

SPECIAL ISSUE

Z-Score LORETA Neurofeedback as a Potential Therapy for ADHD

J. Lucas Koberda, MD, PhD, Paula Koberda, Andrew Moses, Jessica Winslow, Andrew Bienkiewicz, and Laura Koberda

Tallahassee Neurobalance Center, Tallahassee, FL

Keywords: attention deficit hyperactivity disorder (ADHD), neurofeedback, z-score, LORETA, EEG

Attention deficit hyperactivity disorder (ADHD) is a disorder of relatively high prevalence and frequently contributes to poor school and work performance. Neurofeedback (NFB) has proven to be an effective therapeutic modality in the treatment of ADHD. Recently introduced z-score LORETA neurofeedback offers promise as a tool, and appears to provide a more efficient therapy than standard two-channel neurofeedback. This advantage is based on the ability to train 19 channels simultaneously, and the ability to directly target an electrically dysregulated area of the brain, which may be more difficult to access with standard neurofeedback therapy (areas addressed with LORETA neurofeedback include the cingulate gyrus and hippocampal structures). This paper presents our experience with Z-score LORETA neurofeedback in the treatment of ADHD.

Introduction

Attention deficit hyperactivity disorder (ADHD) is one of the most prevalent childhood disorders affecting 7%–10% of Americans (Berger, Slobodin, Aboud, Melamed, & Cassuto, 2013) and 4%–7% of individuals around the world (Yuce, Zorogly, Ceylan, Kandemir, & Karabekiroglu, 2013). The onset of ADHD typically occurs at the age of 6 or 7, and affects four times more boys than girls. Symptoms of ADHD include inattention (easily distracted or bored, difficulty focusing, not following instructions), hyperactivity (inability to stay still), and impulsivity (impatient, inappropriate). Symptoms may vary from person to person, making ADHD difficult to diagnose. In order to receive a diagnosis, a child must exhibit the symptoms of ADHD for more than 6 months, and these symptoms must be intensified when compared to other children of the same age (National Institute of Mental Health, 2013).

The most frequent finding on quantitative electroencephalograph (QEEG) testing of patients with ADHD is an increase in low-frequency activity, especially frontal and central excess of theta power (Di Michele, Prichep, John, &

Chabot, 2005). However, a subgroup of patients with elevated beta frontal power was also reported (Di Michele et al., 2005). In addition, since ADHD is a heterogeneous disorder, several other subtypes of QEEG characteristics of ADHD patients have also been described (Arns, Gunkelman, Breteler, & Spronk, 2008). More recently, low resolution electromagnetic tomography analysis (LORETA)¹ of ADHD individuals revealed evidence of electrical deactivation, which was localized to medial prefrontal regions, the cingulate cortex/precuneus, and temporal regions (Broyd, Helps, & Sonuga-Barke, 2011).

In addition to pharmacotherapy, EEG biofeedback (also called neurofeedback [NFB]) can be used as a treatment option for individuals with ADHD. However, in order for this treatment plan to work, patients must willingly participate and want to learn without becoming disengaged or distracted (Robbins, 2008). NFB is a form of operant conditioning using visual or acoustic reinforcements. Patients with ADHD undergoing this treatment option can learn to self-regulate “normalizing EEG patterns, which results in the normalization of behavior” (Ogrim & Hestad, 2013, p. 448). NFB can help those with ADHD to focus, gain self-control, and earn higher grades in school (Robbins, 2008).

Moriyama et al. (2012) described a randomized study in which NFB was shown to display positive results in relation to ADHD. Subjects undergoing NFB training showed that their central alpha activity increased, and theta decreased; these results were correlated with the improvement of ADHD symptoms. Additional trials compared NFB sessions

¹LORETA is an inverse solution technique utilized to analyze surface EEG signals, and project the regions and processes likely producing the surface electrical activity. Today's LORETA software produces a real time display of subcortical processes on the surface of the cortex and below, usable for neurofeedback training. “LORETA z-score training” involves training brain processes toward normalcy, based on a comparison to a normative database. The z-score is based on how many standard deviations a signal or pattern is from the statistical mean of a normative database.

