CARDIAC COHERENCE AND POSTTRAUMATIC STRESS DISORDER IN COMBAT VETERANS

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Background • The need for treatment of posttraumatic stress disorder (PTSD) among combat veterans returning from Afghanistan and Iraq is a growing concern. PTSD has been associated with reduced cardiac coherence (an indicator of heart rate variability [HRV]) and deficits in early stage information processing (attention and immediate memory) in different studies. However, the co-occurrence of reduced coherence and cognition in combat veterans with PTSD has not been studied before.

Primary Study Objective • A pilot study was undertaken to assess the covariance of coherence and information processing in combat veterans. An additional study goal was assessment of effects of HRV biofeedback (HRVB) on coherence and information processing in these veterans.

Methods/Design • A two-group (combat veterans with and without PTSD), pre-post study of coherence and information processing was employed with baseline psychometric covariates.

Setting • The study was conducted at a VA Medical Center outpatient mental health clinic.

Participants • Five combat veterans from Iraq or Afghanistan with PTSD and five active-duty soldiers with comparable combat exposure who were without PTSD.

Intervention • Participants met with an HRVB professional once weekly for 4 weeks and received visual feedback in HRV patterns while receiving training in resonance frequency breathing and positive emotion induction.

Primary Outcome Measures • Cardiac coherence, word list learning, commissions (false alarms) in go–no go reaction time, digits backward.

Results • Cardiac coherence was achieved in all participants, and the increase in coherence ratio was significant post-HRVB training. Significant improvements in the information processing indicators were achieved. Degree of increase in coherence was the likely mediator of cognitive improvement.

Conclusion • Cardiac coherence is an index of strength of control of parasympathetic cardiac deceleration in an individual that has cardinal importance for the individual's attention and affect regulation.

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The number of returning Afghanistan (Operation Enduring Freedom, OEF) and Iraq (Operation Iraqi Freedom, OIF) combat veterans seeking treatment for posttraumatic stress disorder (PTSD) is expected to increase in the coming years. A study of OEF/OIF combat veterans immediately on return from deployment shows that 5% of active duty and 6% of reserve personnel had a significant mental health problem, but when reassessed 3 to 6 months later, 27% of active duty and 42% of reserve personnel had a mental health problem.[1] The VA has already provided PTSD treatment to more than 52 000 OEF/OIF veterans. At this time, more than 1.5 million active duty soldiers have deployed to the two conflicts. Estimates of the incidence of mental health problems, including PTSD as well as depression and substance abuse, among returning combat veterans range from 11% to 35%.[1-3] The RAND Corporation estimated that the total number of psychiatric casualties from service in Iraq and Afghanistan by 2006 was 300 000 veterans.[4]

Heart rate variability (HRV), measured as variance in cardiac inter-beat intervals, or power, has been reported to be reduced in PTSD.[5-9] Efferent parasympathetic output from the vagus cranial nerve (vagal tone) is the major contributor to HRV power and an index of the parasympathetic/sympathetic balance. Normal vagal tone is necessary for maintenance of the physiological background necessary for initial perception and registration of environmental stimulation and events, suggesting that PTSD has an underpinning of physiological abnormality (lower HRV), which also may adversely affect early-stage information processing. Cardiac coherence, described below and elsewhere in this issue, is a key measure of HRV that with the appropriate proto-

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cols can provide a better index of parasympathetic function than measures such as high-frequency power as well as indicate the degree of synchronized activity in the autonomic nervous system (ANS) and some higher-level brain systems.[10]

Several studies have shown that increased HRV power is significantly associated with improved cognitive performance in adults, measured as academic measures in middle school students with ADHD,[11] immediate memory,[12] working memory,[13] and auditory discrimination reaction time.[14] Additional but indirect evidence of this comes from a study of patients with Alzheimer's disease who cognitively improved after vagal nerve stimulation.[15]

Evidence that there are deficits in attention (ATTN) and immediate memory (IM) associated with PTSD in combat veterans can be found in the literature.[16-21] However, the impact of reduced HRV on ATTN/IM deficits in combat veterans with PTSD has not been studied. This pilot study aimed to assess the extent to which HRV and ATTN/IM covary in combat veterans. If normal vago-sympathetic balance is altered in favor of sympathetic tonus in combat-related PTSD (PTSD+), it follows that restoration of a normal balance may lead to amelioration of the effects of PTSD. The goal of this pilot study was to further test this idea by assessing the effects of HRV biofeedback, an intervention that is known to improve HRV and increase coherence, on HRV and ATTN/IM in these veterans.

