Development of a Deployable HRV Assessment and Training System

by

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Abstract

PTSD is a debilitating psychological condition that is difficult to treat and has been directly connected to depression, anxiety, and somatic complaints consistent with a hyperaroused autonomic nervous system (ANS). In 2012, the Institute of Medicine (IOM) published a report on PTSD and concluded that current efforts were inadequate to ensure the psychological health of our fighting forces and requested new intervention programs with demonstrated efficacy. (IOM, 2012). Heart rate variability (HRV) measurement and training has been shown to be effective in diagnosing and ameliorating ANS dysfunction in physical, psychological, and neurocognitive conditions. A pilot study was organized using the Mobile Telehealth System to analyze the effectiveness of the system before conducting an upcoming study that will determine whether mobile HRV biofeedback training can improve symptoms of PTSD in Active Duty Military Service Members (ADSM) by assisting them in learning how to gain control over their ANS. The underlying theory posits that HRV biofeedback training will improve ANS control, which is adversely affected by exposure to extreme stress and trauma. The MTS was used to determine its effectiveness in improving HRV and found to increase HRV both while seating and standing through paced breathing. For the impending study, biofeedback training will consists of 32 sessions: two 10 minute sessions per day, 4 times a week for one month in duration. Participants will train for 10 minutes in the morning prior to breakfast and again in the evening before bed. Baseline and post training data on physiological and psychological changes include HRV, Patient Health Questionnaire (PHQ), CAPS-Military version, and Profile of Mood States (POMS). The MTS has a number of other potential applications including the ability to assess and provide intervention for the following conditions: cardiovascular, addictions, sleep disorders, depression, anxiety, effectiveness of pharmaceuticals, pain management, physical and cognitive performance, posttraumatic stress, and concussions.

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Introduction:

Background

16.7 percent of active troops and 24.5 percent of reservists who served in Iraq and Afghanistan have been diagnosed with posttraumatic stress disorder (PTSD). This percentage is even higher for Vietnam Veterans (30 percent). PTSD results in billions of dollars loss in the United States because these Veterans and others with PTSD are often unable to work or cannot work to their full capability due to the debilitating disorder. There are three symptoms that are linked to the diagnosis of PTSD: recollection of the event, evading of stimuli, and elevated arousal. Hyperarousal is frequently a sign of autonomic dysregulation, consisting of a weakened parasympathetic nervous system (PNS) and heightened sympathetic nervous system (SNS) (Tan, Wang, & Ginsberg, 2013).

The sympathetic nervous system controls the fight or flight response, while the parasympathetic nervous system controls the rest and digest response (Luft, Takase, & Darby, 2009). Veterans are constantly in fight or flight mode when deployed, but are unable to reduce the increased activation of the SNS when returning home. Sufficient prefrontal cortex function is needed to inhibit SNS activation (Luft, Takase & Darby, 2009). Vagal (parasympathetic) activation is independent of sympathetic activation. The two systems should work together to create a balance. When the sympathetic system increases, the parasympathetic system should increase as well to counteract the effects of the increased SNS. However, as a result of the two systems working independently of one another, an increase in the SNS can occur without an increase in the PNS (Stein, 1994). Often accompanying this autonomic dysregulation is elevated heart rate which is also a result of an increased SNS and a weak PNS or both (Tan, Wang, & Ginsberg, 2013). A high heart rate combined with an increased breathing rate may predict the onset of PTSD (Zucker, Samuelson, Muench, Greenberg, &Gervitz, 2009).

