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LOMA LINDA UNIVERSITY
School of Behavioral Health
in conjunction with
Faculty of the Psychology Department

Comparison of Neurofeedback Treatment on PTSD Symptoms within Military and Non-Military Populations

by

Lelah S. Villalpando

A Dissertation submitted in partial satisfaction of
the requirements for the degree
Doctor of Philosophy in Clinical Psychology

December 2019

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Each person whose signature appears below certifies that this dissertation in his/her opinion is adequate, in scope and quality, as a dissertation for the degree Doctor of Philosophy.

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ABBREVIATIONS

AAQ	Auditory Attention Quotient
APD	Auditory Processing Difficulties
ARCQ	Auditory Response Control Quotient
BCI Device	Brain Computer Interactive Device
EEG	Electroencephalogram
IVA-2 CPT	Integrated Visual and Auditory Continuous Performance Test - Version 2
PTSD	Post-traumatic stress disorder
VAQ	Visual Attention Quotient
VPD	Visual Processing Difficulties
VRCQ	Visual Response Control Quotient

ABSTRACT

Comparison of Neurofeedback Treatment on PTSD Symptoms
within Military and Non-Military Populations

by

Lelah S. Villalpando

Doctor of Philosophy, Graduate Program in Clinical Psychology
Loma Linda University, December 2019
Dr. Connie McReynolds, Chairperson

Novel, effective, and accessible therapeutic interventions for treating Posttraumatic Stress Disorder (PTSD) symptoms are in demand given the significant physical and psychosocial impairment associated with the disorder. Although PTSD is largely treated using various forms of cognitive behavioral therapy, treatment-resistance, or non-response, rates continue to remain high. Research has shown that talk-therapies can often trigger the limbic system, keeping it in a continual state of fight or flight. Consequently, many trauma survivors are motivated to consider alternative treatments for PTSD, such as artifact corrected EEG neurofeedback training, shifting the primary focus of the intervention away from the emotional part of the brain.

Artifact corrected EEG neurofeedback therapy addresses two primary facets identified through the Integrated Visual and Auditory Continuous Performance Test – 2 (IVA-2). The IVA-2 assesses whether or not, and to what degree, a person's visual and auditory processing systems have the capacity to interpret information from the environment. Secondly, when assessment results are coupled with neurofeedback, individuals learn to train their brain for better self-regulation. Impaired visual and auditory processing may prevent information from being accurately interpreted, and

therefore, increases the likelihood of maintaining a person's perceptual distortions, in perpetuity.

This study explored the relationship between trauma related symptoms (i.e., inattention and impulsivity) and visual and auditory functioning by analyzing archival data, based on a population of veterans and non-military adults with self-reported PTSD. The results of this study suggest that EEG neurofeedback therapy is clinically effective for improving visual and auditory attentional functioning in both military and non-military persons, in the context of trauma. Improved attentional functioning may boost organizational skills, decision making, frustration tolerance, and comprehension. This is crucial information because there continues to be high levels of treatment non-response and drop-out rates among veterans with PTSD who are participating in cognitive behavioral therapy (CBT) based programs. Two-thirds of veterans who complete CBT programs remain in the clinical range for PTSD, with notable attention deficits. Treatment-outcome research, such as this study, is vital to improve the effectiveness of therapeutic interventions for persons diagnosed with PTSD, particularly within specific populations that have high non-response rates, such as veterans.

CHAPTER ONE

INTRODUCTION

During any given year, approximately 8 million people in the U.S. meet criteria for PTSD (post-traumatic stress disorder). Although PTSD is gaining more attention through public outlets and literature, treatment-resistant PTSD is not as widely talked about (Feduccia & Mithoefer, 2018). Approximately 70% of the world's population has been exposed to some type of traumatic event, with 5.6% of those people meeting DSM-5 criteria for PTSD (Bomyea & Lang, 2012). Commonly used interventions for treating PTSD include various types of cognitive behavioral therapies (CBT), such as cognitive processing therapy (CPT), trauma-focused cognitive behavioral therapy (TF-CBT), and eye movement desensitization and reprocessing (EMDR). Although these interventions may be equally effective, there is a high drop-out rate from these treatments, as well as high non-response rates. According to Bomyea and Lang (2012), two-thirds of veterans who complete CBT based programs remain in the clinical range for PTSD, with notable attention difficulties and chronic hypervigilance.

EEG (electroencephalographic) neurofeedback training is an emerging therapeutic approach identified as effectively reducing PTSD symptoms by training individuals to self-regulate brainwave frequencies using the concept of operant conditioning (La Marca, 2018). Neurofeedback therapy is administered through a brain-computer interaction (BCI) device, which provides a structured training program tailored to each participant's profile. Standard training frequency and duration can vary depending on visual and auditory processing needs, which are identified at baseline using the IVA-2 CPT (Integrated Visual and Auditory Continuous Processing Test – Version 2). As reported by

McReynolds et. al. (2018), IVA-2 intervention programs generally range anywhere from two 30-minute sessions per week over 10 weeks (total of 20 sessions; 10 hours) to two 30-minute sessions per week for 20 weeks (total of 40 sessions; 20 hours). The current study used archival data that included the former duration and frequency (total of 20 sessions; 10 hours). During each training session, neural activity is monitored and recorded from electrodes placed on the scalp. Visual and auditory biofeedback are displayed on a computer monitor in live time, using a simple video game format, which is designed to alter neural signals and activity (McReynolds, Villalpando, & Britt, 2018). BCI devices have been used in a variety of settings and applied to diverse populations over the past three decades. For example, BCI devices utilizing neurofeedback therapy are used in physical rehabilitation hospitals to improve cognitive functioning in patients with a history of stroke. In addition to physical disability, EEG neurofeedback is often used for performance enhancement or to treat clinical conditions, such as learning and memory, sustained attention, sleep, ADHD, PTSD, depression, and anxiety (Van der Kolk et al., 2016).