METHODS

Study Setting

The study was conducted onsite at Dorn VA Medical Center, Columbia, South Carolina, after all regulatory approvals were obtained.

Participants

PTSD+ veterans were recruited from the VA Medical Center's mental health outpatient clinic. Inclusion criteria for PTSD+ subjects were combat experience in either Afghanistan or Iraq, a diagnosis of PTSD, and receiving current treatment for PTSD. Exclusion criteria for potential participants were known or suspected histories of acquired neurocognitive deficits including even mild traumatic brain injury; any neurological disorder; history of PTSD, depression, or alcohol or other substance abuse/dependence prior to OIF/OEF deployment; history of diagnosis or treatment for seizure disorder; current prescription for an acetylcholine esterase inhibitor, beta-blocker, serotonin-norepinephrine reuptake inhibitor, or neuroleptic (typical or atypical antipsychotic); evidence of active substance abuse or dependence; lifetime history of major depression, bipolar, psychotic, panic and/or obsessive-compulsive disorders; cardiovascular disease including use of pacemakers, bypass surgery, or heart transplant. Combat veterans without PTSD served as controls. Controls were active-duty soldiers from the nearby Air National Guard base. Inclusion criteria for controls was combat experience in Afghanistan or Iraq. Exclusion criteria were the same as for the PTSD+ subgroup. Five combat PTSD+ veterans and five control veterans were enrolled in the pilot study.

Intervention

Baseline HRV was measured using the emWave HRV monitoring system (HeartMath, LLC, Boulder Creek, California) with application software that records and exports R-R interval data. HRV was measured for 10 minutes during the first session before any training in the HRV biofeedback (HRVB) technique was delivered. During the initial pre-training HRV session, all participants were presented with a scenic picture on the computer screen during HR recording. Thus, no visual feedback on heart rate was provided before training. The post-training resting HRV also was recorded for 10 minutes while participants passively viewed a scenic picture.

The HRVB training intervention used the emWave system. HRVB is an interactive procedure using a hardware/software system to monitor and display individuals' HRV patterns in real time. During biofeedback training, the participant viewed a split computer screen monitor that shows the HRV power spectrum in real time so that the participant can visualize the impact of the techniques. Visual feedback of HRV (either quantitative display of the power spectrum or as animated challenge games) was provided as participants practiced the techniques of attention focusing, resonant frequency breathing (RFB), and positive emotion induction. As a result, changes in HRV patterns can be readily seen. The visual feedback enables associations to be formed between the techniques and HRV patterns indicative of shifts toward higher vagal parasympathetic output (0.1 Hz wave), which leads to self-regulation of the ability to achieve coherence.

Participants received HRVB training from an HRVB professional during weekly sessions over a 4-week period using the Quick Coherence Coach method. Before HRVB training, the biofeedback professional (BFP) discussed individual issues (pain, stress, sleep issues, relationship issues, etc) and goals. During HRV baseline recording, the BFP observed irregular breathing patterns, and the physiological connection between RFB and HR (accelerating on inhale, decelerating on exhale) was introduced, which leads to RFB pattern. The physiological connection between RFB and HR (accelerating on inhale, decelerating on exhale) was then introduced, leading to corrective breathing and the RFB pattern (5-6 breaths per minute).

The BFP then developed a positive emotional state in the subject with the statement, "Engage your emotions by recalling and thinking about something you are grateful for or are appreciative or proud of or love." After the positive emotion aspect was introduced, the BFP instructed the visualizer to "experiment" with the various positive emotions and find which produced the greatest 0.1 Hz peak. There were occasional shifts between the visualizer screen and the power spectrum screen so that the actual development of a 0.1 Hz peak could be seen. A home unit Personal Stress Reliever (PSR) was loaned to the participant to use at home and throughout the day, enabling them to practice the skills and transfer them to life situations in times of increased stress.

Variables

Baseline psychometric variables were assessed with the following instruments. PTSD was assessed with the Clinician-Administered PTSD Scale (CAPS); depression was assessed with the Zung Depression Scale; anxiety was assessed with the Spielberger State-Trait Anxiety Inventory. Baseline psychometric variables were used as potential covariates and were not measured post-HRVB training.

