



The opportunities of virtual reality in the rehabilitation of children with attention deficit hyperactivity disorder: a literature review

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Attention deficit hyperactivity disorder (ADHD) is one of the most common psychiatric disorders in childhood. This disorder, in addition to its main symptoms, creates significant difficulties in education, social performance, and personal relationships. Given the importance of rehabilitation for these patients to combat the above issues, the use of virtual reality (VR) technology is helpful. The aim of this study was to highlight the opportunities for VR in the rehabilitation of children with ADHD. This narrative review was conducted by searching for articles in scientific databases and e-Journals, using keywords including VR, children, and ADHD. Various studies have shown that VR capabilities in the rehabilitation of children with ADHD include providing flexibility in accordance with the patients' requirements; removing distractions and creating an effective and safe environment away from real-life dangers; saving time and money; increasing patients' incentives based on their interests; providing suitable tools to perform different behavioral tests and increase ecological validity; facilitating better understanding of individuals' cognitive deficits and improving them; helping therapists with accurate diagnosis, assessment, and rehabilitation; and improving working memory, executive function, and cognitive processes such as attention in these children. Rehabilitation of children with ADHD is based on behavior and physical patterns and is thus suitable for VR interventions. This technology, by simulating and providing a virtual environment for diagnosis, training, monitoring, assessment and treatment, is effective in providing optimal rehabilitation of children with ADHD.

Key words: Attention deficit hyperactivity disorder, Rehabilitation, Virtual reality, Child, Virtual environment

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Introduction

According to the American Psychiatric Association, ADHD is a brain disorder that usually occurs in childhood. This condition is characterized by ongoing attention deficiency, hyperactivity, and impulsivity that interfere with functionality^{1,2)}. Some primary and secondary issues, such as the absence of self-confidence, relationship maladjustments with friends, and incompatibility with social and academic environments, can be caused by this disorder²⁾. ADHD rehabilitation is based on medication therapy such as methylphenidate, dextroamphetamine, and pemoline, as well as behavior therapy or a combination of both approaches. Behavior therapies include school accommodations, social skills training, and cognitive rehabilitation. Other approaches, such as speech therapy and family therapy, are also effective in the rehabilitation of children with ADHD²⁻⁴⁾. These approaches have disadvantages including drug side effects, no behavioral improvement, time expenditures, and the effects of external factors. Developing virtual reality technologies to combat these issues is the best therapeutic strategy

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for rehabilitation of psychological disorders such as ADHD^{2,3,5-7}. This technology presents a real-life situation to the users and is more effective and safer than traditional treatments^{3,4}. This study highlights the use of virtual reality for better rehabilitation of children with ADHD.

Methodology

This mini review examined articles published in English since 2000 that were available as full texts through databases and e-journals, such as Web of Science, PubMed, and Science Direct. The keywords for the search included “ADHD,” “virtual reality,” and “children.” In addition, studies that were not defined as a journal article were excluded from this study. By investigating 308 articles in Science Direct, 22 in PubMed, and 11 in Web of Science, and by applying the search limits, the authors found 20 relevant studies that had used VR technologies in the diagnosis, treatment, assessment, and training of children with ADHD.

Definitions

1. Attention deficit hyperactivity disorder

According to various sources of evidence, the frontal/striatum areas have a key role in the psychopathology of the brain's executive and functional disorders. In these areas, abnormal structure and/or function can create inattention and distraction, which are identified as ADHD symptoms^{8,9}. ADHD is a neuro-developmental disorder that is characterized by inattention, hyperactivity, and impulsivity^{10,11}. According to the Diagnostic and Statistical Manual of Mental Disorders, 4th edition, ADHD is one of the most common psychiatric conditions^{1,12} and according to the Center for Disease Control and Prevention, this condition represents a public health issue, which is one of the most common functional disorders in childhood, with a 5%–9% prevalence rate¹³. Almost 5% of school-age children are affected by ADHD and their behavioral competencies in many aspects are poorer compared to their normal peers¹⁴. The symptoms experienced by these children may improve^{3,14}. Nevertheless, ADHD symptoms may develop and affect children in their daily functioning, social behaviors, interpersonal relationships, and education^{3,5}. Currently, the rehabilitation of children with ADHD includes psychological counseling, medication, and behavioral therapies^{6,15,16}.

