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The Effects of Exergaming and Neurofeedback on Working Memory in Children with Attention-Deficit/Hyperactivity Disorder

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ABSTRACT

This study aimed to compare the immediate and sustained effects of neurofeedback and exergaming on working memory in children with attention-deficit/hyperactivity disorder. This applied experimental study used a randomized pretest–posttest–follow-up design with four groups. The participants were 52 boys aged 7–10 years with attention-deficit/hyperactivity disorder who attended mainstream primary schools in Qazvin, Iran, during the 2021–2022 academic year. After matching for intelligence and selected demographic characteristics, participants were randomly assigned to neurofeedback, sham neurofeedback, exergaming, and control groups. The neurofeedback and exergaming groups each included 14 participants, whereas the sham neurofeedback and control groups each included 12 participants. The intervention groups completed 30 sessions, conducted three times per week for 45 minutes. Working memory was assessed using the computerized N-Back Task at pretest, posttest, and one-month follow-up. Data were analyzed using a two-factor mixed analysis of variance and bootstrapped Bonferroni-adjusted pairwise comparisons in SPSS version 26. The main effect of time on working memory was significant, $F(2, 96) = 53.04$, $p < .001$, partial $\eta^2 = .52$. The main effect of group was also significant, $F(3, 48) = 3.66$, $p = .019$, partial $\eta^2 = .18$, and the time-by-group interaction was significant, $F(6, 96) = 15.07$, $p < .001$, partial $\eta^2 = .48$. At posttest, neurofeedback produced significantly greater improvement than sham neurofeedback ($p = .018$) and control ($p = .010$), while exergaming outperformed control ($p = .002$). At follow-up, neurofeedback remained superior to sham neurofeedback ($p = .001$) and control ($p = .004$), and exergaming remained superior to control ($p = .001$). No significant differences were found between neurofeedback and exergaming at posttest or follow-up. Both neurofeedback and exergaming were effective in improving working memory in children with attention-deficit/hyperactivity disorder, and their effects were maintained one month after treatment; however, neither intervention demonstrated clear superiority over the other.

Keywords: *Attention-deficit/hyperactivity disorder, working memory, neurofeedback, exergaming, executive functions, children*

1. Introduction

Attention-deficit/hyperactivity disorder (ADHD) is a neurodevelopmental condition characterized by developmentally inappropriate and persistent patterns of inattention, hyperactivity, and impulsivity that interfere with academic, social, behavioral, and family functioning. The conceptualization and diagnostic boundaries of ADHD have evolved considerably over time, reflecting changes in clinical knowledge regarding symptom presentation, developmental course, functional impairment, and the heterogeneity of the disorder. Contemporary diagnostic approaches recognize that ADHD is not merely a behavioral problem but a complex condition involving deficits in cognitive control, self-regulation, motivational processing, and executive functioning (Adam & Young-Walker, 2014). ADHD commonly begins in childhood and can affect children's capacity to follow instructions, organize schoolwork, maintain attention, regulate motor activity, wait for rewards, and adapt their behavior to environmental demands. These difficulties may persist across developmental stages and contribute to poor educational achievement, strained peer and family relationships, reduced self-esteem, and increased vulnerability to emotional and behavioral problems.

Epidemiological evidence indicates that ADHD is one of the most prevalent neurodevelopmental disorders among school-aged children. Although prevalence estimates vary according to diagnostic criteria, informants, assessment procedures, geographical setting, and methodological quality, international evidence suggests that ADHD has remained a substantial public health and educational concern across recent decades (Polanczyk et al., 2014). Research conducted among elementary school populations has similarly demonstrated that symptoms of inattention, hyperactivity, and impulsivity are frequently recognized by both parents and teachers, although estimated prevalence can differ depending on the perspective of the informant and the criteria used to define clinically significant symptoms (Arjmandi et al., 2015). The high prevalence of ADHD in primary-school settings is especially important because this developmental period places increasing demands on sustained attention, behavioral inhibition, memory, planning, and goal-directed learning. When these capacities are impaired, children may experience cumulative disadvantages in academic learning and classroom participation.

The functional consequences of ADHD cannot be understood solely through observable behavioral symptoms. Neuropsychological research has shown that children with ADHD often exhibit weaknesses in executive functions, including inhibitory control, sustained attention, planning, cognitive flexibility, processing speed, and working memory. Neuropsychological assessment is therefore important for clarifying how cognitive deficits contribute to children's everyday functioning and for identifying intervention targets that may not be captured adequately through behavioral symptom ratings alone (Pritchard et al., 2012). Among executive functions, working memory is particularly important because it enables individuals to temporarily maintain, update, and manipulate information while performing an ongoing task. It supports reading comprehension, mathematical reasoning, problem solving, following multistep instructions, note-taking, classroom participation, and the regulation of behavior in accordance with current goals.

Working-memory deficits may be especially disruptive for children with ADHD because many classroom activities require the simultaneous processing and retention of information. A child may need to remember the teacher's instructions while beginning an assignment, retain intermediate steps while solving a mathematical problem, or monitor previous responses while adjusting behavior to changing task requirements. When working-memory capacity is limited, information may be lost before it can be used, resulting in incomplete tasks, careless errors, difficulty following instructions, and apparent inattentiveness. These difficulties can also intensify frustration and avoidance, particularly when the child is repeatedly exposed to tasks that exceed cognitive capacity. Computerized working-memory training has been investigated as one method of directly strengthening these processes. Evidence from children and adolescents with learning disabilities and comorbid ADHD suggests that structured computerized training may improve aspects of working memory and attention, although the extent to which gains generalize to academic performance and everyday behavior remains an important question (Gray et al., 2012).

Movement-based computerized cognitive rehabilitation has also been proposed as a means of improving working memory through the integration of cognitive demands and bodily activity. Such interventions require children to process visual information, update task rules, inhibit incorrect responses, and coordinate movement with rapidly changing stimuli. Research on movement-based

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computerized rehabilitation has reported improvements in working-memory performance among children with ADHD, suggesting that cognitive engagement may be enhanced when training is presented through interactive physical activities rather than repetitive sedentary exercises (Jalili et al., 2019). Computer-based cognitive rehabilitation has also been associated with improvements in behavioral and executive-function outcomes, including attention, inhibitory control, and risk-related decision-making (Nazerieh & Niknam, 2024). More recent tele-cognitive rehabilitation findings further indicate that targeted attention training can improve executive functions and reduce behavioral symptoms among children with ADHD, supporting the adaptability of game-based and technology-assisted approaches across clinical and home-based contexts (Nejati & Derakhshan, 2024).

Treatment of ADHD commonly involves pharmacotherapy, behavioral interventions, parent training, educational accommodations, cognitive rehabilitation, or combinations of these approaches. Stimulant medication is among the most established treatments and can produce meaningful reductions in core ADHD symptoms. Evidence-based pharmacological guidelines nevertheless emphasize the need for individualized treatment selection, monitoring of adverse effects, consideration of comorbidities, and integration of medication with psychosocial and educational support when appropriate (Bolea-Alamanac et al., 2014). Comparative studies have found that both neurofeedback and medication may improve ADHD-related difficulties, although their mechanisms, immediacy, durability, and acceptability may differ (Mohammadi & Hosseini, 2018). Diet and nutritional modification have also been examined as potential treatment components, but the evidence varies according to the dietary strategy and study design, and dietary approaches generally require careful methodological evaluation rather than being treated as universal substitutes for established interventions (Stevenson et al., 2014). Physical and mind–body interventions, including yoga, have also been associated with improvements in visual and auditory attention among children displaying hyperactivity symptoms (Mollazadeh et al., 2018).

