4-CHANNEL Z-SCORE NEUROFEEDBACK: A SINGLE CASE STUDY

Nancy Wigton, M.A., LPC, BCIA-EEG, QEEG-T
Applied Neurotherapy Center - Scottsdale, Arizona - www.appliedneurotherapy.com
08-29-2008

Introduction

In 2006, at the ISNR conference, a new Neurofeedback technique was made available. This new technique is called "Z-Score Neurofeedback". Z-Score Neurofeedback is a system that combines "real-time Neurofeedback training, using state-of-the-art signal processing, the NeuroGuide normative database analysis, and new computational methods". (5) Since that time, the burning question has consistently been "does it work?" And if it does work, "does it work better than what we've previously had available?". While there are some longer-term, multi-subject research projects underway, to-date none have been published or presented. Therefore, single case evidence and individual clinician experience is all that is currently available to evaluate this new technique. This case is presented in hopes of adding to our field's knowledge base in an effort to lend data towards addressing the "does it work" question.

Currently there are three manufacturers that have incorporated the use of the Neurodguide Z-Score DLL module in their software: Brainmaster Technologies, Inc., Thought Technologies, Inc., and Deymed Diagnostic. Also newly available from Brainmaster Technologies in 2006 was a 4-channel hardware platform. The case presented here was conducted using the Brainmaster Technologies 4-channel hardware with the Z-score Neurofeedback software. In 4-channel mode, the Z-Score DLL provides a total of 248 real-time normative EEG values, computed on a continuous basis, which are available for either viewing and/or training. "These calculations are performed more than 30 times per second, and consist of Z-scores for the following estimators: Absolute Power (4 channels, 8 bands), Relative Power (4 channels, 8 bands), Power Ratios (4 channels, 10 ratios), Amplitude Asymmetry (6 pairs, 8 bands), Coherence (6 pairs, 8 bands), and Phase Difference (6 pairs, 8 bands)". (5)

Z-Scores provide an instantaneous measure that is similar to, and consistent with, data as provided in a NeuroGuide-based QEEG. Scores are based upon the EEG signal, the sensor locations, the age of the trainee, and whether eyes are open or closed. With this information, the Z-Score system is able to provide values of 0.0 (mean), positive (above mean) and negative (below mean) scores. A Z-Score of -1.0, for example, means the trainee is 1.0 "standard deviation" below the mean for their population. This is of considerable value in amplitude and power measurements, but is even more essential for coherence, phase, and asymmetry scores. (5) Since it is not possible to easily tell whether a given trainee's coherence is "OK" without a normative comparison, this system now makes possible EEG connectivity-related training with a much lower risk of over-training in an undesirable direction.

An added component of the Brainmaster Z-score software is the ability to use a training variable that says "reward" only when a certain percentage of Z-score values are within a particular standard

deviation range, and to provide a value of the percent-of-time that the condition is met. This method has come to be termed as the "Percent Z-OK" (%ZOK) protocol. This training variable has also been expanded to be able to isolate certain categories of Z-scores trained, such as only Absolute or only Relative values, or only all Coherence values, or only all "connectivity" values (Asymmetry, Coherence, Phase). So while the basic equation metric is the same with %ZOK protocols, the clinician must make individual judgments as to what percentage of values to train, what standard deviation range to use, and what desired percent-of-time met goal should be. The above description of protocol implementation should be viewed as only the "tip of the iceberg" as to the capabilities of the Brainmaster software for Z-score Neurofeedback.

Technical Specifications

Neuropulse "NP-Q 10/20" QEEG hardware, using the NeuroGuide direct data collection software. Digital EEG data was recorded from 19 different scalp locations referenced to linked-ears utilizing the 10-20 electrode placement system, with a sampling rate of 128 sps, with impedance measures balanced and below 5k ohm at all sites. Data was collected in both the eyes closed and eyes open conditions (client was alert, relaxed, and awake). Artifacting, via the Neuroguide software, was used to edit the digital EEG tracings to remove artifacts such as eye movement, muscle tension, cardiac artifact, and drowsiness. First, the auto-selection artifacting feature was used, then a manual inspection was conducted to accept or reject selections made via the auto-selection feature. The split-half and test-retest reliability measures for both the eyes closed and eyes open data averaged 0.98 (split-half) and 0.92 (test-retest). The edited data was then subjected to computer analysis for measures of Amplitude, Power, Coherence and Phase Lag. FFT analysis of the selected EEG data were computed and compared to age matched norms.

Brainmaster "Atlantis I" 4x4 hardware with Neuroguide Z-score DLL software. Neurofeedback was conducted using 4 independent channels utilizing the "Percent Z-OK" protocols.

Braintrain "IVA" Continuous Performance Test. An IVA CPT assessment was performed on the same day as each QEEG.

