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Connectivity-Guided EEG Biofeedback for Autism Spectrum Disorder: Evidence of Neurophysiological Changes

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Abstract

Recent studies have linked neural coherence deficits with impairments associated with Autism Spectrum Disorders (ASD). The current study tested the hypothesis that lowering neural hyperconnectivity would lead to decreases in autistic symptoms. Subjects underwent connectivity-guided EEG biofeedback, which has been previously found to enhance neuropsychological functioning and to lessen autistic symptoms. Significant reductions in neural coherence across frontotemporal regions and source localized power changes were evident in frontal, temporal, and limbic regions following this treatment. Concurrently, there were significant improvements on objective neuropsychological tests and parents reported positive gains (decreases in symptoms) following the treatment. These findings further validate EEG biofeedback as a therapeutic modality for autistic children and suggest that changes in coherence anomalies may be related to the mechanism of action.

Keywords: EEG biofeedback, autism, ASD, connectivity, coherence, LORETA

Introduction

The Centers for Disease Control and Prevention now indicates that the current prevalence of Autism Spectrum Disorder (ASD) is 1 in 68 (CDC, 2014). Furthermore, the U.S. Department of Education reported that from the 1992-1993 to 2001-2002 school years the rate of Autism increased 528% and seems to continue to be on the rise (Safran, 2008; Yeargin-Allsopp, Rice, Karapurkar, Doernbert, Boyle, & Murphy 2003). Ganz (2006) found that in the United States approximately $3.2 million is spent to care for a single individual with Autism over the course of his or her lifetime, which in turn equates to a total cost of $35 billion annually.

Beyond the monetary costs, countless other collateral effects are felt by family members who care for those with ASD and by the individuals themselves.

Autism is a neurodevelopmental disorder characterized by a triad of impairment in social interaction, communication, and restricted patterns of behavior or interests (APA, 1994). The Diagnostic and Statistical Manual-Fourth Edition (DSM-IV) criteria states that autism cannot be diagnosed before three years of age; however, a recent survey has found that parents have reported autistic symptoms as early as 18 months and have even sought medical treatment before the age of two (APA, 1994; Filipek et al., 1999). The heterogeneous range of pervasive developmental disorders includes the following classifications: autistic disorder, Rett's syndrome, childhood disintegrative disorder, Asperger's disorder, and pervasive developmental disorder not otherwise specified (PDD-NOS; DSM-IV, APA, 1994). These classifications are categorized by a broad range of common symptoms coupled with levels of severity. Speech may be inflexible and unresponsive to the context as well as limited to echolalia or narrow topics of expertise in which discourse can proceed without conversational interplay (Belmonte, Beckel-Mitchener, Boulanger, Carper, & Webb 2004). Moreover, social behaviors are often characterized by lack of interaction; play lacks cooperation in which the child usually confines himself or herself to playing on the periphery of the group. Additionally, the imagination of a child with ASD is usually deficient and the individual narrowly focuses on repetitive behaviors (Belmonte et al., 2004).

Recent research points to a theory of faulty neural connectivity as a mechanism underlying the symptoms of ASD (Baron-Cohen, 2004; Belmonte et al., 2004). "Connectivity" can be defined as any number of means of measuring the communication between two or more neural locations within the brain (Coben, 2007). Rippon, Brock, Brown, and Boucher (2007) suggested a model of Autism associated with information integration deficits resulting from reduced connectivity between specialized local neural networks and over-connectivity within individual neural assemblies, most notably within the frontal lobes. Over-connectivity, or hyperconnectivity, refers to excessive communication between neural locations in the brain. Over-connectivity of neural assemblies within and between the frontal lobes have been found to lead to disruptions in the integration of information from emotional, language, sensory, and automatic systems (Courchesne & Pierce, 2005). Mizuno, Villalobos, Davies, Dahl, and Muller (2006) found though the use of fMRI data that individuals with ASD have areas of excessive connectivity within numerous neural locations, most notably the right postcentral and middle frontal regions as well as the left insula. Likewise, Buxhoeveden, Semendeferi, Schenker, and Courchesne (2004) reported evidence that Autism is a disorder of excessive connectivity within the frontal lobes, which in turn impacts the neural connectivity between the frontal cortex and other brain systems. Diffusion Tensor Imaging (DTI) studies of subjects with ASD have revealed evidence of the following neural abnormalities: increases in cerebral white matter volumes within the frontal cortex, abnormally small minicolumns in the frontal area, and abnormally long dendritic spines present in high densities. Variable resolution electromagnetic tomography (VARETA) images of patients with ASD also showed increased activity in the cerebellum, thalamus, hippocampus, parahippocampal, cuneus, cingulate, and lingual gyrus as well as in temporal, precentral, postcentral, parietal, and occipital cortical regions (Coben, Chabot, & Hirschberg 2013). All of the aforementioned evidence is indicative of frontal dysfunction consistent with hyperconnectivity for subjects with ASD (Barnea-Goraly et al., 2004; Herbert et al., 2004; Buxhoeveden et al., 2004; Semendeferi et al., 2004; Belmonte et al., 2004). It has recently been hypothesized that reducing neural hyperconnectivity within the autistic brain can lead to improvements in realms such as, but not limited to, attention, self-regulatory functions, social behavior, and communication skills (Coben & Myers, 2008).

Electroencephalographic (EEG) analysis provides real time neural data of electrical activity across multiple regions with excellent temporal resolution. Cantor, Thatcher, Hrybyk, and Kaye (1986) conducted computerized EEG analyses of 11 children with ASD between the ages of 4 and 12 years, in contrast to three other groups of children: (a) 88 normal children, (b) a matched group of 18 mentally handicapped children, and (c) a group of 13 mental age-matched normal toddlers. The findings indicated that children with ASD had significantly greater coherence between hemispheres in the beta band than mentally handicapped, normal children, or normal toddlers. Children in the autistic group had higher coherence in the alpha band than did those in the normal group, and had less interhemispheric and intrahemispheric asymmetry than participants in the normal or mentally handicapped group. "Coherence" is one means of measuring connectivity based on EEG data and represents a specific mathematical calculation of the cross-correlation between two waveforms within a frequency band. These findings would appear to suggest that the EEG is a useful and valid means of measuring coherence anomalies in this population. Continuing, Murias, Webb, Greenson, and Dawson (2007) used EEG analysis to assess connectivity in 18 adults with ASD in comparison to 18 healthy adult controls in eyes-closed resting states. Their results showed that there was locally elevated coherence in the ASD group, particularly within the left hemisphere in a low frequency (theta) band. In the lower alpha range (8–10 Hz), far-reaching reduced coherence was evident for the ASD group within frontal regions, and between frontal regions and all other scalp locations (Murias et al., 2007). These results indicate a pattern of over-connectivity and under-connectivity in the brain of subjects with ASD. Coben, Clarke, Hudspeth, and Barry (2008) compared 20 children with and without ASD, matched for gender, age, and IQ. Findings were suggestive of dysfunctional integration of frontal and posterior sites with patterns of extensive coherence anomalies. Coben et al. (2013) studied 91 children with ASD and compared them to 91 normal controls. The findings showed differences for EEG power, asymmetry, and coherence. There was a combination of both hyper- and hypocoherence with high coherence over frontal regions and with low coherences across temporal and posterior brain regions.

Preliminary research suggests that EEG biofeedback may be an effective form of therapy for reducing autistic symptoms in children (Coben & Padolsky, 2007; Jarusiewicz, 2002). EEG biofeedback enables the clinician to train the brain to work in a new, more efficient way through the use of underlying operant conditioning paradigms. This treatment involves providing a subject with visual and auditory "feedback" for particular neural behaviors (Monastra, Monastra, & George, 2002). Through conditioning, the subject is taught to inhibit EEG frequencies that are excessively generated and to augment frequencies that are deficient. With continuous training and coaching, subjects are taught to maintain brainwave patterns concurrent with healthy neural functioning. Recently, Walker, Kozlowski, and Lawson (2007) presented evidence demonstrating the ability of neurofeedback training to successfully train neural functioning to more normal states, while simultaneously showing reductions in autistic symptoms. For more in-depth information regarding EEG biofeedback the interested reader is referred to Hammond (2007). The efficacy of EEG biofeedback for autistic children was initially assessed by Jarusiewicz (2002), in which she reported a 26% decrease in autistic symptoms in the experimental group and a 3% reduction in a wait-list control group. Further, this therapy is a therapeutic intervention that can be achieved over the course of a few months, has no demonstrable side effects, and is useful for a wide array of disorders including ADHD, epilepsy, dyslexia, and other areas of functioning (Leins et al., 2007; Hammond, 2007; Lubar, Swartwood, Swartwood, & O'Donnell, 2005; Egner & Sterman, 2006; Evans & Park, 1996).

In our previous study (Coben & Padolsky, 2007), we presented evidence supporting the efficacy of connectivity-guided EEG biofeedback for ASD. Parental judgment of clinical improvement was positive in 89% (33 of 37 subjects) of the experimental group. This was significantly different from the control group in which 83% of parents reported no change. Importantly, no subject in either group reported a worsening in autistic symptoms. Parental ratings on the Autism Treatment Evaluation Checklist (ATEC; Rimland & Edelson, 2000) showed a 40% decrease in core autistic symptoms as a result of this intervention in the experimental group. Decreases in autistic symptoms were also found on the Gilliam Asperger's Disorder Scale (GADS; Gilliam, 2001), Gilliam Autism Rating Scale (GARS; Gilliam, 1995), Personality Inventory for Children, Second Edition (PIC-2; Lachar, & Gruber, 2001), and Behavior Rating Inventory of Executive Function (BRIEF; Gioia, Isquith, Guy & Kenworthy, 2000). In comparison, no such changes were evident in the wait-list control group. Finally, pre-post neuropsychological evaluations of attention, visual perceptual, language, and executive functioning revealed increases in the experimental group's neuropsychological performance, as much as a one standard deviation improvement per domain, by the completion of the study.

In the present study we expand on these previous findings by presenting data regarding changes in brain functioning. Source localized changes in EEG power and coherence will be explored. We hypothesize that connectivity-guided EEG biofeedback is an intervention capable of changing the autistic brain in a therapeutic manner. We further hypothesize that reducing neural hypercoherence underlies the above reviewed clinical efficacy of this approach.

Method

Participants

Thirty-seven children diagnosed with ASD were utilized for this study as the experimental group, while 12 children also diagnosed with ASD served as the wait-list control group. The groups did not differ significantly in terms of age, gender, race, handedness, other treatments, or severity of ASD as indicated by the ATEC. The experimental group received at least 20 sessions of connectivity-guided EEG biofeedback training, while the wait-list control group received no experimental treatment. Finally, the necessary informed consent was obtained and all procedures were fully explained to parents in order for their children to participate in the study.

The experimental group included 31 males and 6 females with ages ranging from 3.92 to 14.66 years with a mean age of 8.92 years. This group contained 36 Caucasians and one Asian American. Among the experimental group 56.8% ($n = 21$) were diagnosed with PDD-NOS, 18.9% ($n = 7$) with Autism, 13.5% ($n = 5$) with Asperger's syndrome, and 10.8% ($n = 4$) with childhood disintegrative disorder. The wait-list control group included 10 males and two females with ages ranging from 5.83 to 10.92 years with an average age of 8.19 years.

Materials

EEG data collection. EEG data was collected in part as the basis for evaluating coherence differences in this study. EEG data was obtained under two conditions, eyes closed and eyes open. A stretchable electrode cap embedded with 19 sensors attached to the scalp was used to collect data, with frontal reference, prefrontal ground, and linked ears. Each recording lasted 20 minutes, where 10 minutes were spent in both conditions. All the data

collected was manually artifacted and analyzed for measures of multivariate coherence/connectivity in NeuroRep (Hudspeth, 1999). Further, Neurometric Analysis System (NxLink, 2001; John, Prichep, Fridman, & Easton, 1988) and Neuroguide (Thatcher, Walker, Biver, North, & Curtin, 2003), both of which are FDA approved, were used to analyze absolute power, relative power, and coherence (Thatcher et al., 2003). The reliability and validity of quantitative EEG (QEEG) have been sufficiently assessed and confirmed (Thatcher et al., 2003).

QEEG involved recording and digitizing EEG readings based on the International 10/20 System of electrode placement utilizing the Deymed Diagnostic (2004) TruScan 32 Acquisition EEG System. This system included 32 channels with sampling at 128 cycles per second and filtering between 0.1–40 Hz. All recordings were done with impedance less than 5 kOhms. The common mode rejection ratio for this system is 102 dB and the isolation mode rejection ratio is 140 dB. QEEG analysis mathematically compares an individual EEG reading to matched normative samples for age and gender. Through this analysis inconsistencies in EEG neural functioning can be located and addressed. Moreover, it has been found that QEEG analysis provides reliable descriptors of normative brain activity (John et al., 1988). QEEG analyses were performed both before and after the administration of connectivity-guided EEG biofeedback.

Neurofeedback equipment. The NeuroCybernetics EEGer Training System (NeuroCybernetics Inc., 2006) was used to perform connectivity-guided EEG biofeedback training. The sensors (Grass Silver Disc 48" Electrodes with SafeLead protected terminals; Grass SafeLead, 2006) were applied to the subject's scalp to measure EEG activity. The signal was then fed back to the subject in visual and aural form based on relative amplitude/threshold values. The visual feedback consisted of simple graphics (presented in the form of computer games), providing a continuous display of the ratio of amplitude to threshold for each stream of data. The aural reward consisted of a pre-recorded sound file of a short quarter of a second beep, occurring no more often than once per every half second and activating when specific amplitude/coherence conditions were met (NeuroCybernetics Inc., 2006). Treatment was personalized to each individual on the basis of his or her original QEEG findings for power and coherence. Based on each participant's QEEG analysis, areas showing the most prominent hypercoherence were targeted for training. QEEG analysis involved analytically comparing a participant's individual EEG data to normative data indicative of such factors as age, gender, etc. For example, based on pre-treatment QEEG analysis, one patient was found to have maximal hypercoherence in the right frontal region primarily in alpha. A protocol was designed for this patient to reward alpha (the frequency range of maximal hypercoherence) and to inhibit lower and higher frequency EEG activity at electrode sites F8/F7. This was achieved by increasing or rewarding the EEG amplitude between sequential EEG sensors on the scalp within the frequency range of maximal hypercoherence.

EEG amplitude can be defined as the difference between frequencies measured from an active and a reference sensor site. Therefore, increasing EEG amplitude (difference) implies decreasing coherence (similarity) between the EEG electrode sites; intrinsically this process causes two electrode sites to become more disparate. This is the crux of application of connectivity-EEG biofeedback as a means to decrease hypercoherence in children with ASD. Moreover, amplitude was chosen for training due to the relative ease in manipulation as described above. For a more in-depth discussion into the personalization of protocols, the interested reader is referred to Coben (2007).

eLORETA. Exact Low Resolution Brain Electromagnetic Tomography (eLORETA) is a functional tomography that uses EEG data to create three-dimensional slices of neural activity highlighting areas of underactivity and overactivity (Pascual-Marqui, 1999). From these three-dimensional image slices of cortical grey matter, the neurofeedback clinician can better assess activity deep within the brain beyond the EEG detectable at the surface. To localize these power differences we chose eLORETA, which is the third incarnation of the LORETA system. eLORETA is currently considered the most exact version, and has been evaluated and found to be a useful tool for localizing power differences (Pascual-Marqui, 2007). Further, the empirical validity of eLORETA has been sufficiently substantiated (Pascual-Marqui, Esslen, Kochi, & Lehmann, 2002).

Assessment scales. GARS is a behavioral checklist. This scale is comprised of four subtests (Stereotyped Behaviors, Communication, Social Interaction, and Developmental Disturbances) of 14 items each. The scale was normed on a sample of 1,092 children and young adults (aged 2 to 28) across 46 U.S. states, the District of Columbia, Puerto Rico, and Canada. The internal consistency reliability coefficients for all subtests and total Autism Quotient range from .88 to .96. The stability or test-retest reliability ranges from .81 to .88 for all subtests and total Autism Quotient. These results indicate high levels of stability required for pre-post treatment assessment of individuals with ASD. The construct validity was confirmed by analyses finding that: Items of the subscales are representative of the behaviors associated with Autism; GARS scores strongly relate to each other and to performance on other screening tests for Autism; GARS scores are not related to age; and individuals with other diagnoses score differentially on the GARS. The GARS is a scale shown to discriminate between autistic and non-autistic subjects with a 90% accuracy rate.

GADS is a behavioral rating scale. The GADS consists of 32 items divided into four subscales including: Social Interaction (10 items), Restricted Patterns of Behavior (8 items), Cognitive Patterns (7 items), and Pragmatic Skills (7 items). The GADS was normed on a sample of 371 individuals (aged 3 to 22; males [$n = 314$], females [$n = 57$]) diagnosed with Asperger's disorder from across 46 U.S. states, the District of Columbia, Canada, Great Britain, Mexico, Australia, and other countries. Internal consistency reliability coefficients ranged from .87 to .95 for total Asperger's Disorder Quotient across samples of children with and without identified disabilities. The test-retest reliability for the Asperger's Disorder Quotient is .93 ($p < .01$). These results indicate that the GADS has a high level of stability for use as a pre-post treatment measure of individuals with Asperger's disorder. Construct validity was indicated by analyses finding that: GADS scores are minimally related to age; items on the subscales are representative of behaviors associated with Asperger's disorder; persons with other diagnoses score differentially; GADS scores are strongly related to each other and performance on other tests that screen for serious behavioral disorders; and the GADS can discriminate among individuals with Asperger's disorder and those with behavioral disorders. The GADS has been found to have an 83% accuracy rate in discriminating Asperger's and non-Asperger's subjects (Gilliam, 2001).

Procedure.

A diagnostic interview was conducted with the parents to ascertain core behavioral, cognitive, and social/emotional issues of concern as part of a comprehensive neurodevelopmental history. Additionally, all participants involved in this study met the criteria for either: autistic disorder, Asperger's disorder, childhood disintegrative disorder, or PDD-NOS as described by the DSM-IV (APA, 1994). A second inclusion criteria for this study were scores on the GADS and the GARS. Only subjects with a total Asperger's

Disorder Quotient of 70 or greater on the GADS or an Autism Quotient of 70 or greater on the GARS were used in this study.

All participants underwent QEEG analysis both before the start of connectivity-guided EEG biofeedback training as well as at the completion of no less than 20 sessions. A QEEG was performed before the administration of connectivity-guided EEG biofeedback in order to assess baseline levels of hyperconnectivity, coherence, and power. Again, this baseline is assessed by analytically comparing each participant's individual EEG data to a normative QEEG prior to treatment. Based on this original analysis, personalized EEG biofeedback protocols were designed so as to optimally and efficiently decrease hypercoherence in each subject. QEEG analysis performed after the administration of connectivity-guided biofeedback was used in tandem with pre-condition analysis to assess significant changes.

Data Analysis.

Source-localized (eLORETA) measures for absolute power were used as the initial set of dependent variables. In regards to EEG data collection, average cross-spectral matrices were computed for bands delta (2–3.5 Hz), theta (4–7.5 Hz), alpha (8–12.5 Hz), beta (13–21 Hz), low frequency (2–7 Hz), high frequency (13–32 Hz), alpha1 (8–10 Hz), alpha2 (10–12 Hz), beta1 (12–16 Hz), beta2 (16–20 Hz), beta3 (20–24 Hz), beta4 (24–28 Hz), and beta5 (28–32 Hz).

For every frequency band and subject in the two groups, the current density modules at each voxel (current density amplitude) were smoothed with a three-dimensional moving average filter, normalized, and finally log-transformed. Log-transformation of power estimates is routinely performed in EEG and eLORETA to approximate data Gaussianity (John, Prichep, & Easton, 1987). With eLORETA, some smoothing is advisable to reduce anatomical and localization errors due to inter-individual differences in head geometry and electrodes placement. In general, local maxima can be visualized in slightly different locations. Spatial normalization consists of normalizing the square root of the sum of squared current density values for each subject at all voxels to equal unity. This manipulation eliminates confounding variables such as the inter-individual variability in skull thickness and electrode impedance, without constraining the analysis on relative power measures. Current density amplitude estimates computed and preprocessed as described provided the data for statistical analysis.

To compare the current density amplitude of the two conditions, we used the randomization-permutation multiple comparison t-max approach (Congedo, Finos, & Turkheimer, 2004) that has recently been utilized by Sherlin et al. (2007). Data-permutation approaches can adaptively account for the correlation structure of the variables, an embedded feature of all electrophysiological measurements (Holmes, Blair, Watson, & Ford, 1996). We performed one test for each of the 13 frequency band-pass regions (delta, theta, alpha, beta, low frequency, high frequency, alpha1, alpha2, beta1, beta2, beta3, beta4, and beta5). For the whole data set (2,394 x 9 variables), voxel-by-voxel within *t*-tests were computed; this is the *t*-test for paired designs. The mean of the pre-condition (A) is compared to the mean of the post-condition (B). Individuals in the two conditions are the same. The test-statistic is the well-known student-t, with positive values indicating mean (A) > mean (B), and negative values indicating mean (A) < mean (B). In this test the mean of two conditions are compared. A threshold of significance (if the global null hypothesis was false) was then computed by the t-max method. For all bands, we tested the hypothesis that the mean

LORETA current density amplitude of the two conditions differed by subtracting the values for the pre-condition from the post-condition (Congedo et al., 2004).

The eLORETA variables for each subject in each group (pre-post training) cross-spectral matrices were computed and averaged over 4-second epochs resulting in one cross-spectral matrix for each subject and for each of the discrete frequencies within each band. Based on previous LORETA analyses (Lubar, Congedo, & Askew, 2003), we used a rectangular window. Sliding overlapping windows (overlap 93.8%) allowed reliable and smooth spectral estimates. The LORETA-Key software package (Pascual-Marqui, Michel, & Lehmann, 1994) was used to compute LORETA current density in the frequency domain directly from the average cross-spectral matrix (Frei et al., 2001). This LORETA implementation incorporates a 3-shell spherical head model registered to recognized anatomical brain atlas (Talairach & Tournoux, 1988), and makes use of EEG electrode coordinates derived from cross-registration between spherical and realistic head geometry (Towle et al., 1993). The solution space is restricted to cortical gray matter using the digitized probability atlas of the Brain Imaging Center at the Montreal Neurological Institute (Collins, Neelin, Peters, & Evans, 1994), divided in 2,394 voxels measuring 7 x 7 x 7 mm).

To analyze coherence, subject groups were first prepared in the NeuroRep program NDAC. NDAC allows the user to identify and select a subset to compile raw connectivity indices for 171 pairwise combinations of 19 electrodes, with each having five frequency bands: delta (0.5–3.5 Hz), theta (3.5–7 Hz), alpha (7–13 Hz), beta (13–22 Hz) and total (amplifier bandwidth) and then compute 171 final group means, standard deviations, skewness, and kurtosis. Once the groups were prepared, the statistical program Compare was used to test for significant changes in coherence. Compare allows the user to compute correlated Student's *t*-tests between average connectivity indices for 171 pairwise electrode combinations (from NDAC). The significance of the *t*-test probabilities was evaluated with False Discovery Rate methods (Benjamini & Hochberg, 1995; Miller et al., 2001) to control for multiple comparison errors. All connectivity indices can optionally be Fischer z-transformed to improve Gaussianity of the resulting distribution. The total band limited refers to an EEG amplifier bandwidth of 0.5–40 Hz. Recursive filter bandwidths refer to four exacted bands: delta (0.5–3.5 Hz), theta (3.5–7 Hz), alpha (7–13 Hz), beta (13–22 Hz). The program compares means by use of Pearson correlations and correlated *t*-tests. Additionally, normalization of connectivity values can be achieved by using Fisher's z-score transformation. Further, Compare accounts for multiple comparison error by use False Discovery Rate (FDR; Benjamini & Hochberg, 1995) threshold values for judging significance. Connectivity indices were computed with software derived from the "COHER" programs written by Michael Hrybyk (Thatcher, Krause & Hrybyk, 1986) and were widely used in commercial computerized EEG software: Quantitative Signal Imaging, NeuroRep, NeuroData, Lexior, and NeuroGuide. The routines implement the equation reported in Bendat and Piersol (1980) and they include the results from a calibration EEG recording. To the authors' knowledge, all commercial programs produce results identical to COHER's results for the EEG calibration file. In this equation, the signals are normalized over the entire record to minimize the influences of signal amplitudes and thereby emphasize the relationship between the pair of EEG profiles (Bendat & Piersol, 1980). The values produced by Compare (coherence analyses) were a second set of dependant variables for this study.

Results

There were significant differences between pre- and post-conditions for source-localized absolute power. The maximum t-statistic, or maximum t-value across the entire volume, for

each frequency band follows. Absolute power significant t-values: delta (-2.63), theta (-2.43), and low frequency (-2.57).

