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

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Case Studies – Live Z-Score Training

**ABSTRACT**

*Background.* This report summarizes clinical results using a neurofeedback approach that has been developed over the last several years, and is seeing increasing clinical use.

*Method.* All participants used a form of live z-score training (LZT) that produces sound and video feedback, based upon 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.

*Results.* 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.

*Conclusions.* In this series of case studies LZT training 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 or neurofeedback that can be demonstrated to be effective in a variety of clinical scenarios.

**KEYWORDS.** Neurofeedback, Biofeedback, QEEG, Normative Database, Live Z-Score Training, Multivariate Proportional Training
INTRODUCTION

This report 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. While employing 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 upon a published data base, and computed using the same software code that exists in the analysis software, when used in “dynamic JTFA” mode. The database includes over 600 people, ages 2 to 82. The system computes real-time z-scores using JTFA (joint time-frequency analysis) rather than using the FFT (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, e.g. “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 et. al. 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), and Collura et. al. (2009). These reports included 6 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 upon 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 4-channels of what we now call LZT (Live Z-Score Training) in their practices. This report 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 report used the same approach to LZT training, which is described in more detail below. This report will also discuss 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 4-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 reliable “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 the difference between watching a baseball game or 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.

**Insert Figure 1 about here**

![Live Z-Score text display](image)

**Figure 1** – Live Z-Score text display (4 channels = 248 Z-Scores). Z-scores are colored to show when they are above normal range (yellow, orange, red) or below normal range (green, turquoise, blue)

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
also the percentage of z-scores which must be within these bounds, in order 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 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, in order 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.

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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, is no different from simply ignoring some set of scores, or setting an upper range where 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 3 – Relationship between size of LZT targets, and the use of PercentZOK to establish reward criteria. Within this model, clinicians can choose which aspects of training to emphasize, and which to vary.
Figure 4 shows the LZT review and selection screen. This is used to select z-scores for graphical analysis, and also 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, so that combinations of amplitude or connectivity scores that tend to “go out” together, or show definite patterns, are readily recognized.

Figure 4 - Live Z-Score selection screen, used for review of session data
Case Studies – Live Z-Score Training

Figure 5 shows a typical graphical summary of progress. This is the change in the most deviant z-scores during a 40-minute 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 sessions, by watching which scores move in various directions.

Figure 5 – Live Z-Score changes plotted across 40 minutes, 1 session with a naïve trainee
Case Studies – Live Z-Score Training

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 is an important aspect of LZT training.

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Figure 6 – Progress of Multivariate Proportion (Percent of z-scores meeting criteria) plotted across 40 minutes, one session with a naïve trainee

This approach allows the brain to develop its own strategy, since 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 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 the current report represents 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 the table.

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 Z OK” algorithm in live z-score training. 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. While 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, while others focus on the percentage of Z-Scores as the key variable. However, since 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 upon the observed clinical and electrophysiological changes.
Summary of Cases

Details for all cases are presented in Table 2 at the end of the report. 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 used 10 sessions of 4-channel LZT training on each of 3 patients. Figure 7 summarizes the percent of amplitude Z-scores (absolute power, relative power, power ratios) that were outside the nominal range of +/- 1.0 standard deviations. This illustrates the repeatable reduction in deviant z-scores, while revealing some difference between subjects. It is interesting that the subjects who presented with the most deviant z-scores on the outset, showed the least number of deviant scores after training.

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Figure 7 – Percent of Amplitude z-scores outside +/- 1.0 standard deviations for 3 subjects “S”, “Z” and “C”, 10 sessions each.
Figure 8 shows the percent of connectivity z-scores (coherence, phase, asymmetry) outside the range +/- 1.0 standard deviations for the same 3 subjects. While uniform reduction is seen in two subjects, an actual increase is seen in one. It will be shown later that this reflects a compensatory mechanism, in which the brain evidently allows some scores to become deviant, in order to achieve greater overall normalization. Note that this phenomenon likely depends on the ability of the training software to allow some scores to remain outside normal bounds, while continuing to reward for training.

Figure 8 – Percent of Connectivity z-scores (asymmetry, coherence, phase) outside +/- 1.0 standard deviations, 3 subjects, 10 sessions each.
Figure 9 shows the number of amplitude z-scores outside specified target ranges, for one subject. 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.

