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Original Article

Effectiveness of Virtual Reality Intervention for Impulsivity, Sustained Attention, and Divided Attention in Children with Attention-deficit Hyperactivity Disorder

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Abstract

Introduction: Attention-deficit/hyperactivity disorder (ADHD) is a neurodevelopmental disorder that usually begins in childhood. Inconsistent with one's developmental stage, this condition is marked by attention deficit, impulsivity, and hyperactivity. The present study aimed to investigate the effect of virtual reality intervention (VRI) on impulsivity, sustained attention, and divided attention in children with ADHD.

Methods: This is a quasi-experimental study with a pretest-posttest control group design. The study population consisted of 103 boys and girls diagnosed with ADHD seeking treatment at Baqiyatullah Hospital in Tehran in 2021. Thirty children who met the inclusion criteria were purposefully selected and allocated to two groups: a control group (only taking Ritalin) and an intervention group (n=15 per group). The intervention group received VRI (twelve 60-minute sessions held three times weekly). The research instrument included the integrated visual and auditory continuous performance test. Data analysis was conducted using analysis of covariance (ANCOVA).

Results: The results revealed that VRI improved impulsivity, sustained attention, and divided attention in children diagnosed with ADHD (P<0.001).

Conclusion: Based on the findings, VRI can improve sustained attention, divided attention, and impulsivity in children with ADHD.

Keywords: Virtual reality, Impulsivity, Attention, Attention deficit hyperactivity disorder, Children

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Introduction

Attention deficit, a major symptom of attention-deficit/hyperactivity disorder (ADHD), is considered as the first diagnostic criterion in the fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (1, 2). Some researchers view distraction as the key criterion in this disorder and believe that it contributes to children's difficulties in following the necessary instructions related to completing the assigned tasks (3, 4). Other researchers highlight the challenges of holding attention in these children (5). ADHD is characterized by a pattern of sustained attention deficit, hyperactivity, and impulsive behaviors that are more pronounced than what is typically observed in children and adolescents in similar stages of development (6). ADHD is a neuropsychiatric disorder and one of the most prevalent disorders of childhood (7). Research conducted across various societies has revealed that ADHD affects approximately five percent of children worldwide (8).

The presence of these symptoms in individuals with ADHD leads to behaviors that usually prevent them from focusing on a subject for extended periods. They tend to experience fatigue after only a few minutes of engaging in a task and ignore what those around them say to them. If left untreated, they will have this disorder in their adolescence and adulthood. Although their hyperactivity may disappear during these stages of development, their attention deficit will persist (9, 10). Attention, one of these children's most serious problems, is defective in various dimensions. The inability to concentrate on a particular task is a key indicator of ADHD. In psychology, distractibility is a common term used to describe the inability to concentrate on a specific subject (11). These children

exhibit impaired attention at various levels, including selective attention, sustained attention, attention transfer, and divided attention. Selective attention is considered a fundamental aspect of attention (12). This study examines two specific components: sustained attention and divided attention. Sustained attention refers to the ability to hold one's attention to a particular stimulus or specific stimuli for a relatively long time (for example, several minutes) (13).

Children with ADHD can manage a series of certain stimuli but are not able to resist more appealing ones. Therefore, the inhibition of unnecessary stimuli is a component of the attention process (14). Selective attention is an intricate behavior where one response is held onto while another response is deliberately avoided. This filtering mechanism is necessary for maintaining and taking care of the information that is being processed (15). The inefficiency of selective attention affects a child's performance in educational settings, particularly when faced with complex and lengthy information that demands high precision and simultaneous processing (16).

Another component of the attention process is sustained attention (i.e., the ability to maintain a behavioral response while performing a continuous activity). This requires inhibition of and resistance to other external stimuli (17). Sustained attention is the ability to hold one's attention over time. It is the simplest and most fundamental level of attention that is needed by the other types of attention. That is why a possible failure of sustained attention may suggest a failure of other types of attention (18). During both sustained and divided attention, an area of the nervous system is activated. This area primarily involves the right-side network, including dorsolateral and ventrolateral prefrontal structures, superior and inferior parts of cortices, and anterior cingulate gyrus (19, 20). Based on the metacognitive demands of divided attention, the activity of these structures is increased, and the similar sections on the left side are activated. Therefore, sustained attention and divided attention are both largely dependent on interference by the sublayers in the neural networks (21).

