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Original Article

The Effectiveness of Virtual Reality Intervention on Sustained Attention, Divided Attention, Impulsivity of Children with Attention Deficit and Hyperactivity Disorder

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Abstract

Background and Aim: Attention deficit hyperactivity disorder (ADHD) research is of great interest due to the prevalence of 9%-17% among Iranian children and its negative effects on several aspects of life, including students' academic future. This study evaluates the effectiveness of virtual reality therapy plus Ritalin use versus Ritalin consumption alone on sustained attention, divided attention, and impulsivity in children diagnosed with this disorder.

Materials and Methods: This was a semi-experimental study with a control group with pre-test, post-test, and follow-up designs. The statistical population consisted of 30 children randomly assigned to the experimental and control groups recruited by convenience sampling. The experimental group participated in twelve 90-minute virtual reality intervention sessions. The Integrated Visual and Auditory (IVA-2) Continuous Performance Test was utilized to collect data, which were then analyzed using MANOVA in SPSS-26.

Results: In addition to continuing to take Ritalin, the virtual reality group showed considerable improvement in all research parameters, and their scores were significantly higher than those in the group that continued to take Ritalin alone ($p<0.05$). Moreover, the observed effects were persistent after 45 days of follow-up.

Conclusion: The results of this study demonstrate that virtual reality therapy effectively addresses cognitive difficulties in children with attention deficit hyperactivity disorder ages seven to twelve. It is suggested that therapists employ virtual reality therapy to help these children's challenges since it can significantly enhance the efficacy of Ritalin.

Keywords: Attention deficit disorder, Hyperactivity disorder, Children, Virtual reality, Effectiveness

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Introduction

Trouble paying attention, managing impulsive actions (may act without considering the consequences), or being excessively active are the primary symptoms of attention deficit and hyperactivity disorder (ADHD) (**Error! Reference source not found.**1-2), which would hinder the individual's ability to multitask and result in personal and interpersonal problems (**Error! Reference source not found.**3). ADHD is one of the most prevalent childhood and adolescent disorders, with a prevalence rate of approximately 5% in children and adolescents and 2.5% in adults across most cultures (4). Also, according to epidemiological studies, the least and greatest prevalence of ADHD in Iran is 9.5% and 17%, respectively (**Error! Reference source not found.**5). In general, ADHD is treated with a combination of pharmaco-psychotherapies, however, the side effects of prescribed drugs and the negative attitude toward taking them have limited their acceptability in the population of individuals with ADHD (6-7), highlighting the importance of researching non-invasive treatments such as virtual reality-based interventions.

Attention deficit hyperactivity disorder (ADHD) is characterized by problems in arousal regulation and caring, selective attention, sustained attention, inhibition, impulsivity, and behavior control (8); however, the focus of this study is on the primary characteristics of ADHD, namely sustained attention, divided attention, and impulsivity.

Sustained attention is the most fundamental and simple level devoted to stimuli control and responses, (i.e., sustaining attention) over time (9), which is the primary complaint that people have due to their inability to shift their attention or their predisposition to be easily distracted by other stimuli, which could be alleviated by enhancing their sustain attention (10).Divided attention is also concerned with paying attention to multiple stimuli or stimuli in various ways (11) or the ability to simultaneously process high levels of cognitive load (12, 13); as cognitive load increases, deficiencies in divided attention will lead to slower cognitive processing and will interfere with other mental processes, necessitating interventions to improve the ability to divide attention in individuals with ADHD (13).Impulsivity or acting without thinking is also one of the leading symptoms of ADHD (14). Consequently, individuals with ADHD cannot establish a connection between their behaviors and consequences; therefore, addressing impulsivity is of the utmost importance.

