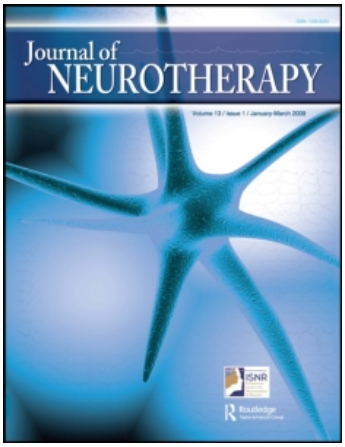

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EEG Biofeedback Case Studies Using Live Z-Score Training and a Normative Database

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ABSTRACT. This article summarizes clinical results using a neurofeedback approach that has been developed over the last several years and is seeing increasing clinical use. All participants used a form of live Z-score training (LZT) that produces sound and video feedback, based on a computation using a normative database to produce multiple targets. The client receives simple feedback that reflects a complex set of relationships between amplitude and connectivity metrics. Changes in the EEG are readily seen that conform to the reinforcement parameters being used in relation to the live Z-scores. In addition, over multiple sessions, QEEG data are seen to change significantly, generally on a path toward overall remediation. In this series of case studies LZT is seen to effectively address EEG abnormalities in a structured fashion and to facilitate normalization of the EEG. In individual cases, specific changes are observed, related to the initial conditions, and the brain's ability to respond with appropriate changes. Overall, LZT is found to be a relatively efficient form of neurofeedback that can be demonstrated to be effective in a variety of clinical scenarios.

KEYWORDS. Biofeedback, live Z-score training, multivariate proportional training, neurofeedback, normative database, QEEG

INTRODUCTION

This article discusses the technical background, and initial clinical results obtained, in an implementation of live Z-score based training (LZT) in an EEG biofeedback system. This approach makes it possible to compute, view, and process normative Z-scores in real time as a fundamental element of EEG biofeedback. Although employing

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Dr. Collura has a financial interest in BrainMaster Technologies, Inc. Certain of the methods described here are patent pending in the United States, Canada, and Europe. We acknowledge the following for their contributions to the case studies in this article: Doerte Klein, PhD; Penijean Rutter, MA; Nancy Wigton, MA; Harry Kerasidis, MD; Charles R. Stark, MD; and Jonathan Walker, MD.

the same type of database as conventional QEEG postprocessing software, LZT software is configured to produce results in real time, suiting it to live assessment and training, rather than solely for analysis and review.

The Z-scores described here are based on a published database and computed using the same software code that exists in the analysis software, when used in "dynamic JTFA" (joint time-frequency analysis) mode. The database includes more than 600 people, ages 2 to 82. The system computes real-time Z-scores using joint time-frequency analysis rather than using the Fast Fourier Transform, which is more commonly used for obtaining postprocessed results. As a result, Z-scores are available instantaneously, without windowing delays, and can be used to provide real-time information.

Initial LZT implementations have used a single Z-score, or a small number of Z-scores, for example, "all coherences," to develop the feedback. In our work, we have come to use generally all available Z-scores in the training, providing an effective boundary around the EEG activity, within which the trainee learns to put their EEG.

All of the cases described here use a specific form of Z-score training that has evolved over several years (Collura, 2008a, 2008b, 2009; Collura, Thatcher, Smith, Lambos, & Stark, 2009). Using this method, up to 248 simultaneous Z-scores are trained at once, using a single metric that reflects the instantaneous state of all of the Z-scores. The method makes it possible to target particular Z-scores for normalization, while avoiding overtraining "outliers" and while also giving the brain sufficient freedom to choose a path of self-regulation that is not limited to "training to the norm."

METHODS

The concept of using Z-scores to provide biofeedback in real time was proposed by Thatcher (1998, 1999, 2004). Collura and Thatcher (2006) discussed details and implications of a practical design approach. The first reported implementation with clinical results were reported by DuRousseau (2007), Smith (2008), Stark (2008), Wigton (2008), and Collura et al. (2009). These reports included six case studies with documented QEEG and clinical benefits, and employed the Lifespan Database reported by Thatcher (1998) as a means of computing Z-scores in real time. Based on these scores, feedback variables were computed and reflected to the user in the form of sounds and graphic feedback of the type normally used for conventional neurofeedback. Since these reports were published, a number of clinicians have adopted the use of four channels of what we now call LZT in their practices. This article compiles a set of case studies that were submitted upon request, as a means for disseminating clinical findings, as well as psychometric and QEEG data that are available. All of the cases in this article used the same approach to LZT training, which is described in more detail next. This article also discusses possible relationships between the specific training algorithms used, and the EEG changes that were observed.

Figure 1 shows the Live Z-score Text display panel that is used by the practitioner. All 248 Z-scores are displayed for the four-channel montage. The display updates continually, and the color of the text indicates whether the Z-score is currently within or outside of the standard boundaries of 1.0, 1.5, and 2.0 standard deviations. Clinicians learn to watch this screen, to quickly identify deviant scores, and to watch for patterns in time and space, as the brain adjusts to the training parameters being presented. The color coding rules for this text display are not adjustable and do not depend on the training criteria. They are therefore a consistent representation of the client's brain state; changes in this screen reflect objective changes in the EEG, and this screen can be relied upon to give a dependable "reading" of the client's brain. The screen becomes, in a sense, a navigational panel that guides the assessment and treatment in real time. This approach compresses the usual hours, days, or weeks required to get a quantitative EEG assessment into a fraction of a second and performs the assessment continually. The difference between watching live Z-scores and reading a conventional QEEG report is similar to

FIGURE 1. Live Z-score text display (four channels = 248 Z-scores). *Note.* Z-scores are colored to show when they are above normal range (yellow, orange, red) or below normal range (green, turquoise, blue).

SITES: O1 Pz (EO)	Abs	Rel	Rat/T	Rat/A	Rat/B	Rat/G
Delta (1.0-4.0)	0.6	0.1	-0.4	0.4	0.3	0.5
Theta (4.0-8.0)	1.0	0.7		0.8	0.6	0.8
Alpha (8.0-12.5)	-0.0	-0.6			-0.2	0.0
Beta (12.5-25.5)	0.2	-0.3				0.0
Beta 1 (12.0-15.5)	-0.1	-0.5				
Beta 2 (15.0-18.0)	0.3	-0.1				
Beta 3 (18.0-25.5)	0.8	0.4				
Gamma (25.5-30.5)	0.2	-0.2				
Delta (1.0-4.0)	1.0	0.3	-0.1	0.5	0.2	0.6
Theta (4.0-8.0)	1.1	0.4		0.6	0.3	0.7
Alpha (8.0-12.5)	0.2	-0.6			-0.3	0.0
Beta (12.5-25.5)	0.7	-0.1				0.4
Beta 1 (12.0-15.5)	0.2	-0.5				
Beta 2 (15.0-18.0)	0.8	-0.0				
Beta 3 (18.0-25.5)	0.9	0.2				
Gamma (25.5-30.5)	0.5	-0.2				

SITES: T4 P4 (EO)	Abs	Rel	Rat/T	Rat/A	Rat/B	Rat/G
Delta (1.0-4.0)	1.7	0.2	-0.2	0.5	0.2	0.4
Theta (4.0-8.0)	1.8	0.5		0.8	0.4	0.6
Alpha (8.0-12.5)	0.8	-0.6			-0.4	-0.1
Beta (12.5-25.5)	1.3	-0.1				0.3
Beta 1 (12.0-15.5)	0.9	-0.4				
Beta 2 (15.0-18.0)	1.4	-0.1				
Beta 3 (18.0-25.5)	1.7	0.3				
Gamma (25.5-30.5)	1.1	-0.2				
Delta (1.0-4.0)	1.3	0.4	0.0	0.7	0.4	0.8
Theta (4.0-8.0)	1.3	0.4		0.8	0.4	0.8
Alpha (8.0-12.5)	0.2	-0.8			-0.4	-0.0
Beta (12.5-25.5)	0.8	-0.2				0.4
Beta 1 (12.0-15.5)	0.2	-0.7				
Beta 2 (15.0-18.0)	0.9	-0.1				
Beta 3 (18.0-25.5)	1.1	0.1				
Gamma (25.5-30.5)	0.7	-0.3				

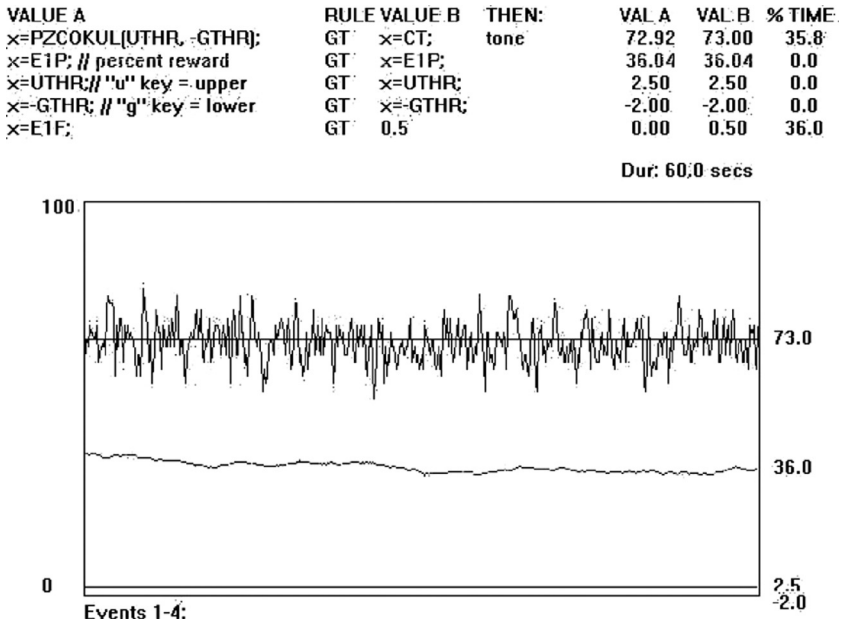
	O1-Pz ASY	COH	PHA	O1-T4 ASY	COH	PHA	O1-P4 ASY	COH	PHA	Pz-T4 ASY	COH	PHA	Pz-P4 ASY	COH	PHA	T4-P4 ASY	COH	PHA
Delta (1.0-4.0)	-0.4	-0.5	0.4	-0.9	0.4	-0.3	-0.8	-0.1	0.1	-0.6	-0.0	0.1	-0.4	-1.7	1.4	0.4	0.1	0.1
Theta (4.0-8.0)	-0.1	0.5	-0.2	-0.7	1.0	-0.5	-0.3	0.6	-0.3	-0.7	1.1	-0.5	-0.3	0.4	-0.1	0.7	1.1	-0.6
Alpha (8.0-12.5)	-0.3	0.3	-0.2	-0.8	-0.3	-0.1	-0.2	-0.0	-0.0	-0.6	-0.3	-0.0	-0.0	-0.1	0.1	0.7	0.2	-0.2
Beta (12.5-25.5)	-0.5	1.4	-0.4	-0.9	1.0	-0.4	-0.6	1.5	-0.4	-0.6	0.8	-0.3	-0.2	0.7	-0.2	0.5	0.5	-0.2
Beta 1 (12.0-15.5)	-0.3	0.2	-0.1	-0.8	-0.0	-0.0	-0.3	0.5	-0.3	-0.6	-0.3	0.0	-0.1	-0.0	-0.1	0.6	-0.3	0.1
Beta 2 (15.0-18.0)	-0.5	0.8	-0.4	-0.9	0.2	-0.4	-0.5	0.7	-0.4	-0.5	0.2	-0.3	-0.2	0.4	-0.2	0.4	0.2	-0.1
Beta 3 (18.0-25.5)	-0.2	1.0	-0.6	-0.8	0.6	-0.6	-0.3	1.1	-0.7	-0.7	0.5	-0.4	-0.2	0.5	-0.4	0.6	0.3	-0.2
Gamma (25.5-30.5)	-0.3	1.0	-0.4	-0.7	0.3	-0.3	-0.4	1.1	-0.5	-0.5	0.2	-0.2	-0.2	0.4	-0.2	0.5	0.2	-0.2

the difference between watching a baseball game or a golf match compared with reading the statistics after the fact. They both give a valuable indication of the condition and state of the subject, but the live representation allows the practitioner to understand how the numbers got to be what they are, in terms that are dynamic and neurophysiologically meaningful.