Table. Computerized neurocognitive testing (NeuroTrax) results before and after neurofeedback (NFB) initiation.				
Time	January 2013	March 2013	June 2013	November 2013
NFB Sessions	0	12	30	60
Global cognitive score	72.4	80.1	85	94.1
Memory	58.1	76.7	69.7	85.1
Executive function	49.1	74	70.8	91.2
Attention	31.6	62.7	73.5	86
Information processing speed	–	–	–	73.9
Visual spatial	97.7	92.7	97.7	118.6
Verbal function	116.3	83.9	105.5	108.6
Motor skills	81.3	90.4	92.5	95.5

with a placebo effect. Those in the NFB group were successful in lowering theta and beta activity, while better regulating their brain's electrical activity. A further study by Cannon et al. (2006, 2007) targeted the anterior cingulate (AC) gyrus. After 30 sessions of NFB, positive changes could be seen in this region (AC) of the brain, resulting in better decision making and self-control. Teachers and parents also reported NFB to be effective in altering attention and metacognition (Moriyama et al., 2012).

In z-score NFB, a real-time comparison to an age-matched population of healthy subjects is used for data acquisition, simplifying protocol generation and allowing clinicians to target modules and hubs that indicate dysregulation and instability in networks related to symptoms (Thatcher, 2013). Z-score NFB increases specificity in operant conditioning, providing a guide that links extreme z-score outliers to symptoms, and then reinforcing z-score shifts toward states of greater homeostasis and stability. The goal is increased efficiency of information processing in brain networks related to the patient's symptoms (Thatcher, 2013).

A recently introduced method called LORETA z-score NFB is capable of targeting specific dysregulated anatomical structures, many of which are in deeper cortical locations (Koberda, Koberda, Bienkiewicz, Moses, & Koberda, 2013; Thatcher, 2013). For example, the insula and anterior cingulate (AC) have been identified as potential NFB target sites to improve pain control in patients who display electrical dysregulation of these areas (Koberda et al., 2013).

We have previously reported effectiveness of LORETA NFB in the patient with cognitive deficits and attention deficit (Koberda, Moses, & Koberda, 2012). In our center we have completed LORETA NFB therapy in 20 patients with

symptoms of ADHD. Subjective improvement of 90% (18 patients) was reported, and objective improvement of QEEG abnormalities of 80% (16 patients) response was noted. Many of the patients completed pre- and post-NFB (after 10 NFB sessions) computerized neurocognitive testing using NeuroTrax™ testing (NeuroTrax, Bellaire, TX) with cognitive enhancement rate of 75%. One representative ADHD case will be presented here in more detail.

Case Study

An eight-year-old male with ADHD came with his mother for an examination. She described his problems at school, including learning and behavioral difficulties. He had trouble paying attention, which resulted in poor grades, and was enrolled in the special education program at school. He had a history of speech delay, clumsiness, and was often fidgety and unable to sit still. The mother reported neither prior medical problems nor pregnancy complications. She explained that her son did not have a problem interacting with other children, nor did he exhibit behavioral issues at home. During the examination, he often interrupted and squirmed around in his chair; he was alert and able to follow instructions.

Equipment and NFB Protocol

Deymed Truscan 32 (Deymed Diagnostic, Payette, ID) EEG equipment was combined with NeuroGuide (Applied Neuroscience, Inc., St. Petersburg, FL) software. The NFB protocol included surface and LORETA (NF1/NFB2) feedback, in an alternating protocol while focusing on a symptom checklist including: anxiety, attention deficits, concentration problems, executive function problems, and short-term memory. NFB sessions were conducted with a