On the other hand, hyperactivity is accompanied by increased impulsivity in children (22). Impulsivity refers to the tendency to do something without thinking about it or considering its consequences (23, 24). In other words, the arousal in these children stems from acting before taking the time to think about it rather than from the inability to think before acting (25). Children with impulsive behavior, in contrast to the children lacking this behavior, do not seem to learn from the outcomes of their actions. Despite facing the consequences of, even punishment for, their bothersome behaviors, they continue repeating them (26). For instance, if someone fails to complete a task for them, they become enraged and annoyed very quickly, mirroring the behavior of children several years younger than their age. Many therapeutic methods have been used to treat ADHD including virtual reality intervention (VRI).

Virtual reality-based interventions are a new therapy used across the globe (27). They involve a presentation of multidimensional visual and auditory stimuli by clinicians to help them assess and treat ADHD in patients through cognitive rehabilitation (28). These interventions can be used successfully, particularly for children, as they are interested in computer graphics and games (29). Research has provided evidence that VRIs can improve children's cognitive functioning and coping abilities (30, 31). In a recent study by Corrigan et al. (29), it was demonstrated that virtual reality (VR) could enhance attention and working memory in individuals diagnosed with ADHD. Cunha et al. (32) showed that VRI was able to improve visual working memory, attention skills, processing speed, and fluid reasoning in children with ADHD. Overall, evidence has indicated the efficacy of VRIs in enhancing the attention of children with ADHD.

Based on the above-mentionedpoints, understanding efficient strategies for treating children with ADHD can alleviate the concurrent problems of these children such as learning disorders, anxiety, academic setbacks, poor quality of life, and family issues (33). As such, it can reduce personal and community (including the education sector) expenses and treatment costs. The necessity of studies investigating the effect of VRI on symptoms of ADHD lies in the potential for innovative and effective treatment approaches for this neurodevelopmental condition. ADHD is known to have significant impacts on individuals' daily functioning, particularly in areas of attention, impulsivity, and hyperactivity. Traditional treatment methods often involve medication and behavioral therapy, but there is a growing interest in exploring alternative interventions like VRI. The identified gap in the existing literature is the limited research on the specific effects of VRI on impulsivity, sustained attention, and divided attention in children with ADHD. While some studies have explored the use of VR in addressing various aspects of ADHD symptoms, there is a need for more focused research on the specific cognitive domains affected by the disorder. The present study contributes to filling this

gap by demonstrating the positive impact of VRI on impulsivity, sustained attention, and divided attention in children with ADHD. Further research in this area is essential to establish the efficacy and potential of VRI as a complementary or alternative treatment approach for individuals with ADHD. Based on the presented materials and research background, the present study aimed to investigate the effectiveness of VRI on impulsivity, sustained attention, and divided attention in children with ADHD.

Methods

In this quasi-experimental study, a pretest-posttest control group design was used. The study population included 103 children aged 7 to 12 years diagnosed with ADHD in Tehran who visited Baqiyatullah Hospital between May and June 2021. The inclusion criteria included children aged between 7 to 12 years diagnosed with ADHD based on standardized diagnostic criteria (e.g., DSM-5), the absence of acute or severe physical diseases and other psychiatric disorders, use of Ritalin exclusively, non-participation in any psychological interventions or other types of intervention, and submission of written informed parental consent forms. Unwillingness to participate in any phase of the study, acute and severe medical and psychiatric issues during the research, use of drugs other than methylphenidate (Ritalin) during the study, and absence in two consecutive treatment sessions constituted the exclusion criteria. From the statistical population, 30 eligible individuals who met the inclusion criteria were chosen and randomly allocated into two groups; 15 participants were assigned to the VRI group, while the remaining 15 were placed on a waiting list, using a random number table. In this study, participants were randomly assigned to either the VRI group or the control group to minimize the impact of unknown or unmeasured variables that could affect the results. Participants in both groups were also matched based on relevant characteristics such as age, gender, severity of ADHD symptoms, and other related factors to reduce the potential influence of these variables on the results. The sample size consisted of 15 children with ADHD per group, based on G*Power software with an effect size of 1.13, a test power of 0.90, and an alpha level of 0.05. The parents or legal guardians of children with ADHD were informed and consented to the nature of the intervention, potential risks, benefits, and the right to withdraw at any time. Privacy and confidentiality of the participants' personal information and study data were also assured to prevent unauthorized access or disclosure.