Despite the effectiveness of medication for many children, interest in nonpharmacological interventions has increased because of concerns regarding side effects, incomplete symptom response, treatment adherence, parental preference, and the need to target cognitive processes directly. Neurofeedback is one of the most extensively investigated technology-based interventions for ADHD. Neurofeedback is a form of operant conditioning in which individuals receive real-time information about aspects of their brain activity and learn, through repeated reinforcement, to modify targeted patterns of neural activation. The historical and technical foundations of neurofeedback were developed through work demonstrating that electroencephalographic activity could be shaped through feedback and reinforcement (Sterman & Egner, 2006). During neurofeedback sessions, brain signals are recorded through scalp electrodes, processed by specialized software, and translated into visual or auditory feedback. Desired brain-activity patterns are rewarded through progress in a game, animation, or sound, whereas feedback is reduced or interrupted when activity moves away from the target range.

The proposed relevance of neurofeedback for ADHD is based on evidence that altered patterns of cortical activation and self-regulation may contribute to attentional and executive-function difficulties. Neurofeedback protocols aim to enhance the child's capacity to regulate brain activity associated with attention, inhibition, and cognitive control. Theoretical and clinical literature has described neurofeedback as a potentially valuable intervention for ADHD while emphasizing the importance of standardized protocols, adequate training intensity, appropriate control conditions, and valid outcome assessment (Heinrich et al., 2016). Clinical reviews have generally concluded that neurofeedback may reduce ADHD symptoms and improve selected neuropsychological outcomes, but they have also highlighted variability in protocol type, blinding, control conditions, and the specificity of treatment effects (Holtmann et al., 2014). Questions regarding specificity are particularly important because improvement may partly reflect repeated practice, therapist attention, expectancy, motivation, or exposure to computer-based training rather than direct regulation of neural activity (Brandeis, 2011).

Meta-analytic evidence from randomized controlled trials has suggested that neurofeedback can produce improvements in clinical and neuropsychological outcomes among children with ADHD, although effect sizes may differ according to outcome informant, methodological rigor, and control condition (Cortese et al., 2016). More recent systematic review and meta-analytic evidence specifically focused on executive functioning has strengthened the rationale for examining neurofeedback as a means of improving cognitive control in children with ADHD (Zhong et al., 2025). Nevertheless, the literature remains heterogeneous, and not all studies have

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demonstrated clear superiority over active comparison treatments. For example, a randomized trial comparing neurofeedback with stimulant medication and physical activity found that the relative effects of these interventions depended on the particular cognitive outcome examined (Gelade et al., 2016). Such findings indicate that neurofeedback should be evaluated not only against no-treatment controls but also against credible sham and active interventions.

Individual investigations provide further support for the possible cognitive benefits of neurofeedback. Neurofeedback training has been reported to improve sustained attention and working memory in elementary-school boys with ADHD (Dasht Bozorgi et al., 2016). Studies combining neurofeedback with computerized cognitive exercises have also found improvements in working memory, suggesting that the simultaneous targeting of brain regulation and task-specific cognitive practice may produce complementary benefits (Heidari Nasab et al., 2016). Research has additionally reported reductions in hyperactivity and attention-deficit symptoms following neurofeedback among school students and young adults (Narimani et al., 2013; Seilsapour et al., 2015). Case-based evidence has similarly indicated that repeated neurofeedback training may strengthen neuronal self-regulation in individuals with attention-deficit symptoms (Fauzan & Nazaruddin, 2012). Reviews of the field have therefore regarded neurofeedback as a promising treatment, while noting that conclusions depend on training protocol, sample characteristics, outcome selection, and methodological quality (Nemati & Alizadeh, 2017).

Recent developments have expanded neurofeedback beyond conventional ADHD protocols. Reviews across neurological and psychiatric conditions describe biofeedback and neurofeedback as increasingly adaptable clinical technologies, while stressing the need for protocol-specific evidence and appropriately controlled trials (Melo et al., 2025). Different electroencephalographic protocols may produce distinct clinical effects, as illustrated by comparative research on sensory-motor rhythm and alpha–theta neurofeedback (Lotfinia et al., 2025). Neurofeedback has also been examined in relation to depression and anxiety through real-time functional magnetic resonance imaging (Zhang et al., 2025), in combination with mindfulness meditation using consumer-grade systems (Treves et al., 2025), and for the enhancement of self-regulation and performance in sport contexts (Yu et al., 2025). These broader applications support the general principle that feedback-based training may strengthen learned regulation of cognitive, emotional, and physiological states, although findings from one clinical population cannot be assumed to transfer directly to another.

Multicomponent interventions have also emerged. A recent approach combining respiratory biofeedback, neurofeedback, and median nerve stimulation reported beneficial effects among children with ADHD, illustrating growing interest in nonpharmacological protocols that engage several regulatory systems simultaneously (Santamaría-Vázquez et al., 2025). Reviews focused on children and adolescents with ADHD and learning disabilities likewise suggest that neurofeedback may improve executive and academic functions, although stronger studies are required to determine the durability and practical significance of these gains (Sadeghi Ahouei et al., 2025). The question of durability is particularly important because immediate post-intervention improvement may reflect short-term task familiarity, whereas meaningful rehabilitation requires that gains persist after structured training has ended.

Exergaming represents another promising nonpharmacological approach. Exergames are interactive digital games that require bodily movement to control game events. Motion-sensitive systems, including camera-based and sensor-based consoles, permit the child's movements to be captured and translated into actions on a screen. Unlike conventional sedentary games, exergames combine physical activity with cognitive stimulation, immediate feedback, goal pursuit, and reward. Studies of video game play have shown that digital games can engage attention, memory, visuospatial processing, and executive control, although benefits depend on game characteristics, training intensity, and the similarity between practiced and assessed cognitive processes (Boot et al., 2008). The motivational structure of games may also be important. Anticipation, prediction, feedback, and reward contribute to sustained engagement and influence how individuals respond to unfolding events (Huron, 2007). In children with ADHD, whose attention and persistence may decline during monotonous tasks, the immediate and repeated feedback provided by exergames may increase adherence to cognitively demanding practice.

Exergaming may improve executive function through several interacting mechanisms. Physical exercise can increase physiological arousal, cerebral blood flow, and activation of neural systems involved in attention and cognitive control. Simultaneously, the game requires the child to monitor stimuli, remember instructions, inhibit premature actions, coordinate movements, and adapt to changing rules. Xbox Kinect-based interventions have been shown to facilitate motor performance in children with movement-related difficulties, demonstrating that motion-controlled gaming can support structured, repetitive, and progressively challenging practice (Rostamipour et al., 2019). For children with ADHD, these features may be particularly useful because cognitive training is embedded within an engaging activity that limits prolonged sitting and converts repeated practice into goal-oriented play.

Controlled studies have increasingly examined exergaming in ADHD populations. A randomized trial found that exergaming improved attention in children with ADHD, supporting the use of cognitively demanding physical games as a therapeutic tool (Ji et al., 2023). Exercise training delivered through a hit-sport-game format has also been associated with improvements in self-control and regulation among children with ADHD (Salleg-Cabarcas et al., 2024). These findings suggest that interactive movement training may influence not only physical fitness but also executive processes central to behavioral regulation. However, the potential benefits of digital games must be distinguished from problematic or excessive gaming. Video game addiction has been associated with anxiety, depression, and ADHD-related characteristics in children and adolescents, indicating that therapeutic gaming should be structured, supervised, time-limited, and directed toward specific developmental goals (Alrahili et al., 2023).

