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SPECIAL ISSUE

Heart Rate Variability and Posttraumatic Stress Disorder

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The psychophysiology of posttraumatic stress disorder (PTSD) points towards autonomic dysregulation—specifically, elevated sympathetic response and attenuated parasympathetic response. In view of this, heart rate variability (HRV) biofeedback has been applied and tested as a treatment for PTSD. Review of existing published research suggests that HRV biofeedback seems promising as a treatment for PTSD, both in significantly alleviating the symptoms and in improving cognition for those suffering from PTSD. Drop-out rate is low, and inexpensive and portable HRV biofeedback devices such as the Stress Eraser make it a viable alternative to traditional treatment such as prolonged exposure therapy (PET), cognitive behavior therapy (CBT) and cognitive processing therapy (CPT). More recent research has also shown that combining HRV biofeedback with CBT, PET, and Acceptance and Commitment Therapy (ACT) improved the efficacy of these therapies in treating PTSD. More larger-scale and rigorous controlled trials are needed to confirm these outcomes.

Posttraumatic stress disorder (PTSD) is an anxiety disorder characterized by intense fear and helplessness in individuals following exposure to a traumatic event. There are three other clusters of symptoms associated with PTSD, including intrusive recollection of the event, avoidance of stimuli associated with the trauma or numbing of general responsiveness, and persistent state of increased arousal (United States Department of Veteran Affairs, 2013).

PTSD was initially thought to be a rare disorder with a lifetime prevalence rate of 1%–2% (Kessler, 2000). However, recent studies in the United States (e.g., Kessler et al., 2005) have indicated a higher lifetime prevalence of 6.8%. Apart from being a highly distressing disorder for the individual, PTSD can also prove to be damaging for society, as work impairment resulting from PTSD could translate to an annual loss of $3 billion or more in the United States (Kessler, 2000). Rates among veterans are significantly higher, ranging from 30% for the Vietnam War (Kang, Natelson, Mahan, Lee, & Murphy, 2003) to more recent estimates for the Iraqi and Afghanistan wars of 16.7% for active troops and 24.5% for reservists (Millikan, Auchterlonie, & Hoge, 2007). In addition to the untold sufferings for those diagnosed with PTSD and their families, the economic burden to society is very significant. The RAND Corporation estimated the economic costs of PTSD to be between $4 billion and $6.2 billion over two years, with an average cost per case ranging from $5,904 to $10,298 (Tanielian, 2009).

Given this state of affairs, it is important that effective treatments are made available to those suffering from PTSD in order for them to cope with the disorder and improve their life functioning. While reports have been published on psychological interventions (including prolonged-exposure therapy (PET) and cognitive-processing therapy (CPT; DeAngelis, 2008), little attention has been accorded to interventions from a psychophysiological perspective.

Psychophysiology of PTSD and Heart Rate Variability

The persistent state of hyperarousal that characterizes PTSD suggests autonomic dysregulation—in particular, a weakened parasympathetic nervous system (PNS) and an elevated sympathetic nervous system (SNS; Blechert, Michael, Grossman, Lajtman, & Wilhelm, 2007). The elevated heart rate found in individuals suffering from PTSD also supports this idea. Because heart rate is regulated by both PNS and SNS, such heart rate increases could be due to increased sympathetic activity, attenuated parasympathetic activity, or both (Pole, 2007). As heart rate variability (HRV) can be used as a simple, noninvasive indicator of the autonomic nervous system (Sztajzel, 2004), there is the potential for individuals suffering from PTSD to benefit from HRV interventions, such as HRV biofeedback.

The article by Lehrer in this special issue has eloquently described the principle behind HRV biofeedback, which

trains individuals to control their breathing such that they will become accustomed to breathing at resonant frequency. By doing this, individuals can produce large increases in both HRV and baroreflex gain and patient PTSD symptoms can be alleviated as a result. Van der Kolk, a leading authority on trauma, has argued that interoceptive body-oriented therapies can directly confront the core clinical issue in PTSD and that traumatized individuals are prone to experience the present with physical sensations and emotions associated with the past. In order for therapy to be successful, these individuals need to focus on physical self-experience and increase self-awareness rather than focusing on the meaning and narrative of the past (van der Kolk, 2006). HRV biofeedback would appear to fit the bill.

Evidence for the Efficacy of HRV Biofeedback with PTSD

Tan, Dao, Farmer, Sutherland, and Gevirtz (2011) conducted a pilot study at the Houston VA Medical Center in order to assess current HRV among veterans, as well to determine the efficacy of HRV biofeedback as a treatment of veterans suffering from combat-related PTSD. By comparing 20 veterans diagnosed with PTSD with 10 healthy control participants, they found that the veterans with PTSD displayed lower HRV than individuals without PTSD (mean standard deviation of the normal-to-normal heartbeat interval [SDNN] for PTSD group = 48.10 versus mean SDNN for control group = 138.70, $p < .001$; $d = 1.89$). In addition to supporting Sztajzel's (2004) argument that HRV can be used as an indicator for autonomic nervous system dysfunction, Tan et al.'s (2011) finding also highlights how HRV can be used to distinguish individuals with PTSD and those without.

