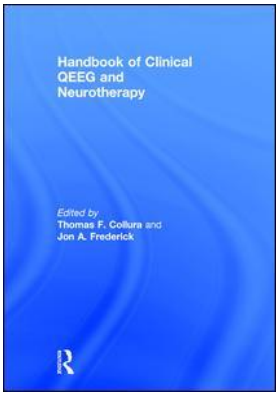

Handbook of Clinical QEEG and Neurotherapy

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The Efficacy of Z-Score Neurofeedback Training

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THE EFFICACY OF Z-SCORE NEUROFEEDBACK TRAINING

Joseph Guan

Abstract

This chapter traces the use of Z-score neurofeedback training in diverse clinical settings utilized by Brain Enhancement Centre Private Limited. All the clients used a form of live Z-score training (LZT) that produces audio and visual feedback. Over multiple sessions, QEEG brain maps indicate positive changes toward overall normalization of brainwaves. Other assessment tools were used, for example psychological reports, assessments from speech and occupational therapists and interviews with parents/guardians were compiled to provide a comprehensive and composite picture of the issues of the clients. From these multiple sources of data, treatment protocols were designed for the respective clients. Z-score training is a scientifically validated approach and this new intervention significantly reduces guesswork, particularly with brain connectivity training. In this book chapter, a variety of clients with different issues are presented to give the reader a flavor of how Z-score neurofeedback training can effectively treat clients with many different clinical issues.

Since 2008, Z-score training has been the most common neurofeedback intervention at the Brain Enhancement Centre Private Limited. It has demonstrated a remarkable efficacy with a wide and diverse range of clients. Issues such as global developmental delay, autism, dyslexia, ADD, ADHD, slow learners, sleep disorders, migraine headaches, Parkinson, stroke recovery, dementia patients, tinnitus, bipolar and vertigo have been treated.

The majority of the time, an initial assessment is done with a QEEG (Quantitative Electroencephalogram) brain map which gives a pictorial view of the areas of the brain and assists in identifying regions that have specific problems. The results provide targets for relevant interventions (Thatcher, 2012).

Research suggests that QEEG has a high level of reliability. A comprehensive literature review (Hughes & John, 1999, p. 191) in the *Journal of Neuropsychiatry and Clinical Neurosciences* reported, "Of all the imaging modalities, the greatest body of replicated evidence regarding pathophysiological concomitants of psychiatric and developmental disorders has been provided by EEG and QEEG studies."

Besides the QEEG brain map, psychological reports, assessments from speech and occupational therapists, and interviews with the clients and the parents of the clients were employed. From the multiple sources of data, a treatment protocol was designed for the respective clients.

The interventions utilized were Z-score training, sLORETA and Infra Slow Fluctuation training protocols. BrainDx and Neuroguide normative databases were used for assessment and training. For

Z-score training, the Atlantis 4x4 amplifier and 4 channel training was utilized. In addition, the Discovery 24 channel amplifier was employed for 19 channel and sLORETA training.

Z-score neurofeedback training is a scientifically validated approach that analyzes selected training sites, compares those sites with the Neuroguide and BrainDx normative databases and automatically trains those sites using a chosen targeted protocol. Protocols automatically train a client's brainwave patterns towards a more normative expression. This new approach significantly reduces guesswork, particularly with brain connectivity training. It is most effective when preceded by a full QEEG assessment.

Training consists of the following estimators: absolute power, relative power, power ratios, asymmetry, coherence and phase. Advanced built-in functions and variable definitions facilitate simple design of complex targeting strategies with intuitive trainee feedback. Any combination of targeted Z-scores may be included in the protocol design, which may train toward normative values, or can be biased for peak performance, self-awareness, mental fitness, healing or other neurofeedback applications.

In a position paper entitled "Standards for the Use of Quantitative Electroencephalography (QEEG) in Neurofeedback: A Position Paper of the International Society for Neuronal Regulation" (Hammond et al., 2004), the panel of authors have this to say about Z-score training:

> The most important thing about live Z Score training is that it is scientific. It is based upon published research and a well-documented normative database. It uses concepts that have been proven in clinical research to lead to beneficial outcomes. It eliminates guesswork, and reduces the risk of over- or under-training key parameters including coherence, phase and asymmetry. These parameters are known to have optimal values, and it is important in neurofeedback training to seek training targets that are beneficial.

Z-score training can address the whole head, normalizing activation and connectivity. It promotes relaxation, concentration, focus and affective regulation.

For a detailed discussion, readers are directed to a white paper written by Tom Collura, Ph.D., and Robert Thatcher, Ph.D., entitled "Real-Time EEG Z-Score Training—Realities and Prospects" (April 2006). In the authors' own words, this paper discusses the realities and possibilities raised by the implementation of "real-time Z-score training" as an emerging neurofeedback paradigm (p. 1). Both authors describe the positive and promising method of training the brain utilizing live Z-scores.

For additional information, please see a paper entitled "EEG Biofeedback training using Live Z-Scores and a Normative Database" (Collura, Thatcher, Smith, Lambos & Stark) published in 2009, which expounds on the technical background and the clinical results using Z-score training together with some case studies.

A more recent article published in the *Journal of Neurotherapy* in 2010, "EEG Biofeedback Case Studies Using Live Z-score Training and a Normative Database" (Collura, Guan, Tarrant, Bailey & Starr) further elaborates the efficacy of Z-score training. This form of neurofeedback makes it possible to compute, view and process normative Z-scores in real time. Towards the end of the article, there are summarized case study details, including clinical, behavioral, psychometric and QEEG changes. This table is very helpful in giving the reader easy comparison of the case studies. In the Discussion and Conclusion section of this article, the authors strongly suggest that the Z-score training "is capable of inducing brain changes that are specific and profound, particularly with regard to whole-brain activation and connectivity" (p. 45).