Although both neurofeedback and exergaming have been linked to improvements in attention and executive functioning, direct comparisons between these interventions remain limited. Neurofeedback focuses primarily on learned regulation of electrophysiological activity, whereas exergaming combines cognitive challenge with whole-body physical activity, sensory feedback, reward, and motor coordination. Both may improve working memory, but they may operate through partly different mechanisms. Moreover, many previous studies have used only pretest–posttest designs, have lacked sham conditions, or have not assessed whether treatment gains remain after the intervention. Inclusion of a sham neurofeedback group is particularly valuable because it helps separate the specific effects of contingent brain-based feedback from expectancy, therapist contact, and participation in an apparently active computerized treatment. A no-intervention control group provides an additional basis for evaluating changes that might otherwise result from maturation, repeated testing, or ordinary educational experience.

The present study therefore addressed several methodological and practical gaps by comparing active neurofeedback, sham neurofeedback, exergaming, and a control condition within a randomized pretest–posttest–follow-up design. Working memory was selected as the primary outcome because of its central role in executive functioning, academic performance, and everyday self-regulation among children with ADHD. Evaluating both immediate and one-month follow-up effects made it possible to determine whether changes were temporary or sustained. Furthermore, comparing neurofeedback with exergaming provided evidence regarding whether one technology-based nonpharmacological intervention was more effective than the other or whether both represented viable approaches for strengthening working memory in children with ADHD.

Accordingly, the aim of the present study was to compare the immediate and sustained effects of neurofeedback and exergaming on the working memory of children with attention-deficit/hyperactivity disorder.

2. Methods and Materials

2.1. Study Design and Participants

This applied study employed a randomized experimental design with pretest, posttest, and one-month follow-up assessments. The study included two active intervention groups receiving neurofeedback training and exergaming, respectively, a sham-intervention group receiving noncontingent neurofeedback, and a no-intervention control group. Before the interventions began, working memory was assessed in all four groups using the N-Back Task. Participants assigned to the three intervention conditions then completed 30 training sessions, conducted three times per week, with each session lasting approximately 45 minutes. The control group did not receive any intervention during the study period and continued its usual educational and daily activities. Immediately after completion of the 30 sessions, working memory was reassessed in all groups under conditions comparable to those used at baseline. A follow-up assessment was conducted one month after the final intervention session to determine whether any observed changes in working memory were maintained over time. The statistical population consisted of male students aged seven to ten years with attention-deficit/hyperactivity disorder who attended mainstream primary schools in Qazvin, Iran, during the 2021–2022 academic year. The required sample size was estimated using G*Power version 3.1, and 52 eligible boys with ADHD were recruited. Their mean age was 8.65 years, with a standard deviation of 1.18 years. Before random allocation, the participants were matched as closely as possible in terms of intellectual functioning, with an average intelligence quotient of approximately 94.5, as well as relevant demographic characteristics. The children generally came from families with moderate socioeconomic and educational backgrounds and had no physical health conditions that would prevent participation in the training activities. Following the matching process, participants were randomly assigned to the neurofeedback group, comprising 14 students; the sham neurofeedback group, comprising 12 students; the exergaming group, comprising 14 students; or the control group, comprising 12 students. Eligibility was determined on the basis of the target age range, enrollment in a mainstream primary school, identification of ADHD, adequate intellectual functioning for understanding and completing the tasks, physical capacity to participate in the movement-based intervention, and willingness of the child and parents to cooperate throughout the study. Children with serious neurological disorders, severe sensory or motor impairments, or medical conditions that could interfere with neurofeedback or physical gaming activities were not included. Participants who were repeatedly absent from the intervention sessions, initiated another structured cognitive intervention during the study, or were unable to complete the posttest or follow-up assessment were considered eligible for withdrawal from the study. The study procedures were explained to the parents and children in age-appropriate language, and participation was voluntary. Confidentiality of the participants' personal information and test results was maintained throughout the research process.

2.2. Measures

Working memory was measured using the N-Back Task, a computerized cognitive task originally introduced by Kirchner in 1958 for evaluating executive functions and the continuous monitoring and updating of information. The task is particularly appropriate for assessing working memory because successful performance requires participants not only to retain recently presented information but also to compare and manipulate that information as new stimuli are presented. It is also regarded as relatively independent of language and cultural background because performance is primarily based on the rapid processing and comparison of visual stimuli. In the version used in the present study, 100 visual stimuli were presented consecutively on a computer screen at intervals of approximately 1,800 milliseconds. For each stimulus, the participant was required to compare the current item with the immediately preceding item. When the child identified the current stimulus as matching the preceding stimulus, the number-one key was pressed; when no match was identified, the number-two key was pressed. Before formal administration, the instructions were explained clearly, and participants were given an opportunity to ensure that they understood the response procedure. The task required approximately two to three minutes to complete. The computerized program recorded the number of correct and incorrect responses, which provided objective indicators of working-memory performance. Higher numbers of correct responses and lower numbers of incorrect responses represented better performance. The same task and administration procedure were used during the pretest, posttest, and one-month follow-up assessments to permit comparison of changes across time and between the four study groups.

2.3. Interventions

The neurofeedback intervention was conducted in a designated room equipped with an electroencephalographic recording and neurofeedback system connected to a computer. Before the beginning of the intervention, participants and their parents were formally informed of the session schedule, and a trained neurofeedback specialist explained the procedure and familiarized each child with the equipment. An individualized timetable was prepared to ensure that each participant attended on predetermined days and at specified times. The intervention comprised 30 sessions conducted three times per week, generally on alternate days, with each session lasting approximately 45 minutes. Sessions were held during morning hours under relatively consistent environmental conditions. At the beginning of each session, the child sat comfortably in front of the computer monitor. The cleanliness of the child's hair and scalp was checked to reduce recording impedance and improve signal quality. The distance between the nasion and inion was measured according to the international 10–20 system for electroencephalographic electrode placement. The EEG cap and relevant contact areas were disinfected and carefully positioned on the child's head. Conductive gel was then applied, and the active electrode was placed at the F4 location, corresponding to the right frontal region associated

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with attentional control, response inhibition, and working-memory processes. The ground electrode was attached to the right earlobe and the reference electrode to the left earlobe. After the signal quality had been checked and artifacts had been minimized, the child completed computer-based neurofeedback exercises using SmartMind Neurofeedback Software, version 3. This software includes game-like cognitive rehabilitation exercises developed to strengthen cognitive functions while simultaneously providing feedback based on brainwave activity. Its exercises are designed particularly to reinforce working memory, attentional control, concentration, response inhibition, decision-making, problem-solving, and cognitive flexibility. The program provided visual and auditory feedback according to the child's real-time EEG activity, meaning that progress within the computerized game was contingent on producing the targeted pattern of brain activity. The difficulty and duration of the exercises were adjusted according to the standardized settings of the software and the participant's performance. The software also permitted artifact rejection, timing of individual games, application of predefined training protocols, and storage of individual performance data in graphical and numerical formats. Throughout each session, the specialist monitored electrode contact, signal quality, child engagement, and possible fatigue. Brief pauses were provided when needed, while the total training time was kept as consistent as possible across participants.

The sham neurofeedback condition was included to control for expectancy effects, contact with the intervention specialist, exposure to the treatment environment, and the possible psychological influence of believing that an active neurofeedback intervention was being received. Participants in this group attended the same designated neurofeedback room and followed a schedule comparable to that of the active neurofeedback group. They completed 30 sessions, three times per week, with each session lasting approximately 45 minutes. At the beginning of the intervention, the neurofeedback specialist explained the equipment and general session procedure without informing the children that the feedback was noncontingent. Electrode preparation and placement followed the same procedures used in the active neurofeedback group. The child was seated in front of the computer, the nasion–inion distance was determined using the international 10–20 system, and the active, reference, and ground electrodes were attached at the same locations used for the active condition. However, the audiovisual feedback presented during the computerized exercises was not systematically contingent on the child's own moment-to-moment EEG activity. Thus, participants experienced the appearance and structure of a neurofeedback session without receiving a genuine reinforcement protocol based on their individual brainwave patterns. The room conditions, session duration, frequency of attendance, interaction with the specialist, computer display, and general instructions were kept as similar as possible to those of the active neurofeedback group. This procedure was intended to ensure that differences between the active and sham conditions could be attributed more confidently to the specific effects of contingent neurofeedback rather than to attention from the therapist, repeated computer use, motivation, or intervention-related expectations.

