Clinic Outcome Assessment of a Brief Course Neurofeedback for Childhood ADHD Symptoms

Kate B. Nooner, PhD
Kirsten D. Leaberry, MA
Julian R. Keith, PhD
Richard L. Ogle, PhD

Neurofeedback (NFB) is a noninvasive neurocognitive intervention that relies on the principles of operant conditioning to retrain brainwave patterns associated with concentration, relaxation, and attention.1 When conducting NFB, electrodes are attached to the scalp and connected to a computer, which reads the brain waves. Brain waves in the desired range are reinforced (e.g., earning points), while brain waves outside of the range are punished (e.g., hearing beeping tone). Typical neurofeedback batteries for childhood attention deficit hyperactivity disorder (ADHD) symptoms involve 30–40 neurofeedback sessions, each lasting 30–60 min.2–4 NFB can help children with ADHD symptoms learn which brain waves are associated with focused attention and which are not.

NFB can involve teaching children to modify specific brainwaves associated with ADHD symptoms. Beta waves (13–30 Hz) are related to concentration and alertness, while alpha (8–12 Hz) and theta (4–8 Hz) waves are associated with relaxation.1,2 Additionally, theta waves are associated with daydreaming and lethargy.1,2 Some NFB treatments for ADHD symptoms utilize theta/beta training to increase beta wave activity to target concentration and decrease theta wave activity to target unfocused behavior.3,4 Other NFB treatments utilize sensorimotor rhythm (SMR) training (13–15 Hz), a brain wave rhythm associated with relaxation and attentiveness.2

NFB has received “Level 1 Best Support” as an evidence-based treatment for childhood ADHD according to the American Academy of Pediatrics.5 Receiving this designation means that there have been studies with sufficient sample size indicating that NFB is safe for use with children.5 It also means that studies have demonstrated that NFB is effective in reducing ADHD symptoms in children.6–10 However, evaluations of neurofeedback outside of research trials have been more limited, meaning it is not yet known how laboratory studies translate to real clinical practice.

Address correspondence to Kate B. Nooner, PhD, Department of Psychology, University of North Carolina Wilmington, 601 South College Road, Wilmington, NC, USA. Email: noonerk@uncw.edu.
Julian R. Keith, PhD, Department of Psychology, University of North Carolina Wilmington, Wilmington, NC, USA.
Richard L. Ogle, PhD, Department of Psychology, University of North Carolina Wilmington, Wilmington, NC, USA.
Kirsten D. Leaberry, MA, Department of Psychological and Brain Sciences, University of Louisville, Louisville, KY, USA.

In randomized clinical trials, NFB studies commonly employ parent\textsuperscript{11} or teacher\textsuperscript{12} reports to assess outcomes pertaining to children’s behavior. While parent and teacher reports are a core component of an ADHD diagnosis, they do not give information about neurocognitive changes that contribute to ADHD symptoms. Another way in which parent reports are somewhat limited is due to expectancy effects.\textsuperscript{6} In a recent meta-analysis conducted by Micoulard-Franchi et al., parent assessments following NFB were compared to teacher assessments, who had no knowledge that children had received NFB.\textsuperscript{7} They found an improvement on parent assessments for overall ADHD score, inattention score, and hyperactivity/impulsivity score in NFB groups compared to control groups. For the teacher assessments, improvements were only found for the inattention score. Parent reports still provide valuable behavioral information on childhood ADHD symptom, which has been demonstrated in several NFB studies\textsuperscript{3,4,11} and other meta-analyses.\textsuperscript{6,8,9} Taken together, these findings indicate that multiple forms of assessment are useful in comprehensively assessing NFB treatment outcomes for childhood ADHD symptoms.