An initial clinical interview was conducted, then a QEEG and IVA CPT were performed, then Neurofeedback was commenced. Various 4-channel Percent Z-OK protocols were used to address the most significant QEEG deviations and matched symptoms. During the initial 25 Neurofeedback sessions, the case Psychiatrist titrated the client off all medications. A new QEEG and IVA was conducted after 10 days of no medications.

Method

The approach used in this case was the 4-Channel Percent Z-OK (%PZOK) protocols.
It is important to note that the %PZOK approach is not an "auto pilot" or replacement for clinical judgment in the Neurofeedback process. There are important decisions to be made as to the specific settings in the software, and it is mostly a matter of clinical judgment that directs what choices are made. This could almost be seen as the element of "art" in how one works the "craft" of Neurofeedback. Besides the choice of which sites to place the electrodes, there are three elements which must be determined: 1) Percentage of the 248 variables to be selected for training, 2) the Standard Deviation (SD) target zone (similar to threshold) level, and 3) desired percentage-of-time conditions are met.

For this case, the following settings were applied:
- **94% - 95% of the available 248 variables were selected to be trained**
- **Desired %-time-conditions-met value was maintained between 20% - 50%**
- **The SD target zone was set in order to maintain the desired %-time-conditions-met value. For example, as the %-time-conditions-met value approaches 40% - 50%, reduce the SD target zone by 0.1 (i.e. from 2.0 to 1.9)**

Each session involved training the client on two separate protocols for 15-20 minutes for each protocol. This allowed for 5 to 6 sites to be worked within the 1-hr session's time. All protocols were "eyes open" unless otherwise indicated.

F3-C3-Pz-F4   F3-F4-Pz-C4
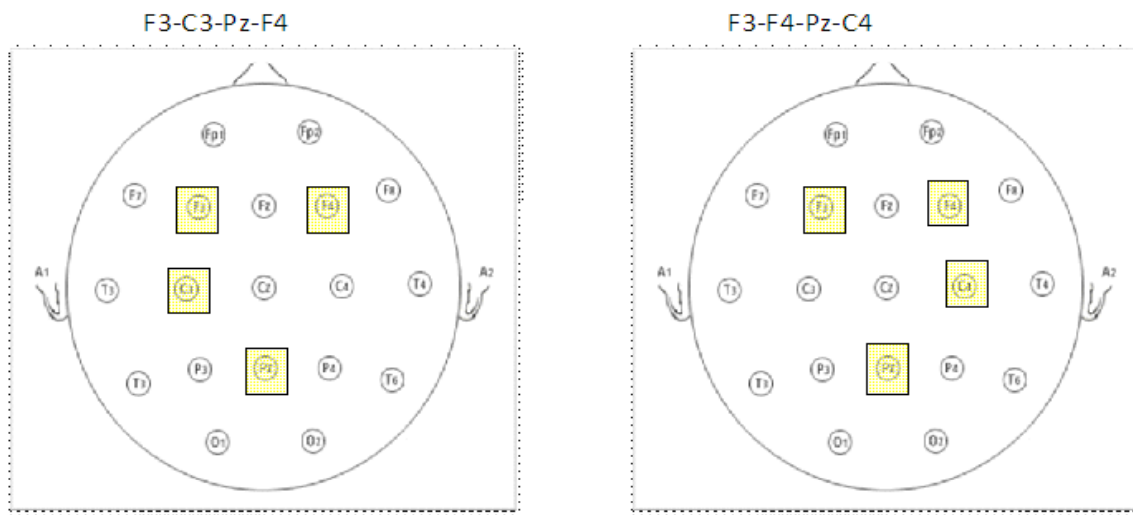
PZOK (Percent Z-OK
13 sessions included 15-20 minutes each protocol
5 sites addressed in a 1-hr session

P3-P4-Cz-Pz (Eyes Closed)   F3-F4-Cz-Pz
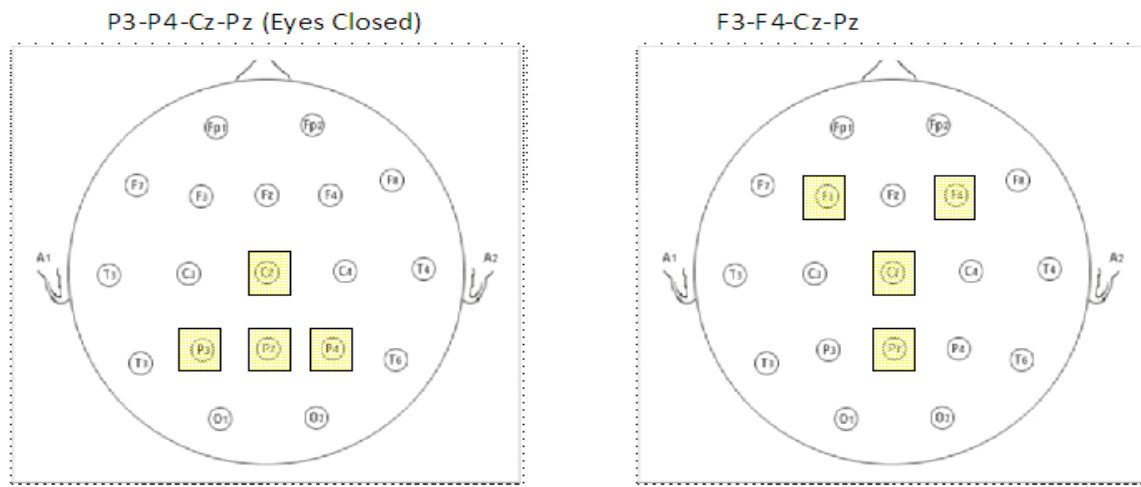
PZOK (Percent Z-OK)
12 sessions included 15-20 minutes each protocol
6 sites addressed in a 1-hr session

