Regence Oregon and Utah | Regence Idaho and select counties of Washington

NOTE: This policy is not effective until April 1, 2023. To view the current policy, click here.

Medical Policy Manual Medicine, Policy No. 65

Neurofeedback

Effective: April 1, 2023

Next Review: September 2023
Last Review: November 2022

IMPORTANT REMINDER

Medical Policies are developed to provide guidance for members and providers regarding coverage in accordance with contract terms. Benefit determinations are based in all cases on the applicable contract language. To the extent there may be any conflict between the Medical Policy and contract language, the contract language takes precedence.

PLEASE NOTE: Contracts exclude from coverage, among other things, services or procedures that are considered investigational or cosmetic. Providers may bill members for services or procedures that are considered investigational or cosmetic. Providers are encouraged to inform members before rendering such services that the members are likely to be financially responsible for the cost of these services.

DESCRIPTION

Neurofeedback describes techniques for providing feedback about neuronal activity, as measured by electroencephalogram biofeedback, functional magnetic resonance imaging, or near-infrared spectroscopy, to teach patients to self-regulate brain activity. Neurofeedback may use several techniques in an attempt to normalize unusual patterns of brain function in patients with various psychiatric and central nervous system disorders.

MEDICAL POLICY CRITERIA

The use of neurofeedback as a treatment for any disorder is considered **investigational**.

NOTE: A summary of the supporting rationale for the policy criteria is at the end of the policy.

CROSS REFERENCES

1. Sphenopalatine Ganglion Block for Headache and Pain, Medicine, Policy No. 160
2. Biofeedback, Allied Health, Policy No. 32

BACKGROUND

Behavioral (non-drug) treatments, including neurofeedback, result in both nonspecific and specific therapeutic effects. Nonspecific effects, sometimes called placebo effects, occur as a result of therapist contact, positive expectancies on the part of the patient and therapist, and other beneficial effects that occur as a result of being a patient in a therapeutic environment. Specific effects are those that occur only because of the active treatment, above any nonspecific effects that may be present.

In order to isolate the independent contribution of neurofeedback on health outcomes (specific effects) and properly control for nonspecific treatment effects, well-designed clinical trials with the following attributes are necessary:

- Randomization helps to achieve equal distribution of individual differences by randomly assigning patients to either neurofeedback or sham treatment groups. This promotes the equal distribution of patient characteristics across the two study groups. Consequently, any observed differences in the outcome may, with reasonable assuredness, be attributed to the treatment under investigation.
- A comparable sham control group helps control for placebo effects as well as for the variable natural history of the condition being treated.
- Blinding of study participants, caregivers, and investigators to the active or sham assignments helps control for bias for or against the treatment. Blinding assures that placebo effects do not get interpreted as true treatment effects.
- A large study population is needed to ensure the ability to rule out chance as an explanation of study findings.
- Follow-up periods must be long enough to determine the durability of any treatment effects.

REGULATORY STATUS

Several EEG feedback systems (EEG hardware and computer software programs) have been cleared for marketing by the U.S. Food and Drug Administration (FDA) through the 510(k) process. For example, the BrainMaster™ 2E (BrainMaster Technologies) is "…indicated for relaxation training using alpha EEG Biofeedback. In the protocol for relaxation, BrainMaster™ provides a visual and/or auditory signal that corresponds to the patient's increase in alpha activity as an indicator of achieving a state of relaxation." Although devices used during neurofeedback may be subject to FDA regulation, the process of neurofeedback itself is a procedure, and, therefore, not subject to FDA approval. FDA product codes: HCC, GWQ.

EVIDENCE SUMMARY

ATTENTION DEFICIT HYPERACTIVITY DISORDER (ADHD)

Systematic Reviews

Louthrenoo (2022) published a systematic review (SR) with meta-analysis on the potential effects of neurofeedback to improve functional outcomes in people with Attention Deficit/Hyperactivity Disorder (ADHD).[1] The review focused on randomized controlled studies of children and adolescents aged 5 to 18 years. Data from 10 studies (N=383) were included in the review. Participants received 18 to 40 sessions of neurofeedback across 3 to 25 weeks. No significant effect of neurofeedback on response inhibition, sustained attention, or working

memory domains was found. Meta-regression revealed a trend-level association between response inhibition and number of neurofeedback sessions (p=0.06). Limitations to existing data are noted as small sample sizes and lack of appropriate control.

Lee (2022) published a SR with meta-analysis focusing on theta/beta-based neurofeedback (T/B NF) training in children and adolescents aged 6 to18 with ADHD. Nineteen studies (13 RCTs and 6 non-RCTs) met selection criteria for systematic review (N=1059), 12 of which (7 RCTs and 5 non-RCTs) were included in the meta-analysis. Methodological quality of the RCTs ranged from 4 to 10 on the PEDro scale, indicating fair-to-excellent quality. Risk of bias assessment of the RCTs found four had an overall low risk of bias, seven had some concern of bias, and two had high risk of bias. Within-group effects on attention were medium at post-treatment (pooled Hedge's g=0.65) and large at follow-up (pooled Hedge's g=0.87). Between-group analyses revealed neurofeedback had a larger effect than no treatment, waitlist control, physical activities, and sham neurofeedback, however, the effect of neurofeedback was not superior to stimulant medication (Hedge's g=-0.25).

Riesco-Matias (2021) published a SR of RCTs of neurofeedback applied to children with ADHD.[2] The review included 17 trials (16 RCTs) of neurofeedback compared to active and nonactive controls in children and adolescents with a primary diagnosis of ADHD. The study designs were unblinded evaluation in 11 trials (n=674) and blinded evaluation in nine trials (n=573). RCTs were found to support the efficacy of neurofeedback to improve inattention symptoms when blinded evaluators assess symptoms. The meta-analysis also found results suggesting stimulant medication is more effective than neurofeedback. Additional RCT data are needed to evaluate symptom measurement and longer-term outcomes.

A SR published by Sampedro Baena (2021) evaluated nine RCTs comparing neurofeedback to control or other interventions in 620 children and adolescents with ADHD.[3] This was a qualitative review of trials; no pooled analysis was conducted. Comparing neurofeedback to methylphenidate (MPH) treatment, teachers reported significantly lower ADHD symptoms in the MPH group, but there were no differences between groups in parental report. Combined treatment of neurofeedback and MPH improved ADHD symptoms (p=0.01), which was more effective compared to single medication treatment in one study. Mixed outcomes were found on the superiority of neurofeedback or medication with respect to attention, hyperactivity, impulsivity, and visual attention capacity. Small trial sample size, variability in the duration of the intervention and limited longer-term outcomes are noted limitations across trials.

Lambez (2020) published a SR with meta-analysis of the effectiveness of non-pharmacological interventions for in ADHD, with a specific focus on objective cognitive outcomes.[4] A total of 18 RCTs (N=618) were included in the analyses. Interventions were categorized into neurofeedback, cognitive-behavioral therapy, cognitive training, and physical exercises. Among these interventions, physical exercises had the highest average effect size (Morris d=0.93). Across trials, a homogenous, medium to large effect size of improvement across interventions was found, with inhibition having the largest average effect size (Morris d=0.685, SMD, 0.61 [-3.77 to 4.82], I^2 (p)=0% [<0.05]). Six trials (N=203) evaluated the domain of inhibition.

A SR with meta-analysis by Van Doren (2019) sustainability of neurofeedback and control treatment effects in RCTs which included neurofeedback or control treatment in children and adolescents with ADHD.[5] The analysis included data from ten studies on neurofeedback (N=256) and nine studies with control data (N=250). Parent behavior ratings were calculated

and analyzed. Within-group neurofeedback effects on inattention were of medium in size (ES) (SMD=0.64) at post-treatment and increased to a large effect size (SMD=0.80) at follow-up (range 2-12 months). For hyperactivity/impulsivity, effect sizes for neurofeedback were medium at post-treatment (SMD=0.50) and follow-up (SMD=0.61). Non-active control conditions yielded small significant effects on inattention at post-treatment (SMD=0.28) but no significant effects at follow-up. Active treatments (mainly methylphenidate) had large effects for inattention (post: SMD=1.08; follow-up: SMD=1.06) and medium effects for hyperactivity/impulsivity (post: SMD=0.74; follow-up: SMD=0.67). Between-group analyses favored neurofeedback over non-active controls [inattention (post: SMD=0.38; follow-up: SMD = 0.57); hyperactivity/impulsivity (post: SMD=0.25; follow-up: SMD=0.39)] and favored active controls for inattention only at pre-post (SMD=- 0.44). The authors note limitations in existing data including challenges in blinding the intervention and limited data on longer-term follow-up.

