NeuroRegulation

QEEG-Guided Neurofeedback Treatment for Anxiety Symptoms

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Abstract

Anxiety represents one of the most commonly diagnosed mental illnesses among adults in the United States, affecting an estimated 19.1% of the adult population annually, with a lifetime occurrence of 31.1% (NIMH, 2017). This retrospective study intended to assess whether qEEG-guided amplitude neurofeedback (NF) is a viable treatment for anxiety symptom reduction. Forty participants were assessed for anxiety using symptom and EEG measures. Demographics include age ranges from 19 to 62 (*M* = 37.7, *SD* = 13.87). Gender identification comprised 21 male and 19 female. Fifteen clients self-identified as White (Non-Latino; 38%), 14 as Latino/Latina (35%), and 11 did not self-report ethnicity (28%). Pre- and postassessments were given to the participants. Symptom assessments included the Zung Self-Rating Anxiety Scale and Achenbach System of Empirically Based Assessment (ASEBA) Adult Self-Report (ASR). A qEEG was used to determine protocols for each participant. Participants were scheduled to receive 30-min NF treatment sessions twice a week for one academic semester. The range of attended sessions was 7–19 (*M* = 12.72, *SD* = 2.78), where accurate number of session data was unavailable for four of the subjects. Symptom measures showed statistically significant improvement. Limitations include small sample size and no control group or sham NF group. Suggestions are included for future studies.

Keywords: anxiety; anxiety symptoms; qEEG-guided amplitude neurofeedback; neurofeedback

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Introduction

According to the National Institute of Mental Health (NIMH), anxiety disorders rank as the top leading diagnosis by clinicians within the mental health field. Anxiety disorders affect approximately 19.1% of the U.S. adults annually, with a lifetime prevalence of approximately 31.1% (NIMH, 2017). While the majority of Americans experience stress periodically within their lifespan, individuals diagnosed with anxiety have severe pervasive symptoms that interfere with their daily lives (NIMH, 2018). Psychotherapy, cognitive behavioral therapy (CBT), meditation, or support groups may be helpful in reducing symptoms (NIMH, 2018).

With the onset frequently developing during childhood, many anxiety disorders can be persistent if not treated and present more frequently in women at a 2:1 ratio (American Psychiatric Association, 2013). A variety of symptoms are reported by individuals with anxiety disorders including sleep problems, fatigue, muscle tension, or intense fear (NIMH, 2018). More severe symptoms can include sudden and repeated attacks of fear, pounding and racing heart, and purposely excluding oneself from certain people or places.

Literature Review

Various biofeedback modalities have been implemented by clinicians in the treatment of anxiety including electromyography (EMG), peripheral temperature, and electrodermal response (EDR) prior to neurofeedback's (NF) popularization (Price & Budzynski, 2009). NF, a subcategory of biofeedback, has been used to lower anxiety

symptoms in a variety of populations, as addressed throughout the following reviewed literature.

Singer (2004) used NF on two female dancers, 27 and 52 years of age, who had persistent levels of performance anxiety. A State-Trait Anxiety Inventory (STAI; Spielberger, 1983) assessment was taken by each participant before a NF session and before each of their major dance performances. The course of NF treatment included 20 sessions at the time interval of 30 min per session. Sensors were placed on site locations T3 and T4, and thresholds were adjusted during each session dependent upon the participant's response. Postassessments indicated a significant decrease in anxiety symptoms associated with performance. The trait anxiety portion of the first participant's assessment indicated a decrease in score from 59 to 43.5, while the state portion underwent a decrease in score of 66 to 44. The trait anxiety portion of the second participant's assessment indicated a decrease in score as well, from 52 to 36, while the state portion underwent a decrease in score of 56 to 30. Limitations to this study included a small sample size, lack of individualized protocols, and no control group.