Discussion

"Does Z-Score Neurofeedback work"? In short, given the significant improvement in this case in terms of QEEG changes, outcome measure changes, and most importantly symptom resolution for the client, it is safe to say that (in this case) the answer is a resounding "YES".

"Does Z-Score NF work better than non Z-Score NF"? For this clinician, the answer is "it appears so"; at least in cases where there are several areas of QEEG abnormalities that need to be addressed. Given this clinician's eight years of NF experience, the amount and degree of positive change obtained in this case, in the first 25 sessions, was not anticipated and was a very pleasant surprise. Therefore it does seem apparent that Z-Score NF works at least as well as non Z-Score NF. However, it is important to keep in mind that this is a single case, N=1, and more research with larger sample sizes is needed to better answer this question.

An interesting point in this case was regarding the amount of abnormalities that were found in the initial QEEG in the Coherence and Phase measures. First, without Z-Score NF, the clinician in this case was not likely to conduct direct Coherence or Phase training. However, having the availability to both directly train and monitor the Coherence and Phase measures, as compared to normed values, allowed for more confidence in this task and less concern of going "too far" and over-training these measures. But it is believed that to be able to train both amplitude and connectivity measures at the same time, in a 4-channel format, allowed for more progress to be made in less time. Second, in this case, with so many abnormal Coherence and Phase measures, a 2-channel NF method would likely have required many more sessions to achieve similar results.

References

1. Horvat, Joseph; Coherence and the Quirks of Coherence Training: A Clinical Perspective; HANDBOOK OF NEUROFEEDBACK, Editor James R Evans, Ch 9, Pg 213-227

2. Duff, Jacques; The Usefulness of Quantitative EEG (QEEG) and Neurotherapy in the Assessment and Treatment of Post-Concussion Syndrome; CLINICAL EEG and NEUROSCIENCE ©2004 VOL. 35 NO. 4

3. Brainmaster Technologies website; www.brainmaster.com

4. Applied Neuroscience, Inc. (ANI) website; www.appliedneuroscience.com

5. http://www.appliedneuroscience.com/ANI%20and%20BrainMaster%20Announcement.pdf

PRE NF	CASE CONDITIONS	POST 25 NF Sessions

Background:
- 44-year-old male
- Presenting diagnostic history: ADHD, Bipolar disorder, w/ occasional Anxiety symptoms
- Rarely, if ever, having any specifically identified manic episodes. However described his "cycling" in terms of going between experiencing very disabling depression and then "climbing up to" a level of more adequate functioning
- Various psychotropic medications since 2001
- Consistent theme for the client was a lack of adequate successful symptom resolution from the psychotropic medications over the years
- Clinical interview revealed a history of multiple incidents related to blows to the head during childhood, and one significant incident related to a car accident in adolescence
- No alcohol or substance use/abuse issues
- Client had recently stopped working due to severity of symptoms

Medications:
- Vyvanse, Lexapro, Depakote, Abilify, Benztropine (only when needed for sweating)
- Prior medications: Ritalin, Adderal, Wellbutrin, and Celexa

Assessments:
- QEEG (client was still taking Lexapro, Depakote, & Abilify)
- IVA Computer Performance Test

Assessment Results:
- QEEG: a pattern indicative of a prior head injury (which frequently can include attention and mood disregulation symptoms) due to Coherence & Phase issues
- QEEG: Multiple Amplitude, Asymmetry, Coherence and Phase abnormalities
- IVA: Extremely low scores; most scales in "extremely impaired" range
- IVA: Supported working diagnosis of ADHD, Combined Type
- IVA: 50+ behavioral symptoms / functioning issues identified in IVA report, all affirmed by client in post assessment follow-up

Significant Events:
- Client began obtaining the beginnings of symptom resolution at session #5
- Able to continue functioning adequately after medication titration, initially client did not feel it necessary to re-start medications after re-assessments

Update:
- After two months and 25 Neurofeedback sessions the client had been successfully titrated off of all medications and a new QEEG was performed to obtain non-medicated QEEG data