Yan (2019) published a SR with meta-analysis comparing neurofeedback and pharmacological treatment with methylphenidate (MPH) for the treatment of ADHD.[6] The analysis included data from 18 RCTs were included (778 individuals with ADHD in the neurofeedback arm and 757 in the MPH group, respectively) with follow-up ranging from one to six months. MPH was significantly more effective than neurofeedback on ADHD core symptoms (ADHD symptoms combined: SMD=-0.578, 95% CI (-1.063 to -0.092)) and on neuropsychological parameters of inattention: -0.959 (-1.711 to -0.208) and inhibition: -0.469 (-0.872 to -0.066). Study attrition, however, was significantly lower in neurofeedback than MPH (OR=0.412, 0.186 to 0.913). Removing Chinese studies and non-funded studies from the analysis resulted in no differences between MPH and neurofeedback. Treatment-specific outcomes at study follow-up were mixed, with no significant difference in neuropsychological measures between groups, teachers' evaluation favoring MPH in total score and HI (Hyperactivity/Impulsivity), but parents' evaluation favoring neurofeedback. Heterogeneity in drug dosing, feedback protocols, and outcome rating scales was noted as limiting. High risk of bias was found for allocation concealment and blinding of participants/personnel in all studies.

Catalá-López (2017) published a SR comparing pharmacological, psychological and alternative medicine treatments for ADHD, one of which was neurofeedback.[7] There was lack of methodologically sound evidence to support neurofeedback and results should be interpreted cautiously. In addition, the authors stated the balance between benefits, costs, and harm should be weighed when selecting therapies for ADHD.

Cortese (2016) published a SR evaluating RCT outcomes on the efficacy of neurofeedback, for attention deficit/hyperactivity disorder.[8] Thirteen RCTs, with 520 participants were included. Neurofeedback was not found to be an effective treatment for ADHD.

Micoulaud-Franchi (2014) published an updated SR with meta-analysis of RCTs published through August 2014.[9] Five studies[10-14] (N=263) that compared standard neurofeedback with either a semi-active or sham neurofeedback control group in children with ADHD met inclusion criteria. Parent assessment reported significant improvement in all scores with neurofeedback compared to controls; however, the authors noted that the parents were probably not blinded to the treatment assignments. In blinded teacher assessment, significant improvement with neurofeedback compared to controls was reported only in inattention scores. No significant effect was found for overall ADHD scores or hyperactivity/impulsivity scores. The methodological strengths of this meta-analysis were noted to be the stringent inclusion criteria and the inclusion of inattention and hyperactivity/impulsivity scores in addition to overall ADHD scores. The principal limitations included the small number of studies, the small number of

subjects enrolled in the individual studies, and the heterogeneous methodological protocols between studies. The authors also noted the inclusion of studies with somewhat non-standard protocols[10, 11] such as the use by Maruizio[11] of tomographic neurofeedback that is rarely used in the clinical setting, as well as the exclusion of a study[15] that was not based on the basic learning theory used in standard neurofeedback protocol. The authors concluded that the studies included in their meta-analysis reported efficacy of neurofeedback only for the inattention dimension of ADHD and recommended additional studies in which parents and teachers are blinded to the treatment assignments.

Randomized Controlled Trials

Purper-Ouakil (2022) published the results of the NEWROFEED trial, a prospective multicenter RCT of personalized at-home neurofeedback training versus methylphenidate in children aged 7 to 13 years with ADHD.[16] The trial randomized participants from nine study sites across five European countries to the neurofeedback and methylphenidate groups in a 3:2 ratio; the neurofeedback group (n=111) underwent eight visits and two treatment phases of 16 to 20 at-home sessions and the control group (n=67) received optimally titrated long-acting methylphenidate. Data from a total of 149 participants were included in the per-protocol analysis. Reduction in the Clinician ADHD-RS-IV total score was found between baseline and final visit for both groups, with 26.7% (SMD=0.89) in the neurofeedback and 46.9% (SMD = 2.03) in the control group. Noninferiority of neurofeedback versus methylphenidate was not demonstrated (mean between-group difference 8.09 90% CI [8.09; 10.56]). Study limitations include absence of sham neurofeedback or another nonactive group and lack of mid- or long-term follow-up.

Hasslinger (2022) published the results of a multi-arm RCT in 202 children and adolescents (age 9 to 17 years) with ADHD that evaluated two neurofeedback treatments (slow cortical potential [SCP, standard neurofeedback protocol] and Live Z-score (LZS, nonstandard neurofeedback protocol) compared to working memory training (WMT, active comparator) and treatment as usual (passive comparator).[17] The active conditions (SCP/LZS/WMT) consisted of daily working week sessions (five sessions/week) during five consecutive weeks (25 sessions in total). The prespecified primary outcome measure was the self-, teacher- and parent-reported assessment of ADHD symptoms post-treatment and at six months using the Conners 3rd Edition scale. Neither neurofeedback treatment was superior to working-memory training for these outcome measures. Significant differences between SCP and treatment as usual were observed post-treatment for teacher- and parent-rated inattention, with no difference for other outcome measures at either timepoint. A statistically significant difference in Live Z-score over treatment as usual was only observed at the six-month endpoint for teacher-rated inattention and hyperactivity/impulsivity. No other differences between Live Z-score and treatment as usual were observed. Secondary outcomes in this study included measures of teacher- and parent-rated executive function and self-assessed health-related quality of life using the Behavior Rating of Executive Functions (BRIEF) and KIDSCREEN-27 scales, respectively. There were no consistent differences between neurofeedback interventions and control interventions for these outcomes except for teacher-assessed executive function at six months follow-up, which found both neurofeedback interventions superior to working-memory training and treatment as usual. Limitations in the study include lack of blinding of parents of, presence of missing data, limited measures of functioning and impairment, and patients being drawn from a single site.

Arnold (2021) published the 13-month outcomes of a two-site double-blind RCT in 144 children with moderate to severe ADHD randomized to neurofeedback and sham control.[18] Both groups showed significant improvement ($p<0.001$, $d=1.5$) in parent/teacher-rated inattention from baseline to treatment end and 13-month follow-up and neurofeedback was not significantly superior to the control condition at either time point on this primary outcome ($d=0.01$, $p=0.965$ at treatment end; $d=0.23$, $p=0.412$ at 13-month follow-up). No significant difference in responder rate, defined as Clinical Global Impression-Improvement [CGI-I] = 1-2 was found between groups. At 13-month follow-up, a nonsignificant improvement from treatment end for was found for neurofeedback (d 0.1) and a mild deterioration was found for controls ($d=-0.07$). Neurofeedback participants required significantly less medication at follow-up ($p=0.012$). Longer-term (25-month) follow-up data are anticipated.

Aggensteiner (2019) published the six-month outcomes of a multisite RCT of slow cortical potential (SCP)-neurofeedback or electromyogram biofeedback (EMG-BF) in the treatment of ADHD in 144 children age 7 to 9.[19] Participants were not blinded to study condition. Both groups showed improvement of ADHD symptoms compared to baseline at six-months follow-up with large effect sizes for SCP-NF ($d=1.04$) and EMG-BF ($d=0.85$). No between-group differences were found. A group-by-time interaction was found with SCP-NF showing stable improvement following treatment up to six months, but EMG-BF showing a relapse from post-test timepoint one to post-test timepoint two, and subsequent remission at follow-up ($p<0.05$). Power estimates were not reported.

