

Comparative Effectiveness of Neurofeedback and Cognitive Behavioral Therapy on Inattention, Anxiety, and Hyperactivity in Children With Attention-Deficit/Hyperactivity Disorder

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ABSTRACT

This study aimed to compare the effectiveness of neurofeedback and cognitive behavioral therapy (CBT) in reducing inattention, anxiety, and hyperactivity among children with attention-deficit/hyperactivity disorder (ADHD). This quasi-experimental study employed a three-group pretest–posttest–follow-up design with a no-treatment control group. Sixty children aged 7–12 years with DSM-5-confirmed ADHD in Karaj, Iran, were purposively recruited and randomly assigned to neurofeedback, CBT, or control groups ($n = 20$ each). Neurofeedback consisted of 20 twice-weekly 40-minute sessions, whereas CBT consisted of nine weekly 45–60-minute sessions. Inattention, hyperactivity, and anxiety were assessed using the Integrated Visual and Auditory Continuous Performance Test, Conners Parent Rating Scale, and Spence Children's Anxiety Scale, respectively. Data were analyzed using mixed repeated-measures analysis of variance and Bonferroni-adjusted pairwise comparisons in SPSS 26. Significant time-by-group interactions were observed for inattention, $F(4, 114) = 357.89$, $p < .001$, partial $\eta^2 = .926$; hyperactivity, $F(4, 114) = 498.74$, $p < .001$, partial $\eta^2 = .946$; and anxiety, $F(3.56, 101.65) = 677.19$, $p < .001$, partial $\eta^2 = .960$. Neurofeedback significantly outperformed CBT for inattention at posttest (mean difference = -1.40 , $p = .006$) and follow-up (-1.50 , $p < .001$), and for hyperactivity at posttest (-1.50 , $p = .006$) and follow-up (-1.35 , $p \approx .028$). Both interventions significantly outperformed the control condition. Although CBT produced lower anxiety scores than neurofeedback, between-treatment differences were not significant at posttest ($p = .080$) or follow-up ($p = .090$). Both neurofeedback and CBT appear effective in producing sustained improvements in inattention, hyperactivity, and anxiety among children with ADHD. Neurofeedback demonstrated a comparative advantage for core attentional and hyperactivity symptoms, whereas the two interventions showed comparable effectiveness for anxiety reduction. These findings support symptom-oriented treatment selection while emphasizing the need for larger and methodologically rigorous comparative trials.

Keywords: Attention-deficit/hyperactivity disorder; neurofeedback; cognitive behavioral therapy; inattention; hyperactivity; anxiety; children.

1. Introduction

Attention-deficit/hyperactivity disorder (ADHD) is one of the most prevalent neurodevelopmental disorders of childhood and is characterized by persistent patterns of inattention, hyperactivity, and impulsivity that interfere with academic performance, social functioning, behavioral regulation, and everyday adaptation. The manifestations of ADHD are heterogeneous, and affected children may present with varying combinations of attentional deficits, excessive motor activity, impulsive responding, emotional dysregulation, academic difficulties, and problems in peer and family relationships. These difficulties often extend beyond the core diagnostic symptoms and can influence broader developmental outcomes, particularly when the disorder is accompanied by anxiety, stress sensitivity, low self-confidence, learning problems, or impaired executive functioning. The consequences of ADHD are therefore not limited to classroom behavior or concentration; they may affect children's ability to organize tasks, regulate emotions, maintain motivation, and respond adaptively to environmental demands. Recent research has accordingly shifted toward examining interventions that address both core symptoms and associated functional difficulties. Physical activity, for example, has been investigated as a complementary strategy capable of influencing variables that are closely related to the behavioral characteristics of children with ADHD, highlighting the importance of multidimensional approaches to symptom management (Karimi Aliabad et al., 2024). The disorder can also place substantial psychological demands on families. Mothers of children with ADHD may experience elevated stress and reduced psychological well-being, and interventions aimed at enhancing parental coping, self-esteem, and psychological flexibility have consequently been examined as part of a broader family-centered approach (Kiani et al., 2025). These findings underscore that ADHD should be understood within a wider system of cognitive, behavioral, emotional, academic, and family functioning rather than as an isolated problem of attention or activity level.

Among the clinically important problems that may accompany ADHD, anxiety deserves particular attention. Children with ADHD frequently experience worry, tension, social discomfort, performance concerns, fear of failure, and heightened emotional reactivity, all of which may intensify functional impairment even when the core symptoms of ADHD are being addressed. Anxiety may also interact with inattention and hyperactivity in complex ways. Excessive

worry can reduce concentration, increase avoidance, disrupt sleep, and exacerbate irritability, while repeated experiences of academic failure, social criticism, or behavioral correction can themselves generate anxiety and negative self-evaluation. The presence of anxiety therefore complicates treatment planning because an intervention that reduces hyperactivity or improves attentional control may not necessarily address maladaptive cognitions, fear responses, or emotional distress. Conversely, an intervention that primarily targets anxiety may not sufficiently reduce neurocognitive or behavioral manifestations of ADHD. This issue has increased interest in treatments capable of influencing multiple domains simultaneously. Cognitive-behavioral approaches have a well-established theoretical basis for modifying maladaptive interpretations, avoidance patterns, physiological arousal, and ineffective coping strategies, and recent work has continued to demonstrate their usefulness across a range of emotional and behavioral problems. Cognitive-behavioral therapy (CBT) has been applied not only to conventional anxiety disorders but also to distress associated with tinnitus, hyperacusis, and misophonia, illustrating the adaptability of its core principles across conditions involving cognitive and emotional dysregulation (Aazh, 2025). Similarly, recent evidence suggests that interactive media-based CBT, particularly when combined with expressive approaches such as art and music therapy, may reduce generalized anxiety symptoms in vulnerable children (Xu et al., 2025). These developments support the broader proposition that CBT can be flexibly adapted to developmental level and symptom profile, making it potentially relevant for children with ADHD who also experience anxiety.