As mentioned, another limitation in establishing the effectiveness of NFB is the lack of outcome assessment in community practice settings. While work in clinical settings is emerging,\textsuperscript{13} the majority of published research consists of randomized controlled trials (RCTs) utilizing 30+ sessions of NFB with stringent inclusion criteria.\textsuperscript{2,3,7–9} Though RCTs are needed to establish an evidence base, their results may not always generalize to heterogeneous clinic populations where strict inclusion criteria, treatment-naive clients, and many NFB sessions are often not feasible, particularly for moderate- and low-income families.\textsuperscript{10}

To begin to address generalizability, a recent outcome assessment of clinic-delivered NFB for childhood ADHD found improvements in behavioral ratings of aberrant behavior (not ADHD symptoms) as well as a neuropsychological task after only 12 NFB sessions.\textsuperscript{13} A limitation noted by this outcome assessment evaluation was that it failed to utilize the Conners’ Rating Scale for parents or teachers following NFB, which is an important tool for assessing childhood ADHD symptoms. In addition, it had strict inclusion criteria that did not allow for comorbidity or prior ADHD treatment. Still, given these positive outcome assessment findings, further behavioral and neurocognitive outcome assessment is warranted to establish the effectiveness of NFB to treat childhood ADHD in clinic settings.

The current outcome assessment examines the behavioral and neurocognitive effectiveness of a brief course of NFB delivered in an ADHD clinic. The goal was to deliver fewer sessions to minimize burden on families, who may find it challenging to bring children in for the typically required 30–40 sessions. A second goal was to compare parent report on a standardized ADHD questionnaire with results on a neurocognitive test of ADHD symptoms.

The intent of this outcome assessment was to see whether 12 NFB sessions delivered in a clinic are effective in reducing behavioral and neurocognitive symptoms of ADHD. The objectives pertain to the examination of the outcome measures collected following NFB delivered in a clinic. Based on the results of the outcome assessment and meta-analytic findings for RCTs of NFB by Hillard et al.,\textsuperscript{7–9,13} the following are hypothesized:

1. There will be pre- to post-NFB reductions in ADHD symptoms on both behavioral and neurocognitive outcome measures after 12 sessions of NFB delivered in a clinic. There are intentionally fewer sessions than most published RCTs (30–40 sessions)\textsuperscript{7–9} because it is hypothesized that fewer sessions (12 sessions) will be effective and more manageable for parents/caregivers in a typical clinic setting.

2. There will be measurable effect sizes after 12 NFB sessions for both behavioral and neurocognitive outcome assessment.\textsuperscript{8} It is expected that there will be larger effect sizes for the behavioral measure of ADHD symptoms than for the neurocognitive task.
Methods

Clinic participants

Thirty-one children (males, \(n=27\); females, \(n=4\)) of ages 8–14 years (\(M \text{ age}=11.13, \ SD=1.98\)) were recruited to participate in an IRB-approved program evaluation that included NFB clinic services provided at no cost to community children. Demographics of the clinic children, including sex, race, medication status, and diagnosis, can be seen in Table 1. Children were initially assessed for ADHD according to the Diagnostic and Statistical Manual of Mental Disorders—IV-TR (DSM-IV-TR)\(^{14}\) and received 12 sessions of clinic-based NFB. Children could not currently be receiving treatment for ADHD, but could have had prior treatment; if they were taking ADHD medication, they were asked to refrain from taking it on the day NFB was delivered.\(^{7-9}\)

Children and adolescents were referred to the clinic from community sources including schools and healthcare providers. Eligible children were required to have enough symptoms of ADHD to meet DSM-IV-TR criteria\(^{14}\) according to semi-structured clinical interview and have an IQ over 70. Exclusion criteria included current suicidal ideation, homicidal ideation, self-injury, mania, psychosis, autism spectrum disorder, and psychiatric medication other than ADHD medication; other comorbidity and ADHD medication was permitted. Due to challenges for the clinic in receiving Conners’ Rating Scale from teachers, children were included based on the following at pretreatment: semi-structured DSM-based clinical interview with parent and child, Conners’ Rating Scale for parents, and Conners’ Continuous Performance Test.\(^{15-17}\) Of the participants recruited, the parents of 12 of the children (males,

<table>
<thead>
<tr>
<th>Variable</th>
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<th>Percent</th>
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<tr>
<td>Sex</td>
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<tr>
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<tr>
<td>Female</td>
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<tr>
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<tr>
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<td>52</td>
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<tr>
<td>ODD</td>
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</table>

GAD generalized anxiety disorder, PTSD posttraumatic stress disorder, ODD oppositional defiant disorder.
In the current outcome assessment, interviews and measures were used to evaluate the effectiveness of NFB sessions. The study included 10 males and 2 females, aged 8–14 years (M age = 11.42, SD = 1.98), who agreed to complete the Conners’ Rating Scale for parents at posttreatment. These parents stayed during NFB sessions and filled out this additional survey on a computer in a private study room.

