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Usability of Serious Games on Visual Attention in Children with High-Functioning Autism Spectrum Disorder

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ABSTRACT

The present study aimed to evaluate the usability of serious games in increasing visual attention among children with high-functioning autism spectrum disorder (ASD). The research had a quasi-experimental design with a pre-test, post-test, and control group with a follow-up period. The statistical population consisted of elementary school students with autism in Tehran in 2024. Using a convenience sampling method, 20 children diagnosed with autism from a specialized autism school were randomly assigned to experimental and control groups. The experimental group participated in 20 sessions of serious game content through computer games but the control group received no interventions. Data were collected using the Visual-Auditory Integration Test before, after, and two months after the intervention. Repeated measures analysis of variance was used to analyze the data. The results indicated that serious games had a significant effect on the visual attention of children with autism spectrum disorder (ASD). These results suggest that serious games can improve visual attention in children with autism. Therefore, it is suggested to use such interventions to improve executive functions and academic performance in children with ASD.

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Introduction

Autism spectrum disorder (ASD) is a neurodevelopmental disorder that emerges in early childhood. Most studies highlight deficits in social and communication skills among children with this condition. ASD can be diagnosed by the age of three but it may remain undetected until preschool age (Waizbard-Bartov & Miller, 2023). Recent reports indicate that the prevalence of ASD is one in every 36 births. Various symptoms of ASD emerge during early growth and can significantly affect daily functions (CDC, 2021).

Individuals with ASD show substantial variability in executive function abilities (Demetriou, DeMayo & Guastella, 2019). Executive functions encompass the cognitive skills necessary for goal-directed behavior (Friedman & Sterling, 2019). Learning challenges in these individuals are due to impairments in executive functions (American Psychiatric Association, 2022; Demetriou et al., 2019). Research evidence highlights deficits in executive functions among individuals with ASD (Lai et al., 2017; Granader et al., 2014; Johnson et al., 2019). These deficits increase the risk of academic challenges and learning difficulties (John, Dawson & Estes, 2018). Such impairments may persist in adulthood and cause significant problems in daily tasks, and professional and social responsibilities (Smith-Spark et al., 2016).

Attention, as a higher-order cognitive activity, plays an important role in processes such as perception, memory, and intelligence (Shah Mohammadi et al., 2019). Attention precedes perception, learning, and problem-solving. Initially, individuals focus on a specific stimulus, which they process and use for thinking and problem-solving (Emadifar & Gorji, 2017). Attention is essential for learning and is often classified into visual and auditory types based on a hierarchical model. One common challenge in children with ASD is maintaining sustained attention or focused attention over time. Sustained attention involves vigilance and concentration over periods of several minutes (Caplan, Kreutzer & DeLuca, 2018). Due to the relatively stronger perception of visual stimuli in children with ASD, any impairment in visual attention may challenge their learning process; hence, this aspect should be taken into consideration in the learning process.

Computer-based cognitive interventions have recently become popular due to their unique advantages, including user engagement, ease of management, and accessibility. Evidence shows that training executive functions can cause positive outcomes for diverse populations (Apter, 2012; Klingberg, 2010; Melby-Lervag & Hulme, 2016; Morrison & Chein, 2011; Shipstead, Hicks & Engle, 2012; Macoun et al., 2020; Lee et al., 2016; Kerns et al., 2017; Martin-Moratinos, Bella-Fernández & Blasco-Fontecilla, 2023; Barletta et al., 2023). Computer-based executive function training is viewed as a viable approach for children with ASD (Benyakorn et al., 2018; Macoun et al., 2020; Kerns et al., 2017; Weckstein et al., 2017). Given the increasing prevalence of ASD, early identification and intervention are essential. According to previous research, serious games via computers play a significant role in engaging children's multiple senses and improve their challenges.

Serious games are designed with objectives beyond mere entertainment. These games are intended to support educational, therapeutic, or mental health goals and come in various formats, including physical, card, video, and online games. Serious games aim to engage participants in enjoyable yet purposeful ways that align with specific goals (Damaševičius et al., 2023). A primary advantage of serious games is their goal-oriented nature, which challenges skills such as attention, speed, performance, and problem-solving. These games have proven effective in improving performance among children struggling with attention, focus, or problem-solving abilities (Shamsi, Qamrani, & Siadatian, 2018).

Nowadays, the cognitive, emotional, and academic development of children with special needs has become a central therapeutic goal. Given the significant role of executive functions in enhancing cognitive and behavioral skills, these abilities should receive greater attention in

treatment plans. Recognizing the impairments in executive functions and cognitive deficits among children with ASD highlights the necessity for effective interventions. Therefore, this study aimed to assess the usability of serious games in improving visual attention among children with high-functioning ASD.

