PRINCIPLES AND PRACTICE OF CLINICAL RESEARCH
A Global Journal of Clinical Research

Effect of Video Games or Virtual Reality in Reducing Symptoms of Cognitive Deficits in Children and Adolescents with ADHD: A Systematic Review

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Abstract

Introduction: *Attention-deficit hyperactivity disorder (ADHD) is one of the most frequent neurodevelopmental diseases affecting children and adolescents worldwide. Standard treatments often include a combination of pharmacotherapy and cognitive interventions. In the last decade, the effects of video game- and virtual reality (VR)-based treatments have been investigated as viable additional strategies to tackle ADHD symptoms.*

Methods: *A systematic literature review was conducted to identify studies that compared video game or VR-based interventions with standard care in children and adolescents affected by ADHD, evaluating cognitive, motor, and behavioral outcomes. The RoB-2 and MINORS tools were utilized to assess the risk of bias in included studies.*

Results: *Five studies published between 2001 and 2021 were included (437 patients, mean age: 10.74). Four studies investigated a video game-based intervention, and the remaining study employed VR. Collectively, the studies showed little to no effects on investigated outcomes. However, most of them were also affected by severe methodological issues carrying a moderate-to-high risk of bias.*

Discussion: *ADHD is a complex disorder often needing a multi-dimensional, individualized therapeutical approach. Video games and VR carry substantial advantages, such as higher patient involvement, cost-effectiveness, and subtle improvements in cognitive and behavioral outcomes. However, additional well-designed clinical trials are needed to prove their efficacy in pediatric patients with ADHD.*

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Received: November 14, 2022 **Accepted:** December 30, 2022
Published: July 10, 2023
Editor: Felipe Fregni **Reviewers:** Alessandra Carvalho, Victor Anculle
Keywords: ADHD, cognitive deficits, virtual reality, video games, exergaming
DOI: http://dx.doi.org/10.21801/ppcrj.2023.91.4

Introduction

Among neurodevelopmental disorders, attention-deficit hyperactivity disorder (ADHD) is most common in childhood and adolescence (prevalence: 3%–7%) (Benzing & Schmidt, 2019). The most frequent symptoms are cognitive disabilities affecting attention and impulsive behavior. Currently, pharmacological and non-pharmacological treatments provide robust evidence for reducing ADHD symptoms in children and adolescents. However, there is no indication that such interventions have long-term efficacy; prior research has evaluated new and multimodal approaches for ADHD treatment. (Hinshaw, 2015)

Individuals with ADHD show structural and functional irregularities in their brains because of the dysregulation of catecholaminergic pathways. Despite the prevalence in this age group and the recent studies on the impact on the nature of this problem, a systematic review is yet to be conducted and remains poorly understood. From a neurobiological perspective, it has been shown that moderate-to-vigorous physical exercise stimulates catecholamine neurotransmission, neurogenesis/angiogenesis, and neuroplasticity, thereby improving cognitive function by activating the same brain areas that govern higher-order cognition (Benzing & Schmidt, 2019; Cortese & Coghill, 2018). Furthermore, it has been demonstrated that combined with or without physical exercise; digital interventions may improve cognitive functions by providing cognitive training. (Benzing & Schmidt, 2019; Bikic et al., 2018)

We performed a systematic review to evaluate the effect of video games and VR interventions in reducing cognitive symptoms in children and adolescents with ADHD.

Materials and Methods

A systematic search on PubMed Database was performed for studies published from its inception to 29th September 2022. We sought to identify studies investigating the effect of video games or VR interventions compared with the standard of care in children and adolescents with ADHD. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were used to improve the review reporting(Page et al., 2021).

Inclusion/exclusion criteria and the search string

The bibliographic search included randomized controlled trials (RCTs) and non-randomized controlled trials (NRCTs) with the population of interest as children and adolescents with ADHD under the age group of 18 years, intervention as a video game or virtual reality or exergame in comparison with the standard of care and executive function as the outcome of interest. Only human studies with abstracts written in English were considered. The definitive search string comprised as follows: ("Video Games"[MeSH Terms] OR "Exergaming"[MeSH Terms] OR ("Virtual Reality"[MeSH Terms] OR "Virtual Reality Exposure Therapy"[MeSH Terms]) AND "Attention Deficit Disorder with Hyperactivity"[MeSH Terms] AND ("Child"[MeSH] or "Adolescent"[MeSH]).