Cognitive-behavioral interventions are particularly relevant to ADHD because they focus on the reciprocal relationships among thoughts, emotions, physiological states, and behavior. In children, CBT commonly incorporates psychoeducation, identification of automatic thoughts, cognitive restructuring, relaxation, problem solving, behavioral activation, self-monitoring, assertiveness, and relapse-prevention strategies. These techniques may be useful for children with ADHD because the disorder is frequently associated with impulsive responding, poor planning, low frustration tolerance, negative self-appraisal, and difficulty regulating behavior under stress. CBT may help children create a deliberate pause between stimulus and response, recognize maladaptive interpretations, organize behavior more effectively, and develop coping strategies that generalize

across school, home, and social contexts. Earlier evidence has demonstrated that cognitive behavior-based play therapy can reduce anxiety and improve self-esteem in children with ADHD, suggesting that cognitive-behavioral principles can be successfully adapted to younger populations through developmentally appropriate methods (Hassani et al., 2013). More recent studies have also demonstrated the effectiveness of cognitive-behavioral play therapy in reducing social anxiety and improving emotional competencies in children with developmental vulnerabilities, reinforcing the relevance of structured cognitive-behavioral methods for children who require concrete, experiential, and engaging forms of intervention (Jalil-Abkenar, 2025). Beyond childhood populations, CBT has also been reported to reduce ADHD-related symptoms in adults with substance use disorder, indicating that cognitive-behavioral methods can target attentional and behavioral dysregulation across different clinical contexts (Nasiri & Abizadeh, 2025). Collectively, these findings suggest that CBT may be particularly valuable when emotional symptoms such as anxiety coexist with ADHD, although its comparative effect on core attentional and hyperactivity symptoms in children remains an important empirical question.

Alongside psychological treatments, neurofeedback has attracted considerable attention as a nonpharmacological intervention for ADHD. Neurofeedback is based on principles of operant conditioning and self-regulation, whereby individuals receive real-time information regarding aspects of their neural activity and are reinforced for producing patterns considered more adaptive. In EEG-based neurofeedback, protocols for ADHD often target abnormalities in frequency-band activity associated with attention, arousal, and behavioral control, such as excessive theta activity or insufficient beta and sensorimotor rhythm activity. Through repeated practice, children are encouraged to learn more stable patterns of neural regulation that may translate into improved sustained attention, reduced impulsivity, and better behavioral control. Recent clinical and review literature has continued to examine neurofeedback as a treatment for ADHD, particularly in school-age children. Neurofeedback has been reported to reduce ADHD symptoms in elementary students, supporting its potential as an intervention directed toward attentional and behavioral regulation (Shojaei, 2024). Review evidence has also suggested that neurofeedback may improve executive and academic functioning in children and adolescents with ADHD and learning disabilities, although

findings vary across protocols, outcome measures, and methodological quality (Sadeghi Ahouei et al., 2025). Network meta-analytic approaches have further attempted to compare different neurofeedback protocols for childhood ADHD, indicating that treatment effects may depend on the specific form of neurofeedback employed rather than representing a uniform effect across all protocols (Wu et al., 2024). Similar comparative evidence has highlighted heterogeneity in the relative efficacy of neurofeedback approaches for children with ADHD, reinforcing the need to identify the symptom domains for which particular protocols may be most beneficial (Zhang et al., 2024).

The potential relevance of neurofeedback extends beyond attentional control and hyperactivity. Neurofeedback has increasingly been examined for anxiety and emotional regulation, raising the possibility that its effects may encompass both cognitive and affective processes. EEG-based protocols such as sensory motor rhythm training and alpha-theta training have been compared in individuals with generalized anxiety disorder, suggesting that different neurofeedback configurations may influence anxiety through distinct patterns of arousal and neural regulation (Lotfinia et al., 2025). A systematic review of neurofeedback training protocols in sports has likewise shown growing interest in neurofeedback for performance enhancement, anxiety reduction, and emotional regulation, indicating that self-regulation of neural activity may have applications extending well beyond clinical ADHD treatment (Tosti et al., 2024). In psychiatric populations, EEG neurofeedback has also been investigated as an adjunct to pharmacotherapy for anxiety symptoms, with meta-analytic evidence indicating potential benefits while simultaneously emphasizing variability in protocol design and study quality (Li et al., 2024). These findings are important for ADHD research because they suggest that a neurofeedback protocol incorporating attention-related and relaxation-related components may plausibly influence both core ADHD symptoms and accompanying anxiety. Nevertheless, the extent to which such benefits compare with those produced by a structured psychological intervention remains uncertain, particularly when both treatments are administered to the same clinical population and evaluated using identical outcome measures.

Advances in real-time functional magnetic resonance imaging neurofeedback provide additional evidence that neural self-regulation may influence anxiety-related processes. Research targeting the insula has shown that real-time fMRI neurofeedback can reduce trait anxiety,

suggesting that individuals may learn to modulate neural systems involved in interoception and emotional salience (Kim et al., 2024). Similarly, multi-session neurofeedback targeting amygdala downregulation has been investigated in generalized anxiety disorder, with findings supporting the feasibility of training individuals to regulate brain regions centrally implicated in threat processing and anxiety (Nicholson et al., 2024). A recent systematic review of real-time fMRI neurofeedback for depression and anxiety has further demonstrated increasing interest in neurofeedback-based modulation of affective neural circuitry, while also emphasizing the importance of methodological rigor, target selection, and replication (Zhang et al., 2025). Although EEG neurofeedback used in children with ADHD differs technologically and mechanistically from fMRI-based neurofeedback, these converging findings strengthen the broader conceptual basis for neurofeedback as a method of training self-regulation in neural systems relevant to both cognition and emotion. For children with ADHD and anxiety symptoms, this dual potential is especially important because an intervention capable of improving attentional regulation while simultaneously reducing arousal could provide advantages over treatments that target only one domain.