A recent paper from *Clinical EEG and Neuroscience Society*, "Neurofeedback Training Induces Changes in White and Gray Matter" (Ghaziri et al., 2013), is a defining moment for us in the field of neurofeedback. The above authors utilized structural magnetic resonance imaging (MRI)

to investigate whether neurofeedback training could induce structural changes in gray and white matter in the brain. This article describes how their findings, using diffusion tensor imaging (DTI), demonstrates that neurofeedback can induce measurable changes in white matter architecture. The authors emphatically conclude that "after 50 years of research in the field of neurofeedback, their study constitutes the first empirical demonstration that NFT can lead to microstructural changes in white and gray matter" (p. 1).

The purpose of the following case studies is to demonstrate the efficacy of Z-score training using appropriate 4 channel Z-score neurofeedback training.

Case Study 1: 5-Year-Old Boy with Pervasive Developmental Delay (February 2009) before Purchasing Discovery Amplifier

Timothy and his mother came to see me when I visited Surabaya in February 2009. I did not have my Discovery amplifier at that point in time so I depended on the medical reports given by the pediatrician and also a description of Timothy's condition given to me by his mother as my initial assessment. Due to the client's diagnosis of pervasive developmental delay, the intervention strategy started with a Z-score training program that would address most of his issues by training all 19 electrode sites. I was only in Suraybaya for a week and treated him for 10 sessions at two sessions a day for a period of five days. I returned to Surabaya in four weeks and initiated another 10 sessions of Z-score training for Timothy. On my third visit to Surabaya, a final round of 10 sessions of Z-score training was implemented. In the meantime, I trained a local practitioner to continue the treatment under my supervision. In all Timothy had 60 sessions of neurofeedback. His training protocol is supplied below:

T3 T4/C3 C4 (5 sessions)—For emotional and physiological stability, to impact the client's sensory motor cortex to address fine and gross motor skills. In addition, attention and mental processing speed, manual dexterity, sensory and motor integration were addressed with these placements. It was hoped that this training combination would help with the initiation, activation and performance of motor activity and normalization of affective response.

T3 T4/Fp2 P4 (5 sessions)—Addresses emotional and physiological stability, promoting positive emotions, attachment issues and helps to promoter deep physiological calming by addressing sensory processing regions.

T3 T4/Fp1 Fp2 (5 sessions)—Impacts attention and impulse control, planning and organization, mental clarity, compulsive behaviors and tics, obsessive and impulsive thoughts, behavior contentment or equanimity.

T3 T4/F7 F8 (5 sessions)—F7, which lies in the Broca's area, and its homologous site F8 are involved with speech production, speech initiation, language fluency and word finding. These areas are central hubs of language processing and comprehension.

F7 F8/C3 C4 (5 sessions)—This montage coordinates the motor component of speech production with the primary language areas involved with productive speech. The goal of this electrode array was to promote verbal fluency and clarity of speech.

T3 F7/P3 P4 (5 sessions)—This electrode array addresses the combination of language pathways and sensory processing.

T3 T4/F3 F4 (5 sessions)—Besides treating emotional and physiological stability, this treatment protocol engages in fine motor coordination, initiation and sequencing of movements, increases motivation and self-confidence, and reduces depression and anxiety.

T3 T4/P3 P4 (5 sessions)—Deals with primary somatosensory processing (awareness of body-somesthetic, kinesthetic and proprioceptive information, sensory integration), especially the visual and somatosensory including body position, body movement and awareness of movement through space.

After 40 sessions, Timothy's mother gave the following testimonial:

> *My son is 5 years old and was diagnosed with pervasive developmental disorder. He was speech delayed, kept to himself most of the time and did not express his emotions and could not interact with others. He had difficulties in two way communication. He also exhibted a lack of understanding of instructions given to him. I was so distressed that I had to take antidepressant medication.*
>
> *However I started neurofeedback with Dr. Guan in February 2009, and my son has made tremendous progress ever since. He talks appropriately and in context, interacts well with others, and expresses his emotions. I am so hopeful that I have stopped my medication and I am no longer depressed. His concentration and focus has also improved a lot. I am confident that my son will make greater progress in the coming months. His father has come closer to him and he plays and interacts with his elder brother.*

T3 T4/T5 T6 (5 sessions)—This treatment combination entails the deeper structures of the amygdala, hippocampus, thalamus and tail of the caudate nucleus. T5 is aimed at issues involving linguistic short- and long-term memory (both auditory and visual). The functions of T6 include facial recognition and spatial awareness. This region is involved with social skills. The processing of auditory stimuli occurs here especially with regard to discerning the location of sounds, identification and recognition of nonverbal environmental sounds, and music and sounds conveying emotional meaning.

T3 T4/O1 O2 (5 sessions)—The occipital lobe contains neurons that, although predominantly concerned with the analysis of visual stimuli, respond to vestibular, acoustic or somesthetic input as well as processing of primary visual input and visual perception. This combination is very good for clients with visual processing issues like dyslexia.

T3 T4/Cz Fz (5 sessions) and T3 T4/Cz Pz (5 sessions)—Fz and Cz are located in the medial cortex. Directly below the medial cortex is the cingulate gyrus, an integral part of the limbic system. The cingulate is responsible for emotional processing, learning and memory. It is highly influential in linking motivation and behavior. The cingulate has a role in attention. The anterior cingulate specifically is central in shifting one's attention from one subject to another, adapting with changing circumstances, or seeing options and promoting flexibility.

Pz—The parietal lobe is commonly thought to be concerned predominantly with processing of somesthetic, kinesthetic and proprioceptive information. However, in addition, the networks of this region are responsive to a variety of divergent stimuli, including movement, hand position, objects within grasping distance, audition, eye movement, as well as complex and motivationally significant visual stimuli.

After 60 sessions of Z-score training, Timothy finished his neurofeedback sessions and his mother was very pleased with the outcome of the program.