### Interviews and measures

The Kiddie Structured Clinical Interview—Present & Lifetime Version (K-SADS-PL) is a widely used semi-structured diagnostic clinical interview assessing childhood psychopathology according to the DSM-IV-TR. Trained interviewers asked child participants and parent/guardians separately how often psychiatric symptoms were experienced and combined these ratings to create a summary and a diagnosis. Interviewers differentiated between combined, inattentive, and hyperactive subtypes of ADHD. Children with no prior ADHD diagnosis, but with sufficient symptoms according to the K-SADS-PL, were enrolled in the current outcome assessment (n = 4). Table 1 contains a summary for the clinic children. In evaluating psychometric properties of the K-SADS-PL, significant correlations were reported for all convergent validity scales (ρ = 0.3–0.4 across diagnoses, p ≤ 0.001); inter-rater kappa coefficients for all diagnoses were within acceptable ranges (κ = 0.7–0.9, p < 0.01).

Conners’ Continuous Performance Task (CPT) is a standardized continuous performance test of attention-related difficulties in children 8 years and older. This 14-min computerized task examines inattentiveness, impulsivity, sustained attention, and vigilance. In psychometric evaluation, the three dimensions of the CPT that were evaluated (i.e., combined commission/omission, reaction time, and target detection) were significantly related to DSM-IV ADHD symptoms. The CPT evidenced moderate test–retest reliability (coefficients, 0.65–0.075; p < 0.05); however, practice effects were low over a 1-month interval (coefficients, 0.3–0.4; p < 0.05). In examining construct validity, the CPT was highly correlated with the tests of variables of attention (TOVA), another commonly used, commercially available, computerized attention task (r > 0.8). Table 2 contains the means and standard deviations for the clinic children’s CPT scores for each dimension.

Conners’ Rating Scale Parent (CRS-P) is a widely used, standardized, 45-item parent and teacher report that assesses ADHD symptoms in children ages 6–18 years. Items are rated on a Likert scale: 0 = Not true at all, 1 = Just a little true, 2 = Pretty much true, 3 = Very much true. This measure contains several subscales: inattention, hyperactivity/impulsivity, learning problems, executive functioning, aggression, and peer relations. These subscales are summed

### Table 1

<table>
<thead>
<tr>
<th>Measure</th>
<th>Pre-NFB</th>
<th>Post-NFB</th>
<th>n</th>
<th>t</th>
<th>p</th>
<th>Effect size (d)</th>
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<tr>
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<td>M (SD)</td>
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<td></td>
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<td>0.724</td>
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<td>49.69 (8.52)</td>
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<td>1.19</td>
<td>0.237</td>
<td>0.0</td>
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<td>CPT-C</td>
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<td>49.69 (8.52)</td>
<td>31</td>
<td>2.21</td>
<td>0.035</td>
<td>0.3</td>
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<tr>
<td>CRS-P</td>
<td>42.08 (11.31)</td>
<td>28.67 (10.33)</td>
<td>12</td>
<td>4.05</td>
<td>0.002</td>
<td>1.19</td>
</tr>
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</table>

CPT-T Conners’ Continuous Performance Task target detection, CPT-R Conners’ Continuous Performance Task reaction time, CPT-C Conners’ Continuous Performance Task combined commissions and omissions, CRS-P Conners’ Rating Scale—Parent

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to create a total ADHD behavioral symptoms raw score. The Conners’ has robust psychometric properties with internal consistency from 0.77 to 0.97 and test–retest reliability coefficients from 0.71 to 0.98 (for all $p<0.001$). Inter-rater reliability coefficients were from 0.52 to 0.95. Table 2 contains the means and standard deviations of the CRS-P total score for the clinic children.

### Procedures

The parent/guardian and child completed the initial eligibility assessment at the clinic. Trained staff conducted clinical interviews with parent and child using the K-SADS-PL. Parent, child, and teacher completed survey measures on the computer at baseline and post-NFB on a HIPAA-compliant online questionnaire manager. Eligible clinic children were then administered the CPT. Instructions were e-mailed to teachers to allow online completion of measures; however, despite multiple follow-up attempts, none were completed. Therefore, they were not included in the present analyses.