Medication:
- NONE

Assessment:
- QEEG (no medications)
- IVA

Improvements:
- Client reported being able to overall function better than before NF, even without medications. On a Likert scale (1-10) client reports pre-NF with medications functioning at "1-2" and now with no medications at between "2-3" to "4-5"
- Better able to stay focused and complete tasks and projects
- Able to stay more engaged and function well in business meetings
- IVA: Very dramatic improvements; no longer support a working diagnosis ADHD
- IVA: Only 11 behavioral / functioning issues identified in report
- QEEG: Significant overall improvements
- QEEG: Frontal & Central regions balanced, most R/L asymmetries resolved
- QEEG: Great deal of improvement of Coherence in Theta & Beta, some Delta
- QEEG: Improvement of the Phase Lag in Delta
- QEEG: Eyes closed Alpha Peak forming (in relation to Delta)

Post-Assessment Remaining Issues:
- Still some remaining mild mood disregulation symptoms; mostly anxiety related
- Still had some issues with organization skills and focus/attention issues
- Still many QEEG issues to resolve, mostly in Delta at Pz, low diffuse Alpha, frontal Alpha Coherence, Phase measures, and low peak Alpha frequency
- 9 more NF sessions were done, but client needed to stop due to financial reasons; chose to address the remaining mood deregulation symptoms with medication (only Lithium)
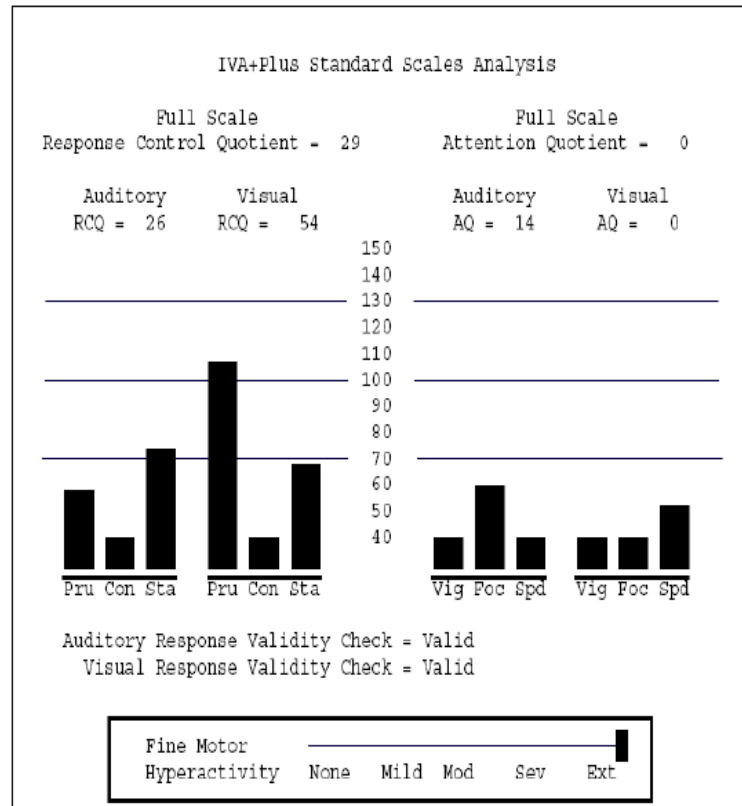
Post 2-month Follow-up:
- Client had returned to work and reported he was able to focus and perform job duties well
- Client stated that he felt his improved cognitive abilities were directly due to NF training and that he no longer needed to continue with NF for ADHD related symptoms
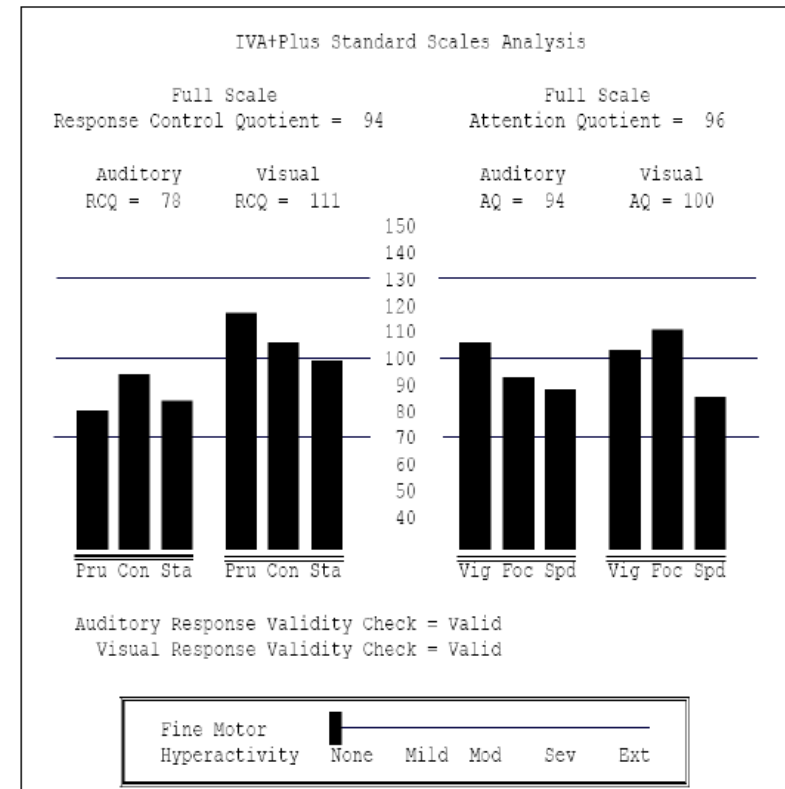
PRE NF   **IVA RESULTS**   **POST 25 NF Sessions**