In this pilot study, the veterans diagnosed with PTSD (experimental group) were also administered the Lehrer's treatment protocol (Lehrer, Vaschillo, & Vaschillo, 2000) in addition to treatment as usual. The treatment was provided in eight sessions. Results indicated that the HRV biofeedback was efficacious for reducing PTSD symptoms as assessed by the Clinician-Administered PTSD Scale (CAPS) and the PTSD Checklist-Specific (PCL-S). Both instruments indicated significantly reduced scores from baseline to the posttreatment follow-up for those who received the HRV biofeedback treatment ($p < .001$ for CAPS, $d = 0.80$; $p < .035$ for PLC-S, d=1.08). The control group (who received treatment as usual only) showed no statistical differences in pre- to posttreatment scores for both CAPS and PCL-S. The findings indicated that HRV biofeedback significantly reduced symptoms of PTSD and provided benefits in treating PTSD beyond those of treatment as usual.

The results in Tan et al. (2011) are not only statistically significant, but are also clinically significant and important. In a meta-analysis by Hoffman and Smits (2008), the average Hedges g (comparable to the d scores in this study) was 0.64 for six well-controlled trials; the values of 0.80 for the CAPS and 1.08 for the PCL in this study would compare favorably. Freed et al. (2009) used a Preference-Weighted Health Status (PWHS) measure to assign clinical meaning to PCL scores and reported that a change of 0.041 units would be considered clinically important. Based on the PCL improvement in this study, the differential PWHS was 0.06, a large improvement in overall health status.

In addition to efficacy, the Tan et al. (2011) study also showed a very high adherence rate for the HRV biofeedback protocol of 95%. This was most likely due to the high satisfaction and acceptability patients felt towards the treatment. A post follow-up phone interview of participants confirmed this suspicion, and all participants reported looking forward to the treatment sessions, which is in contrast to other veterans at the same facility who had participated in the more traditional PET and CPT treatments where adherence has often been a problem for many therapists. The high adherence rate indicated that HRV biofeedback would be well-received by clients as an alternative treatment to the more commonly used PET and CPT interventions.

More recently Ginsberg and colleagues presented preliminary findings from an ongoing research project entitled "Heart Rate Variability Biofeedback for OIF-OEF Combat Veterans with PTSD," during the AAPB Annual Meeting in Portland, OR (Ginsberg et al., 2013). This is a pre-post, single-blind, sham-controlled study of the effects of HRV biofeedback on PTSD symptoms and cognition in Operation Iraqi Freedom–Operation Enduring Freedom combat Veterans, funded by the Deployment-Related Medical Research Program (DRMRP). Combat veterans with PTSD who agreed to participate were randomly assigned to one of two groups: (1) active HRV biofeedback training, or (2) sham HRV biofeedback training (see the Table).

After signing the consent form, participants underwent 15 minutes of passive HRV monitoring (without visual feedback) followed by psychological assessment. The HRV monitoring and psychological assessment was administered at three time points: pretraining, posttraining, and eight weeks follow-up (i.e. 16 weeks from pretraining). During the 15-minute passive HRV recording period, subjects viewed a static relaxing nature picture on the computer screen (e.g., mountains, sky, and clouds) while HRV was recorded with a fingertip plethysmograph. Visual HRV

Table. Ginsberg et al. Training Protocol for combat Veterans with PTSD		
	Active Training Group	**Sham Training Group**
Pretraining passive HRV recording + psychological assessment	yes	yes
Six weekly lab sessions	25-minute HRVB training followed by 15-minute passive HRV recording	25-minute passive computer screen viewing followed by 15-minute passive HRV recording
Home practice	EmWave Personal Stress Reliever	"Squeeze stress reliever"
Posttraining passive HRV recording + psychological assessment	yes	yes
Follow-up passive HRV recording + psychological assessment	yes	yes
Note. PTSD = posttraumatic stress disorder, HRV = heart rate variability, HRVB = HRV biofeedback.		

feedback was not provided during passive HRV recording. The psychological assessment consisted of the Posttraumatic Stress Disorder Checklist-Military Version (PCLM; Orsillo, 2001; Weathers, Litz, Herman, Huska, & Keane, 1993) and the CAPS (Blake et al., 1995; Orsillo, 2001; Weathers, Keane, & Davidson, 2001).

Treatment of the PTSD groups consisted of a six-week training protocol with active and sham HRV biofeedback. The active HRV biofeedback training consisted of a 25-minute biofeedback training and coaching period (with visual HRV feedback), followed by a 15-minute passive HRV recording period. During the 15-minute passive HRV recording period, subjects were instructed to put into practice the technique they had just been coached on. Sham training participants viewed a static relaxing picture for 25 minutes (without visual HRV feedback) and were told to relax by the biofeedback coach. They then had a 15-minute passive HRV recording period. Active HRV biofeedback subjects were issued an EmWave® Personal Stress Reliever (a handheld biofeedback training device, which assists individuals to increase heart rate variability) and encouraged to practice at home while sham training subjects were issued a "squeeze stress reliever" (in the shape of a brain) and encouraged to practice at home.

