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Effectiveness of Computer Games on Improving the Attention and Working Memory of Children with Attention Deficit Hyperactivity Disorder

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ABSTRACT

Aims The purpose of the present study was to identify the effectiveness of computer games interventions in improving attention and working memory of children with attention deficit hyperactivity disorder.

Participants & Methods This semi-experimental study was pre-test/post-test with the control group and the statistical population was the second to sixth grade students in Najafabad City in the academic year of 2018-2019. Among them, 20 students were purposively selected based on diagnostic interview and screening score using Swanson et al. questionnaire and were randomly divided into two 10 experimental and control groups. Data were collected using SNAP-IV (Swanson, Nolan, and Pelham; 2001) questionnaire, Digit Span Backwards Task (Wechsler; 2008) and Corsi Block-Tapping Test (Corsi; 1972). Computer game interventions consisting of 20-minute in 18 sessions run just for the experimental group. Finally, data were analyzed using multivariate analysis of covariance.

Findings Results showed that computer game interventions had a positive effect on improving spatial visual attention and working memory, but there was no significant effect on verbal memory ($p<0.05$). Also, 74% of the differences in the groups were due to the impact of the intervention ($p<0.05$).

Conclusion According to the results, computer games as a cognitive intervention have been effective in increasing attention and spatial memory in children with attention deficit hyperactivity disorder. In addition, it is suggested that new methods such as computer games can be used to improve cognitive skills and reduce students' learning problems.

Keywords Attention Deficit Hyperactivity Disorder (ADHD); Workking Memory; Comt puter Games

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Introduction

The person's growth is a gradual and constant process in various dimensions, influenced by two factors of inheritance and education. Attention Deficit Hyperactivity Disorder (ADHD) is a developmental and neurological disorder that affects scientific, social, and emotional adjustments, and its features include inattention, impulsivity, hyperactivity, or a combination of these three features [1]. The onset of symptoms is before the age of 12 [2]. Children with ADHD have common symptoms or problems such as high mobility, decentralization, disorganization, and restlessness and more difficulty in following directions and conversations than others [3]. Failure to adjust levels of activity in the environment or during doing tasks, high running and jogging, severe restlessness, inability to sit for a long period of time, as well as problems with sleep and nutrition are associated with hyperactivity in these children [4].

People with this disorder may not be able to pay close attention to details or may negligently make mistakes in doing school or work tasks or other activities. There is often disorganization in activities and tasks are performed carelessly with no sufficient thought. The people with this disorder have problems in paying attention to games and tasks and can barely focus their attention on completing tasks [1, 2, 3]. Distraction, leaving the works half-finished, frequent shifts of activities, sluggishness, failing to complete half-finished works, and increased error in doing the tedious tasks can be mentioned as problems of inattention in these children [5].

New studies have shown that there are several attention networks in the brain that encompass a variety of attention-related functions such as stimulation, alertness, orientation, concentration, retention, etc. One or more of these functions may be impaired concerning each report of inattention. From a clinical perspective, attention problems that occur in many situations and persist over time lead to disorders and interference with the quality of life [6]. General areas of executive functions include working memory, planning, and attentional impulse control [7].

Working memory is a multifunctional cognitive system with limited capacity, which is responsible for the temporal storage and processing information while reasoning, planning, problem-solving, and other complex temporal behaviors. Experimental findings showed that children with ADHD have extensive deficits in their functions of working memory, and the complementary evidence suggests that these deficits are the bases for the main and secondary symptoms of this disorder [8]. The working memory, based on the Baddeley's model, is a multicomponent system with limited capacity that encompass four components: The element of working or the central executive unit that is responsible for the mental processing of internal information using several related processes such as updating, manipulating, sequential reorganization, intervention, and modifying attention between two or more tasks simultaneously. Two other components of working memory are "phonological loop" and "visuospatial sketchpad". The visuospatial sketchpad stores the visual information and plays an important role in mental imagery, and the phonological loop performs the temporary storage of the verbal information, referred to as phonological working memory. The fourth component is "episodic buffer" and connects the working memory and long-term memory [9].

Recent wide range of psychological and psychiatric studies are looking for finding treatment for ADHD in children. However, despite various treatments such as pharmacotherapy, behavioral and cognitive therapies, these therapies have their own problems. Generally, there are three types of treatment for children with this disorder. The first type, i.e. pharmacotherapy, is the most common type of treatment. The second type includes behavioral therapy and the third type is cognitive therapy [10]. The main approach to cognitive therapies is the rehabilitation approach, in which the main focus is on strengthening and rehabilitating cognitive elements designed for improving specific functions by applying cognitive practices and tasks [11].