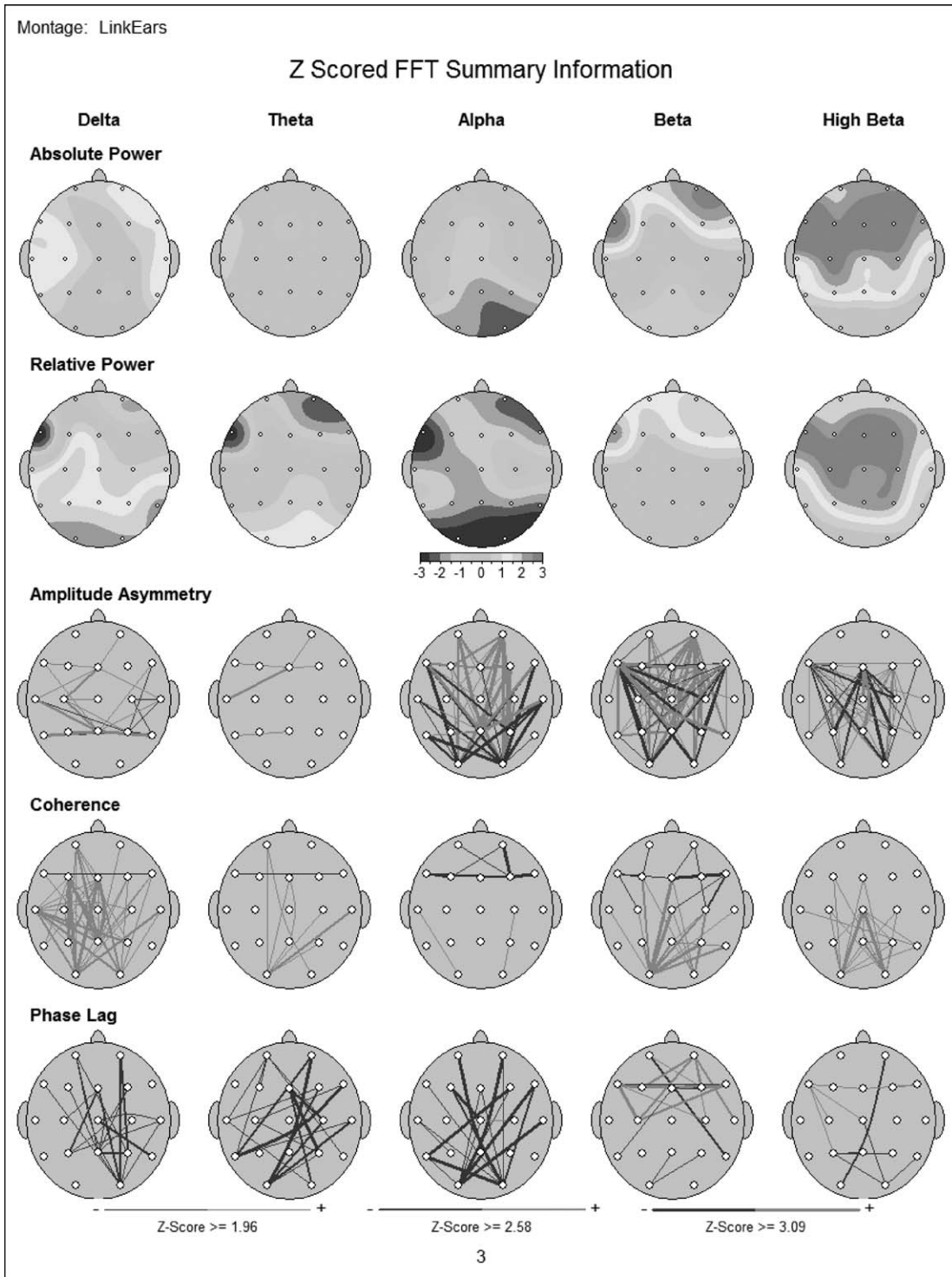


Figure 1. Quantitative electroencephalograph before neurofeedback initiation. Noticeable prominent excess of frontal beta and high beta activity depicted in red color (see frontal gray area). Green color shows brain power within 1 SD, yellow color within 2 SDs.

frequency of once to twice per week, using auditory or auditory and visual feedback combined.

Before NFB therapy was initiated, the eight-year-old boy was tested using computerized neurocognitive testing.