Preliminary findings indicated that among the 42 veterans enrolled, 31 were assigned to a group (13 HRV treatments, 14 sham, 4 controls). Controls were only assessed at baseline (pretraining) and did not receive active or sham biofeedback. Eighteen combat veterans with PTSD have completed through follow-up (7 HRV, 11 sham). Among completers, active HRV biofeedback reduced the severity of PTSD on both measures at posttraining and at follow-up, while only negligible differences were noted for the sham HRV biofeedback group from pretraining levels. Repeated measures analysis (three time periods × two groups) showed similar results for both PCLM and CAPS, with significant effects for PTSD (both ps $< .004$) and PTSD × Group (both ps $< .02$), and main effect of Group (both ps $< .05$). Simple paired t tests of preTraining versus follow-up PTSD among active HRV biofeedback (HRVB) completers were both significant (55.6 versus 48.9 on PCLM, 77.0 versus 57.4 on CAPS, both $ps(1t) < .02$). The authors provided the following tentative conclusion: Combat veterans with PTSD appeared to experience improvement in their PTSD symptoms immediately following six weeks of HRV biofeedback, and although the effect decreased at follow-up, the benefit from pretraining through follow-up was nonetheless significant.

Using the Stress Eraser® (SE; a portable electronic device displaying heart rate oscillations, and enabling self-guided HRV biofeedback training), Zucker, Samuelson, Muench, Greenberg, and Gevirtz (2009) conducted a study to examine the effect of respiratory sinus arrhythmia (RSA) on PTSD. Zucker et al. (2009) defined their intervention as RSA biofeedback. They did not assess resonance frequency or train resonance frequency breathing; rather they instructed the participants to use the Stress Eraser® device to create optimal heart rate oscillations. The participants who received the RSA intervention significantly reduced their PTSD symptomatology, as measured by the Post-

traumatic Stress-Total scale of the Detailed Assessment of Posttraumatic States and the PTSD Checklist-Civilian Version (PCL-C) (all $ps < .01$). Such decrease was due to an increase in HRV in these participants as standard deviation of the normal-to-normal beats (SDNN) noted increases in HRV postintervention.

The significance of Zucker's et al. (2009) study is that a community sample is used. This is crucial because the samples used in the earlier studies discussed were made up of veterans, which leaves one to question if the findings can be generalized to civilian populations. The fact that Zucker et al. (2009) found the alleviation of PTSD symptoms by increasing HRV in their participants is a strong indication that such results can be generalized to community populations. Specifically, individuals who suffer from PTSD can reduce their symptoms by increasing their HRV, regardless whether the origin of their PTSD stems from combat experience or otherwise.

Other Benefits of HRV Treatment for PTSD

Research by other investigators suggests that in addition to the alleviation of PTSD symptoms following HRV biofeedback, veterans with PTSD who underwent the HRV biofeedback treatment also exhibited improvements in attention and immediate memory performance when compared to their counterparts who did not have a PTSD diagnosis (Ginsberg, Berry, & Powell, 2010). A follow-up grant is currently investigating the cognitive effect of HRV biofeedback training on veterans suffering from PTSD (Ginsberg et al., 2013). Preliminary data analysis suggests that the PTSD biofeedback group showed more improvement in cognitive performance tasks posttreatment as compared to those receiving sham treatment. These findings, though preliminary, suggest that HRV biofeedback may also improve cognitive performance in addition to relieving symptoms of PTSD among veterans.

A series of research is being conducted at the Trauma Research Institute (Gevirtz & Dalenberg, 2008) to investigate the efficacy of integrating HRV biofeedback with more traditional psychological therapies including PET, CBT, and ACT. Their protocol for treatment of PTSD has four components: psycho-education, CBT, ACT, and HRV biofeedback. Preliminary findings are encouraging, showing significant improvement in PTSD symptoms achieved by 24 of 27 (88%) consecutive patients.

Finally, a number of ongoing research investigations are showing promise to further delineate the effect of HRV biofeedback for PTSD among veterans. First, a meta-analysis has recently been completed showing the effect sizes of various HRV parameters for samples of veterans of PTSD as compared to control (Nagpal, Gleichauf, & Ginsberg, unpublished). Second, an animal model is being tested to identify individual differences in PTSD-like phenotypes that are resistant to extinction of conditioned cardiovascular responses, including reduced HRV to repeated trauma exposure in a VA Merit Review funded grant project, (Marlene Wilson, PhD, Principal Investigator).

Conclusion

In a nutshell, PTSD affects many individuals, and although there are several psychosocial treatment approaches that have been well researched, the same cannot be said for psychophysiological treatment approaches to PTSD. A promising form of psychophysiological intervention involves increasing HRV in order to alleviate PTSD symptoms and improve information processing in PTSD patients. However, research is still lacking in this area and only pilot studies have been published, and larger scales controlled research is still lacking. However, we have identified at least one larger scale controlled study that is still pending completion.

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