The exergaming intervention was conducted in a separate room equipped with a Microsoft Kinect motion-sensing device connected to an Xbox One console and a 49-inch Samsung LED television. Before the intervention began, the children and their parents were invited to an orientation session during which a trained specialist explained the operation of the Kinect system, demonstrated the required movements, and introduced the rules and safety considerations associated with the games. Each participant received an individualized schedule specifying the days and times of attendance. The intervention consisted of 30 sessions conducted three times per week, with each session lasting approximately 45 minutes. The principal intervention was based on the Shape Up exergame, developed by Ubisoft for the Xbox One platform. Shape Up is a movement-based sports and fitness game that uses motion sensors to capture and reproduce the player's body movements on the screen. The game incorporates a broad range of activities, including jumping, running in place, punching, lifting simulated weights, performing push-up-like movements, and completing other dynamic whole-body tasks. These activities require the player to attend continuously to visual instructions, coordinate bodily responses, inhibit irrelevant actions, remember movement sequences, and modify performance according to immediate feedback. The game presents physical exercise in a playful and competitive format and automatically adapts aspects of task difficulty to the player's performance level. Many activities are organized into brief, approximately 90-second exercise sequences, allowing children to complete repeated bouts of cognitively engaging physical activity while reducing monotony and excessive fatigue. During each session, the specialist selected age-appropriate activities, monitored correct movement execution, and ensured that the child

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maintained a safe distance from the equipment and surrounding objects. The sessions included sufficient time for familiarization, active gameplay, brief recovery intervals, and progression to more demanding exercises when the participant demonstrated adequate mastery. The same overall session duration and weekly frequency were maintained across participants. The intervention was intended to combine the physiological benefits of movement with the attentional, inhibitory, visuospatial, and information-updating demands of interactive digital games, thereby providing repeated stimulation of cognitive processes involved in working-memory performance.

2.4. Data Analysis

The collected data were analyzed using IBM SPSS Statistics, version 26. Descriptive statistics, including the mean, standard deviation, frequency, and percentage, were used to summarize the participants' demographic characteristics and working-memory scores at the pretest, posttest, and one-month follow-up assessments. Because working memory was measured repeatedly across three assessment occasions and compared among four independent groups, the principal inferential analysis was conducted using a mixed-design repeated-measures analysis of variance. In this analysis, time, consisting of the pretest, posttest, and follow-up assessments, was treated as the within-subject factor, while group, consisting of active neurofeedback, sham neurofeedback, exergaming, and control conditions, was treated as the between-subject factor. The main effect of time was examined to determine whether working-memory performance changed across the three assessments, and the main effect of group was evaluated to determine whether the groups differed in their overall performance. Particular attention was given to the time-by-group interaction, because a statistically significant interaction would indicate that the pattern of change over time differed among the four conditions. Before conducting the main analysis, the relevant statistical assumptions were evaluated, including the identification of extreme values, approximate normality of score distributions, homogeneity of variances, and sphericity of repeated measurements. When the assumption of sphericity was violated, an appropriate correction, such as the Greenhouse–Geisser adjustment, was applied. Where significant main or interaction effects were identified, pairwise comparisons with an appropriate adjustment for multiple testing were used to determine which assessment occasions and intervention groups differed significantly. Effect-size indices were also considered to evaluate the magnitude of the observed intervention effects beyond statistical significance. All statistical tests were two-tailed, and the level of statistical significance was set at $p \leq .05$.

3. Findings and Results

Before conducting the inferential analyses, the mean and standard deviation of working-memory scores were calculated for the neurofeedback, sham neurofeedback, exergaming, and control groups across the pretest, posttest, and one-month follow-up assessments. As presented in Table 1, the groups had relatively comparable working-memory scores at pretest. However, the scores increased at posttest and follow-up in both active intervention groups, whereas only minor fluctuations were observed in the sham neurofeedback and control groups.

Table 1

Descriptive Statistics for Working-Memory Scores by Group and Assessment Time

Assessment	Neurofeedback Group (n = 14), M	SD	Sham Neurofeedback Group (n = 12), M	SD	Exergaming Group (n = 14), M	SD	Control Group (n = 12), M	SD
Pretest	56.80	11.20	52.50	15.20	48.10	12.30	51.08	19.01
Posttest	66.20	7.20	53.30	11.70	60.30	11.30	46.90	17.40
Follow-up	72.90	8.10	52.90	13.70	68.00	8.60	54.00	

As shown in Table 1, the mean working-memory score in the neurofeedback group increased from 56.80 at pretest to 66.20 at posttest and 72.90 at follow-up. Similarly, the mean score in the exergaming group increased from 48.10 at pretest to 60.30 at posttest and 68.00 at follow-up. In contrast, the sham neurofeedback group demonstrated little change across the three assessments, with mean scores of 52.50, 53.30, and 52.90, respectively. The control group also showed no consistent improvement, as its mean score decreased from 51.08 at pretest to 46.90 at posttest and subsequently increased to 54.00 at follow-up. These descriptive findings indicate that both neurofeedback and exergaming were associated with improvements in working-

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memory performance, and that these improvements were maintained or further increased at the one-month follow-up.

A two-factor mixed analysis of variance was conducted to examine changes in working-memory scores across the pretest, posttest, and follow-up assessments and to determine whether the pattern of change differed among the four study groups. Time was considered the within-subject factor, while intervention group was treated as the between-subject factor. The complete results of the analysis are presented in Table 2.

Table 2

Results of the Two-Factor Mixed Analysis of Variance for Working Memory

Source	Sum of Squares	df	Mean Square	F	p	Partial η²
Group	5,091.90	3	1,697.30	3.66	.019	.18
Between-subject error	22,243.30	48	463.40	—	—	—
Time	2,483.50	2	1,241.70	53.04	< .001	.52
Time × Group	2,116.90	6	352.80	15.07	< .001	.48
Within-subject error	2,247.30	96	23.40	—	—	—

The results of the mixed analysis of variance indicated a statistically significant main effect of time on working-memory scores, $F(2, 96) = 53.04$, $p < .001$, partial $\eta^2 = .52$. This finding indicates that working-memory performance changed significantly across the pretest, posttest, and follow-up assessments, regardless of group membership. The main effect of group was also statistically significant, $F(3, 48) = 3.66$, $p = .019$, partial $\eta^2 = .18$, indicating an overall difference in working-memory performance among the four groups. More importantly, the interaction between time and group was statistically significant, $F(6, 96) = 15.07$, $p < .001$, partial $\eta^2 = .48$. The large interaction effect demonstrates that the pattern of change in working-memory scores over time differed significantly among the neurofeedback, sham neurofeedback, exergaming, and control groups. Therefore, bootstrapped Bonferroni-adjusted pairwise comparisons were conducted to identify the immediate effects at posttest and the sustained effects at the one-month follow-up.