While observing the LZT Text display, clinicians set up reward training by specifying three key parameters: the upper and lower bounds of the Z-score "target window" and the percentage of Z-scores that must be within these bounds to achieve a reward. The use of the percentage of Z-scores is a nonobvious yet critical step and has profound impact on the training. Its value has been found through repeated clinical treatment sessions and by observing the LZT Text display during the training process.

Figure 2 shows two additional panels of the training screen. The upper area shows

FIGURE 2. Live Z-score display panels used to control feedback.



the current value of the "PercentZOK" value, which is the percentage of Z-scores meeting the training criteria at the current moment. In addition, the percentage of time that the trainee meets the conditions, being the "percent reward" is also shown. The upper and lower Z-score targets are then shown. The lower area shows the progress of the training, as the PercentZOK variable is being monitored and trained. There is a threshold that it must meet, to get a reward, and there is also the percentage of time that this is being met, shown in a trend graph. The clinician watches all of these values closely and watches the trend graph throughout training. This gives the clinician control of the variables that determine how the feedback is produced.

This method employs a Z-score "target" that is expressed in standard deviations (e.g., −1.5 to 2.0 *SD*s) and produces rewards when a specified percentage of all Z-scores meet the criterion. It does not require all Z-scores to be within the target window. The percentage of Z-scores achieved thus becomes a "proportional" feedback variable, rather than a simple "on/off" feedback signal.

One might consider widening the target window to accommodate all Z-scores. However, this was observed in early studies to provide the brain with too much freedom in which to operate. For example, using a wide-enough window to accommodate highly deviant amplitudes would allow other parameters to move from a normal to an abnormal range, while the EEG continued to meet the overall training condition. This motivated the approach that allows some Z-scores to remain outside the target range yet effectively be ignored.

Figure 3 shows the important relationship between target size and percentage of Z-scores required, in various training scenarios. This concept was not obvious when work began, and it is not necessarily obvious to other developers of real-time Z-score systems. Naively, one might think that by allowing a subset of Z-scores to provide the feedback, it is no different than simply ignoring some set of scores, or setting an upper range where

FIGURE 3. Relationship between size of LZT targets, and the use of "Percent ZOK" to establish reward criteria. *Note.* Within this model, clinicians can choose which aspects of training to emphasize, and which to vary.

Z-scores are allowed to go. But neither of these methods produces the same effect. When one overtly ignores Z-scores, then the practitioner has decided what is important and what is not. If an upper band of Z-scores is rewarded, this would produce a "vortex," or attractor, that would pull certain scores into the abnormal range.

By specifically allowing a percentage of any of the Z-scores to be out of the target range, the brain is allowed to decide how it meets the strategy of normalization. Extreme outliers are effectively ignored, but which scores they are may change from moment to moment. Finally, by selecting the target size and position, it is possible to "comb" through the tangle of Z-scores, and give the brain information relating to a certain boundary of its function, and allow it to learn from different regions of its function.

Different practitioners give different emphasis to the use of this range of reward strategies. One clinician (NW) emphasizes working at the low end of the reward range, using 25% to 40% feedback rates. Other practitioners work at higher levels of reward, up to and above 90% reward. Generally, it is found that adjusting these values during the session is valuable, and provides important flexibility to the training.

Figure 4 shows the LZT review and selection screen. This is used to select Z-scores for graphical analysis and to search for deviant Z-scores to include on the report. By specifying the condition for Z-scores to be viewed, the system then selects those that have met that condition and allows them to be viewed and graphed. This is useful when checking Z-scores after a session, to determine how they have changed. As in the training display panel, patterns in the deviant Z-scores are visible evident, so that combinations of amplitude or connectivity scores that tend to "go out" together, or show definite patterns, are readily recognized.

Figure 5 shows a typical graphical summary of progress. This is the change in the most deviant Z-scores during a 40-min demonstration session. The change in Z-scores within the session is clearly evident. This graph is extremely useful in seeing the brain's progress during a session and between

FIGURE 4. Live Z-score selection screen, used for review of session data.

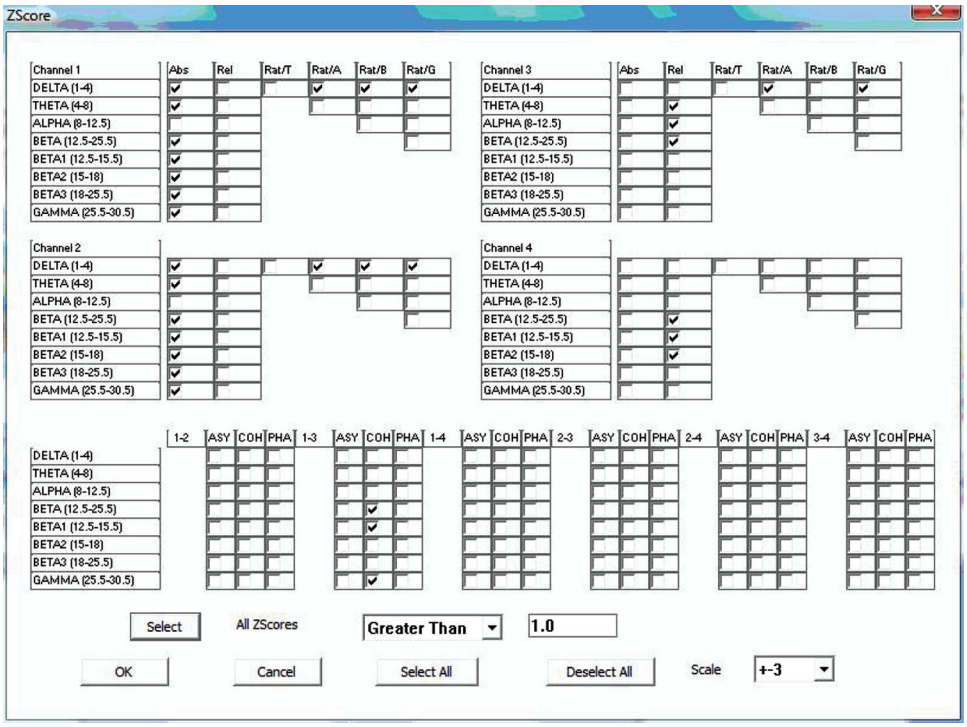
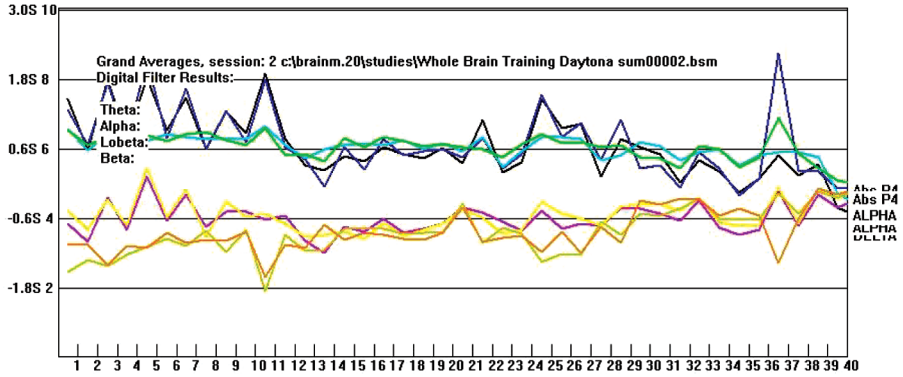


FIGURE 5. Live Z-score changes plotted across 40 min, one session with a naïve trainee.

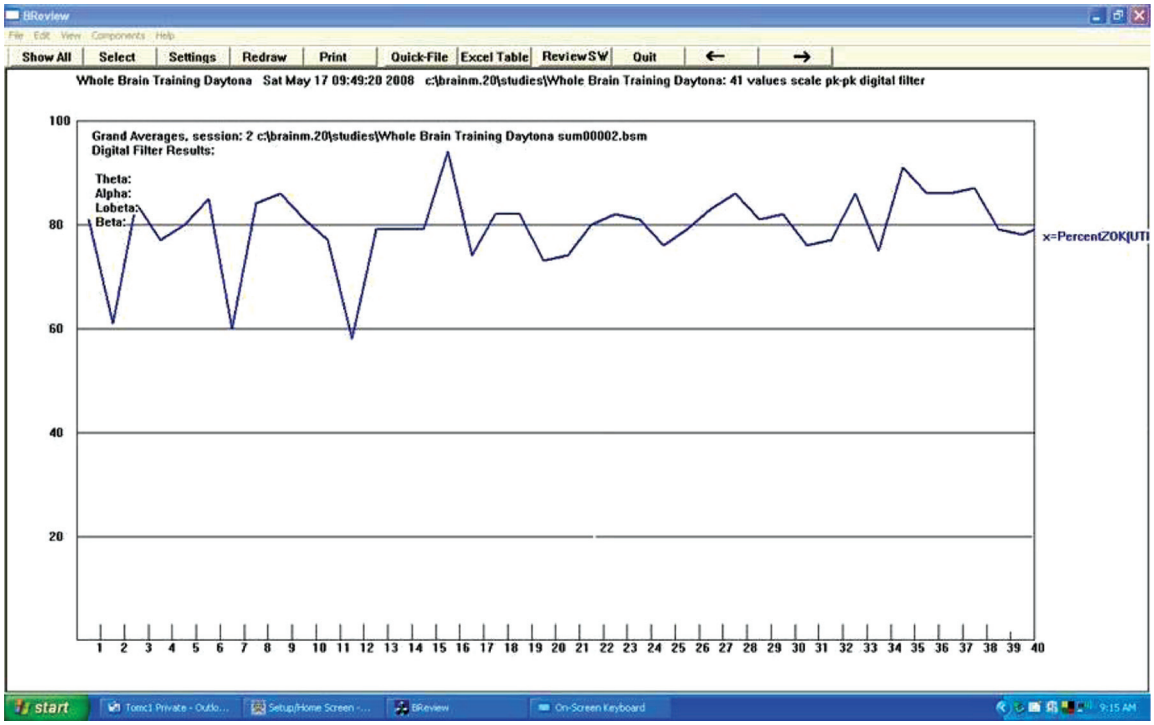


sessions, by watching which scores move in various directions.

Figure 6 shows the progress of the Multivariate Proportion value during the session. This is an important aspect, as it shows that the trainee has "acquired the task," in operant conditioning terms, and is able to improve their performance. This improvement proves that learning has occurred, and it is an important aspect of LZT training.