Novel, effective, and accessible therapeutic interventions for treating PTSD symptoms are in demand at unprecedented levels given the significant physical and psychosocial impairment associated with the disorder, and the burden placed on both the individual and the healthcare system, including rising costs for ongoing care, loss of work, and disability benefits. In 2012, the VA spent approximately $3 billion and the DoD spent about $294 million on PTSD care for service members and veterans (Institute of Medicine, 2014).

The purpose of this archival study is to evaluate the clinical effectiveness of neurofeedback therapy on various attentional and behavioral symptoms, specifically, response control and impaired attention in adults with PTSD who either reported having military background or no military background. It is hypothesized that the IVA-2 CPT, a global measure of visual and auditory attention processing, will show a significant improvement in attention and response control over time, after 20 sessions of training. Given the critical need for effective, affordable, and accessible PTSD services, future research should aggressively strive to identify factors that influence PTSD treatment response, as well as determine which underlying mechanisms and individual characteristics explain how these factors operate. These data will provide critical information necessary to improve interventions aimed at providing services to individuals with PTSD.

CHAPTER TWO

LITERATURE REVIEW

Database and Literature Searches

Several literature searches were conducted in 2019 to identify new treatment interventions, services, or treatment-outcomes related to PTSD and EEG neurofeedback in both military and non-military persons. The search was limited to papers in English published between 2000 - 2019, and studies had to be conducted in either military or non-military populations with PTSD. Search categories for PTSD included, alternative therapies, prevention and resilience, treatment and diagnosis, rehabilitation and related topics, and healthcare reports. Search categories for EEG neurofeedback included, IVA-2 CPT, artifact correction, visual and auditory processing, therapeutic interventions, treatment protocol, performance enhancement, and neuroplasticity. Table 1 lists the databases that were used for the literature searches (see Table 1 for a list of databases and websites used in this literature review).

Auditory Processing System

Auditory processing is much more than a measure of a person's hearing ability; it is the way in which auditory information is received and interpreted specific to auditory sensory pathways (Taneja, 2019). Auditory processing is a fundamental component of communication. One of the important roles auditory processing plays in communication is phonological awareness, in which sounds are linked to letters, letters are encoded to form words, and words form sentences. Once all of this information has been processed and interpreted, the receiver can use the information to form a response. When the auditory processing system is impaired, either due to developmental causes, or acquired from trauma, information heard is not interpreted accurately (Solberg Okland, Todorovic, Luettke, McQueen, & de Lange, 2018).

Auditory Processing Difficulties

Auditory processing difficulty (APD) does not pertain to hearing loss as measured in standard audiological screenings, rather, it is the manner in which the brain processes auditory stimuli (McReynolds et al., 2018). APD can develop at any age; etiology can be either developmental or acquired through TBI, stroke, neurodegeneration, exposure to neurotoxic substances, or even aging (American Academy of Audiology, 2010; Taneja, 2017). Reportedly, approximately 5% of school-aged children and 76% of adults struggle with some level of impaired auditory processing (Taneja, 2017).

Although, the underlying etiology of APD is controversial, deficits in performance of school-aged children are thoroughly documented, specifically, trouble comprehending speech in the presence of background noise (Choudhury & Sanju, 2019; McReynolds et al., 2018; Thomas & Mack, 2010). Individuals with APD have difficulty identifying phonemes and linking them to their representative letters, which subsequently interferes with comprehension and storage of information being received through auditory channels (Thomas & Mack, 2010). This chronic distortion of information on a daily basis can negatively impact quality of life, effective communication, academic success, and overall mental health and wellbeing. Studies have shown people with APD often experience significant levels of frustration, irritability, and clinical depression (Serafini, Engel-Yeger, Vazquez, Pompili, & Amore, 2017).

Impaired auditory processing makes it difficult to attend to target stimuli (e.g., conversations, spoken instructions, introductions to new people) in the presence of competing background noise. Processing auditory information is quite complex, involving both serial and parallel processing (i.e. the dorsal stream processes spatial information and the ventral stream processes non-spatial information, respectively) (Li et al., 2018; Recanzone & Cohen, 2010). The auditory system involves shared processing with higher order cognitive structures and other sensory systems (e.g., executive functioning, memory, language, and attention). APD is manifested in a myriad of ways and may have different presentations in each individual due to the complex nature of the auditory nervous system.

Due to the non-modular structure of the brain and multiple sensory systems working together to process information (Ghazanfar & Schroeder, 2006), APD symptoms often overlap with those observed in individuals with other sensory deficits, such as, visual processing difficulties (Musiek et al., 2010) (see Table 2 for examples of identified difficulties in individuals with APD).