NeuroTax is a computerized cognitive testing examining memory, executive functioning, attention, information processing speed, visual spatial, verbal functioning, and motor skills (Doniger, 2013). The test is scored based on the

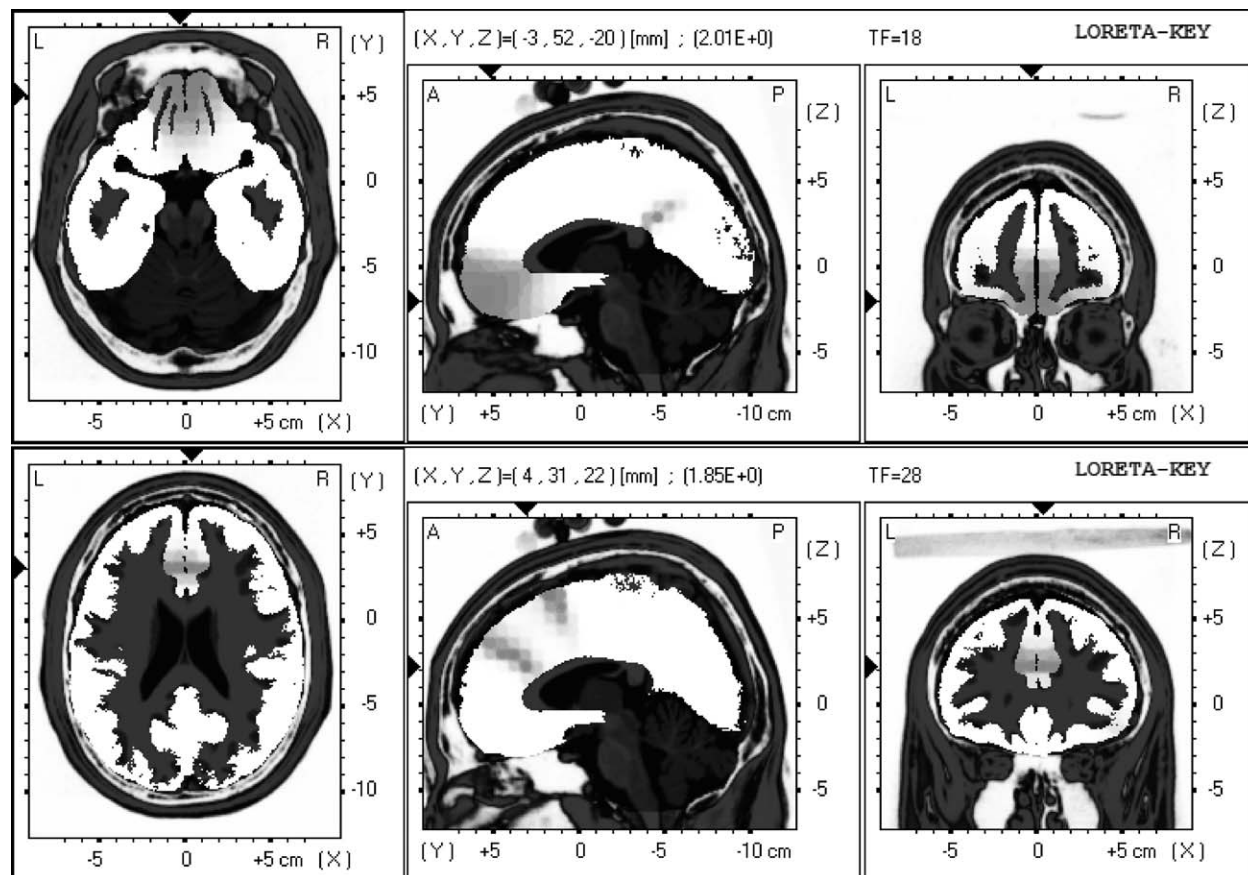


Figure 2. Before neurofeedback low resolution electromagnetic tomography analysis showed electrical dysregulation of anterior cingulate gyrus (Brodmann Area 32 and 24) in beta frequency.

comparison to age and education matched controls with expected score of 100 and a standard deviation of 15. During the patient's first testing session before NFB, he scored 72.4 points overall (Global Cognitive Score), reflecting a below average score in every area except for verbal functioning (Table).

Each time the patient came with his mother for NFB, they were first asked if any progress had been made in his behavior/school performance; their response was recorded as a subjective response.

