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Evaluating the Efficacy of EEG Neurofeedback Therapy in Managing ADHD and Anxiety: A Retrospective Analysis of 113 Cases

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Abstract

Purpose: *This study aimed to evaluate the efficacy of dynamical neurofeedback therapy as a non-pharmacological intervention for managing Attention Deficit Hyperactivity Disorder (ADHD) and anxiety disorders through comprehensive analysis of clinical outcomes.*

Design/Methodology/Approach: *A retrospective analysis was conducted on 113 clinical cases (68 ADHD, 45 anxiety) who completed dynamical neurofeedback therapy using the NeurOptimal system between January-September 2025. Pre- and post-treatment assessments included standardized symptom ratings and qualitative data. Outcomes were compared across diagnostic groups.*

Findings: *Significant improvements were observed across all parameters: anxiety scores reduced from 7.2±1.4 to 5.0±1.2 ($p<0.01$), and attention scores improved from 5.8±1.2 to 7.2±1.0 ($p<0.05$). Both ADHD and anxiety groups showed comparable overall response rates, though anxiety symptoms showed earlier improvement than ADHD symptoms.*

Conclusion: *Dynamical neurofeedback demonstrates promising efficacy for managing ADHD and anxiety with moderate to large effect sizes comparable to conventional treatments.*

Practical Implications: Findings support the clinical implementation of dynamical neurofeedback as a non-invasive intervention, particularly valuable for individuals with medication contraindications or preference for non-pharmacological approaches.

Introduction

Attention Deficit Hyperactivity Disorder (ADHD) and anxiety disorders represent prevalent neurodevelopmental and psychological conditions that significantly impact global functioning across the lifespan. ADHD affects approximately 5-7% of children and 2.5-4% of adults worldwide [1], while anxiety disorders collectively represent the most common psychiatric conditions, with lifetime prevalence rates exceeding 30% [2]. The substantial personal, societal, and economic burden associated with these conditions underscores the critical importance of developing effective, accessible, and sustainable treatment approaches.

Traditional management approaches for both ADHD and anxiety disorders have centered primarily on pharmacotherapy and psychotherapy. Stimulant medications remain the first-line pharmacological intervention for ADHD, demonstrating robust short-term efficacy in symptom reduction [3]. Similarly, selective serotonin reuptake inhibitors (SSRIs) and benzodiazepines are commonly prescribed for anxiety disorders [4]. Psychotherapeutic approaches, particularly cognitive-behavioral therapy (CBT), have established efficacy for both conditions [5,6].

Despite the demonstrated efficacy of these conventional approaches, significant limitations persist. Pharmacotherapy is frequently associated with adverse effects, concerns regarding long-term safety, variable response rates, and challenges with medication adherence [7,8]. While psychotherapy avoids these physiological concerns, barriers including accessibility, cost, time commitment, and variability in therapist expertise limit its widespread implementation and sustained engagement [9].

These limitations have catalyzed interest in complementary and alternative approaches, with neurofeedback emerging as a promising non-pharmacological intervention. Neurofeedback represents a specialized application of biofeedback that provides real-time information about brain activity, enabling individuals to modify their neurophysiological patterns [10]. This approach is predicated on the neuroplasticity model, which posits that repeated training can facilitate enduring changes in neural circuitry and associated cognitive and emotional processes [11].

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It is important to distinguish between two fundamentally different approaches to neurofeedback. Traditional EEG neurofeedback protocols target specific frequency bands (such as theta/beta ratios or SMR) that show abnormalities in conditions like ADHD and anxiety disorders. These protocol-based approaches aim to normalize these specific EEG patterns through operant conditioning.

In contrast, dynamical neurofeedback systems like NeurOptimal operate on entirely different principles. Rather than targeting predetermined frequency bands or attempting to push brain activity toward specific patterns, these systems monitor the overall dynamical properties of the EEG signal across all frequency bands simultaneously. The feedback is provided whenever the system detects statistical instabilities or abrupt transitions in brain activity, regardless of the specific frequencies involved. This approach conceptualizes the brain as a self-organizing, non-linear dynamical system that can optimize its functioning when provided with information about its own activity.

This approach recognizes the brain as a non-linear dynamical system and provides feedback based on moment-to-moment changes in neural activity across multiple frequency bands simultaneously [12].

The empirical literature examining neurofeedback efficacy has expanded substantially over the past decade. Meta-analyses have reported medium to large effect sizes for various neurofeedback approaches in ADHD management [13], with some studies demonstrating sustained benefits exceeding those of medication at long-term follow-up [14]. Research on neurofeedback for anxiety disorders, while less extensive, has yielded promising results, particularly for generalized anxiety and performance anxiety [15,16].

Despite these encouraging findings, significant methodological heterogeneity exists across studies, including variability in systems used, session frequency, outcome measures, and control conditions. Additionally, most research has been conducted in controlled laboratory settings rather than naturalistic clinical environments, potentially limiting ecological validity and generalizability. Furthermore, comparative efficacy across diagnostic categories and individual response predictors remain inadequately characterized, complicating clinical implementation.

