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SPECIAL ISSUE

Post Traumatic Stress Disorder—The Neurofeedback Remedy

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The application of neurofeedback to post traumatic stress disorder (PTSD) in returning veterans is described herein and is illustrated with two case histories. Initially, frequency-based electroencephalogram training was employed to promote functional recovery, in the manner of the traditional sensorimotor rhythm/beta approach. An optimization procedure was employed in which the reinforcement frequency is tailored to the client on the basis of symptom response, with particular regard for the regulation of arousal. Low frequencies, down to .01 Hz, have been found especially useful in the remediation of post-traumatic stress disorder. This training was complemented with traditional alpha-theta work as pioneered at the Menninger Foundation and by Peniston. The objective here is experiential, because prior traumas typically are revisited in a nonforced, nontraumatic manner. The benign witnessing of traumas consolidates the experience of safety for which the prior training laid the groundwork. Collectively, this approach has been found to be much better tolerated than traditional exposure therapies. In addition, it is helpful in the shedding of substance dependencies that are common in treatment-resistant PTSD

Introduction

Neurofeedback protocols have continued to evolve in clinical practice to cover domains of function that were not originally envisioned in the application of sensorimotor rhythm/beta (SMR/Beta) training to seizure management and attention-deficit/hyperactivity disorder. The breadth of applications is now such that our thinking with respect to neurofeedback should not be organized around specific clinical conditions at all. It may be argued that neurofeedback impinges on entire regulatory systems, and these now include not only the domain of cognitive and executive function but of emotional control, autonomic regulation, and interoception as well. This opens the door to the remediation of conditions such as post-traumatic stress disorder (PTSD) that involve rather global dysregulations in the "body-mind."

The human regulatory regime can be modeled as a network, quite irrespective of whether we are speaking of the neural networks specifically. And if we impinge upon the functional organization of our neural networks through feedback, then the effects are communicated to the entire regulatory network through both synaptic and nonsynaptic interactions. Advantage is taken of the high level of functional integration of our regulatory regime. Hence, neurofeedback is a candidate approach even if matters concern primarily autonomic dysregulations that, to date, have been the domain of the standard peripheral biofeedback approaches. A choice between them must be made on the basis of relative clinical efficiency rather than of mere efficacy.

The most characteristic and troublesome symptom of PTSD is that of reexperiencing, and this involves an evocation of the original system response to the trauma in all its particulars. By virtue of the salience of the original trauma, the entire event is registered in the body-mind as a unitary memory. (There is survival value in the trauma being remembered permanently, so in that sense the system is working as it should.) Subsequent recall of the event then involves the whole memory, including not only the specific, explicit "event memory" but also the accompanying implicit "state memory" that is diffusely registered throughout the body. With a concatenation of traumatic events, the body-mind eventually accommodates to a perpetual state of anticipating threat, at great cost to the person's well-being and functionality. Unsurprisingly, this state of readiness typically defies therapeutic attempts to effect its extinction because it is grounded in our most basic survival mechanisms.

The remedy lies in giving the body-mind the visceral experience of calmness to which it no longer has access, and in reinforcing that state to the point where the body can once again live there in the steady state. Cognitively based methods don't accomplish this task very well. A psychophysiological approach is called for. Neurofeedback is one such approach, and in the following we report on our experience using this method.

Models for Neurofeedback Intervention

Neurofeedback lends itself to this task for several reasons. First of all, it is a ready means for shifting the arousal level of the trainee in a controlled fashion. Second, in contrast to biofeedback techniques, the control is bidirectional—one can move the person up or down in arousal level arbitrarily. Third, with neurofeedback one is operating in a much larger variable space than is the case with peripheral biofeedback. The whole frequency range of the electroencephalograph (EEG) is available, as well as all scalp locations. This provides the opportunity for both specificity in the pursuit of training objectives and the fine-tuning of the particulars. That allows the process to be implemented with a finesse that simply is not available with other methods.