After only 12 sessions of NFB, his NeuroTrax global cognitive score rose to 80.1 points overall (Table). His memory score increased from 58.1 to 76.7, executive functioning from 49.1 to 74, and attention from 31.6 to 62.7. His family could see improvements with his vocabulary and overall functioning. He was tested again after another 18 sessions (total, 30 sessions) scoring 85 points (global cognitive score) on NeuroTrax, and then another time after an additional 30 sessions (Table). After 60 NFB sessions, his global cognitive score rose to 94.1

points on neurocognitive testing (Table). The patient's memory score was now 85.1, his executive functioning had reached 91.2 points, and his attention scored 86. His information processing speed (previously too low to score) now achieved 73.9 points, and his visual spatial score was above average at 118.6 points. In addition to marked improvement on the neurocognitive testing, academic performance in school had also accelerated.

QEEG testing before z-score LORETA NFB showed marked increase in frontal and central beta power (Figure 1). LORETA revealed an area of electrical dysregulation in the AC gyrus (Figure 2). Subsequent NFB sessions led to gradual improvement of the patient's school performance. After 12 sessions of therapy, QEEG findings indicated marked improvement of excessive beta activity (Figure 3). Further NFB therapy accomplished even better reduction of beta activity (Figures 4 and 5), and reduction of cingulate electrical dysregulation. However, some intermittent inter-session fluctuations of beta power were also visible during the course of the treatment.