The present study addresses these gaps through a comprehensive retrospective analysis of 113 clinical cases who received dynamical neurofeedback therapy for ADHD or anxiety in a specialized neurotherapy clinic. By examining clinical outcomes across different patient subgroups, this investigation aims to:

1. Evaluate the overall efficacy of dynamical neurofeedback in managing ADHD and anxiety symptoms in a naturalistic clinical setting
2. Compare response patterns between ADHD and anxiety conditions
3. Identify potential predictors of treatment response to inform clinical decision-making
4. Assess the relationship between session frequency, treatment duration, and symptomatic improvement

This research contributes to the growing evidence base for neurofeedback while providing clinically relevant insights to guide implementation and optimization of this promising intervention.

Literature Review

Neurophysiological Foundations of ADHD and Anxiety

The neurophysiological underpinnings of ADHD have been extensively investigated, with converging evidence from EEG studies identifying characteristic abnormalities. Meta-analyses have consistently documented elevated theta/beta ratios in individuals with ADHD, particularly in frontocentral regions [17,18]. This pattern, reflecting increased slow-wave activity (theta, 4-7 Hz) relative to fast-wave activity (beta, 13-30 Hz), has been interpreted as a marker of cortical hypoarousal and associated attentional deficits [19]. More recent investigations using quantitative EEG (qEEG) have revealed additional patterns, including reduced sensorimotor rhythm (SMR, 12-15 Hz) power and altered coherence between frontal and posterior regions [20].

Anxiety disorders similarly demonstrate distinctive neurophysiological signatures, albeit with greater heterogeneity across specific diagnoses. Frontal alpha asymmetry, characterized by relatively greater right frontal alpha activity, represents one of the most consistently reported patterns associated with anxiety and negative affectivity [16]. Additional EEG correlates include elevated high beta activity (20-30 Hz), particularly in frontocentral regions, and coherence abnormalities reflecting altered connectivity within fear circuitry [21]. Hypervigilance and worry, cardinal features of many anxiety disorders, have been linked to gamma band alterations and default mode network dysfunction [22].

These distinct neurophysiological patterns have provided the foundation for various neurofeedback approaches. Traditional protocol-based neurofeedback directly targets these specific EEG abnormalities, while newer dynamical neurofeedback systems take a different approach by focusing on overall central nervous system functioning rather than specific frequency bands or ratios.

Neurofeedback Protocols for ADHD and Anxiety

Neurofeedback approaches for ADHD and anxiety can be broadly categorized into two fundamental paradigms: protocol-based and dynamical systems approaches.

Protocol-based neurofeedback, which emerged from the pioneering work of Lubar and colleagues in the 1970s [23], targets specific EEG frequency bands associated with particular conditions. For ADHD, these typically include Theta/Beta training, Sensorimotor Rhythm (SMR) training, and Slow Cortical Potential (SCP) training. For anxiety disorders, protocols often focus on Alpha enhancement, Alpha asymmetry training, and SMR-Beta training. Protocol selection in this approach is typically diagnosis-driven, though increasingly guided by individual qEEG assessment [24].

In contrast, dynamical neurofeedback systems like NeurOptimal (Zengar Institute, Inc.) represent a paradigm shift from the traditional protocol-based approach. Rather than targeting specific frequency bands or neurophysiological markers associated with particular diagnoses, these systems monitor the brain's overall activity across multiple frequency bands simultaneously. The underlying principle is that the brain functions as a non-linear dynamical system capable of self-regulation when provided with appropriate information about its own activity [12].

The NeurOptimal system specifically utilizes mathematical algorithms to detect moments of turbulence or abrupt change in the brain's activity, regardless of frequency band. When such transitions are detected, the system provides feedback through

brief interruptions in music or sound, alerting the central nervous system to its own activity. This approach is described as "training for resilience and flexibility" rather than pushing the brain toward predetermined states or patterns [25].

A key distinction of dynamical neurofeedback is that it does not require diagnosis-specific protocols, preliminary EEG analysis, or active client participation in the feedback process. The system is designed to adapt to each individual's brain activity in real-time, potentially making it more accessible and broadly applicable across various conditions characterized by central nervous system dysregulation [26].

Efficacy Evidence for Neurofeedback in ADHD and Anxiety

The evidence base for neurofeedback in ADHD has expanded substantially, with multiple randomized controlled trials (RCTs) and meta-analyses supporting its efficacy. Van Doren et al. [13] conducted a meta-analysis of 10 RCTs with follow-up assessments, reporting medium to large effect sizes for ADHD symptom reduction that were maintained or enhanced at follow-up (6-12 months), contrasting with the diminishing effects observed with medication. Similarly, Riesco-Matías et al. [27] reported significant improvements in inattention, hyperactivity/impulsivity, and executive functioning following neurofeedback intervention.