Inevitably, of course, the availability of a large variable space has resulted in the proliferation of clinical methods to exploit the new feedback possibilities that have opened up. An attempt to categorize all of the major approaches has just been published in a book chapter (S. Othmer, 2008). For present purposes, however, a different classification is appropriate. Broadly speaking, neurofeedback approaches either target specific dysfunctions that are observable in the EEG or they promote function more generally. In practice, these disparate approaches are often combined.

These two basic approaches each have their relative strengths. The specific targeting has its advantages for conditions with a strong cortical representation, such as specific learning disabilities. The more general mechanisms-based targeting is appropriate for the deeper, more diffuse, more thorough-going, and nonspecific dysregulations that characterize many of the mental health issues that have been hitherto intractable. PTSD falls in the latter category.

In our application of mechanisms-based training, we orient primarily to the person's state of arousal. Reference here is to tonic rather than phasic arousal, and even though our immediate observations indicate arousal state, we are really interested in trait arousal. The neurofeedback challenge gently moves the person in level of arousal to permit exploration of his or her "state space." The immediate objective is to find the person's comfort zone, the point at which the challenge of neurofeedback can be best tolerated going forward. This comfort zone is highly individual, and indexes for us the person's intrinsic trait arousal level (Othmer & Othmer, 2007).

The analogy to "still-point" training in movement therapy may be helpful here. Feldenkrais (1949) found that small excursions around the point of ease served to reorganize the control of movement in a gentle and unforced manner. What Feldenkrais accomplished externally we are accomplishing in top-down fashion via the EEG. In both instances, the exercise serves to improve regulatory capacities more generally. Motor function is the observable for Feldenkrais; arousal regulation is the observable for us.

Arousal, as we use the term, can be thought of as a composite of many specific activations, for example, cognitive arousal; autonomic arousal and balance; excitability of our sensory systems; set-point of motor system excitability; and activation of the executive control system. The most basic of all of these systems, and perhaps for that reason the most obscure, is the state of our emotional ambient, related to our intrinsic sense of safety in the world. The strongest inputs to our brainstem arousal regulation mechanisms are from the limbic system.

Systemic Approaches: Alert State Training

With every potent neurofeedback challenge we affect the state of arousal in general, and by means of specific electrode placements we can bias the training toward certain system activations. In the case of PTSD, for example, we bias the EEG feedback training toward the right hemisphere, which is dominant for the organization of our affective domain. Physical calming is achieved by targeting the right parietal region; emotional calming and stability are targeted with right prefrontal training. Other placements may be included for other aspects of dysfunction. All right-side trainings employ T4 as a common reference in bipolar montage, and all left-side trainings employ T3 as a common reference. Overall system stability is promoted with the interhemispheric bipolar placement T3-T4.

The reward frequency is adjusted during the first session to the state in which the person is maximally calm, alert, and as euthymic as the nervous system is capable of being at that moment. The fine-tuning is done on the basis of client report on their own status. This approach is often referred to as optimum reward frequency (ORF) training. The reward frequency can be anywhere in the EEG frequency range below nominally 45 Hz, but it tends to be very low in PTSD, extending down to as low as .01 Hz. The use of rewards set at such low frequencies is a relatively new emphasis in our approach to neurofeedback, discussed in greater detail in S. Othmer (2008).

At such low frequencies, one may well ask whether we are still targeting the EEG or whether we are interacting with peripheral physiology. Operationally, of course, it does not matter. All that can be said at this point is that the behavior we observe is on a complete continuum with what we observe at higher EEG frequencies. In particular, the narrowness of the optimum frequency range can be quite striking in both domains. A person who responds well to .02 Hz reinforcement may respond less well to .04 Hz and .01Hz. At higher frequencies, a person who responds well to 14 Hz reinforcement may respond less well to 13.5 and 14.5 Hz. We therefore appear to be interacting with a resonant system (which is how the EEG is organized) in both domains. Additionally, a recent publication speaks of the EEG rhythmicity being observable down to .01 Hz (Kelly, Uddin, Biswall, Castellanos, & Milham, 2008).