A study by Kerson, Sherman, and Kozlowski (2009) illustrates how the various modalities of earlobe temperature training, alpha suppression, and alpha symmetry training were used in eight adults who either were diagnosed with generalized anxiety disorder or presented with multiple anxious behaviors. Participants were assessed for high alpha frequency at the International 10-20 Electrode system sites Fp1, Fp2, F3, F4, F7, and F8. A 5-min baseline electroencephalogram (EEG) of the participants was recorded with their eyes open for the initial measurement and with their eyes closed for the secondary measurement. Postbaseline measures were also recorded 1 week after the last NF training occurred. The initial six sessions were used to increase the participants earlobe temperature. The following 6–16 sessions consisted of decreasing alpha magnitude by 10% in the anterior lobes for 30 or more minutes. Once alpha was suppressed, the protocol shifted to improvement of alpha symmetry by a 15% increment for 30 minutes or more during 8–32 sessions. All sessions were conducted on a biweekly basis. Continued assessment of participants was conducted throughout the study by means of the STAI, in which a significant improvement in scores resulted. The pre- and postmean change in EEG was 1.41 *z*-scores towards the mean. Limitations mentioned within the study include a limited amount of participants, lack of variance in protocols, and the lack of a control group.

Walker (2009) implemented a study based upon whether NF could lower anxiety symptoms for 19 clients diagnosed with posttraumatic stress disorder (PTSD). Four clients, who were originally diagnosed with PTSD and in the NF group but had dropped out after the quantitative electroencephalography (qEEG), were included in the control group. Each received a qEEG examination using the Neuroguide software and Lifespan Normative database. Excessive high frequency beta (21–30 Hz) was then downtrained for 5–7 sessions for each site that presented excessive high frequency beta;10 Hz activity was uptrained at the same sites. The sites were in various and multiple areas depending on where the excessive beta was located, as protocols were determined by a qEEG. A self-rated anxiety Likert scale from 1–10 was also used to determine the amount of anxiety each participant had felt. The number of sessions per individual ranged from 5–7. Participants who had NF training had a significant reduction in self-rated anxiety with a pretreatment score of 5/10–7/10 to a posttreatment score of 0/10–2/10, and 1 month after NF training the scores remained at 0/10–2/10. Subjects who did not have NF training had little or no reduction in self-rated anxiety 3 months after their qEEG. Limitations with this study include using a self-rating scale for anxiety rather than an evidence-based assessment.

A study by Scheinost et al. (2013) evaluated 10 subjects with contamination anxiety to undergo functional magnetic resonance imaging (fMRI) NF training and compared their neural connectivity with real-time functional magnetic resonance imaging (rt-fMRI). A matched control group of 10 subjects that received sham fMRI-NF (SNF) of their matched pair was used. Subjects had an initial fMRI to localize their activity in the orbitofrontal cortex (OFC) from contamination anxiety. They then met with a psychologist to discuss strategies for manipulating brain activity that could later be refined during fMRI-NF. There were eight sessions total where subjects were shown contamination-related photos and asked to rate their anxiety on a scale of 1–5. The first and the last session consisted of subjects being asked to implement the personal coping mechanisms which they would typically use to try to lessen their anxiety. The middle six sessions consisted of 90 min of fMRI-NF. The fMRI-NF sessions consisted of subjects receiving cues of when to increase activity their OFC area, when to decrease activity, and when to rest based on their OFC output. Resting cues included a neutral image.

Between-group differences in fMRIs were identified using Wilcoxon's rank-sum test. The fMRI-NF group reported greater self-reported reduction in anxiety (p = .02) compared to the SNF group (p = .45). The fMRI-NF group had significant (p < .05) neural changes compared to the SNF group as recorded by the last fMRI taken several days after the last fMRI-NF session. The fMRI-NF group had significant decrease in connectivity for the brain regions associated with emotion processing, including the insula and adjacent regions, the hippocampi, parahippocampal and entorhinal cortex, the right amygdala, the brain stem in the vicinity of the substantia nigra, the temporal pole, superior temporal sulcus, thalamus and fusiform gyrus. The fMRI-NF group also had an increased degree of connectivity that was seen in prefrontal areas associated with emotion regulation and cognitive control, including right lateral prefrontal cortex and bilateral portions of Brodmann's area 8. This study illustrated how changes directly resulting from fMRI-NF were possible and how structural changes can last days after a fMRI-NF session. This study also supported the idea of finding and confirming a localized area related to a symptom and using that area for fMRI-NF. Limitations to this study include low number of fMRI-NF sessions and a small sample size.