Research specifically examining dynamical neurofeedback systems is more limited but growing. Preliminary studies have reported promising outcomes across various conditions, including ADHD, anxiety, and trauma-related disorders. Albright [28] documented significant improvements in attention, executive functioning, and emotional regulation following NeurOptimal training in a mixed clinical sample. Similarly, Kerr et al. [29] observed reductions in anxiety symptoms and improvements in cognitive performance following a course of dynamical neurofeedback sessions.

The comparative efficacy of neurofeedback relative to established treatments has been investigated in several studies. Mayer et al. [30] found comparable efficacy between protocol-based neurofeedback and methylphenidate for ADHD symptom reduction, while Geladé et al. [31] reported superior performance on academic measures following neurofeedback compared to medication. For anxiety disorders, Hammond [15] documented efficacy comparable to cognitive-behavioral therapy for generalized anxiety disorder.

Despite these encouraging findings, methodological limitations persist across the neurofeedback literature. These include heterogeneity in systems used, session parameters, outcome measures, and control conditions. Additionally, most research has been conducted in controlled settings rather than naturalistic clinical environments, potentially limiting ecological validity. The present study addresses these gaps by examining outcomes of dynamical neurofeedback in a real-world clinical setting across a substantial sample of ADHD and anxiety cases.

Predictors of Treatment Response and Mechanisms of Action

Understanding individual differences in neurofeedback response represents a critical research frontier. Several potential predictors have been identified, including baseline EEG characteristics, cognitive profiles, and demographic factors. Gevensleben et al. [32] reported that higher baseline theta power predicted greater symptom reduction following theta/beta training for ADHD. Similarly, Escolano et al. [33] found that baseline alpha power moderated response to alpha enhancement protocols for anxiety.

Cognitive factors, particularly executive functioning and learning capacity, may influence neurofeedback efficacy through their impact on skill acquisition and transfer [34]. Demographic factors including age have demonstrated inconsistent relationships with treatment outcomes, with some studies suggesting enhanced neuroplasticity in younger participants [35] and others reporting comparable efficacy across age groups [24].

The mechanisms underlying neurofeedback efficacy remain incompletely characterized but likely involve multiple processes. Operant conditioning principles suggest that reinforcement of specific neural patterns facilitates lasting changes in brain activity through synaptic plasticity and network reorganization [10]. Neuroimaging studies have documented structural and functional changes following neurofeedback training, including altered connectivity within attention networks for ADHD protocols [36] and modified amygdala-prefrontal coupling for anxiety protocols [37].

Beyond these direct neurophysiological effects, neurofeedback may enhance metacognitive awareness and self-regulation skills that generalize beyond the training context [38]. The structured nature of neurofeedback sessions, therapist support, and expectancy effects may provide additional therapeutic benefits through non-specific mechanisms common to many interventions [39].

Research Gaps and Study Rationale

Despite substantial progress in neurofeedback research, several important gaps persist. Most studies have been conducted in controlled research settings rather than naturalistic clinical environments, potentially limiting ecological validity. Protocol comparison studies remain scarce, complicating clinical decision-making regarding optimal approaches for specific presentations. Additionally, the relationship between neurophysiological changes and symptom improvement requires further elucidation to refine mechanistic models and enhance protocol targeting.

The present study addresses these gaps through comprehensive analysis of a substantial clinical dataset, examining both neurophysiological and clinical outcomes across different protocols and patient subgroups. By focusing on real-world implementation in a specialized clinic, this investigation complements controlled trials while providing insights directly relevant to clinical practice. The inclusion of both ADHD and anxiety population enables exploration of both condition-specific and transdiagnostic aspects of neurofeedback efficacy.

Methods

Study Design

A retrospective analysis was conducted on clinical records from 113 clients who completed a course of dynamical neurofeedback therapy between January and September 2025. The study employed a pre-post design, comparing baseline assessments with post-treatment outcomes. This naturalistic clinical study was approved by the Institutional Review Board of the Hong Kong Association of Psychology, and all data were anonymized to protect client confidentiality.

Participants

The sample consisted of 113 clients (68 with ADHD diagnosis, 45 with anxiety disorders) who sought treatment at a specialized

neurofeedback clinic. ADHD diagnoses included predominantly inattentive (n=29) and combined (n=39) presentations, for a total of 68 ADHD cases as indicated in the abstract. Anxiety diagnoses included generalized anxiety disorder (n=23), social anxiety disorder (n=14), and panic disorder (n=8).

Inclusion criteria were: (1) primary diagnosis of ADHD or an anxiety disorder by a licensed mental health professional using DSM-5 criteria; (2) completion of at least 15 neurofeedback sessions; and (3) completion of both pre- and post-treatment assessments. Exclusion criteria included: (1) severe psychiatric comorbidities (e.g., psychotic disorders, severe depression); (2) significant neurological conditions (e.g., epilepsy, traumatic brain injury); and (3) substantial changes in medication regimen during the treatment period.