Case Study 2: Vertigo

A 64-year-old woman suffered from vertigo for many years. When the attack comes, she has the sensation that objects in the environment are moving and she has to remain in bed for several days. Occasionally, this attack is accompanied with vomiting. During an attack, she would take medication to stabilize the dizzy feeling and rest in bed for a few days. She came to me for help because when the attack comes, she feels miserable and helpless.

Nineteen channel Z-score training was implemented for her. After 12 sessions spanning a period of six weeks, the incidence of vertigo disappeared. In addition to the 19 channel Z-score training, I also treated her using 4 channel Z-score training at T3 T4/C3 C4 since the probable cause of her vertigo was due to the disturbance in the balance organs of the inner ear.

Case Study 3: Dementia

A 77-year-old woman with dementia came to my clinic. Her daughter-in-law provided me with a history of memory problems. She misplaced objects very frequently and often repeated instructions to her son and maid several times, not realizing that she had already given the instructions. This frequent occurrence annoyed members of her family. She also had bouts of depression for the last few years. She has been taking medication for her dementia. She has been suffering from this ailment since 2008.

After taking a full history of her condition, I started treatment. For this case study, I did not do a QEEG brain map. She resisted having the electro-cap placed on her head. The symptoms of her condition determined the placements of the Z-score training protocol.

I employed the 4 channel Z-score training with electrode placements at T3 T4/T5 T6. This targets the temporal lobe which includes the Hippocampal Gyrus. The Hippocampal Gyrus plays a central role in information processing, including memory, new learning, attention, behavioral arousal and orienting reactions in social interactions. She came for treatment twice a week for her Z-score neurofeedback sessions. After 20 sessions of the above training, I changed the sites to T3 T4/F3 F4 to reduce anxiety and depression and increase her self-confidence.

After a total of 40 sessions of 4 channel Z-score training, her condition improved significantly. Her symptoms of depression have resolved. Her short-term memory has improved. She continues once a week of neurofeedback training for maintenance. She continues to make steady progress with attention and memory.

Case Study 4: Parkinson

A 64 year-old man was referred to address the symptoms for Parkinson disorder. He had been suffering from Parkinson for nine years. He had been prescribed three kinds of medication. He was undergoing physical therapy twice a week. His condition was considered quite severe. He needed help from his wife or nursing aide in order to walk. He had difficulty eating, chewing and swallowing his food. His right upper arm was very stiff. If he needed to walk more than 10 yards, he would use a wheel chair. As a result of his immobility, neurofeedback treatment was performed in his residence three times a week.

Four channel Z-score training was used for his treatment. The training sites were T3 T4/C3 C4 targeting the sensory motor strip. These sites are concerned with the initiation, activation and performance of motor activity. It was hoped this would help with his fine and gross motor skills including chewing and swallowing food.

C3 C4/F3 F4 (central strip and frontal region) for motor planning and sequencing of movements was also employed. The target range of Z-score training was from -1 (standard deviation) to +1.5 (standard deviation).

After the first 10 sessions of Z-score training at T3 T4/C3 C4, there was marked improvement in his condition. His sleep improved. His ability to maintain restful sleep improved from one to six hours. His wife reported that he was able to speak with greater clarity. He was able to eat, chew and swallow his food more easily. His right arm was less rigid and the range of movements had improved. He is now able to walk with a steadier gait and he made the remark, "I feel that I can now get better." When his wife heard this, she interjected and said, "This is the first positive comment he had uttered in the last three to four years."

After 20 sessions of neurofeedback, there is further progress in his condition. His wife reports that occasionally, John has seven hours of uninterrupted sleep. His movements are more flexible and his speech has improved with less slurring and hesitation in expressing his views. He now manages to walk with a cane. At the time of writing this article, this client finished 30 sessions of Z-score training.

Case Study 5: Bipolar Client

A 26-year-old woman with bipolar disorder presented in treatment recently. She was under the care of a psychiatrist and was taking four different kinds of medication. I performed a QEEG. The brain map revealed excessive theta waves in the pre-frontal and frontal areas. The excessive theta at F3 F4 represented an electrophysiological signature, consistent with her reports of having depression. In addition, she reported anxiety and difficulty maintaining affective equilibrium. She had 4 channel Z-score training on:

T3 T4/C3 C4—for emotional stability. The temporal lobe is central in the regulation of emotional processing.

T3 T4/F3 F4—targets depression and anxiety and motivation and self-confidence.

T3 T4/Fp2 P4—helps in deep physiological calming and promoting of positive emotions and attachment issues.