IVA+Plus Standard Scales Analysis

Full Scale
Response Control Quotient = 29

Full Scale
Attention Quotient = 0

Auditory
RCQ = 26

Visual
RCQ = 54

Auditory
AQ = 14

Visual
AQ = 0

Auditory Response Validity Check = Valid
Visual Response Validity Check = Valid

Fine Motor
Hyperactivity   None   Mild Mod   Sev   Ext

- Pre Neurofeedback assessment
- Medications: Lexapro, Abilify, Depakote
- 50+ Behavioral/functioning issues identified in report, all of which were endorsed by client

IVA+Plus Standard Scales Analysis

Full Scale
Response Control Quotient = 94

Full Scale
Attention Quotient = 96

Auditory
RCQ = 78

Visual
RCQ = 111

Auditory
AQ = 94

Visual
AQ = 100

Auditory Response Validity Check = Valid
Visual Response Validity Check = Valid

Fine Motor
Hyperactivity   None   Mild Mod   Sev   Ext

- Post 25 Neurofeedback sessions
- Medications: NONE
- Only 11 Behavioral/functioning issues identified in report

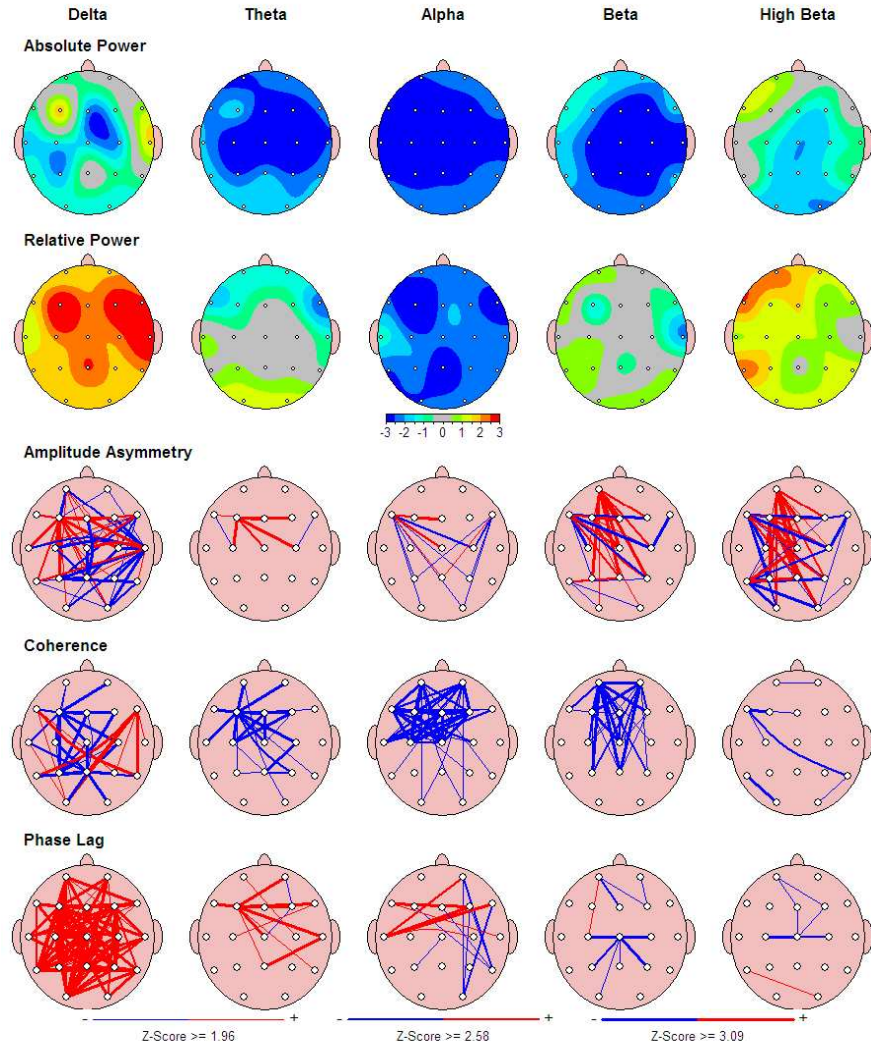**PRE NF**　　　　**EYES OPEN - LAPLACIAN**　　　　**POST 25 NF Sessions**
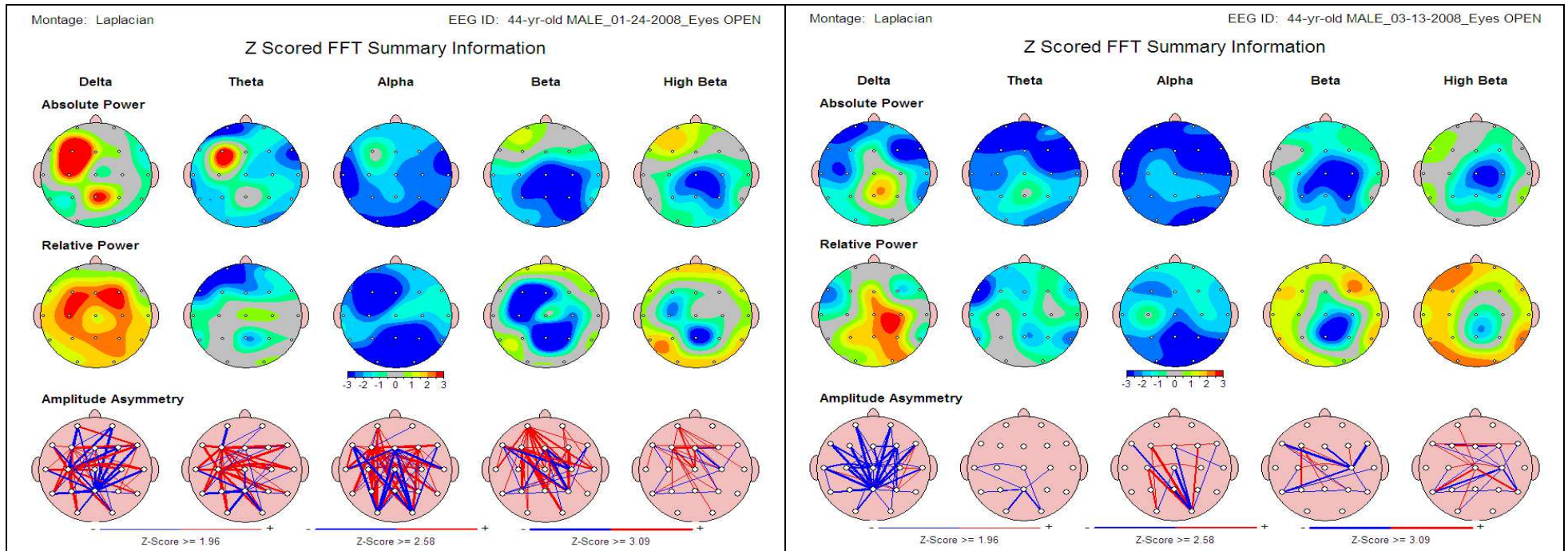
PRE NF **EYES CLOSED – LINKED EARS** **POST 25 NF Sessions**