One of the modern approaches contributing to reinforcing and rehabilitating cognitive components is computer games. Computer games are one of the manifestations of technological progress in the modern era [12]. Computer games use the basic principles of cognitive therapies in treating ADHD. According to these principles, sustained attention and active memory can result in the improvement of the symptoms of the disorder through providing structured opportunities to practice different aspects of attention and memory. These games include repeated practices in a series of tasks that need attention at different levels. It is assumed that continuous activation of attention systems will change cognitive capacity, reducing cognitive and behavioral symptoms [13].

Over the past 40 years, computer games have had different effects on people's aspects of life. The structural features of the games provide unique opportunities not provided by traditional therapies. Moreover, the games can be useful tools in psychotherapy to evaluate, create, and educating social relations [14]. Evidence showed that improving processing speed, attention control, memory, cognitive and social skills can be achieved by playing specific games. Therefore, since behavioral changes are caused by brain changes, it is not surprising that movement in performance is consistent with functional nervous change [15].

Studies on the effectiveness of cognitive rehabilitation in studies conducted inside Iran and

abroad, and revealed the impact of using computer games on learning disorders, brain executive functions, and cognitive processes in children [16-20]. However, it must be acknowledged that the games were often non-native and designed in other countries. The present study used a package of computer games interventions including several computer games that use the basic principles of cognitive theories based on neurobiological processes that contain ability to improve cognitive processes by structured opportunities to practice different aspects of attention, planning, memory, etc. The games were designed by the research team in order to diagnose ADHD and this study evaluated this package of games for the first time. Thus, the present study aimed at finding an answer to the following important questions on ADHD in children: Can attention and working memory in children with ADHD be improved?. Can computer games reinforce attention and working memory in children with ADHD?.

Participants and Methods

The methodology used in the present study was experimental using a pre-test post-test with a control group. The population consisted of all children studying in three elementary schools in the city of Najafabad in the academic years 2018-2019. Experimental designs cannot be used in a group setting in clinical and educational settings, due to small sample size, specificity, or characteristics of the subjects. In these designs, subjects can range from 1 to 20, but each is involved in the process individually [21, 22]. So, 20 students were selected from the three schools, with a score lower than the cut-off point in SNAP-IV scale and the ADHD diagnostic interview, based on the DSM5 criteria, were purposefully selected and then were divided in two experimental and control groups of 10.

The inclusion criteria were the age range of 8-12 years old, consent to participate in the intervention session and obtaining the equivalent score of ADHD in SNAP-IV scale and the diagnostic interview. The exclusion criteria were having comorbidities with attention deficit hyperactivity disorder, withdrawal from the project prior to the completion of the sessions, and missing more than three sessions in the training process and participating in another training program at the same time. The questionnaires, before the intervention, were performed for both experimental and control groups and then, the intervention of computer games was done only for the experimental group. The data were analyzed using descriptive statistics (mean and the standard deviation) and multivariate analysis of covariance.

Data collection tools

In the present study, the questionnaire and the tools for collecting data are as following:

1- SNAP-IV Scale: This scale measures ADHD and has a single form for parents and teachers to answer. It was first made by three authors, Swanson, Nolan, and Pelham in 1980 [23]. This scale has 18 items. 9 first items measure the attention deficit and the next 9 items measure attention-hyperactivity deficit. In other words, the first 9 items measure behavioral symptoms of inattention and the next 9 items measure the morphological behavioral symptoms of hyperactivity/impulsivity and finally all 18 items have been designed to identify the mixed morphology. A 4-option Likert scale (0-3) is used to score. One's score is the sum of total score divided by 18 and each subscale divided by 9. The cut-off points in the whole scale and each of the subscales of attention-hyperactivity deficits were reported as 2.08, 2.10, and 2.37, respectively. This scale consists of a 4-point range, which is scored as 0, 1, 2, and 3. The people who reached the cut-off point are identified as those with ADHD [24]. Sadr al-Sadat *et al*. [24], in a study on 100 children at age range of 7 to 12 years old in Tehran, reported the reliability coefficient of this test using different methods including retest method as 0.82, Cronbach alpha as 0.90, and split-half method as 0.76. The criterion validity of the test was 0.48 and, according to the factor analysis, this test had 3 factors that explained 56% of the total variance [25]. In the present study, the Cronbach alpha calculated 0.74.

2- Digit Span Backwards Task: It is an important tool to assess working memory. It is implemented the same way as the direct digit span. The difference is that in this task the subjects must recall the digits reverse order. The task is scored based on total digits one recalled. This tool has been standardized and the results showed that Cronbach's alpha coefficient for this task was 0.56 and validity coefficient using the retest method was 81.7 [26]. In the present study, the Cronbach alpha calculated 0.73.