Lim (2019) published a RCT of 172 participants age 6 to 12 years old diagnosed with ADHD not receiving concurrent pharmacotherapy or behavioral intervention from a single site in Singapore.[20] The participants were randomized to eight weeks of neurofeedback attention training or untreated waitlist control for eight weeks followed by neurofeedback attention training for 20 weeks. Modified intention to treat analyzes conducted on 163 participants with at least one follow-up rating. At eight weeks, clinician-rated inattentive symptoms (ADHD-Rating Scale. ADHD-RS) was reduced by 3.5 (SD 3.97) in the intervention group compared to 1.9 (SD 4.42) in the waitlist-control group, which was a difference of 1.6; 95% CI 0.3 to 2.9 $p=0.018$). Patients, parents, and investigators were unblinded.

Lee and Jung (2017) published a small RCT that compared neurofeedback with medication to medication alone in 36 children 6 to12 years of age, with ADHD.[21] Neurofeedback consisted of 20 sessions. Outcome measures (cognitive performance scores, ADHD rating scores completed by parents, and brain indices) pre- post-treatment occurred. Neurofeedback patients had improved symptom variables and reduced theta waves, but no additional intelligent functioning when compared to patients on medication management alone. Although the authors stated neurofeedback can be considered a possible effective treatment option for ADHD, this study was limited in size. Larger RCTs, with longer follow-up times are needed.

In addition to the initial report from the RCT by Steiner[12] included in the meta-analyses above, a secondary analysis[22] was also reported. This article was excluded from the meta-analysis in order to ensure that patients were not included more than once. In this RCT,104 children with ADHD age 7 to 11 years were randomized to receive neurofeedback, cognitive training, or a no-intervention control condition in their elementary school. Both the neurofeedback and cognitive therapies were administered with commercially available computer programs (45-min sessions three times per week), monitored by a trained research assistant. The neurofeedback EEG sensor was embedded in a standard bicycle helmet with the grounding and reference sensors located on the chin straps on the mastoids. No data was presented on the technical

performance of this system. There were some differences in baseline measures between the groups, although these differences were not large. The slope of the change in scores over time was compared between groups. Children in the neurofeedback group showed a small improvement on the Conners 3-Parent Assessment Report (effect size [ES] = 0.34 for inattention, ES=0.25 for executive functioning, ES = 0.23 for hyperactivity/impulsivity) and subscales of the Behavior Rating Inventory of Executive Function Parent Form (BRIEF global executive composite, ES=0.23) when compared with baseline. Interpretation of these findings is limited by the use of a no-intervention control group and lack of parental blinding. Evaluator-blinded classroom observation (Behavioral Observation of Students in Schools) found no sustained change with a linear growth model but a significant improvement with a quadratic model. No between-group difference in change in medication was observed at the six-month follow-up.

In 2012, Duric reported a comparative study of neurofeedback versus methylphenidate in 91 children with ADHD.[23] The children were randomized into three groups, consisting of 30 sessions of neurofeedback, methylphenidate, or a combination of neurofeedback and methylphenidate. The neurofeedback sessions focused on the theta/beta ratio. Parental evaluations found improvements in ADHD core symptoms for all three groups, with no significant differences between groups. Alternative reasons for improvement with neurofeedback include the amount of time spent with the therapist and cognitive-behavioral training introduced under neurofeedback. In a 2014 publication of self-reports from this study, there was no improvement in attention, hyperactivity, or school achievement when adjusted for age and sex.[24] Only the neurofeedback group showed a significant improvement in self-reported school performance.

Nonrandomized Studies

Additional studies have compared neurofeedback to medication (stimulant) and/or behavioral therapy in patients with ADHD.[25-27] In these nonrandomized studies, patients in both groups reported improvements in various measures of attention; however, nonrandomized studies limit the ability to reach scientific conclusions concerning the efficacy of neurofeedback in the treatment of AD/HD due to the lack of design attributes described above.

Section Summary

Several systematic reviews and meta-analyses as well as additional moderately sized RCTs have compared neurofeedback with methylphenidate, biofeedback, cognitive behavioral therapy, cognitive training, or physical activity These studies found either small to moderate or no benefit of neurofeedback and sustained long-term benefit has not been consistently demonstrated. Studies using active controls have suggested that at least part of the effect of neurofeedback might be due to attention skills training, biofeedback, relaxation training, and/or other nonspecific effects. Two of the RCTs indicated that any beneficial effects were more likely to be reported by evaluators unblinded to treatment (parents), than by evaluators blinded (teachers) to treatment, which would suggest bias in the nonblinded evaluations. Moreover, a meta-analysis found no effect of neurofeedback on objective measures of attention and inhibition. Additional research with blinded evaluation of outcomes is needed to demonstrate the effect of neurofeedback on ADHD.

AUTISM SPECTRUM DISORDER

Systematic Reviews

Vasa (2014) published a SR that included studies of the safety and effectiveness of psychopharmacological and non-psychopharmacological treatments, including NF, for anxiety in children with autism spectrum disorder (ASD).[28] While neurofeedback showed a possible benefit, studies were small and short-term; outcomes must be verified in large RCTs with adequate blinding and appropriate controls.

Frye (2013) conducted a SR on the treatment of seizures in patients with autism spectrum disorder.[29] Studies were selected systematically from major electronic databases and then reviewed by a panel of ASD treatment experts. Authors concluded there was limited evidence to support the use of neurofeedback in patients with seizures associated with ASD.

In a 2009 single-author SR of novel and emerging treatments for ASD, neurofeedback received a grade C recommendation (Grade C recommendation: supported by one nonrandomized controlled trial).[30] The author reviewed literature in the PubMed and Google Scholar databases for clinical trial reports on numerous biological (e.g., nutritional supplements, special diets, medications) and nonbiological (e.g., neurofeedback, massage) treatments. Due to the extensive amount of literature, a critical analysis of the quality of the studies was not included. The study referenced for neurofeedback was a nonrandomized pilot study that included 12 children with ASD who received neurofeedback and an untreated control group of 12 children who were matched by sex, age, and disorder severity.[31] The study found a greater reduction in ASD symptoms based on the Autism Treatment Evaluation Checklists (A TEC) and parental assessments in the group treated with neurofeedback compared with the control group. While this trial is useful in informing hypothesis formation, it does not permit conclusions on efficacy due to the lack of randomized treatment allocation, small patient population, lack of a sham control group, and short-term follow-up period. Randomized sham controlled trials in larger numbers of patients are required to validate these findings due to the possibility of nonspecific effects (e.g., attention training) and confounding variables (e.g., parental engagement and expectation).

Randomized Controlled Trials

Kouijzer (2013) performed a small RCT to evaluate the effects of EEG-neurofeedback in ASD.[32] Thirty-eight participants were randomly allocated to the EEG-biofeedback (n=13), skin conductance (SC)-biofeedback (n=12) or waiting list (sham control) group (n=13). At six months follow up, 54% of the patients in the EEG-biofeedback group were able to influence their own EEG activity, with significantly reduced delta and/or theta power during EEG-biofeedback sessions. However, within this group no statistically significant reductions of symptoms of ASD were observed, but they did show significant improvement in cognitive flexibility as compared to participants who managed to regulate SC. Overall, the EEG- and SC-biofeedback groups, regardless of whether they could regulate their own activity, showed no improvement in clinical symptoms of ASD.

COGNITIVE PERFORMANCE

Systematic Reviews

Renton (2017) published a SR evaluating the impact of neurofeedback therapy on cognitive rehabilitation for stroke patients.[33] Eight studies met inclusion criteria. The authors stated although cognitive benefits were found with neurofeedback, the studies had methodological limitations. Additional studies should attempt to standardize neurofeedback protocols, so that the relationship between neurofeedback and improved health outcomes can be understood.

Emmert (2016) published a review evaluating twelve studies that examined nine different target regions in the brain, for 175 subjects.[34] The studies showed real-time fMRI activates regions of the regulation network in the brain, but the authors stated it was unclear why and could have been related to successful regulation versus the regulation process. More studies are needed to determine if neurofeedback can impact the regulation network.

Randomized Controlled Trials

De Ruiter (2016) published a double-blinded placebo-controlled RCT that evaluated the impact of neurofeedback on neurocognitive function, for pediatric brain tumor survivors (PBTS).[35] Patients age 8-18 years old were given 30 sessions (two/week) of neurofeedback (n=40) or placebo feedback (n=40). An assessment was performed six months after the sessions ended. The authors stated neither neurofeedback nor placebo feedback was superior.