2. Virtual reality technology

Virtual reality, which is also known as computer-simulated reality or video-generated environments, is a computer technology that simulates an imagined or real environment such as a classroom^{17,18}. By using this technology, users can interact in 3-dimensional environments and behave as they would in the real world¹⁹. The

application of this technology has emerged in educational and training, entertainment, military, medical and surgical areas^{17,20,21}. Immersive VR, desktop VR, projective VR, and CAVE (C-Automatic Virtual Environment) are the most used types of virtual reality. The ability of this technology is based on the quick construction of different life-like environments for training and for controlling irritants^{3,22,23}. The development of VR systems offers numerous advantages such as creating an environment that meets the patient's requirements, providing stability between users and stimuli, as well as providing a complete record of patients' behaviors and functionalities, facilitating rapid feedback and time and cost savings, and delivering a more entertaining tool to motivate patients use this technology^{3,22}. In the rehabilitation domains, VR technologies allow people with impairments and disabilities related to brain damage to experience anything that is difficult or impossible for them in reality^{24,25}.

3. Virtual reality side effects

Health guidelines list possible side effects of VR ranging from headaches, seizures, nausea, fatigue, drowsiness, disorientation, apathy, and dizziness. These symptoms are related to cybersickness or virtual reality sickness, which can endanger health and safety, as well as the effectiveness of VR. Cybersickness as a complex problem is the psychophysiological answer to exposure to VR environments^{26,27}. Studies have indicated that cybersickness is a barrier to the use of training or rehabilitation tools in virtual reality environments^{28,29}. Therefore, cybersickness can be prevented or managed by understanding its causes and factors that influence its incidence²⁶. Depending on the VR system type, the purpose of the tasks, and the characteristics of the individual user, a variety of measures may be taken to fix or manage VR's side effects. Studies have indicated several methods to prevent cybersickness, including correct calibration of a VR system, adaptation and customization according to users' needs, enabling a more natural user interface (UI) and using haptic interfaces, making the head-mounted display (HMD) lighter, as well as ensuring moderate usage of a VR system^{26,29-31}.

Findings

1. Virtual reality in the rehabilitation of ADHD patients

Virtual reality has the ability to render some neuropsychological tests, such as the continuous performance test (CPT), of cognitive processes, including attention, memory, and executive function, in a more reliable way^{32,33}. Pollak et al.³⁴ reported that CPT embedded in VR (VRC-CPT) has higher ecological validity and that children with ADHD prefer VRC-CPT over classic CPT. In addition, the studies of Adams et al.³⁵ and Díaz-Orueta et al.³⁶ have confirmed these results and suggested that VRC-CPT testing is a suitable tool to assess the

symptoms of ADHD in children. VR combined with interactive tests, by providing specific stimuli, can remove distractions and hold patients' attention and concentration for a long time and can also be helpful in the rehabilitation of children with ADHD^{3,22,37,38}. Recently, using VR technologies as computer graphics for simulating the real world have reduced the malfunction of patients in their daily life^{39,40} in that knowledge gained from VR can be transmitted to a real environment⁴¹. Virtual reality environments make it possible to observe individuals' behavior and detect their cognitive deficits³⁴.

Numerous studies confirmed the advantages of virtual reality in cognitive performance, such as working memory, executive function, and attention^{32,42-44}. Deficits in attention, as a main cognitive process, are common and a major disability for persons with ADHD. Studies have indicated the potential of VR in the assessment and training of attention without any distractions^{33,45,46}. They have demonstrated that, when participants with ADHD performed cognitive tasks targeted on attention assessment through VR use, they obtained better scores than when using traditional techniques²². Rizzo et al.³² designed a VR classroom to assess attention performance. In their study, participants used a HMD to

solve tasks while visual and auditory stimuli were presented. Since participants with ADHD make many mistakes and excessive body movements in their tasks, other studies showed the significant role of virtual reality in improving these conditions and reducing behavioral symptoms and problems^{3,14,25,33,39,47}. Moreover, the study of Pollak et al.⁴⁸ showed that, methylphenidate reduced omission errors and reaction time variability with VR-CPT compared to without VR-CPT. Furthermore, this technology has an effective role in safe training programs and enhancing academic performance for these patients, whereas these programs in real life may be dangerous, difficult, or costly¹⁷. The present article investigated numerous studies that have used various types of virtual reality technologies, such as virtual classroom, virtual gaming, and virtual reality traffic gap-choice, for diagnosis, monitoring, evaluation, treatment, and training of 6- to 18-year-old children with ADHD^{14,15,33,49-52}. Table 1 presents a brief description of these finding including the aim of study, characteristics of patients with ADHD, VR technology types, and results.