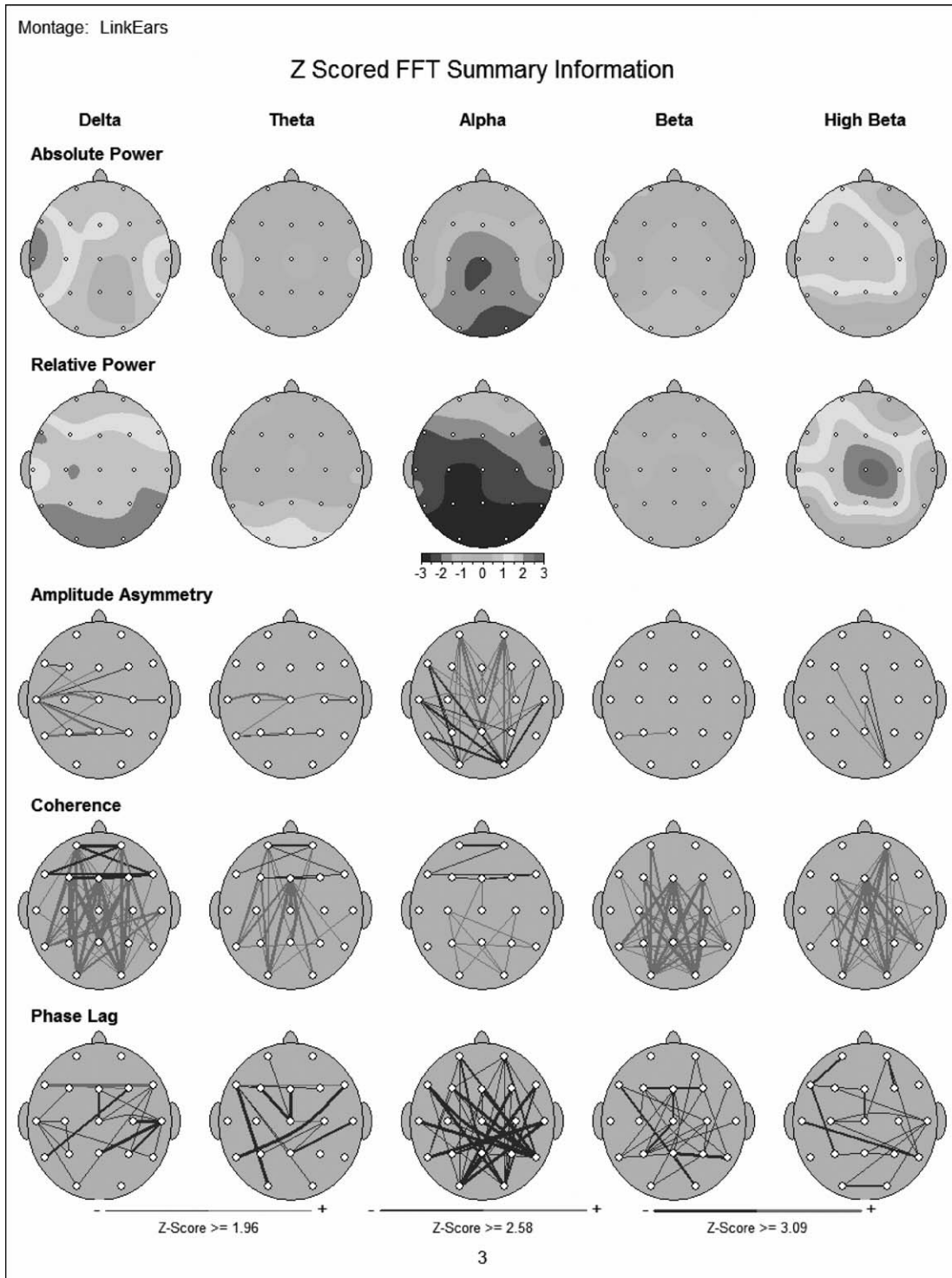


Figure 3. Quantitative electroencephalograph after 10 neurofeedback sessions. Marked reduction of frontal beta and high beta power was recorded.

Discussion and Conclusion

Our experience with z-score LORETA NFB delivers encouraging results for future use of this treatment modality in patients suffering from ADHD. The AC dysregulation seen in our patient has already been

previously implicated as a potential factor contributing to this disorder by other authors (Wang et al., 2013). Frequently encountered AC dysregulation of ADHD patients, as well as other potential targets (middle frontal gyrus, middle temporal gyrus, left precuneus), may be

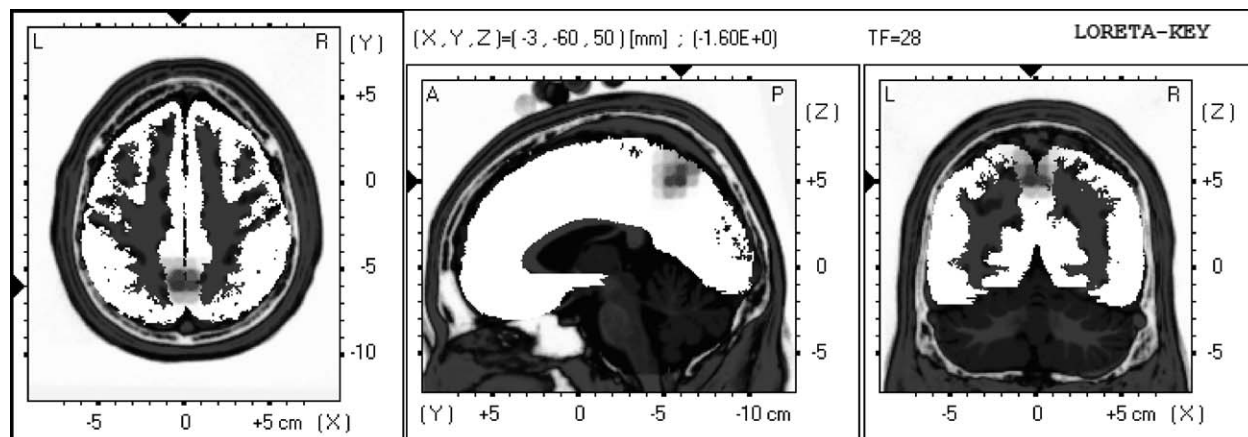


Figure 4. After 30 sessions of neurofeedback low resolution electromagnetic tomography analysis. Shows no evidence any longer of anterior cingulate electrical dysregulation.

targeted effectively and possibly corrected using LORETA NFB therapy. Individuals with ADHD subjected to z-score LORETA NFB therapy may benefit from as few as 10 NFB sessions. However, in order to fully benefit from this type of treatment, more NFB sessions are recommended, especially in those patients who present with initial low cognitive scores and who continue to improve.

