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The effectiveness of cognitive games on the working memory of sixth-grade borderline students

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Original Article

Abstract

BACKGROUND: Cognitive games are one of the effective ways to improve the working memory of borderline students. The game plays an effective role in the development of students, and during the game, you can find out many characteristics, problems, and growth of borderline students. The present study aimed to investigate the effectiveness of cognitive games on the working memory of sixth-grade borderline students in Saqqez City, Iran.

METHODS: The research method was semi-experimental with pretest-posttest, with a control group. The statistical population included borderline students studying in the sixth grade of schools in Saqqez City, Kurdistan Province, Iran, in the academic year of 2021-2022. 24 borderline students were selected purposefully and randomly placed in two groups of 12 people, intervention and control. The educational program of cognitive games such as Lomocyte and Tetris was conducted in 8 sessions of 60 minutes twice a week for the test group. Then the simultaneous post-test was conducted for both performance groups and the data were analyzed using analysis of covariance (ANCOVA) and SPSS software.

RESULTS: Cognitive games improved memory ($P < 0.01$), and they also caused the expansion of active memory, central processing, phonological loop, and visual-spatial memory.

CONCLUSION: According to the results of this research and the importance of improving working memory, it is suggested that cognitive games be used in schools and medical centers to improve the working memory performance of borderline students.

KEYWORDS: Cognitive; Working Memory; Borderline Students; Cognitive Functions

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Introduction

Borderline children have an intelligence quotient (IQ) between 1 and 9 standard deviations (SD) below average intelligence.[1] These students have difficulty understanding abstract concepts, need more time to understand the material, have limited vocabulary and poor memory, have difficulty to find relationships and similarities of reasoning, and are unable to generalize or transfer skills and knowledge compared to their peers.[2,3]

Working memory is one of the executive functions that is considered as one of the basic functions and it includes brain processes and processes that are used for short-term storage of information and their manipulation.[4] Working memory is one of the executive functional components, which has received attention due to its performance in various aspects of memory.[5] Working memory ability plays an important role in various aspects of life, including reading comprehension, writing, problem-solving, mathematical reasoning, written language, and various

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behavioral domains.[6,7] One of the characteristics of many children with learning disabilities especially borderline children is the presence of defects and weakness in working memory and its executive actions can have a significant impact on the accuracy and efficiency of students' performance; for this reason, these students cannot process information quickly and expected performance is different from realized performance.[8,9]

Working memory and processing speed are among the abilities that students will need in the future to learn educational content and concepts, and appropriate educational and therapeutic interventions can help the growth and improvement of learning disorders.[10,11] One of the ways to provide working memory training is to teach learners how to use memory strategies. These strategies include: mental efforts and goal-directed processing to increase memory performance, and people's use of these mechanisms is at least partially effective for increasing transformation in working memory.[12,13]

Many methods for improving attention and memory have been included in various research texts; one of these methods is cognitive game, because most of the processes related to teaching and learning are related to cognitive skills.[11,14,15]

Passarotti et al. have shown that teaching and practicing cognitive games for children is very enjoyable and exciting; it is usually related to strengthening memory by using exercise, mental visual imagery, story making, and categorization. If borderline students receive special educational support in the field of cognitive education, probably their problems in the areas of attention and memory will decrease.[16]

Nowadays, in the field of learning and teaching concepts, computer games have found a special place, and they are not just entertainment; rather, they have been significantly highlighted in the lives of children and teenagers. Children informally acquire considerable digital literacy through these games. In computer games, users are attracted to the game for non-educational reasons, but they learn learning skills while playing; of course, it is possible that the content of the games is not obviously educational, but it requires cognitive operations and processes that can lead to useful educational results.[17]

Flores Gallegos and Mayer[8] and Behrooz Sarcheshme et al.[18] reported that computer games attracted the attention of many researchers, because cognitive computer games have a significant contribution in strengthening children's attention and cognitive processes. One of the most important advantages of cognitive games compared to other forms of games is that computer cognitive games provide a new window in the development of children's skills and it can affect children's cognitive and behavioral skills. Fresh and original ideas allow the learner to reach beyond what is currently available and reach new areas of divergent thinking.[19,20] Ellis et al.[21] and Gee[22] have shown that teaching cognitive exercises regarding the transfer of concepts is useful in helping students to reduce recovery problems and increase problem-solving ability and creativity. According to these findings, such an approach has not been taken into consideration in the society of borderline students. It seems that the exercises of cognitive games –focusing on increasing the capacity of visual-spatial working memory– can improve working memory performance in borderline children. Therefore, the present study aimed to investigate the effectiveness of cognitive games on the working memory of sixth-grade borderline students in Saqqez City, Kurdistan Province, Iran.