Visual Processing System

Visual processing is not a measure of nearsightedness or farsightedness, rather it is the manner in which the brain, not the eyes, processes visual stimuli (McReynolds et al., 2018). Visual processing involves comprehension of visual information, such as written letters, symbols, images, and spatial localization of objects (Janarthanan, 2018).

Visual Processing Difficulties

Visual processing difficulties (VPD) is the brain's inability to accurately process visual stimuli (McReynolds et al., 2018). Similar to the auditory processing system, the visual processing system is highly complex, involving other sensory structures and higher order cognitive processing (Ghazanfar & Schroeder, 2006). As such, VPD may be misdiagnosed or go undetected all together when relying solely on standard vision screens (Janarthanan, 2018). Symptoms of VPD frequently overlap with those observed in individuals with other sensory difficulties, such as, auditory processing difficulties (American Academy of Audiology, 2010) (see Table 3 for examples of identified difficulties in individuals with VPD).

There are eight types of visual processing concerns that have been identified by neuroscientists; individuals can have one or more at the same time (Janarthanan, 2018).

Visual perception concerns. Individuals with this type have a difficult time distinguishing the difference between similar letters, symbols, shapes, or objects. During reading and writing tasks, an individual may have trouble with letters such as, d and b, or p and q.

Visual figure-ground discrimination concerns. Individuals with this type have trouble pulling contours and shapes from the contextual background. This makes it difficult to identify a specific piece of information on a piece of paper, which may cause an increase in anxiety.

Visual sequencing concerns. Individuals with this type struggle with interpreting the order of words, images, and symbols. This makes reading a frustrating task because words and letters may become misinterpreted or reversed, and lines are often skipped or repeated.

Visual-motor handling concerns. Individuals with this type have trouble coordinating visual feedback with execution of body movements. For example, it would be difficult to copy an image from a book because the image would be perceived, interpreted, and replicated based on distorted visual-motor processing abilities. Other identifying markers for visual-motor handling deficits, are clumsiness and bumping into things.

Long- or short-term visual memory concerns. Individuals with this type may have difficulty remembering things that were initially perceived visually. This can make it hard to recall anything that was read, such as details of a story or detailed instructions.

Visual spatial concerns. Individuals with this type have problems identifying the spatial localization of objects in relation to self and other objects. This makes it difficult to interpret maps and keep track of time.

Visual closure concerns. Individuals with this type have trouble decoding an object if it is missing a part, or a drawing that is not complete, such as a bus missing tires, or a picture of a person without facial features. This creates problems with spelling and reading because the predictive nature of visual information processing is obstructed if a word is missing a letter.

Letter and symbol reversal concerns. There are two types of reversal deficits, static reversals and kinetic reversals. Static reversals occur when letters are written in the wrong direction (e.g., b and d; p and q; 5 and 2). Kinetic reversals occur when words are written as a mirror image of the target word (e.g., ton, not; was, saw). Letter and symbol reversal production usually resolves around age 7.

IVA-2 CPT

The IVA-2 CPT (Integrated Visual and Auditory Continuous Performance Test – Version 2) provides a brain-computer interactive (BCI) diagnostic tool for trained clinicians to identify visual and auditory processing deficits, as well as strengths. Test-retest reliability has been established, with a reported range of 0.66 – 0.75 for auditory quotient scores (inattention) and 0.37 – 0.41 for response control quotient scores (impulsivity)(Sandford & Sandford, 2015).

To date, research has not widely established a correlation between visual and auditory processing difficulties and the role they play in an individual’s susceptibility to developing PTSD (post-traumatic stress disorder) and/or non-response to treatment. However, a recent study (McReynolds, Bell, & Lincourt, 2017) uncovered some degree of a positive relationship between PTSD symptoms and visual and auditory processing difficulties, such that, as visual and auditory processing difficulties were reduced (i.e., improved attention), PTSD symptoms were also reduced (i.e., improved feelings of general well-being).

Neurofeedback Therapy

The brain’s activity determines the way a person experiences the world, everything that is felt and expressed is motivated by the sensory system. Neurofeedback therapy, or EEG biofeedback, was first introduced in the late 1950’s by scientists who discovered that brain wave activity could be manipulated by using a simple reward system (Fisher, Lanius, & Frewen, 2016). Further studies indicated that modulating brain activity provided long-term neural-network stability and neuroprotection against various toxins and neurodegeneration (Da Silva-Sauer, De La Torre-Luque, Silva, & Fernández-Calvo, 2019). Throughout the 1970's, neurofeedback became popular within the meditation and spiritual fields, and quickly became trapped between religion and science. During the 1980's and 90's, neurofeedback was applied to attention deficit disorders, central nervous system conditions, and psychological distress. Today, neurofeedback therapy has gained recognition as an appropriate intervention for conditions ranging from PTSD, ADHD, learning disabilities and emotional dysregulation (Hammond, 2011).