Despite the growing literature on both CBT and neurofeedback, direct comparisons between these interventions remain limited, particularly in child populations with ADHD when inattention, hyperactivity, and anxiety are examined simultaneously. The two approaches are theoretically distinct. Neurofeedback primarily targets self-regulation of neural activity through repeated feedback and reinforcement, whereas CBT targets conscious cognitive appraisal, behavioral responses, coping strategies, and emotional regulation. Their differences may therefore lead to domain-specific treatment effects. Neurofeedback may be particularly advantageous for core ADHD symptoms such as inattention and hyperactivity because of its direct emphasis on attentional arousal, inhibitory control, and electrophysiological regulation. CBT, by contrast, may be especially effective for anxiety because it explicitly addresses dysfunctional thoughts, threat interpretations, physiological arousal, avoidance, and maladaptive coping. However, the boundaries between these effects are unlikely to be absolute. Neurofeedback protocols that include alpha or sensorimotor rhythm training may influence anxiety, while CBT may improve attentional and behavioral functioning by strengthening self-monitoring, problem solving, and deliberate responding. This overlap

makes direct comparative research particularly valuable. Moreover, studies of other structured psychological and neurobehavioral interventions have increasingly emphasized the importance of examining outcomes across multiple domains rather than assuming that improvement in one symptom cluster automatically generalizes to another. The heterogeneous nature of ADHD and its associated emotional difficulties further supports the need for comparative treatment studies capable of clarifying which intervention may be most appropriate for specific symptom profiles.

Another important consideration is the persistence of treatment effects. Improvements observed immediately after treatment may have limited clinical significance if they are not maintained after the intervention ends. Both CBT and neurofeedback are intended, at least theoretically, to produce learned self-regulation skills that continue beyond the treatment setting. CBT seeks to equip children with cognitive and behavioral strategies that can be independently applied to future stressors, while neurofeedback seeks to establish more stable patterns of neural regulation through repeated training. Follow-up assessment is therefore essential for determining whether treatment-related changes represent transient responses or more durable improvements. The current literature provides encouraging but still incomplete evidence regarding maintenance effects, and direct comparisons using pretest, posttest, and follow-up assessments remain comparatively uncommon. In addition, the use of multiple outcome measures is necessary because parent-reported hyperactivity, objective attentional performance, and child-reported anxiety represent different aspects of functioning that may respond differently to intervention. A design that integrates these domains can provide a more clinically informative picture of comparative effectiveness than studies relying on a single symptom measure.

Within this context, the present study addresses an important gap by directly comparing neurofeedback and CBT in children with ADHD using three clinically relevant outcomes— inattention, hyperactivity, and anxiety—across pretest, posttest, and three-month follow-up assessments. Such a comparison is valuable because it may clarify whether the two interventions produce broadly similar improvements or demonstrate different patterns of effectiveness across cognitive, behavioral, and emotional domains. The available evidence supports both approaches but also points to variability in treatment mechanisms, protocol characteristics, and outcome domains, making direct comparison necessary rather than assuming

equivalence. The inclusion of a control condition further permits assessment of whether observed changes exceed those associated with repeated measurement or the passage of time. In addition, evaluating maintenance at follow-up provides information about the durability of improvement and the potential clinical usefulness of both approaches. Given that ADHD treatment increasingly emphasizes individualized and multimodal decision-making, identifying relative strengths across interventions may help clinicians select treatments according to the child's dominant difficulties rather than treating ADHD as a uniform condition.

Accordingly, the aim of the present study was to compare the effectiveness of neurofeedback and cognitive behavioral therapy in reducing inattention, hyperactivity, and anxiety in children with attention-deficit/hyperactivity disorder and to determine whether treatment gains were maintained at three-month follow-up.

2. Methods and Materials

2.1. Study Design and Participants

This quasi-experimental study employed a three-group pretest–posttest–follow-up design to compare the effects of neurofeedback and cognitive behavioral therapy (CBT) on inattention, hyperactivity, and anxiety in children with attention-deficit/hyperactivity disorder (ADHD). The study population consisted of approximately 200 children aged 7–12 years with suspected or established ADHD who were referred from schools and counseling centers in Karaj, Iran, during the 1404–1405 Iranian academic year. Participants were initially identified through purposive sampling and subsequently underwent eligibility assessment. ADHD diagnosis was confirmed according to DSM-5 criteria by a child psychiatrist or clinical psychologist. Sixty eligible children were then assigned by simple random allocation to three equal groups: neurofeedback ($n = 20$), CBT ($n = 20$), and a no-treatment control group ($n = 20$). Assessments were conducted at three time points, including baseline before the interventions, immediately after completion of the intervention phase, and three months after the posttest. The inclusion criteria were being 7–12 years of age, having a confirmed ADHD diagnosis, obtaining scores above the study cutoffs on the Conners Parent Rating Scale and the Spence Children's Anxiety Scale, having received neither neurofeedback nor CBT during the preceding six months, having an estimated intelligence quotient of at least 80, having no severe psychiatric or neurological comorbidity

likely to interfere with participation, and obtaining written parental consent together with child assent. Exclusion criteria consisted of absence from more than three intervention sessions, a major medication change during the study period, inability to cooperate with the intervention procedures, severe irritability interfering with treatment participation, development of a relevant medical condition, and voluntary withdrawal. Baseline demographic characteristics indicated no statistically significant differences among the three groups in age, sex distribution, or school grade. The mean age was 8.70 years ($SD = 1.72$) in the neurofeedback group, 8.95 years ($SD = 1.70$) in the CBT group, and 8.70 years ($SD = 1.72$) in the control group, and each group included 10 girls and 10 boys. Parents received information about the study procedures and provided written informed consent, while children received age-appropriate explanations and provided assent. Participation was voluntary, confidentiality was emphasized, and participants were informed that they could withdraw at any stage without penalty.