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**Figure 9** – Number of Amplitude Z-Scores outside target range as a function of target size, subject “S”. The number of Z-Scores outside the narrow range 1.0 actually rises, while the overall distribution pulls strongly within the 1.5 and 2.0 ranges.
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 10 – Number of Connectivity Z-Scores outside target range as a function of target size, subject “S”. While 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 shows pre- and post- QEEG maps for subject “DQ” presented by clinician JT. Improvements are visible in both the power and the coherence maps, after 39 sessions.

INSERT FIGURE 11 ABOUT HERE
Figure 11 - pre- and post-treatment QEEG maps for subject DQ
Figure 12 shows pre- and post- QEEG maps from subject “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, while others normalize. For example, a slight excess of right delta and theta appears, while 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.

INSERT FIGURE 12 ABOUT HERE
Z-Score FFT Pre and Post Comparisons of Absolute Power and Coherence

Pre- and post-treatment maps (26 sessions) for subject TB. Top pair: Absolute power maps, Bottom pair: Coherence maps.
Figure 13 shows pre-QEEG maps, and Figure 14 shows post-QEEG maps after 20 sessions, for subject “Norb” (clinician FS) using a Laplacian derivation. All evident power and asymmetry abnormalities are seen to effectively normalize. While 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 13 pre (left) and post-treatment (right) QEEG maps after 20 sessions, patient Norb
Case Studies – Live Z-Score Training

Figure 15 shows IVA+Plus Standard Scales Analysis for subject “Norb”. The Full Scale Response Control Quotient rises from 94 to 101, while the Full Scale Attention Quotient rises from 62 to 95.

Figure 14 pre- and post-treatment IVA+Plus, patient Norb, 20 sessions
Case Studies – Live Z-Score Training

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

Figure 15 – pre (left) and post-treatment (right) QEEG maps, 25 sessions, patient 44YOM
Figure 16 shows IVA results from subject “44YOM.” Full-Scale Response Control Quotient rises from 29 to 94, while Full Scale Attention Quotient rises from 0 to 96.

Figure 16 pre (left) and post-treatment (right) IVA Standard Scales Analysis, 25 sessions, subject 44YOM.
Figure 17 shows the progression of subject “12YOM”, clinician PR in 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, while 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, while hypocoherence across frequency bands is seen to remediate, there is a significant hypercoherence in high beta the 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.

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Figure 17 – Overview of client 12YOM progress in Eyes Open condition, after 20 and 40 sessions.
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 18 – Overview of client 12YOM progress in Eyes Closed condition, after 20 and 40 sessions
Figure 19 summarizes the progress of subject “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 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 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 19 – Summary of changes EC and EO.
Figure 20 shows pre- and post- QEEG maps from subject 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.

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Figure 20 – pre- and post-treatment maps before and after 1 session (session 16) for SonjaK
Figure 21 shows pre- and post- QEEG maps from subject “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 21  pre- and post-treatment QEEG maps for subject NW, 38 sessions. Top pair: Absolute Power maps, Bottom pair: Coherence Maps
Figure 22 shows pre- and post- QEEG maps from subject 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 22 pre (left) and post (right) QEEG maps, 20 sessions, subject TA.
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 below.

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**Table 1 – Summary of Case Studies submitted**

<table>
<thead>
<tr>
<th>Total Cases Reported</th>
<th>Number Reported</th>
<th>Visible Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reporting Clinical/Behavioral Outcome</td>
<td>17</td>
<td>17</td>
</tr>
<tr>
<td>Pre- and post-treatment LZT data</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Pre- and post-treatment QEEG Data</td>
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<td>8</td>
</tr>
<tr>
<td>Pre- and post-treatment IVA Data</td>
<td>5</td>
<td>4</td>
</tr>
</tbody>
</table>

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

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 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, for example, +/- 3 standard deviations. 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 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, abractions 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 pre-treatment EEG is initially clearly abnormal. Mild abractions 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 4-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, since 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 percent 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 4 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 4 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 4 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 4 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 4-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 4 monopolar leads provides benefits of simplicity. It is fair to say that 4-channel LZT training has being proven in, and that it is a robust and effective method.

**Statement of Disclosure**

Dr. Collura has a financial interest in BrainMaster Technologies, Inc. Certain of the methods described here are patent pending in the US, Canada, and Europe.
INSERT TABLE 2 ABOUT HERE
REFERENCES