A study conducted by Cheon et al. (2015) researched NF implemented on 77 adults diagnosed with various psychiatric disorders within a psychiatric setting. The following disorders are listed in order of prevalence according to the research: depressive disorders, anxiety disorders, sleep disorders, somatoform disorders, adjustment disorders, bipolar disorder, schizophrenia, attention-deficit/hyperactivity disorder, alcohol dependence, game addiction, and impulse control disorder. Protocols were designed depending on the participant's chief complaint (e.g., anxiety, emotional instability, lethargy, etc.), the opinion of the attending psychiatrist, neuropsychiatric evaluation results, and the subjective symptom rating scale. The Clinical Global Impression-Severity Scale (CGI-S; Busner & Targum, 2007) and the Hill–Castro Checklist (Hill & Castro, 2002) were also implemented on a weekly basis as a measure of treatment effectiveness. NF protocols included training sensorimotor rhythm (SMR), beta, and/or also contained alpha-theta training. The various frequency bandwidths which were rewarded during training, included SMR between 12–15 Hz, beta between 15–18 Hz, theta between 5–8 Hz, and alpha between 8–12 Hz. The individualized site locations in which training was implemented included Fp1, Fp2, F3, F4, F7, F8, T3, T4, C3, C4, P1, P2, O1, O2, and Oz based on the International 10–20 Electrode system. Alpha-theta training was conducted at the PZ site location. Protocols were evaluated and finalized during weekly NF meetings which included a team of three psychiatrists trained in NF, as well as a trained NF therapist. The number of appointments for client's training ranged from 1 to 20 or more sessions. The Hill–Castro Checklist score showed an improvement in multiple symptom areas including anxiety (p < .001). The pre- and post-CGI score showed a significant reduction in the severity of symptoms (p < .001). Limitations mentioned within the study included having a heterogenous group and no control group, as well as not utilizing the qEEG to determine protocols.

Dreis et al. (2016) published a pilot study of NF provided to 14 anxious clients at a university-based community counseling center, showing significant improvements in symptoms measured by the Zung Anxiety Scale and Achenbach System of Empirically Based Assessment (ASEBA) checklists. This study is a continuation of that pilot.

These studies illustrate how NF can be a viable tool in lowering anxiety symptoms. They each have their strengths and limitations. A substantial limitation is either using the same protocol for each patient and/or using a protocol based on symptoms alone. Hammond (2010) expresses the importance of using a qEEG to identify heterogeneity in brain wave patterns, finding comorbidities, and looking for effects from medication.

The correlation between frontal alpha symmetry, negative affect and anxiety was studied by Mennella et al. (2017), comparing two neurofeedback treatments of F4-F3 alpha asymmetry with Fz alpha uptraining on respective groups of 16 right-handed females each. The findings indicated a significant increased frontal alpha asymmetry, which correlated with symptom improvements, as compared to the midfrontal alpha group.

Krigbaum and Wigton (2014) argue the importance of qEEG-guided and z-score NF as it allows the clinician to develop a more individualized treatment plan which encompasses a qEEG baseline, clinical status, and history of the client. Wigton and Krigbaum (2015) further assert how 19-channel z-score NF (19ZNF) protocols facilitate identifying the link between localized cortical dysfunctions and connectivity issues associated with mental health symptoms. In this modality, qEEG metrics are compared to a normative database to create z-

scores; then, those *z*-scores are incorporated into the NF protocol in real time during the session. This allows for pretreatment assessment, a helpful tool in measuring progress with the client, and combining real-time assessment with the operant conditioning of NF. Thus, 19ZNF training is used to bring these scores closer to the mean, otherwise known as *normalizing*. Moreover, 19ZNF protocols also reduce the number of sessions which is more economical for the clients. Wigton and Krigbaum's pilot study used 19ZNF to train the deviant *z*-scores.

Unlike Wigton and Krigbaum (2015), this research is a study which used single-channel amplitude training, rather than *z*-score training, for three reasons: (1) it is commonly used by many practitioners, (2) it is a straightforward method for students in training to learn before advancing to other modalities, and (3) the numerous one-channel amplitude training studies which exist in the literature, as reviewed by Wigton (2014). Therefore, based on the literature review, this study sought to assess whether individualized qEEG-guided amplitude NF is a viable treatment for anxiety symptom reduction.

Methods

Clients

Clients contacted the Sarabia Family Counseling Center at the University of Texas at San Antonio (UTSA) to receive therapy and NF treatment free of charge. Clients learned about the clinic through community referral sources and/or university media relations. Upon calling, clients were screened by master- or doctoral-level students in the UTSA Department of Counseling to determine if they met the criteria for receiving NF treatment, including primary anxiety symptoms, availability, and age requirements. If the individual satisfied the clinical criteria, as well as the required biweekly availability and willingness to complete the treatment requirements on an ongoing basis, the clients were then scheduled to meet with a NF student clinician. Prior to completing any formal assessments of anxiety, student clinicians acquired a comprehensive informed consent from each client. As retrospective research, the study was deemed to be exempt from review by the UTSA Institutional Review Board.