2.2. Data Collection Tools

Inattention was assessed using the Integrated Visual and Auditory Continuous Performance Test (IVA-CPT), a computerized measure designed to evaluate attentional functioning and response control. The task presents more than 500 visual and auditory stimuli over approximately 20 minutes and is suitable for use with individuals beginning at approximately six years of age. The IVA-CPT generates indices related to sustained attention, response consistency, inhibitory control, and attentional performance across visual and auditory modalities. For the purposes of the present study, the inattention score reported in the source dissertation was used as the primary indicator of attentional impairment. Higher scores were interpreted as reflecting greater inattention or poorer attentional functioning. Because the measure is performance-based and computerized, it provided an objective complement to parent-reported measures of ADHD-related behavior and reduced exclusive reliance on subjective ratings.

Hyperactivity was measured using the 48-item Conners Parent Rating Scale employed in the source dissertation. This parent-report instrument evaluates the frequency and severity of behavioral manifestations commonly associated with ADHD, particularly hyperactivity and related disruptive or impulsive behaviors. Parents rated their child's behavior according to the response format specified by the

scale, with higher total or designated subscale scores indicating more pronounced ADHD-related behavioral difficulties. In the present study, the hyperactivity score designated in the dissertation was used as the outcome variable for analysis. The use of the parent form allowed assessment of the child's behavior across everyday contexts outside the treatment setting; however, because parental ratings can be influenced by expectations and awareness of treatment allocation, the hyperactivity findings were interpreted in conjunction with the computerized measure of attentional performance.

Anxiety was assessed using the child version of the Spence Children's Anxiety Scale (SCAS). The version reported in the dissertation consisted of 45 items scored from 0 to 3 and covered several major dimensions of childhood anxiety, including separation anxiety, social fears, obsessive-compulsive symptoms, panic and agoraphobic symptoms, generalized anxiety, and fears related to physical injury. Higher total scores represented greater anxiety symptom severity. The SCAS was used at baseline, posttest, and three-month follow-up to evaluate changes in anxiety over time. The original instrument has demonstrated a coherent multidimensional structure and satisfactory reliability for assessing anxiety symptoms in children, and the dissertation reported reliability coefficients ranging from .70 to .92 in previous studies. In the present study, the total anxiety score served as the principal anxiety outcome for evaluating treatment-related changes across the three study groups.

2.3. Interventions

The neurofeedback intervention consisted of 20 sessions delivered twice weekly, with each session lasting approximately 40 minutes. Training was administered using a four-channel eWave neurofeedback system with eLife software, and electrode placement followed the international 10–20 system. Participants sat in front of a computer and received real-time visual and auditory feedback contingent on the production of targeted electroencephalographic activity. During the first phase of treatment, corresponding approximately to sessions 1–10, the protocol focused on inhibiting theta activity in the 4–8 Hz range while reinforcing beta activity in the 16–20 Hz range at the Cz electrode site. During the subsequent phase, approximately sessions 10–20, theta inhibition was continued while sensorimotor rhythm activity in the 13–20 Hz range was reinforced at central or centroparietal locations, primarily Cz

and Pz. In addition, alpha activity in the 8–13 Hz range was reinforced at Pz throughout the intervention to support reduction of physiological arousal and anxiety regulation. Ear or mastoid reference electrodes were used, and reinforcement thresholds were adjusted dynamically during sessions to maintain participant engagement while ensuring that the task remained sufficiently challenging but achievable. The protocol was therefore structured to progress from beta-oriented attention training toward sensorimotor rhythm regulation while simultaneously incorporating alpha reinforcement for anxiety and arousal control.

The CBT intervention consisted of nine weekly sessions, each lasting approximately 45–60 minutes. The treatment was developmentally adapted for children and combined psychoeducation, cognitive techniques, behavioral strategies, coping skills, and relapse-prevention procedures. The first session focused on establishing therapeutic rapport, conducting initial assessment, providing psychoeducation about symptoms and the treatment process, and teaching relaxation skills. The second and third sessions emphasized identifying and recording automatic thoughts and increasing awareness of the relationship among thoughts, emotions, and behavior. The fourth and fifth sessions focused on evaluating maladaptive cognitions and irrational beliefs and replacing them with more realistic and adaptive interpretations. The sixth and seventh sessions addressed stress management, structured problem solving, assertiveness training, and activity scheduling to improve behavioral organization and coping. The eighth session was devoted to review, practice, and consolidation of previously acquired skills, whereas the ninth session focused on relapse prevention, maintenance planning, and strategies for applying therapeutic skills beyond the intervention period. Sessions included child-appropriate explanation, guided practice, worksheets, behavioral rehearsal, and between-session exercises. The control group received no therapeutic intervention from the research team during the active treatment period and participated only in the scheduled assessments at baseline, posttest, and follow-up.