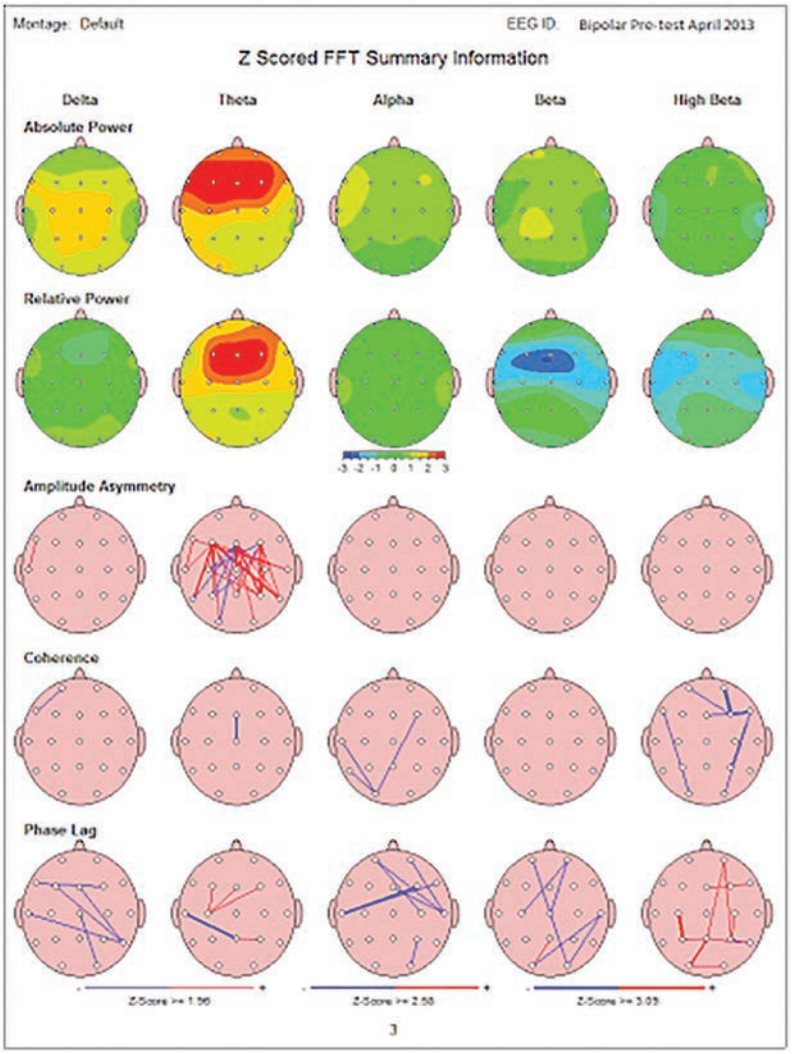

Figure 17.1 Pre-treatment QEEG.

Excessive theta waves in the frontal region suggesting anxiety and depression.
From April 2013 to August 2013, she had 40 sessions of 4 channel Z-score training.

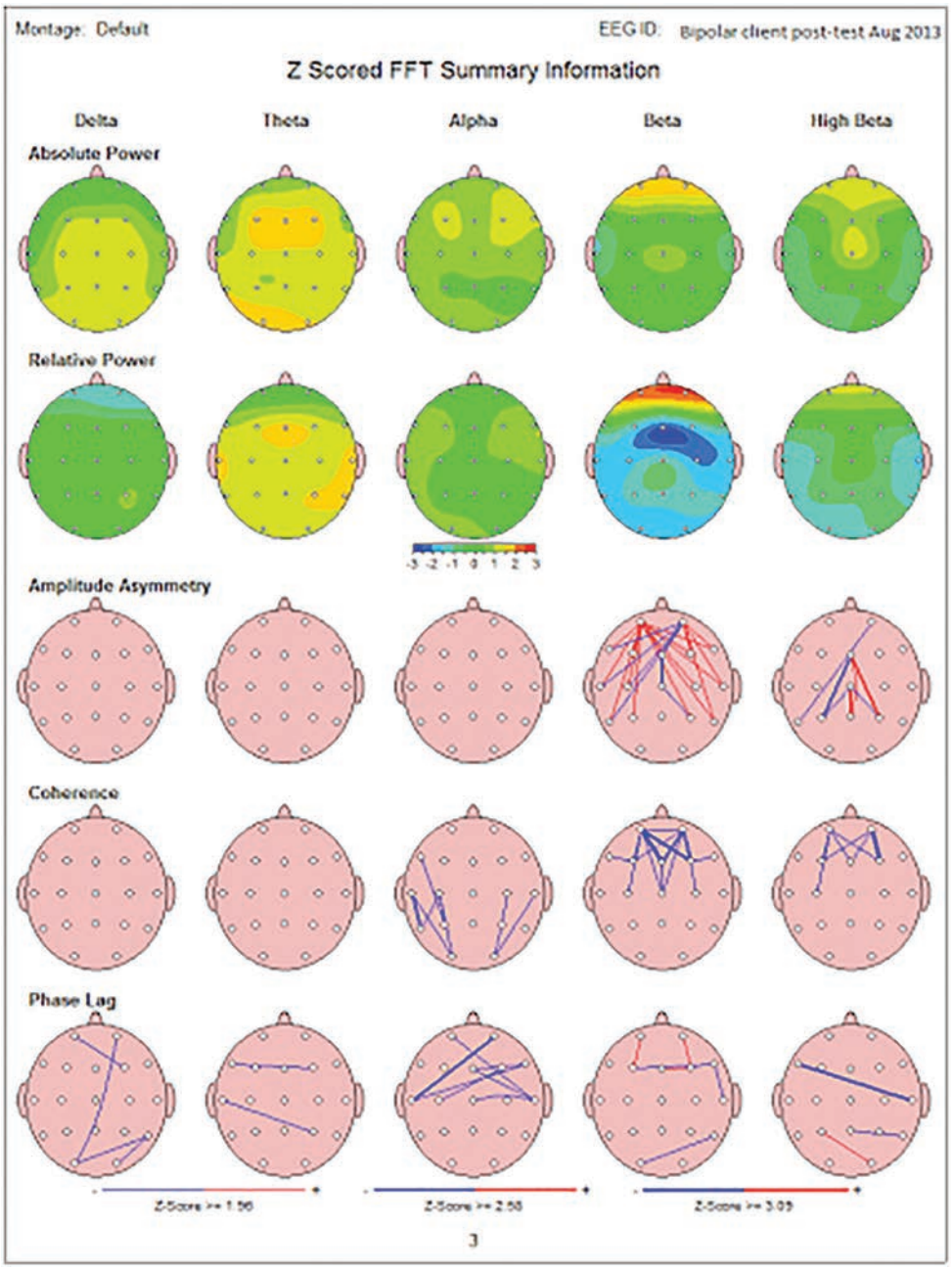

Figure 17.2 Bipolar client post-test August 2013.

The post-treatment QEEG demonstrated that the excessive theta waves have been reduced globally. She is emotionally stable now with reduced severity and frequency of mood swings. She smiles more and is more expressive in her speech. She is more postively oriented. This client's medication regimen currently includes only one medication. She is now planning to pursue an overseas educational program, a long-time goal that had been deferred due to illness.