This approach allows the brain to develop its own strategy, as the rewards are achieved when a criterion is reached, and the brain is able to compute its own "cost function" to optimize rewards. In some of the studies shown here, certain Z-scores remained outside the normal range during training, reflecting the fact that the brain was adopting specific mechanisms to cope with the reward strategy. This amounts to the brain

FIGURE 6. Progress of multivariate proportion (% of Z-scores meeting criteria) plotted across 40 min, one session with a naïve trainee.



discovering dynamics that allow it to reduce the overall index of abnormality while allowing certain features to remain outside normal, and to function as coping or compensatory mechanisms. This is significant, as it avoids the pitfall of "training to an outlier" that may result when all Z-scores are required to meet the training targets.

RESULTS

Practitioners who adopted the LZT approach and had been instructed on its use were invited to submit case studies that illustrated their experience with the technique. Not all cases were submitted, so this article presents selected successful cases that were submitted. The details for each case, as well as clinical, behavioral, psychometric, and QEEG changes, when available, are summarized in Table 2.

Application of Training Protocol

All of the reported cases used a form of what we refer to as "multivariate composite targeting," in which a number of Z-score targets are continually assessed in a particular way, and used to produce the feedback. All of the reported cases used this capability in the form of the "Percent ZOK" algorithm in LZT. In all cases, there were individual differences in the precise strategy and control methodology used. The protocol provides sufficient freedom for the clinician to determine the nature and extent of information presented to the brain, relative to the current state of the multiple Z-scores. This is to be distinguished to more simple "training to the mean" that may be assumed to be used, if one is not knowledgeable of the relevant details.

Various practitioners differ in their precise use of the controls and options within the LZT paradigm. Although all practitioners make use of target size and percentage of Z-scores as control variables, the exact process used varies. Some practitioners emphasize adjusting target size and allowing the brain to learn the various levels of task difficulty, whereas others focus on the percentage of Z-scores as the key variable. However, as the values are interrelated, there is always a dynamic interplay in changing one, the other, or both. The LZT approach allows the practitioner to emphasize different aspects of the Z-score training, based on the observed clinical and electrophysiological changes.

Summary of Cases

Details for all cases are presented in the second table. This section summarizes specific results including Z-score statistics, QEEG maps, and relevant psychometric results, which illustrate the clinical and electrophysiological changes which were observed.

Three cases ("S," "C," and "Z") were presented by one clinician (JG), who uniformly

FIGURE 7. Percentage of amplitude Z-scores outside ±1.0 *SD*s for 3 participants "S," "Z," and "C," 10 sessions each.

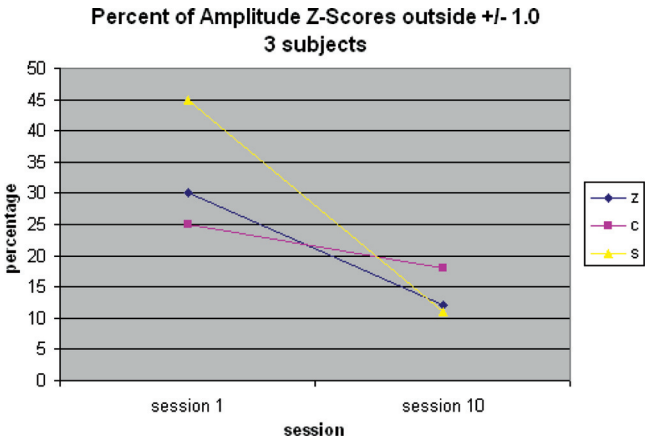
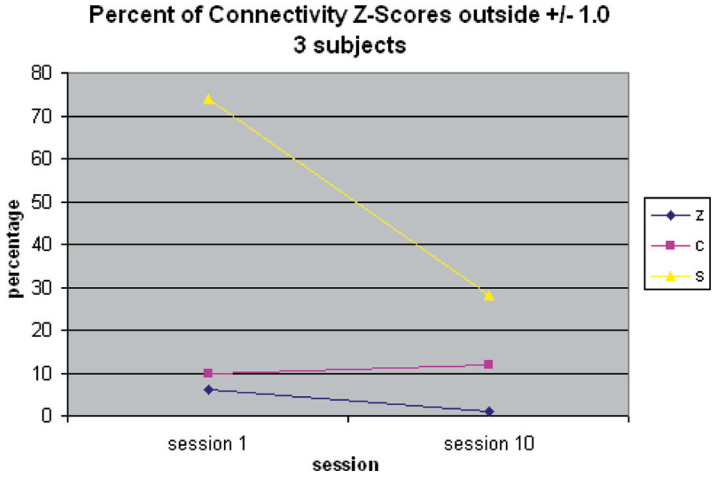


FIGURE 8. Percentage of connectivity Z-scores (asymmetry, coherence, and phase) outside ±1.0 *SD*s, 3 participants, 10 sessions each.



used 10 sessions of four-channel LZT training on each of three patients. Figure 7 summarizes the percentage of amplitude Z-scores (absolute power, relative power, power ratios) that were outside the nominal range of ±1.0 *SD*s. This illustrates the repeatable reduction in deviant Z-scores while revealing some difference between participants. It is interesting that the participants who presented with the most deviant Z-scores on the outset showed the least number of deviant scores after training.

Figure 8 shows the percentage of connectivity Z-scores (coherence, phase, asymmetry) outside the range ±1.0 *SD*s for the same three participants. Although uniform reduction is seen in two participants, an actual increase is seen in one. It is shown later that this reflects a compensatory mechanism, in which the brain evidently allows some scores to become deviant, to achieve greater overall normalization. Note that this phenomenon likely depends on the ability of the training software to allow some scores

FIGURE 9. Number of amplitude Z-scores outside target range as a function of target size, participant "S." *Note.* The number of Z-scores outside the narrow range 1.0 actually rises, whereas the overall distribution pulls strongly within the 1.5 and 2.0 ranges.

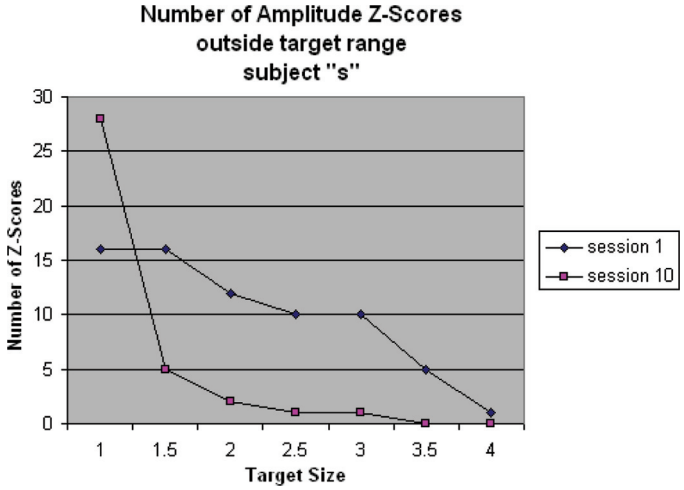


FIGURE 10. Number of connectivity Z-scores outside target range as a function of target size, participant "S." *Note.* Although many scores begin outside the 2.0 and 2.5 *SD* ranges, all Z-scores fall within the range 1.5 *SD* after 10 sessions.

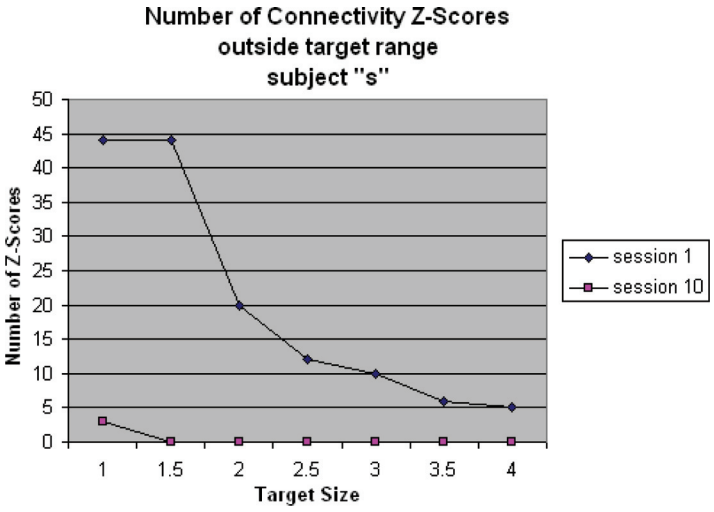
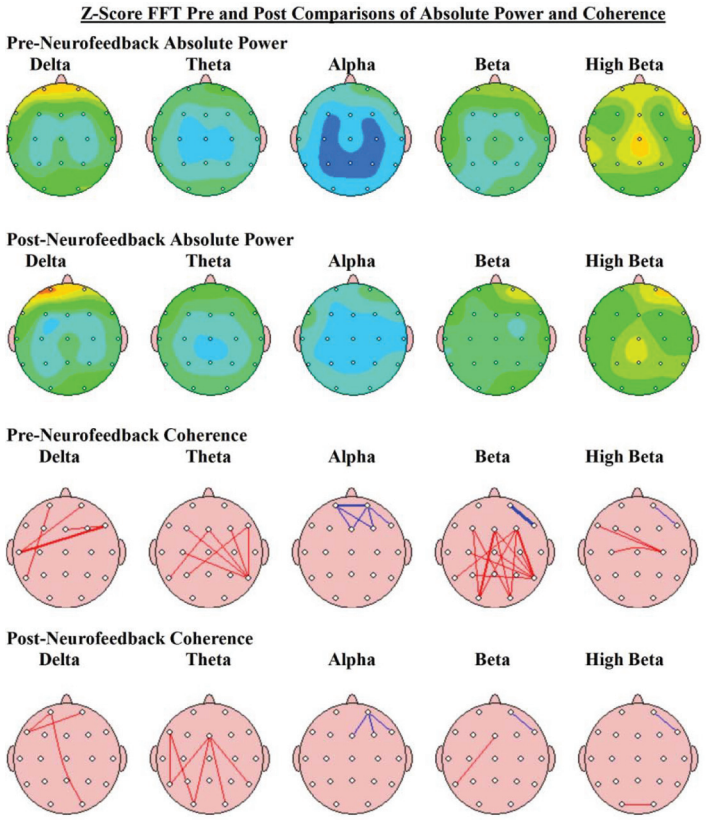


FIGURE 11. Pre- and posttreatment QEEG maps for participant DQ.



to remain outside normal bounds while continuing to reward for training.

Figure 9 shows the number of amplitude Z-scores outside specified target ranges, for one participant. Note that, at the outset, a great many scores are outside even the larger targets of 2.5, 3.0, and larger targets. After training, the number of scores outside of the larger ranges has reduced dramatically. At the same time, the number of scores outside the range ± 1.0 has increased, as a result of "packing" of the scores into the narrower ranges. This reflects the ability of the brain to achieve overall normalization while having room to move at the lower limits of the training targets.

Figure 10 shows the number of connectivity (coherence, phase, asymmetry) Z-scores outside of specified target sizes. The reduction of scores outside the range ± 1.5 is essentially complete, as no Z-scores are found outside this range after the training. This demonstrates the brain's ability to process dozens of Z-scores in a single training paradigm, and effectively normalize all of them, while performing a simple training.

Figure 11 shows pre- and post-QEEG maps for participant "DQ" presented by clinician JT. Improvements are visible in both the power and the coherence maps, after 39 sessions.

FIGURE 12. Pre- and posttreatment maps (26 sessions) for participant TB. *Note.* Top pair: Absolute power maps, Bottom pair: Coherence maps.