Figures 1 through 4 illustrate the statistically significant differences between the two conditions in absolute power along with the Brodmann's Area (Brodmann, 1909/2005) label of the voxel with maximum differences. eLORETA current source density is displayed in the given frequency band. Coordinates and t-values for the maximal different voxel are printed above the picture of the sagittal section. All t-statistics that are positive are displayed in red (the mean of post-condition is greater than the mean of the pre-condition). All t-statistics that are negative are displayed in blue (the mean of the post-condition is less than the mean of the pre-condition). Displayed are the horizontal (left), sagittal (middle), and coronal (right) sections through the voxel with maximal t-statistic. Further, errors associated with multiple comparisons were accounted for by our implementation of the randomization-permutation multiple comparison t-max approach (Congedo et al., 2004). Only significant results (images) are shown (Refer to Figures 1 through 4).
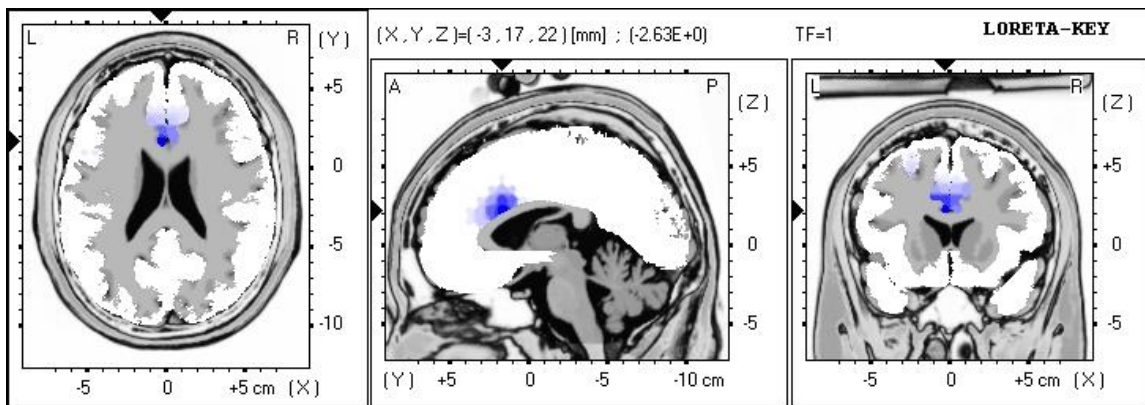
Figure 1. eLORETA analysis showing source localization of absolute delta power. Significant differences localized to Brodmann area 33, anterior cingulate, and limbic lobe.
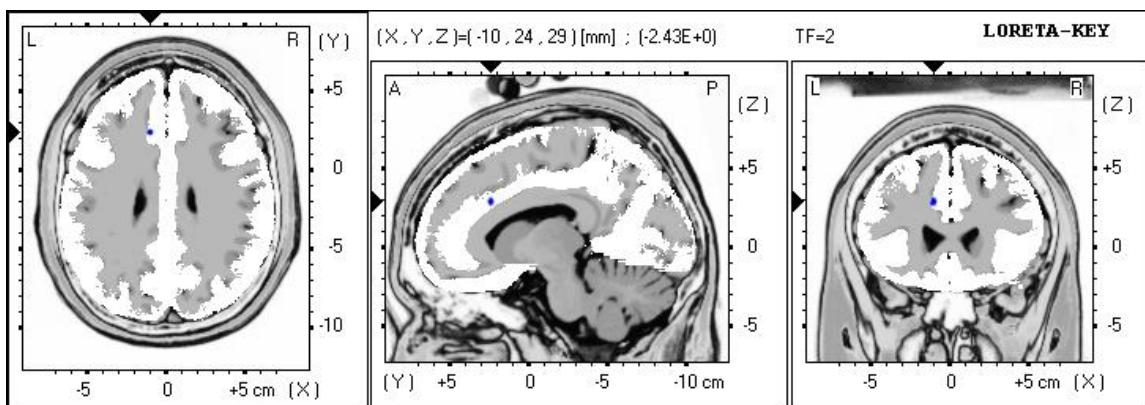
Figure 2. eLORETA analysis showing source localization of absolute theta power. Significant differences localized to Brodmann area 32, anterior cingulate, and limbic lobe.
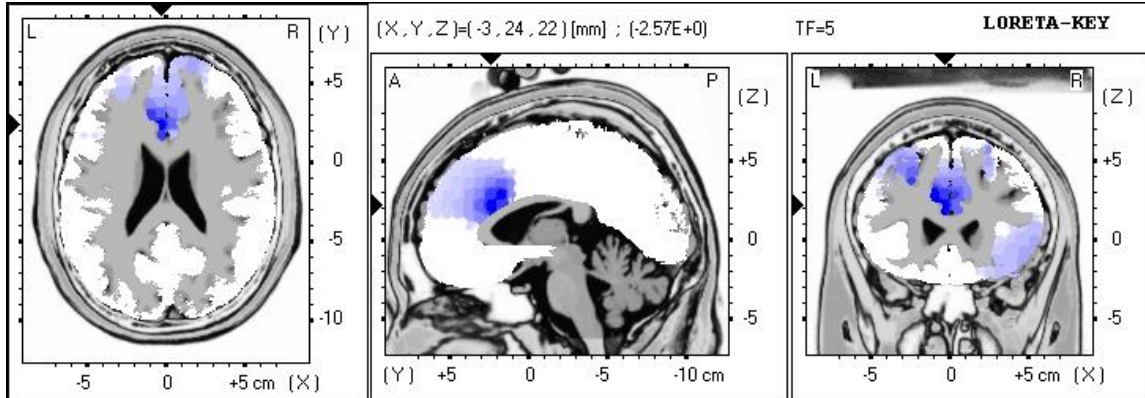
Figure 3. eLORETA analysis showing source localization of absolute low frequency power. Significant differences localized to Brodmann area 24, anterior cingulate, and limbic lobe.
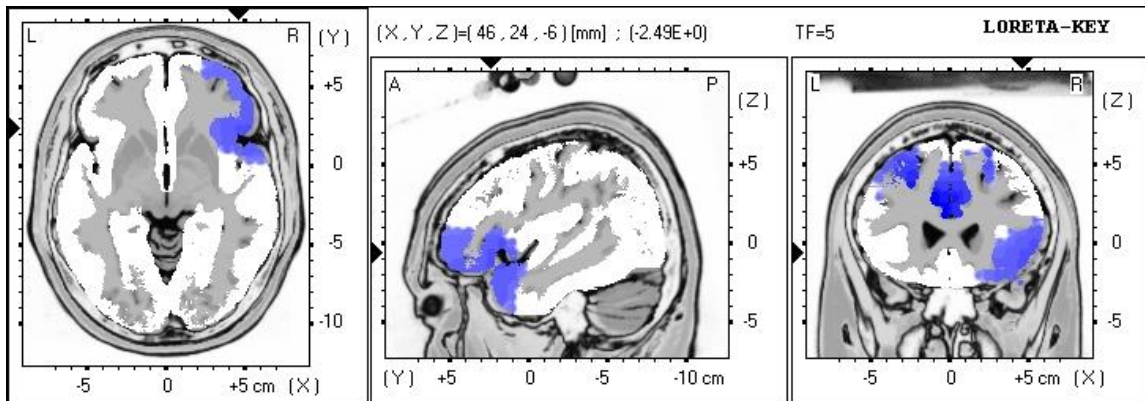
Figure 4. eLORETA analysis showing source localization of absolute low frequency power. Significant differences localized to Brodmann areas 10 and 47, frontal gyrus, and frontal lobe.

The significant differences between the pre- and post-conditions were localized to decreased slow wave activity (2–7 Hz) in the anterior cingulate and the right frontal gyrus. The strongest findings of decreased slow activity were found in Brodmann areas 32 and 33 that are located in the associational cortical area of the frontal lobes and that participate in prefrontal cortical networks, which are thought to govern personal and social behavior, emotion, and decision-making (Salloway, Malloy, & Duffy, 2001; Courchesne & Pierce, 2005). Brodmann area 24 is located in associational cortical area in the anterior part of the cingulate gyrus. This area is a cortical component of the limbic system that is involved in emotional processing, the control of facial expressions, and the affective dimensions of pain (Williams, White, & Mace, 2005). Additionally, there was decreased low frequency band absolute power in Brodmann areas 10 and 47 of the right hemisphere. This area is in the associational cortical area in the anterior-polar prefrontal region of the frontal lobes and participates in prefrontal cortical networks that govern executive functions (Koechlin & Hyafil, 2007).

Pre- and post-EEG data groups were prepared and generated in NDAC. Differences between these groups, in terms of coherence values, were analyzed in the statistical package Compare. This statistical package made comparisons between 171 pairwise means using Pearson correlations and correlated *t*-tests. Two-tailed probabilities were utilized for paired *t*-tests in the delta, theta, alpha, beta bands, and across the total frequency as well. FDR indices were used to control for errors due to multiple comparisons (Benjamini & Hochberg, 1995). Similar to eLORETA, pre-condition scores were subtracted from post-condition scores in Compare. Blue results indicated a decrease in connectivity, while red results indicated increases in connectivity. As figures 5 through 7 show, the statistical analyses indicated numerous significant reductions in connectivity between neural locations predominately in the alpha and beta bands, as well as in the total coherence.

Figure 5 shows the statistical analysis of the alpha band values. Eleven electrode pairs were found to have significant decreases in neural connectivity within this band, while only one pair was found to have a significant increase in connectivity.

	Fp1	Fp2	F7	F8	F3	F4	T3	T4	C3	C4	T5	T6	P3	P4	O1	O2	Fz	Cz
Fp2	-0.562																	
F7	-0.814	-0.511																
F8	-0.133	-0.089	-0.400															
F3	0.154	0.440	-0.042	-0.298														
F4	-0.272	-0.991	-0.028	0.874	-0.051													
T3	-0.090	-0.653	-0.071	-0.807	-0.039	-0.130												
T4	-0.000	-0.001	-0.134	-0.003	-0.001	-0.001	0.342											
C3	-0.058	-0.069	-0.025	-0.019	-0.039	-0.010	-0.123	-0.012										
C4	-0.002	-0.008	-0.002	-0.017	-0.005	-0.001	-0.288	-0.163	-0.023									
T5	0.558	0.159	-0.245	0.158	-0.246	0.424	-0.220	0.104	-0.202	0.831								
T6	0.011	0.103	0.003	0.806	0.017	-0.859	0.041	-0.268	0.433	-0.487	0.179							
P3	-0.181	-0.916	-0.043	-0.827	-0.107	-0.076	-0.104	-0.745	-0.162	-0.128	0.910	0.395						
P4	-0.743	-0.914	-0.926	-0.705	-0.341	-0.141	0.878	-0.332	-0.118	-0.625	0.589	0.563	-0.519					
O1	0.560	0.133	-0.882	0.190	-0.437	0.874	-0.504	0.262	-0.685	0.870	0.782	0.234	0.942	0.950				
O2	0.101	0.007	0.092	0.061	0.210	0.189	0.612	0.689	-0.931	0.643	0.774	0.084	-0.382	0.095	-0.228			
Fz	0.608	0.307	-0.031	-0.264	-0.111	-0.072	-0.042	-0.002	-0.015	-0.003	-0.960	0.261	-0.052	-0.194	-0.835	0.379		
Cz	-0.193	-0.255	-0.026	-0.068	-0.071	-0.017	-0.148	-0.006	-0.040	-0.023	-0.431	-0.852	-0.060	-0.133	-0.932	-0.787	-0.039	
Pz	-0.016	-0.108	-0.017	-0.013	-0.048	-0.009	-0.380	-0.058	-0.185	-0.143	-0.886	-0.654	-0.629	-0.441	-0.581	-0.635	-0.016	-0.104

Figure 5. Compare findings of changes in alpha coherence, with a False Discovery Rate (FDR) of alpha *p* <= .0053.

As Figure 6 shows, the analyses of the beta band found 43 electrode pairs to have significant decreases in neural connectivity.

	Fp1	Fp2	F7	F8	F3	F4	T3	T4	C3	C4	T5	T6	P3	P4	O1	O2	Fz	Cz
Fp2	-0.023																	
F7	-0.151	-0.035																
F8	-0.007	-0.014	-0.011															
F3	-0.604	-0.247	-0.198	-0.024														
F4	-0.019	-0.121	-0.016	-0.391	-0.045													
T3	-0.059	-0.337	-0.177	-0.485	-0.056	-0.054												
T4	-0.001	-0.030	-0.086	-0.183	-0.007	-0.090	0.526											
C3	-0.051	-0.010	-0.055	-0.014	-0.038	-0.009	-0.079	-0.002										
C4	-0.003	-0.003	-0.002	-0.030	-0.005	-0.012	-0.026	-0.266	-0.004									
T5	-0.650	0.270	-0.056	0.147	-0.028	-0.499	-0.227	0.152	-0.056	-0.536								
T6	0.438	-0.176	0.274	-0.197	-0.534	-0.042	0.070	-0.262	-0.267	-0.159	-0.624							
P3	-0.005	-0.004	-0.010	-0.007	-0.003	-0.002	-0.069	-0.076	-0.004	-0.020	-0.758	-0.484						
P4	-0.046	-0.007	-0.032	-0.037	-0.006	-0.018	-0.134	-0.174	-0.008	-0.188	-0.448	-0.581	-0.100					
O1	0.529	0.234	-0.312	0.508	-0.018	-0.076	-0.260	0.939	-0.064	-0.209	0.538	-0.689	-0.917	-0.245				
O2	0.420	0.791	0.159	-0.481	-0.250	-0.115	-0.298	-0.714	-0.040	0.990	-0.328	0.142	-0.755	0.196	-0.077			
Fz	-0.094	-0.310	-0.012	-0.051	-0.040	-0.139	-0.023	-0.027	-0.013	-0.006	-0.041	-0.175	-0.003	-0.008	-0.032	-0.177		
Cz	-0.022	-0.019	-0.006	-0.039	-0.007	-0.068	-0.033	-0.073	-0.005	-0.022	-0.136	-0.179	-0.012	-0.040	-0.110	-0.507	-0.017	
Pz	-0.002	-0.001	-0.005	-0.006	-0.002	-0.008	-0.036	-0.048	-0.004	-0.063	-0.598	-0.698	-0.214	-0.325	-0.408	0.849	-0.005	-0.023
	Fp1	Fp2	F7	F8	F3	F4	T3	T4	C3	C4	T5	T6	P3	P4	O1	O2	Fz	Cz

Figure 6. Compare findings of changes in beta coherence, with a False Discovery Rate (FDR) of alpha $p <= .064$.

As shown in Figure 7, the analyses for the total connectivity revealed 42 neural locations to have significant reductions in connectivity. The total connectivity is an analysis of connectivity encompassing the entire EEG spectrum (0.5–22 Hz).

	Fp1	Fp2	F7	F8	F3	F4	T3	T4	C3	C4	T5	T6	P3	P4	O1	O2	Fz	Cz
Fp2	-0.059																	
F7	-0.432	-0.339																
F8	-0.016	-0.016	-0.243															
F3	0.832	-0.754	-0.135	-0.357														
F4	-0.005	-0.081	-0.019	-0.789	-0.016													
T3	-0.047	-0.089	-0.095	-0.032	-0.045	-0.022												
T4	-0.002	-0.040	-0.007	-0.342	-0.001	-0.025	-0.055											
C3	-0.016	-0.048	-0.083	-0.225	-0.045	-0.039	-0.091	-0.014										
C4	-0.000	-0.015	-0.008	-0.441	-0.005	-0.015	-0.022	-0.100	-0.024									
T5	-0.004	-0.010	-0.040	-0.008	-0.024	-0.017	-0.083	-0.060	-0.126	-0.103								
T6	-0.001	-0.010	-0.003	-0.068	-0.003	-0.013	-0.014	-0.139	-0.032	-0.183	-0.228							
P3	-0.002	-0.006	-0.022	-0.037	-0.020	-0.023	-0.082	-0.090	-0.195	-0.164	-0.617	-0.335						
P4	-0.003	-0.012	-0.009	-0.137	-0.011	-0.036	-0.012	-0.130	-0.034	-0.432	-0.087	-0.296	-0.095					
O1	-0.008	-0.008	-0.027	-0.012	-0.065	-0.067	-0.126	-0.153	-0.286	-0.377	0.238	-0.910	-0.943	-0.229				
O2	-0.008	-0.011	-0.014	-0.052	-0.030	-0.108	-0.020	-0.425	-0.122	-0.928	-0.079	0.096	-0.086	0.195	-0.067			
Fz	-0.031	-0.440	-0.028	-0.222	-0.161	-0.040	-0.029	-0.006	-0.033	-0.010	-0.024	-0.010	-0.020	-0.026	-0.095	-0.086		
Cz	-0.020	-0.093	-0.046	-0.557	-0.045	-0.107	-0.040	-0.069	-0.077	-0.154	-0.111	-0.100	-0.149	-0.192	-0.369	-0.329	-0.068	
Pz	-0.002	-0.008	-0.013	-0.102	-0.018	-0.034	-0.050	-0.073	-0.123	-0.263	-0.430	-0.421	-0.355	-0.430	-0.493	-0.531	-0.028	-0.261
	Fp1	Fp2	F7	F8	F3	F4	T3	T4	C3	C4	T5	T6	P3	P4	O1	O2	Fz	Cz

Figure 7. Compare findings of changes in total coherence, with a False Discovery Rate (FDR) of alpha $p <= .0164$.

Figure 8 presents a graphical representation of our Compare calculations. Blue lines between focal points indicated deceases in connectivity, while orange lines indicated increases in connectivity. Moreover, only significant findings are shown. As our analysis shows, connectivity-guided EEG biofeedback predominately produced reductions in neural connectivity. Further, these decreases in connectivity seemed to occur mostly within the frontotemporal region, especially on the right side.
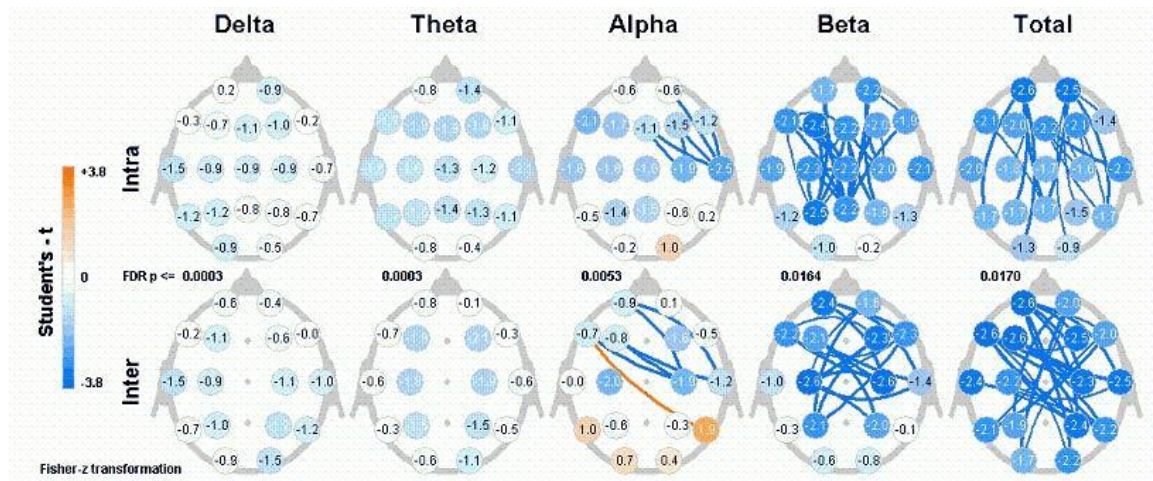
Figure 8. Graphical representation of Compare findings illustrating focal changes in neural connectivity.

eLORETA analysis was also computed for the control group from pre- to post-conditions. Analogous to the experimental group to compare the current density amplitude of the two conditions of the wait-list control, we used the randomization-permutation multiple comparison t-max approach (Congedo et al., 2004). Data-permutation approaches can adaptively account for the correlation structure of the variables, an embedded feature of all electrophysiological measurements (Holmes et al., 1996). Again, we performed one test for each of the 13 frequency band-pass regions (delta, theta, alpha, beta, low frequency, high frequency, alpha1, alpha2, beta1, beta2, beta3, beta4, and beta5). For the whole data set (2,394 x 9 variables), voxel-by-voxel within t-tests were computed. This is the t-test for paired designs. In this test the mean of two conditions are compared. A threshold of significance (if the global null hypothesis was false) was then computed by the t-max method. For all bands, we tested the hypothesis that the mean LORETA current density amplitude of the two conditions differed by subtracting the values for the pre-condition from the post-condition (Congedo et al., 2004). Further, the results revealed that there were no significant changes from pre- to post-conditions among the participants in the wait-list control group using an alpha level of $p < .10$.

Statistical analyses performed on the experimental group were also implemented for the 12 participants of the control group in order to test for significant changes in coherence. The analysis revealed that from pre- to post-conditions the control group had no significant changes in coherence. Similar to the experimental group analysis, the inclusion of FDR (Benjamini & Hochberg, 1995) protects this analysis from errors associated with multiple comparisons. Further, the analysis showed that in the control group no electrode location approached a $p < .10$ level, let alone significance.

Discussion

The major finding of this study is the evidence that connectivity-guided EEG biofeedback is a treatment capable of causing therapeutic neurophysiological changes in the brains of children with ASD. Significant reductions in coherence between numerous neural regions occurred as a result of this intervention. These findings were further substantiated by the eLORETA analysis, which showed prominent source localized changes in power in crucial regions of the brain for such children. These changes were evident across frontal, temporal, and limbic regions. The results of the current study also support and expand upon the findings found previously (Coben & Padolsky, 2007). In our earlier study, we achieved an 89% success rate that was coupled with a 40% reduction in core ASD symptoms. Moreover, significant improvements were noted for the experimental group on measures of attention, executive, visual perceptual, and language functions. In contrast, our analysis revealed that the control group did not significantly differ from the experimental group at the conclusion of our previous study insomuch that 83% of the parents of this group reported no change and presently no significant pre- to post-conditions changes were seen. The significant clinical findings previously reported are now bolstered by the neurophysiology changes found presently. This now provides preliminary evidence that connectivity-guided EEG biofeedback is capable of producing neurophysiological changes while concurrently reducing autistic symptoms. Specifically, the findings found previously, coupled with our current findings, provide evidence that seemingly links reductions in hypercoherence and source-localized power with reductions in autistic symptoms.

This has a two-fold importance. First, our analysis showed that the resulting decreases in hypercoherence derived from connectivity-guided EEG biofeedback seemed to conglomerate in and around the frontotemporal region. These were the regions targeted for treatment. This suggests that training over specific regions can have specific, localized effects. Second, this finding provides support to the theory of frontal system involvement in ASD indicated by previous investigations (Courchesne & Pierce, 2005; Buxhoeveden et al., 2004; Rippon et al., 2007).

The theory of hypercoherence/connectivity, as it relates to autistic symptoms, has been the subject of several investigations. Courchesne and Pierce (2005) reported patterns of over-connectivity within the frontal lobes, as well as under-connectivity between the frontal lobe and other brain regions. Courchesne, Redkay, and Kennedy (2004) previously attributed these findings to abnormal increases in the gray and white matter neurons of the frontal and temporal lobes occurring between the ages of 2 to 4 years old. These abnormal increases in brain matter or early developmental neuroinflammation are thought to cause malfunctions in the brain, particularly in frontal minicolumn microcircuitry (Courchesne & Pierce, 2005). Neuroinflammation is also thought to explain the finding of enlarged head sizes found in children with ASD (Herbert et al., 2003; Herbert et al., 2004). It is theorized that over-connectivity can result from this neuroinflammation, due to the tendency of neurons that are excited to communicate more readily with other neurons that are close in proximity (Courchesne & Pierce, 2005). Furthermore, as neural regions expand the neuropil space is reduced, causing an increase in neuron proximity that in turn will increase hyperconnectivity (Buxhoeveden et al., 2004). Likewise, under-connectivity of the frontal cortex to other neural regions is produced due to the hyperconnected brain's inability to form sufficient communications with other areas. Consistent with this, recent findings have indicated that neuroinflammation of white matter impedes the autistic brain's ability to connect or integrate information from other parts of the brain (Herbert, 2005). This inability to communicate efficiently between neural assemblies may result in deficits in domains that require more

coordination and communication between brain areas, namely language and executive functioning. Further, this phenomenon can readily be described as too many local services competing within themselves, in turn decreasing the quality of long distance communication. These neural anomalies of hyper- and hypoconnectivity in autism have also been prescribed as the consequence of a faulty pruning system. Frith (2003) speculated that the neurophysiological brain deficits associated with autism are the result of a neural pruning system that fails to eliminate faulty connections within the brain during keys stage of development. This pruning system plays a key role in coordinating neural functioning in the healthy individuals. The failure of these inutile connections to be eliminated interferes with normal neural connections both locally and long distance within the brain.

When long-distance frontal neural assembly connections are disrupted, resulting deficits in integration of information from emotional, sensory, language, and automatic systems can occur (Courchesne & Pierce, 2005). Moreover, disruption of white matter tracts, as described previously, may cause deficit in social cognition associated with neural areas responsible for face and gaze processing, awareness of mental states, and emotional processing (Barnea-Goraly et al., 2004). Further, deficits of frontal cortical networks are thought to lead to executive functioning impairments in areas of personal and social behavior, emotion, and decision-making (Salloway et al., 2001; Courchesne & Pierce, 2005). Likewise, deficits within the cortical area of the limbic system, most notably the anterior part of the cingulate gyrus, are theorized to result in deficiencies in emotional processing, the control of facial expressions, and the affective dimensions of pain (Williams et al., 2005). Insufficiencies within the temporal lobe, particularly the amygdala, have been correlated with autistic impairment related to social functioning and behavior (Baron-Cohen et al., 2000). Finally, by therapeutically reducing hypercoherence within these neural areas, as was achieved in this study, it is thought that the previously mentioned deficits and pathophysiology can be reduced and that positive behavioral changes can be gained.

Our current study contributes to the aforementioned research by presenting evidence that shows that reducing hypercoherence may play an integral role in the improved treatment outcomes that result from connectivity-guided EEG biofeedback. The evidence presented linking reductions in frontotemporal hypercoherence, as a means to produce therapeutic gains in autistics, is further confirmation of the critical roles these brain regions play in the symptoms of autistic disorders.

This is the first study to present evidence of a treatment of ASD that is capable of therapeutically changing the neurophysiological dysfunction that is at the heart of autistic symptoms. The decreases in neural coherence that were achieved in the present study included frontal, temporal, and underlying limbic structures. As stated previously, these areas have been confirmed to be associated with autistic impairment (Salloway et al., 2001; Courchesne & Pierce, 2005; Williams et al., 2005; Baron-Cohen et al., 2000). As such, the positive gains achieved by therapeutically impacting these neural areas confirms their involvement in ASD, as well as provides an insight into the overall neurophysiological mechanisms responsible for the efficacy of this therapy.

The significant neurophysiological changes reviewed can be ascribed to the treatment with little risk of error due to the implementation of FDR indices (Benjamini & Hochberg, 1995) and randomization-multiple permutation analyses (Congedo et al., 2004). Moreover, these changes can be confidently regarded as ameliorative in nature due to subjects' reports of positive therapeutic gains and reductions in autistics symptoms at the completion of 20 sessions of connectivity-guided EEG biofeedback. These results are further strengthened by

our analysis, which revealed that the wait-list control group reported no significant changes from pre- to post-conditions.

Our analysis showed that there were positive changes in source-localized power (eLORETA) within lower frequency bands; while findings also indicated that changes in coherence were seen predominately in the higher frequencies of alpha and beta band. The reason for this discrepancy is not yet clearly understood. Further, it would take increasingly more investigation to fully understand the implications of this difference.

Recently, Pineda et al. (2007) investigated behavioral changes as a result of neurofeedback in children with autism. The results showed that indeed positive behavioral changes were seen within the Speech/Language, Sociability, and Health/Physical behavior subscales of the ATEC as well as the Total score. However, when comparing this data to the current investigation, it was revealed that the intervention implemented presently produced about a three times greater rate of efficacy. Moreover, our current study saw no degradation or worsening of symptoms as assessed by any subscales of the ATEC. Conversely, Pineda et al. (2007) presented evidence of negative changes in behavior in terms of the Sensory/Cognitive Awareness subscale of the ATEC. Continuing, Pineda et al. (2007) chose to train the Mu rhythm mainly on the right hemisphere of the brain focusing on electrode site C4 as well as areas chosen based on EMG activity. This technique produced a significant decrease in coherence for only one neural pair (C3–C4; Study 1) and three neural pairs (T3–T4; C3–C4; F3–F4) for study two (Pineda et al., 2007). We, on the other hand, based the course of therapy on each individual's QEEG analysis which revealed specific areas of maximal hypercoherence and we postulate that this served as an underlying reason why our investigation was able to significantly decrease coherence between far more neural pairs (Refer to Fig. 5 through 7). We would prescribe our increased success and lack of negative effects to our use of personalized QEEG analysis to plan and carry out neurofeedback, resulting in far greater reductions. Similarly, Coben and Myers (2008) have recently compared data from their connectivity-guided EEG biofeedback study to Jarusiewicz's (2002) earlier symptom-based neurofeedback investigation. The results of this analysis indicated that connectivity-guided EEG biofeedback accomplished, on average, a full standard deviation greater improvement as compared to symptom-based neurofeedback, while still preventing any unwanted effects. The implication of the aforementioned research comparisons would suggest that personalization of EEG protocols among subjects plays a positive role in the efficacy of our treatment.

Others have recently hypothesized that the positive effects of neurofeedback for individuals with autism might be due to non-specific factors (Heinrich, Gevensleben, & Strehl, 2007; Kouijzer, van Schie, Gerrits, Buitelaar, & de Moor, 2013). For example, Kouijzer et al. (2013) showed no difference in effect between EEG biofeedback and skin conductance biofeedback, but both were better in reducing autistic symptoms as compared to a non-treatment control group. They concluded that the beneficial effects might be due to treatment expectancy, implicit training of attention and/or intensive one-to-one contact with a therapist. However, their training was only at midline locations and did not involve connectivity or coherence training. Our current findings indicate improvements in clinical functioning associated with treatment-related neurophysiological changes in brain functioning that did not occur in the wait-list comparison group. This indicates a strong likelihood that there were specific effects from the training and that the mechanism of action is the alteration of coherence in a therapeutic direction. Interestingly, different types of neurofeedback trainings may have different impacts.

In terms of the limitations of our study, the participants consisted of a selected pool of subjects. When subjects or, in this case, parents of subjects, select their preferred treatment, there is a risk of selection bias that may interact with the treatment effect. Therefore, randomized assignment of experimental and control groups would be needed to test for any interactions between the treatment effect and the subject selection. Also, efforts could be made to include more subjects with increased severity of symptoms as well as more homogeneity in terms of age. This would help better assess whether the severity of autistic symptoms moderates the efficacy of the treatment. Additionally, to more precisely measure the effects of our treatment, a double-blind study design, in which subject assignment would be unknown by both the subjects and experimenters, would be recommended. Furthermore, the addition of an alternative treatment or a placebo-controlled (i.e., sham neurofeedback) comparison group could help better assess the efficacy of connectivity-guided EEG biofeedback and help demonstrate that our results were not likely due to chance or an uncontrolled variable. Periodic future follow-up assessments would also be beneficial in determining the efficacy of our intervention over an extended period of time. This would help better demonstrate the continuing efficacy over time of connectivity-guided EEG biofeedback. We would also recommend future studies more precisely analyze the relationship between connectivity/coherence and autism. This investigation provided evidence linking these two concepts to each other and to autistic impairments; however, further research would need to be conducted to enduringly validate this claim. Finally, the addition of alternative imaging techniques (i.e., MRI or DTI), used in tandem with EEG analysis, would help better validate the neurophysiological changes found presently.