A very practical issue arises of how one gives good feedback on such low-frequency signals. The utility of the low-frequency training actually was uncovered with the same instrumentation that is used at higher reward frequencies. In both cases, the client is only given information on short-term changes in the EEG signal. The brain is biased in favor of the detection of change, and thus to the highest frequency components of the reward signal. In order to make the brain sensitive to the slower components of the EEG, the higher frequency components have to be masked. As in heart rate variability training, attention focuses on the moment, but ultimately, the entire low-frequency waveform is affected by the experience.

Systemic Approaches: Deep State Training

The second phase of our approach to PTSD is essentially the alpha-theta training pioneered at the Menninger Foundation and first formally investigated for PTSD by Eugene Peniston (Peniston & Kulkosky, 1999). In our implementation we employ two-channel sum training at P3 and P4 to promote global synchrony in the parietal and occipital region. The nominal theta band is centered on 7 Hz and the alpha band is centered on 10 Hz for most individuals.

The principal objective here is experiential. Alpha and theta synchrony moves the person to deactivated states and promotes disengagement, particularly under the eyes-closed conditions in which the session transpires. The state silences the inner verbal censor and it expands the dimensions of self-awareness. The state is experienced nonlexically, that is, in terms of imagery. Trauma-related imagery that arises in this context typically does so without evoking the usual physiological response. The benign experience of the trauma event essentially reprograms the memory as a merely historical one. The success of this strategy, as well as the relative absence of abreactions, is attributable to the fact that the ground has been prepared by the prior alert-state training to acclimate the nervous system to living in calm states. The training program is illustrated by the following two case histories.

Two Cases of PTSD

We are providing neurofeedback to veterans with PTSD at no cost as part of our nationwide program of participating neurotherapists, Homecoming for Veterans. In return, some veterans are giving us the right to talk about their cases in detail. One allowed his entire training experience to be videotaped for the benefit of other neurofeedback professionals. This case is presented briefly below in order to illustrate the flow of the work.

Case One: "K."

K. is a Canadian veteran of the Bosnian conflict. He had been through 10 years of various conventional therapies for PTSD, but in the course of these his deepest traumas could never be touched. His wife initially discouraged his participation in neurofeedback, fearing yet another disappointment. The early history of this person disclosed that he was born prematurely and spent the first 3 weeks in an incubator, with possible implications for early attachment. Later in life he experienced a concussion in an automobile accident, which is likely to have been a psychological trauma as well as a physical one. Both of these may have served as priming events for the subsequent trauma formation.

The initial evaluation disclosed the following primary symptoms: flashbacks, panic attacks, phobias, daily headaches, hypervigilance, mood swings, anxiety and depression, fatigue, anger, chronic body pain, tinnitus, bruxism, irritable bowel, asthma, hand tremor, nail biting, poor memory and concentration, and a tendency to bump into things while walking. He complained of fitful sleep (3 hours at a time), nightmares, and night sweats. He reported out-of-body experiences. There was also a problem of binge drinking, and K. exhibited a lack of appetite awareness. He scored four standard deviations below norms on omission errors, and two standard deviations below norms on variability of reaction time. Medications included Remeron for depression; Zopiclone for sleep; Clonazepam for anxiety; Flovent for asthma; and Tramacet for pain. Ongoing therapies included massage and chiropractic.

The burden of the first neurofeedback session is to characterize the response of the nervous system and find the optimal training conditions. K. came into the session with a headache and with body tension in the back and hands. He complained of back pain and fatigue. These symptoms are used to judge the quality of the training. The initial placement of T3-T4 is commonly used to establish the optimum reward frequency. The first trial reward frequency was 9.5 Hz. After 3 minutes K. reported reduced tension in the jaw. His headache had moved and decreased in severity.