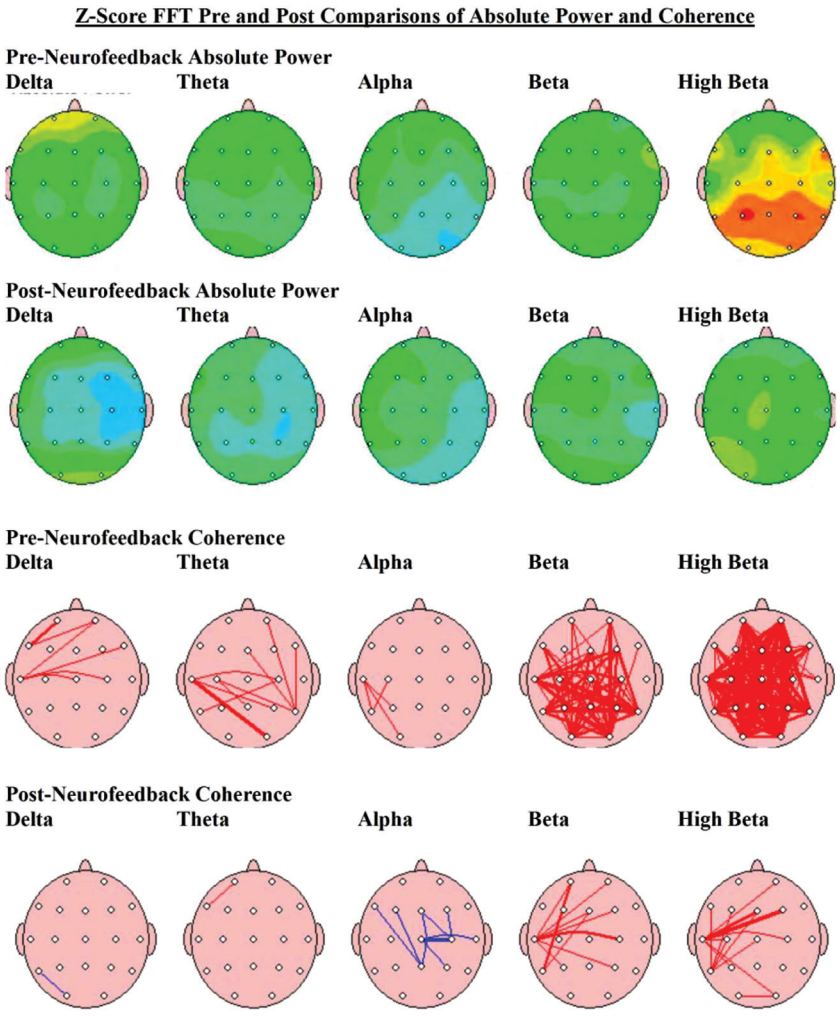


FIGURE 13. Pre- (left) and posttreatment (right) QEEG maps after 20 sessions, patient Norb.

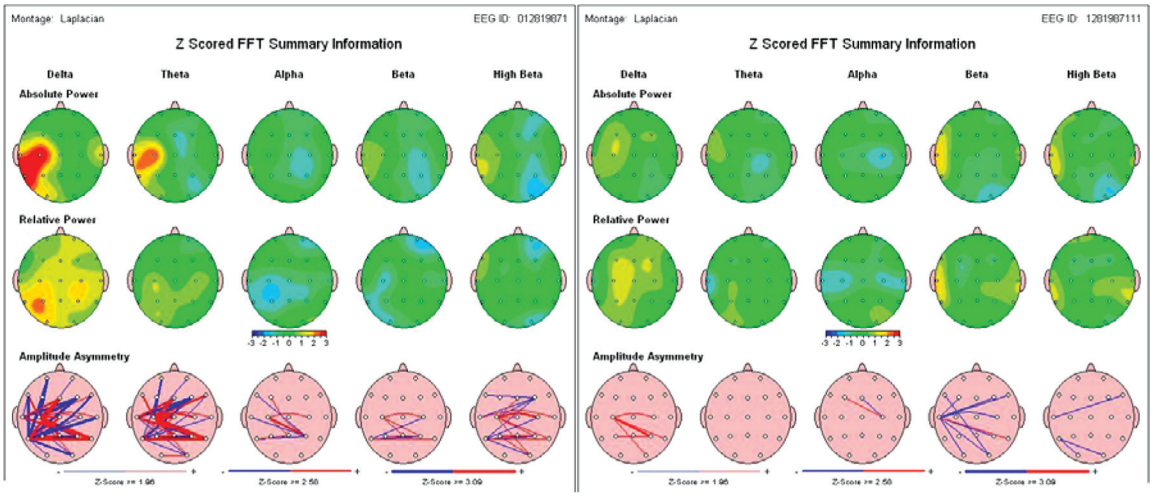


Figure 12 shows pre- and post-QEEG maps from participant "TB" (clinician JT). The normalization of power as well as coherence maps is visibly evident after 26 sessions. It is interesting to note examples of "overshoot" in which one value moves out of normal range, whereas others normalize. For example, a slight excess of right delta and theta appears, whereas the excess of high beta and alpha normalizes. Also, there is a slight alpha hypocoherence that appears, along with the significant normalization of other coherences.

Figure 13 shows pre- and post-QEEG maps, and Figure 14 shows post-QEEG maps after 20 sessions, for participant "Norb" (clinician F8) using a Laplacian derivation. All evident power and asymmetry abnormalities are seen to effectively normalize. Although the pre maps show significant delta and theta excess, and a deficit of high frequencies, the post maps are essentially normal, with only a very slight beta excess on the left, which may be muscle related.

Figure 14 shows IVA + Plus Standard Scales Analysis for "Norb." The Full Scale Response Control Quotient rises from 94 to 101, whereas the Full Scale Attention Quotient rises from 62 to 95.

FIGURE 14. Pre- and posttreatment IVA + Plus, patient Norb, 20 sessions.

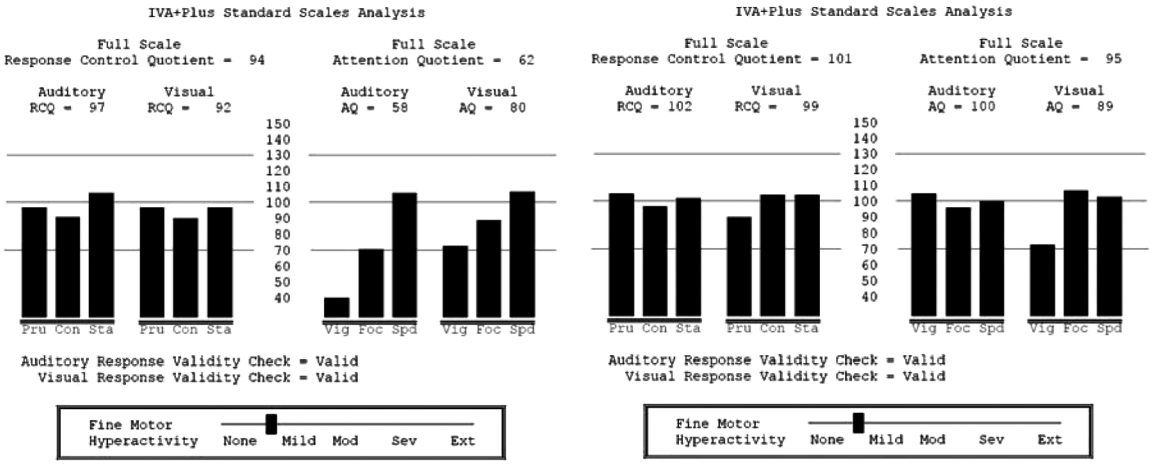


FIGURE 15. Pre- (left) and posttreatment (right) QEEG maps, 25 sessions, patient 44YOM.

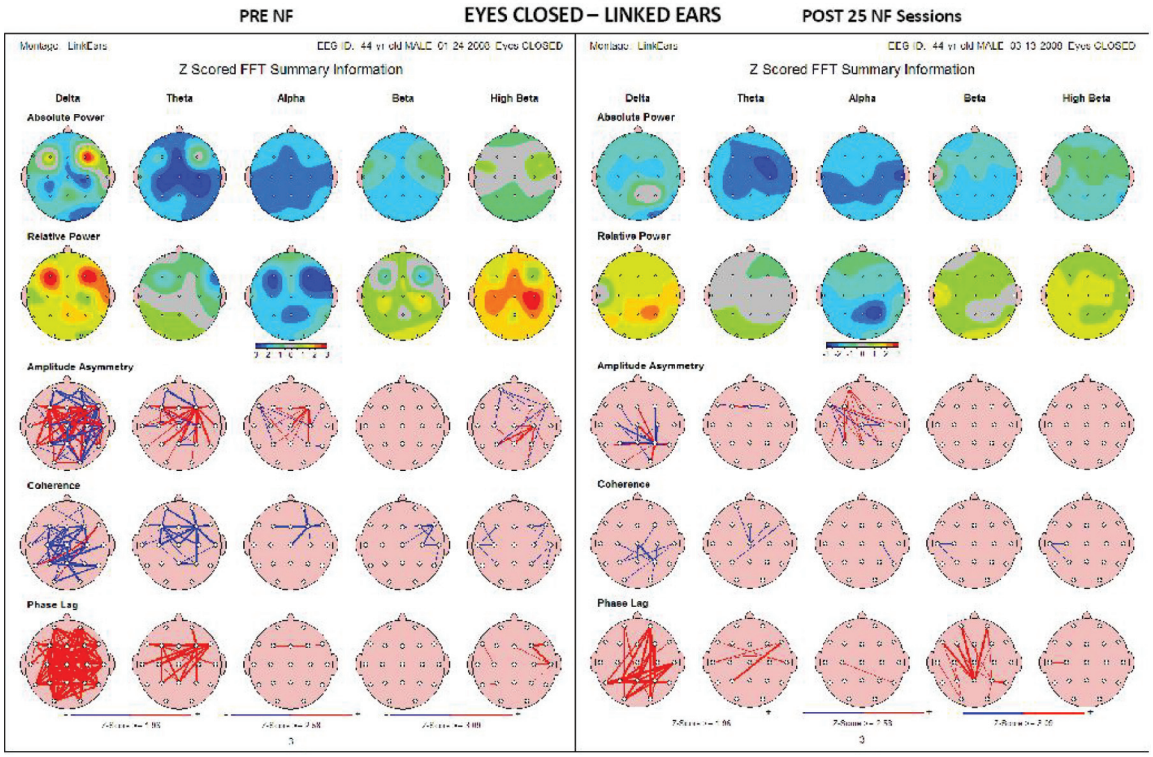


Figure 15 shows pre- and post-QEEG maps for participant "44YOM" (clinician NW), after 25 sessions. Visible trends include a reduction in coherence and phase abnormalities, and some improvement in relative power.

Figure 16 shows IVA + Plus results from participant "44YOM." Full-Scale Response Control Quotient rises from 29 to 94, whereas Full Scale Attention Quotient rises from 0 to 96.

Figure 17 shows the progression of participant "12YOM," clinician PR, with eyes open, after 20 and after 40 sessions. This progression shows definite compensatory mechanisms at work, as the post-20 session maps show interesting adaptations to the training. In absolute power, areas that were deficient in delta are normalized in 20 sessions, whereas surrounding areas exhibit a delta excess. This suggests a global reregulation mechanism wherein surrounding areas adjust their function, as a compensation for the normalization of other areas. Similarly, whereas hypocoherence across frequency bands is seen to remediate, there is a significant hypercoherence in high beta that emerges, again likely as a compensating mechanism. The final condition characterized by overall normalization in the presence of hypercoherent beta, suggests a mechanism involving cortico-cortical binding, as a strategy toward producing the requisite overall normalization.