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NeuroRegulation

Determination of the Effects of Neurofeedback Training in the Neuropsychological Rehabilitation in Inattentive and Combined Subtypes of Attention Deficit/Hyperactivity Disorder

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Abstract

Introduction: The aim of the present study was to compare the effect of neurofeedback in neuropsychological rehabilitation of attention in children with combined (C) and predominantly inattentive (IA) subtypes of ADHD. **Method**: This research is a quasi-experimental study by which, from among 7–12 year old children referred to the Atiyeh Psychiatric Center, 30 children diagnosed with either Combined or predominantly Inattentive subtypes of ADHD (15 children in each subtype) underwent 30 sessions (3 sessions per week) of neurofeedback therapy. For assessing children's cognitive performance, the children in both treatment groups were administered before and after treatment with a time interval of 10 weeks, both the visual and auditory continuous performance tests (IVA). Patient diagnosis for assignment to either of two ADHD subtypes was carried out with the Conner's rating scale, a Clinical Interview Checklist, and Psychiatrist evaluation. **Results**: Neurofeedback training significantly increased all IVA subscales scores, with the exception of the Balance scale, in all subjects, regardless of treatment group (subtype). Results of MANOVA analysis indicated that the two subtypes did not differ in terms of effectiveness of neurofeedback training with the exception of the Readiness scale. **Conclusion**: The present findings supported the efficacy of Neurofeedback training in increasing children's scores on the IVA-CPS battery of tests, regardless of subtype classification. These findings are interpreted within recent theoretical and developments regarding the validity of subtypes and the usefulness of a dimensional approach.

Keywords: neurofeedback, attention-deficit/hyperactivity disorder, combined subtype, predominantly inattentive subtype

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Introduction

One of the most common neurodevelopmental disorders is Attention-deficit/hyperactivity disorder (ADHD); it begins in early childhood (between 3 to 7 years of age), usually continues during adolescence, and continues into adulthood in more than half of the cases (Barkley, 1997). Behaviorally, it is most commonly characterized by sustained attention deficits, hyperactivity and impulsivity, and its major determinants include neural (e.g., Casey et al., 1997), cortical (e.g., Makris et al., 2007), neuro-cortical maturational (e.g., Shaw et al., 2007), neurodevelopmental trajectories (Shaw, Gogtay, & Rapoport, 2010), as well as neurocognitive anolamies (Sergeant, Oosterlaan, & van der Meere, 1999; van Mourik, Osterlaan, & Sergeant, 2005; Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005). In terms of the prevalence of this disorder, it has been estimated to affect 9% of American school children (Pastor & Reuben, 2008); between 2 and 29% of the general population at international levels (American Psychiatric Association, 2000; Barkley, 2005; Linden, Habib & Radojevic, 1996); and, between 3 and 12% in Iran (Mashhadi, 2009). In most instances, its prevalence is higher among males than females (American Psychiatric Association, 2000).

In past years, with the use of factor analytic techniques, three distinct behavioral symptoms (inattention, hyperactivity and impulsivity) have been reconceptualized in the form of two dimensions: attention deficiency and hyperactivity/impulsivity or disinhibition (Barkley, 2006; Burns, Boe, Walsh, Sommers-Flannagan, & Teegarden, 2001; Pillow, Pelham, Hoza, Molina, & Stulz, 1998) and based on these two dimensions, three different subtypes of ADHD disorder have been identified: (1) ADHD predominantly inattentive subtype (ADHD-IA); (2) ADHD predominantly hyperactive/impulsive subtype (ADHD-HI); and, (3) ADHD combined subtype (ADHD-C; American Psychiatric Association [APA], 2000).

Although there is limited information on the different prevalence rates of these subtypes, the combined subtype has been found to occur with the highest frequency and the hyperactivity/ impulsivity subtype with the least. The prevalence of the inattentive subtype falls between the two former subtypes (Millstein, Wilens, Biederman, & Spencer, 1998). For instance, in the Millstein and colleagues study (Millstein et al., 1998), the diagnosis of ADHD among 149 children patients, indicated a prevalence of 2, 37, and 56 percent for the IA, HI and C subtypes, respectively.

The research literature on ADHD subtypes based on DSM-IV criteria indicates that the underlying determinants for the three ADHD subtypes are basically different, including differences in demographic characteristics, nature of functional impairments, level of comorbidity with other disorders, neuropsychological profiles and neurocognitive deficits (Barkley, 1997; Booth, Carlson & Tucker, 2005; Diamond, 2005; Milich, Ballentine, & Lynam, 2001). Some other researchers also believe that the ADHD predominantly inattentive (IA) subtype is a distinctive disorder and should not be considered as an ADHD subtype (Barkley, 2006; Brown, 2006; Diamond, 2005; Geurts, Vert, Oosterlaan, Roeyers, & Sergeant, 2005; Milich et al., 2001; Wilcutt, Doyle, Nigg, Farone, & Penningtone, 2005).

Review of the literature also indicates that there is a clear difference in executive functioning between the C and IA subtypes (Milich et al., 2001), and Barkley (1997, 2005) has, similarly, considered executive function as the main factor discriminating among ADHD subtypes. Moreover, Chemark, Hall and Musiek (1999) have proposed that the combined (C) and predominantly hyperactive/impulsive (HI) subtypes conform an externalizing disorder involving primarily executive function and behavioral regulation deficits, instead of attention deficits per se. In contrast, Chemark and colleagues suggest that the predominantly

attention deficiency (IA) subtype is an internalizing disorder with the primary cause being a deficiency of processing and information inputting where attention plays a major role; and thus, executive dysfunction, in this condition should be considered as a secondary cause.

Although the cause of the ADHD is not presently known (Barkley, 2006; Kaplan, Sadoc & Grebb, 2003; Nigg, 2006; Nigg, Willcutt, Doyle, & Sonuga-Barke, 2005), a very active research agenda is expanding in order to understand the complexity of this disorder and its neuropsychological underpinnings. For instance, recent neuroimaging evidence suggests an important role of the frontal and, especially, the prefrontal cortex (PFC) in executive dysfunctions (Fuster, 2008; Barkley, 1997). For a thorough review of this literature, the readers are recommended to consult Halperin and Healy's (2011) article. Given the role of executive dysfunction in ADHD disorder and its relationship with the prefrontal brain region (Barkley, 1997; 2003; 2006), stimulant medication is considered one of the best-supported interventions for ADHD (Faraone & Buitelaar, 2009). By facilitating the transfer of dopamine neurotransmitter in the PFC, stimulant drugs, improve executive function performance. Although stimulant drugs, such as methylphenidate, can to a great extent, decrease hyperactivity/impulsivity behavior and even in some cases, have significant short-term effects in improving educational performance, the results of evaluation of reading tests and performance in cognitive tests (such as the continuous performance test) show that the long-term effects after treatment with stimulant medication are limited to cortical levels of the brain. However, researchers (e.g., Arnsten & Dudley, 2005; Lubar, Swartwood, Swartwood, & Timmermann 1995; Patoine, 2009) also believe that long-term improvements in subcortical functioning could be possible and should not be discarded.

Despite the positive effects of drug therapy in reducing the symptoms of hyperactivity and impulsivity (two pivotal ADHD symptoms of C and HI subtypes), its effectiveness in decreasing attention deficits has been found to be limited (Barkley & Cunningham, 1979; Camobel, 2003; Chemark et al., 1999). In a review article, Swanson, Nolan, and Pelham (1993) reported that 25 to 40 percent of children with ADHD may not respond to medication. Moreover, ADHD children who respond well to drug therapy (i.e., C and HI subtypes), although they may show a reduction of symptoms of hyperactivity and impulsivity, this improvement is temporary and depends on continuous medication use. Furthermore, the side effects of medication, which include sleep disorders, poor appetite, mild interruption of physical growth, and restlessness, cannot be ignored (Lubar et al., 1995). Some research (e.g., Barkley, McMurray, Edelbrock, & Robbins, 1990) has also provided empirical evidence regarding the fact that the use of medication and stimulant drugs leads to side effects such as decreased appetite, insomnia, stomach aches, and headaches, with a recent study (Goldman, 2010) replicating these findings. In line with this evidence, Molina and colleagues' eight-year longitudinal study (Molina, Hinshaw, Swanson, & Arnold, 2009) investigating the effectiveness of the stimulant drugs in reducing ADHD symptoms concluded that even though medication is an effective treatment, with therapeutic effects of up to about 14 months, long-term effects of drug therapy could not be confirmed. However, long-term effects of drug treatment are required if ADHD symptoms persevere throughout life.

One innovative, recent, non-medicinal training paradigm in the treatment of ADHD is neurofeedback training (Barbaraz & Barbaraz, 1996). Neurofeedback investigations have focused on the study of brain wave activity in people with ADHD in comparison to those without ADHD, and they have shown that those individuals with ADHD have higher slow wave (theta) activity and lesser fast wave (beta) activity (Mann, Lubar, Zimmerman, Miller, & Muenchen, 1992). Neurofeedback is a neurobehavioral treatment aimed at acquiring self-control over certain brain activity patterns and implementing these self-control skills in daily-

life situations (Gevensleben et al., 2009). Two well-known training protocols include: (1) training of slow cortical potentials (SCPs); and (2) theta/beta training, which are typically used in children with ADHD. The SCPs training is related to phasic regulation of cortical excitability. Negative SCPs reflect increased excitation and occur during states of behavioral or cognitive activation, while positive SCPs are thought to indicate reduction of cortical excitation of the underlying neural networks and appear during behavioral inhibition. In the theta/beta training, the goal is to decrease activity in the theta band (4–8 Hz) and to increase activity in the beta band (13–20 Hz) of the electroencephalogram (EEG), which corresponds to an alert and focused but relaxed state. Thus, neurofeedback training addresses tonic aspects of cortical arousal. The rationale of applying neurofeedback in the treatment of ADHD is based on findings from EEG and event related potentials (ERP) studies. For the contingent negative variation (CNV; a typical SCP), reduced amplitude was measured during cued continuous performance tests (CPT) in children with ADHD (for a review, see Banaschewski & Brandeis, 2007). This finding may be seen in line with the dysfunctional regulation/allocation of energetically resources model of ADHD (Sergeant, Oosterlaan, & Van der Meere, 1999).

Review of the literature indicates that SCPs training (e.g., Heinrich, Gevenesleben, Freisleder, Moll, & Rothenberger, 2004; Drechsler et al., 2007; Gevensleben, et al., 2009; Strehl et al., 2008) and theta/beta training (e.g., Rossiter & Lavaque, 1995; Monastra, Monastra, & George, 2002; Fuchs, Birbaumer, Lutzenberger, Gruzelier & Kaiser, 2003; Rossiter, 2004; Levesque, Beauregard, & Mensour, 2006; Bakhshayesh, 2007; Holtmann et al., 2009; Xiong, Shi, & Xu, 2005; Leins et al., 2007; Kaiser & Othmer, 2000) have a beneficial influence in the treatment of ADHD symptoms. Skills for the regulation of brain wave activity are learned over the course of neurofeedback training, which may last for a time between of 6 months (e.g., Gevensleben, Holl, Albrecht, Schlamp, & Kratz, 2009; Strehl et al., 2006; Sherlin, 2010) to 2 years (e.g., Gani, Birbaumer, & Strehl, 2009), and, even 10 years (Lubar, 2003).

Lubar (1991) has emphasized the important role of neurofeedback training in reducing ADHD symptoms, especially attention deficiency symptoms. He suggests that the attention disorder observed in the ADHD attention deficiency subtype, which does not respond to drug treatment, will considerably improve with neurofeedback training. In corroboration with Lubar's suggestion, Levesque and colleagues (Levesque, Beauregard, & Mensour, 2006) have shown that neurofeedback training, via normalizing performance in the anterior cingulate cortex area of the brain, leads to improved performance in selective attention tests. The reason behind the limited effectiveness of stimulant drugs seems to be related to the impact drugs have at the cortical level of brain and neurotherapy is linked directly to changes in cortical functioning such as cognitive processes associated with prefrontal cortex. While medication attempts to rectify neurotransmitter (chemical) imbalances in the subcortical area of brain, neurotherapy attempts to challenge the brain to self-regulate and redress the imbalance (Lubar, Swartwood, Swartwood, & O'Donnell, 1995).

In terms of treatment methods for ADHD management and control, due to the complex and ambiguous nature of this disorder (Sonuga-Barke, Sergeant, Nigg, & Wilcutt, 2008), a wide variety of interventions have been developed by researchers and psychotherapists, including cognitive-behavioral (Young & Amarasinghe, 2010) and behavioral (Sonuga-Barke, Daley, Thompson, Laver-Bradbury, & Weeks, 2001), to mention two. These and other interventions were designed to improve a wide range of deficits, primarily, executive functions (Karatekin, 2006, White & Shah, 2006), and working memory (Klinberg, 2009). In the last two or three

decades, these efforts have culminated in the consolidation of EEG Biofeedback, or Neurofeedback, as a viable intervention for the neuro-rehabilitation of ADHD patients.

Review of the literature on the effectiveness of neurofeedback in reducing ADHD symptoms indicates that after Lubar and Shouse's pioneering work (1976), research performed during the period of time from 2004 to 2010 has shown neurofeedback to be efficient in the improvement of cognitive and behavioral difficulties in ADHD patients, especially the improvement of attention skills (e.g., Butinik, 2005). Of particular relevance for the present research are the studies by American researchers, Gouts and Eagle (1994), Lubar and colleagues (Lubar et al., 1995) and by Yaghubi (2007) in Iran, which have provided empirical evidence for the effectiveness of neurofeedback training in improving performance on the TOVA continuous performance test and also have shown that neurofeedback training can increase IQ scores as measured by the Revised Wechsler Intelligence Scale for Children (WISC-R, 1991). More recently, Sherlin and colleagues (Sherlin, Arns, Lubar, & Sokhadz, 2010) have reported in their position paper, evidence regarding the long-term effects of neurofeedback via the regulation of brain waves at cortical levels leading to long-term improvements of behavior. These findings and many more have been summarized in several review studies (e.g., Arns, deRidder, Strehl, Breteler, & Coenon, 2009; Lofthouse, Hersch, Hurt, DeBeus, & Heurt, 2012; Gani, Birbaumer, & Strehl, 2009; Fox, Tharp, & Fox, 2005; Gevensebelen et al., 2009; Monstra et al., 2005).

Contrary to the confidence with which earlier research studies (e.g., Camobel, 2003; Chemark et al., 1999; Loo & Barkley, 2005), emphasized treatment with stimulant drugs, more recent research (e.g., Young, 2010) has shown much caution is warranted regarding the effectiveness of stimulant drugs in the treatment of attention deficit symptoms of ADHD, as stimulant drugs have shown to be effective only in C and HI subtypes. Similarly, many research studies in Iran (Babaei, 2001; Esmaili, Bahreyniyan, & Hashemiyan, 2004; Mashhadi, 2006; KarAhmadi, 2007; Imani, 2009; Shirazi, 2005; Yaghoubi, 2006), as well as Abedi, Jamali, Faramarzi, Aghayi, and Behruz's 2012 meta analysis, have provided support for the facilitating effect of stimulant drugs in the transfer of dopamine neurotransmitter in the prefrontal cortex leading to a considerable decrease of ADHD symptoms; although as noted earlier, this improvement has not been sustained after termination of treatment or cessation of drug intake and has not been supported with the IA subtype.

Based on parental reports of ADHD children regarding the effectiveness of stimulant drugs in reducing their children's symptoms, the evidence indicates that, despite some positive effects of drugs in academic performance, ability to concentrate and reduce aggression and hyperactivity behaviors, children under medication still have difficulties in reading, social skills, and understanding of rules for complying with the underlying reasons of inappropriate behavior (Lubar, 2003).

In general, most studies have shown that neurofeedback training is efficient in reducing symptoms of all three subtypes of ADHD; although, some studies (e.g., Carmody, Radvansik, Wadhwani, Sabo, & Vergara, 2002; Monstra et al., 2005) have shown that the effect of neurofeedback is more efficient in patients with attention deficiency, rather than in those with hyperactivity and impulsivity symptoms, to such an extent that neurofeedback has been considered to be a systematic training of attention (Butinik, 2005). In fact, many research studies (Arns et al., 2009; Fox et al., 2005; Gani et al., 2009; Gevensebelen et al., 2009; Lofthouse et al., 2010; Monstra et al., 2005; Sherlin et al., 2010; Williams, 2010) have confirmed the effectiveness of neurofeedback in improving attention and cognitive skills. Sherlin et al. (2010), in a position paper about the effectiveness of neurofeedback on

reducing the ADHD symptoms, concluded that neurofeedback training is most efficient in reducing attention and impulsivity symptoms although less so regarding hyperactivity symptoms. Based on a thorough review of the literature, Sherlin and colleagues believe that new research studies are needed for exploring the different mechanisms involved accounting for subtype's differences, which may help explain the cognitive deficits specific to each subtype. Previous research has mainly focused on the effectiveness of neurofeedback training on the decrease of a specific and/or a single clinical symptom; however, ADHD is associated with different phenotypes, each with particular properties related to multiple cognitive deficits (Bidwell, McClernon, & Kollins, 2011).

Review of the literature also indicates that most researches (e.g., Arns et al., 2009; Fox et al., 2005; Gani et al., 2009; Gevensebelen et al., 2009; Lofthouse et al., 2010; Monstra et al., 2005; Sherlin et al., 2010; Williams, 2010) have focused on the combined subtype of ADHD, and in follow-up assessments regarding the effectiveness of neurofeedback, on the decline of clinical symptoms; however, these studies have not evaluated the role of neurofeedback in the improvement of cognitive deficits taking into account different subtypes. Hence, given the extreme importance of cognitive deficits in the perseveration and severity of ADHD symptoms (e.g., Butcher et al., 2000; Fischer, Barkley, Smallish, & Fletcher,2005), and given the effectiveness of neurofeedback training in ADHD patients' neuropsychological rehabilitation (e.g., Arns et al., 2009; Fox et al., 2005; Gani et al., 2009; Gevensebelen et al., 2009; Lofthouse et al., 2010; Monastra et al., 2005; Sherlin et al., 2010; Williams, 2010), the aim of the present research was to determine the effectiveness of neurofeedback training in decreasing cognitive deficits considering C and IA subtypes.

METHOD

Participants

Using a purposeful sampling method, 30 male children (15 patients for each ADHD subtype) were drawn from a larger sample of children (aged 7–12 years) who were consecutive referrals to a psychiatrist in Atiyeh Clinic. In order to secure sound subtype diagnoses in the selected sample of participants in the present study, inclusion criteria involved several assessments for subtype diagnosis: a) a psychiatrist diagnosis for ADHD subtypes, b) the implementation of a clinical interview checklist based on the DSM-IV-TR criteria, and c) the administration of the SNAP-IV questionnaire. Those participants who had used stimulant drugs were excluded from the study, due to drug effects on brain functioning and its interference with the aim of this study of examining neurofeedback training effects only. Additional exclusion criteria included confirmed co-morbid disorders, sensory-motor disability, epilepsy, and IQ scores lower than 85. Age and gender of participants was controlled in this study. Thus, all participants were 7–12 year old male children with an IQ score range of higher than or equal to 85, and had not taken medication for 3 months and two weeks (approximately 100–114 days) prior to participation in this study.

Procedure

The participants performed 40 sessions of neurofeedback (NF) training. The NF training protocol used consisted of theta/beta training. The goal was to decrease activity in the theta band (4–8 Hz) and high beta (18–30 Hz) and to increase activity in the beta band (13–20 Hz) of the EEG in (FZ), and to decrease activity in the theta band (4–8 Hz) and high beta (18–30 Hz) in (CZ). Pre-training assessments encompassed several behavior rating scales (DSM-

IV-TR Clinical Interview Checklist, SNAP-IV, IVA). The IVA scale was performed before and after 40 sessions NF training.

Instruments

DSM-IV-TR Clinical Interview Checklist.   The clinical interview checklist based on DSM-IV-TR was used as one measure for the diagnosis ADHD participants. The substance of this checklist is in fact the same diagnostic criteria of DSM-IV-TR for inclusion and exclusion criteria of ADHD. It is structured on a question format and was completed by the mothers of the participating children.

SNAP-IV Rating Scale-Parent Form. The SNAP-IV Rating Scale used in the present study was the revised version of the Swanson, Nolan and Pelham (SNAP) Questionnaire (Swanson, Nolan, & Pelham, 1993). The SNAP-IV consists of Inattention, Hyperactivity/ Impulsivity, and Oppositional subscales (Bussing et al., 2008; Swanson et al., 2001). The SNAP-IV includes items from the DSM-IV (1994) criteria for two ADHD subsets of symptoms: inattention (items # 1–9) and hyperactivity/impulsivity (items # 10–18). Also, items are included from the DSM-IV criteria for Oppositional Defiant Disorder (ODD, items # 19–27) since ODD often is present in children with ADHD. The items are scored on a 4-point response scale, ranging from "0" to "3" (*Not at All* = 0, *Just A Little* = 1, *Quite a Bit* = 2, and *Very Much* = 3). The Chinese version of the SNAP-IV was reported to have satisfactory levels of reliability and concurrent validity (Liu et al., 2006). Results from an Iranian study, examining the psychometric properties of this test reported three orthogonal constructs following factor analysis, criterion validity (.48) and high alpha coefficient for reliability (.82).

Wechsler Intelligence Scale for Children-Revised (WISC-R). In this research, the revised version of WISC-R was used, which has been standardized with Iranian children 6–13 years old by Shahim (1998). Shahim's (1998) research reported reliability coefficients ranged between .44 and .94.

The Integrated Visual and Auditory (I.V.A.) Test Battery. The Continuous Performance Test (CPT) is a subtest from the Integrated Visual and Auditory (IVA) battery of tests, used as a screening tool in conjunction with other diagnostic procedures (e.g., parent and teacher behavior rating scales, QEEG, T.O.V.A.) to assist in the screening of individuals with Attention Deficit Hyperactivity Disorder (ADHD). The computerized CPT involves the presentation of target and non-target stimuli. The test runs for 14 minutes and primarily assesses attention and impulse control (Conners, 1985; 2004). Briefly, participants are required to respond to the stimuli on a computer screen by pressing a space bar for every letter except for the letter "X". In addition administration and scoring are computerized, removing the element of human errors. All IVA scores are presented both as raw scores and as quotient scores. The basis for statistical analysis is the same as that used for more IQ tests; all quotient scores have a mean of 100 and a standard deviation of 15 (Conners, 1985; 2004). The CPT was designed to discriminate ADHD populations from individuals with Conduct Disorder and those without behavior problems and is based on extensive research evidence (Chee, 1989; Connors, 2004). It has also been used to monitor the effectiveness of neurofeedback training and/or medication (Riccio, Reynolds, Lowe, & Moore, 2002). Reliability coefficient reported by Seckler, Burns, Montgomery, and Sandford (1995) with the test-retest method was 0/37- 0/75, and IVA was found to be a significantly stable measure of performance both globally and in terms of specific scales. The sensitivity of the IVA in being able to correctly identify ADHD children who were previously diagnosed by health professionals is 92%. The specificity (proportion of non-ADHD children who received a

negative finding) was 90%. The positive predictive power is 89% and the number of false negatives 7.7% (lower than most other CPT subscales).

Results

In order to evaluate the effectiveness of neurofeedback training in neurocognitive rehabilitation of children diagnosed with ADHD subtypes IA and C, several steps were followed in data analysis. First of all, a t-test for dependent groups, without considering experimental groups, was computed for all participants between pre- and post-neurofeedback training scores for all IVA subscales. Results indicated that neurofeedback training had a significantly enhancing effect for all participants on all IVA subscales, with exception of one subscale (balance). These findings are depicted in Table 1.

Table 1

*Means, Standard Deviations, and Difference Score t-tests for IVA Subscales for
All Participant without Considering C and IA Subtypes*

Subscale of IVA	M		SD			
	Pre test	Post test	Pre test	Post test	Pre-Post t-test	Sig.
Response control	74.00	110.86	42.26	8.58	4.69	0.05
Attention	37.46	76.33	26.15	16.70	8.71	0.001
Prudence	117.68	16.80	52.38	11.90	4.53	0.001
Consistency	122.38	165.40	47.56	14.22	4.76	0.001
Stamina	127.21	158.53	47.64	21.86	3.40	0.001
Vigilance	54.58	132.23	43.25	30.06	10.36	0.001
Focus	131.64	170.08	54.11	21.43	3.99	0.001
Speed	70.00	82.28	30.54	25.23	2.72	0.05
Readiness	134.43	159.53	49.03	16.14	2.88	0.001
Comprehension	70.03	126.53	46.17	26.64	3.35	0.001
Persistence	148.11	156.06	20.32	15.01	1.97	0.05
Sensory/motor	92.06	131.23	28.97	13.00	7.32	0.001
Sustained Attention	50.25	113.26	29.36	27.75	12.19	0.001
Balance	92.16	102.03	38.26	12.34	1.34	0.70
Hyperactivity	92.66	107.23	27.03	5.93	2.93	0.001

A MANCOVA analysis was computed in order to evaluate the effectiveness of neurofeedback training on IVA post-training performance. This analysis enabled a comparison of pre- post-training performance of two experimental groups, controlling for pre-training performance, as well as the simultaneous consideration of multiple IVA dependent

measures. Results from this analysis yielded only one significant finding regarding IVA readiness subscale scores. The participants in the IA subtype obtained significantly higher readiness scores (F = 4467/61, P= 0/01) in comparison to participants from the C subtype, indicating a highly specific effect of neurofeedback training when comparisons are made considering these two categories of ADHD. No other results reached significance. Overall indices of significance of the MANOVA analysis are presented in Table 2. Table 3 depicts results from ANCOVA analysis. The result of this table, consistent with Table 2, showed that the effect of neurofeedback training did not differ in the two subtypes, except in the readiness subscale (F= 729/08, P=0/05).

Table 2
MANCOVA Analysis Overall Significance Indices of IVA Pre-Post Test Difference Scores Comparing Two ADHD Subtypes

Test	Value	F	df of the error	Sig.	Effect size
Pillai,s trace	1	4467.61	13	0.01	1
Wilk,s lambda	0	4467.61	13	0.01	1
Hotteling,s trace	58078.93	4467.61	13	0.01	1
Roy's Largest Root	58078.93	4467.61	13	0.01	1

Table 3
ANCOVA Analysis of IVA Pre-Post Test Difference Scores Comparing Two ADHD Subtypes

Variable	SS	df	MS	F	Sig.
Response control	71.32	1	71.32	2.10	0.17
Attention	24.90	1	24.90	0.08	0.74
Prudence	187.28	1	187.28	2.46	0.14
Consistency	398.51	1	398.51	2.08	0.17
Stamina	23.81	1	23.81	0.03	0.87
Vigilance	1007.21	1	1007.21	0.79	0.39
Focus	1193.14	1	1193.14	2.46	0.14
Speed	519.60	1	519.60	0.75	0.40
Readiness	729.08	1	729.08	3.97	0.05
Comprehension	609.96	1	609.96	0.75	0.40
Persistence	431.69	1	431.69	1.48	0.24
Sensory- motor	25.47	1	25.47	0.14	0.71
Sustained attention	81.58	1	81.58	0.10	0.75
Balance	100.79	1	100.79	0.51	0.48
Hyperactivity	4.16	1	4.16	0.15	0.70

Discussion

The main finding of the present study refers to the effectiveness of neurofeedback training in enhancing the neurocognitive rehabilitation of ADHD children, regardless of subtype classification. More specifically, participant children 7 to 12 years of age, who were diagnosed with ADHD, either IA or C subtypes, and who underwent neurofeedback training, showed improved performance on all IVA sub-scales, with exception of the readiness subscale (Table 1 and Table 3). An extensive number of research studies (Arns et al., 2009; Fox et al., 2005; Gani et al., 2009; Gevensebelen et al., 2009; Lofthouse et al., 2010; Monstra et al., 2005; Sherlin et al., 2010; Williams, 2010) support the effectiveness of neurofeedback training on decreasing the clinical symptoms associated with ADHD. In particular, the literature review performed by Sherlin and colleagues (2010) provide evidence of empirical findings supporting the effects of neurofeedback interventions in decreasing ADHD symptoms in all subtypes.

