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Article *in* The Psychiatric clinics of North America · March 2013

Impact Factor: 1.87 · DOI: 10.1016/j.psc.2013.01.005 · Source: PubMed

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# Neurofeedback

## An Emerging Technology for Treating Central Nervous System Dysregulation

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### KEYWORDS

• Neurofeedback • QEEG • PTSD • ADHD • Seizure • Treatment

### KEY POINTS

- Neurofeedback, a subspecialization of biofeedback, is based on learning theory (eg, classical and operant conditioning).
- Neurofeedback is best administered by a qualified or licensed professional who has received training in one or more subspecializations.
- Neurofeedback is often used in combination with other treatments such as medication or psychotherapy.
- Neurofeedback is efficacious for epilepsy, Attention Deficit Hyperactivity Disorder (ADHD), and anxiety disorders.
- Neurofeedback is probably efficacious for traumatic brain injury, alcoholism and other substance abuse, insomnia, and optimal/peak performance.
- Evidence of efficacy for neurofeedback monotherapy is insufficient for depression, autism, Post Traumatic Stress Disorder (PTSD), and tinnitus, although outcomes are positive in the limited available studies.

### BACKGROUND AND CLINICAL APPLICATIONS

Biofeedback is a method of treatment in which patients are trained to become aware of and learn to control their own physiology to improve physical and psychological health. Neurofeedback, a subspecialization of biofeedback, also called electroencephalogram (EEG) biofeedback, uses the patient's EEG as feedback to modify the brain's electrical activity patterns.<sup>1</sup> In contrast, other biofeedback modalities use physiologic measures, such as pulse, skin temperature, or heart rate variability as

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feedback to alter brain activity and physiologic functions. The history, research, and clinical effects of neurofeedback have been reviewed in-depth elsewhere.<sup>2-4</sup>

Classic conditioning of the human EEG, specifically the “alpha blocking response,” was accomplished in France<sup>5</sup> and in the United States.<sup>6</sup> During the 1940s, Gibbs and Knott<sup>7</sup> noticed that the frequencies of brainwaves measured in Hertz (Hz), cycles per second, gradually increase through the life-cycle: slower brain waves, delta (0.5–3.5 Hz) and theta (4–7.5 Hz), predominate in infants and young children. These slower frequencies are associated with injury or functional immaturity in awake adults. Excessive slow wave activity was found to be associated with symptoms consistent with what is known today as ADHD.<sup>8</sup> By 1962, it was demonstrated that individuals could learn to modulate their own EEG through operant conditioning.<sup>9</sup> For a comprehensive review of the history connecting classic/operant conditioning to neurofeedback see Sherlin and colleagues.<sup>3</sup> The idea of volitional control over one’s brain activity led to the theory that changing the EEG could lead to clinical improvements among patients with mental health diagnoses.

High-quality randomized controlled trials (RCTs) have shown significant benefits from neurotherapy, primarily in treatment of ADHD. Strehl and colleagues<sup>10,11</sup> conducted an RCT in which subjects received training in theta/beta neurofeedback or slow cortical potential neurofeedback. Both interventions showed positive and similar improvements in ADHD symptoms, which were sustained at 6-month follow-up<sup>12</sup>; Holtmann and colleagues completed an RCT of theta/beta neurofeedback versus a control group using Captain’s Log training.<sup>13</sup> Both groups participated in attention training programs for the same amount of time. This study found a specific and clinically relevant improvement in impulsivity on a go-no go task only in the neurofeedback group. Parent rating scales indicated significant improvements in inattention, hyperactivity, and impulsivity. A multicenter double-blind RCT of 94 patients with ADHD found that treatment with neurofeedback resulted in significant improvements in subscales of attention and hyperactivity/impulsivity symptoms measured by an ADHD rating scale<sup>14</sup> and in reduction of the theta band EEG compared with no change in the control group given a credible sham attention training.<sup>15</sup> Postevaluation analysis of data from this sample demonstrated specificity of neurofeedback and reduced EEG theta power in the neurofeedback group but not in the control group.<sup>16</sup>

### ***Seizure Disorders***

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M. Barry Sterman discovered that cats were able to become seizure resistant by learning to produce a particular morphological wave form in the low beta frequency range (12–15 Hz), called sensory motor rhythm, over the sensory motor cortex. The National Aeronautics and Space Administration contacted Sterman to investigate seizure activity in astronauts and service personnel exposed to monomethyl hydrazine, a highly volatile rocket-fuel additive. This investigation led to the development of neurofeedback protocols to control epilepsy.<sup>17</sup>

### ***Attention-Deficit/Hyperactivity Disorder***

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Joel F. Lubar detected outcomes of increased calmness in those trained with neurofeedback for seizure disorders and postulated efficacy for the hyperkinesis and disorganization of ADHD, predominantly hyperactive-impulsive type.<sup>18</sup> Lubar found the EEG ratio of theta to beta waves at the vertex (CZ in the International 10-20 system) to be the most reliable indicator of attention problems and pioneered neurofeedback protocols for treating ADHD.<sup>19</sup> The characteristic pattern in ADHD, excess theta and insufficient beta (13–21 Hz), is associated with deficits in activation and occurs primarily in the frontal lobe. Neurofeedback training protocols that reduce theta and

increase beta (eg, theta/beta ratio training) therefore positively affect ADHD symptoms. Subsequent research confirmed and extended his findings such that ADHD, both predominantly inattentive and combined types, became the best-documented disorder illustrating neurofeedback efficacy.<sup>2,20,21</sup>