2.4. Data Analysis

Statistical analyses were conducted using SPSS version 26. Descriptive statistics were first calculated for the three outcome variables across the neurofeedback, CBT, and control groups at pretest, posttest, and three-month follow-up. The principal inferential analysis was mixed repeated-

measures analysis of variance, which was used to examine the within-subject effect of time, the between-subject effect of group, and the time-by-group interaction for inattention, hyperactivity, and anxiety. When statistically significant effects were identified, Bonferroni-adjusted pairwise comparisons were performed to evaluate differences among groups at posttest and follow-up while controlling for inflation of Type I error due to multiple comparisons. Statistical significance was set at $p < .05$, and partial eta squared (partial η^2) was reported as the measure of effect size. Assumptions for repeated-measures analysis were also examined. Skewness and kurtosis values for the study variables were within ± 2 , supporting approximate normality. Mauchly's test indicated that the sphericity assumption was satisfied for inattention, $W = .961$, $p = .325$, and hyperactivity, $W = .923$, $p = .105$, but was violated for anxiety, $W = .879$, $p = .027$; therefore, the Greenhouse–Geisser correction was applied to the anxiety analyses, with $\epsilon = .892$. Box's M tests were statistically significant for inattention ($p = .005$), hyperactivity ($p = .001$), and anxiety ($p = .001$), indicating that equality of covariance matrices

was not fully supported, and Levene's tests were also significant for some outcomes at posttest or follow-up. Accordingly, the inferential results, particularly the very large observed effect sizes, were interpreted cautiously. The equal sample sizes across the three groups provided some robustness to violations of homogeneity assumptions but did not eliminate the methodological limitation.

3. Findings and Results

The study included 60 children with ADHD who were equally allocated to the neurofeedback, cognitive behavioral therapy (CBT), and control groups ($n = 20$ per group). The mean ages were 8.70 ($SD = 1.72$), 8.95 ($SD = 1.70$), and 8.70 ($SD = 1.72$) years in the neurofeedback, CBT, and control groups, respectively. Each group consisted of 10 girls and 10 boys. No statistically significant baseline differences were observed among the groups in age ($p = .101$), sex distribution ($p = .111$), or school grade ($p = .154$), indicating demographic comparability among the three groups before the interventions.

Table 1

Descriptive Statistics for Inattention, Hyperactivity, and Anxiety Across Measurement Occasions

Outcome	Group	Pretest M (SD)	Posttest M (SD)	Follow-up M (SD)
Inattention	Neurofeedback	26.30 (1.59)	18.75 (1.16)	18.45 (0.95)
	CBT	26.65 (1.95)	20.15 (1.22)	19.95 (1.23)
	Control	26.35 (1.66)	26.50 (1.63)	26.50 (1.63)
Hyperactivity	Neurofeedback	27.20 (1.73)	17.70 (1.03)	17.85 (1.22)
	CBT	27.50 (2.03)	19.20 (1.19)	19.20 (1.28)
	Control	27.25 (1.77)	27.35 (1.98)	27.10 (2.10)
Anxiety	Neurofeedback	58.00 (3.38)	44.30 (2.43)	44.75 (2.33)
	CBT	58.80 (3.90)	42.30 (2.43)	42.80 (2.26)
	Control	58.00 (3.38)	58.25 (3.37)	58.30 (3.52)

As shown in Table 1, the three groups had closely comparable pretest scores across all outcome variables. Inattention decreased in the neurofeedback group from 26.30 at pretest to 18.75 at posttest and 18.45 at follow-up, while the corresponding scores in the CBT group decreased from 26.65 to 20.15 and 19.95. Hyperactivity also declined substantially in both intervention groups, from 27.20 to 17.70 and 17.85 in the neurofeedback group and from 27.50 to 19.20 at both posttest and follow-up in the CBT group.

Anxiety decreased from 58.00 to 44.30 and 44.75 following neurofeedback and from 58.80 to 42.30 and 42.80 following CBT. In contrast, the control group demonstrated minimal changes across the three assessment occasions for inattention, hyperactivity, and anxiety. The relatively small differences between posttest and follow-up scores in both active treatment groups further indicated that the observed improvements were largely maintained over the three-month follow-up period.

Table 2*Mixed Repeated-Measures Analysis of Variance for Study Outcomes*

Outcome	Effect	df	F	p	Partial η^2
Inattention	Time	2, 114	1322.14	< .001	.959
	Time $\times$ Group	4, 114	357.89	< .001	.926
	Group	2, 57	79.01	< .001	.735
Hyperactivity	Time	2, 114	1985.51	< .001	.972
	Time $\times$ Group	4, 114	498.74	< .001	.946
	Group	2, 57	93.01	< .001	.765
Anxiety	Time (GG)	1.78, 101.65	2163.32	< .001	.978
	Time $\times$ Group (GG)	3.56, 101.65	677.19	< .001	.960
	Group	2, 57	71.32	< .001	.714

The mixed repeated-measures analysis of variance revealed statistically significant main effects of time, group, and time $\times$ group interactions for all three outcomes. For inattention, the effect of time was significant, $F(2, 114) = 1322.14$, $p < .001$, partial $\eta^2 = .959$, as was the group effect, $F(2, 57) = 79.01$, $p < .001$, partial $\eta^2 = .735$. More importantly, the time $\times$ group interaction was significant, $F(4, 114) = 357.89$, $p < .001$, partial $\eta^2 = .926$, demonstrating that changes in inattention over time differed substantially among the groups. A similar pattern emerged for hyperactivity, with significant effects of time, $F(2, 114) = 1985.51$, $p < .001$, partial $\eta^2 = .972$; group, $F(2, 57) = 93.01$,

$p < .001$, partial $\eta^2 = .765$; and time $\times$ group, $F(4, 114) = 498.74$, $p < .001$, partial $\eta^2 = .946$. For anxiety, Greenhouse–Geisser-corrected results also demonstrated significant effects of time, $F(1.78, 101.65) = 2163.32$, $p < .001$, partial $\eta^2 = .978$, and time $\times$ group, $F(3.56, 101.65) = 677.19$, $p < .001$, partial $\eta^2 = .960$, together with a significant between-group effect, $F(2, 57) = 71.32$, $p < .001$, partial $\eta^2 = .714$. Thus, the significant and large interaction effects indicated that symptom trajectories differed strongly across the three conditions, with substantial reductions occurring in the intervention groups while scores in the control group remained relatively stable.