To understand neurofeedback, and how it trains the brain using biofeedback, it is imperative to understand the basic fundamentals of brainwaves. Brainwaves are electrical impulses that fire when neurons communicate with each other (Broderick, 2015). Brainwaves tell the story of how a person's brain is functioning, such as thought habits, mood, and stress levels. During a neurofeedback training session, brainwaves indicate whether or not an individual is in a comfortable state (Fisher et al., 2016; McReynolds et al., 2017). The biofeedback generated on a computer screen showing brain activity, will respond with a reward (e.g., video games, music, sound bites) when the brainwaves indicate a desired state of arousal has been achieved. With repetition, much like exercise, the neural pathways are strengthened and trained to learn how to self-correct brain activity from a heightened state of arousal and inattention, to a more relaxed state and better able to attend to external sensory stimuli (Butko & Triesch, 2007; Vignoud, Venance, & Touboul, 2018). Research indicates that individuals may experience an improvement in language and learning when sensory processing pathways are structurally strengthened (Boscariol et al., 2010). Additionally, studies have produced evidence that neurofeedback training may enhance neuroplasticity (Hammond, 2011).

Post-traumatic Stress Disorder

PTSD is a psychopathological response that occurs when a person has been exposed to actual or threatened death, serious injury, or sexual assault. It is characterized by nightmares, anxiety, fear in the absence of danger, recurrent re-experiencing of the event, avoidance of reminders of the trauma, emotional numbing, hyper-arousal, and trouble concentrating (Feduccia & Mithoefer, 2018).

The term known today as PTSD has been around for about 40 years after it appeared in the 1980 version of the DSM-III. PTSD has been known by many different names throughout history, such as, “combat hysteria”, “shell shock”, “soldier’s heart”, “battle hypnosis”, and “war neurosis” (Crocq & Crocq, 2000). Psychiatrists in the early 1900’s began comparing the behavioral traits of World War I soldiers with civilians who witnessed mass casualty man-made disasters (e.g., railway disasters following the introduction of steam-driven machinery during the Industrial Revolution). To the surprise of psychiatrists, they found similarities between cases of soldiers who had “war neurosis”, and civilians who witnessed the man-made disasters. Similar symptoms identified among both soldiers and civilians were anxiety, fright brought about by loud sounds, nightmares, sudden muteness, deafness, tremors, and personality changes (Crocq & Crocq, 2000). By mid-twentieth century, psychiatrists understood the urgency for immediate treatment of “traumatic neurosis” symptoms, learning from WWI that when left untreated, this condition could evolve into chronic and irreversible forms of somatic and psychological symptoms (Crocq & Crocq, 2000).

During any given year, approximately 8 million people in the U.S. have Post-Traumatic Stress Disorder, (PTSD). Although PTSD is gaining more attention through public outlets and literature, treatment-resistant PTSD is not as widely talked about. Approximately 70% of the world's population has been exposed to some type of traumatic event, with 5.6% of those people meeting DSM-5 criteria for PTSD (Bomyea & Lang, 2012). Widely used interventions for treating PTSD include various types of CBT, such as cognitive processing therapy (CPT), trauma-focused cognitive behavioral therapy (TF-CBT), and eye movement desensitization and reprocessing (EMDR). Although these interventions may be equally effective, there is a high drop-out rate from these treatments, as well as high non-response rates. According to Bomyea and Lang (2012), two-thirds of veterans who complete CBT based programs remain in the clinical range for PTSD, with notable attention problems and chronic hypervigilance.

In 2012, the VA spent approximately $3 billion and the DoD spent about $294 million on PTSD care for service members and veterans (Institute of Medicine, 2014). Novel, effective, and accessible therapeutic interventions for treating PTSD symptoms are in demand at unprecedented levels given the significant physical and psychosocial impairment associated with the disorder, and the burden placed on both the individual and the healthcare system, including rising costs for ongoing care, loss of work, and disability benefit (see Table 4 for general diagnostic criteria for PTSD).

PTSD and Neurofeedback Therapy

Persons with PTSD show high levels of both impulsivity and inattention, which are quantified by the Prudence and Vigilance Scales on the IVA-2, respectively. Being in a state of chronic hypervigilance creates strong thought patterns, or neural connections, of fight or flight; perceiving a threat of danger when there is no actual threat. Neurofeedback helps regulate emotional and mental states through up-regulation of the prefrontal cortex, which leads to down-regulation of the amygdala (Herwig et al., 2019). While in this constant state of arousal, focused on negative and unpleasant perceived stimuli, an individual may miss other important pieces of information (e.g., pleasant and/or neutral stimuli) necessary to self-regulate. The Prudence scale on the IVA-2 measures errors or commission, or impulsivity. The Vigilance scale on the IVA-2 measures errors of omission, or inattention. High scores on these scales during a baseline IVA-2 test would indicate severe visual and auditory inattention. Following treatment as usual (i.e., 20 neurofeedback sessions), individuals often have IVA-2 scores with significantly fewer errors of commission and omission, indicating improvement in attention and response control (La Marca et al., 2018; McReynolds et al., 2017).