Study selection

Two reviewers conducted the initial search for articles. A third reviewer intervened if there was a disagreement regarding eligibility, and a consensus was reached. The reviewers independently screened the titles and abstracts after removing duplicates. Subsequently, full texts were reviewed if a paper was considered potentially relevant based on the inclusion and exclusion criteria.

Data extraction

The extracted study characteristics included authorship, country, study design, number of participants, mean age, mean follow-up, year of publication, intervention, comparator, outcome measures, complications, and study conclusions.

Risk of bias

Version 2 of the Cochrane tool for assessing the risk of bias in randomized trials (RoB 2) (Sterne et al., 2019) and the Methodological Index for Non-Randomized Studies (MINORS) (Slim et al., 2003) tool were used to assess the quality of the studies. Furthermore, following Cochrane's recommendations, the "Robvis" tool was also used to generate the traffic light plot.

Results

Study selection

The search yielded 107 studies. After removing duplicates, 88 articles were excluded through title and abstract screening. Subsequently, we identified 19 full-text articles. Fourteen were excluded (non-comparative studies, n=3; book chapter, n=1; inappropriate outcome, n=1; languages other than English, n=1; inappropriate comparator, n=5; inappropriate population, n=2; <10 patients per group, n=1). Five studies were included after this process. The article

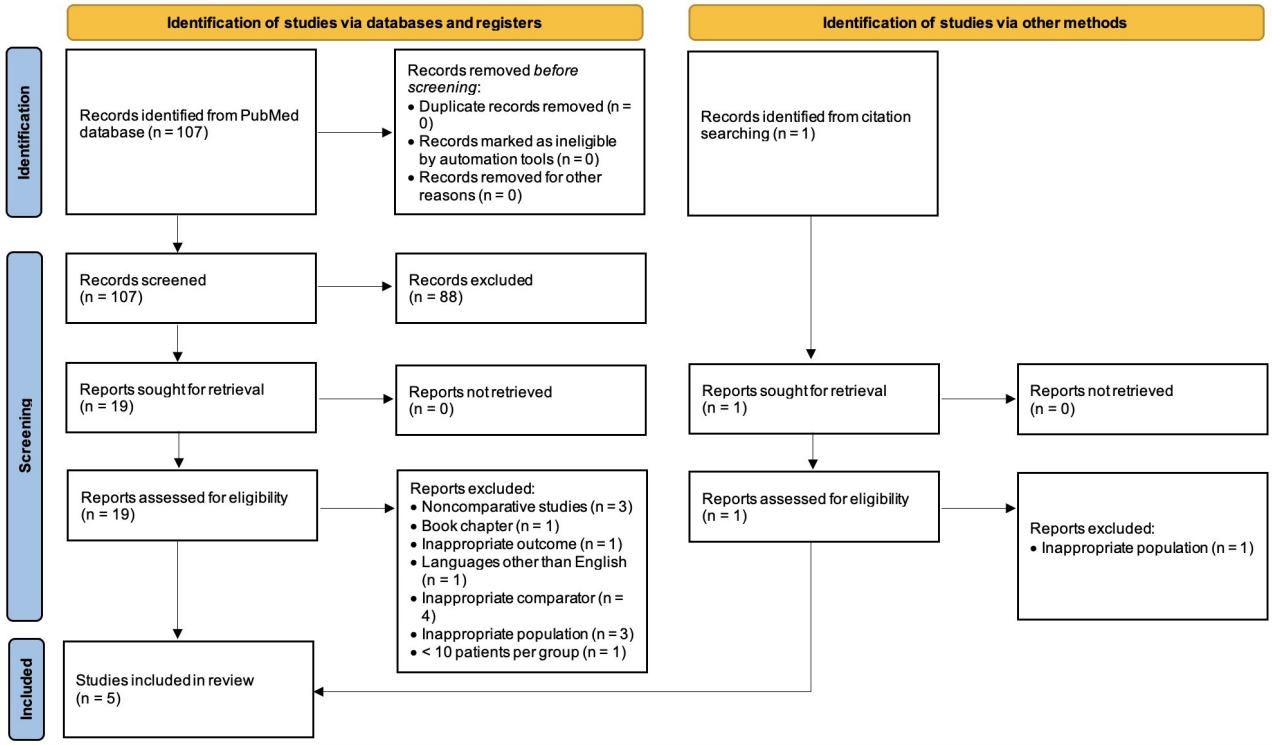

Figure 1: *Search strategy flow diagram in accordance with the Preferred Reporting for Systematic Reviews and Meta-Analyses (PRISMA) protocol.*

selection workflow is shown in a PRISMA flowchart (Figure 1).