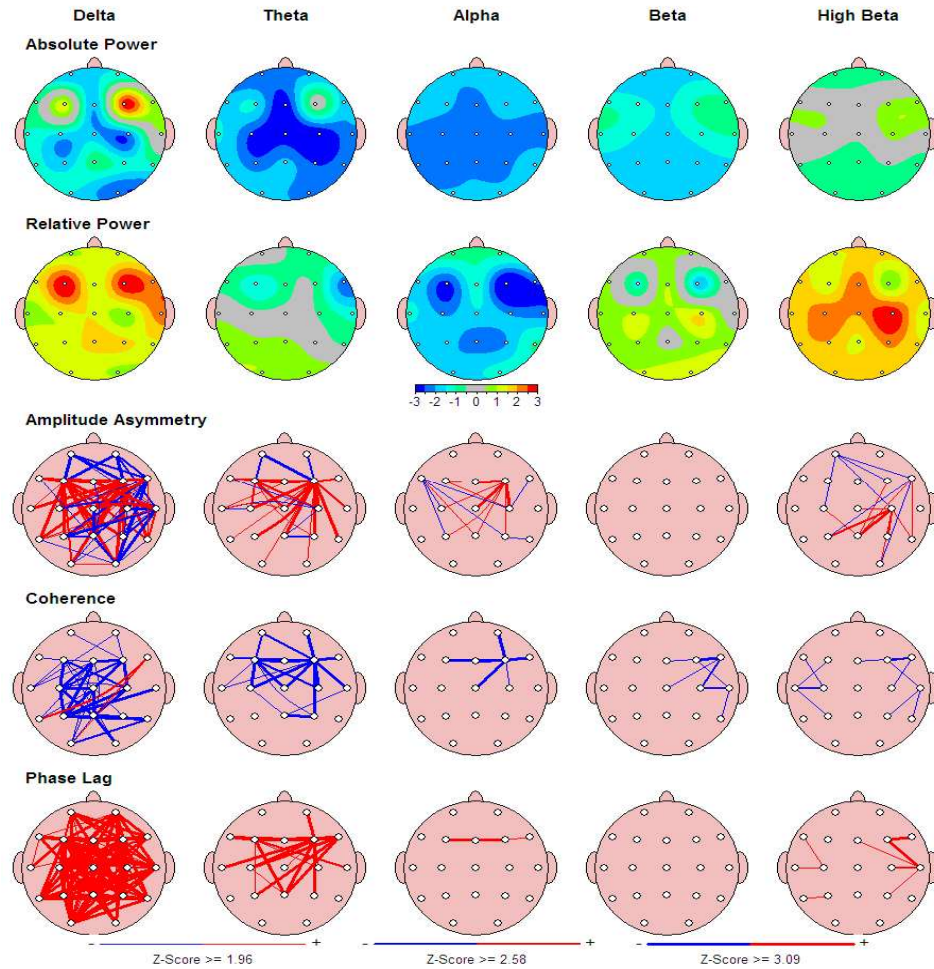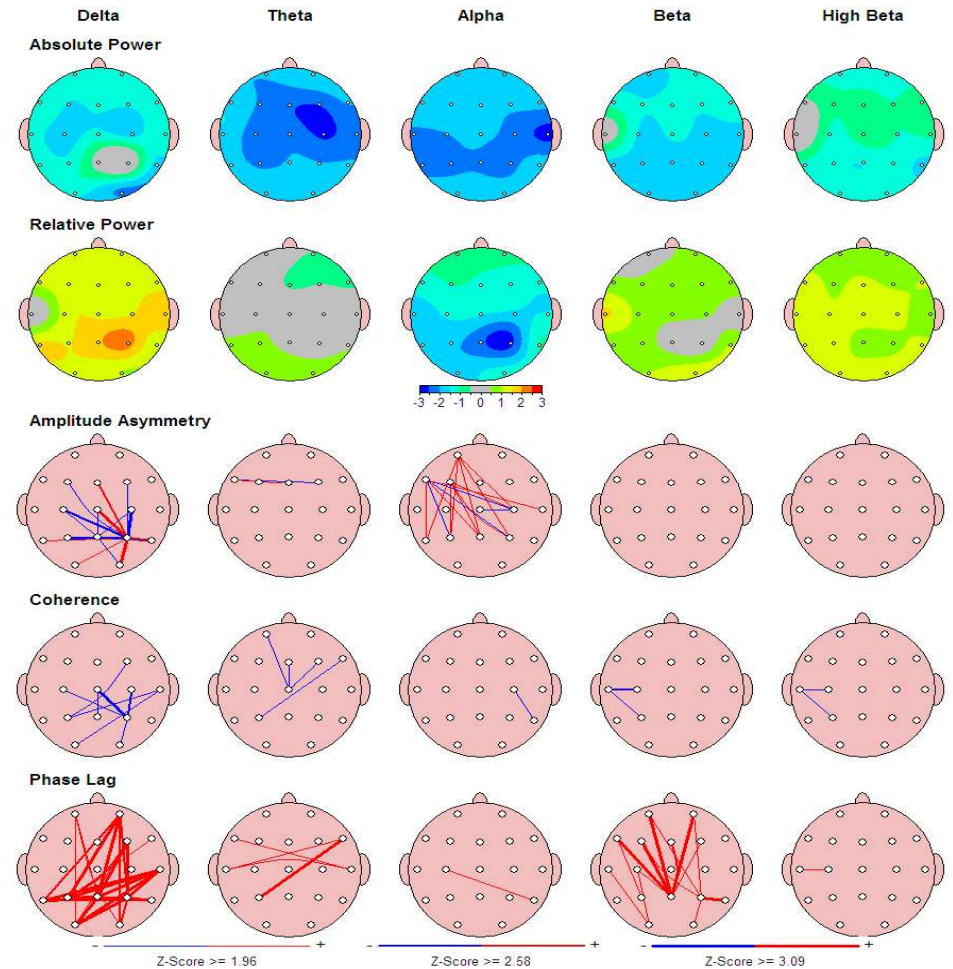Montage: LinkEars EEG ID: 44-yr-old MALE_01-24-2008_Eyes CLOSED