An important indicator of parasympathetic activity is baroreceptor sensitivity. Baroreceptor sensitivity gives insight to vagal control of heart rate caused by changes in blood pressure affecting the baroreceptors in the carotid arteries and the aorta (Keary, Hughes, & Palmieri, 2009). A decrease in vagal tone may lead to a variety of other issues such as cardiac arrhythmia. Tone in the vagal nerve inhibits these arrhythmias by preserving electrical stability of the heart. Stress reduces parasympathetic tone but most people retain enough tone to prevent ventricular arrhythmias (Tan, Wang, & Ginsberg, 2013). PNS cardiac control is reduced during mental stressors in those with PTSD. Clients with PTSD were found to have similar PNS activation levels at rest, but reduced PNS activation levels during stressors (Keary, Hughes, & Palmieri, 2009). Vagal tone is estimated from respiratory sinus arrhythmia (RSA), a phenomenon that occurs when a client breathes at his/her personal resonant frequency (Stein, 1994). Respiratory sinus arrhythmia is caused by paced breathing that usually occurs around 6 breaths per minute and reflects resonance between respiratory and baroreflex rhythms. Baroreflex is strengthened by paced breathing and contributes to the client's overall adaptability (Wheat & Larkin, 2010). PTSD clients frequently have decreased RSA amplitude (Zucker, Samuelson, Muench, Greenberg, &Gervitz, 2009).

An increasingly popular method used to correct this dysregulation of the autonomic nervous system is heart rate variability (HRV) biofeedback. HRV is the beat to beat fluctuation in heart rate and is used as a risk factor for cardiac death since it is a biomarker of the autonomic nervous system (Gamelin, Berthoin, Libersa, & Bosquet, 2007).HRV represents an individual's capacity to adjust to physiological fluctuations (Wheat & Larkin, 2013).Heart rate variability is broken into three ranges: very low frequency (VLF) (less than .04 Hz) reflective of sympathetic activation, low frequency (LF) extending from .04 to .12 Hz (a balance between SNS and PNS), and the high frequency (HF) range representing the parasympathetic system ranging from .12 Hz to .4 Hz (Hughes & Stoney, 2009). Individuals with PTSD are observed to have an increase in LF and reduced HF and RSA shifts from the HF to the LF range during paced breathing (Wheat & Larkin, 2013). Patients with PTSD were seen to have greater reductions in HF during traumatic recall and mental arithmetic (Keary, Hughes, & Palmieri, 2009).

HRV biofeedback is a noninvasive method that uses controlled breathing at the individual's resonant frequency to increase HRV and baroreflex and decrease PTSD symptoms. An increase in HRV reflects autonomic homeostasis and self-regulation of reactions. Insomnia and depression have been observed to accompany PTSD and are also linked with decreased HRV (Zucker, Samuelson, Muench, Greenberg, &Gervitz, 2009). Clients with depression have been found to have lower HRV than their nondepressed equals. Those with higher depression scores also have increased heart rate, which suggests a further decline in parasympathetic control than those with lower depression scores. It was also seen that depressed patients have altered parasympathetic responses to stress (Hughes & Stoney, 2000).

In one study, clients in the RSA group had greater reductions in depression scores and decreased their substance craving and insomnia symptoms when compared to the controls (Zucker, Samuelson, Muench, Greenberg, & Gervitz, 2009). High HRV is reflective of increased prefrontal cortex activity allowing improved performance on executive tasks, selective attention, and affective responses (Luft, Takase, & Darby, 2009). Veterans with PTSD were found to have decreased HRV, but when they trained using HRV biofeedback a decrease in PTSD symptoms was discovered by evaluating Veterans pre and post biofeedback training using the CAPs and PCL-S scales. More importantly, the adherence rate was determined to be 95 percent, which is much higher than other PTSD treatments, such as prolonged exposure. At home practice was encouraged of the clients using the EmWave Personal Stress Reliever and improvements in PTSD symptoms were seen after 6 weeks of HRV biofeedback (Tan, Wang, & Ginsberg, 2013).