Neurofeedback has been found to be equally effective as interventions using medication (Rossiter & La Vaque, 1995; Monastra et al., 2005; Fuchs, Birbaumer, Lutzenberger, Gruzelier, & Kaiser, 2003; Greco & Orlandi, 2004; Le´vesque, Beauregard, & Mensour, 2006), with long-term improvements estimated to last from 6 months (Leins et al., 2007) up to 2 years (Gani, Birbaumer, & Strehl, 2009).

It is important to note that in the present study, neurofeedback training proved efficient not only in decreasing symptoms of both ADHD subtypes, operationalized according to DSM-IV (American Psychiatry Association, 2000) criteria, but also demonstrated its neuropsychological rehabilitative utility, marked by massive decreases in cognitive deficits of participants. The exception to these findings was the result obtained with the IVA - Balance subscale. To the extent that this measure assesses visual or auditory cognitive dominant preferences for learning, it has been found to be sensitive to learning disorders (Standford &Turner, 1995). Since, for the purposes of the present study, it was desired that children conforming the experimental groups, be a free as possible from co-morbid disorders, the screening process in the present study involved excluding all children with learning disorders, and as such, it can be said that children participating in the present study did not have notorious learning disorders and thus, their performance on the Balance subscale fell within normal ranges, and neurofeedback training was irrelevant to the participant ADHD children's performance on this measure.

Another important finding of the present study refers to the equal effectiveness of neurofeedback training, in terms of neuropsychological rehabilitation, for children from both attention deficiency (IA) and combined (C) ADHD subtypes. Neurofeedback training was differentially effective only in relation to the IVA Readiness subscale, having a significantly more enhancing effect upon children diagnosed with IA subtype, in comparison to those diagnosed with ADHD-C subtype. For interpretation of the undifferentiated results obtained regarding post-training performance of participant children from IA and C subtypes, neuroimaging data from structural and functional brain imaging studies indicates that the neural substrates underlying both subtypes could have been affected by NF training. For instance, on the one hand, the prefrontal cortex (PFC) and the anterior cingulate cortex (ACC) have been identified as two areas functionally responsible for ADHD attention deficits, including focusing, selective attention, vigilance, attention stability (deficits fundamentally associated with IA subtype), and, on the other hand, these same areas are equally involved

in cognitive inhibition, response control, physical relaxation, motor response, motor regulation (deficits fundamentally associated with C subtype (Lubar et al., 1995). Moreover, given the assumption that neurofeedback training protocols administered in the present study directly affect brain-activation activity in these areas, it is expected that neurofeedback intervention in the present study should have affected most cognitive deficits associated to these cortical areas. To deepen our interpretation of findings, a description of brain dynamics seems appropriate at this point. Within a dynamic framework, it is assumed that the brain functions according to a complex neural network, conformed by a high number of nerve cells, which are related to each other in a systemic fashion, such that changes initiated in one area, will have an effect on other brain areas. For instance, the ACC sends signals to the Septum, PFC, and parietal cortex, and in this way communication with other brain areas is established (Lubar et al., 1995). Based on this information, it can be said that neurofeedback training affects brain areas involved in all variations of attention deficit and hyperactivity disorder, over and above ADHD subtypes.

Regarding the selective enhancement of performance among IA subtype children on the IVA readiness measure, it can be said that IA children, more so than children in the C subtype, are expected to be more pronouncedly deficient in resisting the inability to continue to pay attention to a task. In the present study, although both groups initially performed at the same level, it seems that neurofeedback training had a differentially rehabilitative enhancing impact on IA subtype children. In the past, the differential effects of neurofeedback training have been documented. For instance, neurofeedback therapy has been shown to be more effective in decreasing symptoms associated with attention deficiency, more so than symptoms related to hyperactivity and impulsivity (Butinik, 2005; Carmody, Radvansik, Wadhwani, Sabo & Vergara, 2001; Monastra, Monastra, & George, 2002).

Some limitations in this study have to be recognized. One main limitation of the present study was the use of DSM-IV-R criteria for subtype selection, which has been questioned due to the ambiguity and overlapping of symptoms. New theoretical and methodological developments in the study of ADHD have challenged the validity of subtype categories in attempting to conceptualize ADHD. Basically, researchers have begun to question whether ADHD subtypes are basically different in nature, and challenge the adequacy of the categorical approach, in comparison to the dimensional approach, in explaining observed differences in the disparate groups of affected individuals that are included within this disorder. Fundamentally, new hypotheses should center on the question of whether phenotypic differences observed in the disorder's symptoms, are differences in degree of severity and represent quantitative differences in hyperactivity, impulsivity and inattention along a single continuum, or these differences reflect separate categories or subtypes which are qualitatively different from each other (Lubke et al., 2007). In addition, it has been said that DSM-IV-R criteria fail to properly discriminate IA and C subtypes as they truly are (Hinshow, 2001; Lahey, 2001). Future research is warranted to include more adequate criteria, beyond that offered by DSM-IV-R, in classifying children according to ADHD subtypes. It is possible that when using different criteria, neurofeedback training may yield different results. Also, more recently, researchers (Chhabildas, Pennington, & Willcut, 2001; Ogrim, Kropotov, & Hestad, 2012; Thompson & Thompson, 2009) are attempting to break new ground in search of better methods for classification of ADHD subtypes, which seriously questions the appropriateness of using DSM-IV-R criteria. In this approach, ADHD individuals are classified based on different neuropsychological patterns of brain wave activity revealed in quantitative electroencephalograms (QEEG). It remains to be seen whether this new approach offers advantages over present methods in terms of clinical utility for diagnosis and treatment of ADHD children. However, it must be mentioned that this new

approach will offer a clear advantage to neurofeedback training in terms of guiding the type of protocols to be used in different interventions based on different wave activity patterns of ADHD patients. Therefore, it is recommended that future research evaluate the neuropsychological profiles of subtypes of ADHD based on DSM-IV-R criteria. Likewise, using different measures to evaluate treatment outcome will be appropriate. For example, the Cambridge Neuropsychological Test Automated Battery (CANTAB), has been used in preterm children, children with typical development, and children with neuro-developmental disorders such as ADHD and autism, is a computerized battery of EF which specifically includes measures of frontal lobe function (Luciana, Lindeke, Georgieff, Mills, & Nelson, 1999; Curtis, Lindeke, Georgieff, & Nelson, 2002).

Another limitation concerns the recordings of baseline in pre- and post-treatment. Our subjects were ADHD boys 8–12 years old that did not take any medication across 40 session's neurofeedback. As such, recording the baseline in the first 5–6 sessions of neurofeedback was not possible due to the hyperactivity and impulsivity of participant children. As a result, a comparison of pre- and post-treatment baseline is not possible in the present study. However, comparison of QEEG data before and after treatment is an alternative for this purpose. In this study we obtained pre-treatment QEEG information only for diagnostic purposes (the comparison of QEEG patterns in two subtypes will constitute a separate research). Such comparative examinations of pre- and post-neurofeedback in two subtypes is suggested for future research studies.

In conclusion, in spite of these limitations, the present findings supported the effectiveness of neurofeedback training in enhancing the neurocognitive rehabilitation of ADHD children, regardless of subtype classification.

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NeuroRegulation

Quality of Work Life Factors for Mental Health Therapists Providing Neurofeedback

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Abstract

The current study investigates factors connected to Quality of Work Life (QWL) for mental health therapists providing neurofeedback (NFB) based on previous NFB conceptual framework and QWL findings (Larson, In Press; Larson, Cothran, Drandorff, Morgan, & Ryan, 2012; Larson, Ryan, & Baerentzen, 2010). One hundred and ninety-eight NFB therapists completed online surveys gathering demographics and ratings of practice behaviors and characteristics. SPSS version 20 was utilized for descriptive statistics, frequencies, means, standard deviations, ranges, Pearson Product-Moment Correlation analyses, independent samples t-tests, and a regular simultaneous regression analysis. Results of this study found that QWL separately correlated with calmness, observant, realistic, and optimistic scores, and therapists with high levels of technique and commitment reported significantly higher QWL scores compared to therapists with moderate levels of technique and commitment. The current findings indicated that 40% of the variance in the QWL can be determined by variance in a significant multiple correlation of confidence, monthly NFB sessions, years of NFB experience, and burnout.

Keywords: mental health, therapists, neurofeedback, EEG biofeedback, quality of work life

Introduction

Research has demonstrated that limited resources, increased role diffusion, increased work demands, burnout, work schedules, reduced employee support, and work stress negatively impact Quality of Work Life (QWL) (Bragard, Dupuis, Razavi, Reynaert, & Etienne, 2012; Maslach, Schaufeli, & Leiter, 2001; Sirgy, Reilly, Wu, & Efraty, 2008; Umene-Nakano et al., 2013). A systematic literature review revealed that career satisfaction, job performance, organizational commitment, quality of work life, and turnover intentions are related to life satisfaction (Erdogan, Bauer, Truxillo, & Mansfield, 2012). Research also connected low QWL with poor worker health outcomes (Page & Vella-Brodrick, 2012). The World Health Organization (2002) reported poor workplace well-being and health has been connected to

absenteeism, work performance, staff attitude and behavior, and work relationships. Two studies indicated that QWL problems existed within NFB settings, and QWL was related to therapist burnout, interpersonal skill commitment, and client adherence (Larson, Ryan, & Baerentzen, 2010; Larson, Cothran, Drandorff, Morgan, & Ryan, 2012). The current study utilized this previous research as a foundation for investigating QWL research for mental health therapists providing NFB therapy. Uncovering these factors leads to improved knowledge of therapists' QWL and potentially guidance for future therapist and client studies.

Since study participation criteria included mental health therapists that provide NFB therapy, an overview of NFB and research findings follows. Neurofeedback, electroencephalographic (EEG) biofeedback, or brain-computer interface, combines operant conditioning and advanced technology to teach individuals to influence and regulate their EEG patterns leading to improved physiological and psychological functioning. The term neurofeedback (NFB) is used for the purposes of this paper, with the understanding that EEG biofeedback and brain-computer interface are also included when the term NFB is used. Berger (1930) detected EEG activity in 76 individuals and demonstrated feasibility of capturing and utilizing EEG in his follow-up studies. Kamiya (2011) and Sterman, LoPrestis, and Fairchild (2010) reviewed and summarized their crucial applied EEG research during the 1960s and 1970s; their research demonstrated the feasibility and utility of combining EEG wave patterns with operant conditioning to improve physiological regulation. Hammond (2011) provided a review of NFB research findings, and Yucha and Montgomery (2008) presented a framework and findings for evidence-based NFB. Arns, de Ridder, Strehl, Breteler, and Coenen's (2009) neurofeedback meta-analysis reported large effect sizes for impulsivity and inattention and a medium effect size for hyperactivity. A randomized controlled trial with a six-month follow-up of children with ADHD indicated significant academic improvements for the NFB intervention group compared to the pharmacological intervention group (Meisel, Servera, Garcia-Banda, Cardo, & Moreno, 2013). Niv (2013) reviewed NFB effectiveness research for various disorders and concluded NFB demonstrated superior or equivalent outcomes when compared to alternative or no treatment.

In addition to NFB efficacy and effectiveness research, current literature highlights the importance exploring therapist and client relationships, establishing NFB practice guidelines, identifying properly trained therapists, highlighting NFB learning principles, and understanding potential directions for future practice and research growth (Aguilar-Prinsloo & Lyle, 2010; Hammond & Kirk, 2008; Hammond et al., 2011; Sherlin et al., 2011; Lyle, 2012). However, a comprehensive literature review found a limited number of investigations related to NFB therapist factors. Rubi (2006) investigated international therapist demographic variables, and a therapist training program highlighted age as a potential variable for specific client types (Thompson & Thompson, 2008). Additional research reported therapist perspectives and factors related to quality of work and NFB outcomes (Larson, Ryan, & Baerentzen, 2010; Larson, Cothran, Drandorff, Morgan, & Ryan, 2012; Larson, In Press).

Based on previous findings and recommendations for future research, the current study explores connections between QWL and factors of mental health therapists providing NFB. First, the variables within the study are defined, with specific measurement details of each variable, in the methods section of this paper. Second, this paper contains a review of current literature and provides the rationale for including these variables in the study. Third, the study hypotheses are listed.

Definitions of Variables

Throughout this section of the paper, the primary variables are in bold type to provide easy reference for the reader. **QWL** is defined as interactions among work outcomes, settings, resources, and worker characteristics. **Calmness** included the ability to remain relaxed with comfortable and engaging conversations throughout NFB sessions; **confidence** described self-assurance in providing effective therapeutic treatment during NFB sessions. **Observant** included the ability to notice and synthesize client comments, behaviors, and responses to NFB sessions. **Realistic** is defined as providing clear and concise expectations of NFB outcomes and **optimism** as maintaining a positive outlook throughout the therapeutic process. **Techniques** is defined as therapist abilities utilizing both NFB technology and interpersonal skills. **Commitment** is identified as the level of importance the therapist places on learning new NFB technology and interpersonal skills. **Dropouts** is defined as the number clients that terminate NFB therapy each month before completing the recommended number of NFB sessions; **successful outcomes** included the number of clients completing the recommended NFB training plan each month. **Monthly NFB sessions** included the total amount of NFB sessions therapists provided each month, and **years of NFB experience** included the total number of years practicing NFB. The current study utilized the Maslach and Leiter (1997) definition of **burnout** as experiencing emotional exhaustion, depersonalization, and personal accomplishments leading to negative emotions and unproductive workplace outcomes.

Study Rationale

In order to connect current study variables to previous research findings, the variables that were used in a previous study by the current authors are placed in parentheses and bold type, followed by the term found in the literature. If the current study utilized the same term found in the research literature, then the variable name is typed in bold without brackets. **QWL** has been connected to job performance (**techniques**), turnover, interpersonal skill commitment (**commitment**), client adherence (**dropouts**), client outcomes (**successful outcomes**), work schedules (**monthly NFB sessions**), career satisfaction (**years of NFB experience**), and **burnout** (Bragard, Dupuis, Razavi, Reynaert, & Etienne, 2012; Erdogan, Bauer, Truxillo, & Mansfield, 2012; Firth-Cozens, 2001; Larson, Ryan, & Baerentzen, 2010; Larson, Cothran, Drandorff, Morgan, & Ryan, 2012; Maslach, Schaufeli, & Leiter, 2001; Page & Vella-Brodrick, 2012; Sirgy, Reilly, Wu, & Efraty, 2008; Umene-Nakano et al., 2013). The current paper investigates **calmness, confidence, observant, realistic,** and **optimistic** because practitioners reported the importance of these traits within NFB settings (Larson, Ryan, & Baerentzen, 2010; Larson et al. 2012). Additional research identified and categorized important therapist traits and characteristics similar to the traits of interest in this study (Imel & Wampold, 2008; Grencavage & Norcorss, 1990; Wogan, & Norcross, 1985; Wampold et al., 1997). Imel and Wampold (1997) defined common factors as practitioner characteristics, role, client bond, context, and relationship qualities, which are separate from the specific therapy method being applied. Their findings and framework are used to organize the therapist traits that are investigating in this study. Since their framework includes a broad range of factors and the current paper focuses on practitioner factors, their common factors model was modified into common NFB therapist factors model, which included the five practitioner factors used in the current study: calmness, confidence, observant, realistic, and optimistic. The hypotheses and rationales, which are based on previous research and a review of the literature, are offered below.

Research Hypotheses:

1. **Calmness, observant, realistic, optimistic, dropout**, and **successful outcome** scores will be separately correlated with **QWL** scores.
2. Group one with high **technique** scores will report higher **quality of life** scores compared to group two with moderate **technique** scores.
3. Group one with high **commitment** scores will report higher **QWL** scores compared to group two with moderate **commitment** scores.
4. A significant and multiple correlation of **confidence, monthly NFB sessions, years of NFB experience**, and **burnout** explains variance in **QWL** scores.

METHODS

Participants and Procedure

With Illinois Institute of Technology institutional review board approval, NFB therapists were recruited through discussion boards and email distributions. The announcement directed participants to an online survey that included a consent process. In response to the announcement, 198 usable therapist surveys were collected. SPSS Version 20.0 was utilized to complete the analyses. Two research assistants entered the 198 surveys into two separate SPSS files; discrepancies were resolved by comparing the two files and the original surveys. A five-step data-set cleaning process was used to identify errors, missing data, and outliers, and to ensure that the data met assumptions for analyses (Mickey, Dunn, & Clark, 2004). The SPSS analyses include descriptive statistics, frequencies, means, standard deviations, ranges, Pearson Product-Moment Correlation analyses, independent samples t-tests, and a regular simultaneous regression analysis.

Instrumentation

For this study, the responses to the 65-item NFB Therapist Survey, which can be found in Appendix A, were collected. This survey was developed by utilizing findings from previous NFB therapist investigations (Larson, Ryan, & Baerentzen, 2010; Larson, Cothran, Drandorff, Morgan, & Ryan, 2012; Larson, In Press). This survey included demographic variables and ratings on therapist characteristics. For the remaining analyses, the following variables from the 65-item survey were utilized. The following variables utilized one survey question: gender (item #1); age (item #2); education (item #3); mental health license (item #4); health care license (item #5); years of NFB experience (item #6); continuing education (item #7); monthly NFB sessions (item #8); monthly successful outcomes (item #9); monthly dropouts (item #10); QWL (item # 15); and burnout (item #16). The following variables utilized two or more survey questions: techniques and commitment. Techniques was measures by adding the scores of two survey questions: "How would you rate your current knowledge about neurofeedback technology?" (item #11), and "How would you rate your interpersonal skills with clients?" (item #12). Both were measured on a seven-point Likert scale with anchors of 1 = poor to 7 = excellent. These questions gathered therapists' perspectives of their own knowledge levels rather than testing their knowledge or someone else's rating of their knowledge. Commitment was measured by adding the scores of two survey questions: "How would you rate your commitment to learning about neurofeedback technology?" (item #13), and "How would you rate your commitment to improving interpersonal skills with clients?" (item #14). Both were measured on a seven-point Likert scale with anchors of 1 = poor to 7 = excellent.

Using seven-point Likert scales, ability, priority, ease, and frequency were measured for: empathic, confident, friendly, and optimistic. For example, "During a neurofeedback session, what is your satisfaction level with your ability to be confident?" (1 = very dissatisfied to 7 = very satisfied); "During a neurofeedback session, what is your priority level for being confident?" (1 = not a priority to 7 = essential priority); "During a neurofeedback session, what is your level of difficulty or ease with being confident?" (1 = very difficult to 7 = very easy); and "During a neurofeedback session, how often are you confident?" (1 = not at all to 7 = frequently). The same method of measurement was used for the remaining four factors of calmness, observant, realistic, and optimistic. The four scores from each question were added together to obtain a composite factor score. For example, the composite confident score was computed as follows: composite confident score = confident ability score + confident priority score + confident ease score + confident frequency score. The composite scores for confidence, calmness, observant, realistic, and optimistic factors were used for remaining analyses of this study.

RESULTS

Table 1 presents demographic information for the research subjects utilized in this study. For 198 subjects, percentages were calculated for gender, education, mental health licensure, and healthcare licensure. In addition, means and standard deviations for age (in years) and monthly continuing education are provided.

Table 1
Demographic Information for Neurofeedback Therapists (N =198)

Item	M	SD	%
Gender			
Female	--	--	48.00
Male	--	--	52.00
Total	--	--	100.00
Education			
Associates	--	--	1.00
Bachelors	--	--	7.60
Masters	--	--	39.90
Doctorate	--	--	51.50
Total	--	--	100.00
Mental Health Licensure			
License	--	--	76.30
Non-License	--	--	23.70
Total	--	--	100.00
Healthcare Licensure			
License	--	--	69.20
Non-License	--	--	30.80
Total	--	--	100.00
Age	55.70	11.19	--
Monthly Continuing Education	6.00	7.38	--

Table 2 provides means, standard deviations, and ranges for variables included within remaining analyses. Pearson Product-Moment Correlation analyses were calculated for QWL, burnout, calmness, observant, realistic, optimistic, dropouts, and successful outcome results. Independent samples t-test analyses were performed using QWL, techniques, and commitment results. Finally, a regular simultaneous regression analysis was performed for QWL, confidence, monthly NFB sessions, years of NFB experience, and burnout results.

Table 2
Means, Standard Deviations, and Range of Quality of Work Life, Techniques, Commitment, Confidence, Monthly Sessions, Years of NFB Experience, Burnout, Attentive, Calm, Observant, Realistic, Optimistic, Careful, Dropout, and Successful Outcome Scores (N =198)

Measure	*M*	*SD*	Range
Quality of Work Life	9.17	1.58	1.00 - 10.00
Techniques	11.31	1.57	7.00 – 14.00
Commitment	12.04	1.81	7.00 – 14.00
Confidence	23.79	3.11	14.00 – 28.00
Monthly Sessions	62.45	69.82	0.00 – 400.00
Years of NFB Experience	9.96	7.61	1.00 - 40.00
Burnout	2.66	1.96	1.00 - 10.00
Calm	25.05	2.53	4.00 - 28.00
Observant	25.10	2.42	4.00 - 28.00
Realistic	24.54	2.65	4.00 - 28.00
Optimistic	24.00	2.94	4.00 - 28.00
Dropouts	0.69	1.00	0.00 - 5.00
Successful Outcomes	5.72	11.67	0.00 - 95.67

Table 3 provides Pearson Product-Moment Correlations for the variables of interest within this study. Results indicated significant and positive correlations between the variables of quality of work life, calmness, observant, realistic, and optimistic. Non-significant correlations were found between QWL and dropouts, and successful outcomes.

Table 3

Findings from Correlations of NFB Therapists' Quality of Work Life, Calmness, Observant, Realistic, Optimistic, Drop Out, and Successful Outcome Scores (N =198)

Scale	QWL	Ca	Ob	R	Op	DO	SO
QWL	--	.34**	.38**	.41**	.41**	-.04	.03
Ca	--	--	.59**	.59**	.62**	.007	.09
Ob	--	--	--	.69**	.59**	-.04	.12
R	--	--	--	--	.58**	-.05	.13
Op	--	--	--	--	--	-.06	.09
DO	--	--	--	--	--	--	.15*
SO	--	--	--	--	--	--	--

Note: QWL = Quality of Work Life, Ca = Calmness, Ob = Observant, R = Realistic, Op = Optimistic, DO = Drop Out, and SO = Successful Outcome, *$p < .05$. **$p < .01$.

An independent samples t-test was conducted to compare QWL scores in the high techniques condition ($n = 91$) and the moderate techniques condition ($n = 107$). There was a significant difference in the scores for high techniques (M = 9.60, SD = 1.67) and moderate techniques (M = 8.80, SD = 1.37) conditions; $t(196) = 3.65$, $p = 0.000$. These results suggested that level of NFB and interpersonal techniques affects QWL; specifically, these results indicated that when therapists report high levels of NFB and interpersonal skills, their QWL increases. Another independent samples t-test was conducted to compare QWL scores in high-commitment-to-technique-improvement condition ($n = 89$) and moderate-commitment-to-technique-improvement condition ($n = 109$). There was a significant difference in the scores for high commitment (M = 9.54, SD = 1.63) and moderate commitment (M = 8.87, SD = 1.49) conditions; $t(196) = 3.01$, $p = 0.003$. These results suggested that commitment to skill improvement affects QWL; specifically, the results indicated that when therapists demonstrate high levels of commitment to improving NFB technical and interpersonal skills, their QWL increases.

Table 4 provides a regular simultaneous regression analysis for NFB therapists, with QWL scores being the dependent variable and confidence, monthly sessions, burnout, and years of NFB experience combined being independent variables. Regular simultaneous regression results, with an alpha level of .05, indicated that as confidence, monthly sessions, and years of experience increase together with burnout scores decreasing, QWL scores increase. Results indicated a multiple correlation of .63 ($p < .001$), and 40% of the variance in QWL

can be determined by the variance in confidence, monthly sessions, burnout, and years of NFB combined.

Table 4

Findings from Regular Simultaneous Regression Analysis Predicting Neurofeedback Therapist's Quality of Work Life Scores and Confidence, Monthly Sessions, Burnout, and Years of NFB Experience Combined (N =198)

Variable	Beta	t-test	p	R	R^2
DV = Quality of Work Life				.63***	40%
IVs = Confidence	.43	7.59	.000		
Monthly Sessions	.24	4.20	.000		
Burnout	-.25	-4.51	.000		
Years of NFB Experience	.15	2.61	.010		

Note: ***$p < .001$

DISCUSSION

The first hypothesis was partially supported by Pearson Product-Moment Correlation analysis findings; significant and separate correlations were found between QWL and calmness, observant, realistic, and optimistic scores. It was postulated that therapists utilize these traits to support client life goals and to facilitate their own work life goals. With an optimistic outlook, therapists set realistic work goals through calmly observing their own personal needs and work resources. Improving QWL may include therapists setting aside time to utilize these traits to develop and to evaluate personal work goals. Another method for QWL improvement may include identifying educational opportunities for advanced development of calmness, observant, realistic, and optimistic traits within NFB sessions. Overall, identifying these four NFB therapist traits added to the knowledge base of which factors influence QWL. Non-significant and separate correlations between QWL and dropouts and successful outcomes were found in this study. Potentially, these two factors do not influence NFB therapists' perspectives about QWL. It was also proposed that the current study design, measurement methods, and analyses may be limited in measuring and identifying dropout and successful outcomes. Further research may include surveying clients on therapist factors that promote QWL.

The second hypothesis was supported by an independent samples t-test. The high technique group reported significantly higher QWL scores compared to the moderate technique group. These results suggested that level of NFB and interpersonal techniques affects QWL;

specifically, the results indicated that when therapists reported high levels of NFB and interpersonal skills, their QWL increases. High levels of technique afford therapists more time to reflect on client and personal outcomes versus spending time focusing and reflecting on professional skill improvement. Potentially, therapists with more time to relish outcomes leads to improvements in their QWL. Ways to increase techniques may include therapists engaging in mentoring and training opportunities related to NFB and interpersonal skill enhancement. Future research may include investigating effective and user-friendly skill enhancement methods for NFB therapists.

The third hypothesis was supported by an independent samples t-test. The high-commitment-to-improving-technique group reported significantly higher QWL scores compared to the moderate-commitment-to-improving-technique group. These results suggested that level of commitment to improving technique affects QWL; specifically, these results indicated that when therapists reported high levels of commitment, their QWL increases. Potentially, high commitment demonstrates high engagement with work leading to increased QWL. Engaging in skill improvement may also provide new professional and personal growth opportunities that positively influence QWL. Furthermore, therapists may also utilize high commitment when pursuing their own work goals leading to high QWL.

The fourth hypothesis was supported by regular simultaneous regression analysis findings: a significant and multiple correlation of confidence, monthly NFB sessions, years of NFB experience, and burnout explains variance in QWL scores. Neurofeedback therapists deciding to improve their QWL may explore methods focusing on increasing confidence, reducing burnout, and increasing monthly NFB sessions. Therapist that experience high confidence in their own work goals may have higher work satisfaction and QWL. Furthermore, therapists that model confidence during NFB sessions appear to have clients with more improvements, which leads to higher QWL. Ways to increase confidence may include: attending NFB workshops, utilizing mentorship opportunities, completing NFB certifications, increasing NFB technology knowledge, and increasing interpersonal skills. Increasing monthly sessions provides more opportunities for skill improvements, which in turn increases client outcomes leading to higher QWL. Therapists may focus on strategies to increase available time to complete NFB sessions. One strategy may include hiring/contracting personnel to coordinate scheduling, billing, marketing, and other administrative tasks that take time away from completing NFB sessions. Therapists may engage in burnout reduction strategies to eventually improve QWL. Burnout interventions typically address personal physical and psychological wellbeing, individual values, workload versus reward, and workplace stressors. Future burnout research may include identifying and testing burnout interventions that match workplace demands and needs specific to NFB therapists.