CHAPTER THREE

Research Design

Aims and Hypotheses

The first aim of this proposal is to investigate whether 20 sessions of EEG neurofeedback training will improve symptoms of PTSD, such that errors of commission and errors of omission will be reduced, as measured on the IVA-2. It is hypothesized that 20 sessions of EEG neurofeedback training will significantly reduce symptoms of impulsivity and inattention, in the context of trauma, in adults. Numerous studies have shown beneficial cognitive effects of neurofeedback training using brain-computer interaction devices. For example, studies indicate adults and children with ADHD who received 20 sessions of neurofeedback training, experienced improved attention and response control compared to controls, and showed lower levels of anxiety (McReynolds et al., 2017; McReynolds, Britt, & Villalpando, 2019; McReynolds et al., 2018). Furthermore, previous research from McReynolds et al. (2017) has shown that military veterans with PTSD, who received 40 sessions of EEG neurofeedback training with the IVA-2, reported significant improvements in their overall general wellbeing. Therefore, the second aim of this proposal is to investigate whether EEG neurofeedback effects military and non-military persons with PTSD differently. It is hypothesized that there will be no difference in treatment outcomes among military and non-military persons with PTSD symptoms, as measured by the Prudence and Vigilance scales. '

Methods

Participants. Neurofeedback treatment was provided for 33 adults with self-reported PTSD who have had either some or no previous military experience (*n* = 21 U.S. military - 16 males, 4 females; *n* = 12 non-military - 15 males, 4 females; ages 18 to 40) who completed a total of 40 half-hour sessions of neurofeedback treatment. The participants for this study were drawn, using a stratified random sampling method, from an archival database of adults who previously received individualized neurofeedback training within a university-based clinic setting. Only those adults who completed 20 neurofeedback treatment sessions, self-reported as being previously diagnosed with PTSD, and disclosed military status, were selected for this study (see Table 5 for demographic details).

Neurofeedback Treatment Protocol. Each participant received an individualized neurofeedback treatment plan based on areas of visual and auditory processing strengths and weaknesses. Treatment was administered on a one-to-one basis, in a private room, within a university-clinic setting. Therapeutic goals targeted reduction of mental stress related to anxiety and depression symptoms by strengthening visual and/or auditory attentional functioning. During the first training session, EEG data were collected from each participant at baseline to determine treatment plan and goals. Training parameters are then individually tailored for each participant according to baseline performance.

Treatments were administered using the SmartMind 3 artifact corrected neurofeedback system with a two-channel EEG station (BrainTrain, Inc., North Chesterfield, VA). Artifact correction lends a unique real-time quality to the SmartMind 3 neurofeedback system by filtering out brief facial activity, frequently occurring eye blinks, and eye movement, without interrupting the training program (Sandford & Sandford, 2015). Treatment was administered through a brain-computer interaction (BCI) device, utilizing visual and auditory reinforcement, as well as graphics and a scoring system to generate positive reinforcement through a feedback loop.

Materials

J&J EEG stations were used to collect the EEG signals (see Figure 2). Sensors were attached to participants using 10-20 electrode paste after prepping site locations per protocol. Impedance was measured to meet the manufacturer's requirements prior to the beginning of each training session. All EEG data collected were automatically de-artifacted, recorded, and stored by the SmartMind 3 software.

Test Procedures

Prior to beginning neurofeedback training, each participant underwent a sophisticated intake evaluation conducted by a qualified healthcare professional. Following the intake assessment, during the same visit, participants were administered the IVA-2 CPT. Participants who were too severely impaired in attentional functioning to validly respond to either visual or auditory IVA-2 test stimuli, were given a score of zero for these responses, per test interpretation protocol (Sandford & Sandford, 2015). Immediately upon completion of testing, a comprehensive report is generated, identifying areas of visual and auditory processing strengths and weaknesses. The clinician reviews the report with the participant to provide feedback and psychoeducation, and to formulate a treatment plan.

Participants were scheduled to attend two half-hour EEG neurofeedback sessions per week over the course of 10 weeks. After completing 20 neurofeedback sessions, the IVA-2 test was re-administered.

Measures

Integrated Visual & Auditory 2 Continual Performance Test. The IVA-2 CPT has been found to be a reliable and valid measure of visual and auditory attention processing. It is a test of impulsivity and attention that measures responses to 500 intermixed visual and auditory stimuli, which takes about 15 minutes to complete. All scales are reported as standard scores and have a mean of 100 and a standard deviation of 15 (see Appendix A for descriptions of IVA-2 visual and auditory attention and response control scales). There are two validity measures built into the IVA-2 to ensure comprehension of test instructions and consistent response patterns (Sandford & Sandford, 2015). The global measures of attention used for this study are the Visual Attention Quotient (VAQ) and the Auditory Attention Quotient (AAQ) (see Appendix B for descriptions of IVA-2 visual and auditory attention and response control measures).

VAQ. This measure of attention is made up of three primary visual scales: Vigilance, Speed, and Focus. The Vigilance scale measures errors of omission, the Speed scale measures response time to visual test targets, and the Focus scale measures inconsistency of response time to visual test targets (Sandford & Sandford, 2015).

AAQ. This measure of attention is made up of three primary auditory scales: Vigilance, Speed, and Focus. The Vigilance scale measures errors of omission, the Speed scale measures response time to auditory test targets, and the Focus scale measures inconsistency of response time to auditory test targets (Sandford & Sandford, 2015).