### ***Posttraumatic Stress Disorder***

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Earlier research in neurofeedback pertained to the development of treatment of PTSD in returning war veterans. Although the first protocols showed efficacy in trauma recovery by augmenting the 7-Hz range (theta), often the treatment experience vividly evoked the original trauma or retraumatized the patient. Peniston and Kulkosky<sup>22</sup> found that the addition of alpha (8–12 Hz) to the theta treatment produced a soothing, mitigating affect on the treatment experience, rendering it more tolerable. Although substantial recoveries were reported in Vietnam veterans with drug and alcohol addiction as well as PTSD, they were met with skepticism. The lack of double-blind RCTs left the treatment open to question and controversy.

### **NEUROFEEDBACK: METHODS AND MODALITIES**

Neurofeedback training should begin with a clinical intake and baseline evaluation, which often includes a neuropsychological battery or at a minimum a computerized continuous performance test such as the test of variables of attention, integrated visual and auditory, and/or a Quantitative Electroencephalography (qEEG).

#### ***Quantitative Electroencephalograph***

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The qEEG is a screening instrument in which 19 to 21 sites on the International 10–20 system are measured by an EEG amplifier. The results are processed on a computer, which can display the raw EEG and use the fast Fourier transform to calculate the components of the complex waveform into discrete frequency ranges. This result shows the proportion of the various waveform frequencies such as delta, theta, alpha, beta, and gamma. The analysis provides the magnitude in microvolts and the power (microvolts squared) across frequencies (in hertz), as well as other spectral metrics. In contrast to routine EEG, qEEG entails additional computer processing, and the results are compared with a reference population of healthy individuals (presumed normative). This database comparison analysis is designed to reflect normalcy or abnormality of brain activity by calculating standard deviations from the normative sample. Connectivity measures, such as coherence, asymmetry, and phase, across the sites and across the hemispheres, provide additional information about brain processing.<sup>4</sup>

Normative population data are compiled into databases in a variety of software platforms for processing qEEG data. Some analysis software contains subscales or discriminant metrics that measure the likelihood of the client to be statistically similar to a population of individuals with a known diagnosis, such as traumatic brain injury (TBI), learning disabilities, depression, dementia, obsessive-compulsive disorder, ADHD, or schizophrenia.<sup>23</sup> qEEG-guided neurofeedback treatment is deemed to be a superior method for guiding protocols by most practitioners.<sup>4</sup> Some report that using qEEG analysis to choose treatment protocols may improve efficacy by 50%.<sup>24</sup> In addition, a 3-dimensional imaging technique called low-resolution electromagnetic brain tomography (LORETA) calculates the “inverse solution” and is used to localize the cortical origin of electrical activity in deeper brain structures based on surface electrodes. A higher-resolution version (in voxels) with a demonstrated zero localization error is called exact or eLORETA.<sup>25</sup>

### **qEEG Clinical Administration**

Neurofeedback is usually administered in the clinician's office using at least 3 electrodes at active sites for training, reference, and ground. There may be more active electrodes (as many as 19) used for training, depending on the complexity of the protocol. The client is asked to produce a brain electrical event for which certain feedback effects occur, for example, turn a sound on or off, move the level of an on-screen thermometer or bar graph, or watch a movie that dims or turns off when the client is not performing the task but turns on bright and clear if the client is "on target" (**Box 1**).

Typically, appointments last between a half-hour and an hour, and it is generally agreed that the sessions are of higher quality if the clinician stays in the room to monitor activities and make adjustments as necessary.<sup>4</sup> The number of sessions required to produce long-lasting results varies. Some report that 30 to 40 sessions are needed,<sup>26</sup> whereas others observe that it depends on the type and severity of the disorder. For example, autism spectrum disorders or Asperger syndrome may require 40 to 60 sessions.<sup>27</sup> Some have reported that in some sudden onset or acute problems where the premorbid condition was good, 5 to 10 sessions may produce remission.<sup>28</sup>

### **MECHANISMS OF ACTION**

The primary purpose of neurofeedback is to create learned changes in electrical activity of the brain that are linked to clinical symptoms or are associated with positive states (eg, optimal performance). Neurofeedback contributes to neural plasticity by addressing excesses and deficits in particular frequency bands that are corrected using inhibition or augmentation training, respectively.<sup>29</sup> Gunkelman and Johnstone<sup>26</sup> refer to the concept of "growth through utilization" as being analogous to building muscle mass by repeated exercises and suggest that the training process itself may contribute to the