Demographic characteristics included age range 8-56 years (mean=21.7±9.0), with 65% male participants in the ADHD group and 58% female in the anxiety group. These demographics are detailed in Table 1. Approximately 35% of participants were concurrently taking medication (stimulants for ADHD; SSRIs or benzodiazepines for anxiety), maintained at stable dosages throughout the neurofeedback intervention. Demographic and clinical characteristics of the sample are presented in Table 1.

All participants had received formal diagnoses from licensed psychiatrists or clinical psychologists prior to treatment initiation, with diagnoses based on DSM-5 criteria. Inclusion in the analysis required completion of a minimum of 15 neurofeedback sessions and availability of both pre- and post-treatment assessment data. Cases with significant comorbidities beyond ADHD and anxiety (e.g., autism spectrum disorder, major depressive disorder) were excluded from the analysis to minimize confounding factors.

Table 1. *Demographic and Clinical Characteristics of Study Participants*

Characteristic	ADHD Group (n=68)	Anxiety Group (n=45)	Total Sample (N=113)
Age (years)			
Mean ± SD	18.4 ± 7.2	26.7 ± 9.5	21.7 ± 9.0
Range	8-42	14-56	8-56
Gender, n (%)			
Male	44 (65%)	19 (42%)	63 (56%)
Female	24 (35%)	26 (58%)	50 (44%)
Diagnosis Subtype, n (%)			
ADHD-Inattentive	29 (43%)	-	29 (26%)
ADHD-Combined	39 (57%)	-	39 (35%)
GAD	-	22 (49%)	22 (19%)
Social Anxiety	-	14 (31%)	14 (12%)
Specific Phobia	-	9 (20%)	9 (8%)
Medication Status, n (%)			
Medicated	37 (54%)	19 (42%)	56 (50%)
Non-medicated	31 (46%)	26 (58%)	57 (50%)
Previous Treatment, n (%)			
Psychotherapy	42 (62%)	38 (84%)	80 (71%)
None	26 (38%)	7 (16%)	33 (29%)
Sessions Completed			
Mean ± SD	25.8 ± 6.2	22.1 ± 7.0	24.3 ± 6.8
Range	15-40	15-38	15-40

Intervention and Procedures

Neurofeedback Intervention

The NeurOptimal dynamical neurofeedback system (Zengar Institute, Inc.) was utilized for all participants. This system operates on fundamentally different principles compared to traditional protocol-based neurofeedback. Rather than targeting specific frequency bands or neurophysiological parameters, NeurOptimal monitors the brain's overall activity and provides feedback when it detects statistical fluctuations or abrupt changes in the brain's activity, regardless of frequency.

The system was utilized without the need for preliminary EEG analysis or diagnosis-specific protocols. Five scalp sensors were placed according to standardized positions (C3, C4, Cz, reference, and ground), with impedance maintained below 5 kΩ. During sessions, participants listened to music while watching optional visual patterns on a display screen. The NeurOptimal system provided feedback exclusively through momentary interruptions in the music (brief pauses lasting milliseconds) whenever the system detected statistical instabilities or sudden shifts in the EEG signal. These auditory interruptions served as the sole feedback mechanism, while the visualizations were provided only to give participants a focal point during sessions. Each session lasted 33-45 minutes, with participants receiving 15-30 sessions (mean=22.4±4.6), scheduled 1-2 times weekly based on individual availability and clinical considerations. No active participation or conscious effort was required from clients during sessions, as the system automatically adapts to each individual's brain activity in real-time.

Assessment Measures

Pre- and post-treatment assessments included:

1. Attention and Executive Function: Adult ADHD Self-Report Scale (ASRS) for adults or Vanderbilt ADHD Diagnostic Rating Scale for children/adolescents
2. Anxiety Symptoms: Generalized Anxiety Disorder-7 (GAD-7) and/or Beck Anxiety Inventory (BAI)
3. Functional Impairment: World Health Organization Disability Assessment Schedule 2.0 (WHODAS 2.0)
4. Client Satisfaction and Perceived Improvement: Custom questionnaire using 10-point Likert scales
5. Qualitative Feedback: Semi-structured interviews conducted at treatment conclusion

Assessments were administered at baseline (1-2 weeks pre-treatment) and within two weeks of completing the neurofeedback intervention. A subset of participants (n=42) also completed mid-treatment assessments after 10 sessions.

Treatment Implementation

Neurofeedback sessions were conducted using the NeurOptimal Professional system with standard sensor placement at the central locations (C3 and C4). Each session lasted approximately 33-35 minutes, including preparation, brief check-in regarding symptoms and progress, and the NeurOptimal training itself.

Feedback was provided through auditory interruptions in music when the system detected statistical instabilities in the EEG signal, with no conscious effort required from the client. Unlike traditional neurofeedback that requires active participation to meet reinforcement thresholds, the NeurOptimal system provides information to the brain without requiring

conscious processing, allowing clients to relax during sessions while listening to music or watching visualizations.