Table 3

Bootstrapped Bonferroni-Adjusted Pairwise Comparisons of Changes in Working Memory at Posttest and Follow-up

Assessment and Comparison	Mean Difference	p	Bootstrapped BCa 95% CI	Interpretation
Posttest: Immediate Effect				
Neurofeedback vs. sham neurofeedback	14.70	.018	[4.50, 25.60]	Significant
Neurofeedback vs. exergaming	−9.40	.112	[−20.20, 1.30]	Not significant
Neurofeedback vs. control	24.10	.010	[8.40, 42.30]	Significant
Sham neurofeedback vs. control	9.41	.280	[−5.66, 27.60]	Not significant
Exergaming vs. control	33.60	.002	[16.50, 52.20]	Significant
Follow-up: Sustained Effect				
Neurofeedback vs. sham neurofeedback	27.90	.001	[15.05, 40.70]	Significant
Neurofeedback vs. exergaming	−16.80	.077	[−36.70, 0.37]	Not significant
Neurofeedback vs. control	22.10	.004	[10.40, 34.30]	Significant
Sham neurofeedback vs. control	−5.80	.369	[−19.10, 6.60]	Not significant
Exergaming vs. control	38.90	.001	[22.10, 59.90]	Significant

The bootstrapped Bonferroni-adjusted comparisons indicated that, at posttest, the improvement in working memory was significantly greater in the neurofeedback group than in the sham neurofeedback group, mean difference = 14.70, $p = .018$, BCa 95% CI [4.50, 25.60]. The neurofeedback group also demonstrated a significantly greater improvement than the control group, mean difference = 24.10, $p = .010$, BCa 95% CI [8.40, 42.30]. These findings indicate that neurofeedback produced a significant immediate improvement in the working memory of children with ADHD. However, the difference between the neurofeedback and exergaming groups was not statistically significant, mean difference = −9.40, $p = .112$, BCa 95% CI [−20.20, 1.30], indicating that the immediate effectiveness of the two active interventions did not differ significantly. The comparison between the sham neurofeedback and control groups was also nonsignificant, mean difference = 9.41, $p = .280$, BCa 95% CI [−5.66, 27.60], suggesting that

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exposure to the intervention setting and noncontingent feedback alone did not significantly improve working memory. In contrast, the exergaming group showed a significantly greater improvement than the control group, mean difference = 33.60, p = .002, BCa 95% CI [16.50, 52.20], confirming a significant immediate effect of exergaming on working-memory performance.

At the one-month follow-up, the neurofeedback group continued to show significantly greater improvement than the sham neurofeedback group, mean difference = 27.90, p = .001, BCa 95% CI [15.05, 40.70], and the control group, mean difference = 22.10, p = .004, BCa 95% CI [10.40, 34.30]. These results demonstrate that the beneficial effect of neurofeedback on working memory was maintained one month after the intervention. The exergaming group also showed a significantly greater sustained improvement than the control group, mean difference = 38.90, p = .001, BCa 95% CI [22.10, 59.90], indicating that the effects of exergaming remained significant at follow-up. No statistically significant difference was found between the neurofeedback and exergaming groups at follow-up, mean difference = −16.80, p = .077, BCa 95% CI [−36.70, 0.37]. Thus, neither active intervention was statistically superior to the other in producing sustained improvements in working memory. Moreover, the difference between the sham neurofeedback and control groups remained nonsignificant, mean difference = −5.80, p = .369, BCa 95% CI [−19.10, 6.60], further indicating that sham neurofeedback did not produce a meaningful immediate or sustained improvement. Overall, the findings supported the effectiveness of both neurofeedback and exergaming in improving the working memory of children with ADHD, with the effects of both interventions remaining evident one month after treatment.

4. Discussion

The present study examined the effects of neurofeedback and exergaming on working memory in children with attention-deficit/hyperactivity disorder using a randomized pretest, posttest, and one-month follow-up design that included active neurofeedback, sham neurofeedback, exergaming, and control groups. The results demonstrated significant main effects of time and group, as well as a significant interaction between time and group. These findings indicate that working-memory performance changed across the three measurement occasions and that the pattern and magnitude of change differed among the four groups. More specifically, children who received active neurofeedback showed significantly greater improvement than those in the sham neurofeedback and control groups at both posttest and follow-up. Children who participated in the exergaming intervention also showed significantly greater gains than the control group at both assessment points. In contrast, sham neurofeedback did not produce a significant advantage over the control condition. No statistically significant difference was found between neurofeedback and exergaming at either posttest or follow-up. Overall, the findings suggest that both active interventions produced immediate and sustained improvements in working memory, whereas exposure to the treatment setting and noncontingent feedback alone was insufficient to create comparable changes.

The significant improvement observed following neurofeedback is consistent with evidence indicating that this intervention can strengthen executive functions in children with ADHD. A recent systematic review and meta-analysis found that neurofeedback training can improve executive-function outcomes in children with ADHD, although the magnitude of the effect may differ according to the protocol and executive domain assessed (Zhong et al., 2025). Earlier meta-analytic findings from randomized controlled trials also indicated that neurofeedback may improve clinical symptoms and selected neuropsychological outcomes in children with ADHD (Cortese et al., 2016). The present findings extend this literature by showing that working-memory gains were not limited to the immediate post-intervention assessment but remained evident one month after completion of training. This maintenance effect is clinically relevant because an intervention that produces only short-lived task improvement would have limited rehabilitative value.

The findings also align with previous research specifically addressing working memory and sustained attention. Neurofeedback training has been shown to improve sustained attention and working memory in elementary-school boys with ADHD (Dasht Bozorgi et al., 2016). Similarly, the combination of neurofeedback and computerized cognitive exercises has been associated with improved working-memory performance, supporting the idea that repeated feedback-guided practice may strengthen the cognitive processes involved in maintaining, updating, and manipulating information (Heidari Nasab et al., 2016). Review studies have likewise concluded that neurofeedback can be useful in the treatment of ADHD, particularly when the intervention is delivered through structured and sufficiently intensive protocols (Nemati & Alizadeh, 2017).

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Evidence of reduced inattention and hyperactivity following neurofeedback among school-aged students and young adults further supports the broader regulatory effects of this intervention (Narimani et al., 2013; Seilsapour et al., 2015).

One possible explanation for the neurofeedback findings is that repeated contingent feedback enabled participants to develop greater control over neural activity associated with attention, response regulation, and executive control. Neurofeedback is based on operant learning principles: desirable electrophysiological patterns are reinforced through immediate visual or auditory consequences, gradually increasing the individual's ability to reproduce those patterns. The theoretical and clinical foundations of neurofeedback suggest that repeated self-regulation of brain activity may modify the functional systems underlying attention and cognitive control (Heinrich et al., 2016; Sterman & Egner, 2006). In the present study, the active electrode was placed over the right frontal region, which is relevant to attentional regulation, inhibitory control, and working-memory processing. Repeated activation and regulation of this area may therefore have helped children maintain task-relevant information, resist distraction, and update responses more effectively.

The use of game-like computerized exercises during neurofeedback may also have contributed to the observed improvement. Children with ADHD often have difficulty persisting in monotonous or delayed-reward tasks. Immediate feedback, visible progress, and repeated opportunities for success can increase motivation and sustain engagement. The SmartMind exercises used in this study required participants to coordinate cognitive performance with ongoing brain-based feedback, thereby integrating neural self-regulation with practice in attention, inhibition, and working memory. Findings from computerized working-memory interventions indicate that repeated and adaptive training can improve working memory and attention, particularly when the exercises are structured according to the participant's performance level (Gray et al., 2012). The combination of feedback, repetition, and cognitive challenge may consequently explain why the active neurofeedback group improved more than the sham group.

The absence of a significant difference between sham neurofeedback and the control group is an important finding. It suggests that the improvements associated with active neurofeedback were unlikely to be explained solely by contact with the specialist, sitting in front of a computer, wearing EEG equipment, receiving treatment-related attention, or expecting improvement. Concerns about the specificity of neurofeedback have been raised in the literature because participants may benefit from nonspecific therapeutic factors, repeated assessment, or motivational engagement rather than from modulation of targeted brain activity (Brandeis, 2011). By including a sham condition in which feedback was not contingent on the participant's actual EEG pattern, the present study provided a stricter test of treatment specificity. The significant superiority of active neurofeedback over sham neurofeedback at both posttest and follow-up therefore supports the interpretation that contingent neurophysiological feedback contributed meaningfully to the observed working-memory gains.