In general, psychotherapies and pharmacological prescriptions are used in tandem to treat the primary concerns. Although pharmacotherapies are somewhat successful, their adverse effects, lack of treatment adherence, and negative attitudes regarding drug use would limit their use (6-7). In addition, their effects are transient or will disappear upon cessation of medication administration or pharmacokinetics (15).Moreover, therapies such as neurofeedback, a common therapy option for ADHD, are not without adverse effects; patients may feel headaches after treatment (16), yet, its efficacy has not been conclusively demonstrated (17).Therefore, it is necessary to develop treatments and evaluate their efficiency to enhance these individuals' neurocognitive abilities; treatments with no or little side effects are essential. Virtual reality-based intervention is one of the most innovative treatments in the world (18), which could aid cognitive rehabilitation by offering multifaceted visual and aural stimuli and aid the clinician in assessing ADHD (19). This intervention is of particular interest and utility to children passionate about computers and graphic-based games (20-21). According to studies examining the efficacy of virtual reality-based therapies, children's cognitive function and coping abilities improved significantly (22). This intervention's underlying mechanism is its capacity to engage individuals in learning, which may improve attention and reduce impulsivity. Additionally, it may attract individuals who are not interested in taking a medication that could enhance treatment adherence (23). And its benefit is that what is learned in virtual reality may be transferred to the actual world (24). Moreover, a systematic review by Bashiri et al. (22) on the efficacy of virtual reality-based interventions for ADHD identified some underlying mechanisms of this treatment, including the following: adaptability for being tailored to the individuals' complaints, eliminating distractions and providing a safe place, economic benefits and saving more time for patients and the clinicians, increasing people's motivations for therapy based on their interest, and providing tools for self-management. Given the high prevalence of ADHD in children with diverse characteristics (25), additional research is required to determine the efficacy of computer-based therapies, such as virtual reality, in reducing the core symptoms of ADHD. Given the promising reports on the effects of virtual reality-based intervention, its economic benefits, and fewer side-effects than other types of interventions, as well as the paucity of research on this topic in Iran, the current study aims to determine whether this intervention can improve sustained attention, divided attention, and impulsivity in children with ADHD. In addition, given that Ritalin is the standard treatment for ADHD, this study aimed to examine the efficacy of a virtual reality-based intervention in conjunction with Ritalin vs. Ritalin alone (Routine treatment).

Methods

The study's design was semi-experimental, with one group acting as the experimental group (Virtual reality plus Ritalin) and another serving as the control group (just Ritalin), with a 45-day follow-up. The statistical population consisted of 103 children diagnosed with ADHD between the ages of 7 and 12 who visited Tehran Baghiyatallah Hospital during April and May 2021. Participant selection was purposeful and based on a convenience sample of qualified individuals. The inclusion criteria were a psychiatrist's diagnosis of ADHD, age between 7 and 12, current use of Ritalin, absence of other psychotropic medications, parental informed consent in writing, and concurrent participation in no other therapies. In addition, the exclusion criteria were as follows: lack of enthusiasm to continue therapy at any time, absence from two sessions, diagnosis of another psychiatric disorder, and diagnosis of psychical disorders or disabilities.

Materials

The Integrated Visual and Auditory (*IVA-2*) Continuous Performance Test

The IVA-2 is a computer-based neuropsychological test established in 1987 to evaluate impulsivity and visual and aural attention for ages 6 to 66. Five hundred stimuli followed by an examinee's reaction or response inhibition are administered over 20 minutes to evaluate sustained attention, divided attention, and impulsivity. Moreno Garca et al. (26) revealed that the IVA-2 has a high sensitivity (92%) and strong predictive power (90%) for diagnosing ADHD. Boojari et al. (27) demonstrate a high sensitivity (92%) and strong predictive power (89%) for ADHD diagnosis in the Iranian population. In addition, several Persian investigations support the validity and reliability of IVA-2 (28).

Procedure

Only 30 children were eligible to participate in the trial and were randomly allocated to either the experimental or control group. All participants took the IVA-2 test. The experimental group participated in the virtual reality-based intervention (12 sessions, each 90 minutes long), while the control group remained with their regular treatment (Ritalin). All individuals retook the IVA-2 test 45 days after the completion of treatment, concluding the study. A certified psychologist administered the intervention, and all sessions were supervised. In compliance with study ethics with the approval code (IR.IAU.AHVAZ.REC.1400.104), available at https://ethics.research.ac.ir/IR.IAU.AHVAZ.REC.1400.104, it should be noted that the control group also received the virtual reality-based intervention after the investigation was completed. Table 1 provides an overview of the presented sessions.

