A review on the effects of Virtual Reality treatment in ADHD

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Abstract

Attention deficit hyperactivity disorder (ADHD) is one of the most common psychiatric disorders in childhood. Despite of the core symptoms of ADHD (inattention, hyperactivity and impulsivity), patients often exhibit poor social skills, problems with planning and an inability to complete tasks on time. For what concerns the intervention, recent proposals include the use of board games such as chess, neurofeedback, virtual reality (VR) or serious video games. The efficiency of Virtual Reality is based on the rapid construction of various lifelike environments for training and stimulus control. In addition, there are many advantages such as creating an environment that meets the patient's needs, providing stability between users and stimuli and a full record of patient behavior and functioning, enabling rapid feedback, and saving time and money, and providing a more entertaining tool to motivate patients to use this technology. The aim of this review is to define the effects of VR based treatment on neuropsychological symptoms of ADHD.

Keywords

Virtual Reality, review, ADHD, neuropsychology, treatment

1. Introduction

Attention deficit hyperactivity disorder (ADHD) is one of the most common psychiatric disorders in childhood. In addition to its main symptoms, this disorder leads to significant difficulties in education, social performance, and personal relationships. As it is a heterogeneous developmental disorder, the etiology is unclear, leading to biased and extensive diagnostic assessments when patients are examined through traditional clinical interviews and assessments of patients' behaviour [1,2]

In minor patients, ADHD manifests as hyperactivity (i.e., the inability to control their impulses) and attention deficits that minimally affect their social engagement and the continuation of their normal daily lives. In adulthood, patients with ADHD may have difficulty managing time, getting organized, setting goals, and keeping a job, which can lead to further problems with relationships, self-esteem and possibly addiction.

Attention-deficit/hyperactivity disorder (ADHD) is the most common neurodevelopmental disorder in childhood and adolescence, affecting 4-8% of children worldwide [1]. In addition to the core symptoms of ADHD (inattention, hyperactivity and impulsivity), patients with ADHD often exhibit poor social skills, problems with planning and an inability to complete tasks on time [3]. The prognosis of ADHD is complicated by comorbidities, and impairments may worsen in adolescence or adulthood [4,5]. Treatment of ADHD is multimodal and may include the use of medication, psychoeducation, and psychological intervention [6]. Unfortunately, the current multimodal approach to ADHD treatment has some shortcomings [7]. For example, motivation is crucial for people with ADHD, and sometimes they lack the motivation to engage in treatment [8]. In addition, psychotherapies can be expensive [9] and have a high dropout rate [10,11]. Therefore, the introduction of new treatments that promote high motivation may be a good strategy to improve

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ADHD outcomes and prognosis. Recent proposals include the use of board games such as chess [12], neurofeedback [13,14], virtual reality (VR) [13] or serious video games [14]. All of these new approaches have the potential to motivate and engage people with ADHD during therapy. Serious video games can indeed be very stimulating and provide immediate reinforcement [15]. In addition, they offer several advantages, such as [15] (1) precise control of variables, (2) ease of data collection that allows assessment of a patient's progress, (3) provision of immediate feedback to the user, and (4) a more attractive presentation (i.e., a video game format). It is not surprising that several serious video games have been developed recently for the treatment of ADHD [16-19]. Treatment for many disorders, such as ADHD, can be provided through a well-known type of psychotherapy, cognitive behavioral therapy (CBT). In CBT, patients participate in multiple psychosocial interventions to improve their mental health. This treatment requires patients to attend several sessions with specialized therapists. In the case of ADHD, these sessions may be of increasing difficulty/complexity to allow patients to expand their cognitive abilities and overcome their current behavioral limitations. Given the importance of rehabilitation for these patients, the use of virtual reality technology (VR) is helpful. Various studies have shown that VR can help in the rehabilitation of children with ADHD, including: Flexibility according to the needs of the patients; Eliminating distractions and creating an effective and safe environment away from real-life hazards; Saving time and money; Increasing incentives for patients based on their interests; Providing appropriate tools for conducting various behavioral tests; and Increasing ecological validity; Facilitating a better understanding of the individual's cognitive deficits and improving them; Assisting therapists in accurate diagnosis, assessment and rehabilitation; Improving working memory, executive functions and cognitive processes such as attention in these children. Rehabilitation of children with ADHD is based on behavioral and physical patterns and therefore lends itself to VR interventions. By simulating and providing a virtual environment for diagnosis, training, monitoring, assessment and treatment, this technology is effective for optimal rehabilitation of children with ADHD [13-19].