#### **Box 1**

##### **Neurofeedback methods**

- *Operant conditioning or contingency-based neurofeedback*: the subject is asked to augment one frequency range and inhibit another.<sup>4</sup>
- *qEEG-guided training*: the frequencies selected for operant conditioning training are based on analysis of the multisite EEG assessment and quantified metrics.
- *Z-score training*: the training feedback is based on moving predetermined variables closer to zero standard deviations or "within normal limits" based on a reference population of qEEGs.<sup>2</sup>
- *Low-energy neurofeedback system (LENS)*: this procedure is passive, in which the subject sits with eyes closed during radiofrequency electromagnetic stimulation, said to be little or no more intense than the signals emitted by most EEG amplifiers but using special protocols developed by OchsLabs. This very low intensity treatment (10–18 or 10–21 W/cm<sup>2</sup>) is said to be effective with brief applications and shorter treatment times than conventional neurofeedback protocols.<sup>2,28</sup>
- *Slow cortical potentials (SCP) training*: operant conditioning volitional control of the SCP has shown efficacy in attention, migraine, and seizure disorders.<sup>34–36</sup>
- *Neurofield*: this procedure is both passive and active (has a feedback loop for operant conditioning). It uses electromagnetic frequencies (as does the LENS) but may also have feedback components, such as heart rate variability or Z-score neurofeedback responses to guide treatment.<sup>2,26</sup>

strengthening of synapses. A greater proportion of theta and alpha frequency bands localized frontally correspond to decreased perfusion (blood flow) as seen on positron emission tomography.<sup>30</sup> Correlations between blood flow and EEG findings help explain one way in which neurofeedback might influence the brain. For example, theta activity is associated with decreased blood perfusion and beta with increased blood perfusion. This result implies that correcting the excessive theta activity and deficits of beta seen in the central and frontal areas of the brain in ADHD contributes to improvement in perfusion in areas of impaired or sluggish brain function.<sup>31</sup>

## **CLINICAL CONSIDERATIONS IN NEUROFEEDBACK**

### ***Efficacy Ratings***

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Neurofeedback efficacy is graded on a 1 to 5 scale, where a rating of 1 or not empirically supported consists primarily of case studies or anecdotal reports. A rating of 5 indicates that the therapy has been found to be superior to a placebo in RCTs conducted at a minimum of 2 independent sites.

1. Areas where neurofeedback has been deemed efficacious (level 4) or efficacious and specific (level 5) are epilepsy, ADHD, and anxiety spectrum disorders.
2. Areas where neurofeedback has been deemed probably efficacious (level 3) include TBI, alcoholism/substance abuse, insomnia and optimal/peak performance.
3. Areas where evidence of efficacy is insufficient (level 2) include depressive disorders, autism, PTSD, and tinnitus. This lower rating of efficacy is due to the insufficient number of studies or the minimal sample sizes used in reported studies despite findings of positive outcomes.

### ***Side Effects and Adverse Reactions***

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Any treatment method can cause harm, particularly when used injudiciously. Neurofeedback practitioners, in promoting their method as “holistic” and “noninvasive,” may misrepresent its potential to cure serious illnesses or to destabilize patients who are precariously adapted. Practitioners can be naive or irresponsible in applying treatments that may be too intense, too long, or unlikely to succeed in particular conditions.<sup>32</sup> Sensitivity, over reactivity, or a precarious adaptation can predispose a patient to adverse reactions to neurofeedback sessions. Potential side effects include headache, nausea, dizziness, fatigue, agitation, cognitive interference, or destabilization.<sup>33</sup> These side effects are infrequent and usually resolve within a few hours.

### ***Professional Regulation and Credentialing***

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No government body specifically regulates the licensure of neurofeedback practitioners. Professional credentials and/or licensure in a health profession is required for those who treat disorders described in the Diagnostic and Statistical Manual of Mental Disorders and International Classification of Diseases. In contrast, nonlicensed practitioners, such as optimal performance consultants may use neurofeedback training to enhance the client’s quality of life or performance in a given field.<sup>37–39</sup> The Biofeedback Certification International Alliance (BCIA) certifies individuals who meet education and training standards in biofeedback and neurofeedback. BCIA certification, however, is not a substitute for a state-issued license or other professional credential.

### ***Clinical Guidelines for Neurofeedback***

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When is it appropriate to refer a patient to a neurofeedback consultant? An obvious instance is if the patient has nonresponse or insufficient response to standard

treatments and/or intolerance of medication side effects. Positive indicators for a trial of neurofeedback include the following: deficits in cognition, attention problems with or without hyperactivity, fatigue, sleep disturbance, mood dysregulation, chronic pain or seizures, or other disorders with underlying central nervous system dysregulation. Neurofeedback can be used as a stand-alone or adjunctive treatment. It has been used successfully as an adjunct to medication, psychotherapy, cognitive behavioral therapy, and Alcoholics Anonymous support for relapse prevention in the treatment of substance abusers.<sup>40,41</sup>

## APPENDIX: REFERENCES

The complete reference list is online at <http://www.psych.theclinics.com/dx.doi.org/10.1016/j.psc.2013.01.005>.

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