He felt calmer and more awake. After 3 additional minutes at 8.5 Hz his headache was mostly gone; his hands felt less tense; and he felt more calm and relaxed. After 3 additional minutes at 7.5 Hz, K. felt that back tension was reduced, and he continued to feel more awake. After 3 minutes at 6.5 and 5.5 Hz the back was no longer tense, although it was still sore. After 3 minutes at 4.5 Hz, K. felt some anxiety in the chest and throat. This was possibly better after 3 minutes at 3.5 Hz and nearly gone after 3 minutes at 2.5 Hz. However, now K. complained of eyestrain. This was reduced after 3 minutes at 1.5 Hz. After 3 minutes at 1 Hz, K. reported increased salivation, and after 3 minutes at .5 Hz, then at .25 Hz, and then at .1 Hz, he felt positively hungry. He had not eaten all day. The final training epoch took place at .05 Hz, after which K. felt very relaxed, lighter physically and mentally, and his eyes betrayed the hint of a smile.

On the basis of this initial training experience, subsequent training sessions focused on the very low frequency range. Significant training milestones included the following: After this first session he was able to go to the grocery store, where he was previously troubled by spatial disorientation. His headache did not return, but he came to the second session with neck pain. This was eliminated with 10 minutes of training in the parietal region (P4-T4). No pain was reported after the second session; no need for a nap; tremor was reduced; no nightmares or night sweats—very unusual. After the third session, the sight of garbage bags in the building elevator triggered a flashback. After Session 5 the same scene elicited no reaction.

Alpha-theta (A/T) training was introduced at Session 8. He felt "strangely calm" after the session, and pronounced it "awesome. I can't wait to do it again." Memories came up for him without emotional reaction. He saw the images dissolve in water. He was very energized after the A/T session. He boldly took a trip to Walmart, which went fine until beeping at the checkout counter reminded him of mine detectors. K. went deeper in the second A/T session, reporting a visit from his deceased grandfather. The session reactivated a pain in his right leg. After this session he slept through the night for the first time since beginning the training. The next A/T session was accompanied by muscle pain everywhere. New memories were coming up and being processed.

Seeing the homeless people around the office begging for food triggered a flashback. And seeing a car accident on a mountain highway took him back to Bosnia. After Session 11 he reported smoking less—out of habit more than felt need. He started to feel a need to be creative. After Session 13 he reported feeling "like a million bucks." He planned to go to a movie theater that evening for the first time since he had his first panic attack in a movie theater.

The subsequent pattern was to train alternately with A/T and the alert-state training. At Session 14 he was able to talk about the war. K. also reported less obsessive-compulsive disorder–type checking and rechecking. Alpha-Stim™ Cranial Electrotherapy Stimulation treatment was added between sessions for increased calming. At Session 18, K. reported "craving" a return to neurofeedback after the weekend off. He also was craving the A/T training. As the training drew to a close with Sessions 24 and 25, K. experienced the return of some anxiety about the return home. A pre-post symptom comparison is shown in the Table.

Essentially, all of the symptoms of which K. complained at the outset are robustly on the path toward resolution. The Continuous Performance Test was completely normalized. We would like to have had 40 sessions, but already after 25 sessions K. was moved to tell us: "Thank you for my new life." He had mastered traumas that he could never even broach during earlier therapies, and they had largely left the stage effortlessly. K.'s training is ongoing on a home-training basis to further consolidate his gains.

Case Study: "A."

The second veteran was more challenging, a Marine with a tough outer shell—a warrior's warrior. He came into the program drinking excessively and with no intention of altering his behavior. Normally we would not take such a person, because we cannot provide the complementary services of a residential treatment program, but we had committed to accepting all comers among veterans. This man had gone into Iraq with the initial assault, and he lost most of his buddies either in that campaign or later back home.

During the training his wife continued to support A. in his drinking habits because she found him nicer to be around. The perceived short-term benefits of drugs and alcohol are a reality to which we must accommodate. The initial burden of training is to take the nervous system to such a place of stability, functionality, and ease that the benefits of taking drugs are no longer seen as compelling. This objective was only beginning to be met for A. when his initial set of training sessions drew to a close. The schedule was inflexible because A. was traveling a significant distance for the treatment.

