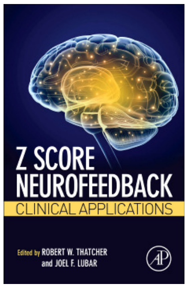

Z SCORE NEUROFEEDBACK:
Clinical Applications

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Preface

EEG biofeedback also called Neurofeedback has a 60 year history in the scientific literature. However, a problem with human neurofeedback methods was inefficiency because improved clinical outcome and changes in the EEG occurred only after many sessions, e.g., 40 to 80 sessions. A large number of sessions are expensive with reduced patient compliance and the need for good clinical outcome in fewer sessions is a pressing need. The first indication that more efficient biofeedback is related to increased specificity of the physiological event was proven in the 1960s when scientist's operant conditioned single neurons, groups of neurons and evoked potentials in only a few sessions. The lack of specificity in human neurofeedback studies was evident by the use of one or two scalp electrodes arbitrarily placed on the scalp in which each electrode was influenced by widespread electrical sources inside the brain and therefore was non-specific as to the Brodmann areas and networks inside the brain. Also, researchers and clinicians had no standards by which to select thresholds to determine if a feedback signal was to be delivered or not. For example, clinicians would argue for different protocols in which the threshold for alpha rhythms may be 20 microvolts for one clinician or 15 microvolts or 25 microvolts for others, etc. Arbitrary thresholds to inhibit rhythms like theta (4-8 Hz) also occurred, e.g., is the threshold 5 microvolts or 10 microvolts or 15 microvolts, etc. Still worse was that different clinicians would use different metrics such as relative power which is a percentage, others would use absolute amplitude in microvolts, others would use ratios of power, others would use ratios of relative power and others would use arbitrary measures of coherence at different scalp locations and different ages, etc.

In the late 1990s it became obvious that the lack of specificity and uniform standards resulted in inefficient clinical applications of neurofeedback. As a consequence the idea of using real-time Z scores to simplify and standardize neurofeedback was suggested by Robert Thatcher in the 1990s and implemented in 2006 with almost an immediate improvement in the efficiency of neurofeedback. That is, good clinical outcome was noticed in less than 20 sessions and often in less than 10 sessions soon after the first application of Z score EEG biofeedback. The reason for the improved clinical efficacy was that different and multiple metrics were reduced to a single common metric, i.e., the metric of a Z score that ranges from ± 2 or 3 standard deviations no matter what the original metric may be. Further, the Z score removes arbitrary guessing about thresholds because the goal is to reinforce any given EEG measure in the direction of Z = 0 which is the center of a reference healthy age matched normal population that has no psychological problems nor a history of clinical disorders. Reinforcing toward Z = 0 is also reinforcing toward greater stability and efficiency in networks of the brain. Dr. Joel Lubar was one of the first to embrace and adopt the Z score EEG neurofeedback method and immediately reported improved clinical outcome in fewer sessions than had been his history prior to the introduction of Z score biofeedback.

It was also noticed in the 1990s that clinicians were not linking a patient's symptoms to the patient's brain. Instead a "one size fits all" approach dominated the field of EEG neurofeedback for decades in which electrodes were placed, for example, at bilateral temporal locations (T3/T4) or midline line central locations (e.g., Cz) for all patients independent of their symptoms and clinical history. As a consequence the concept of seamless integration of a "Symptom Check List" was introduced by which hypotheses can be formed to confirm or disconfirm which networks of the brain were likely linked to the patient's symptoms. This introduced another major increase in specificity since it has long been known that dysregulation in parts of a network called the "weak" system results in compensatory activity by the stronger or healthier networks. Not separating the "weak" network most likely responsible for the patient's symptoms from the compensatory networks is inefficient and results in more sessions before clinical improvement is noticed.

The next innovation was the 2010 introduction of Z scores to real-time 3-dimensional EEG source localization integrated with symptom check lists. This advancement further increased specificity in which one begins with the patient's symptoms and hypothesis formation followed by QEEG assessment to confirm or reject hypotheses followed by low resolution electromagnetic tomography (LORETA) Z score neurofeedback that targets Brodmann areas (network nodes) and connections between nodes linked to the patient's symptoms. This not only increased specificity but also clinician efficiency by seamless integration of QEEG assessment treatment in a single 40 minute session. The goal was to reinforce increased stability and efficiency of information processing in dysregulated network nodes and connections linked to the patient's symptoms. As evidenced in this book the seamless integration and linking of symptoms to dysregulated networks in patient's brains resulted in improved clinical outcome in fewer sessions, which is the ultimate goal of EEG biofeedback.

Biofeedback of functional connectivity in 3-dimensional neural networks linked to symptoms by real-time LORETA coherence, phase difference, phase lock and phase shift referenced to an age matched referenced normal population is one of the main topics in this book. Functional connectivity coupled with LORETA current density of neural networks linked to symptoms has become a standard method of EEG biofeedback now used by hundreds of clinicians and we expect that these scientific advancements will continue into the future. For example, reinforcement of effective connectivity also called "directional connectivity" is currently under development.

Another recent scientific advancement of EEG biofeedback is the introduction of Brain-Computer-Interface (BCI) methods as described in the chapter on BrainSurfer. BCI involves the same neuromodulators and reinforcement toward increased stability in neural networks linked to symptoms as with EEG biofeedback but differs by involving continuous feedback with real-time visualization of the patient's brain network nodes and connections. No discrete feedback by a DVD or video or signal is used with BCI, instead patients employ cognitive and emotional strategies to change networks in their brains by viewing changes in nodes and connections in real-time. The use of Z scores to simplify and guide toward the center of an age matched normal reference is again a central concept designed to reinforce increased stability in networks linked to the patient's symptoms.

Important feedback regarding clinical efficacy and good clinical outcome by Dr. Lubar and others were major factors in the design and development of Z score biofeedback technology. This new technology required step by step improvements in implementation and adherence to the basic scientific principles of EEG operant conditioning as discovered in the 1940s and extensively explored in the 1960s. Given the successes of the past as evidenced in this book, we anticipate further developments and implementation of similar technologies in the near future. We see a bright and maturing future of the field of EEG neurofeedback and see this book as one example of a growing scientific literature going forward.

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