References

- Arns, M., Gunkelman, J., Breteler, M., & Spronk, D. (2008). EEG phenotypes predict treatment outcome to stimulants in children with ADHD. *Journal of Integrative Neuroscience*, 7(3), 421–438.
- Berger, I., Slobodin, O., Aboud, M., Melamed, J., & Cassuto, H. (2013). Maturational delay in ADHD: Evidence from CPT. *Frontiers in Human Neuroscience*, 7, 691. Retrieved April 8, 2014, from: <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3829464/>
- Broyd, S., Helps, S., & Sonuga-Barke, E. (2011). Attention-induced deactivations in very low frequency EEG oscillations: Differential localization according to ADHD symptom status. *PLoS One*, 6(3), e17325. Published online March 8, 2011.
- Cannon, R., Lubar, J. F., Congedo, M., Thornton, K. A., Gerke, A., Kelsay, B. Higdon et al. (2007). The effects of neurofeedback training in the cognitive division of the anterior cingulate gyrus. *International Journal of Neuroscience*, 117, 337–357.
- Cannon, R. Lubar, J. F., Gerke, A., Thornton, K. L., Hutchens, T. A., & McCammon, V. (2006). EEG spectral-power and coherence: LORETA neurofeedback training in the anterior cingulate gyrus. *Journal of Neurotherapy*, 10, 5–31
- Di Michele, F., Prichep, L., John, E. R., & Chabot, R. J. (2005). The neurophysiology of attention-deficit/hyperactivity disorder. *International Journal of Psychophysiology*, 58(1), 81–93.
- Doniger, G. M. (2013). NeuroTrax computerized cognitive tests: Test descriptions. *NeuroTrax brain function made clear*. Retrieved April 8, 2014, from: <https://www.mindstreamshealth.com/docs/TestDescriptions.pdf>
- Koberda, J. L., Koberda, P., Bienkiewicz, A., Moses, A., & Koberda, L. (2013). Pain management using 19-electrode z-Score LORETA neurofeedback. *Journal of Neurotherapy*, 17(3), 179–190.
- Koberda, J. L., Moses A., & Koberda, P. (2012). Cognitive enhancement using 19-electrode z-score neurofeedback. *Journal of Neurotherapy*, 3, 224–230.
- Moriyama, T. S., Polanczyk, G., Caye, A., Banaschewski, T., Brandeis, D., & Rohde, L. A. (2012). Evidence-based information on the clinical use of neurofeedback for ADHD. *Neurotherapeutics*, 9(3), 558–598. Retrieved April 8, 2014, from: <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3441929/>
- National Institute of Mental Health. (2013). Attention Deficit Hyperactivity Disorder (ADHD). Retrieved April 8, 2014, from: <http://www.nimh.nih.gov/health/topics/attention-deficit-hyperactivity-disorder-adhd/index.shtml>
- Ogrim, G., & Hestad, K. A. (2013). Effects of neurofeedback versus stimulant medication in attention-deficit/hyperactivity disorder: A randomized pilot study. *Journal of Child and Adolescent Psychopharmacology*, 23(7), 448–457. Retrieved April 8, 2014 from: <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3779016/>
- Robbins, J. (2008). *A symphony in the brain*. New York: Grove Press.
- Thatcher, R. W. (2013). Latest developments in live z-score training: Symptom checklist, phase reset, and LORETA z-score biofeedback. *Journal of Neurotherapy*, 17, 69–87.
- Yuce, M., Zorogly, S. S., Ceylan, M. F., Kandemir, H., & Karabekiroglu, K. (2013). Psychiatric comorbidity distribution and attention deficit/hyperactivity disorder: A study from Turkey. *Neuropsychiatric Disease and Treatment*, 9, 1791–1799. Retrieved April 8, 2014, from: <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3833407/>
- Wang, S., Yang, Y., Xing, W., Chen, J., Liu, C., & Luo, X. (2013). Altered neural circuits related to sustained attention and executive control in children with ADHD: An event-related fMRI study. *Clinical Neurophysiology*, 124(11), 2181–2190.