Since cognitive deficits frequently affect behavioral and motor abilities in children and adolescents, most selected studies included scales pertaining to this domain and cognition. As a result, we reviewed this as well as our outcome of interest.

Study characteristics

The selected studies included four RCTs (Benzing & Schmidt, 2019; Bikic et al., 2018; Bul et al., 2016; Skalski et al., 2021) and one non-randomized prospective study (Shaffer et al., 2001). Studies were published between 2001 (Shaffer et al., 2001) and 2021 (Skalski et al., 2021). A total of 437 patients (219 treated with videogame- or VR-based interventions vs. 218 receiving standard care) with a mean age of 10.74 and 10.73 years, respectively, were assessed. Follow-ups ranged from 1 month (Shaffer et al., 2001) to 6 months (Bikic et al., 2018) (Table 1).

Risk of bias

For RCTs, we found one study with an overall risk of bias identified as "low" (Bikic et al., 2018), two as "some concerns" (Benzing & Schmidt, 2019; Skalski et al., 2021), and one as "high" (Bul et al., 2016) (Figure 2). The MINORS tool assessed the quality of

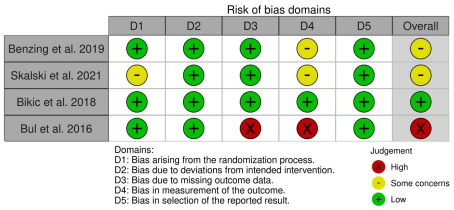

Figure 2: *Risk of bias as assessed by the Risk of Bias of Randomized Controlled Trials (RoB 2) tool based on the Cochrane Handbook for Systematic Reviews of Interventions.*

evidence of the included NRCT (Shaffer et al., 2001), with a total score of 15/24 (Supplementary Table).

Results of individual studies

The intervention procedures with their corresponding comparators and the investigated outcomes and complications are presented in Tables 2 and 3, respectively.

Cognitive function

Benzing et al., in their study, evaluated three core executive functions (EFs), including inhibition, switch-

Study	Country	Sample size (n)		Mean age (years)		Mean follow-up (months)	
		Video games/VR	*Control*	*Video games/VR*	*Control*	*Video games/VR*	*Control*
Benzing 2019	Switzerland	28	23	10.46 ± 1.30	10.39 ± 1.44	1.8	1.8
Bikic 2018	Denmark	35	35	9.77 ± 1.97	10.14 ± 1.52	5.5	5.5
Bul 2016	Netherlands and Belgium	88	82	9.89 ± 1.28	9.82 ± 1.24	4.6	4.6
Skalski 2021	Poland	57[§]	30	13.29 ± 1.55	12.60 ± 1.61	2.3	2.3
Shaffer 2001	USA	38[#]	18	-	-	1.1	1.1

§28 patients underwent VR hemoencephalograhic biofeedback with distractors and 29 patients underwent VR hemoencephalograhic biofeedback without distractors. #19 patients underwent training with Interactive Metronome© and 19 patients with a video game.
Abbreviations: VR = virtual reality.

Table 1: *Study design and patient demographics of included studies.*

ing, and updating, using a modified version of the Simon Task, Flanker test, and color span backward test (Benzing & Schmidt, 2019). The exergaming group showed significantly better performance during inhibition (p=0.049) and switching tasks (p<0.029) than the control group, while no significant difference was observed regarding updating.

The Bikic et al. study evaluated several cognitive outcome measures using the Cambridge Neuropsychological Test Automated Battery (CAN-TAB), including attention, visuospatial working memory, information retention, response inhibition, and reaction time. However, no significant differences were detected between the computer training and the control groups regarding sustained attention per the rapid visual information processing tasks, which was the primary outcome. Nonetheless, the experimental group showed a significantly higher performance in accuracy planning measured with the Stockings of Cambridge (SOC) test (p=0.006), which was maintained at both the 12-week (p=0.03) and 24-week (p=0.017) follow-up (Bikic et al., 2018).