Cardiac coherence was assessed using the latest method.[22] Coherence is characterized by a narrow, high-amplitude, easily visualized peak that falls into the upper low-frequency (LF) or lower high-frequency (HF) bands (0.09-0.14 Hz). Coherence is operationalized by identifying the maximum peak in the 0.04 Hz to 0.26 Hz range (the frequency range within which coherence and entrainment can occur), calculating the integral in a window 0.030 Hz wide centered on the highest peak in that region, then calculating the total power of the entire spectrum. The coherence ratio is formulated as: coherence = peak power / (total power – peak power)^2.[22] This method provides an accurate measure of coherence that allows for the nonlinear nature of the HRV waveform over time.

The ATTN/IM test battery was modeled on Vasterling's studies that have shown deficits in PTSD+ combat veterans.[20,21] Sustained attention was assessed with Conners' Continuous Performance Test (CPT); registration/encoding of information was assessed with the Wechsler Adult Intelligence Scale, Digit Span subtest (DS, total number of trials correctly passed); and IM was assessed with the Rey Auditory-Verbal Learning Test (RAVLT). The functional aspect of the selected ATTN/IM variables in this small battery is its focus on early-stage information processing of stimulus information. The CPT is a well-validated measure of sustained attention that uses the go–no go response output method to assess response inhibition. Commission (false alarm) errors were scored when the participant fails to inhibit responding to the no-go target stimulus. The digit span test is an indicator of attentional capacity for auditory information registration and encoding. List learning is an indicator of immediate recall of meaningful auditory verbal information.

Data Analysis

Movement artifacts in the recording data were eliminated before outcome variables were computed. Pre-post changes in ATTN/IM and coherence were analyzed as a mixed model (group x [pre-post]). Changes in HRV power were analyzed using Mann Whitney U because although HRV power is a reliable intra-individual physiological indicator, it is not normally distributed and shows large inter-individual differences. The three-way relationship between PTSD, HRV, and ATTN/IM was analyzed using univariate (ATTN/IM as outcome) model-building statistical techniques.

Results

The PTSD+ and control subgroups did not significantly differ in composition by sex, race, employment status, or age (Table 1). Psychometric scores all reveal moderate to severe psychopathology in the PTSD+ subgroup compared to little or none in the control subgroup.

TABLE 1 Demographics and Baseline Psychometric Scores of Pilot Study Subjects*

Variable	PTSD (n = 5)	Control (n = 5)	*P* (2-tailed)
Demographics			
Sex (% male)	100	100	>.99
Race (% caucasian/AA)	60/40	60/40	>.99
Employed (%)	20	100	.29
Age	29.4 (SE 2.5)	34.2 (SE 2.6)	.22
Psychometrics			
PTSD lifetime (CAPS)	104.4 (SE 7.1)	27.0 (SE 11.6)	<.01
PTSD current (CAPS)	83.8 (SE 12.1)	6.6 (SE 2.6)	<.01
Depression (BD-II)	29.6 (SE 5.8)	4.6 (SE 1.2)	<.01
State Anxiety (STAI-S)	47.8 (SE 5.3)	24.4 (SE 2.4)	<.01
Trait Anxiety (STAI-T)	57.4 (SE 6.7)	35.2 (SE 4.9)	<.01

*AA indicates African American; SE, standard error; CAPS, Clinician-Administered PTSD Scale; BD, Beck Depression; STAI, State-Trait Anxiety Inventory.

Effects of HRVB Training on Cardiac Coherence and HRV Power

Figure 1 (a-d) illustrates the effect of HRVB training on the 0.1 Hz peak in one study participant (PTSD+ subgroup). These results are typical of all participants: the average post-training power peak for all 10 subjects was equal to 0.11 Hz (SD = 0.02, SE = 0.01) and not statistically significantly different from 0.1 Hz ($t[9] = 1.6$, P [2-tailed] = .15). The coherence ratio in both subgroups increased post-training: PTSD increased from 0.2 to 40.2 and control coherence ratio increased to from 1.2 to 15.0 (Figure 2a). The group x pre-post interaction showed a clear trend (P = .06), while pre-post within-subject and group main effects were both significant (P = .002 and P = .001, respectively). Overall (average of pre- and post-training), coherence for the PTSD+ subgroup was 20.2 (8.0) and for controls was 8.1 (10.7).

Pre-post HRVB changes in HRV power are shown in Figures 2b and 3. The Wilcoxon Signed Rank Test showed that only the increase in LF band power was significant within both groups, and no other pre-post changes in band power within subgroups (very LF, HF, or total) was significant. The increase over baseline of total power among control combat veterans in this study was 122.9% but only 18.2% among the PTSD+ veterans.