Method

This research was applied in terms of purpose and used a quantitative approach with a quasi-experimental design. The study had pre-test and post-test phases, a control group, and a follow-up period. The statistical population consisted of all elementary school boys with Autism Spectrum Disorder (ASD) in Tehran in 2024. Participants were selected through purposive sampling. Initially, one special school for students with ASD in eastern Tehran was chosen, and 20 boys diagnosed with ASD were selected. These participants were then randomly divided into experimental and control groups. The inclusion criteria were a confirmed diagnosis of high-functioning ASD as indicated in the student's educational records, the ability to read and write, voluntary participation, and signed consent from parents. Exclusion criteria were inconsistent attendance, missing more than two sessions, and the presence of comorbid conditions or ongoing treatments (determined through an initial interview with parents).

Research Instruments

Integrated Visual and Auditory Continuous Performance Test (IVA)

The IVA test is a continuous performance assessment first developed by Beck et al. in 1956. It is specifically designed to evaluate sustained attention in children. Key variables measured in this test include omission errors, commission errors, and reaction time. The Persian version of the test has demonstrated reliability coefficients ranging from 0.53 to 0.93. During the test, numerical stimuli are presented both visually on a screen and aurally through headphones. Participants are instructed to press a response key when a target stimulus is detected. The stimulus duration varied between 40 and 500 milliseconds, with shorter durations enhancing test precision. The optimal range for differentiating children with ADHD from their normal peers is 50 to 2000 milliseconds.

This test focuses on three main variables: the number of omission errors, the number of commission errors, and the average reaction time. Omission errors provide insight into the speed of cognitive processing. In total, 500 visual and auditory stimuli are presented, with one appearing every 1.5 seconds. The visual stimuli remain on screen for 167 milliseconds, while auditory stimuli last for 500 milliseconds. Validation studies indicated that IVA-2 could identify children aged 7–12 with ADHD with a sensitivity of 92% and a specificity of 90% for distinguishing unaffected children. Further research confirmed its validity for broader age groups (6–55 years), indicating a 90% accuracy rate when combined with ADHD rating scales as part of a comprehensive psychological evaluation. In this study, the test’s internal consistency, calculated via Cronbach's alpha, was 0.70. This instrument was implemented by an instructor to assess attention and processing speed in students with ASD.

Research Procedure

After obtaining the necessary authorizations, the researcher reviewed educational records to identify high-functioning students with ASD, who were then assigned to either the experimental or control group. Before the intervention, a briefing session was held with parents, and their consent for their children's participation was secured. A pre-test was then conducted for both

groups. Additionally, a series of serious digital games was developed to enhance attention skills. These games were designed in progressive levels, with each level incorporating time constraints for stimulus responses. If a response was not given within the designated timeframe, the participant would lose the round. As the levels advanced, the number of stimuli increased, while the time available to respond decreased. The intervention was delivered in 25 sessions lasting 20–30 minutes each, held twice weekly at the school for students with ASD. Additionally, the researcher used researcher-made card games and worksheets to further develop the participants' visual attention skills. After completing the intervention, a post-test was performed for both groups. A follow-up assessment was conducted for the experimental group two months later. Ethical considerations included ensuring the confidentiality of participants' data, allowing voluntary withdrawal from the study, and safeguarding participants from any harm or adverse effects throughout the research process.

Table 1: Summary of Serious Game Sessions

Session	Objective	Content
1	Introduction and Acquaintance	Introduction to the program and training on its use
2 to 6	Enhancing visual working memory	Practicing the memorization of target shapes and selecting them from among various options using worksheets according to the session's objectives
7 to 11	Developing sustained visual attention and behavioral inhibition	Sustained focus on the presented shape and inhibition of selecting similar shapes; review of previous exercises and worksheet-based practice aligned with the session's goals
12 to 16	Improving visual memory and behavioral inhibition	Memorizing details of the target shape and selecting it from the presented options; review of prior exercises and worksheet-based practice based on the session's objectives
17 to 20	Cognitive flexibility	Shifting attention from the previous shape to focus on the features of a newly presented target; review of earlier exercises and worksheet-based practice

Results

Demographic Description

The collected data were analyzed using repeated measures ANOVA, indicating that in the experimental group, most students (30%) were 13 years old, while in the control group, 30% were aged 11. Furthermore, 30% of the experimental group were in the fifth grade, whereas30% of the control group were third-grade students. The mean and standard deviation of age in the experimental group were 11.40 and 1.42, respectively, while these values were 10.80 and 1.31 for the control group. The descriptive statistics for the variable at the three stages (pre-test, post-test, and follow-up) are summarized in Table 2. The results indicate that in the experimental group, the highest level of visual attention was seen in the post-test stage (mean:62.30), followed by the follow-up stage (mean: 61.10) and the pre-test stage (mean: 55.30). Therefore, the peak level of visual attention was observed first in the post-test stage, then during follow-up, and finally in the pre-test stage. Similarly, the control group exhibited the highest level of visual attention during the post-test stage (mean: 54.70), followed by the pre-test stage (mean:54.60) and the follow-up stage (mean: 54.20).