Results

There were 7 females and 8 males in the virtual reality group and 8 females and 7 males in the control group; the chi-square test indicates that there is no significant difference between the two groups in terms of gender distribution ($X^2(2, N = 45) = 1.260$, $p = .533$). The age distribution of the participants was not significantly different between the experimental group ($M = 8.67$, SD = 1.54) and the control group ($M = 9.13$, $SD = 1.76$; $X^2(10, N = 45) = 2.368$, $p = .993$), indicating that the individuals were evenly distributed by age. Table 2 displays each group's pre-test, post-test, and follow-up

Table 1. Virtual reality-based intervention- sessions summary (28).

Session	Content	Goals
1	IVA-2 pre-test, the introduction of the parents to the virtual reality-based cognitive rehabilitation approach, familiarization with the controllers and headsets used in this method, use of the headset by both parents and children, and getting used to the training environment. The children like the setting while learning how to utilize the controls.	Pre-test and familiarization with cognitive rehabilitation using virtual reality technology
2	Balloon stages 1 and 2 involve the children entering the training game environment, holding the controller, and hitting all the stimuli. Getting the desired stimuli is the next stage. The therapist may adjust the target stimulus each time using the management panel. Rotary Step 1: Using the controller, the children activate a stimulus like the target stimulus (using a simple stimulation).	Improving cognitive functions by emphasizing selective visual attention and sustained selective attention
3	Balloon stages 3 and 4 need the child to interact with the therapist's preferred stimuli. Rotary Step 1: The child uses the controller to strike a stimulus like the goal stimulus. (Using a medium stimulus).	Improving cognitive functions by emphasizing visual and auditory selective attention and sustained attention
4	Stages 5 and 6 of the balloon game require the child to hit the necessary stimulus as the levels get harder. Rotary Step 3: Using the controller, the youngster strikes a stimulus similar to the target stimulus.	Improving cognitive functions by emphasizing visual selective attention and visual sustained attention
5	Step 7 of the balloons: The child must hit the desired stimuli while considering the second target stimulus. Rotary Step 4: Using the controller, the child hits a stimulus like the target stimulus.	Improving cognitive functions by emphasizing selective visual attention and sustained visual attention
6	Step 8 of the balloon: The child must hit the desired stimuli while considering the second target stimulus, which is more complicated. Rotary Step 5: The child hits a stimulus like the target stimulus using the controller (a complex stimulus).	Improving cognitive functions by emphasizing selective visual attention and sustained visual attention
7	Step 9 of the balloons: The child must hit the desired stimuli while considering the second target stimulus, which is more complicated. Rotary Step 8: The child hits a stimulus like the target stimulus using the controller (using mixed stimuli).	Improving cognitive functions by emphasizing selective visual attention and sustained visual attention
8	Step 10 of the balloons: The child must hit the desired stimuli while considering the second target stimulus, which is more complicated. Rotary Step 8: Repeating Step 8 to minimize errors.	Improving cognitive functions by emphasizing visual and auditory selective attention, sustained attention
9	Step 11 of the balloons: The child must hit the desired stimuli while considering the second target and distractor visual stimuli. Rotary Step 6: Using the controller, the child hits a stimulus similar to the	Improving cognitive functions by emphasizing selective visual attention, sustained visual attention

	target stimulus.	
10	Step 12 of the balloons: The child must hit the desired stimuli while the second target and distractor visual stimuli are changed. The previously annoying stimulus is now the second target. Rotary Step 7: The child hits a stimulus similar to the target stimulus using the controller (using 2 complex stimuli).	Improving cognitive functions by emphasizing selective visual attention, and selective sustained attention
11	Step 13 of the balloons are like the previous step, but the target stimulus changes every 3 to 5 hits. Rotary Step 7: Repeating Step 7 to minimize errors.	Improving cognitive functions by emphasizing selective visual attention, and selective sustained attention
12	Step 14 of the balloons: It is like the previous step. Rotary steps 7 and 8: Perform each step with minimal errors. Performing the post-test	Improving cognitive functions by emphasizing visual and auditory selective attention, sustained attention - post-test

Table 2: Means, Standard deviations by pre-test, post-test, and follow-up on dependent variables.