Effects of HRVB Training on ATTN/IM

Before training in HRVB, the PTSD+ subgroup was lower on all measures of ATTN/IM, although none of the differences was significant (Table 2a). When the pre-post difference in ATTN/IM for the subgroups was analyzed using a two-factor mixed model within-subject design (group x pre-post; Table 2b), a significant interaction between PTSD and training was seen in total number of words on list learning (P = .03). Inspection of the table of means reveals that the PTSD+ subgroup increased from 54.4 to 59.0 words learned after training, whereas the control subgroup

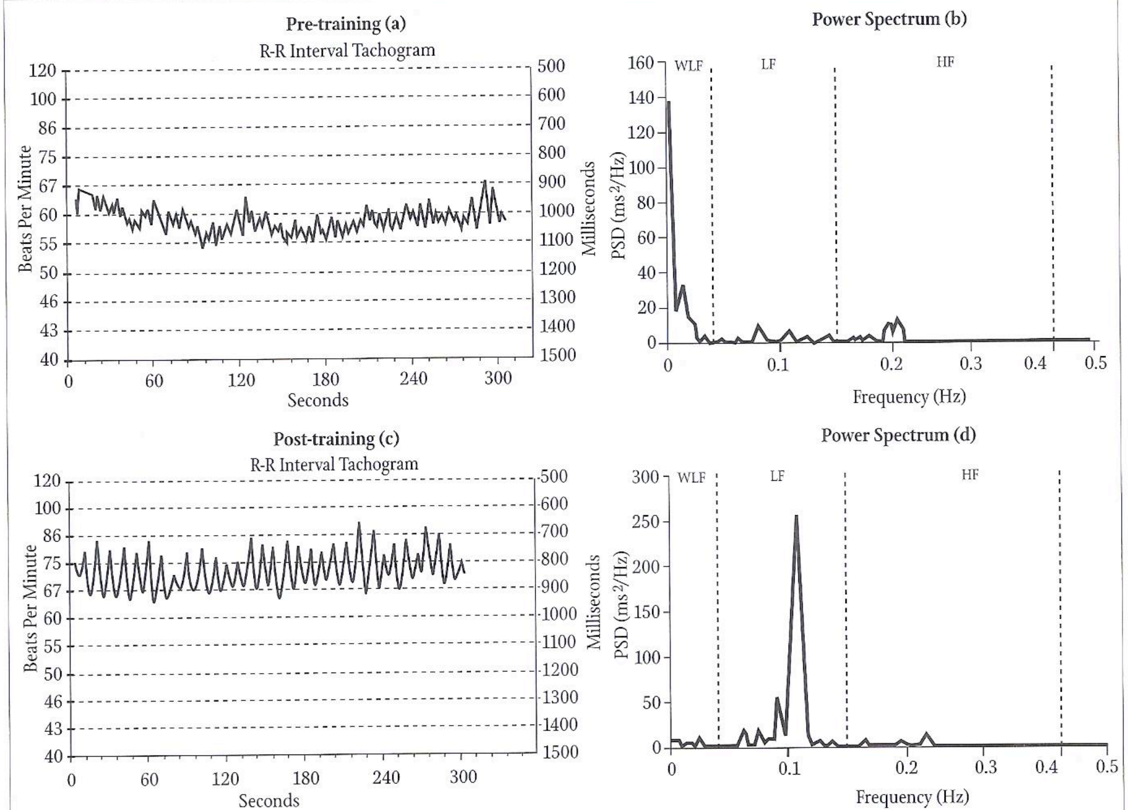

FIGURE 1 (A-D) The Pre-Post HRVB Training, the R-R Interval Tachogram, and Power Spectra Density (PSD) of One PTSD+ Subject

declined negligibly from 56.6 to 56.5 words learned. A significant main effect of training was seen as improvement in commissions T score (a decrease in commissions means a reduction in dysinhibition) and digits backward (P=.05 and P=.03, respectively).

The Relationship Between PTSD, HRV, and ATTN/IM in PTSD+ Combat Veterans

The PTSD+ subgroup was analyzed separately for relationships between HRV and ATTN/IM because it is the population of interest, and there was a significant PTSD x coherence interaction. Variable selection performed to motivate the model revealed that CAPS Criterion C (Avoidance, CAPSA) was the only psychometric measure with acceptable correlations with all psychometric variables. Coherence, quantified as percentage change from pre-training, was chosen as the indicator of HRV change because of its physiological significance and because it was significantly intercorrelated with both CAPSA (P=.01) and change in commissions (P=.02). Partial and semi-partial correlation was used to assess how controlling for percent change in coherence affected the relationship between CAPSA and change in commissions. Results revealed that the zero-order correlation between CAPSA and commissions decreased from .92 to .85 (partial) to .41 (semi-partial), with 1-tailed P going from .01 to .08 to .30, respectively. This result suggests that percent change in coherence, not CAPSA, is predictive of improvement in commissions.