Children received 12 NFB sessions in a 3- to 4-week period. Each session was 1 hour or less in duration. Parents either dropped their child off at the clinic or waited in the clinic during their child’s NFB sessions to prevent distractions. NFB was delivered via BrainPaint® software, which utilized individualized protocols for each participant. NFB consisted of theta/ beta training to increase beta (12–30 Hz) and decrease theta (6–8 Hz) as well as SMR training to increase SMR activity (13–15 Hz). The original protocol for BrainPaint® NFB was examined in a mixed-substance abuse population to improve attention and reduce impulsivity. In developing the NFB protocol with the substance use population, the developers found that the NFB group had significant improvements on a neurophysiological measure of attention, TOVA, after about 13 sessions of beta and SMR protocols compared to those in a control group that received only inpatient substance abuse treatment services. This development work was used to guide the current protocol used with the present clinic with children. It has been adjusted further and tailored for childhood ADHD. Each child’s individual ADHD symptoms and baseline continuous performance task data are input into BrainPaint® to create individualized beta/theta and SMR protocols.

During NFB, children received feedback within 250 ms about target brainwaves via visual and auditory stimuli. When all 12 NFB sessions were completed, children were administered another CPT to assess ADHD symptoms. This study examines whether 12 NFB sessions delivered in a clinic, as opposed to the typical 30–40 sessions cited in randomized controlled trials, is an effective alternative for community children with ADHD symptoms.

### Results

### Data analysis

Statistical analyses were conducted using IBM SPSS, version 19. Paired-sample $t$ tests were conducted for both outcome assessments to examine pre- to post-NFB differences on behavioral and neurocognitive measures of ADHD symptoms. The CPT dimensions were target detection, reaction time, and combined omissions and commissions; higher standard scores indicate poorer performance. The total raw CRS-P score was utilized; higher total scores indicate more ADHD symptoms. Effect sizes were calculated from pre- to post-NFB difference scores. Effect size is a standardized statistic useful for comparing across different outcome assessment measures and unequal $n$. Effect size was interpreted as small ($d=0.20$), medium ($d=0.50$), and large ($d=0.80$).
The means and standard deviations for the pre- and post-NFB CPT appear in Table 2. There were no significant differences for target detection or reaction time ($p > 0.05$). Children made statistically significantly fewer combined commission and omission errors on the CPT following NFB in the clinic ($t(30) = 2.21, p = 0.035$); there was a small effect size from pre- to post-NFB (Cohen’s $d = 0.30$).

The means and standard deviations for the pre- and post-NFB CRS-P appear in Table 2. Parents reported significantly less ADHD symptoms following NFB in the clinic ($t(11) = 4.05, p = 0.002$). There was a large effect size for the CRS-P (Cohen’s $d = 1.19$). In comparing children whose parents did versus did not complete the CRS-P, there were no statistically significant differences between children on any variables measured: ADHD symptoms, other mental health symptoms reported on K-SADS-PL, gender, socioeconomic status, ADHD medication status, pre/post-CPT scores, pre/post-Conners’ scores, or number of NFB sessions ($p > 0.1$ for all).

### Implications for Behavioral Health

This outcome assessment evaluation of clinic children suggests that reductions in ADHD symptoms can be detected with 12 sessions of NFB, providing support for hypothesis 1. Supporting hypothesis 2, there was a large effect size for the behavioral measure of ADHD symptoms (i.e., CRS-P) and a small effect size for one dimension of the neurocognitive assessment (i.e., combined commissions/omissions on CPT). Overall, this outcome assessment demonstrates the initial effectiveness of 12 sessions of clinic-delivered NFB in reducing ADHD symptoms in children according to the behavioral measure. However, results are less clear for the neurocognitive assessment as only one of the three dimensions yielded a measurable effect size and the effect was small. This suggests that it may be feasible to incorporate NFB into community clinics for children with ADHD, but more work is needed to determine whether measurable neurocognitive changes are taking place.