The current findings suggest that a therapist's perceptions of self are crucial components connected to QWL. Quality of work life appeared to be related to therapist traits of calmness, observant, realistic, and optimistic. Technical expertise and commitment for improvement appeared to impact QWL and the combination of confidence, monthly NFB sessions, years of NFB experience, and burnout correlated with QWL. Overall, these findings may be summarized as: factors of high work engagement partially explain high work satisfaction. Therapists that are highly engaged with their work may have increased excitement and pleasure that positively influences QWL.

Most research to date has investigated QWL within organizational settings with large staffing patterns and various types of leadership structures. However, one limitation of the current

study included the investigation of private, independent therapists rather than therapists from organizational settings; this may limit the ability to generalize or to directly connect the findings to previous QWL research. These findings are not offered as a comprehensive list of therapist factors related to QWL; however, this may provide a guide for future QWL research, especially investigations into QWL for private, independent therapists. Moreover, additional factors may have been missed due to the study design, sample size, and method of data collection. Additionally, there are limitations in the ability to connect therapist self-perceptions with client outcomes because only therapist self-perceptions were collected for this study and not client data. A meta-analysis demonstrated a moderate effect for cognitive-behavioral and multimodal interventions and a small effect for relaxation techniques on QWL (van der Klink, Blonk, Schene, & van Dijk, 2001). A potential next research step may test cognitive-behavioral, multimodal, relaxation techniques focused on therapist factors found within this study and the impact on QWL. Potential research questions may include: Do cognitive-behavioral, multimodal, relaxation techniques increase therapist factors and improve QWL?; Do NFB therapists with high QWL produce quicker and more sustainable NFB client outcomes?; and Do therapists with self-perceptions of high levels of calmness, confidence, optimistic, realistic, and observant traits produce quicker and more sustainable NFB client outcomes? Overall, the current study attempted to provide findings to identify therapist self-perceptions of traits and behaviors to guide future QWL research.

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APPENDIX

Neurofeedback Therapist Survey

1. What is your gender?
    Male
    Female
2. What is your age?
3. What is your highest level of education?
    High School
    Associate
    Bachelor
    Master
    Doctorate
4. Are you licensed mental health therapist in your state?
    Yes
    No
5. Are you licensed healthcare therapist in your state?
    Yes
    No
6. How many years of neurofeedback experience do you have?
7. For an average month, how many hours of continuing education do you complete?
8. For an average month, how many neurofeedback sessions do you provide?
9. For an average month, how many clients do you have successfully completing their neurofeedback treatment?
10. For an average month, how many clients quit neurofeedback training before completing their neurofeedback treatment?
11. How would you rate your current knowledge about neurofeedback technology?
    Poor   Fair   Good   Very Good   Excellent
    1   2   3   4   5   6   7
12. How would you rate your current interpersonal skills with clients?
    Poor   Fair   Good   Very Good   Excellent
    1   2   3   4   5   6   7
13. How would you rate your current commitment to learning about neurofeedback technology?
    Poor   Fair   Good   Very Good   Excellent
    1   2   3   4   5   6   7
14. How would you rate your current commitment to improving your interpersonal skills with clients?
    Poor   Fair   Good   Very Good   Excellent
    1   2   3   4   5   6   7
15. My satisfaction level with my work life related to neurofeedback is?
    0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
16. My burnout level related to my neurofeedback practice is?
    0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
17. What is your frequency of doing neurofeedback training on yourself?
    Not at all, Once a month, Once every other week, Once a week, Two times a week, Three   times a week, Four times a week, Five times a week, Six times a week, Everyday
NOTE: Survey participants rated 12 traits for questions 18, 19, 20, & 21. Each question had 12 separate responses for a total of 48 items.

18. During a neurofeedback session, what is your satisfaction level with your ability to be...
(a) ethical, (b) attentive, (c) empathic, (d) calm, (e) observant, (f) humorous, (g) analytical, (h) confident, (i) friendly, (j) realistic, (k) optimistic, (l) careful

Very Dissatisfied	Dissatisfied	Neutral	Satisfied	Very Satisfied	
1	2	3	4	5	6	7

19. During a neurofeedback session, what is your priority level for being...
(a) ethical, (b) attentive, (c) empathic, (d) calm, (e) observant, (f) humorous, (g) analytical, (h) confident, (i) friendly, (j) realistic, (k) optimistic, (l) careful

Not a priority Essential	Low Priority	Somewhat Priority	Neutral Priority	Moderate Priority	High Priority	Priority
1	2	3	4	5	6	7

20. During a neurofeedback session, what is your level of difficulty or ease with being...
(a) ethical, (b) attentive, (c) empathic, (d) calm, (e) observant, (f) humorous, (g) analytical, (h) confident, (i) friendly, (j) realistic, (k) optimistic, (l) careful

Very Difficult	Difficult	Somewhat Difficult	Neutral	Somewhat Easy	Easy	Very Easy
1	2	3	4	5	6	7

21. During a neurofeedback session, what is your satisfaction level with your ability to be...
(a) ethical, (b) attentive, (c) empathic, (d) calm, (e) observant, (f) humorous, (g) analytical, (h) confident, (i) friendly, (j) realistic, (k) optimistic, (l) careful

Not at all		Occasionally		Frequently		
1	2	3	4	5	6	7

NeuroRegulation

Neurofeedback for Chemotherapy Induced Neuropathic Symptoms: A Case Study

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Abstract

This case report highlights qEEG and LORETA measures as well as training protocols for a client experiencing self-reported chemotherapy-induced peripheral neuropathy (CIPN). Specifically, we were interested in whether or not the presentation of visual changes secondary to chemotherapy would be responsive to neurofeedback training (NFB). After 20 sessions of NFB, the client reported improvement in all reported symptoms of neuropathy, although her vision did not improve as drastically as the other symptoms.

Keywords: neuropathy, neurofeedback, LORETA, qEEG

Introduction

This is a case study of a 60-year-old woman who was approximately two years post diagnosis of breast cancer and who suffered from neuropathic symptoms after chemotherapy. Neuropathy is a common consequence of cancer and its treatments, where sensory nerves, motor nerves, and autonomic nerves can be affected, such that daily activities such as driving a car, putting on clothing, using utensils, and walking can become difficult if not impossible. In addition to the more common symptom complaints listed above, patients may also experience other symptoms such as visual disturbances that limit their ability to perform daily activities. Neuropathic symptoms may not only impact quality of life but may also affect patient outcomes because of resulting treatment delays, dose reductions, and treatment discontinuation (Vitacco, Brandeis, Pascual-Marqui, & Martin, 2002). The incidence of chemotherapy-induced peripheral neuropathy (CIPN) is estimated to be as much as 71%, depending on the class of agents used (Taxotere, 2014; Abraxane, 2014; Navelbine, 2014).

Of the complaints patients may have of neuropathic symptoms, chemotherapy-related ocular toxicities are underreported as the medical team prioritizes cancer treatment (Singh & Singh, 2012). Complaints of visual side effects range from blurred vision to decreased visual acuity, optic neuropathy, and rarely produced total loss of vision at the early stages (Caraceni, Martini, Spatti, Thomas, & Onofrj, 1997; Singh & Singh, 2012). Cases of visual disturbances from platinum (cisplatin and carboplatin) chemotherapeutic agents are more prevalent than visual disturbances secondary to paclitaxel; however, previous cases of transient visual disturbance during paclitaxel infusions were reported to affect the retina and optic nerve pathways (Scaioli et al., 2006; Capri et al., 1994).

In most cases, visual changes secondary to paclitaxel typically show signs of improvement or reach stabilization at the end of chemotherapy treatment (van den Bent et al., 1997). One case report linked a patient's loss of vision to optic nerve damage during infusion of the taxane drug, docetaxel. This damage was reversed with high-dose steroid therapy (Moloney et al., 2014); however, not all visual changes after chemotherapy are reversible. Another study reported optic neuropathy and retinopathy in 5 patients with permanent visual damage (Khawly et al., 1996). Therefore visually related signs and symptoms secondary to chemotherapy (such as retinopathy) may be generally reversible, whereas those associated with optic neuropathy often may be permanent (Khawly, Rubin, Petros, Peters, & Jaffe, 1996). Finally, although paclitaxel as a therapeutic agent is efficacious in promoting apoptosis and the proliferation of cancer cells, as the case reports suggest, neurological symptoms affecting the visual field may also lead to discontinuation of anti-tumor remedies (Lee & Swain, 2006), hence the severity of the problem and the need for effective treatment alternatives.

It has been found that the direct causes of CIPN include the presence of inflammation and the loss of nerve fibers in the affected area (Gannon, 1971). However, the mechanisms of pain and other neuropathic symptoms, incorporating peripheral receptors, pain pathways, and cortical and subcortical centers where symptoms are perceived, have brought emphasis to the importance of the corticalization of symptoms (Jensen, Greirson, Tracy-Smith, Bacigalupi, & Othmer, 2007). Since the brain has considerable neuroplastic capabilities, neurofeedback may be of benefit to neuropathy patients presenting with a variety of symptoms.

Background

At the time of presentation, the client was a 60-year-old, Caucasian female who reported symptoms of peripheral neuropathic symptoms secondary to chemotherapy treatment with paclitaxel. The client started chemotherapy in June and noted neuropathic symptoms started immediately after her first treatment. Her presenting symptoms were that she dropped objects, had total body cramps, stumbled over objects such as chairs, felt like she didn't know where her feet were, had trouble dressing herself and putting on jewelry, had trouble writing, and she could not cut up her food. She also reported changes in her vision such that she didn't feel safe to drive and had difficulty reading road signs, and even found it extremely difficult to cut her own nails. The patient described the visual perceptual problems as "not being able to process an entire scene" and this led to an increased anxiety around driving or going to the store. The patient sought out acupuncture for her blurry vision and chemotherapy-induced peripheral neuropathy. She reported that the blurry vision would get better for about 15 minutes, but then would return to the previous blurred state. After completing her acupuncture treatments, the patient consulted with an ophthalmologist.

Initially, the ophthalmologist believed her vision problems were due to either dry eye or thin cornea. Both artificial tears and Muro drops for corneal health were administered to the patient to no avail. The neuro-ophthalmic evaluation did not reveal a visual problem that explained her distress. An MRI of the brain also revealed no cause of visual impairment. The patient was advised to discontinue driving and was referred to the department of neuropsychology at a local medical institution for further testing.

Neuropsychological testing revealed mild to moderate impairments of cognitive processing speed and below-expected hand strength and motor dexterity. These deficits were attributed to chemotherapy treatment. The neuropsychologist indicated that slower processing speed at moments at which higher processing is needed (e.g., while driving) could be contributing to her experience of anxiety. The neuropsychologist suggested various anxiety-controlling methods. After this consultation, the patient sought neurofeedback to help her manage the symptoms of chemotherapy-induced peripheral neuropathy.

Methods

The client underwent an initial qEEG, which showed a decrease in alpha power with a concomitant increase in beta power along the sensorimotor strip and into the parietal and occipital lobes, among other findings (Figure 1).
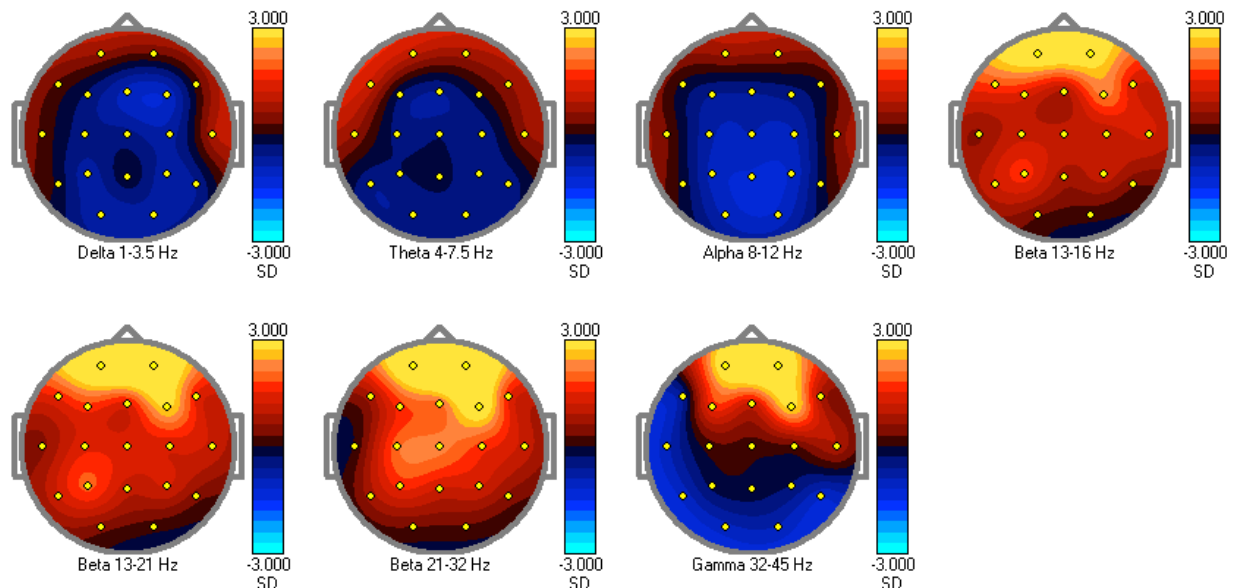
Figure 1. Baseline qEEG (eyes closed).

It was decided to begin neurofeedback with the primary electrode placements at P3, P4 (2-channel referential training), with reward frequency set at 8–11 Hz and inhibit frequencies set at 13–21 Hz and 4–7 Hz. Prior to her first session, she rated her neuropathic symptoms at a six on a numeric rating scale (NRS), with zero being no symptoms and ten being the worst symptoms imaginable, but reported a decrease in her average symptom rating to a five by session number eight (Figure 2).
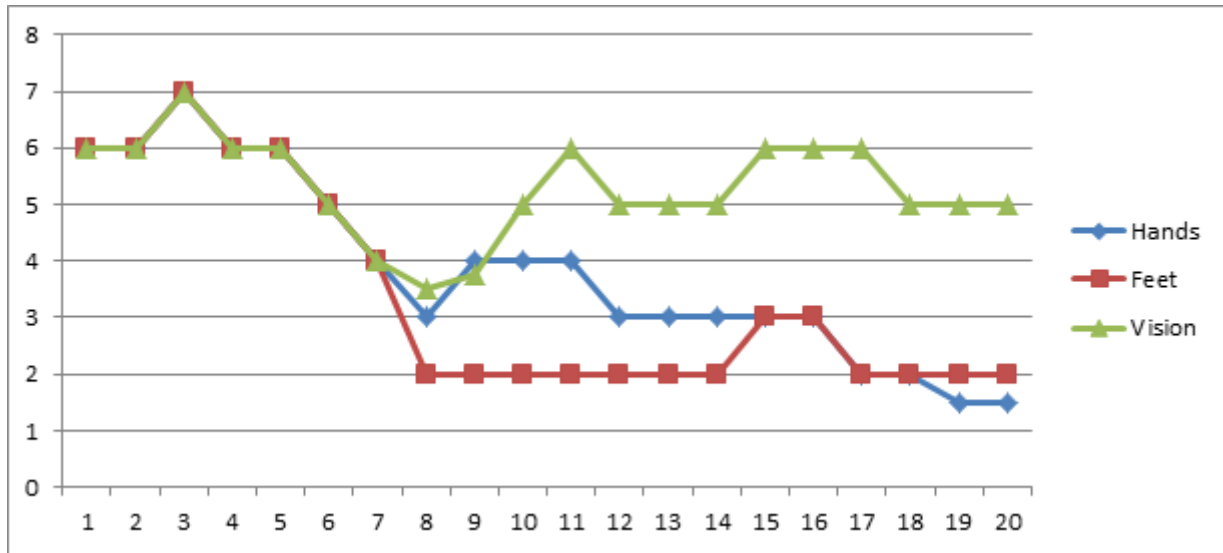
Figure 2. Change in neuropathy scores over 20 sessions of cortical neurofeedback for neuropathic symptoms of hands, feet, and vision.

At that time, we began to ask her to break down her numeric rating scale (NRS) reports to areas she felt were most affected by her symptoms. Her report at session eight was:

	Pre	**Post**
Hands	3	3
Feet	2	2
Vision	4	3.5

The protocol was changed at session nine to F8, F4, two-channel referential training with reward set at 12–15 Hz and inhibit frequencies set at 15–21 and 22–36 Hz.

The first session at this new location resulted in the following report:

	Pre	**Post**
Hands	3	4
Feet	2.5	2
Vision	4	3.75 with transient symptoms of blurriness

The final protocol change was to T3, T4, two-channel referential with reward set at 13–15 Hz, and inhibits set at 1–3 and 8–11 Hz. Upon completion of 20 sessions of neurofeedback, her report was as follows:

	Pre	**Post**
Hands	1.5	1.5
Feet	2	2
Vision	5	5

Results

At the end of 20 sessions, the client reported that she felt her neuropathy had improved overall since neurofeedback. She reported she sewed a button on for the first time and was able to start picking objects up without dropping them. She had transient visual improvement

where she could read road signs and objects were less blurry; however, these improvements were not long lasting. Her overall rating of neuropathy was a four, which was a two-point decrease from baseline. From baseline to post-20 session training, we were able to achieve an increase in alpha, which we hypothesize contributed to the client's reported improvement of CIPN (Figure 3).
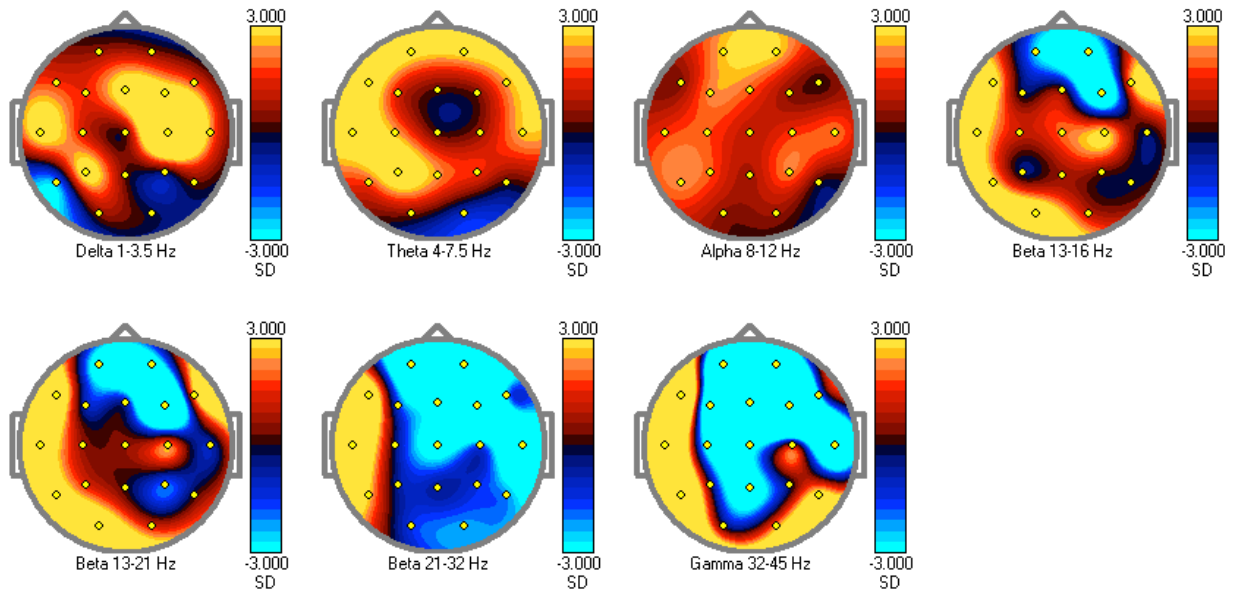
Figure 3. Pre/Post Comparison Maps.

Likewise, LORETA maps demonstrate an increase in alpha activity (Figure 4).

We were also able to assess the client at four months post training. There were no medication changes from post training to the four-month follow up. Her symptom report was as follows:

Hands   1.5
Feet   1
Vision   5
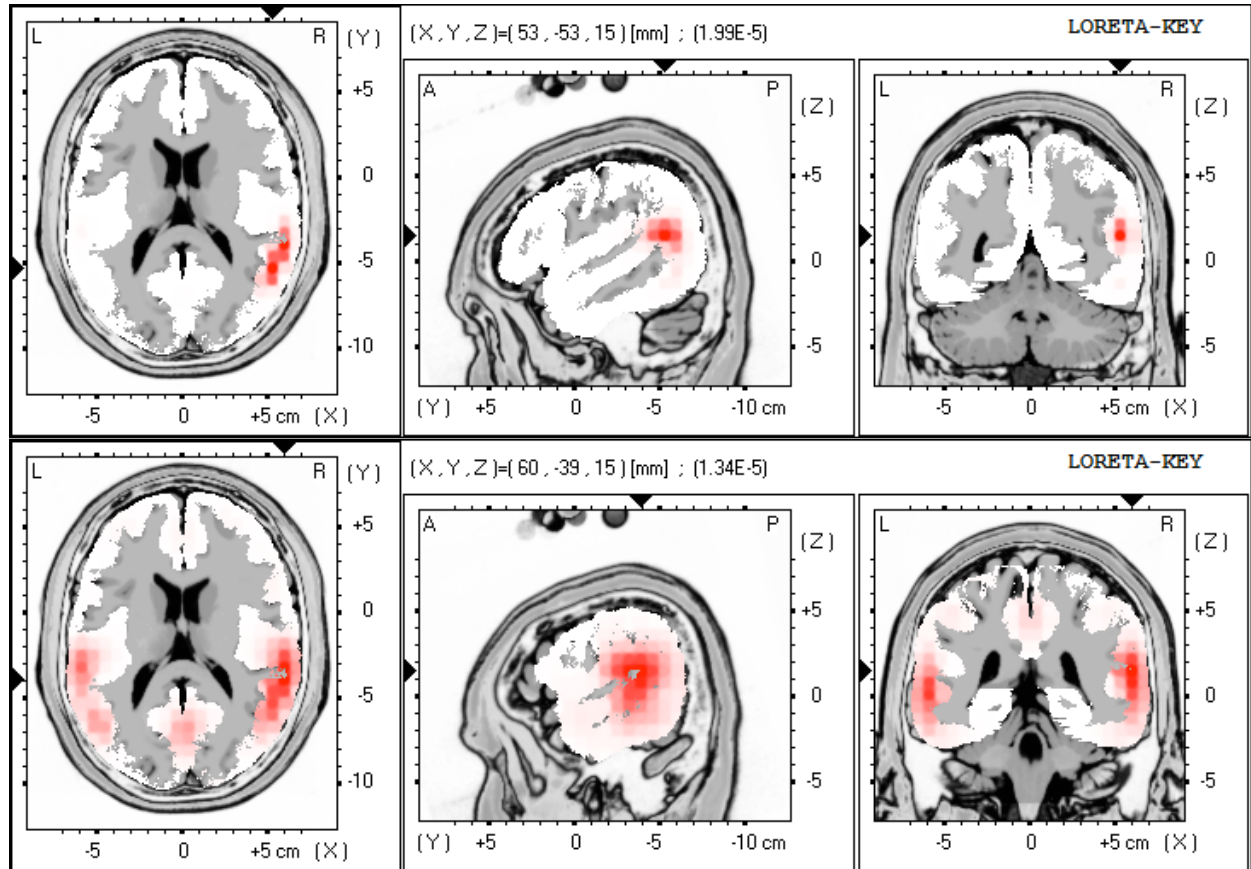
Figure 4. Upper maps: LORETA image for eyes closed alpha (8–12 Hz) baseline assessment. Lower maps: LORETA image for eyes closed alpha (8–12 Hz) post 20 sessions.

Discussion

In conclusion, chemotherapy-induced peripheral neuropathy seems to respond well to cortical neurofeedback, however visual changes secondary to chemotherapy are seemingly not as responsive as neuropathic symptoms in other regions of the body.

Literature suggests that alpha band changes are associated with improvement of visual field detection, improved temporal processing of visual stimuli, detection performance, and visual acuity, specifically with optic neuropathy patients (Sabel et al., 2011). Indeed, this case study suggests that alpha increase after neurofeedback training did in fact correlate with improvement in visual symptom report, even though the training protocols used were decided upon to try to maximize improvement in all symptoms, not solely the client's perception of visual problems. In conclusion, neurofeedback treatment of this patient targeted the full range of neuropathic symptoms and not just those related to vision. However, it was discovered that while somewhat transitory, NFB was also effective with the symptoms related to her vision. It is anticipated that as more and more "baby-boomers" age, we can expect an increase in the types of problems experienced by people receiving chemotherapy. The results of this case offer good evidence that further research into the effectiveness of NFB on CIPN would be of great benefit to many.

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NeuroRegulation

QEEG and 19-Channel Neurofeedback as a Clinical Evaluation Tool for Children with Attention, Learning and Emotional Problems

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Abstract

Attention, learning and emotional problems can have different causes that cannot be easily and clearly distinguished by clinical testing methods. But, QEEG and, even more so, live 19-channel Z-score training under different task conditions can both give very detailed insights about the specific functioning and dysregulations of an individual's brain. The clinical intake evaluation of the child is optimized by including a quantitative, neurometric analysis of an eyes open (EO) and eyes closed (EC) EEG acquisition combined with a real-time analysis of the child's (in vivo) brain functioning during a specific set of conditions, as described below. This method was developed and refined with more than 300 children who were tested between June 2012 and April 2014. The goal is to get as much information as possible in only one session lasting 45 to 60 minutes. The different parts of the evaluation consist of: eyes open (EO) and eyes closed (EC) collection of data, display of the actual brain waves, listing of the Z-score values (also presented as plots or instant brain maps with different task conditions), followed by games to play with a challenge condition. In addition, current source density (CSD) sLORETA of the different wave frequencies (usually delta, theta, alpha, beta, and gamma bands), distribution and velocity are shown as they change, as well as when the brain evaluates emotions. The session ends with a brief, individual 19-channel training with video feedback. Because of the usefulness of the information obtained from using this QEEG method, the author recommends that QEEG and an interactive neurofeedback session be included as a standard component in the diagnosis of and treatment planning for children with attention, learning and emotional problems.

Keywords: QEEG, 19-channel neurofeedback, z-score neurofeedback

Introduction

In the author's developmental clinic, the children and young adults display developmental delays in certain areas; they suffer from ADD and ADHD, processing disorders, and failures in school performance. Some display emotional problems as severe as Autism Spectrum Disorder (ASD), with coexisting family issues at times. In some cases, several disorders appear concurrently.

Clinical testing methods, including a thorough patient history, questionnaires, pediatric neurologic exam and neuropsychological testing, often do not clearly distinguish the different causes of these clinical conditions and are not precise enough in predicting which therapeutic approach will be the most promising in the individual child. In addition to a quantitative analysis of the EO and EC acquired EEG (QEEG), a 19-channel, interactive neurofeedback evaluation session has also proven a strong diagnostic tool and a guide for therapy. Through gathering this data, more criteria for choosing the most beneficial therapeutic options and predicting their outcome for the individual patient can be obtained.

The need for a more personalized treatment and the possibility to achieve this has already been expressed and studied by Martijn Arns et al. (2009, 2012). The suggested approach is also in concordance with a recently published Springer Brief titled, "ADHD As a Model of Brain-Behavior Relationship". Herein, the need for the integration of tests to investigate the brain function into the evaluation process in ADD and ADHD is strongly recommended. There have been recent studies on QEEG for characterizing the autistic brain by Billeci et al. (2013).

The goal of this approach of intake evaluation, however, is less to characterize the patients according to QEEG findings in certain clusters, but to provide the most individualized therapeutic approach.

Methods

The clinically optimized approach adopted in the author's clinic using 19-channel EEG data for quantitative analysis in combination with real-time evaluation of how the child's brain responds to various challenge conditions is described below. It was developed and refined with more than 300 children tested between June 2012 and April 2014. The goal is to get as much information as possible in only one session of 45–60 minutes. The data was collected with the Brainmaster Discovery 24E, a 24-channel EEG and DC amplifier with BrainAvatar software and an EEG cap (Comby EEG caps, different sizes, Pamel), the real-time analysis of the data and the further evaluation is performed through comparing the patient's obtained scores to an FDA 510K compliant normative database (Neuroguide, Brain DX).

This combined QEEG and 19-channel neurofeedback session is scheduled after a verbal patient history, questionnaires, pediatric neurologic exam and neuropsychological testing for most patients aged 3–21, usually with at least one parent present.