Methods

The research method was semi-experimental with a pretest-posttest, with a control group.

The statistical population included borderline students studying in the sixth grade of schools of Saqqez City with an average IQ of 79 (n = 67) in the academic year of 2021-2022, who were identified as borderline according to Leiter, Goodenough, and Wechsler Scales upon entering the school. For accurate identification, the Wechsler IQ sub-test was performed again.

The study sample consisted of 24 students who were selected through random sampling according to the conditions of entry into the research and were assigned to two experimental (n = 12) and control (n = 12) groups. Entry criteria included: lack of movement problems, complete health, confidentiality of information, freedom to participate in the research, and full consent of the person and family to participate in the research. Moreover, the criteria for exiting the research were: the absence of more than two sessions and the occurrence of an unwanted incident that disrupts the possibility of a person attending treatment sessions.

After randomly selecting and placing the test and control groups, a pre-test was conducted for both groups at the same time. It should be noted that after the parents of the participating children were fully aware of the goals and the research process, all parents completed a written consent form to participate in the research process and they were assured that the personal information of the individuals in the research would be kept confidential.

The training of cognitive games such as Lomocyte and Tetris was done during 8 sessions of 1 hour (60 minutes) by the first author and under the supervision of the supervisor for the experimental group; and after completing the training sessions, a post-test was given to two groups. Standard active memory and organization questionnaires were used to collect data. The data were analyzed using analysis of covariance (ANCOVA) and SPSS software (version 24, IBM Corporation, Armonk, NY, USA). This article is an extraction from the master's thesis in Islamic Azad University, Mahabad Branch, Mahabad, Iran (code: IR.IAU.MSHD.REC.1401.007).

Cognitive games protocol and active memory questionnaire were used as follows to collect data.

Cognitive games: The cognitive games used in this study were Tetris and Lomocyte. Tetris game is a kind of puzzle and it is designed to improve the organization and compilation of appropriate patterns, where the puzzle pieces fall from the top of the page to the bottom of the page and the player must arrange the pieces on a line at the bottom of the screen. Lumosity game also measures people's five basic skills of memory, attention, speed, flexibility, and problem-solving. Besides, one of the features of this game is that it is online.

Tetris games: This game is presented by Russian game designer and programmer Alexey Pajitnov. It is a two-dimensional computer puzzle. The puzzle pieces fall from the top of the screen and the player must arrange the pieces on a line at the bottom of the screen. The subjects of the Tetris experimental group received this program individually in 2 sessions per week, 8 sessions in 1 month.

Lomocyte games: Lumosity is a program that was published by Lumos Labs for Android and IOS operating systems with the slogan of brain training. The Lumosity game measures the five basic skills of memory, attention, speed, flexibility, and problem-solving. This game consists of 5 stages; each stage consists of 4 parts. The experimental group received Lumosity games in 2 sessions per week, 8 sessions in 1 month (Table 1).

Results

In this research, 24 sixth-grade borderline students (12 in experimental group and 12 in control group) were investigated, and all the participants were present in the research till the end, and we did not have any sample loss.