Clinical vs Statistical Significance of the Pilot Study Results

The HRVB intervention produced statistically significant outcomes, but as a clinical intervention, the effects must be clinically meaningful also. Review of CPT commissions treatment effect sizes indicated that the statistically significant improvement in CPT commissions found in the pilot study is comparable to effect sizes produced by standard treatments. For example, the effect size of the change in CPT commissions in the PTSD+ subgroup in the pilot study was 0.72, which compares favorably with the published effect size of 0.39 of methylphenidate treatment on decreased CPT commissions.[23] The effect size of transdermal nicotine patch–reduced CPT commissions was reported to be 1.0.[24]

Limitations of the Pilot Study

Though the data from the pilot study suggest that HRVB improves some measures of ATTN/IM, these statistical findings

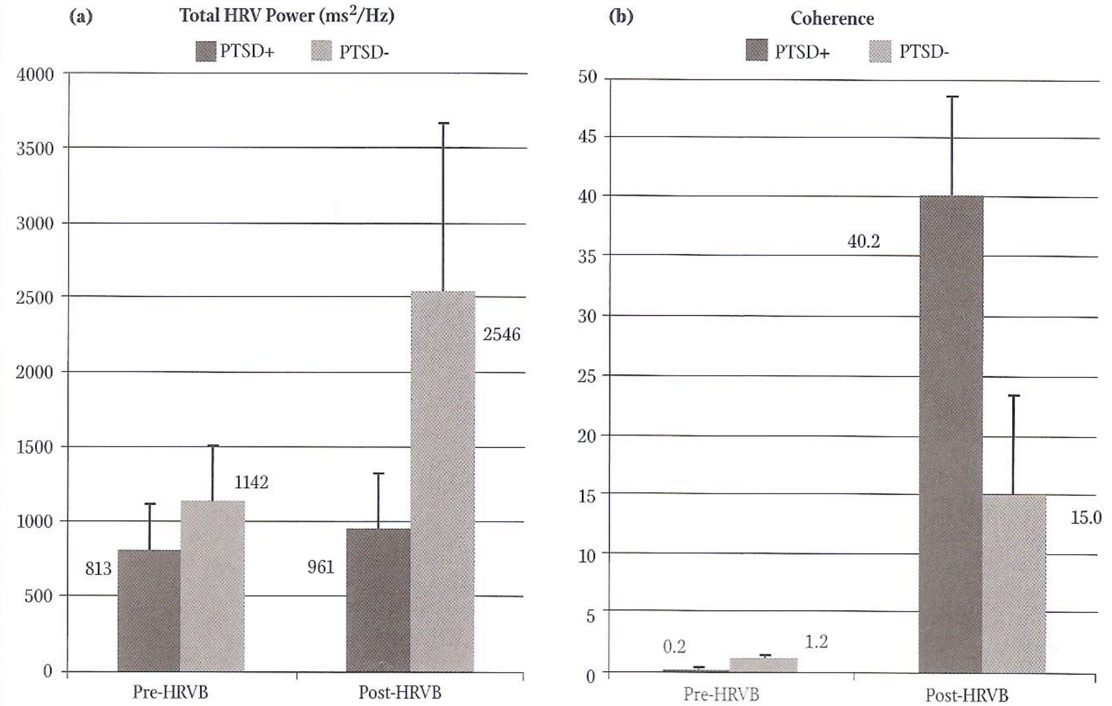

FIGURE 2 Pre-Post HRVB Training (a) Coherence and (b) Total HRV Power in PTSD and Control Combat Veterans

may be unstable due to the small subgroup size. The small subgroup size also lowers validity of the results due to limited generalizability. Another limitation of the pilot study is that the physiological data did not include integrated recording of HRV with respiration rate and/or pulse transit time, two variables whose measurement would be necessary to demonstrate that coherence reflects time-locked physiological entrainment. Changes in severity of PTSD symptoms were also not assessed post-HRVB training. Lastly, post-HRVB improvements were only assessed immediately upon conclusion of the final training session, and so it is not known how persistent over time the observed effects of HRVB will be on improved coherence and ATTN/IM.