ARCQ. This measure of response control is made up of three primary auditory scales: Prudence, Consistency, and Stamina. The Prudence scale measures errors of commission, which indicates level of impulsivity and ability to inhibit responses to auditory stimuli. The Consistency scale measures the ability to stay on task by analyzing the general variability of response times. The Stamina scale is used to identify mental fatigue by monitoring auditory processing speed over time and comparing the mean reaction times of correct responses between the beginning portion and end portion of the IVA-2 test (Sandford & Sandford, 2015).

VRCQ. This measure of response control is made up of three primary visual scales: Prudence, Consistency, and Stamina. The Prudence scale measures errors of commission, which indicates level of impulsivity and ability to inhibit responses to visual stimuli. The Consistency scale measures the ability to stay on task by analyzing the general variability of response times. The Stamina scale is used to identify mental fatigue by monitoring auditory processing speed over time and comparing the mean reaction times of correct responses between the beginning portion and end portion of the IVA-2 test (Sandford & Sandford, 2015).

CHAPTER FOUR

Results

Descriptive statistics for each one-tailed paired-samples *t* test analysis, including pre- and post-treatment IVA-2 scores, are presented in Table 6 (Attention scales) and Table 7 (Response Control scales). To test the first hypothesis, a series of one-tailed paired-samples *t* tests were conducted to test for differences between the means of each Attention and Response Control Quotient scale (AAQ, VAQ, ARCQ, VRCQ) at baseline and after 20 sessions. Using an alpha criterion of .05, a Bonferroni correction was applied, determining an alpha of .01 to be adequate in reducing the chance of making a familywise Type I error. Before running the analyses, tests for multivariate normality, multicollinearity, and outliers were conducted. Outliers were labeled using a boxplot and the interquartile range (IQR); data were transformed and normalized using winsorization (Shete et al., 2004).

As a group (i.e., both military and non-military persons with PTSD), the individuals in this study initially presented with impaired visual and auditory functioning. After 20 half-hour neurofeedback treatment sessions, both their visual and auditory attention abilities improved, falling within the normal range (i.e., defined as a standard score of 77 or higher) (Sandford & Sandford, 2015). On average, change-score differences between pre- and post-treatment IVA-2 attentional scales (i.e., VAQ and AAQ) were clinically significant (M=11, SD=16; M=10, SD=18, respectively), which is defined as a change-score of 8 points or more (McReynolds et al., 2018; Sandford & Sandford, 2015).

VAQ scores were found to be significantly higher after 20 sessions of neurofeedback treatment from a mean of 86 (slightly to moderately impaired) to 97 (average), an 11-point increase, $t(32) = -4.06$, $p < .001$, Cohen's $d = .52$; AAQ scores were found to be significantly higher after 20 sessions of neurofeedback treatment from a mean of 84 (mildly impaired) to 94 (average), a10-point increase, $t(32) = -3.21$, $p < .01$, Cohen's $d = .52$. Both scales of attentional functioning had effect sizes in the medium range demonstrating the clinical efficacy of neurofeedback as a therapeutic intervention for individuals diagnosed with PTSD and present with attentional deficits. There were no significant differences between the Visual (VRCQ) and Auditory (ARCQ) Response Control scale scores before treatment and after treatment, *p*s > .10 (M=4, SD=18 and M=3, SD=18, respectively).

Hypothesis one was partially supported because, the change-scores between pre- and post-treatment on the IVA-2 attentional measures of visual and auditory processing (VAQ and AAQ) indicated statistically significant improvement, while the change-scores between the pre- and post-treatment IVA-2 Visual (VRCQ) and Auditory (ARCQ) Response Control scales did not indicate a significant difference. It should be noted that the data on both response control scales showed an upward change-score trend.

Descriptive statistics for the MANCOVA are presented in Table 8. To test the second hypothesis that there would be no difference in treatment outcomes among military and non-military persons diagnosed with PTSD, a 2x2 between-subjects factorial repeated measures MANCOVA with Bonferroni correction was performed, predicting post-treatment (i.e., 20 sessions of neurofeedback) IVA-2 scale scores (i.e., AAQ, VAQ, ARCQ, VRCQ) from group type (i.e., military vs. non-military persons), controlling for age and gender. The results indicated that whether or not a person diagnosed with PTSD had military experience was not a significant predictor of overall neurofeedback treatment outcome, $F(1, 31) = .592$, Wilks' Lambda = .938, partial η^2 squared = .062, $p > .07$. The second hypothesis was supported because there was no difference between treatment outcomes among military and non-military persons diagnosed with PTSD, following 20 sessions of neurofeedback, across all visual and auditory attention and response control scales.

CHAPTER FIVE

Discussion

To test the first hypothesis, a series of one-tailed paired samples *t* test were performed to compare the change scores between pre- and post-treatments of 20 neurofeedback sessions, as measured by the IVA-2 on the Auditory Attention Quotient (AAQ), Visual Attention Quotient (VAQ), Attention Response Control Quotient (ARCQ), and Visual Response Control Quotient (VRCQ) scales. To test the second hypothesis, a 2 X 2 between-subjects factorial multivariate analysis of covariance (MANCOVA) with Bonferroni correction was performed on four dependent variables (i.e., VAQ, AAQ, VRCQ, ARCQ).