Table 1: A summary of VRI sessions

Session	Content
1	Conducting the pretest; introducing the VR-based cognitive rehabilitation method to the families of the children; introducing the equipment used in this method, such as the headset and joystick; teaching the parents and their children how to use the headsets, initial familiarization with the training environment
2	The child steps into the game training space, grasps the joystick, and successfully hits all the stimuli. The next step is to hit the target stimuli only. Every time, the therapist can alter the target stimuli from the management panel. The child uses the joystick to hit the stimulus that resembles the target stimulus (using simple stimuli)
3	The child has to hit the stimuli specified by the therapist. The child uses the joystick to hit the stimulus that resembles the target stimulus (using moderate stimuli).
4	The child has to hit the target stimuli as the stages become increasingly challenging. The child uses the joystick to strike the stimulus that resembles the target stimulus.
5	The child has to hit the target stimuli while taking into consideration the second target stimulus. The child uses the joystick to hit the stimulus that resembles the target stimulus.
6	The child has to hit the target stimuli while taking into consideration a second more complicated stimulus. The child uses the joystick to hit the stimulus that resembles the target stimulus (using complex stimuli)
7	The child has to hit the target stimuli while taking into consideration a second more complicated stimulus. The child uses the joystick to strike the stimulus that resembles the target stimulus (using combined stimuli).
8	The child has to hit the target stimuli while taking into consideration a second more complicated target stimulus. Step 8 is repeated to minimize errors.
9	The child has to hit the intended stimuli while taking into consideration the second target stimulus and the interfering visual stimulus. The child uses the joystick to hit the stimulus that resembles the target stimuli.
10	The child has to strike the desired stimuli when the position of the second target stimulus has been changed with that of the interfering visual stimulus. The previously interfering stimulus has now become the second target. The child uses the joystick to hit a stimulus that resembles the target stimuli (using two complex target stimuli).
11	It is executed similarly to the previous step, but the target stimulus is changed after every 3 to 5 hits. Step 7 is repeated to minimize errors.
12	Each step is performed until errors are minimized and it is then removed. The posttest is given.

Instruments

The Integrated Visual and Auditory (IVA-2) Continuous Performance Test: This is a neuropsychological test developed to assess impulsivity, visual attention, and auditory attention. This 20-minute test, which includes 500 stimuli to which the participants respond or fail to respond, evaluates the mentioned categories. In this assessment, a higher score indicates better sustained attention and divided attention, while a higher score in impulsivity indicates lower impulsivity in children (34). A study by Moreno-Garcia et al. (35) demonstrated the high sensitivity (92%) and predictive power (90%) of the tool in diagnosing ADHD. The reliability of this tool was confirmed in a study by Tahmoures and Sadati Firoozabadi (36) on a sample of Iranian children using Cronbach's alpha (α=0.77).

Virtual Reality Intervention (VRI): This intervention comprised twelve 60-minute sessions in the hospital consultation office three times a week, as detailed in Table 1. The VRI sessions were conducted by the first author, who had undergone dedicated training courses and workshops.

Statistical Analyses

The Kolmogorov-Smirnov test and Levene's test were used to assess the assumptions of normality and homogeneity of variances, respectively. The data collected during the pretest and posttest stages were analyzed using descriptive statistics, such as mean and standard deviation, as well as analysis of covariance (ANCOVA). The use of ANCOVA in the current quasi-experimental study with a pretest-posttest control group design allows for the adjustment of posttest scores based on pretest scores, increasing statistical power, enhancing sensitivity to treatment effects, and controlling for confounding variables, thereby providing a more robust analysis of the intervention's effectiveness.

Results

The mean age of the VRI group was 8.67 years with a standard deviation of 1.54, whereas that of the control group was 9.13 years with a standard deviation of 1.76. The VRI group comprised seven girls and eight boys, whereas the control group consisted of eight girls and seven boys. Table 2 displays the mean and standard deviation (SD) of the research variables in the intervention and control groups in the pretest and posttest stages.

The assumptions underlying the ANOVA were examined to ensure that the data of this study accurately estimated them. The normality of the data was shown by the non-significance of Kolmogorov-Smirnov Z (P=0.057; Z=0.949 for sustained attention, P=0.632; Z=0.980 for divided attention, and P=0.499; Z=0.977 for impulsivity). Levene's test was employed to assess the assumption of homogeneity of variances. The results were as follows: the sustained attention variable (P=0.192; F=1.717), the divided attention variable (P=0.168; F=1.860), and the impulsivity variable (P=0.828; F=0.190). The results indicated that ANCOVA could be used.