In a crossover trial, Bul et al. examined the effect of a serious game intervention versus treatment using a time management questionnaire, the Plan/Organize of the Behavior Rating Inventory of Executive Function (BRIEF, parent version), and the subscale Cooperation of the Social Skills Rating System (SSRS, parent version). The secondary outcomes were the Working Memory subscale of the BRIEF, the Responsibility, the Assertiveness, the Self-Control, the Total of the SSRS, and the It is About Time Questionnaire (IATQ) administered to parents and teachers. At ten weeks, the experimental group showed significant improvements in parent-rated time management skills (p=0.004), working memory (p=0.02), responsibility skills (p=0.04), and teacher-reported time management skills (p=0.001), maintained during the ten weeks of follow-up, demonstrating a carry-over effect with the intervention. Improvements were also demonstrated when Group 2 was exposed to the intervention after ten weeks (Bul et al., 2016).

In the Skalski et al. study, the authors assessed the effects of hemoencephalographic (HEG) bio-feedback (BFB) along with virtual reality (VR) for treating deficits in vigilance, visual search, and divided attention in children with ADHD. The researchers included 87 participants (9–15 years) assigned to three groups (VR BFB with a limited visual scene, standard 2D BFB in the lab, and VR BFB with a complex visual scene) with ten sessions of HEG BFB. The authors found that children in the VR BFB group showed a higher regional cerebral blood oxygenation slope during BFB and enhanced performance in cognitive tests than children in the 2D BFB group, showing that HEG BFB with VR might have more benefits compared with standard 2D HEG BFB when approaching attention deficits (Skalski et al., 2021).

Shaffer et al. evaluated the effects of Interactive Metronome© training compared to another video-game or no treatment. A battery of 58 tests was administered to the study participants to assess attention, concentration, and clinical functioning (including motor and behavioral tasks), and language skills. Overall, both treatment groups showed a significant improvement, with 53/58 (p<0.001) and 43/58 (p<0.0058) improved scores in the Interactive Metronome© and video game groups, respectively. In addition, individuals treated with the Interactive Metronome© showed a more significant improvement in identifying similarities and differences, decreased aggressive behavior, and better performance in reading and attention tasks (Shaffer et al., 2001).

Behavioral outcomes

Benzing et al. assessed the severity of ADHD symptoms using the global score from the Conners-3 scale and the DSM-IV-TR Symptom Scale. Patients in the exergaming group showed significant improvement

Study	Type of intervention	Intervention	Intervention duration	Control group
Benzing 2019	Video game	Xbox Kinect©	Three 30 minute-training sessions per week for 8 weeks	No intervention
Bikic 2018	Video game	ACTIVATE™	Six sessions per week for 8 weeks	Pharmacological treatment as usual
Bul 2016	Video game	Plan-It Commander©	10 weeks of serious game intervention and a crossover of 10 weeks with treatment as usual	10 weeks of treatment as usual and then 10 weeks of serious game intervention
Skalski 2021	VR	VR BFB with limited visual scenes and VR BFB with complex visual scenes	10 sessions	Standard 2D BFB
Shaffer 2001	Video game	Interactive Metronome©	One 1 hour-session per day, spread out over a 3-week to 5-week period	No intervention

Abbreviations: BFB: biofeedback, VR: virtual reality.

Table 2: *Intervention characteristics of included studies.*

in the total global index score (p=0.022). In contrast, no significant difference was found in the DSM-IV-TR symptom scales (Benzing & Schmidt, 2019).

In the Bikic et al. study, ADHD symptoms were evaluated using the ADHD-Rating Scale-IV; in contrast, the BRIEF test assessed executive function behavior in school and home environments. The Weiss Functional Impairment Rating Scale (parent report form, WFIRS-P) was also used to rate children's functional impairment. No significant differences were observed between the computer-trained and control groups (Bikic et al., 2018).

Motor ability

The Benzing et al. study used the German motor test to assess motor ability. The exergaming group showed a significantly higher total performance compared with those in the control group (p=0.008), as well as in jumping sideways (p=0.039) and push-up (p=0.035) single tasks (Benzing & Schmidt, 2019).