The preliminary results of this outcome assessment indicate that reducing symptoms with NFB may be an option in promoting behavioral changes in childhood ADHD symptoms. Typical ADHD treatments such as medication management and behavioral therapy have not consistently led to improvements in behavioral symptoms of ADHD. As an alternative to these treatments, there have been some positive findings from randomized controlled trials of NFB. The present outcome assessment contributes to the literature in that it provides evidence of behavioral ADHD symptom improvement following NFB in a clinic setting.

The neurocognitive assessment showed small or no reductions in childhood ADHD symptoms. Given that this outcome assessment only administered 12 sessions of neurofeedback, it is not surprising that small effect sizes were detected on one dimension of the neurocognitive task while large effect sizes were found for parent report. Since two of the three neurocognitive dimensions on the CPT did not yield any measurable effects, one should be cautious in attributing improvement to NFB based on the third CPT dimension. Still, this small effect may indicate a real neurocognitive change as measureable neurocognitive changes have been reported in randomized controlled studies of childhood ADHD that were administering 30–40 sessions of NFB. In addition, the combined commission/omission dimension of the Conners’ Continuous Performance Task has been reported to be more sensitive to change than target detection or reaction time, which are
typically more stable dimensions of attention. This could be why effects were detected for the combined dimension, but not for the others. The small effect size for the combined dimension is also not likely to be due to maturation because of the short 4- to 6-week time span of clinic services. Yet, it could mean that 12 NFB sessions are not sufficient to yield measurable neurocognitive changes in ADHD symptoms. Thus, more work is needed to make a determination on neurocognitive changes.

There are limitations of the current outcome assessment. While there have been randomized controlled trials on neurofeedback, there has been little assessment of real-world applications of NFB for childhood ADHD symptoms, a gap that is addressed in the present outcome assessment evaluation. Because this outcome assessment was conducted in a clinic, where treatment was required, a control group was not permitted. This did not allow comparison of the NFB clinic children to another group. Also, since this was a voluntary clinic sample, the sample size was somewhat low, limiting the generalizability of the clinic outcomes. Future outcome evaluations should employ a larger clinic sample with a waitlist control or an alternative treatment as a comparison to NFB. Another limitation was that only 12 parents completed the post-NFB CRS while 31 children completed the post-NFB CPT. Although it was reported that there were no measurable differences in any demographic, diagnostic, behavioral, or neurocognitive criteria for children of parents who completed the voluntary measure versus those who did not, additional outcome assessment is warranted to replicate these findings.

A strength of this outcome assessment includes using a semi-structured diagnostic interview, the CRS with parents, and the CPT with children, which are core components of an evidence-based ADHD diagnosis. Despite repeated efforts, the clinic did not receive the CRS from teachers, which is needed to make a complete ADHD diagnosis. Future clinic policy will require teacher reports before NFB is initiated to facilitate inclusion of this important information. It is for this reason that the term ADHD symptoms and not diagnosis was used throughout this outcome assessment evaluation. Still, this outcome assessment provides support for the report of Hillard et al. on ADHD symptom reduction following moderate exposure to clinic-delivered NFB. The present outcome assessment also added to Hillard et al. with the use of the CRS and the inclusion of more heterogeneous clinic children. However, the present outcome assessment did not clearly demonstrate neurocognitive changes following the brief course of NFB.

Future outcome assessment evaluations could utilize EEG and other neurophysiological tools (e.g., fMRI) to more closely evaluate neurocognitive changes by examining functional brain activity that may be indicative of improvement with NFB. In addition, future outcome assessment could examine various doses of NFB (e.g., 12, 18, and 24 sessions) to see whether neurocognitive differences emerge after a few more NFB sessions are delivered in a community clinic. Lastly, future research should also examine behavioral, cognitive, and academic outcomes in the months following treatment to assess long-term effects of NFB.

This outcome assessment evaluation has behavioral health implications for children impacted by ADHD symptoms in that it offers a novel treatment option that is not dependent on intensive parental involvement or medication. These outcomes also demonstrate ways in which NFB can potentially be delivered to children with fewer barriers pertaining to cost and time commitment for families in typical community settings. Real-world evaluations such as the one presented here are useful for identifying ways to reduce health disparities and provide innovative treatments for childhood ADHD.
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Compliance with Ethical Standards

Conflict of Interests  All authors declare no conflicts of interest.

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References