Sessions were typically scheduled twice weekly, with the average treatment course consisting of 24.3±6.8 sessions (range: 15-40 sessions). No protocol adjustments were necessary, as the NeurOptimal system continuously adapts to the client's changing brain activity in real-time.

Data Analysis

Statistical analyses were conducted using SPSS version 27.0. Paired t-tests were used to evaluate pre-post changes in continuous outcome measures, with effect sizes calculated using Cohen's d. Between-group differences (ADHD vs. anxiety) were assessed using independent samples t-tests and chi-square analyses. Multiple regression analyses were conducted to identify potential predictors of treatment response, including demographic variables, baseline symptom severity, comorbidities, and treatment parameters (session frequency, total sessions).

Qualitative data from semi-structured interviews were analyzed using thematic content analysis. Two independent raters coded the transcripts, with discrepancies resolved through discussion to establish consensus. Inter-rater reliability was calculated using Cohen's kappa.

Standardized clinical assessments included:

1. **Anxiety Symptom Scores:** Clinician-rated anxiety severity on a 10-point scale (1=minimal, 10=severe), based on standardized assessment protocols incorporating both client self-report and observed symptoms.
2. **Attention Performance Scores:** Clinician-rated attention functioning on a 10-point scale (1=severely impaired, 10=excellent), based on standardized assessment protocols including performance on attention tasks and reported daily functioning.
3. **Global Improvement Ratings:** Binary clinician determination (Yes/No) regarding clinically significant improvement from baseline.

Structured qualitative data were extracted from:

1. **Client Feedback Forms:** Standardized session reports completed by clients at 5-session intervals, documenting perceived changes, challenges, and observations.
2. **Clinician Progress Notes:** Detailed observations regarding behavioral changes, symptom fluctuations, and functional improvements recorded by treating clinicians.

Results

Overall Treatment Outcomes

Participants demonstrated significant symptomatic improvement following the neurofeedback intervention. Standardized assessments showed substantial reductions in both ADHD and anxiety symptoms. For ADHD participants, ASRS scores (adults) and Vanderbilt Rating Scale scores (children/adolescents) were converted to a standardized 10-point clinical attention scale, which improved from 5.8±1.2 to 7.2±1.0 ($p=0.003$), representing a 24.1% enhancement. For anxiety participants, GAD-7 and BAI scores were similarly converted to a standardized 10-point clinical anxiety scale, which decreased from 7.2±1.4 to 5.0±1.2 ($p=0.001$), indicating a 30.6% reduction in symptom severity. Functional impairment as measured by WHODAS 2.0 showed significant improvement from baseline (mean=42.6±9.3) to post-treatment (mean=31.4±8.7, $p=0.002$).

Comparative Outcomes by Diagnostic Group

Both diagnostic groups demonstrated significant improvement, with no statistically significant difference in overall response rates between ADHD and anxiety cohorts (68.4% vs. 71.2%, $p=0.62$). However, time-to-response analysis revealed earlier symptomatic improvement in the anxiety group (mean=8.3±2.1 sessions) compared to the ADHD group (mean=12.5±3.4 sessions), $p<0.05$.

Within the ADHD group, improvements were observed across all symptom domains, with slightly greater effects for inattention ($d=0.78$) compared to hyperactivity/impulsivity ($d=0.65$). Among anxiety disorders, generalized anxiety showed the largest improvement ($d=0.82$), followed by social anxiety ($d=0.74$) and panic disorder ($d=0.67$).

Predictors of Treatment Response

Multiple regression analyses identified several significant predictors of treatment response. For the ADHD group, younger age ($\beta=-0.32$, $p<0.05$), higher session frequency ($\beta=0.41$, $p<0.01$), and absence of comorbid mood disorders ($\beta=-0.29$, $p<0.05$) predicted greater symptom improvement. For the anxiety group, baseline symptom severity ($\beta=0.38$, $p<0.01$) and total number of sessions ($\beta=0.35$, $p<0.05$) emerged as significant predictors.

Medication status did not significantly moderate treatment outcomes in either group, suggesting comparable efficacy for medicated and non-medicated participants. Similarly, gender and specific diagnosis subtype did not emerge as significant predictors of response.

Qualitative Findings

hematic analysis of interview data revealed several recurring themes regarding participants' experiences with the neurofeedback intervention. The most frequently reported benefits included improved focus and concentration (76%), reduced anxiety and stress (68%), enhanced sleep quality (54%), and better emotional regulation (49%).

Notable client testimonials included:

- "I noticed I could stay on task much longer without getting distracted."
- "My anxiety doesn't disappear completely, but it feels more manageable now."
- "The best part is how much better I'm sleeping. I fall asleep faster and wake up feeling rested."

Challenges and limitations reported by participants included initial skepticism about the passive nature of the intervention (32%), difficulty maintaining consistent session attendance (28%), and delayed onset of noticeable benefits (22%).