Step 1: Familiarizing the Patient with the Setting and their Brain Activity, Data Collection:

The evaluation starts with a brief explanation of what will be done, leading immediately into the practical process of putting on the EEG cap. The children are included in the process of checking the impedances, and most children/teenagers like to become active in turning the positions on an impedance testing meter. Some patients even get interested in the abbreviations displayed (Fz, P3, etc.), which can lead to an explanation of the different parts of the brain.

Before the actual EEG collection starts, the patient's brain activity is shown on a second screen with the different waveforms briefly explained. Then, artifact is demonstrated through eye opening and closure, teeth clenching and swallowing. During this process, the children also realize that the activity displayed on the screen is activity of both: their brain and

muscles. This "experiment" is followed by the explanation about the difference between muscle and brain activity and that we are most interested in the brain activity during the EEG collection. The children also learn how to do diaphragmatic breathing when the situation gets stressful for them.

The following eyes open EEG collection lasts for 3–5 minutes. The eyes closed data collection follows immediately afterward. During this process, the children are informed every 30 seconds about the elapsed and remaining time.

Step 2: Neurofeedback Training: Different Challenge Conditions

The training is performed as a 19-channel Z-Score training (Z Scores are the normalized transformations of the various EEG measures taken on the patient compared in real time to a normative database). To begin, the patient screen shows a game with a moving object. There is no instruction provided except to watch how fast the object is moving. The training is adjusted in order to give plenty of success to the client. Some children get an idea of how to let the object move faster in this early investigational stage, but for most it is still not clear what this movement has to do with their brain activity.

The next step is a challenge condition. This application involves a race game. In the beginning, the threshold is set to let the child win. In a second step, they are asked to allow it to be harder on each race. During this exercise, the children usually get an idea of how they can get faster or work harder. Some children adjust easily to the more difficult condition, and some adjust only for a short period, but other children are easily irritated when only hearing that it might be harder and get discouraged.

The evaluator/physician gains insights into how the individual's brain deals with increasing difficulty through observing the child's behavior and through the wave pattern displayed; for example, more slow activity, more alpha activity or more fast activity, or less or more disconnection through the actual coherence values. These activation patterns in conjunction with the child's experience are integrated in the instructions to the child: either to try harder or to just observe, in case of over-activation. Others need to learn to not be concerned about winning, and instead to let go and just allow the brain do the work.

When the child is not winning for the first time, then there is a chance to explore how the child deals with failure. The instruction is to give the brain a second chance at the same level of difficulty and often the brain has already accomplished the job and the race is won. Other children get very frustrated or unsure when losing and cannot adjust easily with the difficulty level. In this case, the feedback is adjusted in order for the child to accomplish the task and end with a win.
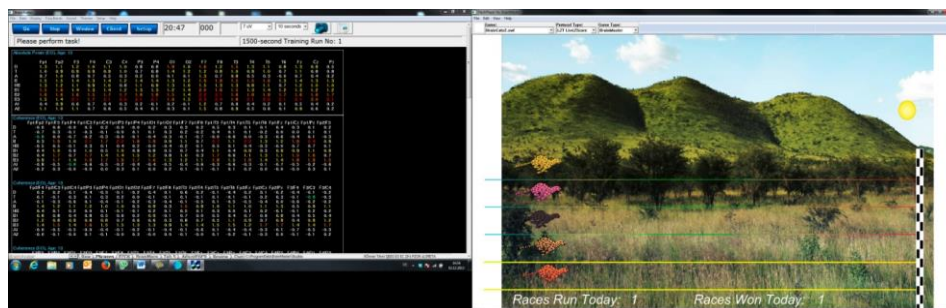
Figure 1. Z-Scores with challenge condition

Step 3: Overview of Brain Power, Coherence and Phase, and Evaluation of Stressors

The next step in the assessment is to look at the brainwaves again and then explain the transformation into Z-score values for power, coherence and phase, which are displayed as numbers or plots or instant maps. Here, there is another opportunity to bring the client in contact with the functioning of his brain.

The first evaluation step here is to ask the client to make their values/plots whiter (normal) if there is dysregulation. When this is instantly possible (in about half of the clients), then there can be challenges applied through the parents, who are usually observing the process. They can talk about what they consider stressful—school itself, reading, writing, math, other subjects, the teacher, or homework and topics which they would consider easy. Here, stress is usually shown by the values/plots becoming higher/more abnormal/less white/more reddish on certain topics. Before bringing up a new topic, however, it is important that the client normalizes the values/plots again.

In this part of the evaluation, stressors are identified, and an assessment of how fast the brain can normalize again is also accomplished. In some children, there are already strong hyper- or hypo-activations that cannot be regulated instantly or easily. This finding suggests that the dysregulation may be more longstanding and fixed or that the accompanying parent is a strong stressor himself/herself.
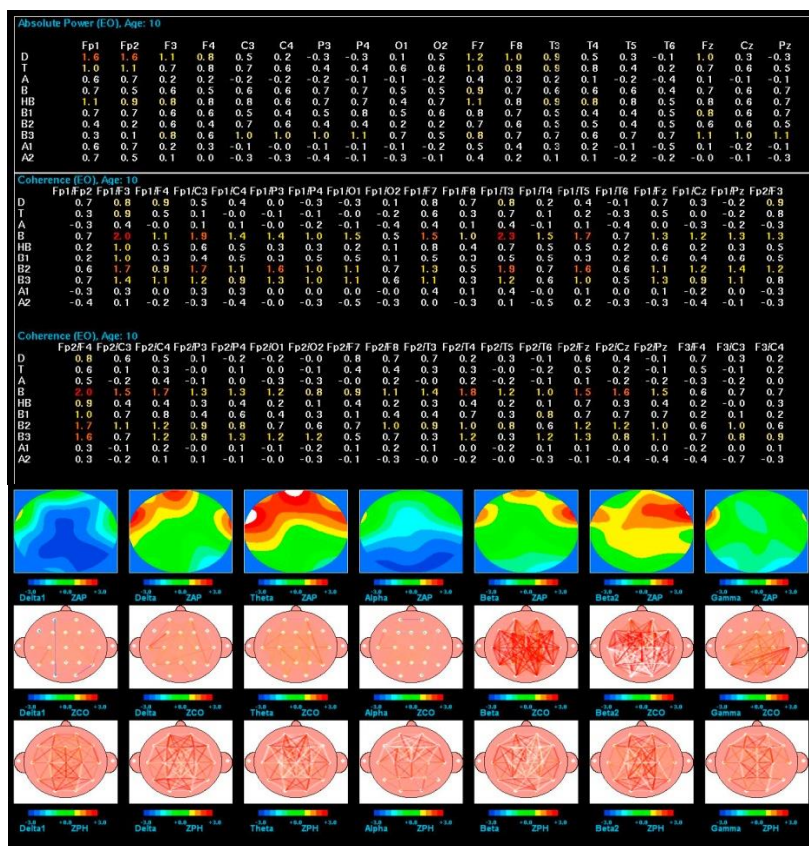
Figure 2. Z-score values displayed as instant brainmaps.
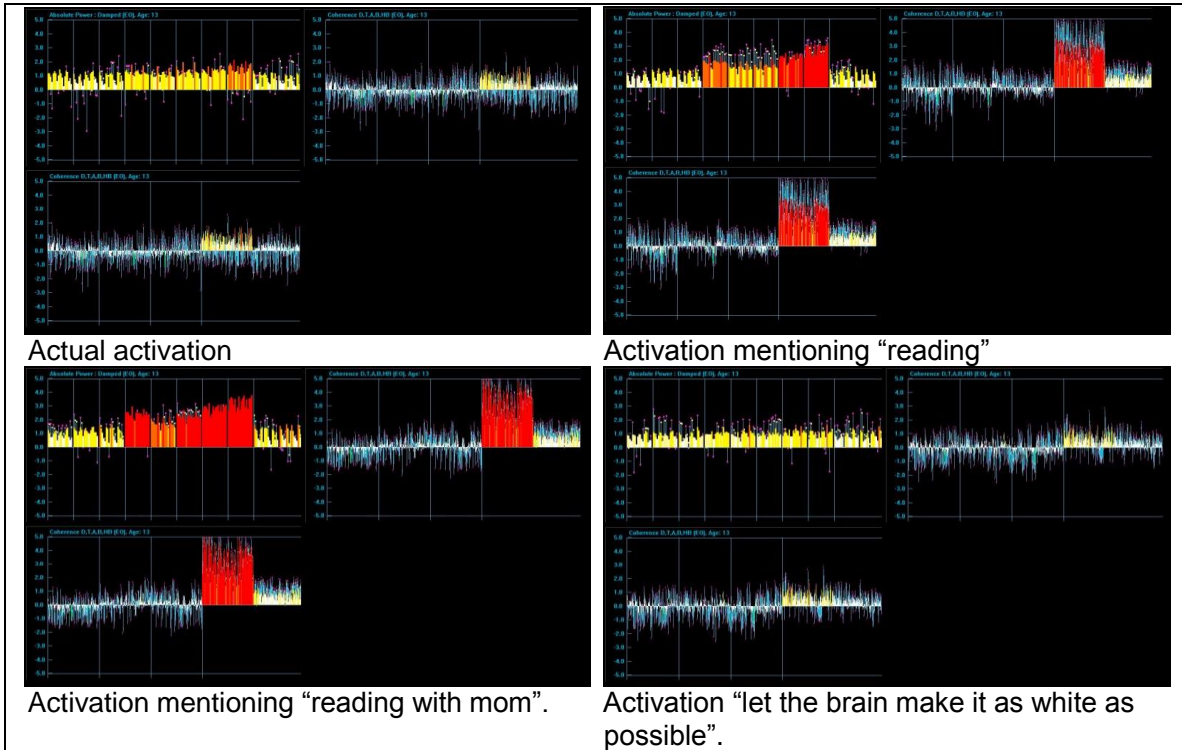
Figure 3. Z-Score values displayed as plots

Step 4: Brainwave Distributions and Emotional Evaluation

The next step is to show the client where the different brainwaves originate and how they spread. This is done by an sLORETA current source density display through BrainAvatar. The voxels can be seen as small cubes; the colors show the amount of activity, with red being the most and blue the least. To begin, the client views the distribution and movement of their delta waves. This is followed by the theta waves and the alpha waves. If there is not very much alpha in the posterior area of the brain, the patients are asked to try to let more of those waves happen by allowing the posterior area of the head display to become red. Often clients can do this instantly. Then they are asked to do this for a short period and they usually describe the feeling that comes with it as relaxing. Regarding beta activity, we look for symmetry especially in the frontal areas. When much beta activity shows up in the back of the brain, then there may be muscle tension in the neck that needs to be reduced.

In order to evaluate the emotional life of the brain, the gamma waves are displayed. There is usually a frontal spreading going from right to left and vice versa, being symmetrical most of the time. To introduce how the brain evaluates emotions, a description is provided of the study that showed that a baby's brain produces more gamma on the left when they taste something pleasant (sugar), but they show more gamma on the right when they taste something aversive (lemon; see Davidson, *The Emotional Life of Your Brain*, page 38). Then the children can evaluate how certain things like food, situations, or people feel more or less pleasant/comfortable to their brain. The parents also usually like to try out certain subjects. Normally, there is a very brief response, then the brain normalizes again. In some children

there is a pronounced lateralized difference, usually more activation on the right side. These are the children who often also display a more negatively focused view.

Neutral without any stimulus

Thinking about favorite dish

Thinking about boy in class who is bullying him.
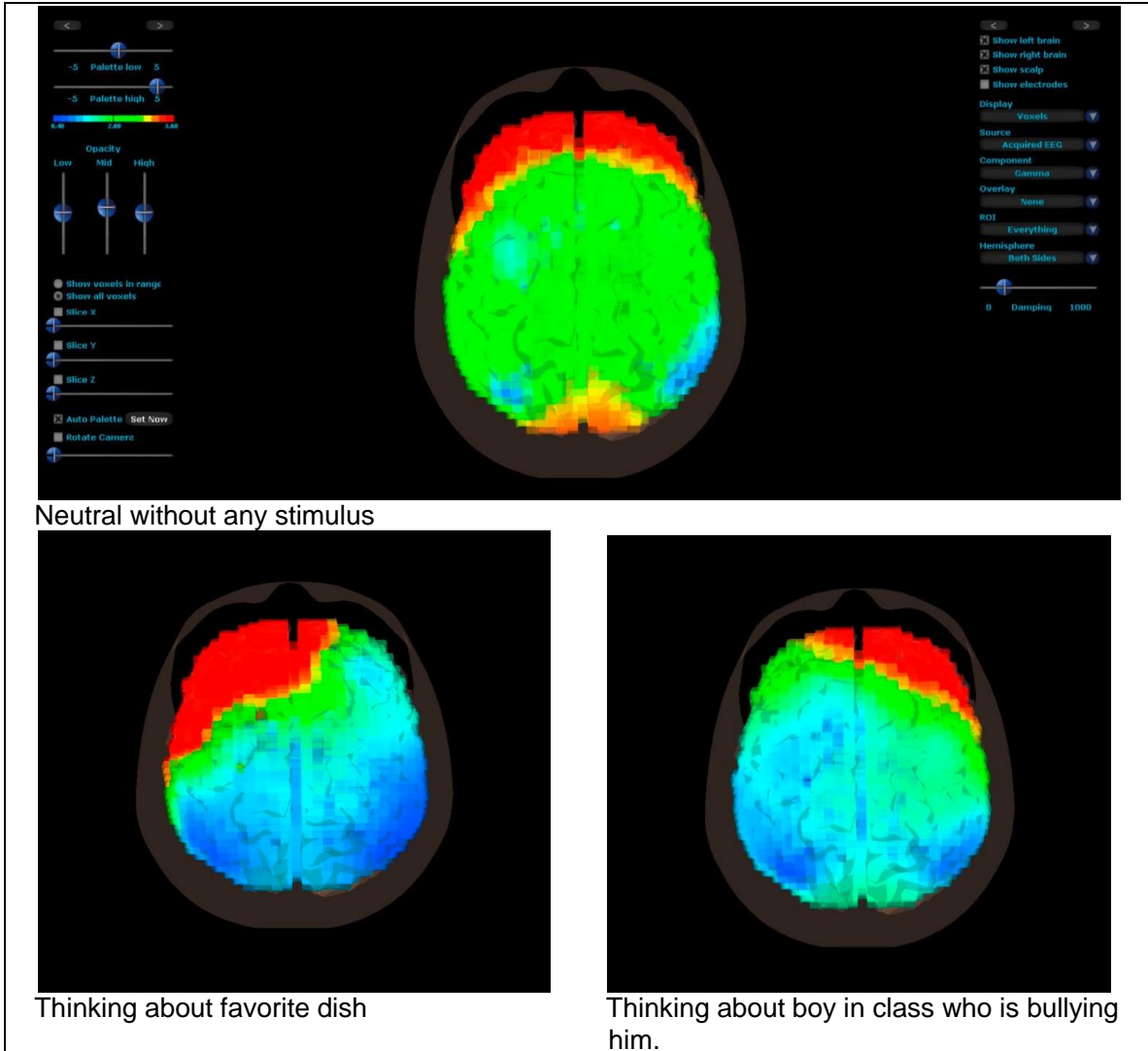
Figure 4. BrainAvatar voxels with symmetrical gamma activation, and right and left dominant activation

Step 5: Neurofeedback Training

The last step is to let the child/teenager experience neurofeedback while watching a movie for 5–10 minutes so they can try another part of real training and learn that it can be fun to do so. The training reflects the individual's dysregulation/pathology, if present, usually as 19-channel surface Z-Score training of power, coherence and phase measures move above the normal thresholds set by the evaluator. As a result, the movie becomes dark or the picture becomes smaller when they don't meet feedback criteria. As it is the first session, the reward is usually on the higher end (70–100% of the time) depending on their personal ability to deal with difficulty. During this period, the investigator can observe the Z-score values and/or

sLORETA display again to see how the child deals with more or less feedback or observe how emotional scenes in the movie impact activation.
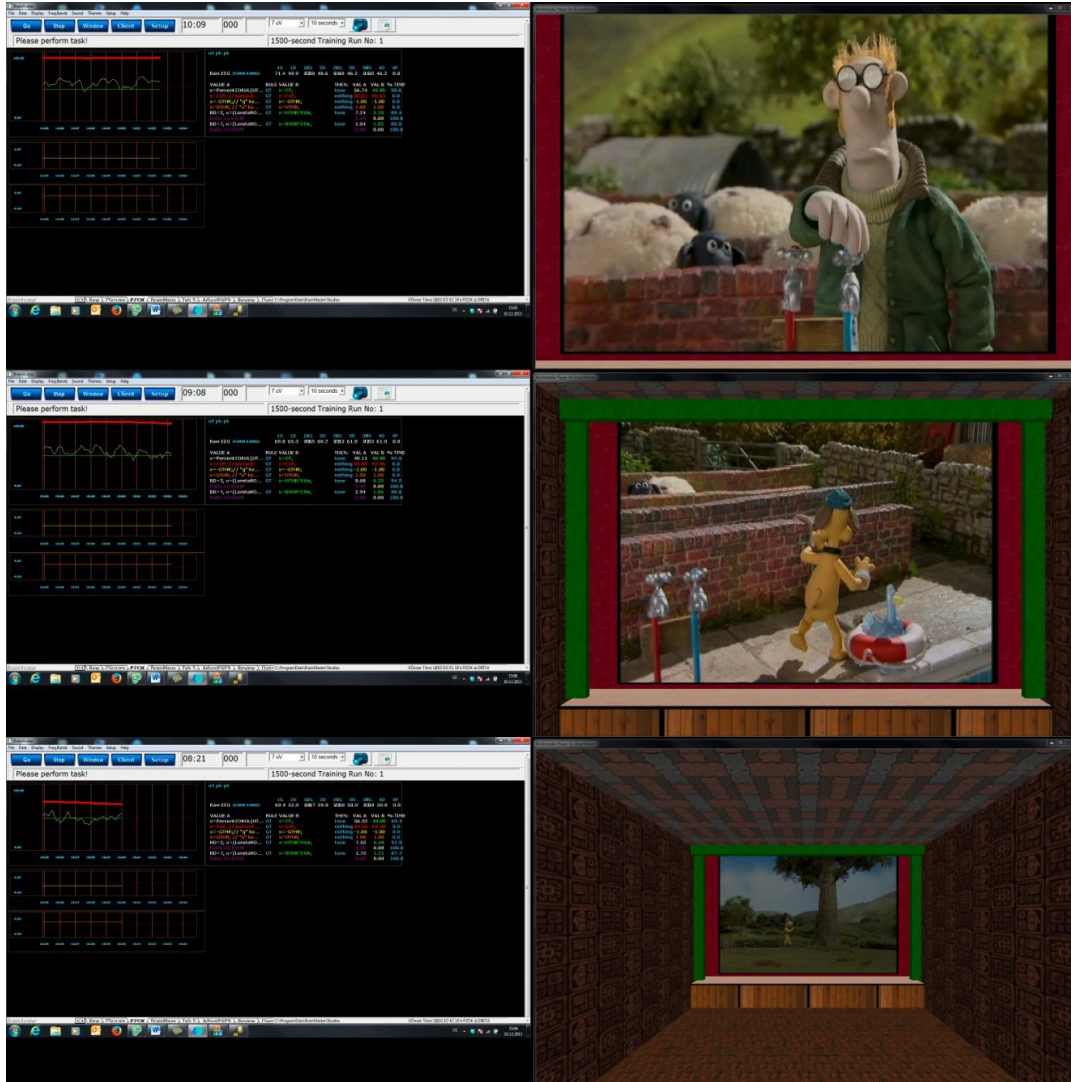
Figure 5. Z-Scores and movie
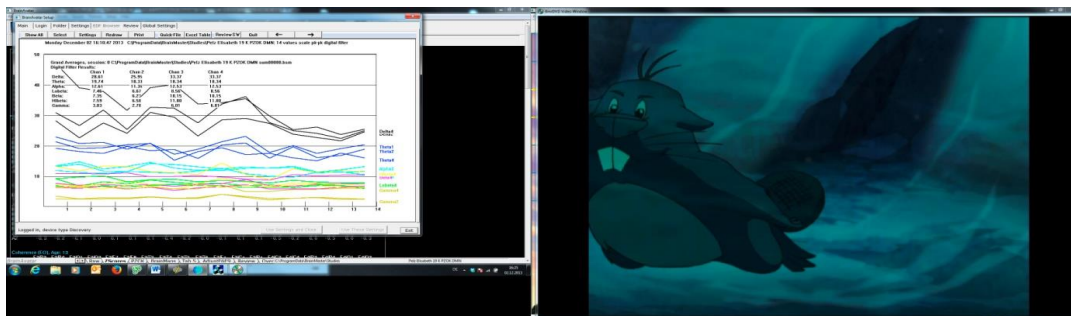
Figure 6. Session trend

Aftermath

After the diagnostic and therapeutic session ends, the parents and the patients are encouraged to watch for reactions and effects and to communicate those to the evaluator/physician through an email the next day. They learn that there can be some tiredness (often), but that there can also be small, short-lasting effects such as homework or learning becoming easier or some event being viewed more positively. Sometimes, strong effects are reported after this single session, like a teenager cleaning up his messy room and starting to organize his learning utensils all by himself. Or the teacher may report very positively about the student the next day, or the child begins to read by himself for the first time. It is important to ask for the email the next day to elicit these effects.

Evaluation Process and Therapeutic Consequences

The more in-depth evaluation of the collected data takes place after the initial assessment session. The first step is to search for paroxysmal activity, followed by surface and connectivity maps, peak frequencies, and sLORETA, as well as TBI and learning disability indices when such problems have been noted in the obtained verbal history.

These results, in combination with the findings from the live Z-Score training with the challenge condition, the information about how the child deals with failure, and the identification of stressors and the emotional situation all lead to suggestions about the most promising therapeutic approach. There is much information now available to take into account in developing the individual child's treatment plan.

The following are only rough guides that provide some examples of how this data can affect the therapeutic approach:

- The recommendation of medication is more likely to be given when immediate change is needed or when there is slowing in the frontal areas, a typical QEEG pattern of ADD, and little endurance in the task condition displayed.

- Family therapy is more likely to benefit the child when there are no typical ADD patterns and they show good adaption to challenges, but signs of stress, even provoked through the parent, are present at the investigation.

- A psychiatric referral, along with neurofeedback training, is considered when there are signs of depression (activation asymmetries) in the brainmaps or, for instance, when there is pronounced fixed gamma activity at the right frontal area in the sLORETA display.

- In a lot of cases, there are findings that warrant the suggestion of neurofeedback therapy, usually performed as 19-channel surface and/or Region of Interest (ROI) LORETA training as a standalone procedure or in combination with other therapies. The most prominent examples of findings that would lead to this recommendation are pronounced power elevations in theta or other bands, power elevations that are even higher under task conditions, disconnections displayed as low coherences in the dorsal attention network, alpha abnormalities, hyperactivation and hyperconnectivity, to name just a few.

- Disconnections are also often found in the author's patients during puberty, especially when there were many failures in school, or they have had many personal disappointments. These usually display as general low coherences in the delta and theta (and alpha) bands, in combination with a negative outlook. Here, often only a few neurofeedback sessions with coherence training and the experience that their brain is still graciously working can lead to huge improvements.

- Examination anxiety also responds well to neurofeedback training by learning to relax/normalize the values/plots while imagining the exam situation.

- Important information for parents, teachers and the therapist on how distressed the individual brain is can be indicated by elevations in the beta and high beta bands, in combination with hypercoherences, the tendency to quickly give up in the challenge/failure situation, and/or low endurance.

- Longer standing stress is usually accompanied by a similar activation pattern in the eyes closed condition and no instant ability to change the pattern through the display of Z-Score values or plots. In this case, it is most important to identify and reduce the stressors and to provide the child with the ability to relax through neurofeedback or biofeedback training.

- Sensitive children often have similar activation patterns to stressed children, but usually the patterns are less fixed or the pattern occurs only when looking at a movie like Tom and Jerry. In such cases, the recommendation is limit the child's exposure to conditions/movies/situations that are too emotionally challenging.

The last step in the assessment process is to review the findings with the parents and clients at a second meeting. At this time, they are informed about possible therapeutic options, the rationale for the recommendations that are given, and ways to follow through with these recommendations.

Discussion and Outlook

Here, only an approximation of all the invaluable information gained through this investigational process can be demonstrated. The value of this process is that a more personalized treatment plan can be chosen and applied. According to the experience of the author, this leads to faster and more pronounced results of therapy.

As this has been developed as a clinical approach, it can be utilized in part or in full by clinicians immediately. When there is 19-channel neurofeedback equipment available, it is only a short step to use it also in an investigational way. To make it a standard procedure in the diagnosis of attention, learning and emotional disorders, however, there should be a systematic evaluation process in order to find the most powerful diagnostic procedures and integrate them into a general evaluation process.

Children, teenagers and parents often express that this is a unique event for them, and they understand more about how their brains function and start to admire their brain's abilities at the end of only one diagnostic and investigational session that last only about 45 minutes. This can be an excellent starting point for any neurological treatment.

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NeuroRegulation

A Research Analysis of Neurofeedback Protocols for PTSD and Alcoholism

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Abstract

A comparative literature research study was conducted and consisted of an analysis of two articles. Study one, by Peniston and Kulkosky, looks at Vietnam veterans with PTSD and the use of neurofeedback as a treatment modality. Study two, by Scott, Kaiser, Othmer, and Sideroff, examines the effect of neurofeedback as an additional therapeutic modality for people with chemical addictions. Both studies employ use of similar neurofeedback training methods.

Keywords: neurofeedback protocols

In the first study, the Minnesota Multiphasic Personality Inventory (MMPI) was used to assess personality changes in Vietnam combat veterans with posttraumatic stress disorder (PTSD) after either traditional medical treatment (TC) or alpha-theta BWT (brainwave neurofeedback therapy; Peniston & Kulkosky, 1991). The subjects were selected based on the following criteria:

> The subjects were randomly selected from a population of Vietnam veterans who were in combat situations and were evaluated for treatment of chronic combat-related PTSD at Fort Lyon VA Medical Center; Diagnosis of combat-related PTSD as defined by DSM-III manual; No evidence of hallucinations or delusions; No known organic dysfunction; and Frequent recurring combat-related nightmares/flashbacks that were anxiety-evoking events (Peniston & Kulkosky, 1991).

All subjects were given a brief introduction to EEG brainwave biofeedback and were told how to interpret the feedback sounds (i.e., Theta 2–7 Hz, Alpha 8–13 Hz, and Beta 15–18 Hz; Peniston & Kulkosky, 1991). This meant that if brainwave activity was maintained a frequency higher than the threshold for alpha, beta, and theta, then the patient was rewarded with an auditory feedback tone and a visual reward consisting of a percentage counter that included the percentage above threshold. The subjects' earlobes and the inion were then

cleaned with alcohol prior to attaching the electrodes. Each alpha-theta training session began with the subjects closing their eyes and sitting in a chair (Peniston & Kulkosky, 1991; Scott et al., 2005). Two ear clip electrodes were attached and the active electrode was referenced to the left earlobe (A1), with the ground on the right earlobe (A2; Peniston & Kulkosky, 1991; Scott, Kaiser, Othmer, & Sideroff 2005). Omni Prep was then used as a conductive medium to fill the electrode cups and in the preparation of the electrode scalp site (Peniston & Kulkosky, 1991).

The EEG system detected information in raw EEG by using three active band-pass filters. Filters consisted of tuning for Alpha, Beta, and Theta with 71 dB per octave attenuation rates (Peniston & Kulkosky, 1991). Resulting information was fed back to the trainee virtually instantaneously with the conceptual understanding that changes in the feedback signal indicate whether or not the trainee's brain activity was within the designated range (ISNR, 2010).

Only BWT subjects received eight 30-minute sessions of pre-training in temperature biofeedback-assisted autogenic training and thirty 30-min BWT sessions (Peniston & Kulkosky, 1991). It is believed that temperature training stimulates the production of the "theta state" (Peniston & Kulkosky, 1991). The subjects were taught temperature biofeedback-assisted autogenic training due to the belief of its production of the "theta state" (Hall, 1977). All subjects, despite category of placement, agreed to participate in the study with the hope of alleviating symptoms associated with their combat-related PTSD (i.e., recurring nightmares and flashbacks, chronic states of anxiety, depression, vivid re-experiencing of traumatic combat events, etc.; Peniston & Kulkosky, 1991).