Nevertheless, the neurofeedback literature has not produced entirely uniform conclusions. Reviews have described neurofeedback as promising while also emphasizing variability in training protocols, blinding, outcome measures, and control conditions (Holtmann et al., 2014). A randomized trial comparing neurofeedback, stimulant medication, and physical activity found that treatment effects varied across neurocognitive outcomes and that neurofeedback was not consistently superior on every measure (Gelade et al., 2016). Such variation may reflect differences in electrode placement, reinforcement thresholds, number of sessions, participant characteristics, concurrent treatment, and the cognitive domain being evaluated. The current study's relatively intensive 30-session protocol may have provided sufficient repetition for children to acquire and consolidate self-regulatory skills, which may partly account for the sustained improvement.

The positive effect of exergaming on working memory is also consistent with previous research. A randomized controlled trial reported that exergaming improved attention in children with ADHD, demonstrating that cognitively engaging physical games can influence functions beyond motor performance (Ji et al., 2023). Movement-based computerized cognitive rehabilitation has similarly been found to improve working memory in children with ADHD (Jalili et al., 2019). In addition, sport-game exercise training has been associated with enhanced self-control and regulation in this population (Salleg-Cabarcas et al., 2024). The present results add to this evidence by showing that the benefits of exergaming extended specifically to working memory and were maintained at the one-month follow-up assessment.

Several mechanisms may explain the effectiveness of exergaming. First, physical activity may facilitate cognitive performance by increasing physiological arousal, cerebral

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circulation, and activation of neural networks involved in executive control. Second, exergames require simultaneous perceptual, cognitive, and motor processing. During Shape Up activities, children had to observe rapidly changing visual cues, retain game rules, anticipate upcoming actions, select appropriate movements, inhibit incorrect responses, and modify performance in response to immediate feedback. These demands closely involve working memory because the child must continuously hold and update task-relevant information while performing physical actions. The combination of exercise and cognitive challenge may therefore generate stronger executive engagement than either passive gaming or repetitive physical exercise alone.

The motivational properties of exergaming may offer an additional explanation. Interactive games provide immediate rewards, clear goals, performance feedback, progressive difficulty, and frequent changes in stimulation. These features can be especially useful for children with ADHD, who may show reduced persistence when tasks are repetitive or rewards are delayed. Video game research has demonstrated that game play can engage attention, memory, and executive control, although the transfer of benefits depends on the cognitive requirements of the game (Boot et al., 2008). The role of anticipation and expectation in maintaining attention may also be relevant, because game events create continuous cycles of prediction, action, and feedback (Huron, 2007). In the present study, short movement challenges and adaptive game difficulty may have sustained children's engagement across 30 sessions and enabled repeated practice of working-memory-related skills without the intervention being experienced as a conventional cognitive exercise.

The exergaming findings may also be understood in relation to evidence that Kinect-based interventions support motor learning through repeated, visually guided practice. Computerized motor training using Xbox Kinect has been shown to improve gross motor skills among children with motor delays (Rostamipour et al., 2019). Although the outcome in the present study was cognitive rather than motor, movement coordination and executive control are not independent. Planning a movement, monitoring its execution, correcting errors, and shifting between action patterns require cognitive control. The motor and cognitive components of exergaming may therefore reinforce one another, resulting in improvements in working memory.

The significant difference between the exergaming and control groups at both posttest and follow-up further indicates that the observed gains were unlikely to reflect only repeated exposure to the N-Back task or ordinary developmental change. Children in the control condition did not show a comparable pattern of improvement. This finding is compatible with research showing that technology-assisted cognitive rehabilitation and structured computer games can improve executive and behavioral outcomes in children with ADHD (Nazerieh & Niknam, 2024; Nejati & Derakhshan, 2024). However, the findings should not be interpreted as evidence that unrestricted video game use is beneficial. Problematic and excessive gaming has been associated with ADHD, anxiety, and depression among children and adolescents (Alrahili et al., 2023). Therapeutic exergaming differs from uncontrolled gaming because it is supervised, time-limited, developmentally appropriate, physically active, and organized around specific cognitive and rehabilitative objectives.

The absence of significant differences between neurofeedback and exergaming at posttest and follow-up suggests that neither intervention was clearly superior in improving working memory. This finding may indicate that different intervention mechanisms can lead to a similar functional outcome. Neurofeedback may act primarily through learned regulation of neural activity, whereas exergaming may influence working memory through physical activation, cognitive-motor integration, motivation, and repeated executive practice. Both interventions provide immediate feedback and require sustained, goal-directed engagement. These shared characteristics may be more important for working-memory improvement than the specific delivery modality. The finding also supports a flexible treatment perspective in which intervention selection can be based on child characteristics, available resources, treatment preferences, cost, and feasibility rather than an assumption that one approach is universally superior.

The comparable effectiveness of the two interventions is consistent with broader evidence that executive functions can be enhanced through multiple forms of targeted training. Recent reviews of neurofeedback in neurological and psychiatric settings emphasize that feedback-guided learning can support self-regulation across diverse conditions (Melo et al., 2025). Neurofeedback has also shown effects across different protocols and functional domains, including anxiety regulation, mindfulness-related self-regulation, and performance enhancement (Lotfinia et al., 2025; Treves et al., 2025; Yu et al., 2025). Similarly, game-based cognitive and physical interventions can stimulate executive functions through adaptive challenge and active engagement. The present results suggest that both

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pathways may be clinically useful for children with ADHD when implemented systematically and intensively.

The sustained effects observed at follow-up may reflect consolidation of learned skills. In neurofeedback, repeated practice may have enabled children to internalize strategies for regulating attention and neural activation even after the external feedback was removed. In exergaming, repeated requirements to remember instructions, shift between tasks, inhibit impulsive actions, and coordinate complex movements may have strengthened executive processes that remained available after training ended. The continued improvement in descriptive scores from posttest to follow-up in both active groups may also indicate that children applied acquired skills in everyday academic and behavioral contexts. Nevertheless, because the study assessed follow-up after only one month, the duration of these effects beyond the short term remains uncertain.

The current findings are also relevant to the increasing demand for nonpharmacological and child-friendly ADHD interventions. Pharmacological treatments remain central to evidence-based ADHD management and can produce substantial symptom reduction (Bolea-Alamanac et al., 2014). However, medication does not directly provide repeated practice in working-memory tasks, and some families prefer nonpharmacological or complementary options. Comparative research has shown that both medication and neurofeedback may produce beneficial outcomes, although they differ in their delivery and mechanisms (Mohammadi & Hosseini, 2018). The current results do not suggest replacing established medical treatment with either intervention. Rather, neurofeedback and exergaming may serve as complementary approaches for children whose treatment plans require additional support for executive functioning.

5. Conclusion

The findings should also be viewed in the context of emerging multimodal interventions. Recent research has evaluated combinations of neurofeedback, respiratory biofeedback, and nerve stimulation in children with ADHD, reflecting a movement toward integrated nonpharmacological treatment models (Santamaría-Vázquez et al., 2025). Reviews focused on children with ADHD and learning disabilities have similarly suggested that neurofeedback may support both executive and academic functioning (Sadeghi Ahouei et al., 2025). It is possible that future intervention programs could combine neurofeedback with movement-based games, computerized working-memory exercises, behavioral training, or educational support. Such combinations may target several mechanisms simultaneously and produce broader transfer to classroom behavior and academic achievement.