Table 3*Bonferroni-Adjusted Post-Hoc Comparisons at Posttest and Follow-up*

Outcome / Time	Comparison (I – J)	Mean Difference	SE	p
Inattention / Posttest	Neurofeedback – CBT	–1.40	.380	.006
	Neurofeedback – Control	–7.75	—	< .001
	CBT – Control	–6.35	—	.001
Inattention / Follow-up	Neurofeedback – CBT	–1.50	.347	< .001
	Neurofeedback – Control	–8.05	—	.001
	CBT – Control	–6.55	—	.001
Hyperactivity / Posttest	Neurofeedback – CBT	–1.50	.463	.006
Hyperactivity / Follow-up	Neurofeedback – CBT	–1.35	.502	$\approx .028$
Anxiety / Posttest	Neurofeedback – CBT	2.00	.879	.080
	Neurofeedback – Control	–13.95	—	< .001
	CBT – Control	–15.95	—	.001
Anxiety / Follow-up	Neurofeedback – CBT	1.95	.876	.090
	Neurofeedback – Control	–13.55	—	.001
	CBT – Control	–15.50	—	.001

Bonferroni-adjusted post-hoc comparisons showed that neurofeedback produced significantly lower inattention scores than CBT at both posttest (mean difference = –1.40, SE = .380, $p = .006$) and three-month follow-up (mean difference = –1.50, SE = .347, $p < .001$). Both neurofeedback and CBT were also significantly superior to the control condition for inattention at posttest and follow-

up (all $p \leq .001$). For hyperactivity, neurofeedback resulted in significantly lower scores than CBT at posttest (mean difference = –1.50, SE = .463, $p = .006$) and follow-up (mean difference = –1.35, SE = .502, $p \approx .028$), indicating a comparative advantage of neurofeedback for this outcome. In contrast, although CBT participants had approximately two points lower anxiety scores than neurofeedback

participants, the direct differences between the two active interventions were not statistically significant at either posttest (mean difference = 2.00, SE = .879, $p = .080$) or follow-up (mean difference = 1.95, SE = .876, $p = .090$). Nevertheless, both neurofeedback and CBT produced significantly lower anxiety scores than the control group at both assessment occasions (all $p \leq .001$). Overall, the post-hoc findings indicated that neurofeedback had a relative advantage over CBT for inattention and hyperactivity, whereas both interventions showed statistically comparable effects on anxiety.

4. Discussion

The present study compared the effectiveness of neurofeedback and cognitive behavioral therapy (CBT) in reducing inattention, hyperactivity, and anxiety among children with attention-deficit/hyperactivity disorder (ADHD) across pretest, posttest, and three-month follow-up assessments. The findings showed significant time-by-group interactions for all three outcomes, indicating that changes over time differed substantially across the neurofeedback, CBT, and control conditions. Both active interventions produced marked reductions in inattention, hyperactivity, and anxiety compared with the control group, and these improvements were maintained at follow-up. However, the magnitude and pattern of change differed between the two interventions. Neurofeedback produced significantly greater reductions than CBT in inattention at both posttest and follow-up and also yielded lower hyperactivity scores at both assessment points. In contrast, CBT produced numerically lower anxiety scores than neurofeedback, although the between-treatment differences were not statistically significant. Thus, the findings suggest that both interventions were effective, but neurofeedback demonstrated a relative advantage for core ADHD symptoms, whereas both interventions appeared similarly effective for anxiety.

The significant reduction in inattention following neurofeedback is consistent with the theoretical basis of neurofeedback and with previous studies indicating that repeated training in the regulation of electrophysiological activity can improve attentional functioning in children with ADHD. In the present study, neurofeedback initially emphasized theta inhibition and beta reinforcement and subsequently incorporated sensorimotor rhythm reinforcement, a structure intended to enhance attentional activation, sustained focus, and behavioral regulation. The

superior performance of neurofeedback compared with CBT for inattention may therefore reflect its more direct targeting of neurophysiological processes related to attentional control. This interpretation aligns with findings showing that neurofeedback can reduce ADHD symptoms in elementary school children and can be particularly useful for attentional regulation (Shojaei, 2024). It is also consistent with review evidence suggesting that neurofeedback may improve executive and academic functions among children and adolescents with ADHD and learning difficulties (Sadeghi Ahouei et al., 2025). Network meta-analytic findings have similarly indicated that neurofeedback interventions can produce meaningful improvements in childhood ADHD, although effectiveness may vary according to protocol characteristics and training targets (Wu et al., 2024; Zhang et al., 2024). The current findings therefore support the view that neurofeedback may be especially appropriate when inattentiveness constitutes a prominent area of impairment.

