abilities (attention, memory, organization and visual perception, etc.), linguistic knowledge and past experiences. In fact, reading is a product of cognitive abilities, Language is prior knowledge and acquisition of skills in specific reading abilities. Teaching cognitive skills directly or indirectly stimulates and increases brain activity in

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the prefrontal cortex, and these interventions have an effect on school assignments (Pasqualotto et al., 2022).

In explaining this discovery, it can also be stated that a child with learning disorders is inherently constrained by neurological limitations that restrict the child's initial interactions with the world. However, early and continuous interventions can effectively address these limitations to a significant degree. Taking into account the matter of brain flexibility and the neuropsychological benefits, as well as the positive emotional aspect of learning through games, teaching the cognitive and neuropsychological components in the form of games within an intensive restorative training program not only enhances treatment outcomes, but also enhances and elevates academic performance. Moreover, it can prove to be impactful in early cognitive and neuropsychological interventions during preschool. Furthermore, in elucidating the current research, it can be asserted that, according to scientific research, children need to acquire a range of skills in order to achieve proficiency in reading (Khademali et al., 2022). These skills encompass neuro-psychological aspects and are acquired through experience, training, and play. While most children acquire these skills effortlessly, dyslexic children encounter difficulties in learning these skills and therefore should be taught through game-based approaches. Extensive research demonstrates that intensive and consecutive exercises engender modifications in cognitive abilities. In general, most parents lack proficiency in fostering neurological stimulation and fail to provide a dynamic emotional and cognitive play environment for their children. Hence, it is highly recommended that parents employ cognitive games to enhance their children's cognitive functions. In addition to the findings obtained, the present study was subject to certain limitations that should be taken into account when generalizing the findings. The limitation of the sample being restricted to children from the city of Bandar Abbas and the use of questionnaires as the data collection method were among the most significant limitations that should be considered in future investigations.

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Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving human participants were reviewed and approved by ethics committee of Islamic Azadn University. The patients/participants provided their written informed consent to participate in this study.

Author contributions

All authors contributed to the study conception and design, material preparation, data collection and analysis. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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