Table 1. Virtual reality experiences for the rehabilitation of children with ADHD

Aim of study	ADHD patients' characteristics	VR technology types	Results	Sources
Study the efficacy of a near-infrared spectroscopy-based Neurofeedback training in VR classroom.	n=90 schoolchildren Range, 6–10 years	VR classroom	Improve training programs and academic performance and decrease of ADHD symptoms.	University Hospital Tuebingen (2016) ⁵¹
(1) Study the diagnostic validity of VC in comparison to a CPT test, (2) explore the task difficulty of VC, (3) address the effect of distractors on the performance of participants with ADHD.	n=33 Range, 7–13 years	Virtual classroom-CPT (VC)	Significant differences between performance in the virtual environment and the traditional computerized one, with longer reaction times in virtual reality.	Neguț et al. (2016) ⁵²
(1) Investigate validity and reliability of the ClinicaVR: Classroom-(CPT); (2) test the relationship between performance in the virtual test and the attendant sense of presence and cyber sickness experienced by participants (3) assess potential effects of gender and age on performance in the test.	n=102 (53 girls and 49 boys) Range, 7–16 years	ClinicaVR: classroom-(CPT)	In this study, test did not cause much cyber sickness. Also ClinicaVR: classroom-CPT recommend as an assessment tool for selective and sustained attention, and response inhibition.	Nolin et al. (2016) ¹⁹
The comparison of the performance in a CPT test in a VR classroom between medicated and unmedicated children with ADHD and healthy children	n=94 (26 medicated children with ADHD and 68 medicated children with ADHD and 34 healthy children) Range, 7–16 years	Virtual reality classroom (CPT-VRC)	Virtual reality technology has potential to evaluate ADHD symptoms in an ecologically valid environment.	Muhlberger et al. (2016) ⁴⁵
Study time of performances in the VR classroom with measures of the CPT II.	n=36 Range, 7–10 years	VR classroom	Decrease performance time in individuals with ADHD.	Bioulac et al. (2012) ¹⁴
Study the efficacy of VR in manipulating and eventually training time perception	n=not mentioned Range, not mentioned	VR game	Training and improvement in time perception of children with ADHD	Gongsook (2012) ¹⁵
Develops a novel assessment based on performance of children with ADHD, behavior & reaction using VR	n=not mentioned Range, 7–13 years	VR classroom	Improve attention and executive function.	Yeh et al. (2012) ³
Explore the efficacy of VR systems as treatment tools in primary impairments of ADHD, autism and cerebral palsy disorders.	n=not mentioned Range, not mentioned	Review past studies	Provide (1) feedback-focused interaction, (2) gesture-based interaction, and (3) haptic-based interaction.	Wang and Reid. (2011) ⁵³

Table 1. Virtual reality experiences for the rehabilitation of children with ADHD (continued)

Aim of study	ADHD patients' characteristics	VR technology types	Results	Sources
(1) Compare the performance of children with ADHD on VR-CPT with TOVA. (2) Assess the how the VR environment is experienced.	n=37 (20 with ADHD and 17 without ADHD) Range, 9–17 years	VR-CPT	The VR-CPT is an enjoyable and user-friendly assessment tool to help diagnosis of children with ADHD.	Pollak et al. (2009) ³⁴⁾
Investigate the ability of the VR classroom to compare between children with ADHD and the 16 same age control group and also evaluate the efficacy of ecologically valid distracters.	n=19 Range, 8–14 years	VR classroom	(1) Introduce lifelike distractions, (2) make test with more ecologically valid test and (3) offer a standardized environment to carry out research.	Adams et al. (2009) ³⁵⁾
Highlight the implementation of the psychotherapeutic principles for children with ADHD in VR classroom.	n=not mentioned Range, not mentioned	VR classroom	(1) Provide high accurate assessment, (2) reduce time (3) control the therapeutic process and (4) applying cognitive behavioral therapy techniques	Anton et al. (2009) ⁴⁹⁾
The comparison of performance of children with ADHD in VR-CPT with NO VR-CPT and TOVA	n=20 Range, 9–17 years	VR-CPT	The VR-CPT is a sensitive and user-friendly assessment tool in children with ADHD.	Pollak et al. (2009) ⁴⁸⁾
Validation of VR technology for the assessment of children with ADHD	n=10 Range, 6–11 years	VR classroom	The efficacy of VR-CPT to identify attentional difficulties in children with ADHD	Gutiérrez-Maldonado et al. (2009) ⁵⁴⁾
A controlled clinical comparison of attention performance in children with ADHD in a VR classroom	n=10 boys Range, 8–12 years	VR classroom	Virtual classroom had good potential for controlled performance assessment within an ecologically valid environment and due to the presence of distraction stimuli, appear significant effects.	Parsons et al. (2007) ²²⁾
Highlight unsafe road-crossing behavior of children with ADHD in a hazardous environment.	n=24 (12 boys and 12 girls) Range, 13–17 years	VR traffic gap-choice task	Virtual reality helps identify and educate those at higher risk of being involved in dangerous traffic situations.	Clancy et al. (2006) ⁵⁵⁾
Investigate VR feedback to increase EEG signal	n=120 subjects with ADHD, epilepsy or mood disorders Range, not mentioned	VR games	Better outcomes with information-rich feedback in virtual reality environments	Othmer and Kaiser (2004) ⁵⁶⁾
Highlight the potential of VR for improving attention	n=26 Range, not mentioned	VR classroom	The effectiveness of integrated VR with cognitive training in attention enhancement and focus on some tasks	Cho et al. (2002) ⁵⁷⁾
Developed the prototype of the Attention Enhancement System using VR and EEG biofeedback	n=50 Range, 13–17 years	VR Neurofeedback	(1) Improve assessment and treatment. (2) enhance attention	Cho et al. (2002) ⁵⁷⁾
Develop the new treatment system for children with ADHD using VR.	n=10 Range, not mentioned	VR classroom	(1) Decrease inattention or impulsivity (2) improve attention and treatment	Lee et al. (2001) ²⁾
Study VR applications in assessment and rehabilitation of cognitive/functional processes	n=15 Range, not mentioned	VR classroom	Improve the reliability of neuropsychological assessments	Rizzo et al. (2000) ³²⁾