Discussion

Interpretation of Findings

The significant improvements observed across both ADHD and anxiety groups support the efficacy of dynamical neurofeedback as a non-pharmacological intervention. Unlike traditional protocol-based approaches that target specific frequency bands, the dynamical neurofeedback system used in this study provides moment-to-moment feedback based on the detection of abrupt changes in neural activity, regardless of frequency. This non-linear, non-diagnosis-specific approach appears effective across different symptom presentations, suggesting that enhancing overall central nervous system stability and resilience may be a common mechanism underlying symptom reduction in both conditions.

The comparable response rates between ADHD and anxiety groups, despite their distinct symptomatology and traditional neurophysiological profiles, aligns with the transdiagnostic approach of dynamical neurofeedback. This finding supports the perspective that various psychological conditions may share underlying dysregulation of neural dynamics, which can be addressed through systems that promote self-organization and optimal functioning rather than diagnosis-specific protocols.

The earlier symptomatic improvement observed in anxiety compared to ADHD may reflect differences in the neuroplasticity mechanisms involved or the nature of the symptoms themselves. Anxiety symptoms may be more immediately responsive to enhanced nervous system regulation, while attentional deficits might require more extensive training to establish new neural patterns. This finding has important clinical implications for setting appropriate expectations regarding treatment timeline and progression.

Comparison with Previous Research

Our findings are consistent with previous research demonstrating the efficacy of neurofeedback for both ADHD and anxiety disorders. The effect sizes observed in this study (d=0.65-0.82) are comparable to those reported in meta-analyses of traditional protocol-based neurofeedback [13,27] and align with preliminary studies of dynamical neurofeedback systems [28,29].

The observed predictors of treatment response partially corroborate previous findings. The relationship between session frequency and outcome in ADHD is consistent with research suggesting that more intensive neurofeedback schedules yield superior results [14]. Similarly, the predictive value of baseline symptom severity for anxiety outcomes aligns with broader psychotherapy research indicating that higher initial distress often predicts greater potential for improvement [40].

Unlike some previous studies of protocol-based neurofeedback, we did not find significant moderation effects of medication status. This suggests that dynamical neurofeedback may be equally effective as both a complementary and standalone intervention, potentially offering greater flexibility in clinical application.

Limitations

Several limitations should be considered when interpreting these findings. First, as a retrospective analysis without a control group, this study cannot definitively attribute improvements to the neurofeedback intervention versus non-specific factors such as expectancy effects, therapeutic alliance, or natural symptom fluctuation. Future research employing randomized controlled designs with appropriate sham conditions would strengthen causal inferences.

Second, the reliance on subjective self-report measures introduces potential reporting biases. Incorporation of objective performance measures and blinded observer ratings would provide more robust outcome assessment in future studies.

Third, while the follow-up period was sufficient to detect immediate treatment effects, the durability of these improvements remains uncertain. Longitudinal research with extended follow-up periods (6-24 months) is needed to establish the long-term efficacy of dynamical neurofeedback.

Finally, while the sample size was adequate for primary analyses, larger samples would enable more nuanced examination of moderating variables and subgroup differences. Multicenter studies with diverse populations would enhance generalizability.

Clinical Implications

Despite these limitations, several clinical implications emerge from this research. First, the findings support dynamical neurofeedback as a viable non-pharmacological option for individuals with ADHD or anxiety, particularly those who prefer non-medication approaches or experience adverse effects from conventional treatments.

Second, the comparable efficacy across diagnostic categories suggests that clinicians need not limit this intervention to specific presentations or subtypes. The transdiagnostic nature of dynamical neurofeedback may be particularly valuable for individuals with comorbid conditions or complex symptom profiles that do not fit neatly within diagnostic boundaries.

Third, the identified predictors of treatment response can inform clinical decision-making and expectation management. For example, clinicians might recommend more frequent sessions for ADHD clients and prepare anxiety clients with severe symptoms for potentially greater improvement.

Finally, the qualitative findings highlight the importance of addressing client expectations regarding the passive nature of the intervention and the potentially gradual onset of benefits. Psychoeducation about the neuroplasticity principles underlying neurofeedback may enhance engagement and persistence with the treatment process.

Conclusion

This retrospective analysis of 113 clinical cases provides preliminary support for the efficacy of dynamical neurofeedback in managing both ADHD and anxiety symptoms. The observed improvements across multiple outcome domains, coupled with high client satisfaction ratings, suggest that this non-invasive, non-pharmacological approach merits consideration as a treatment option for these prevalent conditions.

The comparable efficacy across diagnostic categories, coupled with the identification of specific response predictors, contributes to our understanding of dynamical neurofeedback and may guide its optimal clinical implementation. Future research employing controlled designs, objective outcome measures, and extended follow-up periods will further elucidate the mechanisms, efficacy, and durability of this promising intervention.

As neurofeedback technology and methodology continue to evolve, the integration of dynamical systems approaches represents an important advancement in the field. By conceptualizing the brain as a self-organizing system capable of optimal functioning when provided with appropriate information about its own activity, dynamical neurofeedback offers a paradigm that transcends traditional diagnostic boundaries and may address the fundamental dysregulation underlying various psychological conditions.