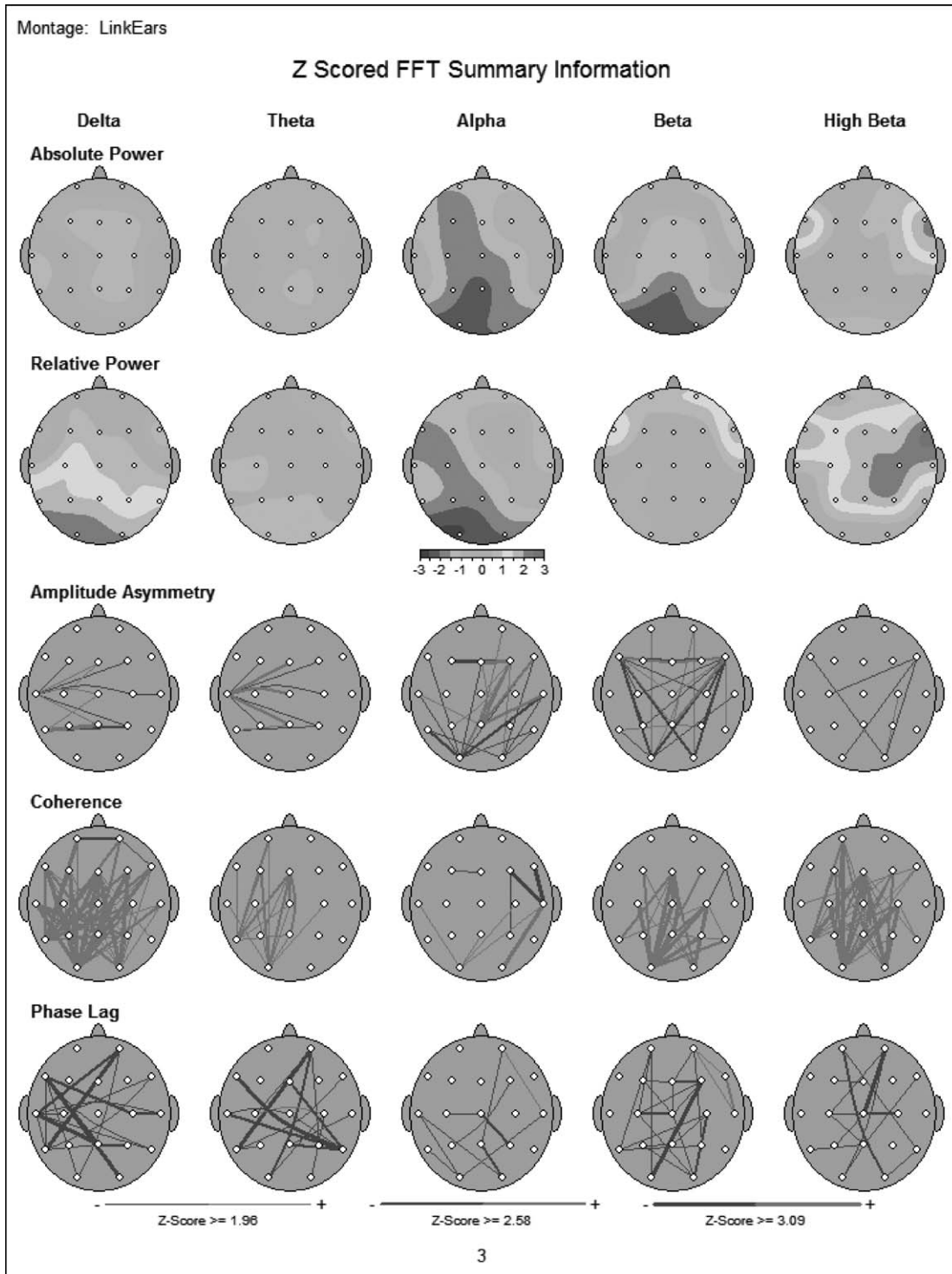


Figure 5. Quantitative electroencephalograph after 30 sessions of neurofeedback. Major reduction of frontal beta and high beta activity is noted (reduction of red [reduction of frontal gray area]).



J. Lucas Koberda



Paula Koberda



Andrew Moses



Jessica Winslow



Andrew Bienkiewicz



Laura Koberda

Correspondence: J. Lucas Koberda, MD, PhD, Tallahassee Neurobalance Center, 4838 Kerry Forest Parkway, Tallahassee, FL 32309, email: jkoberda@yahoo.com, Web: www.TallahasseeNeurobalanceCenter.com.