Z Scored FFT Summary Information

Delta Theta Alpha Beta High Beta

Absolute Power

Relative Power

-3 -2 -1 0 1 2 3

Amplitude Asymmetry

Coherence

Phase Lag

- Z-Score >= 1.96 + - Z-Score >= 2.58 + - Z-Score >= 3.09 +

3

Montage: LinkEars EEG ID: 44-yr-old MALE_03-13-2008_Eyes CLOSED

Z Scored FFT Summary Information

Delta Theta Alpha Beta High Beta

Absolute Power

Relative Power

-3 -2 -1 0 1 2 3

Amplitude Asymmetry

Coherence

Phase Lag

- Z-Score >= 1.96 + - Z-Score >= 2.58 + - Z-Score >= 3.09 +

3

EYES CLOSED - LAPLACIAN

PRE NF   **POST 25 NF Sessions**

Montage: Laplacian   EEG ID: 44-yr-old MALE_01-24-2008_Eyes CLOSED

Z Scored FFT Summary Information

Delta   Theta   Alpha   Beta   High Beta

Absolute Power

Relative Power

Amplitude Asymmetry

Z-Score >= 1.96   Z-Score >= 2.58   Z-Score >= 3.09

Montage: Laplacian   EEG ID: 44-yr-old MALE_03-13-2008_Eyes CLOSED

Z Scored FFT Summary Information

Delta   Theta   Alpha   Beta   High Beta

Absolute Power

Relative Power

Amplitude Asymmetry

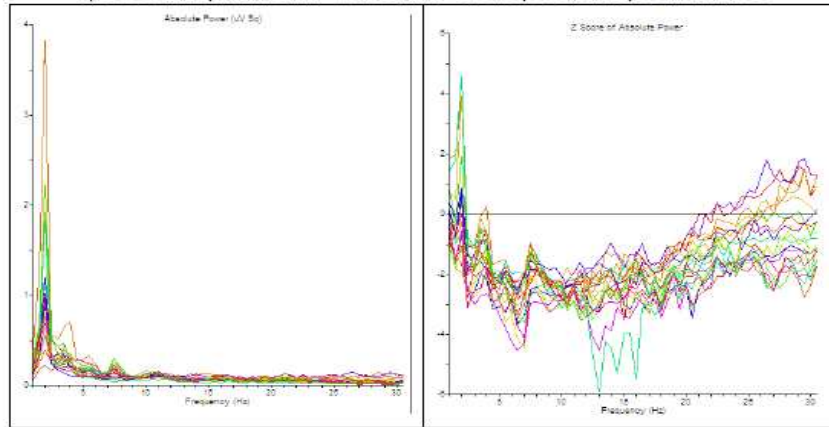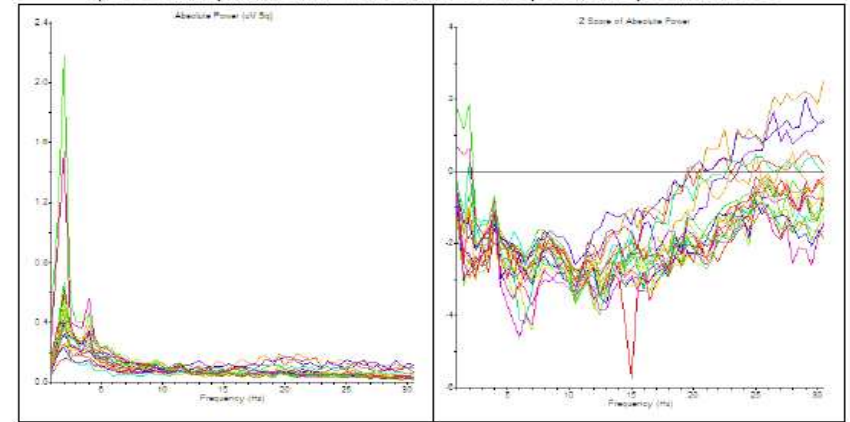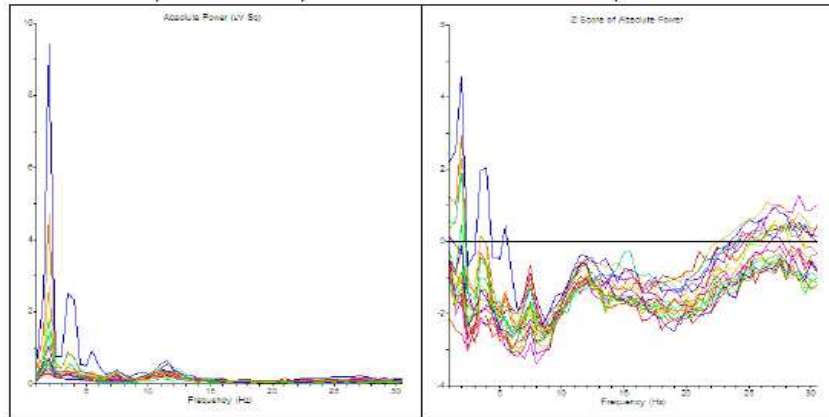Z-Score >= 1.96   Z-Score >= 2.58   Z-Score >= 3.09

Eyes OPEN Dynamic FFT – Absolute Power Spectrum Spectrum 1/08

Eyes OPEN Dynamic FFT – Absolute Power Spectrum Spectrum 3/08

Eyes CLOSED Dynamic FFT – Absolute Power Spectrum

Eyes CLOSED Dynamic FFT – Absolute Power Spectrum