Discussion

In the last decade, the use of video games and VR has seen rising interest in the treatment of children and adolescents with ADHD due to reported improvement of cognitive outcomes and motor abilities while also appearing more involving and motivating compared to traditional cognitive therapies (Primack et al., 2012). Even if the previous systematic review shows evidence of challenging games that can be considered an innovative adjunct in treating children and adolescents with ADHD (Zayeni, 2020), we must consider the methodological flaws observed in each trial. Although encouraging, most included studies reporting a positive effect of video games or VR displayed subtle changes or were affected by significant flaws, including high dropout rate, low adherence, blinding issues, and low statistical power to detect changes of small-to-moderate effect sizes (Table 3). Therefore, most studies analyzed in this review were accompanied by a moderate-to-high risk of bias. Nonetheless, patients who underwent video game or VR training for at least one month in included studies showed improvements in some cognitive abilities. Therefore, these tools may be an option for selected patients in the long-term treatment of ADHD, complementing the current therapeutical options utilized in clinical practice.

Limitations

PubMed was the only database used, and only studies in English were considered. Since this study only included peer-reviewed studies, relevant information from unpublished or non-peer-reviewed studies may have been missed. Furthermore, the included trials had a moderate attrition rate and missing data, which might have negatively influenced the results. There also needed to be more standardization in electronic interventions. Therefore, it is not easy to justify using one strategy over another and evaluate the reproducibility of the data achieved. Finally, the lack of sham video gaming is also a significant issue. It is unknown whether the improvements demonstrated are because of the specific platform or the children playing video games.

Conclusions

Video games and VR may improve the cognitive performance of children and adolescents with ADHD. However, available evidence could be more high-quality and often affected by consistent bias. Therefore, additional well-designed RCTs are required to validate these findings.

Study	Outcomes	Limitations	Conclusions
Benzing 2019	- Modified Simon Task - Modified Flanker task - Modified span backward task - Conners-3 scales - German Motor Test	- Failure to reach the calculated sample size - High dropout rate (>5%)	Exergaming can benefit executive functions, general psychopathology, and motor abilities of children with ADHD. No changes were observed in updating and ADHD symptoms.
Bikic 2018	- CANTAB - SOC	- Failure to reach the calculated sample size - High dropout rate (5.7%) - High risk of attrition bias (only 66.5% performing the expected number of the activities proposed).	There were no significant group differences on any of the cognitive measures. Overall, the results suggest that the proposed intervention is not useful for children with ADHD.
Bul 2016	- Time management questionnaire - BRIEF - SSRS	- High dropout rate (9%). - Lack of blinding of outcome assessors - Lack of a subsequent "sham game intervention" in the group receiving the intervention first	The group undergoing serious game + usual care showed significant improvements in their daily life functioning across domains of time management, social skills and working memory. The group receiving usual care + serious game demonstrated the same benefits when patients were later exposed to intervention.
Skalski 2021	- Mackworth Clock Task - Visual Search Task - Multitasking Test	- Lack of blinding - Lack of simultaneous randomization - Records kept at one research site only - Lack of evidence regarding the impact of BFB on the results	BFB with VR may have more benefits compared to standard 2D BFB when approaching attention deficits
Shaffer 2001	- TOVA - CRSR - Wechsler Intelligence - Test Achenbach Child - Behavior Checklist - Sensory Profile Test - Bruininks-Oseretsky Test - WRAT 3 - Language Processing Test	- Low external validity (only male participants) - Unqualified outcome assessors - Undisclosed allocation concealment	The Interactive Metronome© intervention may have more benefits than either the video game treatment or no treatment.

Abbreviations: BFB: biofeedback; BRIEF = Behavior Rating Inventory of Executive Functioning; CANTAB = Cambridge Neuropsychological Test Automated Battery; CSRS = Conners' Rating Scales–Revised; SSRS = Social Skills Rating System; TOVA = Tests of Variables of Attention; VR = virtual reality; WRAT = Wide Range Achievement Test.

Table 3: *Outcomes, limitations, and conclusions of included studies.*

Funding

This research received no external funding.

Conflicts of Interest

The authors declare no conflict of interest.

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