Case Study 5: ADHD

A 12-year-old girl with ADHD was referred for treatment. She had been taking Ritalin for the last three years. The first session included a QEEG brain map and a consultation with her parents. After collecting five minutes of raw data (Eyes Open), the Neuroguide software was used to generate a QEEG report. We discussed the findings of the brain map and implemented a 4 channel Z-score treatment.

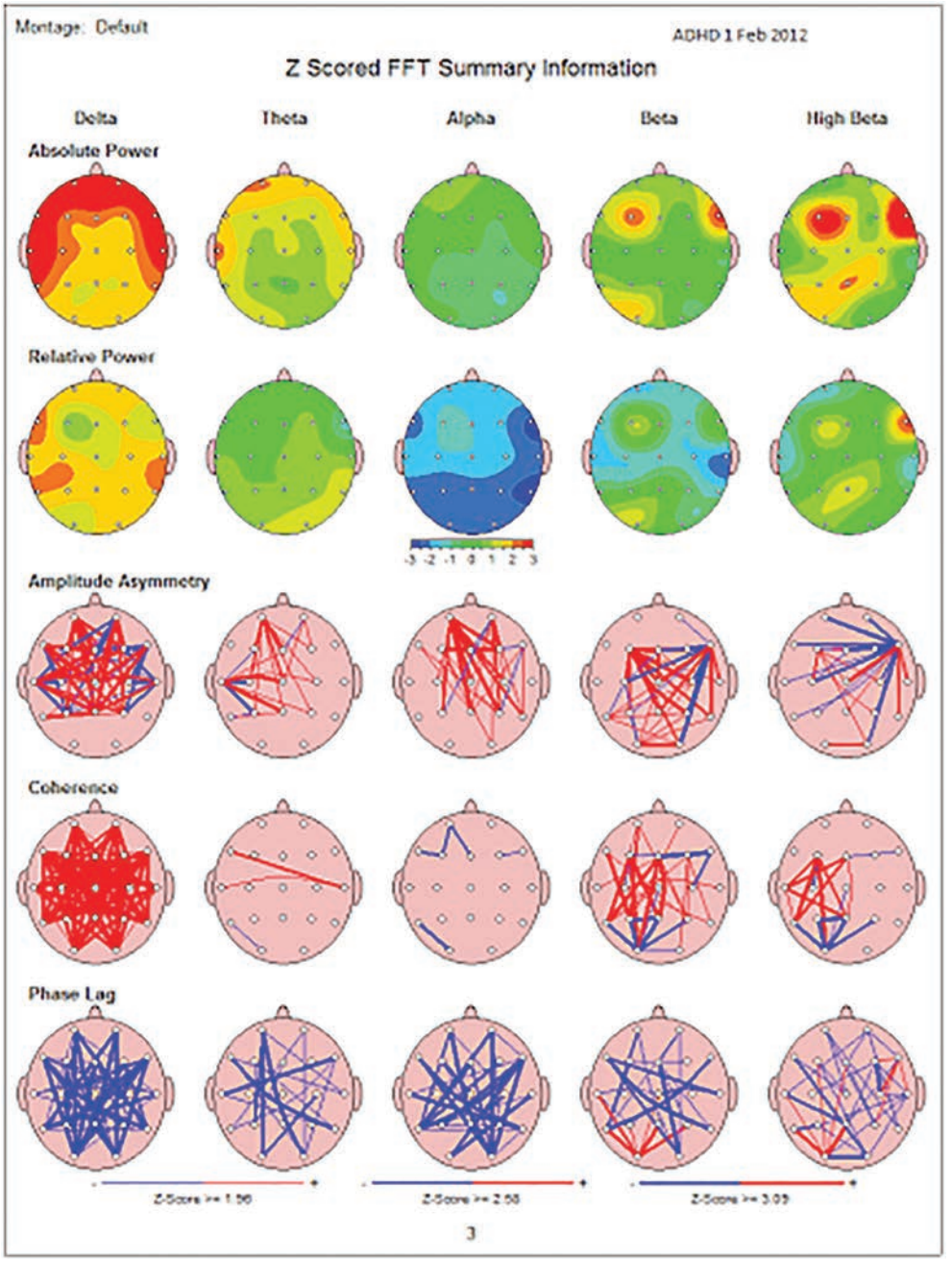

Figure 17.3 ADHD client pre-treatment QEEG brain map February 2012.

The pre-treatment QEEG revealed excessive delta in the pre-frontal and frontal areas. This finding may be influenced by eye movement artifact. However, elevated theta waves were observed in similar frontal regions. The excessive delta and theta waves contributed to difficulty with attention and focus. Excess power was evident in the beta and high beta bands in bilateral frontal regions. Either hyper- or hypo-coherence was discovered in all bands with most deviance in the delta band in hyper-coherence. Abnormal coherence was observed in mixtures of hyper- and hypo-coherence in the beta and high beta bands, predominantly in the left hemisphere. Coherence is a measure of the amount of information