DISCUSSION

The trends of the model tested in this pilot study are promising, and given that the subgroups in this pilot study were small, robust effect sizes large enough to produce statistical significance were observed for some of the outcomes. Results of our pilot study indicate that HRVB produces cardiac coherence, shown as increases in HRV power in the LF frequency band. The beneficial effects of being in a state of increased coherence were then related to improved performance on ATTN/IM, measured as reduced commissions on a go–no go test and increased digit span backward and list learning.

Cardiac coherence appears to be central to a range of fundamental learning and information processing that are part of everyday life. We have previously shown that vagal control of cardiac deceleration is critical for acquisition of eye-blink and heart rate conditioned responding in healthy controls[25] and is also significantly related to these forms of associative learning and ATTN/IM in combat veterans with and without PTSD.[12,26] Furthermore, normal cardiac deceleration associated with the immediate, short-duration registration component of the orienting response appears to be eliminated in PTSD.[26] Low tonic vagal tone, which is associated with PTSD, appears to cause problems maintaining an adequate level of physiological background necessary for attention to environmental stimulation and events.[27] Thus, when sympathetic tonus prevails over normal resting parasympathetic state, vigilance is disrupted.

The relationship between heart rate deceleration and information processing is stated in the intake-rejection hypothesis that heart and brain form an integrated feedback system of perception, autonomic response, and cognitive processing.[28-31] Cardiac deceleration supports motivated attention to the external environment (vigilance) and response selection; cardiac acceleration supports motivated inattention to the environment and internal information processing (sustained attention) and response output. The greater the initial cardiac deceleration (parasympathetic pulse) after stimulus perception, the greater the efficiency of processing of stimulus type (eg, life-threatening,

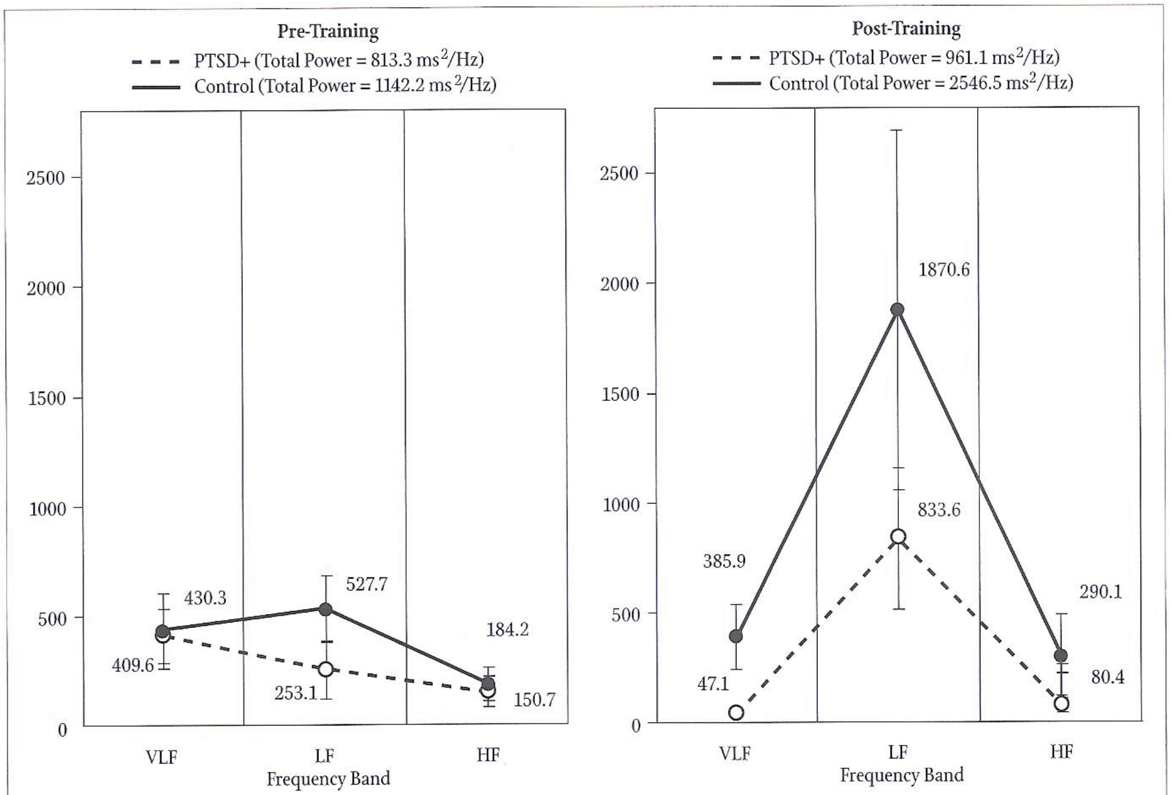

FIGURE 3 Pre-Post HRVB Training HRV Frequency Band Power in PTSD+ (n = 5) and Control (n = 5) Combat Veterans*