However, it is also important to mention some disadvantages. For example, a major problem for people with ADHD is their susceptibility to some addictions, especially addiction to video games. Children and adolescents with ADHD are more likely to have internet gaming disorder [20]. Thus, in developing a serious video game to treat ADHD, a balance must be struck between achieving a high level of user satisfaction and avoiding an increased risk of becoming addicted to that video game. Regardless of the factors that influence addiction in the development of a serious video game, researchers can control the patients who participate in a study because addiction is related to adverse childhood experiences [21,22] and gaming addiction is specifically related to ADHD severity [23]. Another problem is the lack of evidence of transfer of improvements and benefits. In other words, it is not known whether improvements in video game performance would translate into improvements in other cognitive tasks in subjects' daily lives

The aim of this review is to review the studies found in the most popular online research engines (PubMed, Scopus, Google Scholar) on treating children with ADHD with VR. The keywords used are "virtual reality", "ADHD", "treatment", "therapy", "video games". The available literature is limited, but the results of these studies could have a positive impact on the lives of children with ADHD. This corresponds to a multimodal treatment that can improve life in different areas (education, family and private life).

2. Definition of Attention deficit hyperactivity disorder

Attention deficit hyperactivity disorder (ADHD) is defined as a neurodevelopmental disorder. The diagnostic classification is based on the observation of behavioral symptoms. According to the DSM-5, ADHD remains a diagnosis of exclusion and should not be diagnosed if the behavioral symptoms are better explained by other mental disorders (e.g., psychotic disorders, mood or anxiety disorders, personality disorders, substance intoxication or withdrawal) [24]. However, comorbidity with other mental disorders is common. In the DSM-5, the defining symptoms of ADHD are divided into symptoms of inattention (11 symptoms) and hyperactivity/impulsivity (9 symptoms) [24]. The DSM-5 distinguishes between different manifestations of ADHD: predominantly inattentive (6 or more of 11

symptoms present), predominantly hyperactive/impulsive (6 or more of 9 symptoms present) and combined manifestations (both criteria met), as well as a partial remission category. Symptoms must be present in two or more situations for at least 6 months before the age of 12 and must limit or interfere with social, academic or occupational functioning. In adolescents over 17 years and in adults, five symptoms per dimension must be present for diagnosis [24]. In adults, the use of validated instruments such as the Wender-Utah Rating Scale is recommended [25]. In contrast, the ICD-10 classification distinguishes between childhood hyperkinetic disorder (with at least six symptoms of inattention and six symptoms of hyperactivity/impulsivity present before the age of 6 years) and hyperkinetic conduct disorder, a combination of ADHD symptoms and symptoms of oppositional defiant disorder (CD) [26]. In ICD-11 (online publication as of June 2018, printed publication expected in 2022), the latter category has been removed, as has the exact age limit ("onset during the developmental period, typically in early to middle childhood"). In addition, the ICD-11 distinguishes five ADHD subcategories, which are consistent with those of the DSM-5: ADHD in combined form, ADHD in predominantly inattentive form, ADHD in predominantly hyperactive/impulsive form and two further categories, ADHD in other form and ADHD in non-specific form. For a diagnosis, the behavioral symptoms must be outside the normal range of variation expected for the person's age and intellectual abilities [27].

2.1. Neuropsychological models of the disorder

ADHD is related to multiple underlying neurobiological pathways and heterogeneous neuropsychological (NP) profiles. Twenty-five years ago, ADHD was characterized as a disorder of inhibitory self-control [28], and an early model of dual pathways distinguished between an inhibitory/executive function pathway and a motivational/delay aversion pathway (also referred to as the "cool" and "hot" pathways of executive function in later publications), which are associated with distinct neurobiological networks [29-31]. Coghill and colleagues [32] distinguished six cognitive factors in children with ADHD (working memory, inhibition, delay aversion, decision making, timing and reaction time variability) derived from seven subtests of the Cambridge automated battery of neuropsychological tests. Attempts to classify patients empirically into subgroups with selective performance profiles that deviate from the comprehensive NP data collection were inconclusive. Lambek and colleagues [33], for example, expected to distinguish appropriate subgroups of performance profiles in children with ADHD using tasks on delay aversion, working memory and reaction time. However, their analysis revealed subgroups distinguished by severity of impairments rather than selective profiles. However, some other empirical studies searching for subgroups identified ADHD-specific performance profiles ("poor cognitive control", [34] "with attention deficits and rapid processing speed" [35]), among other profiles common to TD controls. Obviously, divergent results regarding subgrouping may also be related to the different composition of the domains tested, leading to limited comparability of these studies.

