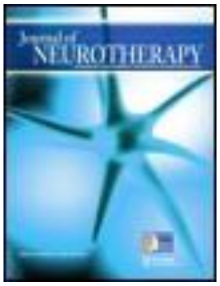

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Optimal Functioning Training with EEG Biofeedback for Clinical Populations: A Case Study

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ABSTRACT. *Introduction*. This case study of a mature female executive with Dissociative Disorder Not Otherwise Specified (DDNOS) demonstrates the Quality of Life Continuum (QLC) and the efficacy of specific EEG biofeedback protocols in enhancing performance and improving global life functioning for people with clinical disorders. The QLC begins with the functioning level of people with severe clinical problems and ends with superior functioning people, with three levels of functioning in between those two ends of the continuum. It is a graphic for demonstrating that any level of functioning can be improved through the use of protocols specifically designed for optimal functioning.

Method. Pre- and post-quantitative electroencephalograms (QEEGs) were done on the subject. Other measures of change were self-report and co-worker feedback. The subject was taught how to train independently with specific peak performance protocols. She did 60 fifteen-minute training sessions in two months.

Results. The changes in her QEEGs were measured by a comparison of her pre- and post-scores on the Thatcher Life Span EEG Reference Database. The subject went from 166 abnormalities with significance levels ranging from $p < .025$ to $p < .001$ to only 17 abnormalities. The subject reported significant life improvement changes, including increased energy and motivation. Among the changes cited by co-workers was a decrease in her anger outbursts from an average of three times per week to two times per month.

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Discussion. The independent use of neurofeedback with specific peak performance protocols can enhance the quality of life for a person with a clinical diagnosis.

KEYWORDS. Peak performance, optimal functioning, EEG biofeedback

INTRODUCTION

From its beginning the field of EEG biofeedback, both in research and clinical practice, has emphasized the treatment of various clinical disorders. Early pioneers in the field did research on utilizing EEG biofeedback in the treatment of such disorders as seizures (Sterman, 1982), Attention Deficit Disorder (Lubar, 1991) and anxiety (Hardt & Kamiya, 1978). Today, clinicians and researchers are using EEG biofeedback to treat a wide variety of other disorders as well: premenstrual syndrome (Noton, 1997), Dissociative Identity Disorder (Brownback & Mason, 1999), and depression (Rosenfeld, 2000).

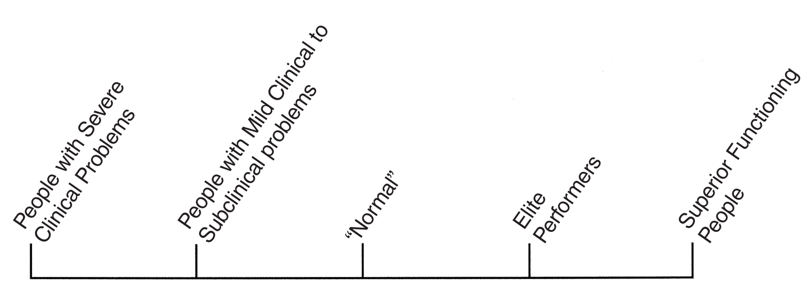
In addition to treating clinical disorders, there also has been research on the brain wave patterns of people with good to excellent performance in various activities, such as meditation (Bennett & Trinder, 1977), rifle shooting (Bird, 1987; Hatfield, Landers & Ray, 1984), creativity (Martindale & Hines, 1975), and aviation (Sterman & Mann, 1995). As with the clinical field, there has been some research on enhancing this well functioning to superior level of performance in archery (Landers et al., 1991) and academic performance (Rasey, Lubar, McIntyre, Zuffuto & Abbot, 1996). Such research supports the concept of peak performance training–performance in a specific activity can improve through the use of EEG biofeedback protocols designed to reward specific brainwave activity that is thought to enhance performance.

This paper looks at a new direction for peak performance training utilizing EEG biofeedback: to help people whose level of functioning is less than it could be due to a clinical problem, thus, the term "optimal functioning training." While the history of the field echoes the popular conception of peak performance training being only for people who are already functioning well to help them function even better, the actual definitions of peak performance training mirror the concept of optimal functioning training. For example, Garfield (1984) offers the definition of "orchestrating, engineering, training for 'optimal human performance.'"

The Quality of Life Continuum (Figure 1) can be used to demonstrate how optimal functioning training might enhance anyone's life. Peak performance protocols using EEG biofeedback could possibly allow a person with a severe clinical problem, such as Dissociative Identity Disorder, Borderline Personality Disorder, or fibromyalgia to have a quality of life comparable to a person with a mild clinical or subclinical problem. Similarly, a person with a mild clinical problem to a subclinical problem, such as generalized anxiety disorder or minimal relational problems might utilize peak performance EEG biofeedback to have a quality of life comparable to a "normal" person. The "normal" person could possibly use these biofeedback programs to become an elite performer in a specific endeavor or in everyday life. Finally, an elite performer might potentially raise everyday functioning to a superior level.