Figure 18 shows the progression of eyes-closed QEEG maps for the same client as Figure 17. A rather different pattern of normalization is evident, suggesting that the brain adopts a different strategy to keeping itself normalized, depending on whether the eyes are open or closed. In this case, the final QEEG shows essential normalization, along with a phase deficit (phase-locking) in alpha across the head. This suggests a stronger-than-normal thalamocortical binding, in which thalamic activity is controlling cortical rhythms with excessively tight timing. In other words, rather than having several somewhat independent alpha generating processes (e.g., occipital, frontal, temporal), the brain is dominated by a single alpha pacemaker.

FIGURE 16. Pre- (left) and posttreatment (right) IVA Standard Scales Analysis, 25 sessions, subject 44YOM.

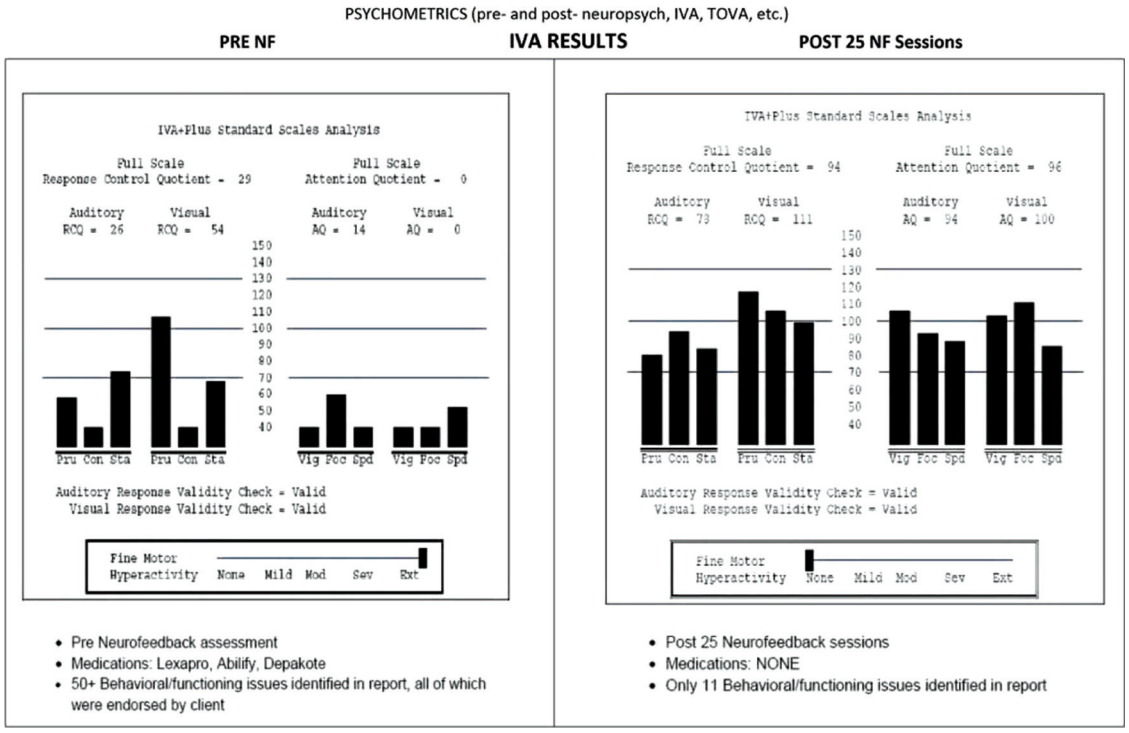


Figure 19 summarizes the progress of participant "12YOM." In our analysis and discussions with clinicians, observed changes in Z-scores may indicate compensating mechanisms in which areas surrounding the original delta excess change their state, as a

FIGURE 17. Overview of client 12YOM progress in Eyes Open condition, after 20 and 40 sessions.

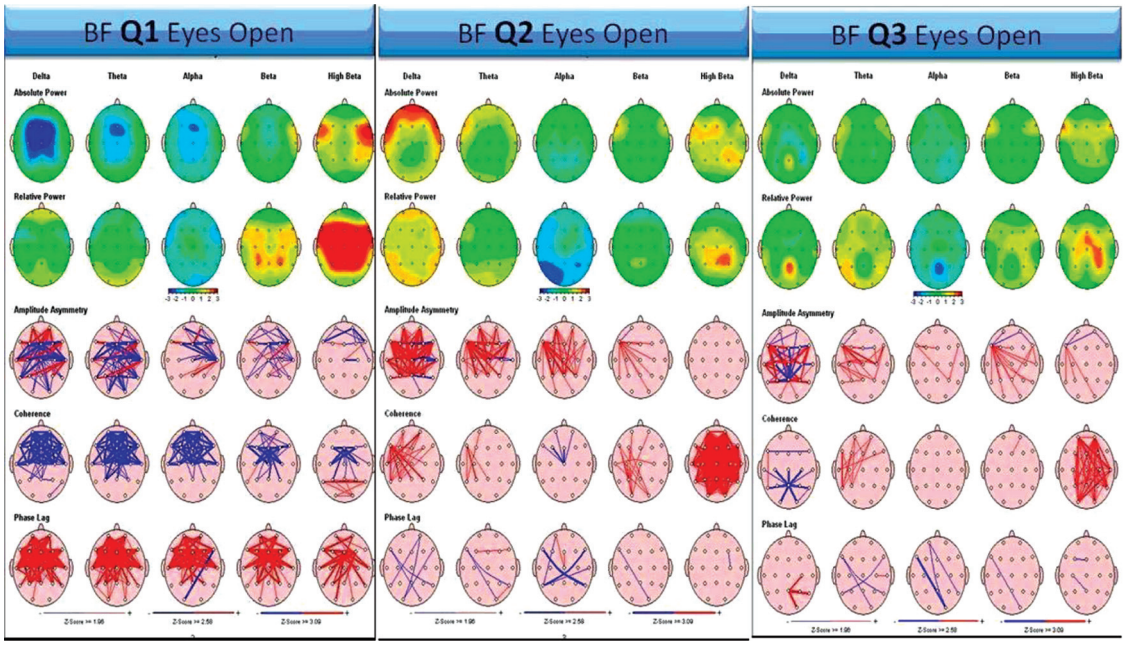
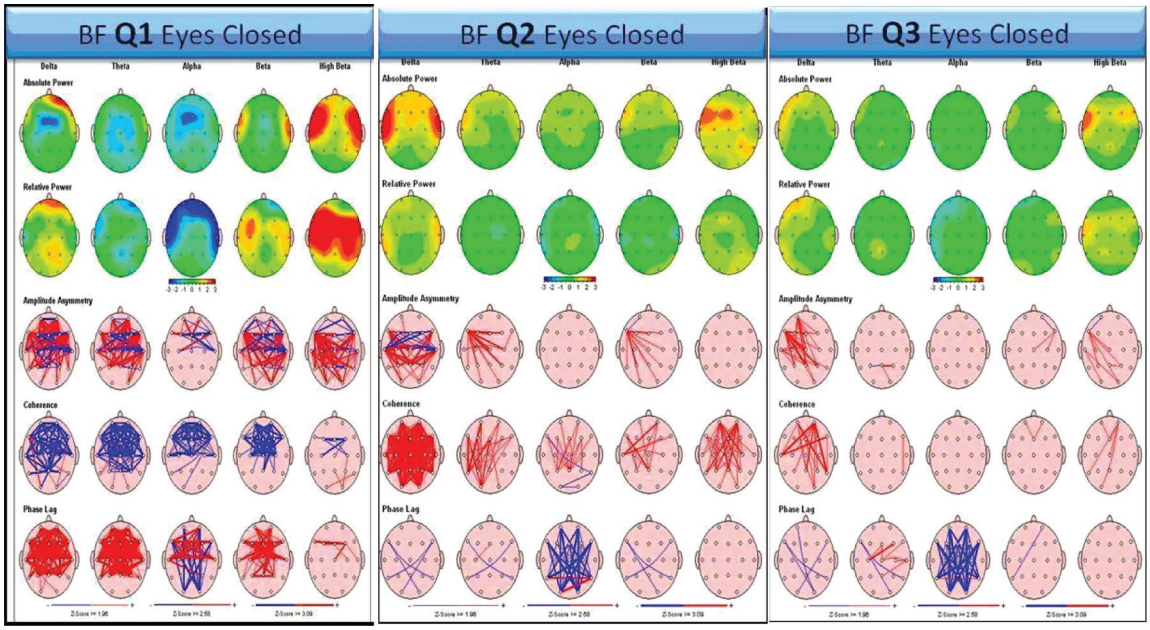


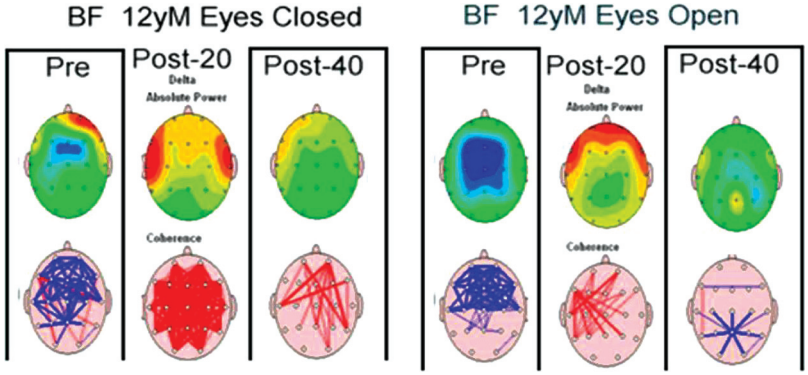
FIGURE 18. Overview of client 12YOM progress in Eyes Closed condition, after 20 and 40 sessions.



way of containing the abnormal areas. When there is a worsening of an EEG deviation, we hypothesize that it may represent a compensatory mechanism. For example, when there is an area with a deficit of delta activity, surrounding areas may exhibit excess delta during the normalization process, even as the previously abnormal areas now become normal. Temporarily, these changes look like a cap or a wrapper around the areas which in fact are normalized in the 20-session maps. So the brain has adopted a strategy to lower its mean scores, by allowing the surrounding areas to provide a containing medium for the abnormal activity, as the brain globally produces higher delta amplitudes. The global nature of the delta is indicated by the newly emerged hypercoherence after 20 sessions.

After 40 sessions, when most all amplitude and connectivity measures are normalized, we are still left with very specific EEG abnormalities that again seem to be coping or compensating mechanisms. As an example, this client had extreme phase synchrony in alpha with eyes closed and extreme beta coherence

FIGURE 19. Summary of changes EC and EO.



with eyes open. We believe that the brain may be setting up its own binding mechanisms, again, to maximize the global normality. In this case, where the remained phase synchrony and coherence abnormalities, it was nonetheless noted that the client experienced significant clinical benefits uniformly from treatment. To quote the clinician,

> Changes in delta absolute power and coherence over the course of the training indicate some interesting possibilities for future research. There may be a mid-training phase that prioritizes allocation of cortical resources for the purpose of reorganizing neural connectivity. Hypercoherence could be a manifestation of increased thalamocortical activity which necessitates a temporary diversion of energetic resources to improve the efficiency of the interactive pathways between the thalamus and the cortex. (Rutter, 2009)

Figure 20 shows pre- and post-QEEG maps from participant SonjaK taken before and after her 16th session, after having had 15 previous weekly sessions (clinician DK). These maps thus document single-session results. The Beta and High Beta power excesses are trained into the normal range. An extreme amount of hypercoherence in delta and theta is reduced during the single session. Specific hypo-phase (phase-locking) in alpha is also slightly reduced.