The study had several limitations. The sample consisted only of 52 boys aged seven to ten years from mainstream primary schools in one geographical area, which restricts the generalizability of the findings to girls, adolescents, children from other regions, and those with different clinical or socioeconomic characteristics. The relatively small sample sizes within the four groups may also have reduced statistical power for detecting modest differences, particularly between the two active interventions. Working memory was assessed using a single computerized task, and repeated administration may have produced some practice effects. Although the sham condition strengthened the methodological design, complete blinding of intervention providers was not possible. The study also did not provide detailed control of medication use, ADHD presentation, symptom severity, sleep, physical activity outside the sessions, or other treatments that could influence cognitive performance. Finally, the one-month follow-up period was relatively short and does not establish whether the observed benefits persist over longer periods or generalize to academic performance, classroom behavior, and everyday functioning.

Future studies should recruit larger and more diverse samples that include girls, different age groups, children from multiple educational and cultural settings, and participants with varying ADHD presentations and levels of symptom severity. Longer follow-up periods of three, six, and twelve months would clarify the durability of treatment effects. Researchers should use several measures of working memory and executive functioning, together with parent, teacher, and behavioral assessments, to determine whether improvements transfer beyond computerized testing. Future trials should document medication status, comorbid conditions, attendance, treatment fidelity, and participant engagement more systematically. Direct comparisons of different neurofeedback protocols and different types or intensities of exergaming would help identify the most effective intervention components. Studies could also examine mediating mechanisms, such as improvements in inhibitory control, sustained attention, physical fitness, motivation, or neural regulation. Factorial designs comparing neurofeedback, exergaming, and a combined

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intervention may determine whether integrating the two approaches produces additive or synergistic benefits.

Clinicians, school psychologists, occupational therapists, and rehabilitation professionals may consider structured neurofeedback and supervised exergaming as complementary options for improving working memory in children with ADHD. Intervention selection should be individualized according to the child's cognitive profile, motivation, physical abilities, treatment preferences, family resources, and access to trained providers and equipment. Neurofeedback should be delivered by qualified practitioners using standardized protocols, careful electrode preparation, continuous monitoring, and age-appropriate feedback. Exergaming programs should be supervised, physically safe, limited in duration, and selected according to their cognitive demands rather than entertainment value alone. Schools may integrate brief movement-based digital activities into individualized support programs, provided that the activities are structured and do not replace academic instruction, behavioral intervention, or necessary medical care. Progress should be evaluated regularly using objective cognitive measures and reports from parents and teachers, and interventions should be adjusted when meaningful functional improvement is not observed.

Authors' Contributions

Authors equally contributed to this article.

Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

Transparency Statement

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Declaration of Interest

The authors report no conflict of interest.

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Ethics Considerations

The study protocol adhered to the principles outlined in the Helsinki Declaration, which provides guidelines for ethical research involving human participants.

References

Adam, B., & Young-Walker, L. (2014). The Evolution of the ADHD Diagnosis and Its Implications for DSM-5. *Journal of Pediatrics and Congenital Disorders*, *1*, 1-2.

Alrahili, N., Alreefi, M., Alkhonain, I. M., Aldakhilallah, M., Alothaim, J. S., Alzahrani, A., Alshargi, A., & Baabbad, N. M. (2023). The Prevalence of Video Game Addiction and Its Relation to Anxiety, Depression, and Attention Deficit Hyperactivity Disorder (ADHD) in Children and Adolescents in Saudi Arabia: A Cross-Sectional Study. *Cureus*. https://doi.org/10.7759/cureus.42957

Arjmandi, S., Keykhaavandi, S., & Sayehmiri, K. (2015). Prevalence of Attention-Deficit/Hyperactivity Disorder among Elementary School Students from the Perspectives of Teachers and Parents: A Systematic Review and Meta-Analysis. *Principles of Mental Health*, *17*(5).

Bolea-Alamanac, B., Nutt, D. J., Adamou, M., Asherson, P., Bazire, S., Coghill, D., Heal, D., Muller, U., Nash, J., Santosh, P., Sayal, K., Sonuga-Barke, E., & Young, S. J. (2014). Evidence-Based Guidelines for the Pharmacological Management of Attention-Deficit Hyperactivity Disorder: Update on Recommendations from the British Association for Psychopharmacology. *Journal of Psychopharmacology*, 1-25.

Boot, W. R., Kramer, A. F., Simons, D. J., Fabiani, M., & Gratton, G. (2008). The Effects of Video Game Playing on Attention, Memory, and Executive Control. *Acta Psychologica*, *129*(3), 387-398. https://doi.org/10.1016/j.actpsy.2008.09.005

Brandeis, D. (2011). Neurofeedback Training in ADHD: More News on Specificity. *Clinical Neurophysiology*, *122*, 856-857. https://doi.org/10.1016/j.clinph.2010.08.011

Cortese, S., Ferrin, M., Brandeis, D., Holtmann, M., Aggensteiner, P., & Daley, D. (2016). Neurofeedback for Attention-Deficit/Hyperactivity Disorder: Meta-Analysis of Clinical and Neuropsychological Outcomes from Randomized Controlled Trials. *Journal of the American Academy of Child & Adolescent Psychiatry*, *55*(6), 444-455. https://doi.org/10.1016/j.jaac.2016.03.007

Dasht Bozorgi, Z., Dadashpour, M., Amin al-Sharia, S., Ashouri, J., & Alizadeh, M. (2016). The Effect of Neurofeedback Training on Sustained Attention and Working Memory in Elementary School Boys with Attention-Deficit/Hyperactivity Disorder. *Shafa Khatam*, *5*(4).

Fauzan, N., & Nazaruddin, M. (2012). Neurofeedback Training to Improve Neuronal Regulation in ADD: A Case Report. *Procedia - Social and Behavioral Sciences*, *33*, 399-402. https://doi.org/10.1016/j.sbspro.2012.01.060

Gelade, K., Bink, M., Janssen, T. W., van Mourik, R., Maras, A., & Oosterlaan, J. (2016). An RCT into the Effects of Neurofeedback on Neurocognitive Functioning Compared to Stimulant Medication and Physical Activity in Children with

E-ISSN: 3060-6713

ADHD. *European Child & Adolescent Psychiatry*, *26*(4), 1-12. https://doi.org/10.1007/s00787-016-0902-x

Gray, S., Chaban, P., Martinussen, R., Goldberg, R., Gotlieb, H., Kronitz, R., & Tannock, R. (2012). Effects of a Computerized Working Memory Training Program on Working Memory, Attention, and Academics in Adolescents with Severe Learning Disabilities and Comorbid ADHD: A Randomized Controlled Trial. *Journal of Child Psychology and Psychiatry*, *53*(12), 1277-1284. https://doi.org/10.1111/j.1469-7610.2012.02592.x

Heidari Nasab, L., Madani, A. S., Yaghoubi, H., Rostami, R., & Kazemi, R. (2016). Effectiveness of Neurofeedback Combined with Computerized Cognitive Exercises in Improving Working Memory in Adults with Attention-Deficit/Hyperactivity Disorder. *Journal of Lorestan University of Medical Sciences*, *18*(1).

Heinrich, H., Strehl, U., Arns, M., Rothenberger, A., & Ros, T. (2016). *Neurofeedback in ADHD*. Frontiers Media SA. https://doi.org/10.3389/978-2-88919-722-4

Holtmann, M., Sonuga-Barke, E., Cortese, S., & Brandeis, D. (2014). Neurofeedback for ADHD: A Review of Current Evidence. *Child and Adolescent Psychiatric Clinics of North America*, *23*(4), 789-806. https://doi.org/10.1016/j.chc.2014.05.006

Huron, D. (2007). *Sweet Anticipation: Music and the Psychology of Expectation*. MIT Press. https://doi.org/10.7551/mitpress/6575.001.0001

Jalili, F., Nejati, V., Asadi, H., & Katanforoush, S. A. (2019). Effectiveness of Movement-Based Computerized Cognitive Rehabilitation in Improving Working Memory in Children with Attention-Deficit/Hyperactivity Disorder. *Medical Sciences Journal of Islamic Azad University*, *29*(2).