> To show the clinical affect on the subjects' life the following example is provided. This was not an isolated case and many of the Vietnam theater veterans' experienced repressed combat anxiety-provoking events during session: an episode of a repressed combat anxiety-evoking event concerned a patient who had nightmares of survivor guilt feelings. When the patient had a flashback at work, he became violent, destroying property, and he often had to be apprehended or sedated. While undergoing BWNT (Brain Wave Neurofeedback Therapy), the patient re-experienced a repressed combat anxiety-evoking when he was out in the bush with his buddy on patrol duty. His buddy was wounded and he hid him in the brush along the trail and returned to the helicopter for assistance. It was getting dark and the helicopter crewmen were apprehensive about remaining in the Viet Cong area after dark. The patient was told that his buddy would be all right until morning and they would return to get him in the early morning hours. The following morning the helicopter crew and patient returned to the area where his body was hidden. The patient saw his buddy nude, hanging by his feet from a tree, his body mutilated. The patient has felt survival guilt feelings for not going back to get his wounded buddy that evening and/or staying with him (Peniston & Kulkosky, 1991).

BWNT appeared to allow those repressed Vietnam combat-related and anxiety-provoking events to become conscious by reliving them emotionally through hypnagogic imagery (Peniston & Kulkosky, 1991). After one week of daily practice of BWT, the drug dosage (tricyclic antidepressants, antipsychotics, anxiolytics) for BWT subjects ($n = 14$) and TC subjects ($n = 13$) was gradually reduced at their request (Peniston & Kulkosky, 1991).

An extension of the Peniston study was done in which 121 volunteers were chosen based on their primary drug of choice reported at admission: 31% heroin, 28% crack cocaine, 26% methamphetamine, 6% alcohol, and 9% other controlled substances; 94% were multiple-drug users (Scott et al., 2005). If the subject was determined to have any other diagnosis or disorder based on the DSM-IV, they were unable to participate in the study (Scott et al., 2005).

> In Phase I, experimental subjects underwent 10–20 sessions of Beta-SMR EEG biofeedback in which operant conditioning was used to augment either 15–18 Hz (beta) or 12–15 Hz (SMR) EEG activity. At the same time, training attenuated elevated activity in the 2–7 Hz (Theta) and 22–30 Hz (high Beta) ranges (Scott et al., 2005).

After ten Beta-SMR EEG biofeedback sessions, participants were reassessed with the TOVA, which is a neurophysiological measurement of attention (Scott et al., 2005). The experimental groups' TOVA results normalized after a mean of 13 sessions, meaning that they scored 85 or above (Scott et al., 2005).

> In Phase II, subjects underwent 30 sessions of Alpha-Theta training. The frequency range for Alpha was 8–11 Hz and for Theta it was 5–8 Hz. The initial sessions were used to train down Alpha levels that were above 12 µV (peak to peak), while augmenting Theta, until there was "crossover." This was defined as the point at which the Alpha amplitude drops below the level of Theta…Before crossover was achieved EEG activity in the range of 15–30 Hz was inhibited to reduce muscle tension (Scott et al., 2005).

Beta-SMR training had previously been shown to be effective in remediating attentional and cognitive deficits (Scott et al., 2005). The experimental group exhibited significant ($p < 0.005$) improvement compared with the changes in the control subjects on the following MMPI scales: Hs (Hypochondriasis), $F(1, 81) = 14.087$; D (Depression), $F(1, 81) = 48.129$; Hy (Conversion Hysteria), $F(1, 81) = 32.682$; Sc (Schizophrenia), $F(1, 81) = 15.241$; and Si (Social Introversion) scales, $F(1, 81) = 24.647$ (Scott et al., 2005). Furthermore, treating therapists reported that they noticed experimental subjects appeared more cooperative and more attentive as EEG biofeedback progressed (Scott et al., 2005).

In conclusion, with the employment of neurofeedback, both studies showed a significantly positive effect. The subjects, despite study type, showed an increase in quality of life following treatment. Both studies also showed how neurofeedback gave the clients the coping skills to decrease medication consumption and eliminate illegal drug usage. The feedback provided was created in "real-time" by the software and was non-invasive (ISNR, 2010). Due to this aspect, this was not an actual treatment in terms of non-organic input to the client; however, it was a learning method similar to that of traditional counseling therapeutic coping mechanisms.

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Infra-slow Fluctuation Training in Clinical Practice: A Technical History

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Abstract

Infra-slow Fluctuation (ISF) electroencephalogram (EEG) biofeedback is a recent development in neurofeedback training. This form of training is focused on the lowest energy the brain produces (< 0.1 Hz). The intervention is performed with a Direct Current (DC) coupled neurofeedback amplifier. It is distinct from Slow Cortical Potential (SCP) training and Infra-Low Frequency (ILF) training. It shares a similar optimization process with ILF that focuses on emergent state shifts within sessions. These state shifts require frequency adjustments that optimize client response to the training in real time. Due to the technical difficulties inherent in recording these frequencies, EEG investigators largely neglected this low energy until recently. As DC amplifiers improved, the slow frequencies became a signal of increasing interest to researchers. Research has demonstrated an important role for the infra-slow oscillations in clinical work. Positive clinical case outcomes suggest that a larger controlled study is warranted. The technical, clinical, and equipment requirements of the intervention make this form of neurofeedback unique in the pantheon of EEG biofeedback interventions.

Keywords: neurofeedback, biofeedback; infra-slow fluctuation; infra-slow oscillation; direct current

History

The traditional method of recording the electroencephalogram (EEG) with an Alternating Current (AC) amplifier and a "corner" or cutoff frequency of approximately 0.5 Hz is more than half a century old (Collura, 1993). These AC amplifiers produced attenuated signals that allowed researchers to focus on the faster oscillations, considered the most salient features in the human EEG at that time. Before that time, attempts to record slow events produced electrode drifts that tended to saturate the amplifiers and so hastened the advent of

the built-in high-pass filters on all amplifiers. The consequence of the ubiquitous initiation of high-pass filtering was a loss of all infra-slow dynamics, whether artifactual or physiological.

The first human DC recordings became possible with the introduction of chopper-stabilized amplifiers in the 1950s. A lack of stable electrodes and the need to manually cancel offset voltages prevented the widespread use of the technology (Tallgren, 2006). As DC equipment improved, researchers began to describe the observed phenomena at frequencies below the conventional limits. One definition proposed that EEG in the frequency range below 0.5 Hz consists of a standing potential (SP) and a slowly changing potential (SCP) (Manaka & Sano, 1979).

In the following decades DC coupled amplifiers became more common. The terms changed from standing potential to "DC potential shifts" and slowly changing potential to "slow cortical potentials" (Birbaumer, Elbert, Canavan, & Rockstroh, 1990; Elbert, Rockstroh, Lutzenberger, & Birbaumer, 1980). DC potential shifts are non-oscillatory fluctuations in amplitude measured in millivolts (Collura, 2009). This rise and fall of the large amplitude of the DC potential shift is frequent and impacts the smaller energy of the frequency domain measured in microvolts.

Slow Cortical Potentials (SCP) are changes of cortical polarization lasting several hundred milliseconds to several seconds. SCPs are related to the excitability level of underlying cortical regions. Negative SCP shifts reflect higher cortical excitability while positive shifts reflect reduced excitability or even inhibition.

SCP training has been employed, largely in Europe, for more than 30 years (Elbert et al., 1980). It has been used to train Epilepsy (Birbaumer et al., 1994), Brain-Computer Interface (Wolpaw, Birbaumer, McFarland, Pfurtscheller, & Vaughan, 2002), and ADHD (Birbaumer & Cohen, 2007; Heinrich, Gevensleben, Freisleder, Moll, & Rothenberger, 2004). SCP training is a "one size fits all protocol" with the majority of the training done at the vertex. As first developed, the client attempted to produce cortical excitation, a negative DC shift, in the case of ADHD; or cortical inhibition, a positive DC shift, in the case of Epilepsy over the course of many short trials (Birbaumer, 1999; Birbaumer et al., 1994). More recently SCP training has evolved to train in both negative and positive cortical shifts in the same session with proportions of negative and positive trials dependent on client presentation (Strehl et al., 2006).

Infra-slow Fluctuation (ISF) training is frequency-based training. These slow rhythms are influenced by changes in amplitude and polarization of the DC signal, but ISF neurofeedback is not SCP training.

ISF training owes its lineage to the early Beta/SMR training of Susan Othmer and EEG Spectrum (Kaiser & Othmer, 2000). That intervention was done with a single channel of EEG and an intra-hemispheric bipolar montage on the motor strip and temporal lobes. The starting frequency was in the 12–18 Hz range depending on the targeted hemisphere. The Othmers and others (Putman, Othmer, Othmer, & Pollock, 2005; Stokes & Lappin, 2010), modified this technique to include inter-hemispheric placements beginning on the temporal lobes. Instead of set reward bands, a 3 Hz window was shifted up or down contingent upon client response. The intervention produced immediate state shifts in the client. The trainer targeted state regulation in real time by discovering an optimum frequency through trial and error for each client. Success was defined by the immediate improvement in affect and arousal regulation in session and ultimately by generalized improvements in behavioral and

state regulation in life. Over time, it became apparent that the vast majority of clients were finding an optimum clinical response at lower and lower frequencies until 2007, when the beginning frequency was established at 0–3 Hz.

It was at that time that a bifurcation in the field took place with one group of practitioners opting for an AC amplifier and another group, including the lead author, choosing a DC coupled encoder. Both groups continued the downward ramp of frequency optimization, narrowing the training window to less than 3 Hz.

As the optimum frequencies trained descended below 0.1 Hz, it became apparent to the DC amplifier users that optimum response was more readily achieved when training was executed with the amplifier in DC mode. The integration of the lower (DC) and higher (AC) energies produced enough "bounce" in the low alternating current domain to filter and to train the Ultradian Rhythms (< 0.01 Hz) (Palva & Palva, 2012) with more clarity and less noise in the signal.

The ISF Signal

Amplifier limitations that led to the elimination of lower frequencies in routine EEG determined the scope of brain research. As commercial DC coupled amplifiers became available, researchers began to address frequencies outside the traditional bandwidth of 0.5–50 Hz. Evidence increased that salient spontaneous EEG activity in human brain activity related to physiological and pathological behavior were being ignored. A group of researchers, largely in Europe, began to investigate this low phenomena. Their process became known as DC-EEG or FB-EEG (Full-band EEG). FB-EEG research suggests that the infra-slow is endogenously driven neuronal activity that is crucial in shaping brain network connectivity (Vanhatalo, Voipio, & Kaila, 2005).

For two decades researchers have proposed that neurons, glial cells, and blood may be regarded as compound generators of these infra-slow bioelectrical phenomena (Hughes, Lőrincz, Parri, & Crunelli, 2011; Zschocke & Speckmann, 1993). Thalamocortical neurons have been observed to exhibit robust infra-slow oscillations (ISOs), in vitro, at approximately 0.005–0.1 Hz (Lőrincz, Geall, Bao, Crunelli, & Hughes, 2009). After a reappraisal of *in vivo* and *in vitro* evidence, Crunelli and Hughes (2010) have proposed a three cardinal oscillator model that identifies one cortical and two thalamic sources of infra-slow frequencies. Astrocytes have recently been identified by Hughes et al. (2011) as a source of ISOs in the 0.003–0.1 frequency range. These researchers observed neurons in cat Thalamus succumbing to a cyclic inhibitory influence that they proposed was generated in the slow regime by Thalamocortical astrocytes.

This lower frequency band is embedded in DC potential shifts in amplitude. A spectral display (Figure 1) clearly images the correspondence of the ISOs and DC standing potential shifts. As DC fluctuates on the mV scale, the frequency domain responds in the lower regime and at much higher frequencies as well. These cross frequency correlations are well documented (Keković, Sekulić, Podgorac, Mihaljev-Martinov, & Gebauer-Bukurov, 2012; Nir et al., 2008; Pfurtscheller, Daly, Bauernfeind, & Müller-Putz, 2012; Vanhatalo et al., 2004; Zschocke & Speckmann, 1993). It is the interaction of frequency and DC potential shift that drove the choice of the designation ISF training. The DC fluctuations were observed to drive the microvolt changes in the slow frequency regime and offer a target for feedback.
In Figure 1, the morphology of the two signals are shown compared to the damped average of each signal. DC is measured in millivolts, while ISF is rendered in microvolts. It is this

recurrent amplitude change in the ISF signal, sometimes only a fraction of a microvolt, which is the focus of reinforcement, not the return of the slow oscillation itself.
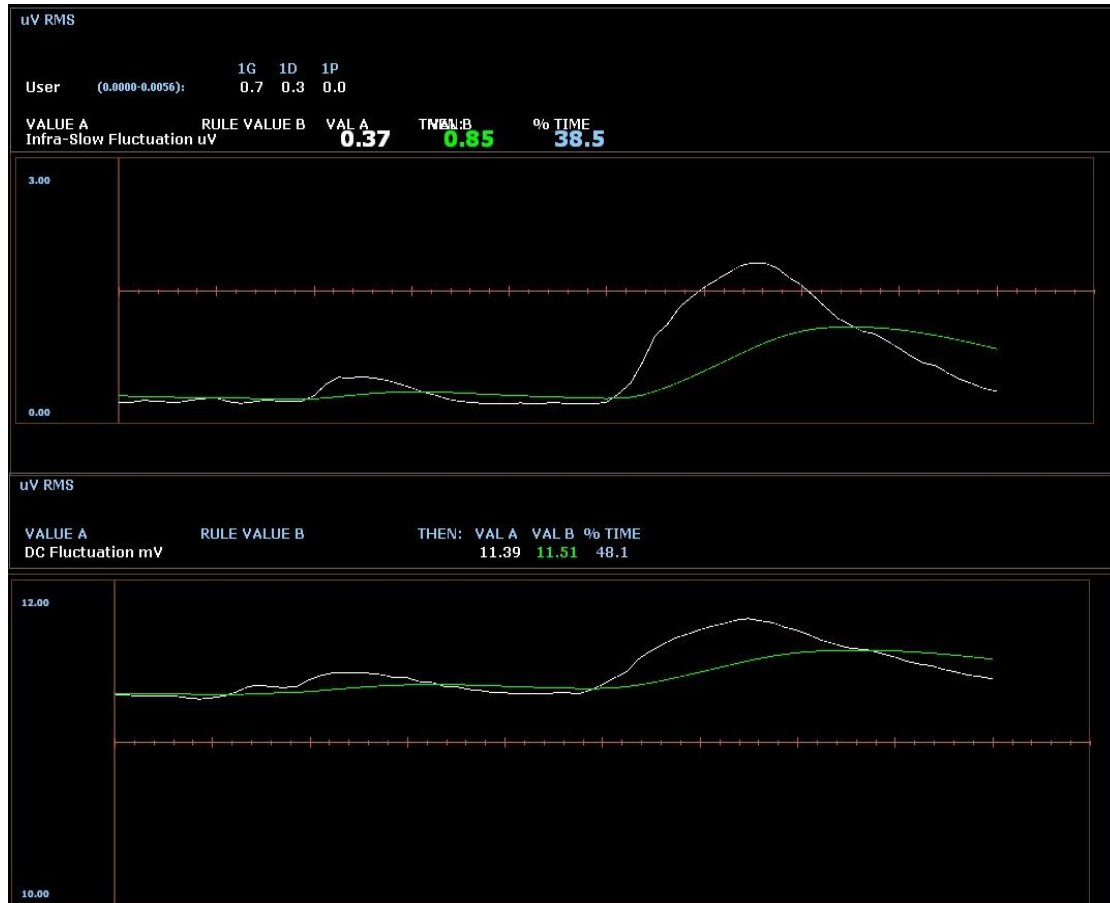
Figure 1. Top graph labeled: Infra-slow Fluctuation uV. Images the Alternating Current ISF signal in microvolts, the white line, with the damped average of the signal, the green line. Bottom graph labeled: DC Fluctuation mV. Images the amplitude fluctuations of Direct current measured in milivolts, the white line, with the damped average of the signal, the green line. Notice the similarity between the rise and fall in amplitudes of the two signals.

It is important to note that when working with very slow signals, although it is possible to quantify the system response as a frequency, it may be equivalently considered as a time-constant. In linear systems theory, it can be shown that for any filter there is a direct trade-off between frequency response and time-response, and that time and frequency can be considered as equivalent, alternative ways to view the system. The following figure (Figure 2) from Collura (1995) illustrates the relationship between the low-cutoff frequency and the time-constant.
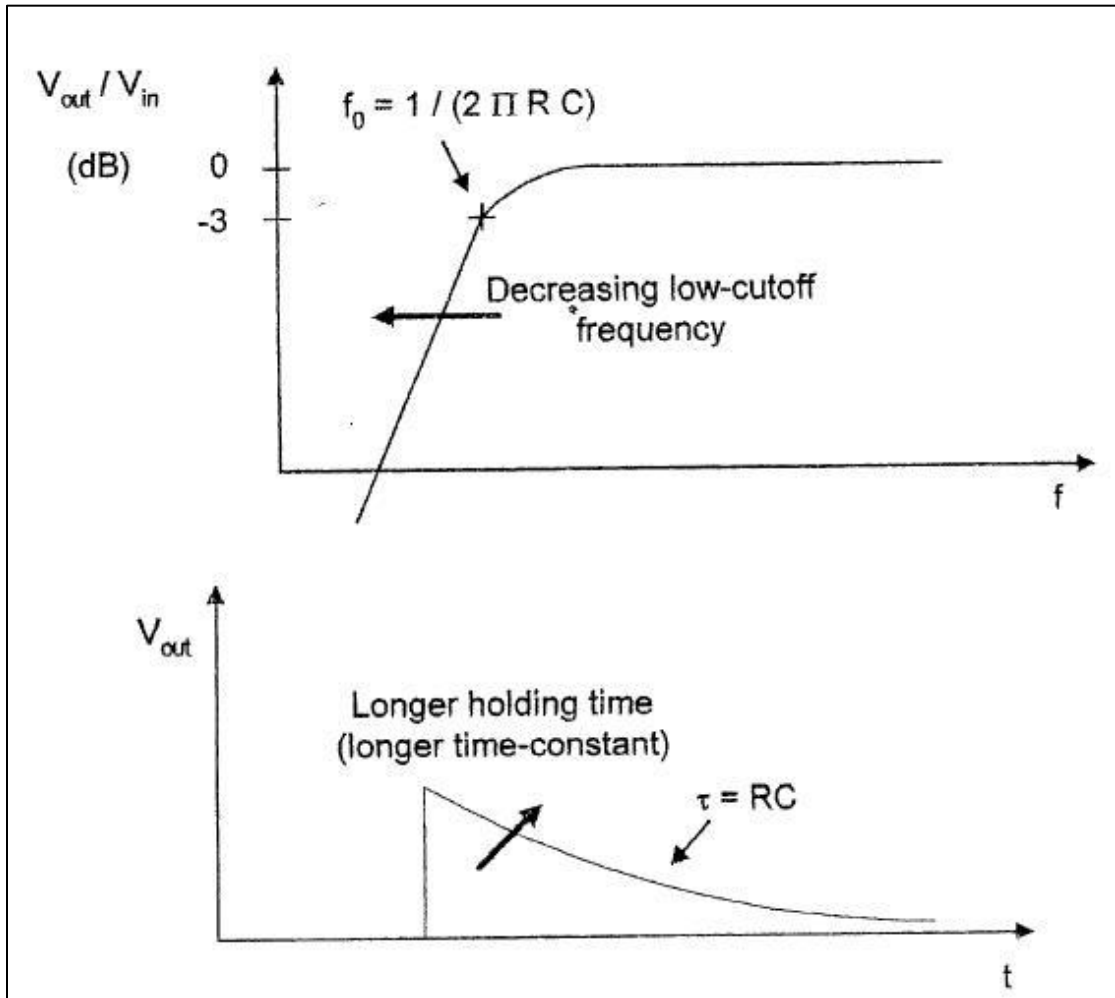
Figure 2. Relationship between cutoff frequency (top) and holding time-constant (bottom). A lower cutoff frequency is associated with a longer time-constant. These are shown for a first-order filter, but are representative of any order filter. Specifically, for a first-order filter, the time-constant is defined (approximately) as: t = 1 / 2 * PI * fc . For example, a low-cut frequency of 0.3 Hz would have a time constant of 1 / 2 * PI * 0.3 = 0.53 seconds. The following Figure 3, of a vintage Grass amplifier, shows how this relationship is implicit in an amplifier. The selector for the low-frequency cutoff, with settings of 0.15, 0.3, 1, 3, and 10 Hz, is shown with a second set of indicators beneath, designating, for this amplifier, time-constants of 0.45, 0.24, 0.1, 0.04, and 0.015 seconds.

Because the filter is removing low frequencies, the time-constant reflects the rate at which the output tends to "recover" to the baseline. The lower the corner frequency, the longer it takes to recover. Therefore, lower cutoff frequencies are associated with the ability to "hold" the baseline longer, hence reflect longer-term processes. The time-constant shows that the input does not have to be cyclic or repetitive, but can be viewed as a transient, or fleeting, event, that is passed by the filter only if it reaches a certain magnitude of displacement within a certain time. With a DC amplifier, the output time-constant is infinite, reflecting the fact that the low cutoff frequency is 0.0000 to an arbitrary precision.

Figure 3. Grass EEG amplifier showing combined "low frequency / time-constant" control, illustrating the interdependence of these two settings.

Methods

Amplification

ISF training uses Ag/AgCl electrodes and a DC coupled amplifier. As configured for ISF training, BrainMaster's Atlantis amplifier uses first-order Butterworth filters utilizing quadrature methods with an implicit envelope detection method that provides information faster than conventional peak-to-peak detection processes. Depending on the low-cutoff frequency applied in the software, the resulting filter will also have a corresponding time-constant. For example, with a setting of 0.002 Hz as described in this report, the associated time-constant would be 175 seconds, or 2.92 minutes. This does not imply that the signal must oscillate with a period of 2.92 minutes, however. It simply indicates that when there is a shift in the baseline, the amplifier would require approximately 3 minutes to move the bulk of its recovery back to baseline. In other words, the amplifier "holds" onto the DC level of the value for a very long time, compared to the occurrences of each fluctuation or baseline shift.

Feedback Parametrics

The optimum frequency is reflected back to the client with two reward sounds, a higher tone when the amplitude increases more than 15% and a lower tone when the amplitude decreases more than 15% compared to a damped average of the signal. There is no sustained reward criteria; the client is rewarded the instant the reward parameters are met and continues for the duration of the condition. In addition there is no refractory period between rewards. The reward structure allows for the rapid transmission of information to the client concerning minute changes in amplitude of the ISF signal.

The ISF reward band typically starts at a low band-pass filter setting of 0 to a high band-pass filter setting of 0.002 Hz, and ranges to a high band-pass filter setting of 0.012 Hz. Additionally, in the basic protocol, the EEG is inhibited from 1 to 40 Hz in small bands: 1–3, 4–7, 8–12, 12–15, 15–20, 20–30, and 30–40 Hz. Each band is inhibited 3% of the time with an auto-thresholding function. These inhibits are fed back to the client via dimming of a DVD or the playing of a video game. Advanced protocols render simultaneous bipolar and referential montages allowing for combinations of ISF and synchrony training and ISF and referential enhancement. These sophisticated protocols are applied based on in-training z-score monitoring and pre/post QEEG analysis.

Optimizing Training

Clinical experience has made it clear that the best treatment response occurs when an Optimum Frequency (OF) is identified for each individual client. This process is undertaken for every client at either of two 10/20 sites: T4/P4 or T3/T4. The OF identification process may take place over several neurofeedback sessions and once identified rarely changes. Once the OF is known, frequency adjustments become necessary depending on the cortical area trained and the hemisphere involved. Some trainee outliers optimize above 0.012 and fewer still optimize below 0.002 with the vast majority between 0.002 and 0.012 Hz. The selection of cortical areas to be trained has traditionally been dictated by the relationship between client complaint and areas of cortical function. Recently the process of training site selection has been increasingly influenced by quantitative EEG (QEEG) assessments.

Optimization of frequency is achieved through a colloquy between therapist and client that leads to an optimum state of affect and arousal regulation in session. In addition, peripheral biofeedback measures such as heart rate, heart rate variability, Galvanic skin response, and skin temperature, are used to aid in the identification of autonomic balance and best response to the frequency parametrics.

Clinical Rationale

Researchers in Russia first identified the infra-slow rhythm nearly 60 years ago (Aladjalova, 1957; Aladjalova, 1964). Scientists at the Institute of Biophysics in Moscow implanted electrodes in the brains of rabbits and observed two general rhythms: one in the 6–8 second, 0.6–0.8 Hz range; and the other slow periodic oscillation was identified in the 60–90 second, 0.023–0.0165 Hz range. Aladjalova labeled these rhythms "infra-slow" to distinguish them from the "slow wave" of the EEG.

The infra-slow band was observed to increase in amplitude and frequency when experimental animals were subjected to stress-producing stimuli. The Russian researchers observed that poisoning, asphyxia, and irritation of subcortical structures intensified ISOs.

They theorized that the increase in amplitude of the ISOs reflected the Hypothalamus's reparative, parasympathetic, response. Supporting a role in the function of the neuroendocrine system, Marshall (Marshall, Mölle, Fehm, & Born, 2000) discovered an association between ISOs and Hypothalamic-Pituitary secretory activity. An increase in the amplitude of infra-slow periodicities between 64 and 320 seconds was coupled with the onset of the pulse of the Luteinizing hormone. This hormone, released by the Hypothalamus, triggers ovulation and stimulates the production of testosterone.

ISOs' prominence during sleep has been established. However, the functional significance of ISOs for sleep physiology remains unclear. The low regime has been postulated to coordinate activity between cortico-cortical networks (Buzsaki, 2006). In this way, the infra-slow frequencies appear to organize a broad dissociation of cortical and sub-cortical activities during sleep (Picchioni et al., 2011) in areas that include the paramedian heteromodal cortices. Simultaneous positive associative correlations were established for the ISOs in the Cerebellum, Thalamus, Basil Ganglia, lateral neocortices, and Hippocampus. According to Picchioni, this suggests a role for ISOs in the organization of sleep-dependent neuroplastic processes generally and the consolidation of episodic memory specifically.

Recent research suggests that ISOs are embedded in and determinant of the excitability cycle of higher frequencies (Ko, Darvas, Poliakov, Ojemann, & Sorensen, 2011; Vanhatalo et al., 2004). Ko and workers revealed that the Default Mode Network (DMN) is characterized by high gamma band (65–110 Hz) coherence at infra-slow frequencies. This coherence, centered at 0.015 Hz, forms the neurophysiological basis of the DMN. Vanhatalo et al. (2004) established a role for the infra-slow frequencies in the control of gross cortical excitability. This research detected a close association between the ISOs and cyclic modulation of fast EEG activity. The phase of the ISO revealed a robust correlation with the amplitude of faster frequencies. Moreover, these low frequencies were observed to be tightly associated with K complexes, the largest event in the human EEG, and interictal epileptiform discharges: high amplitude paroxysmal activity. In fact, Vanhatalo became so convinced of the ISOs' centrality in cortex that he stated that any attempt to attenuate the signal eliminates the most salient features of the human EEG (Vanhatalo et al., 2005).

Pfurtscheller (1976) reported the first observations of embedded frequencies in the human EEG, and observed ISOs in the alpha (8–14 Hz) frequency band. Later studies expanded on this work identifying human fluctuations in the theta, alpha, and beta (14–30 Hz) frequency bands that were power law autocorrelated in time scales from tens to hundreds of seconds exhibiting scale free, fractal like dynamics across the infra-slow frequency band (Ko et al., 2011; Linkenkaer-Hansen, Nikouline, Palva, & Ilmoniemi, 2001). Direct cortical recordings in animals and humans observed the amplitudes and coherence of frequencies from delta to high gamma (100–150 Hz) exhibit robust ISOs and spectral power-law scaling (Ko et al., 2011).