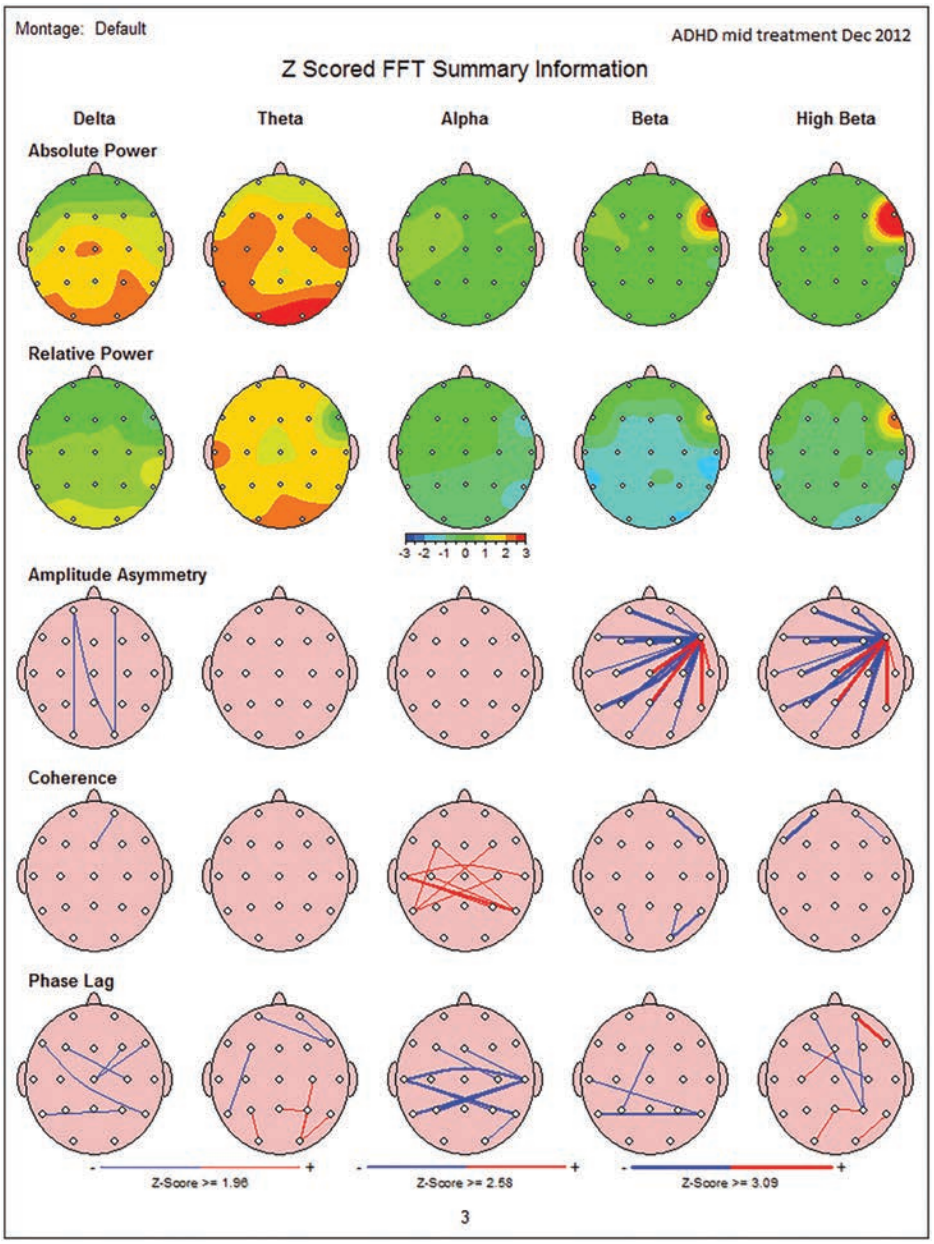

Figure 17.4 ADHD client interim QEEG brain map December 2012.

sharing within functional networks. The disturbances in network sharing in the faster frequencies in the left hemisphere interfered with the client's skilled-based abilities especially with regard to language.

After 40 sessions of 4 channel Z-score training spanning a period of eight months, her ability to focus and sustain attention increased substantially. In addition, she demonstrated increased affective regulation and arousal reduction. Her teachers reported that she was less fidgety and able to remain on task for a longer period of time. Her grades in school have improved and she was able to reduce the dosage of her medication.