Figure 21 shows pre- and post-QEEG maps from participant "NW" (clinician JT) after 38 sessions. Remediation of power abnormalities and coherence deficits is visibly evident. An insignificant amount of hypercoherent posterior alpha remains.

Figure 22 shows pre- and post-QEEG maps from participant TA after 20 sessions (clinician CRS). The remediation of coherence in beta and high beta is striking. There is also a visible reduction in theta absolute power, which was targeted using conventional thresholded feedback in addition to the LZT feedback, in a combined protocol.

FIGURE 20. Pre- and posttreatment maps before and after one session (Session 16) for SonjaK.

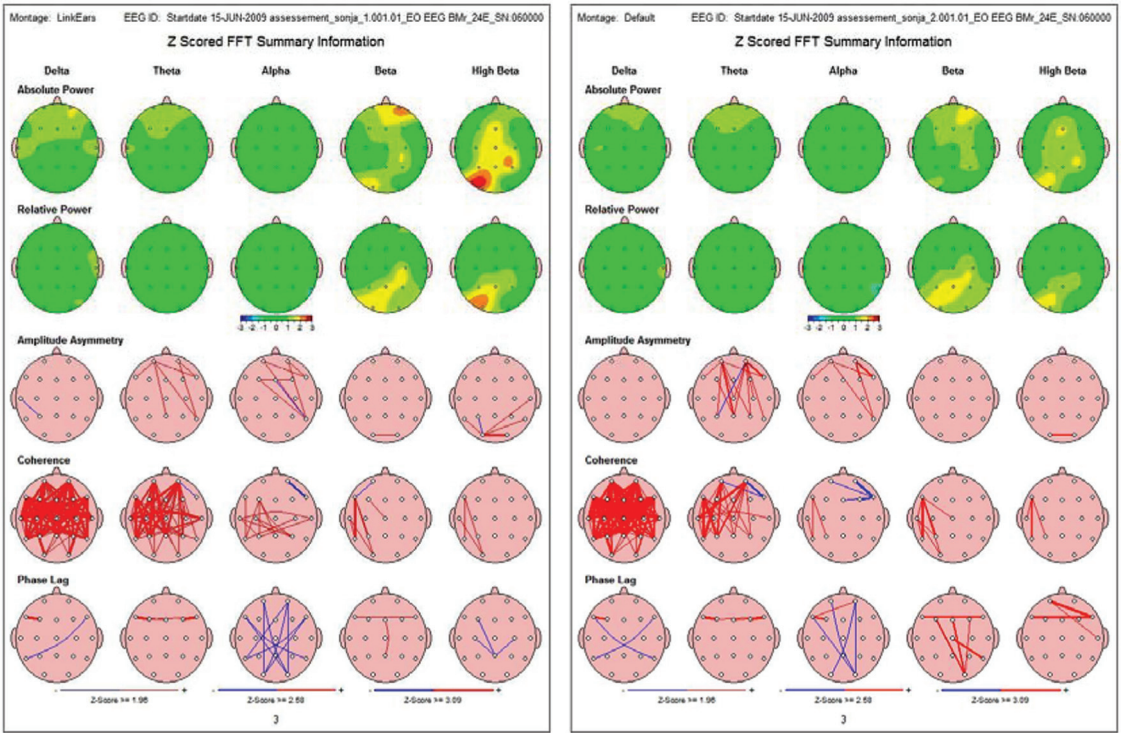
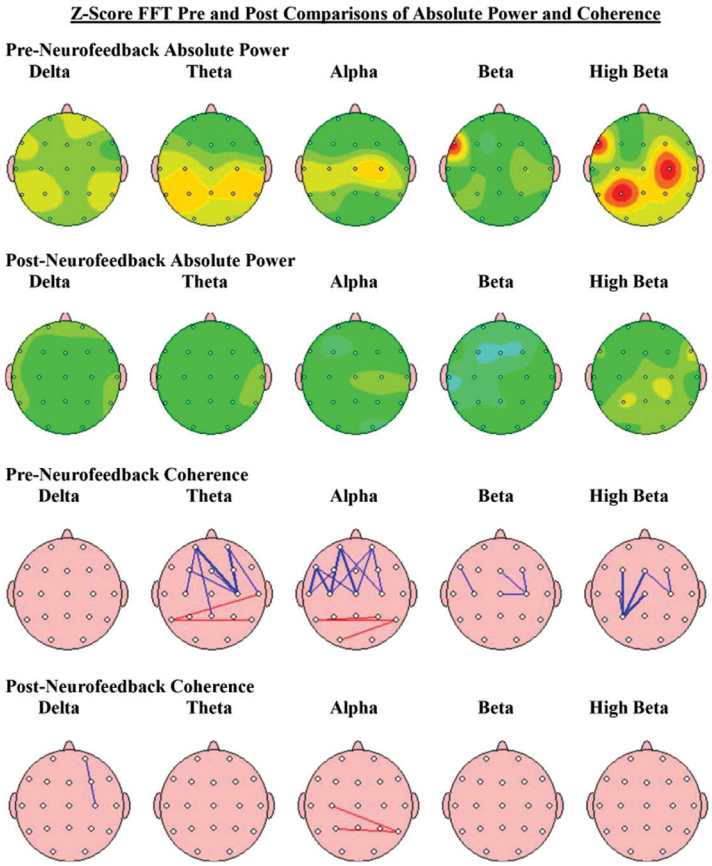


FIGURE 21. Pre- and posttreatment QEEG maps for participant NW, 38 sessions. *Note.* Top pair: Absolute Power maps, Bottom pair: Coherence Maps.



Commonalities in Clinical Results

The overall numbers of studies with outcome reporting, and the numbers showing improvement, are summarized in Table 1. Detailed specific observations are summarized in Table 2.

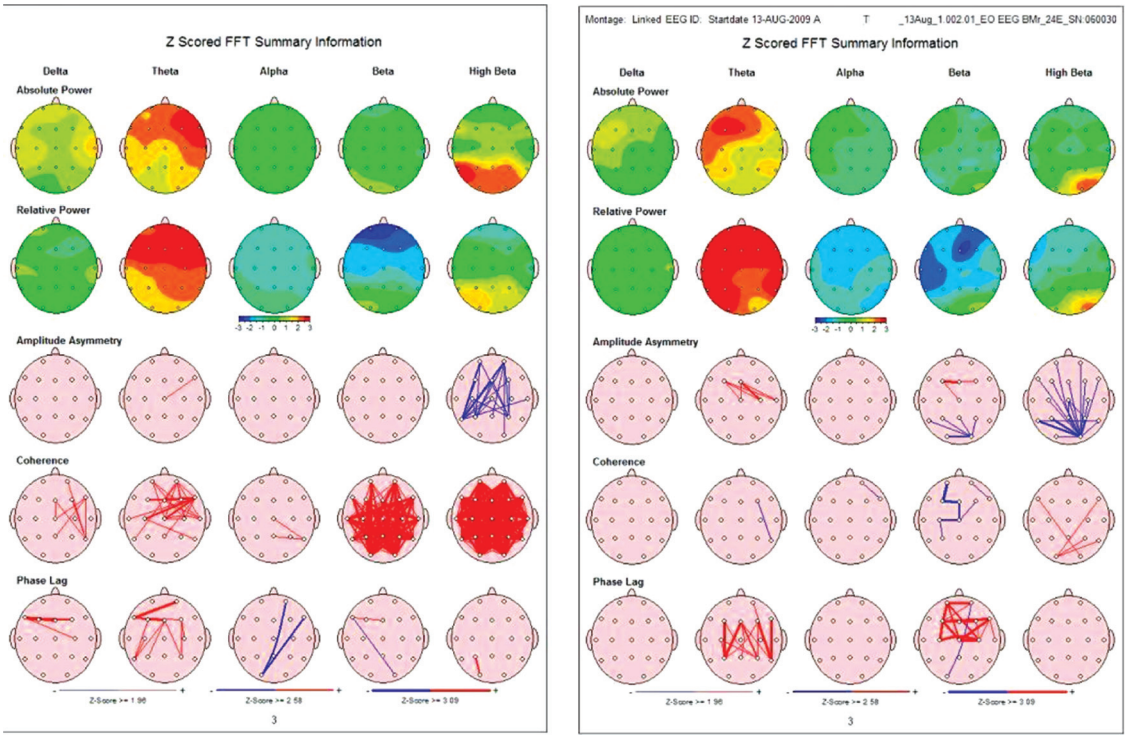
Of the 19 cases reporting presenting symptoms, they were 7 Cognitive and Affective Problems, 5 ADD/ADHD, 3 Autistic Disorder or ASD, 2 Behavioral Problems, 1 Cerebral Palsy, and 1 Traumatic Head Injury.

All respondents reporting clinical outcome identified clinical improvement during the treatment sessions, as noted in Table 2.

QEEG Results

When QEEG data are available, all respondents show visible improvement in QEEG maps relative to the normative database used for analysis. In most cases, the NeuroGuide ANI ("Lifespan") database was included in the analysis. In some cases, the QEEG normalization is dramatic, resulting in essentially normal QEEG maps after the training. In other cases, we see either remaining abnormalities or newly emergent deviations that may reflect compensating mechanisms. The availability of pre- and post-QEEG maps is found to be of considerable value in monitoring and assessing the progress of LZT training. Whereas LZT training can be viewed as an automatic guidance mechanism for feedback, EEG and QEEG analyses provide important information guiding the placement of sensors, choice of protocols, and management of anticipated and observed clinical and behavioral changes. In some of the cases, indices such as the NeuroGuide Traumatic Brain

FIGURE 22. Pre- (left) and post- (right) QEEG maps, 20 sessions, participant TA.



Index or Predicted IQ are reported, and show improvements.

Abreactions/Negative Side Effects

In this clinical series, no abreactions to the LZT training were noted. In earlier clinical work, one initial mechanism identified for abreaction occurred when the target window required for Z-scores was excessively wide (e.g., ±.3.0 *SD*s). In one case (not reported here), an individual presenting with excessive EEG absolute power was trained with a wide window. The result included an "overshoot," in which excessively high power Z-scores were found to become excessively low, in effect finding another limit at which to function. It became necessary, through the software, to provide separate upper and lower limit values, so that the Z-scores could be trained with an upper limit of 3.0 standard deviations but a lower limit of −1.0 standard deviations. Training with this modification eliminated

TABLE 1. Overall studies with outcome reporting and the numbers showing improvement.

	No. Reported	Visible Improvement
Total cases reported	24	
Reporting presenting symptoms	22	22
Reporting clinical/behavioral outcome	23	23
Pre- and posttreatment LZT data	10	10
Pre- and posttreatment QEEG data	12	12
Pre- and posttreatment IVA data	5	4

Note. LZT = live Z-score training; IVA = Integrated Visual and Auditory Performance Test.

TABLE 2. Summarized case details, including clinical, behavioral, psychometric, and QEEG changes.