One small (n=6) quasi-randomized, double-blind pilot study was identified that examined whether increasing peak alpha frequency would improve cognitive performance in older adults (70–78 years of age).[36] Control subjects were trained to increase alpha amplitude or shown playback of one of the experimental subject's sessions. Compared to controls, the experimental group showed improvements in speed of processing for two of three cognitive tasks (Stroop, Go/No-Go) and executive function in two tasks (Go/No-Go, n-back); other functional measures, such as memory, were decreased relative to controls.

EPILEPSY

Systematic Reviews

Tan (2009) published a SR that identified 63 studies on neurofeedback for treatment of epilepsy.[37] Ten of the 63 studies met inclusion criteria; nine of these studies included fewer than 10 subjects. The studies were published between 1974 and 2001 and utilized a pre-post design in patients with epilepsy refractory to medical treatment; only one controlled study was included. The meta-analysis showed a small effect size for treatment (-0.233), with a likelihood of publication bias based on funnel plot. Randomized placebo-controlled trials are needed to evaluate the effect of neurofeedback on seizure frequency in patients with epilepsy.

Randomized Controlled Trials

A RCT by Morales-Quezada (2019) randomized 44 children with focal epilepsy to sensorimotor rhythm (SMR) neurofeedback (n=15), slow cortical potentials (SCP) neurofeedback (n=16), or sham neurofeedback (n=13) for 25 sessions over five weeks.[38] Outcomes including the attention switching task (AST), Liverpool Seizure Severity Scale (LSSS), seizure frequency (SF), EEG power spectrum, and coherence were measured at baseline, postintervention, and at three-month follow-up. At the end of the intervention period, only the sensorimotor rhythm neurofeedback group demonstrated significant improvement in the activity switching task and all groups demonstrated significant improvements in quality of life ($p=<0.05$).

FIBROMYALGIA

Systematic Reviews

In 2015 a Cochrane SR evaluated therapies for fibromyalgia, identifying five RCTs on biofeedback, including the Kayiran study described below, as well as four studies published prior to 2010.[39] There were two studies, both ranked with very low quality of evidence, which

compared biofeedback versus usual care.[40] Neither of these studies found significant advantage of using biofeedback versus usual care for any of the major outcomes assessed, including self-reported physical functioning, pain, mood and overall quality of life. Both studies only assessed outcomes post-intervention, and only one reported three-month follow-up. No long-term follow-up was reported. There only one study, ranked with very low quality of evidence, which compared biofeedback versus attention control.[41] Although this study found significant differences between groups in terms of self-reported functioning and pain, the sample size was small (N=30) for each outcome, and the outcomes were only assessed post-intervention (no three- and six-month follow-up was reported). Overall, the review concluded that no advantage was observed for biofeedback in comparison to usual care controls and no studies reported any adverse events, however the quality of the evidence was so low that it is uncertain if there is any effect or not.

Randomized Controlled Trials

Kayiran (2010) reported a randomized single blind study of neurofeedback versus escitalopram in 40 patients with fibromyalgia.[42] Patients in the neurofeedback group were instructed to widen a river on a computer monitor which corresponded to increasing sensory motor activity and decreasing theta activity. Patients received five sessions per week for four weeks. The control group received escitalopram for eight weeks. Outcome measures at baseline and at weeks two, four, eight, 16, and 24 included visual analog scale (VAS) for pain, Hamilton and Beck Depression and Anxiety Inventory Scales, Fibromyalgia Impact Questionnaire and Short Form-36. Mean amplitudes of electroencephalogram (EEG) rhythms and the theta/sensory motor rhythms were also measured in the neurofeedback group. At baseline, the control group scored higher on the Hamilton and Beck Anxiety Scales and the Hamilton Depression Scale; all other baseline measures were similar between groups. Both groups showed improvements over time, with significantly better results in the neurofeedback group. There were no changes over time in mean amplitudes of EEG rhythms and essentially no change in the theta/sensory motor rhythm ratio (reduced only at week four). This study is limited by the difference in intensity of treatment and contact with investigators between the neurofeedback and escitalopram groups. As previously noted, sham-controlled trials are needed when assessing the effect of neurofeedback on subjective outcome measures.

FOOD CRAVING OR BINGE EATING

Systematic Reviews

No SRs have been identified using neurofeedback for food craving.

Randomized Controlled Trials

Imperatori (2017) evaluated how electroencephalographic (EEG) power spectra associated with alpha/theta (A/T) training reduces food craving.[43] Fifty participants were randomly assigned to receive 10 sessions of either EEG power spectra associated with A/T training [neurofeedback group (NFG)] or to a control group. All participants were administered the same questionnaires, at the end of 10 sessions. The NFG showed a statistically significant reduction in desire to consume food, up to four months post-treatment. Although A/T training appeared to positively affect areas of the brain associated with food desires, the remaining study data was self-reported. Therefore, additional RCTs are needed to evaluate objective long-term outcomes.

Schmidt (2016) published a small RCT evaluating the efficacy of neurofeedback on female binge eating.[44] Seventy-five subclinical threshold participants were assigned to EEG neurofeedback, mental imagery, or a waitlist group. The EEG neurofeedback group was the only one that had reduced binge eating, at a three-month follow-up. The authors stated EEG neurofeedback should be tested as a potential treatment option for binge eating.

MEDICATION OVERUSE HEADACHES

Systematic Reviews

No SRs have been identified using neurofeedback for medication overuse headaches.

Randomized Controlled Trials

Rausa (2016) evaluated the effectiveness of electromyographic (EMG) biofeedback, for medication overuse headache (MOH).[45] Twenty-seven participants were randomly assigned to receive EMG biofeedback with prophylactic pharmacological therapy (n=15) or to a control group that received pharmacological treatment alone (n=12). At the end nine weekly sessions and at four months post-study, participants who received EMG biofeedback had longer symptom free periods and statistically significant improved outcomes, but as the authors noted, additional larger RCTs are needed to validate these findings and determine the long-term effects.

MAJOR DEPRESSIVE DISORDER

Systematic Reviews

Trambaiolli (2021) published a SR of neurofeedback studies employing electroencephalography or functional magnetic resonance-based protocols in patients with major depressive disorder (MDD).[46] There were 24 studies included in the review (N=480 patients in experimental and N=194 in the control groups). While symptom improvements were found in the experimental group compared to control, the authors note that study quality and reporting practices were not stringent. High-quality studies that are adequately powered and appropriately controlled are needed to determine the impact of the technology on health outcomes for people with major depressive disorder.

Randomized Controlled Trials

Young (2017) evaluated the impact real-time fMRI neurofeedback (rtfMRI-NF) had on amygdala hemodynamic response, which the authors stated is blunted in patients with depression.[47] In a small double-blinded, placebo-controlled RCT, unmedicated adults received either two sessions of rtfMRI-NF from the amygdala (n=19) or from a parietal control region (n=17). Clinical scores and autobiographical memory performance evaluations took place at baseline and one week after the last rtfMRI-NF session. No additional follow-up was found. Even though the authors stated rtfMRI-NF increases the amygdala response to positive memories and that data suggests amygdala may play a role in depression recovery, this study was limited in size and larger RCTs with longer follow-up timeframes are needed.

MIGRAINE HEADACHES

Systematic Reviews

Miro (2016) performed a SR to evaluate the efficacy of neurofeedback, meditation and hypnosis for chronic pain in young participants.[48] Only one RCT and one case series were evaluated for neurofeedback. The additional articles evaluated meditation (N=5) and hypnosis (N=8). Participants for neurofeedback ranged from 9 to 21 years of age. The authors concluded that the neurofeedback RCT showed no statistically significant differences in migraine intensity or treatment regime, for those receiving neurofeedback. The study had methodological limitations limiting the conclusions that can be drawn.