Several Veterans with PTSD also experience panic attacks. Heart palpitations, sweating, shaking, shortness of breath, and chest pains are seen in individuals having a panic attack and are reflective of

ANS disturbance, specifically a hypersensitive SNS. Overresponses to stimuli lead to reduced vagal tone. Veterans are hypervigilant when deployed leading to a decrease in vagal tone because the parasympathetic system is not being used. When Veterans return home from deployments, they often experience over activation of the parasympathetic system because there is no long a need for hypervigilance and this over activation of the PNS causes them to lose interest in many things they once enjoyed. Where most people have a balance between the systems, those with PTSD seem to experience one extreme or the other. This loss in tone experienced increases the risk of tachycardia in patients with panic disorder because that balance between the systems is lost. As suggested, high HRV and vagal tone result in adaptive responses to the environment. HRV biofeedback training improved regulation of attention and emotion in those with panic disorder (Friedman & Thayer, 1998).

Endurance training has also been seen to improve HRV, which is important for Veterans because many Veterans are used to conducting physical training five days a week. However, when they return to civilian life they often stop this exercise routine (Gamelin, Berthoin, Libersa & Bosquet, 2007). 12 weeks is the optimal time for maximum improvements in HRV, but as little as 2 weeks of detraining can reverse the effects of HRV biofeedback. Aerobic training increased cardiovascular autonomic control without altering sympathetic balance. As a result, it is important for Veterans to stay physically active after they get out of the military (Gamelin, Berthoin, Libersa & Bosquet, 2007). Similarly, trained soldiers were found to have faster reactions times and accuracy on executive tasks in a study by Luft, Takase, &Darby (2009). Conversely, further increases in exercise intensity resulted in a larger decrease in HRV after exercise. Athletes were able to maintain their cognitive ability despite physical effort and were faster during working memory and executive tasks. Athletes possess greater PNS activation and reduced SNS activation inhibiting anticipated responses, which is extremely important for deployed military (Luft, Takase, & Darby, 2009).

Another important study compared pain with PTSD. Trauma causing pain is a risk factor for PTSD with 20 to 34 percent of clients possessing chronic pain also being diagnosed with PTSD and 45 to 78 percent of individuals with PTSD also having chronic pain. Reductions in pain have been observed with PTSD treatment and this reduction persisted 4 months later. Many of those with physical injuries have increased sympathetic activation and depression. HRV biofeedback increased HRV and reduced pain symptoms. This is important because numerous Veterans with PTSD have experienced some kind of physical injury (Tan et al., 2009).

Purpose

All of the studies examined reflect the importance and effectiveness of HRV biofeedback in ameliorating the effects of numerous disabling conditions associated with PTSD. HRV training has been used to treat or reduce symptoms of PTSD for over a decade, but using a mobile HRV biofeedback system is a novel idea. Using the Mobile Telehealth System will reduce the time and finances that go into transporting Marines to East Carolina or students to Camp Lejeune. The purpose of this study is to determine the effectiveness of the MTS in improving HRV before conducting a study on Active Duty Military Service Members (ADSM) examining improvement in PTSD symptoms by assisting them in learning how to gain control over their ANS.

Hypothesis

The underlying theory of this proposal suggests that HRV biofeedback training will improve ANS control, which is adversely affected by exposure to extreme stress and trauma.

<u>Methods:</u>

Participants

For the upcoming study, thirty male and female ADSM with PTSD will be recruited for HRV biofeedback training to determine if it will reduce their symptoms. Thirty ADSM will be recruited as matched controls. Participants are screened for PTSD and referred by military health care professionals at the Camp Lejeune Naval Hospital. Participants are then randomized into the control or experimental group, and followed for one month via a closed Mobile TeleHealth HRV assessment and biofeedback training system developed by Creative Cybernetics and being tested for the DoD. Due to regulatory approvals still being needed for the study, self-participation was used to analyze the effects of HRV training using the MTS.

Materials

The Heart Tracker Pro application, a mac desktop computer, and a USB plug in photoplesmography ear clip were used to determine resonant frequency. A windows tablet, Mobile Telehealth System application, and blue tooth ear clip were used to practice relaxation training and measure heart rate variability. The Patient Health Questionnaire (PHQ), CAPS-Military version, and Profile of Mood States (POMS) will be used to evaluate PTSD symptoms and mood of the ADSM clients. Repeated measures ANOVA and ANCOVA will be employed to analyze the data.