3. Virtual reality technology

Virtual reality, also called computer-simulated reality or video-generated environments, is a computer technology that simulates an imaginary or real environment such as a classroom [36, 37]. Using this technology, users can interact and behave in 3-dimensional environments as they would in the real world [38]. The application of this technology has developed in education and training, entertainment, military, medicine, and surgery [36,39,40]. Immersive VR, desktop VR, projective VR and CAVE (C-Automatic Virtual Environment) are the most used types of virtual reality. The capability of this technology is based on the rapid construction of various lifelike environments for training and stimulus control [41-43]. There are many advantages to developing VR systems, such as creating an environment that meets the patient's needs, providing stability between users and stimuli and a full record of patient behavior and functioning, enabling rapid feedback, and saving time and money, and providing a more entertaining tool to motivate patients to use this technology [41,42]. In the

rehabilitation field, VR technologies enable people with impairments and disabilities due to brain damage to experience everything that is difficult or impossible for them in reality [44,45].

Nevertheless, health guidelines list possible side effects of VR such as headaches, seizures, nausea, fatigue, drowsiness, disorientation, apathy and dizziness. These symptoms are associated with cyber-disease or virtual reality disease. Cyber-sickness as a complex problem is the psychophysiological response to exposure to VR environments [46,47]. Studies have shown that cybersickness is a barrier to the use of training or rehabilitation tools in virtual reality environments [48,49].

4. Effects of using Virtual Reality in children or adolescents with ADHD

The aim of this review is to determine the effectiveness of VR -based interventions for ADHD children and adolescents. Our online search revealed that there are few studies of VR -based interventions targeting cognitive rehabilitation in ADHD children. Most VR studies in ADHD populations have focused on validating the assessment of attention in a virtual classroom setting [50-54]. Furthermore, there is no consensus on the outcome measures used in the different studies, so there are few studies that can be compared [55]. However, we have tried to include studies with the same outcome measures. The type of vigilance and sustained attention requirements imposed in the studies was significantly lower. It is striking that this is the case when children with ADHD have significant executive deficits in addition to attentional deficits, such as in planning, executing, and monitoring actions, which requires the development of self-regulation. In addition, these children's deficits also affect the scope of activities of daily living, social activities, and leisure time activities

In summary, despite the limited number of studies, the results suggest that VR -based interventions help to improve the cognitive performance of children and adolescents with ADHD on vigilance and sustained attention tasks, reducing the number of omissions and increasing the number of correct responses to target stimuli with large effect sizes [56]. In contrast, a medium effect on performance was observed for reaction time to target stimuli and the number of errors per task. This suggests that the effect is more due to vigilance and less due to improvement in impulsivity or inhibitory control. These results are of interest because they suggest that VR -based interventions could improve inattention symptoms and could therefore be very useful in children with ADHD of the inattention subtype, in whom a greater number of omissions and fewer correct responses were observed [57]. On the other hand, the results of the Bioulac study [58] showed that children who received VR -based interventions were better at inhibiting distractors. Moreover, they also showed less impulsivity (with a lower number of orders). The authors of this study also pointed out the good acceptance of this type of intervention. However, no improvements were observed by the parents, showing that although there was an improvement in the parameters of the attention tasks, there was no transfer to activities of daily living [59], suggesting that there is a need to increase the ecological validity of this type of intervention, as mentioned by the authors themselves. The simple fact that the environment of the task is changed does not mean that the task has ecological validity (pressing a button when a stimulus appears). It is necessary to distinguish between tasks and environment and to carefully analyze and adapt the task so that it has ecological validity in accordance with age-appropriate requirements and with meaningful value for the child [60].

Some authors reported improvements from the training programs and academic performance and a decrease in ADHD symptoms [61]. In addition, a reduction in performance time in individuals with ADHD [62] was associated with better performance on attention and executive tasks [41]. In addition, some studies [63,64] have found that, despite rehabilitation, VR can be useful in identifying attention difficulties in children with ADHD and improving the reliability of neuropsychological assessments.

As it has been described above, the heterogeneity of the results between the studies found in the literature can be seen. Nevertheless, it is not possible to deny the effectiveness of Virtual Reality in the rehabilitation of the symptoms present in ADHD. Moreover, the literature reports advantages not only relative to an improvement of the symptomatology but to a use of the Virtual Reality also in the assessment regarding the cognitive functions that can increase the effectiveness of the traditional instruments. The generalization of the results with respect to the patient’s daily life remains unclear. Studies that provide virtual environments more specific to the patient’s needs are recommended.

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