Table 1. Summary of the content of cognitive games training sessions

Session	Content
1	Briefing meeting for parents of students to actively participate in the implementation of the plan
2	Pretest performance of students with Wechsler and Andre Rey tests
3	Introducing cognitive games to students and installing software on Android phones
4	Learning how to play the Lumosity cognitive game in 5 stages (memory, attention, speed, flexibility, problem-solving)
5	Teaching how to play the cognitive Tetris game (placing cubes)
6	Monitoring the performance of the Lumosity game at home in the form of providing a daily screenshot of the game process and sending it to the researcher for a week
7	Monitoring the performance of the Tetris game at home by providing a daily screenshot of the game process and sending it to the researcher for a week
8	Conducting the post-test and summarizing the topics

The effectiveness of group cognitive games on their working memory components was investigated. Descriptive analysis of data regarding demographic components showed that the mean and standard deviation (SD) of duration of borderline duration among students was 4.75 ± 0.45 and 4.50 ± 0.52 years in the experimental and control groups, respectively. Examining the gender of the subjects also showed that 50% of the members of the experimental and control groups were equal to 6 boys and 6 girls. It was also found that 83.3% of sixth-grade borderline students in the experimental and control groups were only children and the rest were two children. Examining the educational level of the parents also showed that 33.3% of the fathers of the control group had an associate's degree and a diploma, and 41.7% of the mothers of the experimental group had an associate's degree. In the experimental group, it was found that 33.3% of the fathers had a diploma degree and 58.3% of the mothers had a bachelor's degree. Table 2 shows the mean and SD of the components separately for two groups in the pre-test and post-test phases.

To determine the effectiveness of cognitive games on the total score of working memory, univariate ANCOVA was used. Therefore, the presuppositions of this test were checked first. Levene's test was used to check the assumption of homogeneity of error variance of two groups and the results of this test showed that this assumption was true ($F_{1,22} = 0.083$, $P = 0.776$).

Table 2. Mean and standard deviation (SD) of working memory dimensions of slow learning students by two groups

Variable	Group	Test	Mean ± SD
Working memory	Experimental	Pre-experiment	33.16 ± 1.78
		Post-experiment	33.41 ± 1.64
	Control	Pre-experiment	30.18 ± 2.06
		Post-experiment	33.48 ± 1.74
Central executive	Experimental	Pre-experiment	25.08 ± 1.08
		Post-experiment	27.91 ± 1.72
	Control	Pre-experiment	24.91 ± 1.50
		Post-experiment	26.83 ± 1.52
Phonological loop	Experimental	Pre-experiment	24.50 ± 1.48
		Post-experiment	24.90 ± 1.65
	Control	Pre-experiment	25.58 ± 0.99
		Post-experiment	25.83 ± 1.19
Visual-spatial page	Experimental	Pre-experiment	25.18 ± 1.16
		Post-experiment	25.86 ± 1.26
	Control	Pre-experiment	23.00 ± 0.90
		Post-experiment	26.56 ± 1.04

SD: Standard deviation

According to the establishment of this assumption, it can be said that there was no limitation in the use of univariate ANCOVA test.

The results of univariate ANCOVA showed that cognitive games led to a significant difference in the post-test of the total working memory score in the experimental and control groups. Next, multivariate ANCOVA (MANCOVA) was used to investigate the effectiveness of cognitive games on working memory according to the number of dependent variables. Therefore, before the implementation of this test, its presuppositions were first checked. The results of the Box's M test to check the assumption of homogeneity of the variance-covariance matrix showed that this assumption was valid (Mbox = 16.955, $F_{10, 23.94}$ = 1.357, P = 0.194). Levene's test was also used to check the assumption of homogeneity of variance, and the results are presented in table 3.

Table 3. The results of Levene's test to check the assumption of homogeneity of variance

Variable	F	df_1	df_2	P
Central executive	0.133	1	22	0.719
Phonological loop	0.448	1	22	0.510
Visual-spatial page	0.156	1	22	0.696

df: Degree of freedom

According to the results of table 3, the level of F and the level of significance showed that the assumption of homogeneity of variance regarding the components of active retention was also established; therefore, the conditions for using the MANCOVA test were met. Table 4 presents the results of multivariate tests to investigate the effectiveness of cognitive games on the components of working memory.

The results of multivariate tests showed that the provided intervention was effective. Therefore, to investigate the effectiveness of this intervention on each component of working memory, MANCOVA was used, and the results of this analysis are presented in table 5.