Procedure

The first task was to determine my own resonant frequency by practicing breathing at different rates using the Heart Tracker Pro system. Once the resonant frequency was determined, relaxation training using the MTS was conducted in a seated position until a score of 100 was obtained. Once the score of 100 was repeated, training with system was conducted in a standing position until a score of 100 was also reached. For the future study, the resonant frequency will be determined for each of the individuals as well. The study employs a pre and post, within and between, experimental design. Baseline and post training data on physiological and psychological changes include HRV, Patient Health Questionnaire (PHQ), CAPS-Military version, and Profile of Mood States (POMS). Biofeedback training will consist of 32 sessions: two 10 minute sessions per day, 4 times a week for one month in duration.

Participants will train for 10 minutes in the morning prior to breakfast and again in the evening before bed. Experimental participants will be trained how to do home HRV biofeedback during the first session and practice with a trainer during the second session. The participants will then be given a home biofeedback device (a blue tooth Ear clip) and instructed how to conduct their personalized training. The results of the session will be uploaded to a cloud server that is HIPPA compliant and be analyzed.

Results:

A total power of 6111 ms^2/Hz was obtained at the intermediate difficulty level when breathing at 6 breaths per minute, while a total power of 5751 ms^2/Hz was reached when breathing at 6.5 breaths per minute at the intermediate difficulty. However, the achieved score when breathing at 6 breaths per minute was 79 and a score of 93 was obtained when breathing at 6.5 breaths per minute. Therefore, the resonant frequency was estimated to be 6.5 breaths per minute. A complete flatline for very low frequency and high frequency was not reached, however, suggesting that the actual value is in between 6 and 6.5 breaths per minute.

After using the relaxation training system for approximately 4 weeks, a total power of 5804 ms^2/Hz was obtained as well as a score of 93, reflecting an increase in HRV. There was a reduction of VLF power and increase in HF when going from the first session (6 breaths per minute) to the second session (6.5 breaths per minute) indicating greater parasympathetic activation. Both VLF and HF were reduced in the 11^{th} session four weeks subsequent, with a peak in the LF range, suggesting an achieved balance of the two systems through relaxation training (Results for each of the sessions discussed are located in Appendix A). When conducting relaxation training using the MTS, a score of 93 was achieved during seated training. This score was increased to 100 and score of 100 was reached once more before transition to training while standing. However, when training was shifted to being conducted while standing, a lower score resulted (93). This score was once again increased to 100 after several sessions of relaxation training further suggesting an increase in HRV (Results are located in Appendix B).

<u>Discussion:</u>

Limitations and Directions for Future Research

Considering the study involving ADSM with PTSD has not yet been conducted and no clients were available to run consistent MTS training on, the results of the study were extremely limited. Finding my personal resonant frequency and using the MTS was beneficial to witness that increases in HRV occur with relaxation training, even for individuals with normal baseline HRV levels, but in view of I not qualifying for possessing PTSD, the results cannot be applied to the intended population. However, the literature review conducted provides strong evidence that HRV training will improve PTSD symptoms among ADSM and that this population enjoys HRV biofeedback as a method to reduce PTSD symptoms and adheres to at home training (Tan, Wang, & Ginsberg, 2013). The upcoming study will be able to provide information on whether at home training is as effective as biofeedback performed in a lab. This is important for the future of biofeedback because mobile devices will make HRV training as well as other methods of biofeedback easier to conduct.

Significance of the Findings

The results of the study indicate that the MTS is effective in increasing HRV and power and balance. The total power for HRV increased by approximately 1 percent, but a high HRV was observed before training. This is not a drastic increase in total power but if an increase in HRV can be seen for an individual with a HRV value starting in the normal range, then an increase in HRV will most likely be seen for individuals with baseline values of total power reflective of reduced HRV.