Study # CLIN ID	Presenting	Previous Treatment	Preassessment	# LZT Sessions and Sites	Result	EEG Change
1 JG Z	17 YO male severely autistic w/little speech, frequent tantrums, short attention span, does not listen to instructions		LZT: high amplitude generally, coherence deficits	10 sessions F7 F8 T5 T6	more clarity in speech and longer sentences, talks more appropriately, less and less tantrums and much calmer, more willing to carry out instructions and tries all dishes that the maid cooks	Reduction in aberrant Z-Scores: 1st session: 36 Z-scores > 1.0 SD during session. 10th session: 13 Z-scores > 1.0 SD. Reduction in both amplitude and connectivity Z-Scores
2 JG C	7 YO female cerebral palsy, speaks two to three words, limited gross and fine motor skills (can't walk yet", short attention span, dreamy	Othmer wide inhibit site specific 6 mo. Slow but steady progress	LZT: high amplitude generally, coherence deficits	10 sessions F7 F8 T5 T6	more responsive to the environment, speaking more with longer sentences, reciprocate two-way communication, interacts more with other children in school, demonstrates more strength in her movements	Reduction in aberrant Z-Scores: 1st session: 35 Z-scores > 1.0 SD during session. 10th session: 27 Z-scores > 1.0 SD. Reduction primarily in amplitude Z-Scores
3 JG Shaan	52 YO female with occasional memory lapses, difficulty in remembering new learning		LZT: high amplitude generally, coherence deficits	10 sessions F7 F8 T5 T6	able to remember most of the steps of the Chinese classical dancing and is able to absorb more of hear learning of the Korean language. Now when she takes coffee she does not have a headache anymore	Reduction in aberrant Z-Scores: 1st session: 60 Z-scores > 1.0 SD during session. 10th session: 31 Z-scores > 1.0 SD. Reduction in both amplitude and connectivity
4 JT DQ	9 YO male, behavioral problems at school and home, incidents of verbal and physical aggression, inability to control temper, stuttering	placed on 1/2 day attendance, individual behavioral plan, vestibular and proprioceptive training	QEEG map: significant lack of alpha activity, significant excess of delta activity frontally, mixed hyper- and hypo-coherence	39 sessions F3 F4 P3 P4, Fz Pz C3 C4, F3 F4 Cz Pz T3 T4 Fz Cz F3 F4 P3 P4 alpha enhance added with emphasis on parietal via thresholds	speech improved significantly after 15 sessions, much less stuttering at around session 17, less argumentative and stopped temper tantrums after session 22, had stopped taking medications at session 26, seemed happier and friendlier at session 27. improved energy and affect, more cognitive flexibility, able to handle transitions in session and in office, no longer stuttered after 39 sessions. plan to return to full day attendance	BASC behavior assessment system results show improvement 14 of 28 scores improved 2 or more standard deviations, pre- and post-Z-Scores show changes significantly in high beta frontally, and in reductions in hypercoherences
5 JT TB	11 YO male, refusal to complete school work, easily distracted, unorganized work area,	IVA shows diagnosis of ADHD, Combined Type.	QEEG map: significant excess of high beta activity focused in parietal regions,	26 sessions T3 P3 Fp2 P4 then Fp1 Fp2 Fz Cz	many deviations visibly cleared up midway sessions as early as session 2. After 7th session, "has been very	individualized behavior questionnaire provided to mother and checklists scored and averaged as

(*Continued*)

TABLE 2 (continued)

Study # CLIN ID	Presenting	Previous Treatment	Preassessment	# LZT Sessions and Sites	Result	EEG Change
	flat affect, "head twitching", avoidance of physical activities, physical awkwardness/clumsiness, and social immaturity		significant hypercoherence in all bands, especially beta and high beta		cooperative in school this week", "trying new things at swim lessons", "only notice tics occasionally, after session 13, "finally rode a bike!"	pre- and post-treatment scores. IVA performance tests improved, 3 of 6 scores improved more than 2 standard deviations
6 FS Norb	21 YO female, currently on academic leave from college "required to get mental health treatment to go back to school" difficulty making friends, socializing, moderate sx of depression. Engrossed in inner "fantasy life"	diagnosed with ADHD, placed on stimulant. Not currently taking prescribed medication (adderall). Currently taking celexa 20 mg. Previously took prozak 20 mg	QEEG map: excess delta and theta left centrotemporal, anorexia, binge purging type, remission. ADD by report. MDE: moderate, partial remission, mTBI by report. Social Phobia		from mother: I do see improvement in B. Seems to be following through better and completing tasks. Has discussed with me the recommendations about past rigity. Agree that she needs to learn to alter her plans and still accomplish tasks. She has come a long way and I see a great deal of improvement. organization is better and confidence is up.	QEEG map shows significant normalization, amplitudes now normal. TBI discriminant reduced from porobability of 97.5% to 70.0%. IVA plus scores pre- and post show improvement in attention subscales
7 FS bers1	54 YO CF (anesthesiologist), diagnosed with ADD, inattentive type, Generalized Anxiety Disorder, Recurrent Major Depression. Complaints related to inattention, fatigue, worry, and "feeling blue"	Methylphenidate 96 mg daily, Lexapro 20 mg daily. Discontinued and washed out prior to QEEG.	IVA + Plus Q Scores; QEEG EC and EO showed decreased power at 1 Hz, frontal low power F3 and F4. low power 9–10 Hz in all leads. Increased power over T4, T6 from 13–15 Hz and 24–30 Hz, maximal deviation at 28 Hz.	20 sessions conventional training, monopolar to reduce fruntal theta, 10 sessions alpha asymmetry training. 20 LZT sessions EO Fz/T3/T4/Pz using DVD player	IVA + Plus Q Scores show improvement of 10% to 20% in Global Response Control, Global Attention, and Auditory Response Control and Attention Subscales. Hyperactivity index increased from 95 to 109. Improvement in overall attention, occupational functioning, increased productivity, better organization, greater job satisfaction. decrease in Beck Depression from 25 at baseline to 14 at post LZT. Changes persisted at 3 mo. follow-up. Lowered Methylphenidate to 70 mg, discontinued Lexapro	QEEG shows general trend toward normalization, changes of 1.0–2.0 SD noted over all training sites. Low Power at 9–10 Hz completely normalized.
8 FS math1			IVA + Plus Q Scores		IVA + Plus Q Scores show improvement of 10% to 30% in Global Response Control, and Auditory Response Control and Visual Prudence.	

					Hyperactivity index increased from 69 to 86	
9 FS pase1			IVA + Plus Q Scores		IVA + Plus Q Scores show improvement of 10% to 20% in Global Response Control, Global Attention, and Auditory Response Control and Attention Subscales. Hyperactivity index decreased from 95 to 50	
10 FS skeg1	56 YO CF, guidance counselor, difficulties with comprehension, early morning waking over several years. Complaints related to hyperactivity, auditory processing, auditory memory.	long-acting stimulant, SSRI, and non-benzodiazeine sleep aid. Discontinued and washed out prior to QEEG.	IVA + Plus Q Scores consistent with processing prudence and auditory comprehension problems. Global abnormalities over F3, F4, T3, T4, C3, C4, P3, P4, O1, O2. Slow waves predominate over T3 and O2 between 1–3 Hz, fast activity over O2 in 15–20 Hz range. Loreta identifies Brodman areas 10, 30 and anterior cingulate abnormalities.	9 LZT sessions eyes open, 30–40 minutes, P3/P4/O1/O2 using DVD and complex tone reward. +1 SD in delta at F3, F4, C3, C4, T3, T4. Also +1 SD in beta and gamma at T3 and T4. Move to F3/F4/P3/P4 and F3/F4/T3/T4 to target processing and attention.	20 LZT sessions completed. IVA + Plus Q Scores mostly steady, show improvement of 10% to 20% in Auditory Prudence, Auditory Comprehension. Hyperactivity index minimal change from 109 to 111. Subjective report improvement in auditory processing, auditory memory, overall attention. Noted improvements in occupational functioning, increased productivity, better organization, greater job satisaction. Sleep improved most overall, no longer requiring sleep medication.	General trend toward normalization visible in QEEG, most evident in low frequency range (1–3 Hz) in left frontal, left temporal, and occipital leads in mid to high frequencies (16–22 Hz). Decrease in coherence noted between P3 O1 and P4 O2.
11 JB 11YOF	11 YO female, depression and anxiety, irritability, low motication, high forgetfulness & discoganized attention, poor school performance			n sessions F3/Fz/P3/Pz F3/Fp1/P3/Pz F3/F4/C3/C4	could only tolerate DVD feedback of stop/go, but wanted to train for 40 minutes. Did not want to stop NF training	able to reduce LZT target size from +/−2.0 SD to +1.5/−1.2 SD
12 JB 10YOM	10 YO male, pervasive developmental delay (6 weeks premature, 3 weeks in neonatal unit), ADHD symptoms, inattention, hyperactivity, can't handle transitions; lack of cooperativeness, problems in school; difficulty with sleep			19 sessions sites based on QEEG, parental report of symptoms & subjective response to training	Improvement consistently noticed in 2 days post training and by the end lasted for the full week with very noticeable improvement in postivie mood and level of cooperativeness & no reports of problems at school for th elast two months of training	parents tracked improvement on scales for 2–4-6 days post training.

(*Continued*)

TABLE 2 (continued)

Study # CLIN ID	Presenting	Previous Treatment	Preassessment	# LZT Sessions and Sites	Result	EEG Change
13 JB 12YOM	12 YO male, depression & ADHD with hair pulling on left side at C3; complete shutdowns at school with oppositional refusal to do work; not doing any homework	medication had been ineffective & was at risk of being sent to a residential program	QEEG shows frontal slowing at F3	1 session F3/F4/C3/C3; added low alpha coherence reward sound/visual F3F4 & C3/C4, then added low beta coherence reward sound/visual for F3/C3	single session positive response noted after session has lasted - parents and teachers rate it at 75% improvement / no need for residential.	normalized F3 beta1/gamma by first normalizing the low coherences;
14 JB 14YOM	14 YO male, wanted to be off medication, wanted to train his brain, poor school performance, not doing chores, rather irritable and argumentative			5 sessions F3/F4/P3/P4 with added reward for normalizing beta coherence F3/F4	reports 50% improvement in sleep pattern, in homework completion and in doing chores without parental prompting. He reports 75% improvement in sports performance and 75% improvement in being less irritable, and prone to anger or oppositional in responses to parents.	
15 JB 17YOM	17 YO male, Aspergers with severe depression/ Anxiety.	6 sessions traditional neurofeedback (1–6), 10 sessions Othmer (14–23)		23 sessions total, LZT for sessions 7–13	complete symptom relief with both depression and anxiety low and much improved school performance and social relations.	
16 JB 10YOM2	10 YO male, ADHD; IQ in the 70s, distractible, doesn't finish tasks, poor memory, impulsive, emotional outbursts, easily frustrated, misses social cues, problems with reading & comprehension	uses AVE and Captains Log at home	QEEG: diminished beta activity, localized in left parietal & occipital areas; more pronounced EEG abnormalities under task	17 sessions C3/C4/P3/ P4 C3/F3/Fz/C4 C3/ C4/T5/Fz+C4 SMR Fp1/Fp2/F3/F4 C3/ C4/T5/Fz +bipolar T3/Fp1 & T4/P4		Reduction in aberrant Z-Scores
17 NW 44YOM	44 YO male, ADHD, bipolar, occasional anxiety symptoms, rarely has manic episodes, multiple blows to the head, recently stopped working	various psychotropic medications since 2001, lack of adequate symptom resolution from medications	QEEG maps: significant amplitude and connectivity deviations IVA: 50+behavioral symptoms/functioning issues	25 sessions F3/C3/Pz/F4 F3/F4/Pz/C4 P3/P4/ Cz/Pz F3/F4/Cz/Pz	beginning of symptom resolution at session 5. able to function adequately after medication titration. After 2 months and 25 sessions client successfully titrated off of all medications and new QEEG taken. Reports being able to overall function better than before NF, even without medication. better able to focus and function in	QEEG: EO maps show significant normalization, reduction in amplitude excesses, and in hypercoherences; some hypocoherence remains. EC maps show significant normalization, some residual hypercoherence. After 9 more sessions, client returned to work and felt his improvement