*VLF indicates very low frequency (0.010-0.040 Hz); LF, low frequency (0.041-0.140 Hz); HF, high frequency (0.141-0.400 Hz).

warning or danger, safe or neutral) and response selection. Intake-rejection has been found in humans consistently across a wide variety of stimuli and task parameters.[32] Cardiac deceleration is now recognized as being a potent marker of the attention-focusing pre-performance routine found in enhanced performance output of skilled activities such as rifle marksmanship and golf putting.[33] In contrast, during sustained attention to the response performance itself, there is a marked phasic withdrawal of vagal tone and consequent cardiac acceleration to support response output and performance. Among active duty military personnel (without combat stress), enhanced performance under conditions of high stress was associated with greater suppression of vagal tone.[34]

All participants achieved cardiac coherence (0.1 Hz peak) as result of HRVB training. Both subgroups of participants were shown to have consolidated HRV power from across the frequency spectrum into the coherence (LF) frequency band even though total HRV power did not significantly increase in either subgroup. The relatively small increase over baseline of total power among PTSD+ veterans (18.2%) in comparison to controls (122.9%) suggests that PTSD+ veterans, although able to achieve coherence, were in a state of depletion of total HRV power and limited in their ability to marshal a full response to the intervention, at least within the 4-week time frame of this pilot study. In contrast, the surge in HRV power demonstrated by the controls is a likely indicator of enhanced resilience that will be reflected in attention and mental and emotional flexibility and is expected to predict enhanced self-regulation of affect, greater degree of behavioral adaptability, and more positive emotions and relationships.

Veterans in the PTSD+ subgroup demonstrated significant improvements in ATTN/IM accompanied by a significant consolidation of HRV power into the LF frequency band with only a small (nonsignificant) increase in total HRV power, suggesting that some additional factors are contributing to the beneficial effects of cardiac coherence. One possible such factor is increased neural synchronization. Synchronized brain activity resulting from cardiac vagal afference (originally thought to be baroreceptor feedback but later understood to be heart rate) constitutes a mechanism by which performance of perceptual information processing can be modulated.[22,35] Heart rate deceleration is the modulation mechanism by which the onset of synchronized alpha activity is prevented when attending to external sensory information, as synchronized alpha activity interferes with the transmission and processing of external information. In terms of

TABLE 2A Pre-Post HRVB Training Changes in Attention and Immediate Memory (ATTN/IM)

		Commissions Pre-	Commissions Post-	Digits Forward # Trials Pre-	Digits Forward # Trials Post-	Digits Backward # Trials Pre-	Digits Backward # Trials Post-	List Learning Trial 1 Pre-	List Learning Trial 1 Post-	List Learning Total Pre-	List Learning Total Post-
PTSD (n = 5)	Mean	48.5	41.6	10.8	10.8	6.4	8.0	7.0	8.4	54.4	59.0
	(SD)	(9.0)	(9.5)	(4.0)	(3.1)	(1.1)	(2.2)	(1.5)	(1.8)	(8.2)	(10.0)
Control (n = 5)	Mean	46.7	45.2	11.2	12.2	7.2	8.2	7.8	8.0	56.6	56.5
	(SD)	(12.0)	(4.6)	(1.3)	(2.0)	(1.5)	(0.9)	(2.6)	(3.4)	(9.6)	(13.6)
Total	Mean	47.5	43.2	11.0	11.4	6.8	8.1	7.4	8.2	55.5	57.9
	(SD)	(9.2)	(7.5)	(2.9)	(2.6)	(1.3)	(1.6)	(2.1)	(2.4)	(8.5)	(11.0)

TABLE 2B Significance of Pre-Post HRVB Training Changes in ATTN/IM (All Comparisons df = 1,8)

ATTN/IM Variable	PTSD	Pre-Post	Pre-Post x PTSD
Commissions	.85	.05	.25
Digit forward # trials	.58	.40	.54
Digit backward # trials	.60	.03	.40
List learning trial 1	.73	.41	.11
List learning total	.91	.31	.03

the synchronizing effect on cortical alpha rhythm (via thalamus), it is the pattern and stability of the vagal afferent input from the heart that is significant and not the strength or number of these neural afferent signals. In situations involving the intake of sensory information, a decrease in heart rate translates into a reduction in the probability of the occurrence of EEG alpha activity.[36]