The results from all analyses indicate that neurofeedback treatment was effective for individuals diagnosed with PTSD, regardless if they had military experience or no military experience. Of interest, although both groups had statistically similar treatment-outcomes on the VAQ and AAQ (i.e., baseline scores were in the impaired range, and post-treatment scores were in the average range), the military group achieved higher change scores, overall, than the non-military group, such that, military persons had lower IVA-2 scores at baseline and higher IVA-2 scores post-treatment than non-military persons. Conversely, on the ARCQ and VRCQ, the non-military group had lower baseline scores and higher IVA-2 scores post-treatment than the military group. Overall, both groups showed similar rates of improvement across all visual and auditory scales, between baseline scores and scores after 20 sessions. These data indicate that 20 sessions of EEG neurofeedback training were similarly effective for both military and non-military persons diagnosed with PTSD.

Through the use of repetition and reinforcement, neurofeedback training creates and strengthens visual and auditory neural connections in the pre-frontal cortex. The prefrontal cortex makes key contributions to the limbic system, which is involved in generating emotional responses (Arnsten, 2010; Broderick, 2015; Van Eylen, Boets, Steyaert, Wagemans, & Noens, 2015), such as the fight or flight response. The pre-frontal cortex is the part of the brain responsible for executive functioning, which includes prediction outcomes, determining good and bad, social inhibition, differentiation among conflicting thoughts, determination of future consequences, and interpretation of one’s reality (Arnsten, 2010).

Through the strengthening of visual and auditory processing pathways in the pre-frontal cortex, neurofeedback trains individuals to self-regulate physiological responses triggered by the limbic system (e.g., stress and anxiety). The more times a brain completes a specific task, the stronger the neural connections become in that pathway each successive time. This is known as the Hebbian synaptic plasticity theory, which suggests neurons that fire together, wire together by regulating and adapting a neuron’s intrinsic excitability (Butko & Triesch, 2007).

The aftermath of a traumatic event can result in new neural networks forming, which maintain states of fearfulness, rage, and shame, in perpetuity. The repetitive firing of these networks define trauma, triggering chronic activation of the limbic system. Neurofeedback disrupts and weakens those harmful connections by creating new neural patterns. Improving visual and auditory functioning provides faster cognitive processing of environmental cues, which lends the ability to consider more options of how to respond. Response control and paying attention are stabilizing factors in executive functioning, allowing the limbic system to relax (Van der Kolk, 2014).

Healthy executive functioning provides the capacity to organize and plan, to weigh the consequences of one’s behaviors, to be cognitively flexible, and to regulate one’s emotions. Improving visual and auditory processing systemically effects executive functioning and limbic system activation (Van der Kolk, 2014). For this reason, individuals with impaired visual and auditory functioning may not respond to traditional CBT programs by sheer virtue that they lack the fundamental capacity to participate in treatment. Participation in treatment involves higher order complex functioning, such as, learning coping mechanisms, identifying triggers, self-regulation, organization and planning, and regular attendance. Lacking these basic underpinnings of executive functioning, while engaging in trauma re-processing, can severely activate the limbic system. Without the skills to self-regulate, once the limbic system is activated, a person may experience intense flashbacks, anxiety, and emotional distress for several days following therapy (Fisher et al., 2016). Neurofeedback training offers the brain the ability to self-regulate and achieve a state of stability, while simultaneously weakening the neural networks created by shame, fear, and rage.

Conclusion and Future Directions

The results of this study suggest that EEG neurofeedback therapy is clinically effective for improving visual and auditory attentional functioning in both military and non-military persons, in the context of trauma. This is crucial information because there continues to be high levels of treatment non-response and drop-out rates among veterans with PTSD who are participating in CBT based programs. Two-thirds of veterans who complete CBT programs remain in the clinical range for PTSD, with notable attention deficits (Bomyea & Lang, 2012). Additionally, it is estimated that over 80 percent of returning combat veterans who enroll in college on the GI Bill, do not complete their degrees. Reportedly, factors contributing to this dropout rate include problems focusing and paying attention (Van der Kolk, 2014). The burden placed on both the individual and the healthcare system, including costs for ongoing care, loss of work, and disability benefits are rising at an unprecedented rate. In 2012, the VA spent approximately $3 billion and the DoD spent about $294 million on PTSD care for service members and veterans (Institute of Medicine, 2014). Treatment-outcome research, such as this study, is vital to improve the effectiveness of therapeutic interventions for persons diagnosed with PTSD, particularly within specific populations that have high non-response rates, such as veterans.

Many PTSD experts recommend sequenced or phase-based therapeutic interventions that target symptoms which are correlated with PTSD prior to using trauma-focused treatments (Cloitre et al., 2012; Haagen, Smid, Knipscheer, & Kleber, 2015). Phase-based interventions are important to consider, because without first addressing processing deficits and lack of capacity to self-regulate, harm to the patient can result. Neurofeedback therapy builds a stable cognitive foundation through strengthening visual and auditory neural pathways and enhances the brain's capacity to self-regulate; this is achieved without using talk-therapy, accessing traumatic memories, or activating distressing emotions (Da Silva-Sauer et al., 2019; McReynolds et al., 2017).