		Pre-test		Post-test		Follow-up	
Group	**Variable**	M	SD	M	SD	M	SD
Experiment	Sustained attention	73.88	9.08	97.90	4.50	99.16	4.54
	Divided attention	76.19	9.64	99.70	5.35	100.69	5.51
	Impulsivity control	65.98	11.71	98.35	7.62	99.45	7.66
Control	Sustained attention	76.92	8.32	80.25	7.80	80.88	8.12
	Divided attention	75.02	9.84	80.31	8.24	80.63	8.52
	Impulsivity control	66.09	13	73.86	8.84	74.14	9.06

scores on each dependent variable.

Examining the between-subject's effects at the 0.95 significance level revealed that the effect of the group in the pre-test on divided attention (p = 0.242), sustained attention (p = 0.341), and impulsivity control (p = 0.115) is insignificant, indicating that individuals' pre-test scores are equivalent, and that multivariate variance analysis (MANOVA) can be conducted. Before running MANOVA, its underlying assumptions were examined, which included the absence of outliers as measured by Mahalanobis and Cox's distances, normal distribution using the Shapiro-Wilk test, linear relationship between variables using the scatter plot matrix, homogeneity of the covariance matrix using the M-box test and homogeneity of the variance matrix using the Leven's test, and the absence of multicollinearity. Table 3 displays the results of MANOVA to compare the post-test and follow-up stages of dependent variables between groups.

At least one variable demonstrates a substantial difference between the groups, as all tests are significant at the 0.01 level. The between-subjects effects test, displayed in Table 4, was also used to investigate the effects of the given therapies on the post-test scores for each dependent variable.

Table 3: MANOVA for exploring differences in the post-test and follow-up stage.

Test	Value	*F*	Effect' df	Error's df	*p*-value	Eta²
Post-test						
Pillai's trace	0.802	9.158	6	82	0.01	0.401
Wilk's lambda	0.248	13.459	6	80	0.01	0.502
Hotelling's trace	2.835	18.430	6	78	0.01	0.586
Roy's largest root	2.762	37.748	3	41	0.01	0.734
Follow-up						
Pillai's trace	0.793	8.977	6	82	0.01	0.396
Wilk's lambda	0.253	13.188	6	80	0.01	0.497
Hotelling's trace	2.776	18.045	6	78	0.01	0.581
Roy's largest root	2.710	37.03	3	41	0.01	0.730

Given the statistical significance of the group effect on the dependent variables in Table 4, it is possible to conclude that at least one of the treatments had a significant impact on the dependent variables. The Post hoc Bonferroni test was used to obtain additional data, as shown in Table 5.

The post hoc test revealed that the virtual reality-based intervention has significant effects on the

Table 4: Examining the between-subject effects in the post-test and follow-up.

Source	Dependent variable	Type III sum of squares	df	Mean Square	*F*	*p*-value
Post-test						
Regression	Sustained attention	356536.78	1	356536.78	8048.815	0.01
	Divided attention	367112.70	1	367112.70	8706.171	0.01
	Impulsivity control	324211.29	1	324211.29	4672.515	0.01
Group	Sustained attention	2338.07	2	1169.034	26.391	0.01
	Divided attention	2826.97	2	1413.486	33.521	0.01
	Impulsivity control	4635.51	2	2317.755	33.403	0.01
Error	Sustained attention	1860.47	42	44.297	--	--
	Divided attention	1771.01	42	42.167	--	--
	Impulsivity control	2914.25	42	69.387	--	--
Follow-up						
Regression	Sustained attention	369670.85	1	369670.85	9598.796	0.01
	Divided attention	373685.01	1	373685.01	8849.249	0.01
	Impulsivity control	334445.88	1	334445.88	4435.919	0.01
Group	Sustained attention	2538.82	2	1269.410	32.961	0.01
	Divided attention	3039.89	2	1519.946	35.994	0.01
	Impulsivity control	4834.52	2	2417.259	32.061	0.01
Error	Sustained attention	1617.51	42	38.512	--	--
	Divided attention	1773.57	42	42.228	--	--
	Impulsivity control	3166.59	42	75.395	--	--

Table 5: The Post hoc Bonferroni test on the effects of groups in post-test and follow-up.