According to researchers,(Dong et al., 2012; Mairena et al., 2012; Monto, Palva, Voipio, & Palva, 2008) human behavioral performance is correlated with the ISFs in ongoing brain activity. Monto detected a strong correlation between a subject's ability to detect a sensory stimuli and the phase of the low frequency signal. Mairena and co-workers posited that the ISO is nested in six frequency bands and is related to fluctuations in sensory detection.

More broadly, ISO has been associated with the DMN of the human cerebral cortex (Liu, Fukunaga, de Zwart, & Duyn, 2010) and appears to be related to ADHD symptom status (Helps et al., 2010; Tye et al., 2012). Supporting this correlation, Broyd (Broyd, Helps, &

Sonuga-Barke, 2011) found attention-induced deactivations of the ISF signal do not occur in Default Mode areas of cortex in subjects with ADHD, suggesting that they get "stuck" in self-referential processing and are unable to turn off areas of cortex when appropriate. This resting brain network is anti-correlated with a task-positive network. The ISF reflects a toggling mechanism that switches between the DMN, the network of introspective and self-referential thought, and the task positive network that responds to extrospective stimuli.

The ISO becomes intensified by agents that elicit a defense reaction similar to the response to "stress." Although the detailed physiological mechanisms underlying these Ultradian Rhythms have yet to be determined, some of the earliest research may provide data from which we can speculate on a precise mechanism of action of ISF training. In addition to its role in organizing neuronal networks, Aladjalova's research (Aladjalova, 1957, 1964) suggests the efficacy of ISF training may lie in the impact on the Hypothalamus.

The Hypothalamus is situated within the limbic system in the temporal lobes and plays an integral role in affective response as well as a vital role in maintaining homeostasis. It is the control center for many autonomic functions of the peripheral nervous system.

Hypothalamic hormones control pituitary hormone secretion, which in turn manages adrenal secretion of epinephrine and norepinephrine, the hormones that organize sympathetic nervous system response. Known as the Hypothalamic–Pituitary–Adrenal (HPA) Axis, this organ system has feedback loops that promote reparative, parasympathetic nervous system, response as well.

ISF training places an electrode on the temporal lobes as one of two bipolar placements on the scalp. The other placement may be any of the other nineteen 10/20 sites. It is proposed that this configuration may explain the behavioral data of calming, arousal reduction, and attention promotion observed among trainees. Our clinical data suggest that a bipolar electrode configuration and an optimum frequency promote the normalization of activation, as well as the communication between and within neuronal networks. So theoretically it regulates the activation of brain areas linked in chronic autonomic stress and normalizes the communication between the hypothalamic and limbic areas, separating the non-temporal area from the HPA distress signal.

Palva and Palva (2012) make a demarcation between the infra-slow (0.01–0.1 Hz) and the Ultradian rhythm (< 0.01 Hz) and refer to the former as ISFs. They point out in their research that the blood oxygenation-level dependent (BOLD) signals are correlated with constellations of brain regions that are very similar to networks that are correlated with the ISF signal. They note the direct association between ISFs in amplitude and behavioral performance with ISFs in the BOLD signal. The researchers concluded that ISFs arise from local cellular level mechanisms, as well as blood, and reflect the same underlying physiological phenomena: a superstructure of interrelating ISFs that regulates the integration within and decoupling between active neuronal networks.

We propose that ISF neurofeedback addresses this superstructure of interrelating neuronal networks. We submit that our pre-post QEEGs reveal changes in activation measures but especially in network dynamics as reflected by the coherence metric. The modification of information sharing between cortical areas produced by ISF training is consistent with research that demonstrates a role for the ISF in the regulation of neuronal networks. Addressing the integration of networks responsible for memory, affective response,

autonomic regulation, and attention—to mention a few—may account for the reduction in symptom severity among our clients.

Our pre-post behavioral data is consistent with the theory that ISF regulates autonomic function. Appropriate affective behavior in a school setting was the general outcome for special needs children trained in this form of neurofeedback. ASD and emotionally disturbed children demonstrated improvements on the Child Behavior Checklist related to tantrums and aggressive behavior. Moreover, the ability to attend was improved as was social functioning. The pre-post training QEEG data is consistent with the ISO research in demonstrating an interaction with the phase relationships between cortical areas. In addition to improvements in absolute power, our data demonstrates substantial change in coherence relationships between cortical regions. The remediation of coherence values is resonant with the research that suggests a central role for the ISO in functional network communication (See the following case studies).

Clinical Data

What follows are clinical examples of ISF training. First we present pre-post ISF training behavioral data on a group of special needs children trained in a school setting. Two individual cases with pre-post QEEGs are then offered to demonstrate the remediation of network communication and absolute power distribution that results from ISF training.

Results of a School-Based Program

ISF neurofeedback was used as an intervention for a group of school-aged children in New York City. The population consisted of children with varying degrees of learning and developmental disabilities, including some who met criteria for high-functioning autism, others who met criteria for Asperger's syndrome, and still others with disorders of anxiety. All of the children also had sensory processing issues, some more severe than others. In addition, all of the participants were having significant difficulties meeting the demands of their school environment, despite being placed in supportive, specialized academic settings and receiving the services indicated on their Individual Education Plan (IEP). More information about each participant is included below. Admission to the neurofeedback program was based on parent or teacher referral, and students were excluded if they displayed signs of psychosis, uncontrolled seizures, recent traumatic brain injury, or if their medication regimen was too complex and/or unstable.

In total, 17 students were enrolled in the program, ranging in age from 6 to 15 years. In order to help conceptualize the experimental group and the effects of treatment, students were grouped into two broad clinical categories, Emotional Disorders (ED) or Pervasive Developmental Disorders (PDD). Participants in the ED group included students with a primary diagnosis of anxiety or another mood-related disorder, while those in the PDD group included children who were diagnosed to be on the autistic spectrum. Regardless of clinical category, all of the participants were having trouble meeting the academic and/or social demands of their school environment. In the most extreme cases, students were at serious risk of a forced transfer to a different school. Therefore, in addition to being grouped by their main diagnostic category, participants were also grouped according to the amount of difficulty they were having at school (i.e., high, moderate, or low risk) as shown in Table 1.

Table 1
Participants Grouped by Clinical Categories and School Risk

Main Group		
ED (*n* = 7) Participants from the ED group (7 total) included three students with a combination of social and generalized anxiety, three students with reactive attachment disorder, and one student with an atypical form of bipolar depression.		**PDD (*n* = 10)** Participants from the PDD group (10 total) included children diagnosed to be on the autistic spectrum. The group included students with High Functioning Autism (HFA) and Asperger's syndrome.
Subgroups		
Low Risk Student is making adequate academic and social progress.	**Moderate Risk** Student exhibits emotional and/or behavioral difficulties that hinder academic progress and/or leads to behavioral outbursts during school. Student at moderate risk of a forced transfer to a different school.	**High Risk** Exhibits significant emotional and/or behavioral difficulties, including disruptive classroom behavior, that cause student to miss a significant amount of instructional time. Student at serious risk of forced transfer to another school as a result of disruptive classroom behavior and lack of adequate academic and/or social development.

Participants from the ED group (7 total) included those with a primary presentation of anxiety and/or depression. This group included three students with a combination of social and generalized anxiety, three students with reactive attachment disorder, and one student with an atypical form of bipolar depression. The three students with social and/or generalized anxiety were having difficulty initiating and completing tasks at school, which was causing them to underperform and become socially isolated. Regarding sensory issues, these students were hypersensitive, meaning they had a tendency to overreact to seemingly innocuous stimuli (i.e., touch, noises). The remaining four students in this group had difficulty regulating their emotional response to academic difficulties and/or social challenges, which led to serious behavioral disruptions and ultimately to removal from the classroom. Regarding sensory issues, these students were hyposensitive, meaning they were under-aroused and had a tendency to seek out excessive amounts of stimulation.

Participants from the PDD group (10 total) included children with High Functioning Autism (HFA) or Asperger's syndrome. The presenting concern for many of these students was emotional reactivity, or the tendency to overreact in response to certain environmental stressors or challenges. For these students, hypersensitivity toward various environmental stressors led to disruptive outbursts, making it difficult for many of them to either remain in the classroom and/or to transition between different classes and activities. These students are often labeled inattentive; while this may be an accurate description of their classroom behavior, it is important to distinguish them from students with primary disorders of attention (i.e., ADHD). Students with a primary diagnosis of ADHD were not intentionally excluded from the experimental group; however, no students with this profile were enrolled into the program.
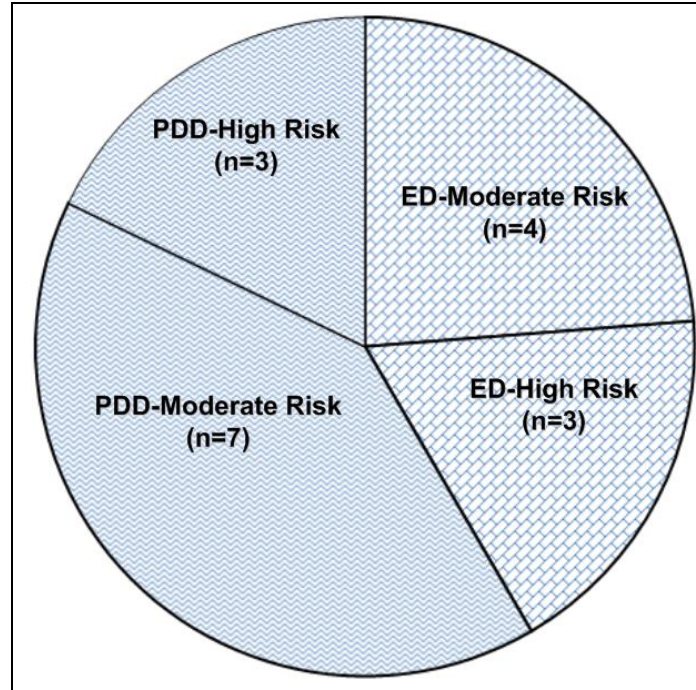
Figure 4. Pre-treatment breakdown of participants by diagnosis and presenting concern *ED = Emotional Disorder or **PDD = Pervasive Developmental Disorder. Results based on operationally defined construct (i.e., low, moderate, or high risk).

Fourteen of the 17 students had a definite positive response to ISF neurofeedback training that involved either: (1) a significant reduction of behavioral disruptions, (2) a reduction or elimination of psychotropic medication, and/or (3) improved ability to sustain attention during class and continued academic progress. Of the remaining two students, one had a positive response that is confounded by the initiation of an SSRI at the beginning of the program (a selectively mute child who saw a tremendous improvement in symptoms after about only one week on the SSRI and two weeks with neurofeedback). The other two students were determined to be at status quo at the completion of treatment.

Table 2

Summary of Treatment Population

#	Group: (ED *or PDD**) DSM Diagnosis	Subgroup, Pre-treatment	Dependant Measure	6-Month Follow-Up	Subgroup, Post-treatment
1	ED Reactive attachment disorder	Moderate Risk	Ability to control behavioral outbursts at school and home.	Controls behavior at school, making continued academic progress	Low Risk
2	ED Social anxiety	Moderate Risk	Avoidance of social activities, procrastination of HW	Increased capacity for social interaction; transferred to a more demanding academic environment and flourishing	Low Risk; now thriving in a mainstream school
3	ED Selective mutism	Moderate Risk	Ability to express knowledge verbally and in writing	Now able to consistently express himself verbally and in writing; transferred to a more demanding environment and flourishing	Low Risk; now thriving in a mainstream school
4	PDD HFA/Asperger's, SPD	High Risk	Behavioral outbursts, ability to remain in classroom	Making continued progress at same school	Low Risk
5	PDD HFA/Asperger's	Moderate Risk	Ability to meet academic demands	Making continued progress at same school	Moderate Risk
6	PDD High-functioning ability to meet demands of environment, Autism	Moderate Risk	Making continued progress at same school academic demands	Making continued progress at same school	Low Risk
7	PDD High ability to meet demands of behavioral outbursts, functioning Autism/Asperger's, SPD	High Risk	Ability to remain in classroom	Status quo	Moderate Risk
8	PDD HFA/Asperger's, SPD	High Risk	Disruptive behavior, ability to remain in classroom	No longer at risk of transfer, making progress	Moderate Risk
9	PDD HFA/Asperger's, SPD	High Risk	Behavioral outbursts, ability to remain in classroom	No longer at risk of transfer, making progress	Moderate Risk
10	PDD HFA, SPD	High Risk	Behavioral outbursts, ability to remain in classroom	No longer at risk of transfer, making progress	Low Risk
11	PDD HFA, SPD	Moderate Risk	Ability to meet academic demands	Making continued progress at same school	Low Risk

#	Group: (ED *or PDD**) DSM Diagnosis	Subgroup, Pre-treatment	Dependant Measure	6-Month Follow-Up	Subgroup, Post-treatment
12	PDD HFA, SPD	Moderate Risk	Disruptive behavior, ability to meet academic demands	Making continued progress at same school	Low Risk
13	ED Reactive attachment disorder	High Risk	Disruptive behavior, ability to remain in classroom	Controls behavior at school, no longer at risk of transfer	Moderate Risk; no longer disrupting classroom, better able to control outbursts
14	ED Reactive attachment disorder	High Risk	Disruptive behavior, ability to remain in classroom	Controls behavior at school, no longer at risk of transfer	Moderate Risk; vulgar language during outbursts has disappeared
15	ED Generalized anxiety	High Risk	Ability to meet academic demands	No longer at risk of transfer, making academic progress	Moderate Risk; maintained on a lower dose of stimulant medication, remains at school
16	ED Depression, severe mood swings	Moderate Risk	Emotional lability, ability to remain in classroom	Status quo	Moderate Risk; No change in emotional lability
17	PDD HFA, SPD	Moderate Risk	Ability to meet academic demands	Making continued progress at same school	Low Risk; promoted within same school

Teacher CBCL results. Pre-post teacher CBCL data was available for 12 students. The Child Behavior Checklist (CBCL) is a standardized measure of emotional and behavioral functioning that is available in parent, teacher, and self-report forms. For the present group, pre-post teacher CBCL rating scales are available for 12 of the 17 participants. The teacher form consists of approximately 113 questions scored on a 3-point Likert scale (0 = absent, 1 = occurs sometimes, 2 = occurs often). Each CBCL item loads onto one or more clinical scales, including eight syndrome scales (i.e., anxious/depressed, depressed, somatic complaints, social problems, thought problems, attention problems, rule-breaking behavior, and aggressive behavior), and six DSM-oriented scales (i.e., affective problems, anxiety problems, somatic problems, ADHD, oppositional defiant problems, and conduct problems).

For 11 of the 12 students for which CBCL data was available, improvements of greater than one standard deviation on relevant clinical scales were demonstrated. Data from each of these students is plotted in Figure 5.
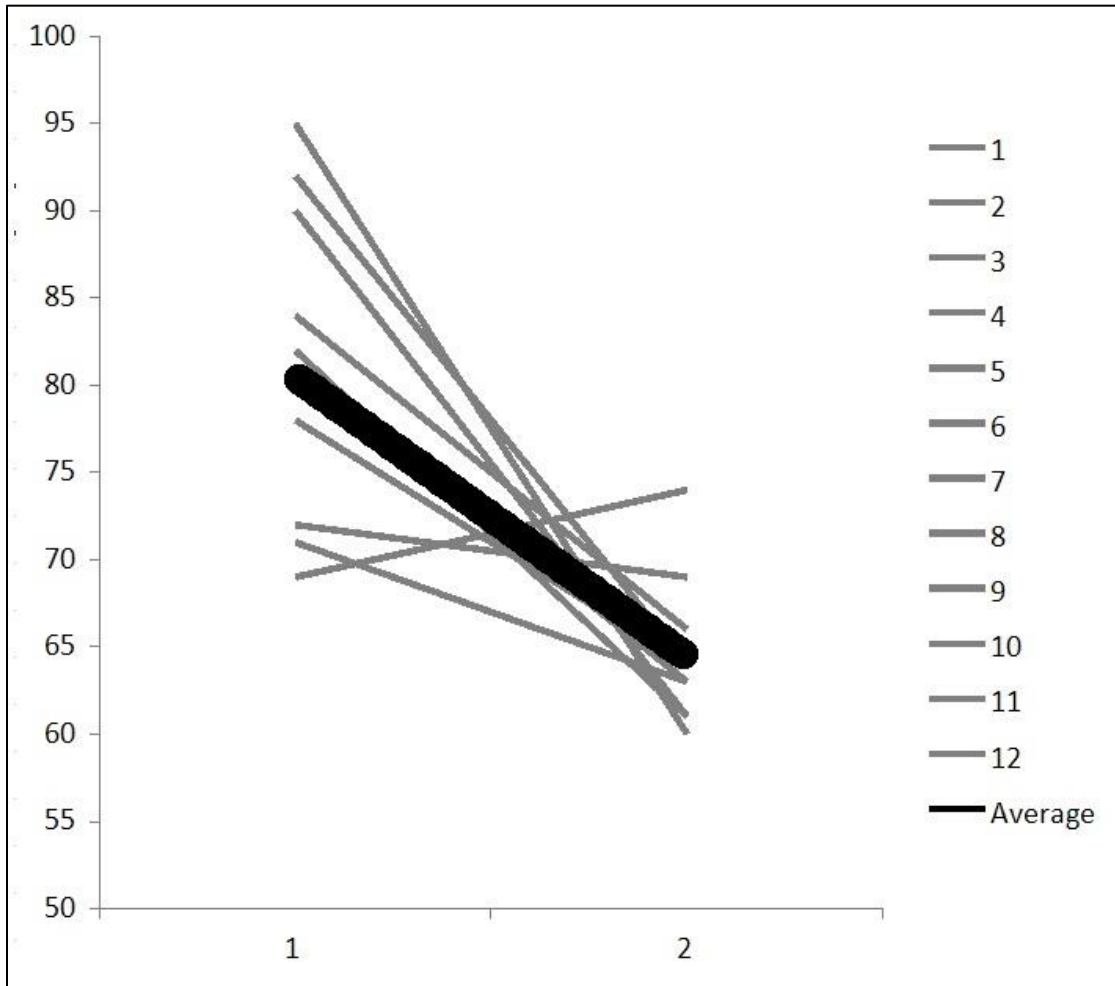
Figure 5. CBCL Results, Change on Marker of Primary Concern. CBCL results were available for 12 of the 17 students. The graph above plots the CBCL scaled score for each student's primary area of concern. There was an average improvement of 16 scaled score points, or 1.6 standard deviations of improvement.

Case study 1. The client, a 12-year-old male, was diagnosed with Autism after undergoing a developmental regression at 15 months old. He was relatively high functioning in his communication and had good eye contact when we started working with him in June 2010. He was 9 years old at the beginning of treatment. His presenting complaints – severe OCD, perseverative thinking, hyperactivity, and significant behavioral problems – prevented him from continuing in a mainstream school setting. He had recently been assigned to a school for children with behavioral problems and was learning at three grade levels below his age. Initial trials with ISF, then limited to a 3-decimal place optimal frequency adjustment, resulted in a hyperactive response.

Initially he received Z-score training, which provided positive results, albeit slowly. Both parents observed other children receiving ISF training and noted the rapid shifts in behavior. Several trials of ISF training were performed at their request, all resulting in short-term hyperactivity but with bigger positive gains following. In November 2010, 4-decimal places of optimal frequency adjustment were made available and the client was switched exclusively to ISF training with a suitable optimal frequency. He completed two ISF sessions each week

and showed a rapid reduction in hyperactivity and behavioral issues. In March 2011 he received the "Student of the Month" award from his school for his exceptional behavior. Over the next year, ISF brain training reduced his level of OCD and perseverative thinking dramatically. At the end of 2012, his academic gap had closed; he tested between the 4th and 5th grade levels on the Structure of Intellect (SOI) rating scale and his OCD issues were resolved. His diagnosis has been changed to high-functioning Asperger's.
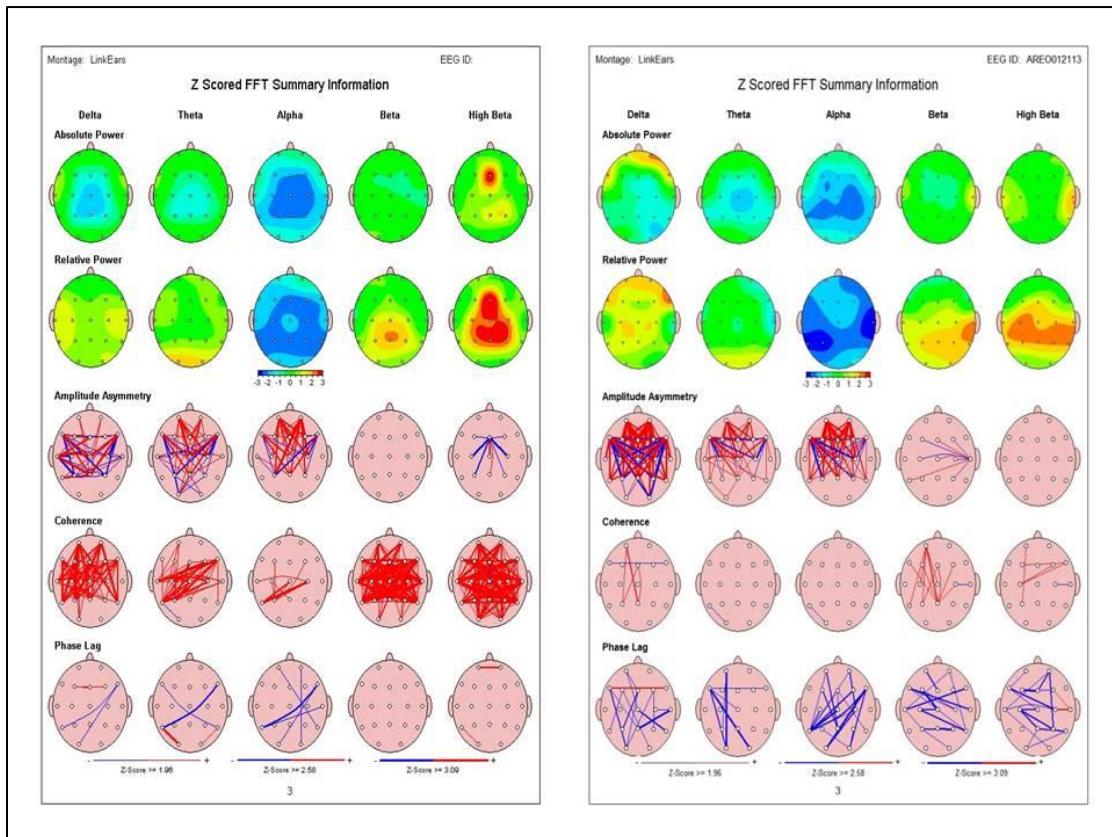
Figure 6. Pre/post QEEGs depicting near global remediation of coherence in all bands, with normalization of the deviant absolute power in the high beta band at the frontal midline.

Case study 2. The client, a 55-year-old African American male, presented with insomnia and PTSD. His early childhood was characterized by brutal, repetitive domestic violence between his parents. He witnessed his father's attempted murder of his mother. His father fractured his skull with a baseball bat. He was removed from the home by Child Services and placed in foster care at age eight. He was witness to beatings and gang rapes in group homes. The client was both shot and stabbed as an adult. He reported being a drug addict and alcoholic who had maintained abstinence for several years. At the beginning of training, he suffered with overwhelming anxiety, depression, and difficulty managing his anger. He reported sleeping with a rifle for protection. At the initiation of treatment, the client was extremely labile. His focus on fear and failure imagery had an obsessive quality that he felt powerless to control.

Treatment consisted of 31 sessions of ISF training targeting anxiety and depression. Areas trained included right pre-frontal and right parietal regions, bilateral temporal, and left pre-

frontal areas. Four sessions of alpha two-channel sum training in parietal regions were implemented at the end of ISF training.

At the termination of treatment, Ct reported better affect regulation: significant relief from his crippling anxiety and sense of hopelessness. Unemployed at the beginning of treatment, he returned to work in the construction trades during the latter stages of training. His problematic relationships with his wife and child improved. He reported breaking his rifle down and storing it in a safe location so as not to endanger his son. Some symptoms of PTSD persisted.

Post treatment brain mapping (Figure 7) revealed improved network relations, as demonstrated by coherence values, in all bands but high beta. The source of the excess absolute power in the high beta band was identified as the Anterior Cingulate Gyrus by LORETA current source density analysis and may have been related to the obsessive quality of the client's failure imagery. The question for further study is whether the appearance of less information sharing in anterior/posterior relations, as reflected by the coherence metric, and slowed rate of information transfer, as reflected by the increase in slowed phase lag, in the high beta band is related to the reduction in frontal high beta absolute power in the surface maps. If so, this may reflect a compensatory mechanism.
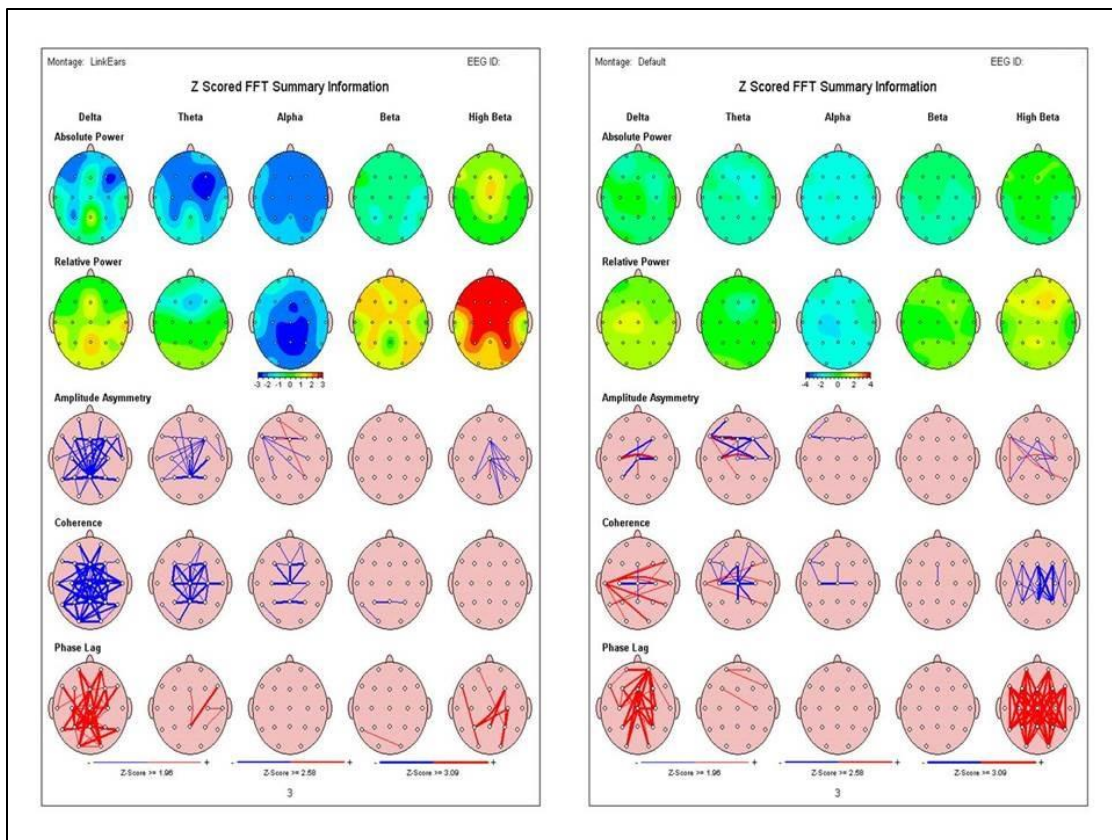
Figure 7. Pre-post training QEEGs. Complete resolution of Absolute Power abnormalities in all bands. Coherence indices improved in all bands but high beta.

Conclusion

Progress in equipment has allowed for the imaging of EEG signals below the traditional limit. Research spanning the last 60 years has demonstrated a functional centrality for ISOs in human and animal behavior. Clinical outcomes in ISF training are consistent with the functional research and demonstrate significant behavioral changes as established by empirically based assessment instruments. Post-treatment QEEG results reveal remediation of excesses of power, insufficiencies of power, and especially in network communications in cortex. This data is suggestive of the clinical efficacy of ISF training. Based on this data, a larger controlled study is warranted.

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