Thus, what distinguishes peak performance protocols from general EEG biofeedback applications are that they are not used to treat a particular problem, but rather they are used to enhance daily functioning or performance in a specific endeavor. While the peak performance protocols that are outlined below have been successfully used to enhance life quality with people at various points on this continuum, this paper focuses on the experience of one individual. Since she had numerous therapeutic experiences, including EEG biofeedback, to treat her clinical symptoms, her case study demonstrates the difference between treating her symptoms directly and focusing on life enhancement. The significant changes in her quality of life after optimal functioning training

FIGURE 1



Quality of Life Continuum

demonstrate the power of these specific protocols. Her pre- and post-QEEGs underscore the efficacy of these protocols.

METHOD

Subject. The subject was a self-referred, single, white female who was 49 at the time she began peak performance training. Her therapeutic history began at age 16, following a suicide attempt. She saw numerous therapists before being properly diagnosed, at age 29, as having Dissociative Identity Disorder (DSM IV, Axis I, 300.14). After ten additional years of therapy, she terminated individual therapy. Over the course of the next ten years, she pursued various self-help methods and focused on her spirituality (greater adherence to the tenets of her faith, increased time spent in meditation, etc.) as avenues for further reducing the dissociation and ameliorating other consequences of severe childhood sexual abuse. She also had approximately 50 neurotherapy sessions with a therapist four years earlier. The subject reported no change from those sessions.

At the time of the peak performance training, a diagnosis of Dissociative Disorder Not Otherwise Specified (DSM IV, Axis I, 300.15) was appropriate, as she no longer manifested individual personality states, a necessary condition for a diagnosis of Dissociative Identity Disorder. Her presenting status included an education level of a master's degree and being employed as an administrator for a health services company. She wanted to try the optimal functioning training to see if it would reduce her feelings of exhaustion, improve her mental flexibility, and allow her to be more consistent at applying the self-help techniques that she had learned.

Measures. Quantitative EEG assessments were done prior to the training and after 60 sessions. A Lexicor NeuroSearch-24 channel data acquisition machine was used with its Lexicor V151 software. An electrode cap from Electro-Cap International Incorporated was used to gather data from 19 scalp electrode sites in the standard International 10-20 montage, with linked ear lobes used as reference and the ground just forward of Fz. Scalp electrode sites were prepared until impedance for each channel was less than 5 K Ohms. The sampling rate was 128 samples per second with a 32 K gain; the high pass filter was off. Fast Fourier Transform filtering was used. The subject was seated upright and was instructed on the importance of reducing muscle artifact. Data was collected in both eyes open and eyes closed conditions. Following the EEG data collection, the data was visually inspected off-line to eliminate artifact prior to data analysis.

The Thatcher Life Span EEG Reference Database (Thatcher, Walker, & Guidice, 1987) was used to analyze the data. This database groups the brainwave activity into four frequency bands: delta (.5-3.5 Hz), theta (3.5-7.0 Hz), alpha (7.0-13 Hz), and beta (13-22 Hz). The database measures coherence, phase, asymmetry and relative power for 16 scalp electrode sites (Fz, Cz, and Pz are excluded). These computations result in 832 raw scores, which are then transformed into Z scores.

As training proceeded, the client's observations of changes in her quality of life and unsolicited comments from her coworkers were noted.

Training Procedures and Process. Since optimal functioning individual training sessions are done independent of a therapist, the subject was taught proper preparation techniques, using alcohol prep pads and Nu-prep. She was taught that impedance readings had to be less than 10 K Ohms and ideally be less than 5 K Ohms.

For the first two protocols, the active lead was centered above her nose at her hairline. (This location would be approximately Fpz in the International 10-20 nomenclature.) One ear lead was used as the ground; the other, as the reference. Training was done on a Lexicor Neuro-Search-24 channel machine, using Biolex software. Training sessions were done in an open office, as the lack of a quiet, private training forum reinforces the goal of optimal functioning training: to be able to function well in any setting. For the same reason, all training was done with eyes open.

Each session was fifteen minutes in length. The subject was taught about the various brainwave bandwidths, the objective of the training protocol, and how to adjust the feedback for optimal learning. She was instructed that for all training sessions she was to begin each session by reminding herself of the goal of the particular program being used in that training session. During the training session she was to focus on breathing diaphragmatically and simply to watch the screen. Should her mind wander, she was to use her breathing to help her refocus on simply watching the screen.