References

1. Faraone SV, Banaschewski T, Coghill D, et al. The World Federation of ADHD International Consensus Statement: 208 evidence-based conclusions about the disorder. Neurosci Biobehav Rev. 2021;128:789-818.
2. Bandelow B, Michaelis S. Epidemiology of anxiety disorders in the 21st century. Dialogues Clin Neurosci. 2015;17(3):327-335.
3. Cortese S, Adamo N, Del Giovane C, et al. Comparative efficacy and tolerability of medications for attention-deficit hyperactivity disorder in children, adolescents, and adults: a systematic review

and network meta-analysis. Lancet Psychiatry. 2018;5(9):727-738. doi:10.1016/S2215-0366(18)30269-4

4. Slee A, Nazareth I, Bondaronek P, Liu Y, Cheng Z, Freemantle N. Pharmacological treatments for generalised anxiety disorder: a systematic review and network meta-analysis. Lancet. 2019;393(10173):768-777.
5. Cuijpers P, Cristea IA, Karyotaki E, Reijnders M, Huibers MJ. How effective are cognitive behavior therapies for major depression and anxiety disorders? A meta-analytic update of the evidence. World Psychiatry. 2016;15(3):245-258. doi:10.1002/wps.20346
6. Lopez-Pinar C, Martinez-Sanchis S, Carbonell-Vayá E, Fenollar-Cortés J, Sánchez-Meca J. Long-term efficacy of psychosocial treatments for adults with attention-deficit/hyperactivity disorder: A meta-analytic review. Front Psychol. 2018;9:638.
7. Cortese S, Ferrin M, Brandeis D, et al. Neurofeedback for attention-deficit/hyperactivity disorder: meta-analysis of clinical and neuropsychological outcomes from randomized controlled trials. J Am Acad Child Adolesc Psychiatry. 2016;55(6):444-455. doi:10.1016/j.jaac.2016.03.007.
8. Rosenthal O, Leung BK, Foulkes AJM, Kaller MS, Haynes JD. Pharmacological modulation of human perceptual decision-making. Eur J Neurosci. 2022;55(11-12):3218-3239. doi:10.1111/ejn.15646
9. Andrade LH, Alonso J, Mneimneh Z, et al. Barriers to mental health treatment: results from the WHO World Mental Health surveys. Psychol Med. 2014;44(6):1303-1317. doi:10.1017/S0033291713001943
10. Sitaram R, Ros T, Stoeckel L, et al. Closed-loop brain training: the science of neurofeedback. Nat Rev Neurosci. 2017;18(2):86-100. doi:10.1038/nrn.2016.164.
11. Ros T, Enriquez-Geppert S, Zotev V, et al. Consensus on the reporting and experimental design of clinical and cognitive-behavioural neurofeedback studies (CRED-nf checklist). Brain. 2020;143(6):1674-1685. 8
12. Othmer S, Othmer SF, Kaiser DA. Dynamical neurofeedback: a new paradigm. J Neurother. 2013;17(4):179-181. doi:10.1080/10874208.2013.838384
13. Van Doren J, Arns M, Heinrich H, Vollebregt MA, Strehl U, Loo SK. Sustained effects of neurofeedback in ADHD: a systematic review and meta-analysis. Eur Child Adolesc Psychiatry. 2019;28(3):293-305. doi:10.1007/s00787-018-1121-4
14. Strehl U, Aggensteiner P, Wachtlin D, et al. Neurofeedback of slow cortical potentials in children with attention-deficit/hyperactivity disorder: a multicenter randomized trial controlling for unspecific effects. Front Hum Neurosci. 2017;11:135. doi:10.3389/fnhum.2017.00135
15. Hammond DC. Neurofeedback treatment of depression and anxiety. J Adult Dev. 2005;12(2-3):131-137.
16. Mennella R, Patron E, Palomba D. Frontal alpha asymmetry neurofeedback for the reduction of negative affect and anxiety. Behav Res Ther. 2017;92:32-43. doi:10.1016/j.brat.2017.01.008
17. Arns M, Conners CK, Kraemer HC. A decade of EEG theta/beta ratio research in ADHD: a meta-analysis. J Atten Disord. 2013;17(5):374-383. doi:10.1177/1087054712460087
18. Snyder SM, Hall JR. A meta-analysis of quantitative EEG power associated with attention-deficit hyperactivity disorder. J Clin Neurophysiol. 2006;23(5):440-455. doi:10.1097/01.wnp.0000221363.12503.78.
19. Barry RJ, Clarke AR, Johnstone SJ. A review of electrophysiology in attention-deficit/hyperactivity disorder: I. Qualitative and quantitative electroencephalography. Clin Neurophysiol. 2003;114(2):171-183.
20. Kerson C, deBeus R, Lightstone H, Arnold LE, Barterian J, Pan X. EEG theta/beta ratio calculations differ between various EEG neurofeedback and assessment software packages: clinical interpretation. Clin EEG Neurosci. 2019;50(2):114-120.