The degree of synchronized activity varies depending on the needs of the moment. It is this flexibility that allows us to quickly adapt to changing demands, such as focusing on external sensory input or an internal process. This is reflected in the alpha rhythm, which increases in amplitude and distribution when the neural populations are more tightly coupled—and are not involved in processing external sensory information.[10,22] Under these circumstances, cognitive performance of tasks involving the processing of external sensory information is reduced. When heart rate increases, the activity and amplitude of the alpha synchronization also tend to increase, the effect of which is to facilitate internal processing and response output at the expense of intake and processing of external information.[36]

The preliminary data from this pilot are consistent with this model. Increased cardiac coherence reflects incorporation of a greater cardiac deceleration component into HRV due to enhanced output of the parasympathetic arm of the ANS. Intake and registration of stimulus information should therefore be facilitated, leading to greater efficiency and level of performance of response output. Prior to HRVB, the tendency (especially among the PTSD+ veterans) is toward underactivation of vigilance and overactivation of response output to environmental stimulation.

The cardiac coherence–improving effects of HRVB are to promote improved intake of stimulus information and accuracy of response output. This is seen as decreased commissions on go–no go testing, which demonstrate reduction in dysinhibition, increased registration on digit span backward, and greater attentional capacity and immediate recall on word list learning. These improvements in early-stage information processing of stimulus information have apparent ecological validity and highly beneficial effects on activities of daily living and everyday function in the real world. There is in addition important and obvious military relevance for fitness and return to duty associated with the better attention, reduced dysinhibition, increased accuracy of responding, and greater registration and immediate recall of information resulting from HRVB.

The effects of vagal control of cardiac coherence on improvement of intake of environmental information attention are related to improvements in self-regulation of affect by the individual.[37-39] Low vagal tone is associated with poor self-regulation, impaired environmental responsivity, lack of behavioral flexibility, imbalance of stress hormones, and proneness to disease; high vagal tone is associated with the ability to self-regulate and thus to have greater behavioral flexibility and adaptability to the environment.[7] HRVB also has been shown to improve symptomatology in clinical groups and heightened well-being in otherwise healthy individuals: increase in positive affect and decrease in cortisol among normal working adults[40]; improvement in self-reported depression in elderly patients with congestive heart failure[41]; significant reduction in anxiety in HIV+ patients[42]; and reduced blood pressure and improved emotional health in hypertensive employees.[43]

All 10 of the pilot study participants expressed enthusiasm about their experience in the HRVB pilot study and their perception of its benefit to everyday living. The PTSD+ veterans were particularly enthusiastic about the benefits of HRVB, as shown by this statement that one of the PTSD+ veterans made to study personnel during the final debriefing:

I am an OIF and Gulf War veteran. I recently returned from Iraq, where I experienced 5 IEDs and 1 RPG explo-

sions. To deal with all the pain I felt after I got back I self-medicated for several months with alcohol and marijuana, but after weaning off of both I was determined not to use narcotics of any kind to cope with the pain. Being part of this experimental HRV biofeedback program has changed my life and given me a practical, non-medicated way to reduce the pain and handle the stress. One time in particular, stress from [the] relationship with my wife was robbing me of sleep and causing me to lose control. I remembered the biofeedback tool and after about 30 minutes of practice I was calm and able to go back to sleep. The benefits of HRVB are so much better than medication because I am learning a way to self-regulate anywhere, anytime without risk of dependency or that drugged feeling. I'm so grateful for being part of this pilot study. My last BP reading was 115/76, compared to previously when it was 120/95. My heart rate has dropped from the 90s to the 70s.

A parasympathetic basis of positive emotional, social, and affiliative responding is provided by Porges' polyvagal theory[44-47]; however, this theory has also been criticized.[48,49] The polyvagal theory states that three phylogenetically ordered autonomic subsystems have developed: (1) immobilization (eg, feigning death, vasovagal syncope, and behavioral shutdown); (2) mobilization ...ht-flight behaviors); and (3) affiliation and social commu-
...d affiliative vagal subsystem is the most
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research studies with PTSD+ OIF/OEF combat veterans for symptom reduction of PTSD. The application of HRVB to increase cardiac coherence thus has significance for improvement of everyday function both for the early stage information processes of attention and immediate memory and for emotional well-being.

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