Demographics include age ranges from 19 to 62 (M = 37.7, SD = 13.87). Gender identification comprised 21 male and 19 female. Fifteen clients self-identified as White (Non-Latino; 38%), 14 as Latino/Latina (35%), and 11 did not self-report ethnicity (28%). Pre- and postassessments were given to the participants. Symptom assessments included the Zung Self-Rating Anxiety Scale and ASEBA Adult Self-Report (ASR). A qEEG was used to determine protocols for each participant. Participants were scheduled to receive 30-min NF treatment sessions twice a week for one academic semester.

Therapists

The student clinicians consisted of master and doctoral-level students within a program certified by the nationally accredited Council for Accreditation of Counseling and Related Education Programs (CACREP). These students are also in the supervision phase of pursuing their Board Certification in NF (BCN); thus, they were overseen by a certified and licensed supervisor. Students had previously completed the required graduate curriculum, which met the blueprint required by the Biofeedback Certification International Alliance (BCIA; www.bcia.org).

Measures

A within-subjects research design was implemented which included the following precondition and postconditional assessments: the Zung Self-Rating Anxiety Scale for adults, the age-appropriate self-reports for the Achenbach System of Empirically Based Assessment (ASEBA), and qEEG. The symptom measurements were selected on the bases of their focus on anxiety symptoms, widespread acceptance in the therapeutic community, and standardization.

The qEEG measures assessed patterns in the EEG and qEEG, such as attenuated alpha, fast alpha tuning, excess beta and/or high beta along the midline, and hypercoherent frontal alpha.

Instrumentation

The qEEGs were acquired via 19-channel recordings in the eyes-closed and eyes-open conditions in a resting state, using a BrainMaster (BrainMaster Technologies, Inc., Bedford, OH) Discovery 24 high-impedance amplifier and Neuroguide (Applied Neuroscience, Inc., Largo, FL) software. Recordings utilized correctly sized Electro-Cap (Electro-Cap International, Inc., Eaton, OH) 10-20 electrode appliances which were fitted as per manufacturer's guidelines and ear-clip leads placed. Preparation of electrodes was performed in a manner adequate to achieve impedance levels of less than 5 kohms (Jones, 2015). NF was provided utilizing BrainMaster Atlantis two-channel amplifiers and BioExplorer (Cyberevolution, Inc., Seattle, WA) software. Electrode site preparation was done by

cleaning the site, ground, and reference locations with rubbing alcohol and abrading using PCI prep pads and Nuprep. Gold-plated electrodes were attached to the clients using Ten-20 paste. Impedance measurements were taken to ensure that interelectrode impedance was less that 5 kohms (Jones, 2015).

Protocols

Clients agreed to attend a minimum total number of 15 NF training sessions that were to be held at the same time, twice per week, and free of charge. Participants were instructed to discontinue the consumption of caffeine or any other nonessential substances on treatment days, prior to their session. At least a 24-hour window prior to the qEEG recording was suggested for clients to restrict consumption for nonessential substances, unless otherwise medically directed. All medically directed substances were factored into qEEG interpretation and protocol development.

The range of attended sessions was 7–19 (M = 12.72, SD = 2.78). An accurate number of session data was unavailable for four of the subjects. The training protocols consisted of amplitude uptraining and/or downtraining of selected frequency bands based on qEEG findings. Protocol selections were based on current research and reflect markers found to be associated with anxiety issues (Dantendorfer et al., 1996; Demerdziev & Pop-Jordanova, 2011; Gold, Fachner, & Erkkilä, 2013; Gunkelman, 2006; Heller, Nitschke, Etienne, & Miller, 1997; Johnstone, Gunkelman, & Lunt, 2005; Price & Budzynski, 2009; Savostyanov et al., 2009; Siciliani, Schiavon, & Tansella, 1975; Stern, 2005, p. 196; Tharawadeepimuk & Wongsawat, 2014; Walker, 2009).