Table 3 presents the ANCOVA results for the posttest scores of the dependent variables. For the dependent variables, the F- ratio test statistic for ANCOVA revealed that there were significant differences between the VRI and control groups in the variables of impulsivity (P=0.001; F=61.80), sustained attention (P=0.001; F=44.72), and divided attention (P=0.001; F=54.81). This meant that the VRI improved impulsivity, sustained attention, and divided attention in children with ADHD.

Table 2: Mean and SD of impulsivity, sustained attention, and divided attention in VRI and control groups

Variables	Groups	Pretest	Posttest
		Mean±SD	Mean±SD
Impulsivity	VRI group	65.98±11.71	98.35±7.63
	Control	66.09±13.00	73.86±8.84
Sustained attention	VRI group	73.88±9.08	97.90±4.50
	Control	76.92±8.32	80.25±7.80
Divided attention	VRI group	76.19±9.64	99.70±5.35
	Control	75.02±9.84	80.31±8.24

Table 3: The results of analysis of covariance on variables in experimental and control groups

Variables	SS	df	MS	F	P	η^2	Power
Impulsivity	4972.05	1	4972.05	61.80	0.001	0.67	1.00
Sustained attention	2657.52	1	2657.52	44.72	0.001	0.63	1.00
Divided attention	2855.45	1	2855.45	54.81	0.001	0.59	1.00

Discussion

This study aimed to investigate the effect of VRI on impulsivity, sustained attention, and divided attention in children with ADHD. The results showed that the VRI improved sustained attention, divided attention, and impulsivity in children with ADHD. These findings agree with the results of the meta-analysis by Romero-Ayuso et al. (28), which demonstrated that VRI improved sustained attention in 125 adolescents diagnosed with ADHD. Alongside other therapeutic methods, VRI has established its position among the other therapeutic methods for this disorder (37). Given the relatively recent introduction of VR as a treatment for various mental disorders, there is reason to be hopeful about its potential to address problems related to attention deficit in the future. In fact, many studies are necessary to optimize the performance of VR. VR is a cost-effective method with minimal side effects. Therefore, it can be an alternative to other methods such as drug therapy and cognitive-behavioral interventions.

Using VR methods offers additional advantages, such as establishing a serene and comforting setting for children diagnosed with ADHD and engaging them in a non-threatening environment (4). The mechanisms through which VR works are similar to the functioning of the human brain. In other words, they involve simulated immersion (i.e., to better inhibit and regulate the activities of the body, the human brain creates a simulated immersion of the body in the real world so that it can provide and predict activities, concepts, and emotions) (27). Studies have suggested that VRI can make external and internal simulations of the human body by designing virtual environments by making changes in the body's experiences and facilitating cognitive modeling (30, 31).

Admittedly, VR transforms a passive learning experience into an active one. It provides a sense of immersion for children with ADHD, and this gives VR great potential for use in training and learning (29). The goal of using VR to treat children with ADHD is to immerse them in the learning experience, get them completely involved with the educational materials, increase their concentration and precision, and also improve their attention and impulsivity. Attractiveness and the ability to get people involved are thought to play an important role in improving concentration and attention. VR is a method that can get children with ADHD involved in the content to be learned (32). Therefore, because of this ability, VR can emerge as an alternative to the other common treatments for ADHD shortly.

VR captures and holds attention. Simulations by VR create the complete concept of presence. Therefore, the child with ADHD enters a simulated world instead of just observing it. The brain of such a child is convinced that this simulated world actually exists. Using VR to treat ADHD allows children to assess their practical skills independently; hence, the learning experience will be enjoyable for them.

Given the small sample size, it is important to be cautious when generalizing these findings to the community. It is important to note that this study focused on children aged 7 to 12 years with ADHD in Tehran. Therefore, it is necessary to exercise caution when applying these findings to other age groups and cities.

Conclusion

The VRI improved sustained attention, divided attention, and impulsivity in children with ADHD. Based on the findings of this study, VR can be used as a suitable method for improving sustained attention and divided attention and for reducing impulsivity in children with ADHD. Utilizing VR as a complementary method alongside drug therapy might effectively enhance attention in children with ADHD.

Ethical Approval

The Ethics Review Board of Islamic Azad University, Ahvaz branch, approved the present study (code: IR.IAU.AHVAZ.REC.1400.104).

Conflict of Interest: None declared.

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