Dependent variable	Groups (I-J) mean differences	Standard error	*p*-value
Post-test			
Sustained attention	17.6547	2.43028	0.01
Divided attention	19.3844	2.37113	0.01
Impulsivity control	24.4909	3.04164	0.01
Follow up			
Sustained attention	18.277	2.266	0.01
Divided attention	20.069	2.373	0.01
Impulsivity control	25.307	3.171	0.01

improvement of sustained attention, divided attention, and impulsivity control in children with ADHD, given the significant differences in the mean scores of dependent variables between the experimental group and the control group. In addition, the temporality of the observed effects on the dependent variables during the follow-up stage was investigated, as shown in Table 3. In addition, the between-subjects effects test, depicted in Table 4, was used to assess the treatments' temporality (stage of follow-up) on the post-test scores for each dependent variable. Given the significant effect of the group on dependent variables in the follow-up stage in Table 4, at least one of the treatments had a significant impact on the variables of interest. The post hoc test in Table 5 demonstrated that the difference between the mean scores of dependent variables in the experiment group and the control group is significantly higher, indicating that the effects of virtual reality remained steady.

Discussion

This study aimed to compare the efficacy of a virtual reality-based intervention to the primary therapy (Ritalin) for children with ADHD. 7 to 12-year-old children were randomly assigned to the experimental group (virtual reality with Ritalin) or the control group (Ritalin as the routine treatment). In terms of gender and age, neither group differed considerably, making it possible to compare pre- and post-intervention scores. The scores for sustained attention, divided attention, and impulsivity control reveal that the experimental group underwent significantly more changes than the control group, indicating an improvement in the main ADHD symptoms. In addition, these results suggest that virtual reality-based intervention may enhance the effects of Ritalin, given that the control group (which received only Ritalin) did not exhibit improvement in the variables of interest. In addition, the observed changes in the experimental group were constant during the follow-up period, whereas the control group's scores remained unaltered, indicating the temporal nature of the observed effects.

The current study confirms prior studies on the significance of multimodal ADHD therapies (6-7). Attributable to the fact that both groups were taking Ritalin as prescribed, we could only conclude that the observed effects were perhaps due to the augmentation effects of the virtual reality-based intervention on Ritalin. Thus, it may be inferred that the effects of Ritalin on the primary symptoms of ADHD could be augmented and maintained for at least 45 days if patients additionally received a virtual reality-based intervention. Also, it might be argued that taking Ritalin alone would not improve the primary symptoms of ADHD, as the control group did not indicate improvement in sustained attention, divided attention, and impulsivity control between the post-test and the follow-up phase. Although a diagnosis of ADHD could not be ruled out for the experimental group, the observed effects of a virtual reality-based intervention are encouraging. These findings highlight the significance of researching various treatments for ADHD to improve treatment efficacy.

One of the merits of this study is that it does not utilize a self-report questionnaire but rather a computer-based assessment that might control for social desirability, one of the sources of bias in survey research. In addition, the sample was representative in that each participant was diagnosed with ADHD and evaluated for eligibility. Moreover, an experienced therapist supervised the entirety of each session delivery. However, any study's conclusions must be interpreted in light of their limitations. Given the age range of the sample (7 to 12 years), it is possible that the results cannot be fully generalized to adolescents and adults. Due to cultural variations and the fact that all participants were from Tehran, the findings may not apply to children from other cities or provinces. In addition, as all subjects were volunteers, their motivation may have confounded the observed results.

Conclusion

In sum, the virtual reality-based intervention boosted the effect of Ritalin on improvement in the main symptoms of ADHD, (i.e., sustained attention, divided attention, and impulsivity); the changes remained stable at the follow-up stage. In contrast, the control group did not reveal any changes during assessments. It is suggested that future studies consider factors that could boost the conjoint effect of virtual reality-based intervention in addition to taking Ritalin, helping children with ADHD to rule out the diagnosis.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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