ADHD, attention deficit hyperactivity disorder; VR, virtual reality; CPT, continuous performance test; VC, virtual classroom; TOVA, Test of Variables of Attention; EEG, electroencephalography.

Discussion

Researchers in the behavioral sciences have shown that VR technologies are increasingly being used in a wide range of areas from training and education to rehabilitation of impairments, disabilities, and handicaps^{17,33,39,53-60)}. The aim of this study was to highlight the opportunities for the use of VR systems in the rehabilitation of children with ADHD. By examining different

studies, our findings indicate that many professionals, including physicians and therapists, adopt VR systems for clinical rehabilitation. Widely different types of rehabilitation therapies based on virtual reality use strategies that consider interaction, the system's usability, and users' perceptions. They provide specific stimuli that can be used to remove distractions and provide safe environments that attract the subjects' attention and increase their ability to concentrate^{37,38)}. VR technologies enable rehabilitation techniques to

provide users the opportunity to function in a safe environment, without threats or dangers that exist in a real environment^{17,61}.

With respect to difficulties in cognitive performance, such as working memory, executive function, and attention in children with ADHD, the findings indicated that VR technologies are very helpful to assess, provide training, and improve these conditions^{17,33,56} and present a stable virtual environment that allows patients to adapt their lifestyle using cognitive training⁶²⁻⁶⁴. Usually, children with ADHD show difficulties in problem solving, managing their behavior, and cognitive flexibility²². Behavioral and physical patterns are base factors for the rehabilitation of ADHD subjects; therefore, they are highly relevant for virtual reality interventions. VR technologies facilitate action-based answers in these children and reduce their behavioral symptoms and problems^{39,53}. Another important point about this technology is its flexibility to modify the tasks of individuals with ADHD according to their attention and cognitive requirements^{17,33,57,63-66}. Other studies indicated the ability of VR for improving memory functionality, sensory processing, and five levels of attention, including focused attention, sustained attention, selective attention, alternating attention, and divided attention in individuals with ADHD^{2,17}.

With regard to the ecological validity of neuropsychological tests as one of the most important factors, some studies reported that, when these tests are combined with VR environments, their ecological validity and the probability of transferring skills and knowledge gained from VR environments to the real world will both increase^{3,22,34,35,37,38}. Another main point that clarifies the importance of VR technologies is that using medication in VR environments is more effective than in nonvirtual environments and can reduce omission errors and reaction time in the assessment of children with ADHD⁴⁸. According to these findings, it seems that VR games, as an artistic medium, demonstrate the wide range of human emotions and, because of their capacity to offer rewards, are very effective in the rehabilitation of children with ADHD. In addition, using a VR classroom, because of its simulation of the school environment, and embedding neuropsychological tests, such as CPT, have higher ecological validity in this domain^{22,35,36,67}. Despite the different opportunities offered by VR technologies, possible side effects, such as cybersickness, are a main issue that can threaten the health and safety of children with ADHD. However, this problem is partially preventable by the customization of VR according to user's needs, correct calibration, and the utilization of a suitable UI and HMD^{26,28-31,68}. However, some studies, such as the one by Neğüt et al. showed that VR does not have any effect on the performance time of these children^{14,52}.

Conclusion

In summary, the results indicated that VR technologies can

support the rehabilitation of children with ADHD by: (1) delivering stable and controlled stimuli to make steady progress; (2) providing feedback-focused and haptic-based interaction; (3) offering flexibility and delivering an immediate response according to patients' requirements; (4) providing safe learning environments that minimize errors, time, and costs; (5) improving users' motivation through enjoyable and user-friendly environments; (6) embedding different neuropsychological tests as required by therapists; (7) managing different stimuli and enabling clinicians to develop diagnosis, assessment, and rehabilitation strategies; and (8) improving behavioral and cognitive skills in children with ADHD. In general, it seems interesting to add these technologies to the neuropsychological evaluation process.

Conflicts of interest

No potential conflict of interest relevant to this article was reported.

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