Randomized Controlled Trials

Walker reported quantitative EEG (QEEG) for the treatment of migraine headaches in a RCT of 46 patients.[49] Results were compared with 25 patients who chose not to do neurofeedback and continued anti-migraine drug therapy. Since baseline QEEG assessment in all 71 patients showed a greater amount of the high frequency beta band (21 to 30 Hz), the five neurofeedback sessions focused on increasing 10 Hz activity and decreasing 21 to 30 Hz targeted individually to brain areas where high frequency beta was abnormally increased. Patient diaries of headache frequency showed a reduction in migraines in a majority of patients in the QEEG group but not the drug therapy group. Fifty-four percent of the QEEG group reported complete cessation of migraines over one year, with an additional 39% reporting a greater than 50% reduction. In comparison, no patients in the drug therapy group reported a cessation of headaches, and 8% had a reduction in headache frequency of greater than 50%. Limitations of this study include the patient self-report of headache status through diary logs which may not be the most reliable measure of symptom improvement. Randomized sham-controlled trials are needed to adequately evaluate this treatment approach.

OBSESSIVE-COMPULSIVE DISORDER (OCD)

Systematic Reviews

No SRs have been identified using neurofeedback for OCD.

Randomized Controlled Trials

Deng (2014) reported the outcomes of a randomized comparison of sertraline and weekly cognitive behavioral therapy with (n=40) versus without (n=39) NF.[50] Treatment was considered effective after eight weeks of therapy in 86.5% and 62.9% of participants, respectively (p=0.021). The authors concluded additional studies are needed to determine the long-term effects of neurofeedback for OCD including the need for booster sessions after the initial training period.

Koprivova (2013) reported a double-blind randomized sham-controlled trial of independent component neurofeedback in 20 patients with obsessive-compulsive disorder.[51] Independent component neurofeedback is based on the individual diagnosis of pathological EEG sources and was directed at down-training of abnormally high activity. All patients were hospitalized and participated in a six-week standard treatment program that included cognitive-behavioral therapy and 25 neurofeedback or sham biofeedback sessions. The neurofeedback group showed greater reduction of compulsions compared to the sham group (56% vs. 21%). However, clinical improvement was not associated with a change in EEG. Larger, long-term RCTs are needed in order to assess the efficacy of neurofeedback treatment on patients with OCD.

POST TRAUMATIC STRESS DISORDER

Systematic Reviews

A meta-analysis by Steingrimsson (2020) evaluated four RCTs of 123 adults with post-traumatic stress disorder (PTSD) treated with neurofeedback.[52] Follow-up ranged from four weeks to 30 months. Compared with sham neurofeedback, no treatment or other treatment, neurofeedback was associated with significant improvement in PTSD symptoms. Other primary outcomes were only reported in one trial each, and the authors conclude there is uncertainty regarding the ability of neurofeedback to improve PTSD symptoms, self-rated suicidality, executive cognitive functioning, or medication use. All studies were at moderate to high risk for bias and were assessed as having some indirectness and imprecision.

Reiter (2016) published a SR that evaluated five studies to determine neurofeedback's effectiveness and which protocol is preferred for patients with PTSD.[53] Neurobiological changes were noted in three of the studies. However, the authors stated that even though there differences and methodological limitations amongst the studies, neurofeedback may be an effective treatment for PTSD.

Randomized Controlled Trials

Van der Kolk (2016) evaluated neurofeedback and its effects on PTSD symptoms.[54] Fifty-two participants with chronic PTSD were randomly assigned to receive neurofeedback for 12 weeks or to a control group. Psychological and behavioral functioning were evaluated at baseline, six weeks, 12 weeks, and 16 weeks. The authors stated PTSD symptoms improved in individuals who received neurofeedback but concluded more long-term sham-controlled studies are needed.

PRIMARY INSOMNIA

Systematic Review

A systematic review by Melo (2019) of biofeedback techniques such as neurofeedback in adults with chronic insomnia included seven RCTs (N=244).[55] Conflicting results were found in comparisons of neurofeedback with other cognitive behavioral therapy techniques, placebo, and no treatment; a majority of outcomes demonstrated no significant differences between comparison groups. A majority of studies had high risk of bias related to blinding of participants and study personnel and incomplete outcome data. The authors conclude higher quality RCTs are needed to assess the effectiveness of biofeedback on chronic insomnia treatment.

Randomized Controlled Trials

Schabus (2017) published a double-blinded placebo-controlled study evaluating the efficacy of sensorimotor rhythm neurofeedback on sleep quality and memory.[56] Patients spent nine nights in the laboratory and received 12 sessions of neurofeedback and 12 sessions of placebo-feedback training (sham). The authors stated they did not find neurofeedback to be more effective than cognitive behavioral therapy.

Cortoos (2010) published a small (n=17) RCT on the effect of neurofeedback training or biofeedback training (placebo control) on objective and subjective sleep in patients with primary insomnia.[57] Of 158 subjects with sleep complaints who were interested in participating, 131 (89%) were excluded due to study criteria or unwillingness to remain medication free during the study period. Following polysomnograph (PSG) recorded sleep in the laboratory, all subjects received 20 sessions of therapist-controlled telefeedback training

at home over a period of eight weeks. The neurofeedback group was trained to increase the sensory-motor rhythm (12-15 Hz) and inhibit theta power (4-8 Hz) and high beta power (20-30 Hz). The biofeedback group was trained to decrease electromyographic (EMG) activity, which was equated with the reinforcement of relaxation (placebo control). Both treatments reduced sleep latency by 40% to 45% (22 minutes at baseline) on post-treatment PSG, measured two weeks after the end of training. Neurofeedback training reduced wake after sleep onset (54% vs. 13% decrease, respectively; however, no interaction was found on the two-way ANOVA) and increased total sleep time (40 minutes vs. less than 5 minutes, respectively, $p<0.05$). This study is limited by the small number of subjects, differences in sleep parameters at baseline, and short follow-up. Additional studies are needed to evaluate this novel treatment approach.

SUBSTANCE USE DISORDER

Systematic Reviews

A 2008 SR of neurofeedback as a treatment for substance abuse disorders described difficulties in assessing the efficacy of this and other substance abuse treatments, including the lack of clearly established outcome measures, differing effects of the various drugs, presence of comorbid conditions, absence of a gold standard treatment, and use as an add-on to other behavioral treatment regimens.[58] The authors concluded that alpha-theta training, when combined with an inpatient rehabilitation program for alcohol dependency or stimulant abuse, would be classified as level three or “probably efficacious.” This level is based on beneficial effects shown in multiple observational studies, clinical studies, wait-list control studies, or within-subject or between-subject replication studies. The authors also noted that few large-scale studies of neurofeedback in addictive disorders have been reported, and a shortcoming of the evidence for alpha-theta training is that it has not been shown to be superior to sham treatment.

Randomized Controlled Trials

Gabrielsen (2022) published the results of a RCT evaluating infralow neurofeedback (ILF-NF) in the treatment of substance use disorder.[59] Ninety-three patients age 19 to 66 years (mean ± SD 38 ± 11.7 years) with substance use disorder were recruited from an outpatient unit and randomized to receive 20 sessions (30 minutes each) of ILF-NF training combined with treatment as usual (TAU) or TAU alone. TAU consisted of cognitive behavioral techniques, psychosocial approaches, and motivational interviews. The primary study outcome was determined *a priori* to be quality of life as assessed by the QoL-5 instrument. Independent-sample t tests showed no significant difference between groups for the primary outcome measure ($p=0.28$).

TOURETTE SYNDROME

Systematic Reviews

In 2011, the working group of the European Society for the Study of Tourette Syndrome conducted a SR of behavioral and psychosocial interventions for Tourette syndrome and other tic disorders.[60] There were no randomized or comparative studies on neurofeedback for Tourette syndrome; the literature was limited to two case series.

Randomized Controlled Trials

Since the SR, no RCTs for neurofeedback for this indication have been published.