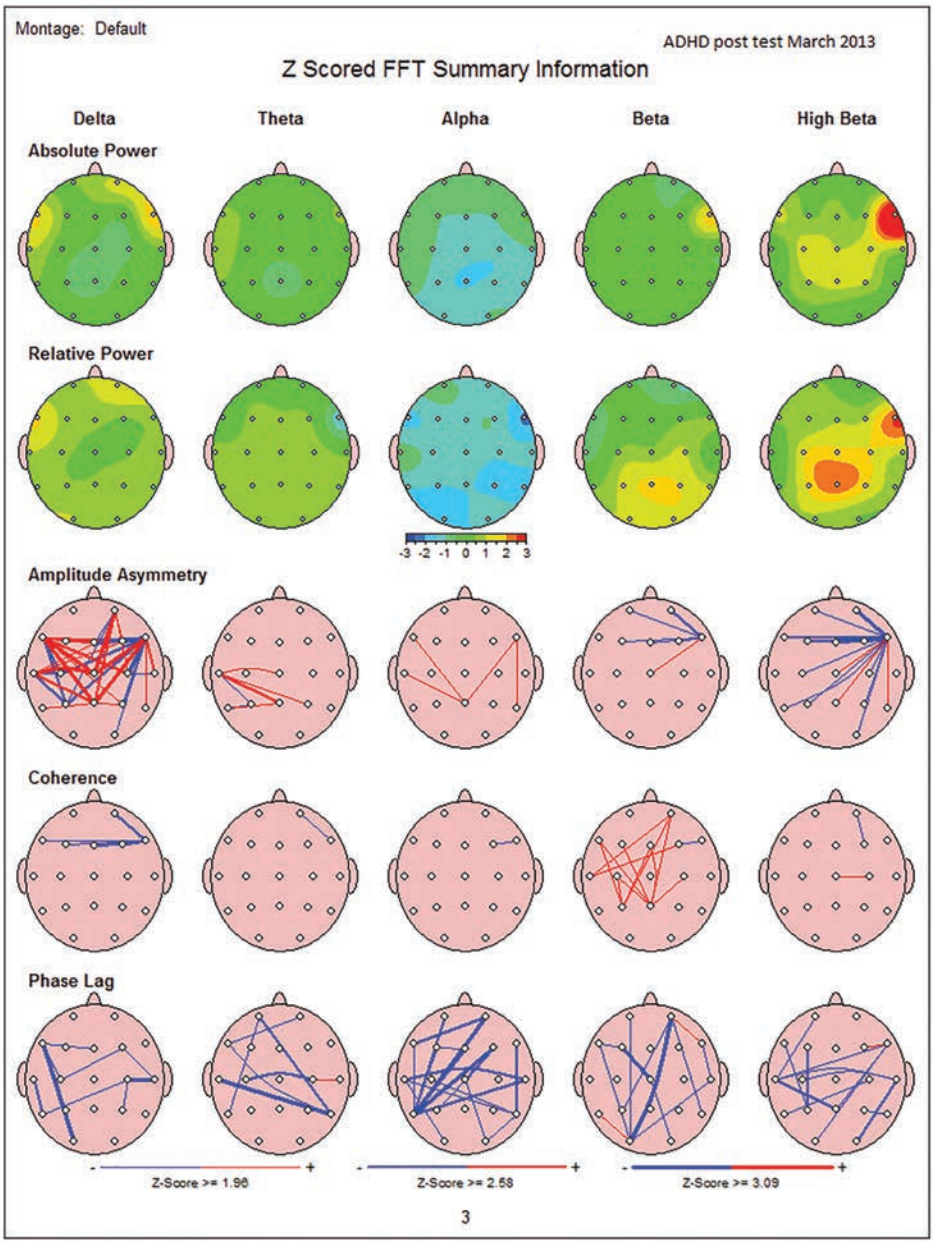

Figure 17.5 A QEEG brain map was done in March 2013.

Occasionally, the client continued to demonstrate episodes of emotional distress.

A post-treatment QEEG was performed to determine the targets for further neurofeedback training.

The QEEG revealed a reduction of excess delta in the frontal and pre-frontal regions. However, excess delta and theta waves were present in the occipital region. Over-activation in F8 in the beta and high beta bands may be the result of muscle artifact.

From the results of the brain map, another 30 sessions of 4 channel Z-score training was applied.

In March 2013, another QEEG was performed in order to observe progress and identify areas of concern. After much discussion with her parents, another 30 sessions spanning a period of three months were carried. At the completion of 70 sessions of 4 channel Z-score training, the client had discontinued her methylphenidate and had demonstrated significant academic improvement. Her attention is now much longer and she has reduced her level of distraction. Her motivation to study has increased and her mother no longer has to nag at her to perform academic tasks. With regard to coherence, all the hyper-coherence in the delta band has disappeared.

With regard to absolute power, there is slight over-activation in the pre-frontal and frontal region in the delta band. In the alpha band, there is insufficient absolute power in the parietal region suggesting that there should be more neurofeedback sessions at the P3 P4 sites to improve understanding and comprehension. It was used to address logical and sequential thinking as well. The high beta band reveal excess absolute power at right inferior frontal region.

In the post-treatment QEEG above, network information sharing has improved in all frequency bands. In addition, the timing of information delivery within function networks has improved substantially.

Case Study 6: Autism

This autistic boy was diagnosed with Autism at the age of four by his pediatrician. He was very delayed in productive language despite two years of speech therapy. At six years old, he was not capable of conversation but could only label objects. His ability to understand instruction was also very poor.

After attending seven sessions of Z-score neurofeedback training, he began to speak in four-word sentences. He became capable of having short conversations with his elder brother. He was able to recall and describe where he had been the previous day. In addition, he was able to articulate his desires for the following day.

The client began treatment in the first week of October 2013. He was hyper-kinetic during application of the electro-cap. It was determined that a QEEG was not possible under the circumstances. As a result, a 4 channel Z-score training at T3 T4/ C3 C4 was implemented for five sessions. Subsequently, the electrode placements were changed to T3 T4/ F7 F8 to address speech issues. Finally, a 19 channel Z-score training of all indices was utilized for 10 sessions.

This autistic boy's QEEG after 20 sessions of 4 and 19 channel Z-score.

In absolute power, there is slight over-activation at F7 and F8 which seems to suggest that more sessions are required to further improve his productive speech and prosody. In the alpha band, there is slight under-activation in the parietal region which implies that this autistic boy still requires more neurofeedback sessions to enhance his level of understanding and comprehension and spatial awareness.

In coherence, there is some hyper-coherence among T3 T4 T5 T6 O1 and O2. It indicates that the affected networks are locked in with each other, thus preventing optimal communication between functional areas. More training was recommended to reduce this hyper-coherence.

Despite the non-optimal QEEG, this autistic boy is now speaking in full sentences and beginning to have conversations with his parents and his peers at school. He is exhibiting a high level of curiosity and has deepened his understanding and comprehension of social interaction. His awareness of his environment and his ability to navigate physical space has improved such that he does not collide with objects in his surroundings.