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Appendices

Appendix A

Figure 1: Session 1, 6 breaths per minute, February 10, 2016

Figure 2: Session 2, 6.5 breaths per minute, February 10, 2016

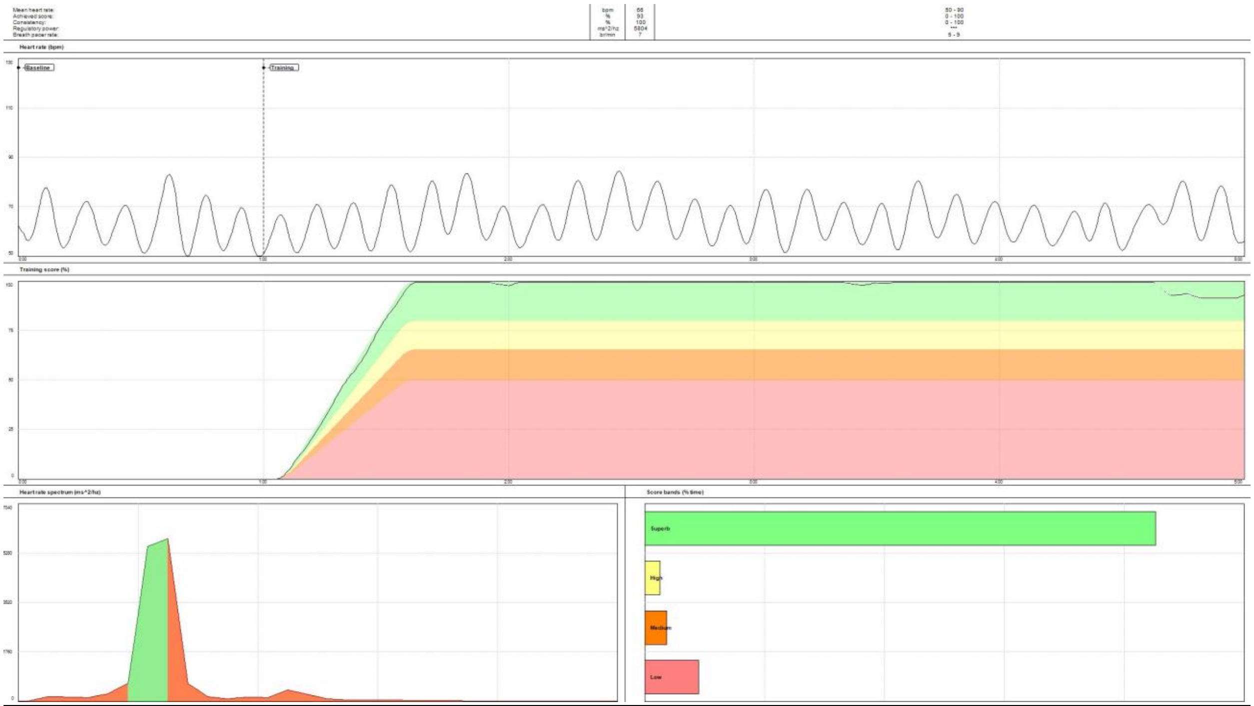

Figure 3: Session 11, 6.5 breaths per minute, March 4, 2016

Appendix B

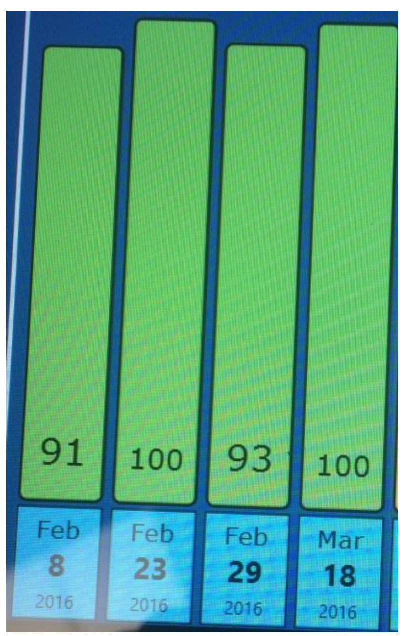

Figure 1: Stress Away Test, MTS, Sitting

Figure 2: Stress Away Test, MTS, Standing