Table 4. The results of multivariate tests to investigate the effectiveness of the intervention on the components of working memory

Effect	Value	F	P	η^2
Pillai's trace	0.929	49.230	< 0.001	0.929
Wilks' lambda	0.071	49.230	< 0.001	0.929
Hotelling trace	13.128	49.230	< 0.001	0.929
Roy's largest root	13.128	49.230	< 0.001	0.929

The results of MANCOVA showed that cognitive games led to improvement of working memory components in the experimental group compared to the control group. In other words, cognitive games were effective in improving the working memory of sixth-grade borderline students.

Discussion

The present study was conducted to determine the effectiveness of cognitive games on the working memory of sixth-grade borderline students. The findings showed that the training of cognitive games had a significant effect on the working memory variable, which was in line with previous research. For example, Eskandari et al. reported that working memory training by targeting learning problems improved reading skills and helped a person to better use his memory capacity to plan and organize things.[23]

These findings are in line with the results of Dehghan and Mahdiserajiyan,[24] who stated that the cognitive rehabilitation programs were effective in improving the cognitive components of children with learning disorders.

Table 5. The results of multivariate tests to investigate the effectiveness of the intervention on the components of working memory

Variable	SS	df	MS	F	P	η^2
Central executive	54.810	1	54.810	152.568	< 0.001	0.894
Phonological loop	25.757	1	25.757	23.003	< 0.001	0.561
Visual-spatial page	25.268	1	25.268	32.077	< 0.001	0.641

SS: Sum of squares; df: Degree of freedom; MS: Mean squares

This type of intervention can be used to improve various cognitive components.

Additionally, these findings are implicitly aligned with the research of Isanejad Bushehri et al.,[25] Shute et al.,[26] and Gee,[27] who reported that the method of computer games significantly increased sustained attention and active memory in children with learning problems.

Karamalian et al. in their research pointed out that child play therapy had a significant effect on the post-test scores of working memory and processing speed of students in the experimental group compared to the control group.[5] They also confirmed that the cognitive game could be effective in improving working memory and processing speed as two cognitive factors influencing neuropsychological learning disorder.

Other researchers showed that teaching cognitive exercises regarding the transfer of concepts was useful in helping students to reduce recovery problems and increase problem-solving ability. Moreover, when students play video games, compared to students who do not play video games, show better results in activities related to cognitive abilities.[21,22] In explaining this finding, it can be acknowledged that working memory, as one of the important components of executive functions, is affected by cognitive games. Because active memory is a mental system whose duty is to collect and process information to perform a series of complex cognitive tasks such as understanding, reasoning, and learning.

Akbari Chermahini et al. reported in their research that computer cognitive games based on memory had a significant effect on improving working memory performance in learning disabilities and could be used as an effective and useful method to improve it,[28] which was in line with the findings of this research. Besides, no research results were found contrary to the results of the present research.

Therefore, based on this research and other research and taking into account the theoretical background of this research, it can be said that borderline students are often weak in terms of academic progress and there is a possibility that they will be rejected. Experiencing frequent failure in class, lack of goals for the future, negative attitudes of classmates, and incorrect teaching methods greatly reduce the academic motivation of these children. Progress and stability in progress require attention to abilities, talents, interests, executive functions, and cognitive strategies. In line with the results of this research and considering its importance, it is suggested that to encourage as many borderline students as possible to play cognitive games, the necessary measures and guidance should be taken by the school principals, coaches, and parents, because cognitive games, as an important factor in life, play an effective role in the development of borderline students, and also have an impact on the comprehensive growth and flourishing of their talent, and make children cheerful and responsible.

The present study was faced with limitations such as time limit, non-randomness of sample selection, limited number of samples, lack of follow-up, and geographic limitation.

It is also suggested that the education of borderline students should be accompanied by games suitable for their cognitive level so that they can grow properly in different dimensions.

Conclusion

Based on the findings of the present study, it can be concluded that cognitive games can be used to improve academic performance and better learning of borderline students who have cognitive and functional problems. Therefore, to further improve the activities and strengthen the abilities of borderline students, the cognitive games, such as Tetris and Lomocyte, can be used, which strengthen memory, attention, speed, and flexibility. Hence, it is suggested that to determine the

effectiveness of this study, follow-up tests should be used for the effectiveness and durability of cognitive games, and also be examined and compared with other psychological tests, and their effectiveness on executive functions and working memory should be assessed.

Conflict of Interests

Authors have no conflict of interests.

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