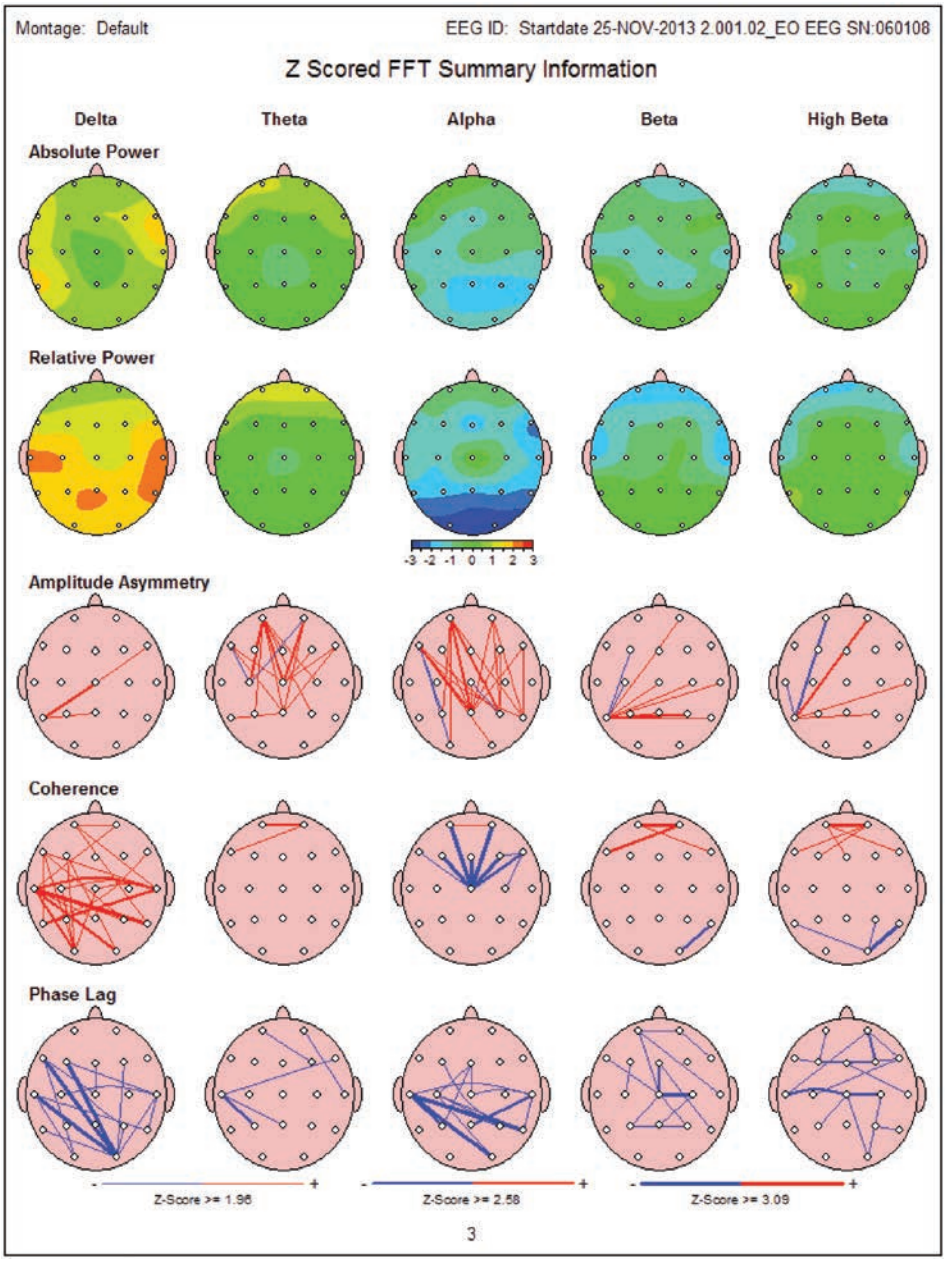

Figure 17.6 Autistic boy's QEEG (post-treatment).

Conclusion

The above case studies demonstrate the effectiveness of Z-score neurofeedback training.

The pre/post QEEGs demonstrated the normalization of outlier Z-scores. More importantly, clients have revealed symptom reduction. This kind of change truly reflects what one paper commented, that Z-score neurofeedback training "is capable of inducing brain changes that are specific and profound, particularly with regard to whole-brain activation and connectivity."

Dr. Collura's excellent scientific paper, "Toward a Coherent View of Brain Connectivity," which was published in the *Journal of Neurotherapy* (2008), suggests that training to the norm or average like what we do in Z-score training is the most logical and intuitive approach to Neurofeedback training or connectivity measures. In this paper, he writes,

> When Z-scores are used for EEG training, a variety of targeting options are available. The most obvious is to train toward the norm or average range in which the protocol is designed to guide the trainee into the normal range. There are various options available when using this approach including the number of z scores available and the type of reinforcement feedback.
>
> *(Collura, 2008, p. 108)*

With the advent of BrainAvatar and sLORETA, we are entering into a more exciting phase in the evolution of neurofeedback both in the assessment and training protocols. These developments will herald an exponential and accelerated body of knowledge with regard to symptoms of diseases and how to effectively treat them with real-time images as featured in the BrainAvatar software. On its website, BrainMaster Technologies Inc. has this to say about BrainAvatar:

> It provides a new standard of excellence and will become the new standard for comparison for the future of the field. It combines all existing BrainMaster capabilities with new features incorporating quantitative EEG (QEEG), peripheral modalities, and integrating assessment with training in a seamless system.

In *NeuroConnections*, Gracefire and Durgin (2012, p. 30) reiterate the power of BrainAvatar in the following words:

> For the first time, practitioners and researchers could observe a three-dimensional display of the current source density in specified areas of the brain in particular frequency ranges in real time. Not only is the activity observable, but it can be utilized as the basis of a feedback paradigm that provides information to the brain, effecting responses in the targeted area. In essence, the BrainAvatar software is rewarding the client when targeted regions of the brain increase or decrease activity in chosen frequency bands.

The technology behind BrainAvatar allows it to measure in real time actual brain electrical activity, whereas other imaging techniques offer only structural or metabolic images. In turn, the system "has significant new value for neurology, psychiatry, mental health assessment and treatment, consumer research, sports, art, peak performance and optimal functioning."

Dr. Collura foresees BrainAvatar in his own visionary words: "We see this invention opening new markets and uses, and changing the face of mental health care due to its extraordinary speed and accuracy, economy and potential importance (Collura, 2012b). A comprehensive description of BrainAvatar can be found in *NeuroConnections* in the Summer 2012 issue where Dr. Collura features BrainAvatar in an article entitled, "BrainAvatar, Integrated Brain Imaging, Neurofeedback and Reference Database System" (2012a).

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