Initial complaints included hypervigilance, nightmares (3 per week), panic (1 per week), flashbacks, anger, mood swings, anxiety/depression, visual sensitivity, tinnitus, episodic hypertension, poor appetite awareness, and headaches with

Table. Pre-post comparisons of symptom severity for veteran K. before and after 24 sessions of neurofeedback	
Pretraining	**Posttraining**
Flashbacks commonplace	Flashbacks less often, less severe, shorter
Nightmares commonplace	Only one nightmare since training began
Night sweats commonplace	Only two night sweats since training began
Tunnel vision leading to panic	Less risk of panic; some precursor symptoms
Hypervigilance	Largely subsided
Sleep period of 3 hours	Sleeping through the night; reduced meds
Out-of-body experiences	No further reports
Bruxism	No longer using mouth guard
Binge drinking	No urge to get drunk
Depression	Depression much improved; still on meds
Tinnitus	No report of tinnitus
Hand tremor	Tremor only apparent when stressed
Irritable bowel syndrome (IBS)	IBS much improved; eating in restaurants
Asthma	Forgetting asthma meds without penalty
Obsessive-compulsive disorder	Only “checking” once a day at bedtime
Appetite awareness	No longer an issue
Headaches commonplace	No headaches after optimization of training
Body pain obtrusive	Body pain much reduced
Nail biting	Nail biting has ceased
Poor physical coordination	Less clumsy
Fatigue	No complaints of low energy
Mood swings	Remediated
Memory and concentration	Improved

exertion. At 24 sessions, the nightmares were resolved and flashbacks were receding as an issue. He felt more optimistic about life. However, many symptoms remained, and he agreed to additional training. The ORF was .05 Hz.

This case remains of particular interest because it illustrates the substantial resolution of core symptoms of PTSD even in the context of continuing abuse of alcohol. In the case of Peniston's work, the finding was typically of the joint resolution of PTSD and of alcoholism. In this case, the progress in training was documented with pre-post single photon emission computed tomography (SPECT) scans, which were done at the Amen Clinic in Newport Beach, California. These are shown in the Figure. The most obvious changes in the SPECT consisted of reduced overactivation of the anterior cingulate, the basal ganglia, and the cerebellum. Overactivation remains at the thalamus, which could indicate a residual propensity to depression.

In a subsequent training sequence, conducted after the post-SPECT were taken, A. was much more future oriented, and he was beginning to acknowledge his drinking habit as a problem. Again, however, the training epoch was limited in time, and more training is needed.

Discussion

Both of the above cases illustrate the essential features of our approach to resolving PTSD. The immediate target is a general improvement in self-regulatory capacity, using protocols to which every nervous system responds.