Ji, H., Wu, S., Won, J., Weng, S., Lee, S., Seo, S., & Park, J. J. (2023). The effects of exergaming on attention in children with attention deficit/hyperactivity disorder: randomized controlled trial. *JMIR serious games*, *11*(1), e40438. https://doi.org/10.2196/40438

Lotfinia, S., Shahkaram, H., Yaseri, A., Kianimoghadam, A. S., & Sarani Yaztappeh, J. (2025). A clinical trial comparing the efficacy of two EEG-based neurofeedback protocols for generalized anxiety disorder: Sensory motor rhythm and alpha-theta. *Iranian journal of psychiatry and behavioral sciences*, *19*(2), e158451. https://doi.org/10.5812/ijpbs-158451

Melo, D. N., Mendonça, A. L. M., Santos, F. C., Coelho, F. R., Teixeira, G. M., & Júnior, V. A. R. (2025). Biofeedback and Neurofeedback in the Clinical Setting: A Review of Their Application and Efficacy in Neurological and Psychiatric Conditions. *International Health Sciences Review*, *1*(4), 21-35. https://doi.org/10.70164/ihsr.v1i4.39

Mohammadi, S. Y., & Hosseini, M. (2018). Comparison of the Effectiveness of Neurofeedback Therapy and Pharmacotherapy in Treating Attention-Deficit/Hyperactivity Disorder in Children in Isfahan. *Neuropsychology*, *12*(1).

Mollazadeh, M., Gharayagh Zandi, H., & Rostamizadeh, M. J. (2018). Effectiveness of Yoga Training on Visual and Auditory Attention in Children with Hyperactivity Symptoms. *Razi Journal of Medical Sciences*, *25*(8).

Narimani, M., Rajabi, S., & Delavar, S. (2013). The Effect of Neurofeedback Training on Reducing Hyperactivity and Attention-Deficit Symptoms in Female University Students. *Journal of Arak University of Medical Sciences*(2).

Nazerieh, N., & Niknam, M. (2024). The Effectiveness of Computer Games Rehabilitation and Cognitive Play Therapy Rehabilitation on the Risk-Taking of Children with Attention Deficit Hyperactivity Disorder. *International Journal of Applied Behavioral Sciences*, *11*(2), 1-7. https://doi.org/10.61838/kman.jarac.7.1.17

Nejati, V., & Derakhshan, Z. (2024). Attention training improves executive functions and ameliorates behavioral symptoms in children with attention-deficit hyperactivity disorder: Implication of tele-cognitive-rehabilitation in the era of coronavirus disease. *Games for Health Journal*, *13*(1). https://doi.org/10.1089/g4h.2023.0002

Nemati, S., & Alizadeh, H. (2017). Examining the Effectiveness of Neurofeedback in Treating Attention-Deficit/Hyperactivity Disorder: A Review Study. *Psychology of Exceptional Individuals*, *7*(28).

Polanczyk, G. V., Willcutt, E. G., Salum, G. A., Kieling, C., & Rohde, L. A. (2014). ADHD Prevalence Estimates across Three Decades: An Updated Systematic Review and Meta-Regression Analysis. *International journal of epidemiology*, *43*(2), 434-442. https://doi.org/10.1093/ije/dyt261

Pritchard, A. E., Nigro, C. A., Jacobson, L. A., & Mahone, E. M. (2012). The Role of Neuropsychological Assessment in the Functional Outcomes of Children with ADHD. *Neuropsychology Review*, *22*(1), 54-68. https://doi.org/10.1007/s11065-011-9185-7

Rostamipour, M., Zareian, E., & Aslankhani, M. A. (2019). The Effect of Computerized Motor Interventions Using Xbox Kinect on Gross Motor Skills in Children with Motor Delay: Emphasis on Modern Exercises. *Motor and Behavioral Sciences*, *2*(1).

Sadeghi Ahouei, J., Haji Mousaei, M., & Banisi, V. (2025). The Effect of Neurofeedback on Improving Executive and Academic Functions in Children and Adolescents with Attention Deficit/Hyperactivity Disorder and Learning Disabilities: A Review Study. *Mental Health in School*, *3*(1), 21-27.

Salleg-Cabarcas, M. J., Robledo-Castro, C., & Monsalve-Vertel, C. P. (2024). Effect of Hit-Sport-Game Exercise Training on Self-Control and Regulation in Children With Attention Deficit Hyperactivity Disorder (ADHD). *Global Pediatric Health*, *11*, 2333794X241287095. https://doi.org/10.1177/2333794X241287095

Santamaría-Vázquez, E., Estudillo-Guerra, A., Ali, L., Martinez, D., Hornero, R., & Morales-Quezada, L. (2025). Effects of a novel non-pharmacological intervention based on respiratory biofeedback, neurofeedback and median nerve stimulation to treat children with ADHD. *Frontiers in human neuroscience*, *19*(1), 1–10. https://doi.org/10.3389/fnhum.2025.1478501

Seilsapour, M., Hamounpeyma, E., & Pirkhaefi, A. (2015). Effectiveness of Neurofeedback Therapy in Reducing Hyperactivity and Attention-Deficit Symptoms among Elementary School Students in Varamin in 2014. *Student Research Committee, Mashhad University of Medical Sciences*, *18*(60).

Sterman, M. B., & Egner, T. (2006). Foundation and Practice of Neurofeedback for the Treatment of Epilepsy. *Applied Psychophysiology and Biofeedback*, *31*(1), 21-35. https://doi.org/10.1007/s10484-006-9002-x

Stevenson, J., Buitelaar, J., Cortese, S., Ferrin, M., Konofal, E., Lecendreux, M., & Sonuga-Barke, E. (2014). Research Review: The Role of Diet in the Treatment of Attention-Deficit/Hyperactivity Disorder—An Appraisal of the Evidence on Efficacy and Recommendations on the Design of Future Studies. *Journal of Child Psychology and Psychiatry*, *55*(5), 416-427. https://doi.org/10.1111/jcpp.12215

Treves, I., Bajwa, Z., Greene, K. D., Bloom, P. A., Kim, N., Wool, E., Goldberg, S. B., Whitfield-Gabrieli, S., & Auerbach, R. P. (2025). Consumer-Grade Neurofeedback with Mindfulness

E-ISSN: 3060-6713

Meditation: Meta-Analysis. *Journal of medical Internet research*, *27*, e68204. https://doi.org/10.2196/68204

Yu, C. L., Cheng, M. Y., An, X., Chueh, T. Y., Wu, J. H., Wang, K. P., & Hung, T. M. (2025). The Effect of EEG Neurofeedback Training on Sport Performance: A Systematic Review and Meta-Analysis. *Scandinavian Journal of Medicine & Science in Sports*, *35*(5), e70055. https://doi.org/10.1111/sms.70055

Zhang, R., Zhang, Y., & Wang, J. (2025). Real-time fMRI neurofeedback for depression and anxiety: A systematic review. *Translational psychiatry*, *15*(3), 123. https://doi.org/10.1038/s41398-025-03123-4

Zhong, X., Yuan, X., & Dai, Y. (2025). Neurofeedback training for executive function in ADHD children: A systematic review and meta-analysis. *Scientific reports*, *15*, 28148. https://doi.org/10.1038/s41598-025-94242-4

E-ISSN: 3060-6713