The observed advantage of neurofeedback for hyperactivity can also be interpreted in light of the intervention's emphasis on sensorimotor rhythm regulation and controlled arousal. Hyperactivity in ADHD is not simply excessive movement but is often associated with difficulty sustaining an optimal level of activation, inhibiting inappropriate responses, and maintaining calm engagement with a task. Reinforcement of sensorimotor rhythm activity is generally intended to support a state of behavioral stillness combined with attentional readiness, which may partly explain the greater reduction in hyperactivity in the neurofeedback group. The present findings are compatible with previous evidence that neurofeedback can reduce behavioral manifestations of ADHD and improve self-regulation (Shojaei, 2024). They are also in line with comparative neurofeedback studies showing that intervention effects differ across specific symptoms and protocol types rather than occurring uniformly across all domains (Wu et al., 2024). The findings can additionally be understood alongside broader evidence that interventions affecting regulation, activation, and executive control may alter behavioral characteristics associated with ADHD. For example, physical activity has been shown to influence several variables related to ADHD symptom expression, including aspects of behavioral and cognitive functioning (Karimi Aliabad et al., 2024). Although physical activity and neurofeedback operate through different mechanisms, both lines of evidence indicate that interventions capable of modifying regulatory processes can influence overt behavioral symptoms.

CBT also produced substantial reductions in inattention and hyperactivity compared with the control condition, even though its effects on these core symptoms were smaller than those observed with neurofeedback. This result is theoretically plausible because CBT does not directly modify EEG activity but instead develops cognitive and behavioral skills that may indirectly support attention and behavioral control. The protocol used in this study included recognition of automatic thoughts, cognitive restructuring, stress management, problem solving, assertiveness, activity scheduling, and relapse prevention. These procedures can increase awareness of internal states, encourage more deliberate responding, improve organization, and reduce impulsive reactions. Previous research has shown that cognitive-behavioral approaches can improve problems associated with ADHD. Cognitive behavior-based play therapy has been found to reduce anxiety and improve self-esteem in children with ADHD (Hassani et al., 2013), while CBT has also been reported to reduce ADHD symptoms in other clinical populations, including adults with substance use disorder (Nasiri & Abizadeh, 2025). Although the latter population differs from the children studied here, the findings support the broader capacity of cognitive-behavioral strategies to influence attentional and behavioral symptoms. Similarly, cognitive-behavioral play therapy has demonstrated benefits for social anxiety and emotional intelligence in children with developmental limitations, suggesting that structured cognitive-behavioral techniques can be adapted effectively to younger populations when presented in developmentally appropriate formats (Jalil-Abkenar, 2025).

The anxiety findings showed a somewhat different pattern. Both neurofeedback and CBT substantially reduced anxiety compared with the control group, and these improvements remained evident at the three-month follow-up. CBT participants had lower mean anxiety scores than neurofeedback participants at both posttest and follow-up; however, the direct differences between the two treatment groups were not statistically significant. The strong improvement following CBT is consistent with its therapeutic mechanisms. CBT directly targets threat-related cognitions, negative automatic thoughts, avoidance, physiological arousal, and ineffective coping, all of which are central processes in anxiety. The present protocol included relaxation, cognitive restructuring, stress management, and relapse prevention, which likely contributed to the observed reduction in anxiety. This pattern is consistent with earlier evidence showing that cognitive

behavior-based play therapy can reduce anxiety among children with ADHD (Hassani et al., 2013). It also corresponds with more recent evidence supporting the usefulness of CBT-based interventions for anxiety and emotional distress across different populations (Aazh, 2025). Furthermore, research combining interactive media-based CBT with art and music therapies has reported reductions in generalized anxiety among vulnerable children, reinforcing the usefulness of structured cognitive-behavioral strategies for childhood anxiety (Xu et al., 2025). These converging findings support the interpretation that CBT is particularly well suited to addressing anxiety symptoms even when anxiety occurs alongside another primary condition such as ADHD.

At the same time, the substantial reduction in anxiety after neurofeedback is also consistent with a growing body of research suggesting that neurofeedback can influence emotional regulation and physiological arousal in addition to attention. In the present study, alpha reinforcement was incorporated throughout treatment to support anxiety regulation, while sensorimotor rhythm training may also have promoted calmer behavioral states. The anxiety findings are therefore compatible with evidence from EEG-based neurofeedback studies showing that neurofeedback protocols can reduce anxiety symptoms. A clinical trial comparing sensory motor rhythm and alpha-theta neurofeedback protocols for generalized anxiety disorder demonstrated that EEG-based training can meaningfully influence anxiety outcomes (Lotfinia et al., 2025). Similarly, a systematic review of neurofeedback training in sport has shown that neurofeedback has increasingly been used not only to enhance performance but also to reduce anxiety and improve emotional regulation (Tosti et al., 2024). Meta-analytic evidence has further indicated that EEG neurofeedback can be beneficial as an adjunctive intervention for anxiety symptoms in psychiatric populations (Li et al., 2024). Although these studies involve populations different from children with ADHD, they provide convergent support for the proposition that neurofeedback may influence neural and physiological mechanisms underlying anxiety.

Evidence from real-time functional magnetic resonance imaging neurofeedback also provides a broader neurobiological framework for understanding the anxiety reduction observed in the present study. Real-time fMRI neurofeedback targeting the insula has been shown to reduce trait anxiety, indicating that individuals can learn to regulate brain systems associated with interoception, salience

detection, and emotional arousal (Kim et al., 2024). Similarly, multi-session neurofeedback aimed at downregulating amygdala activity has demonstrated effects in generalized anxiety disorder, supporting the possibility that learned neural self-regulation can modify anxiety-related processing (Nicholson et al., 2024). A recent systematic review of real-time fMRI neurofeedback for depression and anxiety has also concluded that neurofeedback represents a promising approach to emotional regulation, although methodological heterogeneity and the need for replication remain important concerns (Zhang et al., 2025). The EEG protocol employed in the current study is methodologically different from fMRI neurofeedback, but the conceptual principle is similar: repeated feedback may help individuals acquire greater control over neural states associated with arousal and regulation. This may explain why neurofeedback reduced anxiety to a degree statistically comparable with CBT despite CBT's more direct psychological focus on anxious thoughts and coping.