The subject did ten sessions in which the visual goal (what was displayed on the screen) was to decrease 4-8 Hz activity, and the auditory feedback was for decreasing 4-8 Hz and for increasing the percentage output of 11.5-13 Hz. These ten sessions were followed by ten sessions in which both the visual and auditory goals were to decrease 4-8 Hz and to increase the percentage output of 11.5-13 Hz. This protocol was followed by ten sessions in which the visual and auditory goals were to increase 8-13 Hz activity and to increase the percentage output of 8-13 Hz activity. (These three programs were done using digital filters of the 8th order butterworth design.)

The subject then did ten each of 8-13 Hz phase, coherence, and phase and coherence training. Typically in peak performance training, one attempts to increase phase and coherence; however, this subject's initial QEEG indicated these programs should be revised for her. Thus, her visual display goal was to decrease phase for 8-13 Hz between a lead placed at the edge of her hairline on her right forehead and a lead placed at T3, with linked ears as the reference and the center of the forehead as ground. The auditory feedback was for decreasing phase. Similarly for the next ten sessions, the visual goal was to decrease coherence for 8-13 Hz at the same locations, with a corresponding auditory goal. The last ten sessions had a visual goal to decrease phase and coherence for 8-13 Hz at the same sites, with a corresponding auditory goal.

For these three programs Fast Fourier Transform filtering was used. Phase was computed as the phase angle difference between two channels using the phase component of the Fourier transform. Coherence in this training software was a spectral correlation: a correlation coefficient measure between two frequency magnitude spectrums within the 8-13 Hz frequency range. (Spectral correlation measures functional coupling by measuring the qualitative similarity of two sites in terms of spectral distribution and morphology.)

RESULTS

The training produced subjective self-report changes and co-worker feedback of changes, as well as changes in her pre- and post-QEEGs. Table 1 categorizes the changes in her QEEGs as evidenced by her scores on the Thatcher Life Span EEG Reference Database. In this database, coherence "is analogous to a cross-correlation coefficient in the frequency domain and thus is a metric of the amount of shared activity between two regions, while phase is a measure of the lead or lag of shared rhythms between two regions," (Otnes & Enochson, 1972; Thatcher, Walker, Gerson, & Geisler, 1989). Asymmetry reflects power differences between sites and was derived from the formula (left − right/left + right) for the inter-hemisphere comparisons and (anterior derivation − posterior derivation/anterior + posterior derivation) for

TABLE 1. Pre- and Post-QEEG Abnormalities Using the Thatcher Life Span EEG Reference Database

	Delta			Theta			Alpha			Beta	
Coherence	**Pre**	**Post**		**Pre**	**Post**		**Pre**	**Post**		**Pre**	**Post**
Left Intrahemisphere	17	0		15	0		11	0		16	1
Right Intrahemisphere	20	0		16	0		12	1		17	5
Homologus Intrahemisphere	5	0		4	0		1	0		5	1
Phase											
Left Intrahemisphere	0	0		0	0		0	0		1	0
Right Intrahemisphere	0	6		0	0		0	0		0	1
Homologus Intrahemisphere	0	1		0	0		0	0		1	0
Asymmetry											
Left Intrahemisphere	1	0		0	0		5	0		0	0
Right Intrahemisphere	1	0		0	0		3	0		0	1
Homologus Intrahemisphere	0	0		0	0		0	0		0	0
Relative Power	11	0		0	0		4	0		0	0

(Significance levels of abnormalities ranging from $p < .025$ to $p < .001$).

intrahemisphere comparisons (Thatcher et al., 1989). Finally, the absolute relative power was computed in μV^2.

The subject went from 55 abnormalities with significance levels ranging from $p < .025$ to $p < .001$ in the delta band to 7, from 35 to 0 in the theta band, from 36 to 1 in the alpha band, and from 40 abnormalities in the beta band to 9, for a total decrease of 149 abnormalities. There was an increase of seven phase abnormalities in the delta band. There was one new phase abnormality in beta and one asymmetry abnormality increase in beta.

Besides the changes in the QEEG, the subject reported several lifestyle changes, which she had long wanted, but had previously been unable to achieve consistently. By the end of the training she had lost 20 pounds, which she attributed to eating less due to better impulse control and exercising three times per week. (Prior to training she had exercised sporadically once or twice a month.) The quality of her meditating changed, as she experienced synergy between her spiritual reading, the content of the meditations and life application.

The change that had the most meaning to her was an increase in energy. She explained that prior to the neurofeedback, she was efficient and effective at work, but at the end of her workday, she would consistently collapse in front of the television before going to bed. Now she could finish a workday and still have time and energy to enjoy a satisfying personal life.

Finally, she experienced an increased tolerance for stress and frustration. Both she and her co-workers reported her being more pleasant, patient and cooperative. For example, co-workers said that there was a fourfold increase in how often she smiled. Also, she became angry less often: in the past she would become angry three to four times per week; after the training, her anger flared only once or twice a month. She felt that part of the improvement in coping with frustration was due to obsessing less: whereas an upsetting work event would have previously been mulled over for one to three hours, she could now shift to a more productive focus in less than 20 minutes.