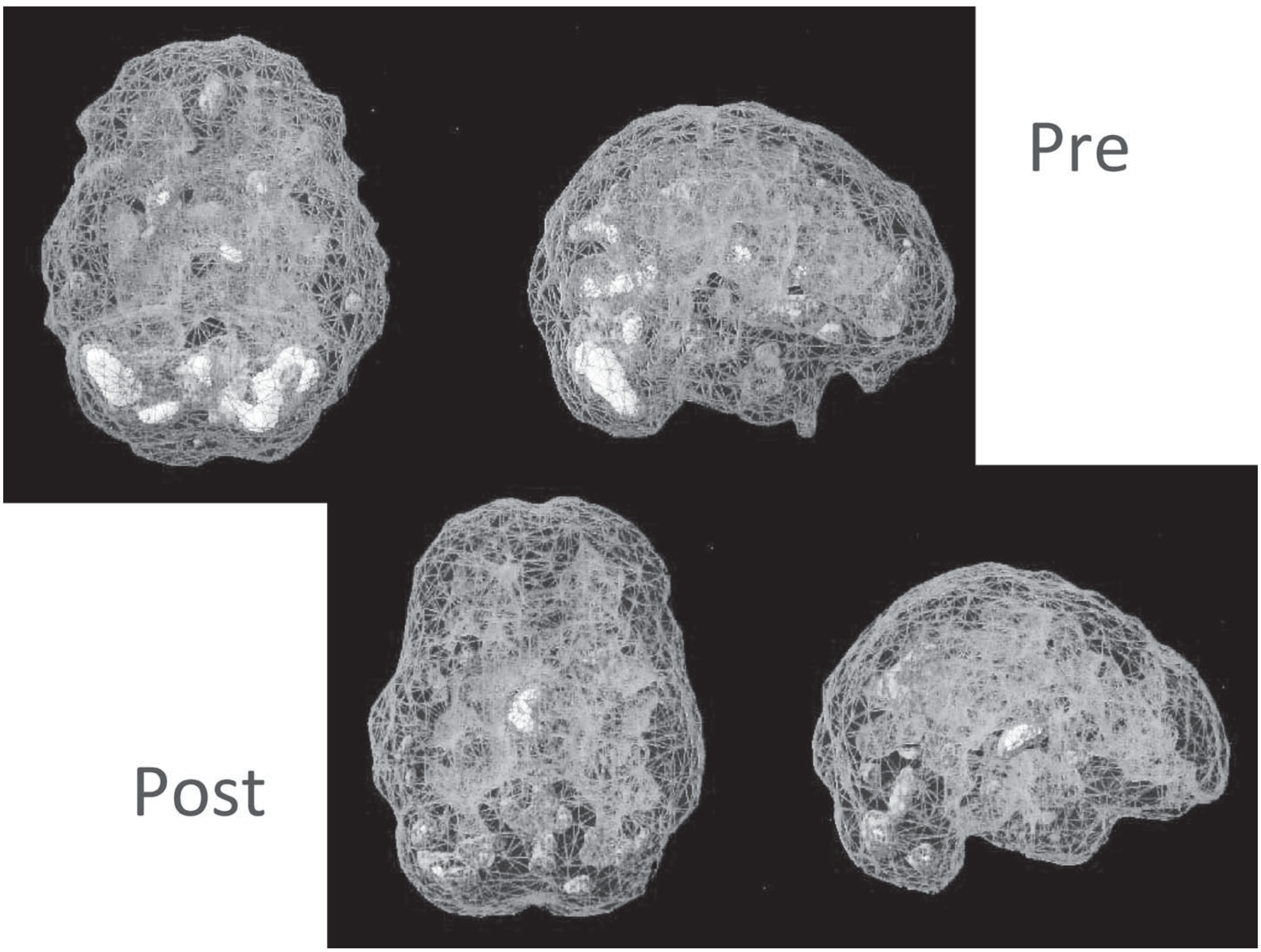

Figure. Pre-post single photo emission computed tomography scan data are shown for veteran no. 2, comparing pretraining conditions with those prevailing after 24 sessions. Classic signs associated with post traumatic stress disorder include elevations in activity at the anterior cingulate, the basal ganglia, and the thalamus. In posttraining data, the activity level at the anterior cingulate and basal ganglia are reduced. Additionally, the high activation of the cerebellum has been reduced. A color version of this figure can be found at http://www.aapb.org/magazine.html.

The guiding philosophy is that better function displaces dysfunction. Symptoms are merely the guideposts of progress; they determine the training procedures only in a very general way. One can think of this as a kind of "zone defense" approach to neurofeedback, in which certain functional domains are targeted in training rather than specific symptoms. Of course symptoms are relied upon to judge training priorities, and finally, outcomes, in addition to the guiding of optimization procedures in the moment.

In the initial thrust toward functional optimization, three or four basic protocols cover the ground and a subset of these is used with nearly everyone. The implication is that successful neurofeedback impinges upon the quality of communication of our neuronal networks in a very general, almost universal fashion. The brain is subtly challenged in its organization of timing and frequency, and the whole system of synaptic information transport is affected in consequence by virtue of its tight integration (S. Othmer, 2007). We get to observe the outcome of this process through explicit functional testing and the subsidence of symptoms.