					business. no longer support working diagnosis of ADHD	was directly due to NF training and that he no longer needed to continue with NF
18 PR 12YOM	12 YO male, autistic disorder, delay in development of verbal and non-verbal communication, lack of social or emotional reciprocity, stereotyped and repetitive motor manners, impaired fine motor, Tourettes-like physical spasms, and high-pitched vocalizations, failure to develop peer relationships		QEEG maps: EC: bilateral excess of high beta, alpha deficit centrally, delta excess rt. Frontal, delta deicit centrally, broad frontocentral hypocoherences.	20 sessions F3/F4/C3/C4	verbalizations changed from primarily prompted and time-delayed to spontaneous and real-time. Spontaneous displays of affection. Decrease in repetitive behaviors and verbalizations. Increased motoric and verbal self-regulation. Increased voluntary interaction with peers in social and school environments, improved sleep patters, and decreased nocturnal enuresis	QEEG maps showed compensation mechanisms at low and high frequency after 20 sessions, "containing" deficit areas with neighboring compensatory amplitude excesses, and connectivity "overshoot". Further normalization seen after 40 sessions. Evidence of specific thalamic and cortical adaptive mechanisms due to operant conditioning
19 WL Sam	7 YO male rapid learner, easily excited and aggressive with other children. Can be classified as AD/HD		QEEG maps: EO: Delta and theta excess frontally, high beta excess over Pz, global hypercoherence in all bands, particularly delta and high beta	21 sessions F3 F4 P3 P4	visible improvement in behavior, notable change in interaction with NF staff, more positive and cooperative, school reports improved behavior and reduction in aggression	QEEG maps show significant normalization. Phase and related measures remain outside norms
20 DK SonjaK	13 YO female, diagnosed ICD 10 early childhood, F94.0 elective mutism, now F93.2 emotional disorder with anxiety, F83.2 discalculia. Emotional diagnostics: emothional stress, total blocking with "open" tasks. Marked social and emotional tendency to withdraw	successful ergotherapy, waldorf-school 7th grade poor math, no medication. HAWIK 3 markedly below average, assumed due to anxiety disorder	QEEG maps: significant excess of delta and theta diffusely, and high beta occipital	15 weekly sessions T3 T4 C3 C4 Fp1Fp2O1O2 F3 F4 T5 T6 C3 T3 T5 P3 Fp1 F4 T4 P4 (address mirror neurons; empathy) high compliance	diminished feelings of being dominated, better ability to stand up to classmates, begins shopping, meeting with friends. Reports increased alertness, awakeness after each session. Thinks of NF display "dolphins" during school tests, increased reasoning. Improved self-assurance, math, social skills, open-mindedness, verbal communication	QEEG maps show normalization during 1 session (session 16), both amplitude and connectivity. T3-C4 hypercoherence reduced, Theta T3, C4, T4, hypercoherence fast waves normalized, T5-P3, prefrontal Delta, overall frontal slowing normalized. IVA, TOVA, CPT forthcoming
21 JT NW	9 YO female mood swings, impulse control problems, concentration difficulties.	18 mg Concerta plus GABA	QEEG maps: excess amplitudes, hypocoherence theta and alpha posterior temporal	38 sessions 4-channel 26 sessions C3 C4 P3 P4 11 sessions F3 F4 Cz Pz	at session 27 teacher reported significant improvements in self control. At session 33, parents indicated that remaining problems were due	BASC behavior assessment system results show improvement, pre- and post- Z-Scores show changes. 24 z-scores

(*Continued*)

TABLE 2 (continued)

Study # CLIN ID	Presenting	Previous Treatment	Preassessment	# LZT Sessions and Sites	Result	EEG Change
					to family dynamics and old behavioral habits - family sought therapy	show > 1 SD change. QEEG maps show essential normalization
22 DS TA	14 YO male, preadolescent LD, concentration problems, impulsive behavior	Several ADD medications previously w/ limited benefits, unacceptable side effects. 10 mg Abilify for 2.5 yr w/ no side effects, some increased concentration		20 sessions LZT w/amplitude training to lower 3–8 Hz, raise 16–19, and lower 22–30 Hz.	self-reported clinical improvement in all symptoms	QEEG maps show light reduction in theta z-scores as well as 20–30 Hz z-scores. 16–19 Hz range rises to ∼−1.6 SD. Essentially complete coherence normalization and moderate theta absolute power improvements visibly evident
23 HK HAR9	23 YO female traumatic head injury (at age 13) with chronic residual cognitive deficits and sleep disturbance. Short term memory and word retrieval problems, impulsivity, difficulty concentrating	Partial right temporal lobectomy and ventriculostomy. Adderall XR 20 mg and Provigil 200 mg daily, helped little with hypersomnolence. Paxil 20 mg since age 16. Imipramine 50 mg then 20 mg daily	Glasgow Coma scale 3 on admission to ER, in coma for 6.5 weeks. Baseline QEEG shows excess Beta and High beta, mostly left frontal. Loreta confirms left frontal and temporal involvement at 9–25 Hz	20 sessions F3/C3/T4/C4 30 minutes once/week sometimes twice/week. Counseling, Vitamin B2 added	after 7 sessions, significant improvement reported by patient and mother in memory and environmental awareness. After 20 sessions, reported significant improvement in sleep patterns, able to fall asleep faster, and return to sleep if she woke up in middle of night. increased awareness of cognitive deficit and "lost time". INcreased awareness of future, and ability to plan for educational activities. Started B2, headaches decreased.	Post-treatment QEEG forthcoming. Continuing weekly sessions, reports steady improvement of memory and cognition
24 JW NK	6 YO F, chronic anxiety, difficulty with anger control, reading difficulty; left-handed	no previous treatment	QEEG shows excess slow 1–10 Hz at T5, O2, T3, T6, T4, F8, Fp1, Fp2. Excess 21–30 Hz at F3, C3, P3, O1, Pz, P4. Coherence deficit delta 5 L, 1 R, theta 3 L, 1 R, and alpha 1 R.	53 sessions 3x/week, various placements	No longer anxious. No further anger outbursts. Reading at grade level. Improved short-term memory. Improved focusing ability.	All QEEG abnormalities normalized.

Note. QEEG Maps: 19-channel EEG recordings analyzed using NeuroGuide (Applied Neuroscience). Othmer refers to the low-frequency bipolar training per Othmer (2008). LZT = Live Z-Score text displays on live screen or on statistical summaries; QEEG = quantitative EEG; IVA = Integrated Visual and Auditory Performance Test; SSRI = serotonin re-uptake inhibitors; NF = neurofeedback; TOVA = Test of Variables of Attention.

the overshoot phenomenon and allowed the feedback to be more effectively targeted.

Once the use of separate upper and lower Z-score limits became the practice, abreactions or negative side effects have not been reported from the field, where the general clinical population is involved. Results from our early clinical reports and trials thus far suggest that well-targeted EEG normalization does not appear to have significant downside risk, when the pretreatment EEG is initially clearly abnormal. Mild abreactions have been observed by one author (TFC) during training demonstrations on some individuals, in which the prominent EEG deviations appeared to potentially represent coping or compensatory mechanisms, and the Z-score training has the effect of reducing the deviations. Such deviations may be in amplitude or in connectivity, or in both. For example, chronic pain sufferers may present with globally decreased alpha power. We hypothesize that this may reflect a state of tension and abnormal activation of the cortex representing some kind of coping mechanism, and thus, when alpha activity is uptrained, it may result in an increased experience of pain as the coping mechanism is reduced. Whether or not this is an abreaction is a matter of terminology, as restoration of sensory awareness, including pain, might be used as a path toward self-regulation and recovery.

As another example, clients with chronic anxiety may exhibit excess alpha, which may be a coping mechanism, or may simply reflect their individual state of activation, particularly where emotional control and regulatory centers are involved. Again, downtraining the alpha, which is an activation procedure, may result in increased perception of anxiety, even as the EEG normalizes. Another example arises when normal, functional, achieving adults present with what the Z-score software interprets as "excess SMR." This excess is not necessarily abnormal, may simply reflect an above-average ability to sit still and remain motionless, or may reflect the normal onset of drowsiness. This variant is in fact commonly seen in clinical professionals, for whom stillness and attentiveness are traits that are cultivated and nurtured, and in training workshops, in which drowsiness may appear under normal circumstances. In some individuals in these circumstances, downtraining the SMR has been seen to result in a feeling of irritation and uneasiness, secondary to the activation of the trained areas.

DISCUSSION AND CONCLUSIONS

It has been seen that the LZT training used here is capable of inducing brain changes that are specific and profound, particularly with regard to whole-brain activation and connectivity. Using this technique in conjunction with QEEG and behavioral data, it is possible to demonstrate clinical effects that are well correlated with objective measures, and support the claim that this approach is an important addition to clinical practice.

It has been found that four-channel LZT training is sufficient to resolve global connectivity issues and that it can effectively target abnormalities visible on the LORETA, and to resolve them. This is likely because the brain has limited degrees of freedom, and in order to bring a predominance of parameters into the normal range, other parameters must also normalize. That is, when sufficiently constrained, the brain cannot conspire to "circumvent" the training, and produce untoward effects.

Nonetheless, when using the MVP approach, it is found that the brain is provided with information that is particularly valuable. By ignoring "outliers," the brain can concentrate on fundamental mechanisms, without being distracted by details that may confound the training. If only some fraction of Z-scores are required to fall within a target for rewards, then the trainee's EEG is given a large dynamic range within which to function. By using smaller targets, and allowing some Z-scores to remain outside the defined range, the brain is provided with options, that it appears to be prepared to use to best advantage.

With LZT training, the brain is exploring its dynamic range, and this is key to the effectiveness. It is broadening its functional

repertoire, and is finding a trajectory and path toward normalization that is not a straight line through state space. It is a circuitous path, but it is a path that the brain seems to be equipped to navigate. Every person may respond differently, but LZT trainees receive concise information with which to develop and implement a strategy toward self-regulation.

Again, because the technique using MVP allows the extreme deviations to be untouched, you are allowing the brain to create its own strategy toward normalization. It is significant that clients may have clinical benefits uniformly through the treatment. It is also important to vary the target size and the percentage of Z-scores required, so that the brain has full information to explore these boundaries, without requiring full normalization from the start.

We have found that four channels is actually very effective at localizing and training the entire brain, and some of our published results show the whole-head EEG being essentially normalized, as a result of judicious choice of the four channels. Most often, montages such as F3/F4/P3/P4 or F3/F3/C3/C4 are used. There is also a "big box" that can be used, which is F7/F8/T5/T6. When four channels are well chosen, the brain does not have a lot of room to move around. We do not generally see problems due to the fact that the four channels have missed anything. It is possible to identify certain montages that appear to isolate functional hubs and subsystems. These provide additional focus and meaning for placements for four-channel training. For example, posterior integration issues associated with stress or aging are well addressed by using C3/C4/P3/P4.

We believe that assessing the client's clinical signs and "complaints" is essential to planning and carrying out the LZT training. It is possible to more flexibly address various brain areas quickly when the channels can be quickly changed, as with a MINI-Q, or when using a full 19-channel cap with LZT training. However, the economy and convenience of applying four monopolar leads provides benefits of simplicity. It is fair to say that four-channel LZT training is being proven and that it is a robust and effective method.

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