The maintenance of improvements at three-month follow-up is another important finding. Both neurofeedback and CBT are intended to generate learned regulatory skills rather than only immediate symptom suppression. In CBT, children practice cognitive restructuring, relaxation, problem solving, and self-monitoring strategies that can continue to be applied after formal treatment ends. In neurofeedback, repeated reinforcement is intended to strengthen learned patterns of neural self-regulation that may subsequently generalize beyond the training environment. The stability of posttest gains at follow-up therefore supports the possibility that both treatments produced effects that extended beyond the active intervention period. This finding is clinically relevant because persistent benefit is particularly important in ADHD, a condition characterized by continuing difficulties rather than brief episodic symptoms. The broader behavioral and emotional environment surrounding the child may also contribute to the persistence of gains. Research involving parents of children with ADHD has shown that psychological interventions targeting parental stress and self-esteem can improve family-related outcomes (Kiani et al., 2025), suggesting that treatment durability may ultimately depend on both child-level and family-level processes. Although the present study did not directly intervene with parents, the findings reinforce the value of viewing ADHD management as an ongoing self-regulatory and environmental process.

5. Conclusion

Taken together, the results support a differentiated rather than uniform interpretation of treatment effectiveness. Neurofeedback appeared particularly effective for inattention and hyperactivity, while CBT produced substantial improvement across all domains and showed a descriptive, though nonsignificant, advantage for anxiety. This pattern is consistent with the distinct mechanisms emphasized by each intervention. Neurofeedback may exert stronger effects on attentional activation, inhibitory control, and physiological self-regulation, whereas CBT may be more directly suited to maladaptive cognitions, anxiety, coping, and behavioral organization. At the same time, the overlap in outcomes indicates that these interventions should not be viewed as affecting entirely separate systems. Neurofeedback influenced anxiety, and CBT influenced core ADHD symptoms. Such overlap supports a multimodal conceptualization in which cognitive, behavioral, emotional, and neural processes interact. The findings are therefore compatible with the growing literature showing that therapeutic outcomes in ADHD and anxiety depend not only on the diagnostic category but also on the specific symptom domain, intervention protocol, and mechanisms targeted by treatment (Wu et al., 2024; Zhang et al., 2024; Zhang et al., 2025).

Several limitations should be considered when interpreting the findings. The sample consisted of only 60 children recruited purposively from one geographic area, which limits the generalizability of the results to broader populations of children with ADHD. Although participants were allocated equally across groups, the sample size was relatively small for estimating comparative treatment effects with high precision. The control group received no active intervention, and therefore nonspecific effects such as therapist attention, treatment expectations, computer exposure, and perceived novelty were not controlled. The neurofeedback and CBT interventions also differed substantially in treatment dose, with 20 neurofeedback sessions compared with nine CBT sessions, making it difficult to determine whether the stronger effect of neurofeedback on some outcomes resulted from treatment content, treatment intensity, or both. In addition, parents and participants were not blinded to treatment allocation, and hyperactivity was assessed through parent report, which may have introduced expectancy effects. Some statistical assumptions of the repeated-measures analysis were not fully satisfied, particularly equality of covariance matrices

and homogeneity of variance for some outcomes, and the very large effect sizes should therefore be interpreted cautiously. Finally, the follow-up period was limited to three months, and longer-term persistence of treatment gains could not be established.

Future studies should replicate these findings using larger, multisite samples and probability-based or broader recruitment strategies to improve representativeness. Randomized controlled trials with concealed allocation and blinded outcome assessment, where feasible, would strengthen causal inference. Active control conditions should be incorporated to account for therapist contact, expectancy, and treatment credibility. Future studies should also equalize the number and duration of neurofeedback and CBT sessions so that differences in treatment dose do not confound direct comparisons. Longer follow-up periods of six months, one year, or more would provide a clearer understanding of the durability of treatment effects. Researchers should include teacher ratings, objective executive-function tasks, behavioral observations, and physiological or EEG indices alongside parent and child reports. Session-by-session measures of neurofeedback learning could clarify whether actual electrophysiological change mediates clinical improvement, while mediation analyses in CBT could examine the roles of cognitive restructuring, coping skills, and emotional regulation. Comparative studies could also include combined neurofeedback-plus-CBT conditions to determine whether integrating neural and cognitive-behavioral self-regulation produces additive or synergistic benefits.

In clinical practice, intervention selection should be based on the child's dominant symptom profile, functional difficulties, family circumstances, treatment accessibility, and capacity to participate consistently. Neurofeedback may be considered particularly when severe inattention and hyperactivity are prominent and when access to trained providers and appropriate equipment is available. CBT may be especially useful when anxiety, negative thinking, emotional dysregulation, avoidance, or poor coping are clinically important alongside ADHD symptoms. Because both interventions improved all three outcomes in the present study, clinicians may consider them complementary rather than mutually exclusive approaches. Treatment planning should also involve regular monitoring of symptom change across home, school, and clinical settings and should include parents and teachers whenever appropriate. For children with mixed attentional, behavioral, and emotional difficulties, an integrated approach combining

neurofeedback with structured cognitive-behavioral strategies may be particularly promising, provided that treatment burden, cost, developmental appropriateness, and family preferences are carefully considered.

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

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Ethical Considerations

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

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