DISCUSSION

All of the training programs used in this case study involve the prefrontal cortex, "the executive of the brain" (Fuster, 1999). The Fpz location for programs one, two and three were chosen because the prefrontal cortex is essential for the "temporal organization of behavior and spoken language" and for the "organized action in rational thinking" (Fuster 1999).

The phase, coherence, and phase and coherence programs also involved the prefrontal cortex. The T3 location was chosen because we were seeking to do interhemispheric training at a location that the client could easily locate independently, yet sufficiently far from the prefrontal cortex to have the program involving more cortical structure. This goal reflects Banquet's research that advanced meditators achieve a "synchronization of anterior and posterior channels" (Banquet 1973) and that of Hatfield et al. (1984), that the cognitive processes of skilled marksmen demonstrates a rapid shifting between the right and left hemispheres in the process of shot preparation and execution.

The goals of the first two programs, to decrease 4-8 Hz activity and increase the percentage output of 11.5-13 Hz, were based on research by Sterman, Mann, Kaiser and Suyenobu (1994), Sterman and Mann (1995), and Rasey et al. (1996). The former demonstrated that as mental challenge increases there is a corresponding suppression of 8-12 Hz activity; and the latter, that training to decrease 6-10 Hz activity can improve attention to a task. Our hypothesis was that rewarding a suppression of slow wave activity and an increase in the upper band of alpha activity would result in an increased ability to concentrate with less mental exertion to do so. The client's self-report of increased energy without any deterioration in her professional performance would support that such a change occurred, as would the reduction in her slow wave activity on the pre- and post-QEEGs.

Program three, increasing 8-13 Hz and the percentage of 8-13 Hz, was intended to continue to enhance her workload mastery (Sterman, Mann et al., 1994; Sterman & Mann, 1995) and decrease anxiety. Perhaps one reason that she did not report any noticeable help from this program was that as Hardt and Kamiya (1978) noted only high anxiety subjects reported a reduction in anxiety with EEG biofeedback and the client was not experiencing anxiety as a problem.

The original intention of the remaining three programs of increasing phase, coherence and phase and coherence for 8-13 Hz was to provide calming and increased physical and mental stamina, since advanced meditators experience alpha synchrony (Banquet, 1973) and since, as Jevning, Wallace, and Boederbach (1992) have noted, such meditators experience being in a simultaneously very relaxed and very alert state and experience such physiological changes as increased cerebral metabolism, decreased heart rate, lowered blood pressure, and decreased respiration rate. However, when the client began to attempt to increase phase, she reported becoming "weepy and irritable" after only three fifteen minute sessions.

Since the training data showed both her phase and coherence to be averaging 85% or higher during those sessions, we decided to have her be rewarded for attempting to reduce phase. She experienced a return to her previous level of emotional functioning within two sessions and by the end of the remaining 25 sessions for the last three programs she was reporting a decrease in anger and an increase in mental flexibility.

The changes in the subject's quality of life, as reflected in her self-report and her coworker's observations, demonstrate the movement possible on the Quality of Life Continuum through the use of neurofeedback for optimal functioning training. The changes in her QEEG results suggest that these changes reflect some change in cerebral functioning. Since increased coherence reflects, "reduced functional differentiation or increased functional redundancy between neuronal systems" (Thatcher et al., 1989), the reduction in her coherence abnormalities from 129 to eight support the subject's experience. The pre-training relative power abnormalities in the delta band were all in the positive direction: might the reduction in excessive slow wave activity be related to the increases in energy?

One limitation of this study is that the retesting was done at the end of 60 sessions, rather than at the end of each peak performance protocol, so one cannot be certain if one program, combinations of programs, or all the programs are responsible for the changes in her QEEG results. (A clinical research study is currently being finished which reflects the gains made only in the first two programs.)

The subject's subjective experience was that programs one and two brought the most life change: the effort to reduce frontal theta and at the same time remain calmly focused and centered gave her an ease, clarity and energy previously unavailable. She did not experience much change from the program to increase alpha and percent alpha. However, she did report that the programs for coherence, phase and synchrony gave her a significant increase in mental and emotional flexibility: she no longer found herself getting "stuck" in an emotion or thinking pattern.

Another limitation is the lack of objective measures of the changes in the subject's life. Since this individual experience, we have added psychological tests to the pre- and post-testing of subjects. We also have clients and their significant others and/or co-workers create rating scales of behaviors of their choosing to help quantify the life changes that they experience from the training.

While these limitations limit the conclusions that can be drawn from this single case study, the QEEG changes, along with the changes the subject and her co-workers observed, suggest that other clinicians might wish to utilize these protocols to determine if their clients experience similar gains in quality of life functioning.

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