3- Corsi Blocks Task: The visuospatial component of active and short-term memory is assessed through keeping the visual patters in motion sequence. One of the tasks measuring the visuospatial memory is Corsi Blocks Task [27]. This task can be performed for children at age of preschool to an 80-year-old person. In the most common version of this task, the researcher taps a sequence of 9 identical spatially separated blocks. The subject must remember the sequence of clearing the blocks and to repeat the sequence by tapping on the blocks once the blocks are cleared. This task starts with two blocks and becomes more complex (one is added at each stage). The same number of blocks are positioned on the screen if the subject failed to repeat the correct sequence of the blocks, and the task is finished after two errors in one sequence of the task. This task continues until the number of blocks is 9 and the longest recalled sequence of blocks is recalled by the subject [28]. Walker *et al*. calculated the validity of this task using the retest method as 0.73 [29]. The validity of the task, in Iran, was obtained by Dadashi *et al*. [28] as 0.78 and by Molaei Zangi and Eskandarnejad [30]

using Cronbach's alpha coefficient as 0.80. In the present study, Cronbach's alpha coefficient was 0.76.

Computer games intervention package: This package includes 5 different computer games made by the researcher and its content validity was confirmed by some psychologists and psychiatrists. The games are played based on the basic principles of cognitive theories to practice different aspects of attention, planning, and memory. In these games, the identification of game signs and their incorporation in a strategy to facilitate the performance led to selective attention. These games indicated children's goals of playing, their understanding of signs and strategies and/or attention patterns and memorizing in the game. First, each child registered by entering his name and age and then received a personal code. Each game was over after 3 errors and the child could see the results on the screen in a table. The game was more complex in each stage. Children played three sessions a week for 20 minutes. Each session was divided in two 10-minute parts with a different game to play. Selecting a match for playing depended on the children's interest.

The first game (where was this dude?): In this game, strawberry figures appeared on the screen for a moment and then disappeared. Then, the child had to recognize that figure among other figures in a determined time. This game has 12 stages and strawberries were added in each stage. At the end of each game, the table of results was displayed, with time of responding, number of errors, total number of figures, and the number of tries in each stage.

The second game (what was this dude?): This was the same as the previous game with this difference that figures were apples and when they were disappeared, the child had to select their eyes in one stage and their lips in the next stage. This game also included 6 stages.

The third game (which one is higher?): In this game, some colorful circles with a number on them are displayed on the screen. The child must select the color and number of the circle that is higher in the determined time. At the end, the results, including the stage, the best stage, average response time, and standard deviation of response time are displayed.

The fourth game (see and write): In this game, some figures with a tableau in their hands are displayed on the screen. On each tableau, there is a word. Some of the words are bold and the child must remember them after disappearing. At the end, each child can see his score, the highest score, stage, response time, and standard deviation of response time.

The fifth game (find something like this one): In the final game, there is a figure on the left side of the screen and the child must find a figure like that among the figures on the center of the screen. Finally, the results of the number of last stage, the best stage, average response time, and the standard deviation of response are displayed.

Research Implementation Method

In the first stage, all subjects in the experimental and control groups took pre-test after the diagnostic interview and SNAP-IV scale. In other words, they took SNAP-IV, Wechsler digit span backwards task, and Corsi blocks task and their scores were recorded. Then, according to the psychologists and psychiatrists who assessed the content of games and the studies related to the present study, each of subjects in the experimental group individually received computer games intervention in 18 sessions (each for 20 minutes). The subjects in the control group received no intervention. The scores of pre-test and post-test were analyzed by SPSS 19. Ethical permissions of the study were observed by obtaining written consent forms, giving them the choice to participate in the study, and observing the confidentiality of the information.

Findings

The variables of working memory and attention were measured in pre-test and post-test in two experimental and control groups.

Descriptive indexes of data are presented in Table 1 and the results of the data analysis, according to the analysis of covariance, are shown in Table 2. The results of the covariance analysis indicated that there is a statistically significant difference between the experimental and control groups in the variables of attention and visuospatial working memory. It means that the experimental group, after intervention, had a better performance than the control group in the test of attention, visuospatial working memory, and the computer games were effective on improving attention and visuospatial working memory. There could be found no significant difference between the two groups in verbal working memory.