Table 2: Data of Descriptive Results for Research Variables

Variable	Group	Stage	Mean	Variance	(SD)	Standard Error
Visual Attention	Experimental	Pre-test	55.30	53.56	7.31	2.31
		Post-test	62.30	41.34	6.42	2.03
		Follow-up	61.10	42.76	6.53	2.06
	Control	Pre-test	54.60	56.71	7.53	2.38
		Post-test	54.70	53.34	7.30	2.30
		Follow-up	54.20	39.51	6.28	1.98

Table 3. Results of Box's M Test for Equality of Variance-Covariance Matrices

Variable	Box's M test	F-value	Degree of Freedom 1 (df1)	Degree of Freedom 2 (df2)	Significance Level
Visual Attention	13.03	1.45	2	2347.47	0.093

Based on the Box's M value (13.03), the variance-covariance matrices for the visual attention variable were not statistically significant at α=0.01 considering both the experimental and control groups. Therefore, the assumption of equality of variance-covariance matrices was met.

Table 4. Results of Between-Subject Effects for the Research Variable in the Experimental and Control Groups

Variable	Source of Variation	Sum of Squares	Degrees of Freedom	Mean Squares	F-value	Significance Level	Effect Size
Visual Attention	Group (Experimental and Control)	144.23	2	72.11	40.35	0.01	0.69
	Error	64.33	36	1.78			

According to the table, the F-value for visual attention is significant at α=0.01 at the three stages (pre-test, post-test, and follow-up), indicating a significant difference in visual attention levels at the three measurement stages. Additionally, referring to the effect size in the final column of the table (0.69), it can be inferred that the serious games had a high level of effectiveness in improving visual attention in students with autism.

Discussion and Conclusion

The results of this study indicate that serious games have a positive effect on increasing visual attention in children with Autism Spectrum Disorder (ASD). This result is consistent with previous research by Martin-Moratinos, Bella-Fernández, and Blasco-Fontecilla (2023) and Barletta et al. (2023). Serious games, which are structured activities usually designed for leisure or entertainment, can also be effectively used for educational purposes. These games, aimed beyond mere entertainment, indicate a new therapeutic approach (Bul et al., 2016). Serious games are used to enhance cognitive functions. In this study, given that attention deficits are one of the most prominent cognitive weaknesses in children with ASD (Redondo et al., 2019), serious games were utilized to improve attention in these children.

Play is recognized as an essential component of educational and rehabilitative interventions, serving as a valuable tool for enhancing the capabilities of children with ASD (Elbeltagi et al.,2023). Computer-based games offer visual information that holds significant appeal for children with ASD (Rezayi, Tehrani-Doost, & Shahmoradi, 2023). Serious games possess considerable potential in educational settings. Since children with ASD may experience anxiety or discomfort in therapeutic or educational environments, potentially missing out on valuable

learning opportunities, educating families and continuing interventions in alternative settings can help sustain treatment and learning efforts.

Serious games improve attention through structured and organized exercises, with these programs grounded in the principle of neuroplasticity. According to this principle, increased brain stimulation enhances neuronal excitability, which strengthens synaptic connections, thereby facilitating neural message transmission (Tertuliano et al., 2024). Based on Hebbian learning principles, the repeated use of specific neural networks enhances their ability to perform broader functions. Serious games, by supporting this aim, contribute to neuronal regeneration, neuroplasticity, and cognitive improvements that lead to positive outcomes (Diniz & Crestani, 2023).

Serious games provide feedback on individual abilities and self-efficacy, enabling children to participate in programs tailored to their capacities. This approach begins with the improvement of foundational skills, followed by exercises that become progressively more challenging. Progress reports are generated to guide subsequent stages of the program. Serious games, designed as digital programs featuring simple games, encourage children to view cognitive tasks as play. The appealing nature of these educational and rehabilitative programs enhances children's willingness to engage and participate (de Carvalho et al., 2024). It is recommended that these interventions should be used to improve executive functions in children with ASD. One limitation of this study is that the program was implemented on children with high-functioning ASD, which requires careful consideration when generalizing the results. Additionally, the presence of individual differences within the sample group, and the use of non-random convenience sampling pose further limitations. Future researchers are encouraged to use random sampling methods, implement the program for lower-functioning children with ASD, and compare the outcomes. They may also explore other aspects of executive and behavioral functions using this program, or extend its application to other groups of exceptional children. Given the positive impact of serious games on executive and behavioral functions in children with ASD, it is recommended that psychologists, psychotherapists, and educators incorporate these programs into both therapeutic and educational settings to enhance cognitive and executive functions. The engaging nature of these games motivates children to perform exercises with increased energy and without fatigue. Furthermore, these programs can be effectively used in educational and therapeutic places, and their use is deeply recommended.

Declarations

Author Contributions

All authors contributed actively to the conception, design, and execution of the research.

Data Availability Statement

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

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Ethical considerations

This study was conducted in full compliance with ethical guidelines and principles. All participants provided informed consent, and their confidentiality and anonymity were

strictly maintained. The research protocol was reviewed and approved by the relevant ethical committee, ensuring adherence to ethical standards throughout the study.

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Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this research.

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