Based on the preferences of the clients and clinical judgment of the practitioners, feedback was presented using a variety of formats: games, animations, sounds, and analog presentations (such as the size of boxes representing the amplitude of the respective bandpass filtered EEG signals). Thresholds were set manually at the beginning of the session based on the aimed percentage of a successful reward rate of approximately 50% of the time. Periodic adjustments were made to the threshold settings within and between sessions as needed to shape behavior towards the client's specific treatment goals. Records were made for each session, which included frequency bands, threshold settings, session average amplitude levels, type of feedback utilized, and significant details from client reports and clinician impressions. EEG data was recorded for each session.

Statistical Analysis

The statistical analysis for the symptom measure assessments were paired t-tests using IBM SPSS Statistics Version 25. Means were compared for pre–post scores on the Zung Anxiety Scale and the ASEBA scales most pertinent to anxiety symptoms: Anxious/Depressed, Anxiety Problems (DSM), and Total Problems. The Total Problems Scales was selected as it represents a wide-range sampling of other scales to reflect overall severity.

Results

Symptom Measures

All grouped, averaged pre–post comparisons of the Zung Anxiety Scale resulted in improvements. A cumulative summary of these results are presented in Table 1. On the Zung Anxiety Scale, for all subjects, the mean of the prescores was 44.90 (SD = 8.32) and the mean of the postscores was 37.18 (SD = 8.19). The t-test yielded a statistically significant improvement, with t(df) = 7.750(39), p < .001, d = 1.23.

On the ASEBA, a statistically significant improvement was measured in three scales deemed most pertinent to the study: Anxious/Depressed, Anxiety Problems (DSM), and Total Problems. The results are presented in Table 2.

Table 1
Zung Anxiety Scale

	Pre *M* (*SD*)	Post *M* (*SD*)	*t*(df)	*p*	*d*
Zung Anxiety Scale	44.90(8.32)	37.18(8.19)	7.750(3)	< .001	1.23

Note. n = 40.

Table 2
Achenbach Behavior Checklist (Adult Self-Report)

Category	Pre *M* (*SD*)	Post *M* (*SD*)	*t*(df)	*p*	*d*
Anxious/Depressed	68.93(10.84)	59.90(11.52)	3.872(39)	< .001 **	1.23
Anxiety Problems (DSM)	65.73(7.85)	61.60(8.49)	3.277(39)	.002 *	1.61
Total Problems	64.68(10.84)	60.79(11.52)	4.381(39)	< . 001 **	2.00

Note. *p < .01, **p < .001. n = 40.

As the number of sessions per client varied, an opportunity existed to compare number of sessions with reductions symptom measures. The Zung Anxiety Scale changes (pre to post) are plotted on a scale of number of sessions in Figure 1. Based on the sixth order polynominal trendline of improvements in the Zung Anxiety Scale measures, it may be inferred that symptom reduction was associated most highly with 11–14 sessions of treatment.