OTHER CONDITIONS

Literature searches have identified small studies (e.g., case reports, case series, comparative cohorts, RCTs) of neurofeedback for the following conditions:

- Aging-associated cognitive decline[61]
- Anxiety and panic disorders[62]
- Asperger syndrome[62]
- Childhood obesity[63]
- Cigarette cravings[64]
- Chronic pain[65]
- Depression (on its own, or in patients with multiple sclerosis or alcohol addiction)[62, 66, 67]
- Dissociative identity disorder[62]
- Fecal incontinence[68]
- Menopausal symptoms
- Parkinson's Disease[69-71]
- Primary headache[72]
- Schizophrenia[62, 73]
- Stress management and relaxation[74]
- Stroke[75, 76]
- Traumatic brain injury (TBI)[77]
- Tinnitus[78]
- Urinary incontinence[79]

PRACTICE GUIDELINE SUMMARY

AMERICAN ACADEMY OF PEDIATRICS (AAP)

The AAP's 2011 clinical practice guidelines on the diagnosis and treatment of ADHD did not include neurofeedback in the treatment recommendations.[80] EEG biofeedback was included on the list of areas for future research. The AAP (2019) published an evidence-based guideline update to the 2011 guideline for the treatment of ADHD in children and adolescents.[81] The guideline states that EEG biofeedback is one of several nonmedication treatments that have either too little evidence to support their recommendation or have little or no benefit.

AMERICAN PSYCHIATRIC ASSOCIATION (APA)

Neurofeedback is not recommended in APA practice guidelines on treatment of substance use disorders (2007),[82] major depressive disorder (2010),[83] obsessive-compulsive disorder (2013),[84] Posttraumatic Stress Disorder (2009),[85] or panic disorder (2009).[86]

INSTITUTE FOR CLINICAL SYSTEMS IMPROVEMENT

Institute for Clinical Systems Improvement (ICSI) released a 2014 update of their clinical practice guideline for the diagnosis, evaluation and management of attention deficit hyperactivity disorder in children and adolescents.[87] The updated guideline does not mention neurofeedback as a treatment option.

INTERNATIONAL SOCIETY FOR NEUROFEEDBACK & RESEARCH (ISNR)

The ISNR 2012 guideline is related to standards for practice but does not address specific treatments, indications, or scientific evidence.[88]

SUMMARY

There is not enough research to show that neurofeedback improves health outcomes for people with any indication. In addition, no practice guidelines based on research recommend neurofeedback for any indication. Therefore, neurofeedback is considered investigational for all indications.

REFERENCES

1. Louthrenoo O, Boonchooduang N, Likhitweerawong N, et al. The Effects of Neurofeedback on Executive Functioning in Children With ADHD: A Meta-Analysis. *J Atten Disord.* 2022;26(7):976-84. PMID: 34697957
2. Riesco-Matias P, Yela-Bernabe JR, Crego A, et al. What Do Meta-Analyses Have to Say About the Efficacy of Neurofeedback Applied to Children With ADHD? Review of Previous Meta-Analyses and a New Meta-Analysis. *J Atten Disord.* 2021;25(4):473-85. PMID: 30646779
3. Sampedro Baena L, Fuente GAC, Martos-Cabrera MB, et al. Effects of Neurofeedback in Children with Attention-Deficit/Hyperactivity Disorder: A Systematic Review. *J Clin Med.* 2021;10(17). PMID: 34501246
4. Lambez B, Harwood-Gross A, Golumbic EZ, et al. Non-pharmacological interventions for cognitive difficulties in ADHD: A systematic review and meta-analysis. *J Psychiatr Res.* 2020;120:40-55. PMID: 31629998
5. Van Doren J, Arns M, Heinrich H, et al. Sustained effects of neurofeedback in ADHD: a systematic review and meta-analysis. *Eur Child Adolesc Psychiatry.* 2019;28(3):293-305. PMID: 29445867
6. Yan L, Wang S, Yuan Y, et al. Effects of neurofeedback versus methylphenidate for the treatment of ADHD: systematic review and meta-analysis of head-to-head trials. *Evid Based Ment Health.* 2019;22(3):111-17. PMID: 31221690
7. Catala-Lopez F, Hutton B, Nunez-Beltran A, et al. The pharmacological and non-pharmacological treatment of attention deficit hyperactivity disorder in children and adolescents: A systematic review with network meta-analyses of randomised trials. *PloS one.* 2017;12(7):e0180355. PMID: 28700715
8. 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. *Journal of the American Academy of Child and Adolescent Psychiatry.* 2016;55(6):444-55. PMID: 27238063
9. Micoulaud-Franchi JA, Geoffroy PA, Fond G, et al. EEG neurofeedback treatments in children with ADHD: an updated meta-analysis of randomized controlled trials. *Frontiers in human neuroscience.* 2014;8:906. PMID: 25431555
10. van Dongen-Boomsma M, Vollebregt MA, Slaats-Willemse D, et al. A randomized placebo-controlled trial of electroencephalographic (EEG) neurofeedback in children with attention-deficit/hyperactivity disorder. *The Journal of clinical psychiatry.* 2013;74(8):821-7. PMID: 24021501

11. Maurizio S, Liechti MD, Heinrich H, et al. Comparing tomographic EEG neurofeedback and EMG biofeedback in children with attention-deficit/hyperactivity disorder. *Biological psychology.* 2014;95:31-44. PMID: 24211870
12. Steiner NJ, Frenette EC, Rene KM, et al. Neurofeedback and cognitive attention training for children with attention-deficit hyperactivity disorder in schools. *J Dev Behav Pediatr.* 2014;35:18-27. PMID: 24399101
13. Gevensleben H, Holl B, Albrecht B, et al. Is neurofeedback an efficacious treatment for ADHD? A randomised controlled clinical trial. *J Child Psychol Psychiatry.* 2009;50(7):780-9. PMID: 19207632
14. Bakhshayesh AR, Hansch S, Wyschkon A, et al. Neurofeedback in ADHD: a single-blind randomized controlled trial. *Eur Child Adolesc Psychiatry.* 2011;20(9):481-91. PMID: 21842168
15. Arnold LE, Lofthouse N, Hersch S, et al. EEG neurofeedback for ADHD: double-blind sham-controlled randomized pilot feasibility trial. *J Atten Disord.* 2013;17:410-9. PMID: 22617866
16. Purper-Ouakil D, Blasco-Fontecilla H, Ros T, et al. Personalized at-home neurofeedback compared to long-acting methylphenidate in children with ADHD: NEWROFEED, a European randomized noninferiority trial. *J Child Psychol Psychiatry.* 2022;63(2):187-98. PMID: 34165190
17. Hasslinger J, Bolte S, Jonsson U. Slow Cortical Potential Versus Live Z-score Neurofeedback in Children and Adolescents with ADHD: A Multi-arm Pragmatic Randomized Controlled Trial with Active and Passive Comparators. *Res Child Adolesc Psychopathol.* 2022;50(4):447-62. PMID: 34478006
18. Neurofeedback Collaborative G. Double-Blind Placebo-Controlled Randomized Clinical Trial of Neurofeedback for Attention-Deficit/Hyperactivity Disorder With 13-Month Follow-up. *Journal of the American Academy of Child and Adolescent Psychiatry.* 2021;60(7):841-55. PMID: 32853703
19. Aggensteiner PM, Brandeis D, Millenet S, et al. Slow cortical potentials neurofeedback in children with ADHD: comorbidity, self-regulation and clinical outcomes 6 months after treatment in a multicenter randomized controlled trial. *Eur Child Adolesc Psychiatry.* 2019;28(8):1087-95. PMID: 30610380
20. Lim CG, Poh XWW, Fung SSD, et al. A randomized controlled trial of a brain-computer interface based attention training program for ADHD. *PloS one.* 2019;14(5):e0216225. PMID: 31112554
21. Lee EJ, Jung CH. Additive effects of neurofeedback on the treatment of ADHD: A randomized controlled study. *Asian journal of psychiatry.* 2017;25:16-21. PMID: 28262140
22. Steiner NJ, Frenette EC, Rene KM, et al. In-school neurofeedback training for ADHD: sustained improvements from a randomized control trial. *Pediatrics.* 2014;133:483-92. PMID: 24534402
23. Duric NS, Assmus J, Gundersen D, et al. Neurofeedback for the treatment of children and adolescents with ADHD: a randomized and controlled clinical trial using parental reports. *BMC psychiatry.* 2012;12:107. PMID: 22877086
24. Duric NS, Assmus J, Elgen IB. Self-reported efficacy of neurofeedback treatment in a clinical randomized controlled study of ADHD children and adolescents. *Neuropsychiatr Dis Treat.* 2014;10:1645-54. PMID: 25214789
25. Fuchs T, Birbaumer N, Lutzenberger W, et al. Neurofeedback treatment for attention-deficit/hyperactivity disorder in children: a comparison with methylphenidate. *Appl Psychophysiol Biofeedback.* 2003;28(1):1-12. PMID: 12737092