The use of protocol-based approaches in neurofeedback has been well established since the very origins of the field. The principal novelty that has recently been brought to this approach is twofold: (a) individual optimization of reinforcement parameters; and (b) the extension of the work to very low EEG frequencies. The optimization strategy is its own justification. At nearly every session, an A/B comparison is made in which adjacent reward frequencies are compared in their effects on the trainee within the session, and different placements are evaluated as to their differential effects as well. This sequential and progressive optimization strategy brings the discipline of an internally controlled design into every neurofeedback training.

The extension of the work to low EEG frequencies simply follows from the first, an extension of the optimization procedure to wherever it might lead. The high "productivity" of the low-frequency challenge in neurofeedback, whenever such training is appropriate, is quite striking and begs for an explanation. One has the sense that the low frequencies may be foundational in the organization of the frequency relationships in the EEG. It is only at the low frequencies that we can even talk about persistent states. Organizing the continuity of states is one of the fundamental challenges for the brain. Much of psychopathology can be framed in terms of an inability of the brain to maintain continuity of function. And on the other end of the functional continuum, working memory capacity can similarly be modeled in terms of maintaining continuity of state under a challenge.

When it comes to the deepest and most thorough dysregulations of cerebral function, the disorder takes us right to these foundational frequencies upon which our cerebral symphony is constructed. Tracking symptoms is a sure way of directing our attention to the part of the frequency domain that is most in need of our attentions. It should come as no surprise that attention to how the nervous system actually responds to our intervention in the moment could lead us to the most effective training strategies.

If this picture is valid, then what we have found to be true for PTSD should have much broader clinical validity, and that is indeed the case. PTSD is at the extreme end of a continuum of responses to trauma. Dissociative identity disorder, borderline personality disorder, and reactive attachment disorder are other extreme manifestations of the same phenomenon. If early attachment does not develop as nature intended, the adverse consequences involve not only our emotional regulation but also the arousal regulation system, and from thence autonomic regulation and the whole orchestration of cerebral function. Unsurprisingly, this will manifest most obviously in those EEG frequencies that are the first to organize in the infant brain, those that underlie our persistent states.

If the brain is not able to maintain functional continuity at these low frequencies, the individual is much more vulnerable to subsequent insult, whether that be minor traumatic brain injury or psychological trauma. The statistics emerging from our clinical practice and that of others using these methods is that more than half of typical clinical populations optimize at the very low frequencies. The hypothesis should therefore be entertained that we are seeing the fallout of a combination of poor early childhood attachment bonding and of the prevalence of traumatic experiences (physical and/or psychological) in our lives. It is perhaps the very ubiquity of trauma even in ordinary lives that has prevented us from seeing the centrality of the trauma response in our understanding of mental dysfunction. Fortunately, we now have a very promising, humane, and comprehensive remedy.

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Homecoming for Veterans is a national outreach program to provide free neurofeedback training for veterans for the rehabilitation of Post Traumatic Stress Disorder (PTSD) and issues of brain performance resulting from traumatic brain injury, blast injury, concussion, whiplash, and chemical exposure.

The EEG Institute and the Brian Othmer Foundation are offering this cutting-edge treatment, at no cost, for veterans suffering from PTSD through a network of clinicians across the country. Each clinician volunteers to provide neurofeedback free for at least one veteran.

Scott Shane of the *New York Times* wrote that "The nation's hard pressed health care system for veterans is facing a potential deluge of tens of thousands of soldiers returning from Iraq with serious mental health problems brought on by the stress and carnage of war..." About one soldier in six is reporting anxiety, depression, or symptoms of PTSD. With a total number of soldiers having served in Iraq or Afghanistan now numbering about one million, perhaps as many as 100,000 will require long term mental health care, assuming standard treatments. Close to 1,000 soldiers have already been evacuated from the war theater because of mental status. On the other hand, PTSD often surfaces months after the return from combat duty.

Neurofeedback practitioners who would like to participate in the Homecoming for Veterans project may contact the project's Administrative Director, Caree Michel, at: Caree@homecoming4veterans.org. More information is available about the Homecoming for Veterans project at: http://www.homecoming4veterans.org/.