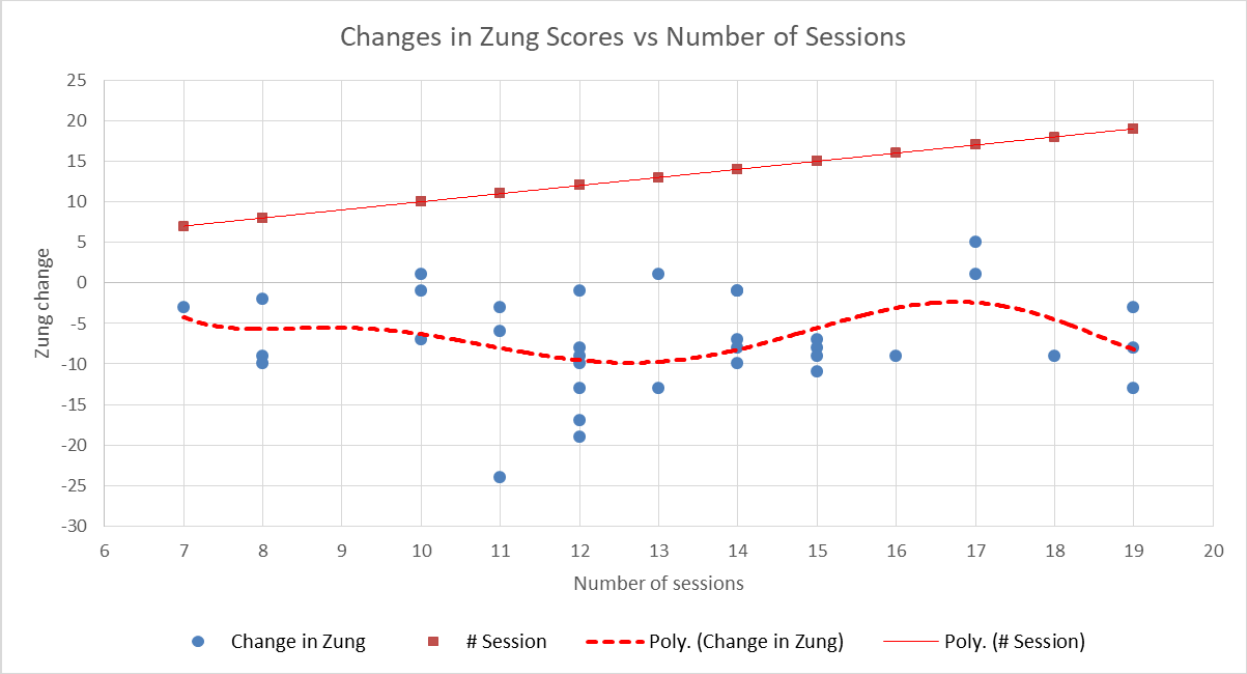

Figure 1. Scatter plot of changes in Zung Anxiety Scale scores (pre to post) by number of sessions. Lower scores reflect improvement.

Discussion

Symptom improvement was made evident with various assessments including the Zung Anxiety Scale and ASEBA. Taken together, the symptom scales present evidence of a significant improvement in clients' anxiety symptoms and sense of well-being.

Due to accreditation restrictions at the university-based counseling center in which the study was conducted, no treatment sessions may be provided between semesters. As a result, the number of sessions was limited to what may be provided during a semester. Therefore, the design was built around the time available for pre- and postassessments and the beginning and end of the semester, respectively, and treatment provided in the intervening weeks. While the results based on an average of approximately 12 sessions were significant, it remains unknown what additional improvements may have been achieved with more treatment

sessions. The scatter plot in Figure 1, however, may indicate that 12 sessions may be an adequate number of treatment events to achieve a significant result.

The variety of sessions per client reflects an additional factor of the study as a retrospective analysis. The researchers were somewhat at the mercy of clients who had varying degrees of motivation and means to complete a full regimen of sessions. For example, some clients struggled with transportation challenges, employment issues and/or schedules, and lack of family support. That sessions were conducted during daytime hours on week days only compounded some of these challenges.

A small sample size and the lack of a sham/control group were roadblocks to an effective research design in some aspects of the study. Given that the study was retrospective, clients were seeking treatment with a valid expectation of receiving bona fide therapy. In addition, the resources and purpose of the program were not compatible for a controlled study.

A pre–post measure of physiological changes would have strengthened the research design. Due to the wide variability in protocols and qEEG findings, significant challenges existed for quantifying specific treatment effects which may then be assessed at a group level. As the program moves forward—and with additional equipment—pre–post ERP findings will be incorporated as one way to measure physiological changes.

There was variability in the skill and experience levels of the student counselors. Students were at various levels in their studies within their degree program and in the NF program. Controls for the effect of student bias and skill level differences were: supervision from the professor who monitored the treatment via informal verbal reports from students and clients, session notes, closed-circuit television, and weekly case conferences.

Client variables that were not controlled for which may have influenced treatment outcomes include adjunct therapies (previously or concurrently used), medications, familial/financial/extraneous life stressors and major life events, injuries/illnesses, changes in sleep, and other therapeutic lifestyle changes (i.e., diet, exercise, and medication). Some of the clients in the study were taking psychotropic medications, such as benzodiazepine-class anxiolytics and SSRIs. While these effects on the EEG were assessed as part of the qEEG analysis, they remain as a confounding variable for treatment outcomes.

Training was conducted using amplitude measures and monopolar site placements only. While this was by design, it excluded other forms of NF which may be based on connectivity measures and multiple site placements.

Finally, it is worth emphasizing that the setting of the study is a community counseling center, located on a university campus, operated as part of a graduate counseling educational program. As such, the prevailing values in the treatment are (1) the well-being and therapeutic needs of clients and (2) the learning opportunities for students. It became obvious to the professor and students that these priorities, at times, took precedence over a purely NF-based research design in ways that may have compromised the acquisition of “clean” data.

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