26. Rossiter T. The effectiveness of neurofeedback and stimulant drugs in treating AD/HD: part II. Replication. *Appl Psychophysiol Biofeedback.* 2004;29(4):233-43. PMID: 15707253
27. Roy S, Mandal N, Ray A, et al. Effectiveness of neurofeedback training, behaviour management including attention enhancement training and medication in children with attention-deficit/hyperactivity disorder - A comparative follow up study. *Asian journal of psychiatry.* 2022;76:103133. PMID: 35551878
28. Vasa RA, Carroll LM, Nozzolillo AA, et al. A systematic review of treatments for anxiety in youth with autism spectrum disorders. *Journal of autism and developmental disorders.* 2014;44(12):3215-29. PMID: 25070468
29. Frye RE, Rossignol D, Casanova MF, et al. A Review of Traditional and Novel Treatments for Seizures in Autism Spectrum Disorder: Findings from a Systematic Review and Expert Panel. *Frontiers in public health.* 2013;1:31. PMID: 24350200
30. Rossignol DA. Novel and emerging treatments for autism spectrum disorders: a systematic review. *Ann Clin Psychiatry.* 2009;21(4):213-36. PMID: 19917212
31. Jarusiewicz B. Efficacy of neurofeedback for children in the autism spectrum: a pilot study. *J Neurotherapy.* 2002;6(4):39-49. PMID: No PMID Entry
32. Kouijzer ME, van Schie HT, Gerrits BJ, et al. Is EEG-biofeedback an effective treatment in autism spectrum disorders? A randomized controlled trial. *Appl Psychophysiol Biofeedback.* 2013;38(1):17-28. PMID: 22903518
33. Renton T, Tibbles A, Topolovec-Vranic J. Neurofeedback as a form of cognitive rehabilitation therapy following stroke: A systematic review. *PloS one.* 2017;12(5):e0177290. PMID: 28510578
34. Emmert K, Kopel R, Sulzer J, et al. Meta-analysis of real-time fMRI neurofeedback studies using individual participant data: How is brain regulation mediated? *NeuroImage.* 2016;124(Pt A):806-12. PMID: 26419389
35. de Ruiter MA, Oosterlaan J, Schouten-van Meeteren AY, et al. Neurofeedback ineffective in paediatric brain tumour survivors: Results of a double-blind randomised placebo-controlled trial. *Eur J Cancer.* 2016;64:62-73. PMID: 27343714
36. Angelakis E, Stathopoulou S, Frymiare JL, et al. EEG neurofeedback: a brief overview and an example of peak alpha frequency training for cognitive enhancement in the elderly. *Clin Neuropsychol.* 2007;21(1):110-29. PMID: 17366280
37. Tan G, Thornby J, Hammond DC, et al. Meta-analysis of EEG biofeedback in treating epilepsy. *Clin EEG Neurosci.* 2009;40(3):173-9. PMID: 19715180
38. Morales-Quezada L, Martinez D, El-Hagrassy MM, et al. Neurofeedback impacts cognition and quality of life in pediatric focal epilepsy: An exploratory randomized double-blinded sham-controlled trial. *Epilepsy Behav.* 2019;101(Pt A):106570. PMID: 31707107
39. Theadom A CM, Smith HE, Feigin VL, McPherson K. Mind and body therapy for fibromyalgia. . *Cochrane Database of Systematic Reviews 2015.* 2015(4). PMID:
40. van Santen M, Bolwijn P, Verstappen F, et al. A randomized clinical trial comparing fitness and biofeedback training versus basic treatment in patients with fibromyalgia. *The Journal of rheumatology.* 2002;29(3):575-81. PMID: 11908576
41. Babu AS, Mathew E, Danda D, et al. Management of patients with fibromyalgia using biofeedback: a randomized control trial. *Indian journal of medical sciences.* 2007;61(8):455-61. PMID: 17679735
42. Kayiran S, Dursun E, Dursun N, et al. Neurofeedback intervention in fibromyalgia syndrome; a randomized, controlled, rater blind clinical trial. *Appl Psychophysiol Biofeedback.* 2010;35(4):293-302. PMID: 20614235

43. Imperatori C, Valenti EM, Della Marca G, et al. Coping food craving with neurofeedback. Evaluation of the usefulness of alpha/theta training in a non-clinical sample. *International journal of psychophysiology : official journal of the International Organization of Psychophysiology.* 2017;112:89-97. PMID: 27845156
44. Schmidt J, Martin A. Neurofeedback Against Binge Eating: A Randomized Controlled Trial in a Female Subclinical Threshold Sample. *European eating disorders review : the journal of the Eating Disorders Association.* 2016;24(5):406-16. PMID: 27121224
45. Rausa M, Palomba D, Cevoli S, et al. Biofeedback in the prophylactic treatment of medication overuse headache: a pilot randomized controlled trial. *J Headache Pain.* 2016;17:87. PMID: 27655371
46. Trambaiolli LR, Kohl SH, Linden DEJ, et al. Neurofeedback training in major depressive disorder: A systematic review of clinical efficacy, study quality and reporting practices. *Neurosci Biobehav Rev.* 2021;125:33-56. PMID: 33587957
47. Young KD, Siegle GJ, Zotev V, et al. Randomized Clinical Trial of Real-Time fMRI Amygdala Neurofeedback for Major Depressive Disorder: Effects on Symptoms and Autobiographical Memory Recall. *The American journal of psychiatry.* 2017;174(8):748-55. PMID: 28407727
48. Miro J, Castarlenas E, de la Vega R, et al. Psychological Neuromodulatory Treatments for Young People with Chronic Pain. *Children (Basel).* 2016;3(4). PMID: 27929419
49. Walker JE. QEEG-guided neurofeedback for recurrent migraine headaches. *Clin EEG Neurosci.* 2011;42(1):59-61. PMID: 21309444
50. Deng X, Wang G, Zhou L, et al. Randomized controlled trial of adjunctive EEG-biofeedback treatment of obsessive-compulsive disorder. *Shanghai Arch Psychiatry.* 2014;26:272-9. PMID: 25477720
51. Koprivova J, Congedo M, Raszka M, et al. Prediction of treatment response and the effect of independent component neurofeedback in obsessive-compulsive disorder: a randomized, sham-controlled, double-blind study. *Neuropsychobiology.* 2013;67(4):210-23. PMID: 23635906
52. Steingrimsson S, Bilonic G, Ekelund AC, et al. Electroencephalography-based neurofeedback as treatment for post-traumatic stress disorder: A systematic review and meta-analysis. *Eur Psychiatry.* 2020;63(1):e7. PMID: 32093790
53. Reiter K, Andersen SB, Carlsson J. Neurofeedback Treatment and Posttraumatic Stress Disorder: Effectiveness of Neurofeedback on Posttraumatic Stress Disorder and the Optimal Choice of Protocol. *The Journal of nervous and mental disease.* 2016;204(2):69-77. PMID: 26825263
54. van der Kolk BA, Hodgdon H, Gapen M, et al. A Randomized Controlled Study of Neurofeedback for Chronic PTSD. *PloS one.* 2016;11:e0166752. PMID: 27992435
55. Melo DLM, Carvalho LBC, Prado LBF, et al. Biofeedback Therapies for Chronic Insomnia: A Systematic Review. *Appl Psychophysiol Biofeedback.* 2019;44(4):259-69. PMID: 31123938
56. Schabus M, Griessenberger H, Gnjezda MT, et al. Better than sham? A double-blind placebo-controlled neurofeedback study in primary insomnia. *Brain : a journal of neurology.* 2017;140(4):1041-52. PMID: 28335000
57. Cortoos A, De Valck E, Arns M, et al. An exploratory study on the effects of tele-neurofeedback and tele-biofeedback on objective and subjective sleep in patients with primary insomnia. *Appl Psychophysiol Biofeedback.* 2010;35(2):125-34. PMID: 19826944