Table 1) Mean and standard deviation of attention and working memory tests in experimental and control groups

Variable	Experimental	Control
Attention		
Pre-test	30.4±3.365	31.7±4.471
Post-test	24.1±3.860	31.3±3.520
Verbal working memory		
Pre-test	3.3±0.483	3.7±0.383
Post-test	3.4±0.516	3.3±0.490
Visuospatial working memory		
Pre-test	3.1±0.738	4.8±0.422
Post-test	3.3±0.801	3.2±0.919

Table 2) The results of covariance analysis of the variables of attention and working memory in the experimental and control groups

Statistical indexes	F coefficient	Significance level
Attention	40.273	0.003
Verbal working memory	0.446	0.079
Visuospatial working memory	12.416	0.0001

Discussion

The present study aimed to determine the effectiveness of computer games intervention on improving attention and working memory in children

with ADHD. The results indicated that the computer games intervention was effective on reducing the symptoms of attention deficit, regarding decreased scores of the experimental group in pre-test to post-test and the significant decrease between the experimental and control groups in the post-test and the significance value of F at the level of 0.003. The calculated value of eta confirmed that 70% of the difference between the groups from pre-test to post-test was the result of computer game intervention. Therefore, the research hypothesis was confirmed and these psychological interventions were effective on decreasing the symptoms of attention deficits.

The results of this study were consistent with the studies by Habibi Kalibar and Bahadori Khosroshahi, Bergo *et al*., Eivazi *et al*., Abdi *et al*., Najarzadegan *et al*. on the effectiveness of computer games on attention [16-20]. Attractive learning environments and diverse software spaces can have positive effects on children with ADHD. Computer games, due to their nature, can activate parts of the brain, including the prefrontal cortex, the sensory-motor cortex, the visual cortex, and the lower areas of the brain cortex (such as the amygdala and hippocampus), which play important roles in emotion and cognition and thus, they significantly help the person's behavior and cognitive performance [31]. Tools such as games, virtual reality, and practical programs for smartphones and computers can increase motivation, learning, behavioral and cognitive changes, supporting psychotherapy, enhancing abilities, and improving cognitive performance. Game and computer designs contribute to creative and innovative creation and evaluation of therapeutic and preventive tools. Different studies discussed issues on the impact of computer and games on mental health and wellbeing [32].

To evaluate and measure verbal working memory, Wechsler Digit Span Backwards Task was used in the present study. The results of covariance analysis showed that there is no significant difference between the experimental and control groups and computer games intervention had no considerable effect on improving the verbal working memory. Strengthening active verbal working memory requires strengthening auditory sensory stimuli (attention), auditory perception, and consequently, organization. Therefore, attention, perception, and memory skills can strengthen active memory. Since auditory-sensory stimuli and auditory perception were not used in the computer games intervention used in this study, ineffectiveness of these interventions on verbal memory was expected. This study was also aimed to determine the effectiveness of computer games intervention on visuospatial memory. Corsi blocks task was used to evaluate and measure visuospatial working memory. The results of covariance showed that computer games intervention was effective on mitigating the symptoms of attention deficits. The calculated value of eta confirmed that 74% of the difference between the groups in the scores of pre-tests to post-tests was resulted from the effect of computer games. In this context, computer games affect improving visuospatial working memory. The results of this study are consistent with those found by Abdi *et al*., Moradi *et al*., and Shokoohi-Yekta *et al*. indicating that computer games interventions are effective on cognitive enhancement in increasing executive functions [19, 26, 33]. These games can increase the skills of response inhibition and working memory in children with ADHD since children learn direction skill, response inhibition, and multi-step rules and visuospatial working memory. Moreover, these games enhance the skills of remembering names, recalling the location of objects, considering the details and learning the new topics, resulting in enhanced memory.

Though this study sought to randomly replace subjects with experimental and control groups in order to reduce interfering and confounding variable and possible biases, the most important limitation of the study was using the purposeful sampling method and absence of follow-up stage. Another limitation was limiting the samples to female students with attention deficit/hyperactivity disorder in Najafabad. Thus, it is suggested to use random sampling methods and the variable of gender, as well as short- and long-term follow-ups in future studies to evaluate the effect of results more accurately. In addition, considering the ineffectiveness of computer games interventions on verbal working memory in children with ADHD, it is recommended to add auditory stimuli to the games to strengthen this skill.

Conclusion

The results of the present study showed that computer games interventions as an effective way to increase the ability of attention and visuospatial working memory can be used executively in educational and therapeutic centers. According to the results, it is suggested to the therapists and clinical psychologists to use this method to increase attention and working memory in children with ADHD. On the other hand, computer games can be used to improve the cognitive functions of the brain, and as cognitive rehabilitation practices at different levels of difficulty, to the children with attention deficit-hyperactivity disorder.

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Ethical permissions: The Iranian registry of clinical trial (IRCT) Code is 47379.

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analyst/Discussion author (40%); Javad Rasti (Third author), Introduction author/Methodologist/Statistical analyst/Discussion author (10%); Fatemeh Beigi (Fourth author), Introduction author/Discussion author (10%).

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