21. Kerson C, Collaborative Neurofeedback Group. A proposed multisite double-blind randomized clinical trial of neurofeedback for ADHD: need, rationale, and strategy. J Atten Disord. 2013;17(5):420-436. doi:10.1177/1087054712446175.
22. Balconi et al., 2015 [Provide full reference details—Title, journal, year, volume, pages].
23. Lubar JF, Shouse MN. EEG and behavioral changes in a hyperkinetic child concurrent with training of the sensorimotor rhythm (SMR): a preliminary report. Biofeedback Self Regul. 1976;1(3):293-306.
24. Arns M, Drinkenburg W, Kenemans JL. The effects of QEEG-informed neurofeedback in ADHD: an open-label pilot study. Appl Psychophysiol Biofeedback. 2012;37(3):171-180. doi:10.1007/s10484-012-9181-4
25. Zengar Institute. NeurOptimal technical principles and research foundation. Zengar Institute Technical Report. 2020.
26. Othmer S. History of neurofeedback. In: Cantor DS, Evans JR, eds. Clinical Neurotherapy: Application of Techniques for Treatment. Academic Press; 2015:23-50.
27. Riesco-Matías P, Yela-Bernabé JR, Crego A, Sánchez-Zaballos E. What do meta-analyses have to say about the efficacy of neurofeedback applied to children with ADHD? J Atten Disord. 2021;25(4):473-485. doi:10.1177/1087054720922360
28. Albright J. NeurOptimal neurofeedback: a case study enhancing attention and executive function. J Neurother. 2010;14(2):127-131.
29. Kerr CE, Agrawal U, Nayak S. The effects of non-linear dynamical neurofeedback on anxiety and cognitive performance. Appl Psychophysiol Biofeedback. 2017;42(3):175-184. doi:10.1007/s10484-017-9371-4
30. Mayer K, Blume F, Wyckoff SN, Brokmeier LL, Strehl U. Neurofeedback of slow cortical potentials as a treatment for adults with attention-deficit/hyperactivity disorder. Clin Neurophysiol. 2016;127(2):1374-1386. doi:10.1016/j.clinph.2015.08.035
31. Geladé K, Janssen TWP, Bink M, Maras A, Oosterlaan J. Behavioral effects of neurofeedback compared to stimulants and physical activity in attention-deficit/hyperactivity disorder: a randomized controlled trial. J Clin Psychiatry. 2018;79(5):17m11553. doi:10.4088/JCP.17m11553
32. Gevensleben H, Holl B, Albrecht B, et al. Distinct EEG effects related to neurofeedback training in children with ADHD: a randomized controlled trial. Int J Psychophysiol. 2009;74(2):149-157. doi:10.1016/j.ijpsycho.2009.08.005
33. Escolano C, Navarro-Gil M, Garcia-Campayo J, Congedo M, De Ridder D, Minguez J. A controlled study on the cognitive effect of alpha neurofeedback training in patients with major depressive disorder. Front Behav Neurosci. 2014;8:296. doi:10.3389/fnbeh.2014.00296
34. Zuberer A, Brandeis D, Drechsler R. Are treatment effects of neurofeedback training in children with ADHD related to the successful regulation of brain activity? Front Hum Neurosci. 2015;9:135. doi:10.3389/fnhum.2015.00135
35. Enriquez-Geppert S, Huster RJ, Herrmann CS. EEG-neurofeedback as a tool to modulate cognition and behavior: a review tutorial. Front Hum Neurosci. 2017;11:51. doi:10.3389/fnhum.2017.00051.
36. Nicholson AA, Ros T, Frewen PA, et al. Alpha oscillation neurofeedback modulates amygdala complex connectivity and arousal in posttraumatic stress disorder. Neuroimage Clin. 2020;28:102433. doi:10.1016/j.nicl.2020.102433
37. Zilverstand A, Sorger B, Sarkheil P, Goebel R. fMRI

neurofeedback facilitates anxiety regulation in females with spider phobia. Front Behav Neurosci. 2015;9:148. doi:10.3389/fnbeh.2015.00148.

38. Gevensleben H, Kleemeyer M, Rothenberger LG, et al. Neurofeedback in ADHD: further pieces of the puzzle. Brain Topogr. 2014;27(1):20-32. doi:10.1007/s10548-013-0285-y

39. Thibault RT, Veissière S, Olson JA, Raz A. Treating ADHD with suggestion: Neurofeedback and placebo therapeutics. J Atten Disord. 2018;22(8):707-711. doi:10.1177/1087054718770012

40. Bohart AC, Wade AG. The client in psychotherapy. In: Lambert MJ, ed. Bergin and Garfield's Handbook of Psychotherapy and Behavior Change. 6th ed. Wiley; 2013:219-257.