58. Sokhadze TM, Cannon RL, Trudeau DL. EEG biofeedback as a treatment for substance use disorders: review, rating of efficacy, and recommendations for further research. *Appl Psychophysiol Biofeedback.* 2008;33(1):1-28. PMID: 18214670
59. Gabrielsen KB, Clausen T, Haugland SH, et al. Infralow neurofeedback in the treatment of substance use disorders: a randomized controlled trial. *J Psychiatry Neurosci.* 2022;47(3):E222-E29. PMID: 35705204
60. Verdellen C, van de Griendt J, Hartmann A, et al. European clinical guidelines for Tourette syndrome and other tic disorders. Part III: behavioural and psychosocial interventions. *Eur Child Adolesc Psychiatry.* 2011;20(4):197-207. PMID: 21445725
61. Laborda-Sanchez F, Cansino S. The Effects of Neurofeedback on Aging-Associated Cognitive Decline: A Systematic Review. *Appl Psychophysiol Biofeedback.* 2021;46(1):1-10. PMID: 33389281
62. Schoenberg PL, David AS. Biofeedback for psychiatric disorders: a systematic review. *Appl Psychophysiol Biofeedback.* 2014;39(2):109-35. PMID: 24806535
63. Chirita-Emandi A, Puiu M. Outcomes of neurofeedback training in childhood obesity management: a pilot study. *J Altern Complement Med.* 2014;20(11):831-7. PMID: 25188371
64. Kim DY, Yoo SS, Tegethoff M, et al. The inclusion of functional connectivity information into fMRI-based neurofeedback improves its efficacy in the reduction of cigarette cravings. *Journal of cognitive neuroscience.* 2015;27(8):1552-72. PMID: 25761006
65. Hesam-Shariati N, Chang WJ, Wewege MA, et al. The analgesic effect of electroencephalographic neurofeedback for people with chronic pain: A systematic review and meta-analysis. *Eur J Neurol.* 2022;29(3):921-36. PMID: 34813662
66. Linden DE, Habes I, Johnston SJ, et al. Real-time self-regulation of emotion networks in patients with depression. *PloS one.* 2012;7:e38115. PMID: 22675513
67. Choobforoushzadeh A, Neshat-Doost HT, Molavi H, et al. Effect of neurofeedback training on depression and fatigue in patients with multiple sclerosis. *Appl Psychophysiol Biofeedback.* 2015;40(1):1-8. PMID: 25362584
68. Kuo LJ, Lin YC, Lai CH, et al. Improvement of fecal incontinence and quality of life by electrical stimulation and biofeedback for patients with low rectal cancer after intersphincteric resection. *Archives of physical medicine and rehabilitation.* 2015;96(8):1442-7. PMID: 25838018
69. Subramanian L, Hindle JV, Johnston S, et al. Real-time functional magnetic resonance imaging neurofeedback for treatment of Parkinson's disease. *J Neurosci.* 2011;31:16309-17. PMID: 22072682
70. Tinaz S, Kamel S, Aravala SS, et al. Neurofeedback-guided kinesthetic motor imagery training in Parkinson's disease: Randomized trial. *Neuroimage Clin.* 2022;34:102980. PMID: 35247729
71. Anil K, Hall SD, Demain S, et al. A Systematic Review of Neurofeedback for the Management of Motor Symptoms in Parkinson's Disease. *Brain Sci.* 2021;11(10). PMID: 34679358
72. Moshkani Farahani D, Tavallaie SA, Ahmadi K, et al. Comparison of neurofeedback and transcutaneous electrical nerve stimulation efficacy on treatment of primary headaches: a randomized controlled clinical trial. *Iranian Red Crescent medical journal.* 2014;16(8):e17799. PMID: 25389484
73. Markiewicz R, Markiewicz-Gospodarek A, Dobrowolska B, et al. Improving Clinical, Cognitive, and Psychosocial Dysfunctions in Patients with Schizophrenia: A Neurofeedback Randomized Control Trial. *Neural Plast.* 2021;2021:4488664. PMID: 34434228

74. Kotozaki Y, Takeuchi H, Sekiguchi A, et al. Biofeedback-based training for stress management in daily hassles: an intervention study. *Brain and behavior.* 2014;4(4):566-79. PMID: 25161823
75. Cho HY, Kim K, Lee B, et al. The effect of neurofeedback on a brain wave and visual perception in stroke: a randomized control trial. *J Phys Ther Sci.* 2015;27:673-6. PMID: 25931705
76. Mihara M, Fujimoto H, Hattori N, et al. Effect of Neurofeedback Facilitation on Poststroke Gait and Balance Recovery: A Randomized Controlled Trial. *Neurology.* 2021;96(21):e2587-e98. PMID: 33879597
77. Nelson DV, Esty ML. Neurotherapy of traumatic brain injury/posttraumatic stress symptoms in OEF/OIF veterans. *J Neuropsychiatry Clin Neurosci.* 2012;24:237-40. PMID: 22772672
78. Barrenechea FV. Efficacy of neurofeedback as a treatment for people with subjective tinnitus in reducing the symptom and related consequences: a systematic review from 2010 to 2020. *Acta Otorrinolaringol Esp (Engl Ed).* 2022. PMID: 36257576
79. Tugtepe H, Thomas DT, Ergun R, et al. Comparison of biofeedback therapy in children with treatment-refractory dysfunctional voiding and overactive bladder. *Urology.* 2015;85(4):900-4. PMID: 25669732
80. Wolraich M, Brown L, Brown RT, et al. ADHD: clinical practice guideline for the diagnosis, evaluation, and treatment of attention-deficit/hyperactivity disorder in children and adolescents. *Pediatrics.* 2011;128(5):1007-22. PMID: 22003063
81. Wolraich ML, Hagan JF, Jr., Allan C, et al. Clinical Practice Guideline for the Diagnosis, Evaluation, and Treatment of Attention-Deficit/Hyperactivity Disorder in Children and Adolescents. *Pediatrics.* 2019;144(4). PMID: 31570648
82. American Psychiatric Association Guideline Watch (April 2007): Practice Guideline for the Treatment of Patients With Substance Use Disorders. [cited 10/26/2022]. 'Available from:' https://psychiatryonline.org/pb/assets/raw/sitewide/practice_guidelines/guidelines/substanceuse-watch.pdf.
83. American Psychiatric Association Practice Guideline for Treatment of Patients With Major Depressive Disorder. Third Edition. [cited 10/26/2022]. 'Available from:' https://psychiatryonline.org/pb/assets/raw/sitewide/practice_guidelines/guidelines/mdd.pdf.
84. APA Practice Guidelines. Guideline Watch (March 2013): Practice Guideline for the Treatment of Patients with Obsessive-Compulsive Disorder. [cited 10/26/2022]. 'Available from:' http://psychiatryonline.org/pb/assets/raw/sitewide/practice_guidelines/guidelines/ocd.pdf .
85. Guideline Watch 2009 Practice Guideline for the Treatment of Patients with Acute Stress Disorder and Posttraumatic Stress Disorder. PMID:
86. American Psychiatric Association Practice Guideline for the Treatment of Patients With Panic Disorder, Second Edition. . [cited 10/26/2022]. 'Available from:' http://psychiatryonline.org/pb/assets/raw/sitewide/practice_guidelines/guidelines/panicdisorder.pdf.
87. Institute for Clinical Systems Improvement (ICSI) Health Care Guideline: Diagnosis and Management of Attention Deficit Hyperactivity Disorder in Primary Care for School-Age Children and Adolescents. 2012. [cited 10/26/2022]. 'Available from:' http://pediatrasandalucia.org/Docs/TDAH/Herramientas/1_ADHD-ICSI_Guideline_2012.pdf.

88. International Society for Neurofeedback and Research (ISNR). Practice Guidelines for Neurofeedback. [cited 10/26/2022]. 'Available from:' https://isnr.org/guidelines-for-practice.

CODES

Codes	Number	Description
CPT	90875	Individual psychophysiological therapy incorporating biofeedback training by any modality (face-to-face with the patient), with psychotherapy (eg, insight oriented, behavior modifying or supportive psychotherapy); 30 minutes
	90876	;45 minutes
	90901	Biofeedback training by any modality
HCPCS	None	

Date of Origin: *July 1998*