EEG neurofeedback training may be a fundamental component for the treatment of military persons with PTSD. The mechanisms of EEG neurofeedback are currently being studied in the field (Da Silva-Sauer et al., 2019; Hammond, 2011; McReynolds et al., 2017, 2018; Van der Kolk, 2014), making it a viable option as a first-line intervention for people diagnosed with PTSD. Future work is needed to explore ways to enhance treatment outcome through complementary pairing of EEG neurofeedback training with other therapeutic interventions. Knowledge regarding the mechanisms (e.g., use of neuroimaging, calcium based pre- and post-synaptic neuron activity, spike-timing-dependent plasticity) (Schaefer et al., 2000; Vignoud et al., 2018) by which neurofeedback intervention is effective would assist in developing an individualized treatment plan that includes an appropriate level of sequenced engagement based on capacity (e.g., neurofeedback training, self-regulation, skill building, behavioral activation, trauma re-processing).

Examining the mechanisms of therapeutic treatment is necessary for the proper treatment of impulsivity and inattention, in the context of trauma, and will play a large role in preventing patient harm. Activation of specific mechanisms may be detrimental to the mental health of persons who lack the cognitive capacity to self-regulate, which is why research needs to be conducted on an individual-level treatment basis through RCTs (randomized control trials) (Bomyea & Lang, 2012). Strengthening the visual and auditory pathways, and improving executive functioning through neurofeedback training, may influence how well a person responds to trauma re-processing, and to what extent they can achieve homeostasis after being severely dysregulated from talk-therapy. Targeting and improving visual and auditory processing deficits through neurofeedback training, may not only predict treatment-outcome for subsequent trauma-focused therapies, but may also predict how well a person will function in relationships, in school performance, and at work (Fisher et al., 2016; McReynolds et al., 2018).

Given the critical need for effective, affordable, and accessible PTSD services, future research should aggressively strive to identify factors that influence PTSD treatment response, as well as determine which underlying mechanisms and individual characteristics explain how these factors operate. One way to do this would be to explore treatment outcomes when combining neurofeedback training with trauma focused therapy (e.g., using neurofeedback training as a pre-requisite to talk therapy). Strengthening the visual and auditory processing pathways through EEG neurofeedback training, may increase the chances for a non-responder to successfully engage in, and benefit from, trauma focused treatment protocols.

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TABLES

Table 1

Databases and websites used for literature review

- Academic Search Premier
- Alt HealthWatch
- Health and Psychosocial Instruments
- Military & Government Collection
- PsycArticles
- Pubmed
- Loma Linda University Del Library Website

Table 2

Symptoms of Auditory Processing Difficulties

- Poor listening skills (e.g., frequently being told to pay attention when requests are being made)
- Miscommunication that causes problems with partners, family, friends, and co-workers
- Difficulty following verbal multi-step directions that result in stress at home and work, due to failing to complete seemingly simple routine tasks
- Listening to the television at a high volume, but still having difficulty understanding what is going
- Easily distracted by background sounds in the environment
- Difficulty following long conversations (e.g., feeling as though you missed something)
- Difficulty following conversations among a group of people (e.g., trouble distinguishing and tracking content of multiple conversations, as well as difficulty task switching between listening and responding)
- Trouble understanding verbal math problems, even though written math skills may be strong
- Difficulty remembering spoken information (e.g., frequently asking others to repeat what was said)
- Difficulty taking notes and/or summarizing spoken content
- Difficulty in focusing, sustaining, or dividing attention
- Difficulty with reading and/or spelling

(Deangelis, 2018; McReynolds et al., 2017; Thorne & Debener, 2014)

Table 3

Visual Processing Difficulties

- Easily distracted by irrelevant visual stimuli
- Difficulty extracting meaning and emotion from written communication and images (e.g., emails, texts, written instructions, signs, pictures)
- Trouble with visuo-spatial object rotation and distance perception, which makes things like map reading and catching a ball difficult (i.e., identifying oneself in relation to another object)
- Difficulty remembering written information (e.g., appointments, payment due dates, information on flyers, lists)
- Difficulty following written multi-step directions that result in stress at home and work, due to failing to complete seemingly simple routine tasks (e.g., making/completing to-do lists, reading/following instruction manuals, making a grocery list but forgetting it at home and not remembering what was on it)

(McReynolds et al., 2018)

Table 4

General diagnostic criteria for PTSD

A. Exposure to actual or threatened death, serious injury, or sexual violence in at least one of the following ways:
    1. Directly experiencing a traumatic event
    2. Being a first-hand witness to a traumatic event
    3. Learning a traumatic event has occurred to a close family member or friend
    4. Experiencing repeated or extreme exposure to aversive details of traumatic events (e.g., first responders collecting human remains; police officers repeatedly exposed to details of child abuse)

B. Presence of at least one of the following intrusion symptoms that begin after the event occurred:
    1. Recurrent, involuntary, and intrusive distressing memories of the traumatic event(s)
    2. Recurrent distressing dreams that are related to the traumatic event(s)
    3. Flashbacks
    4. Intense or prolonged psychological distress when exposed to internal or external cues that resemble an aspect of the traumatic event(s)

C. Persistent avoidance of things associated with the traumatic event(s), beginning after the event (e.g., thoughts, feelings, people, places, activities, objects, situations)

D. Negative alterations in cognitions and mood associated with the traumatic event(s):
    1. Inability to remember important parts of the traumatic event(s)
    2. Persistent and exaggerated negative beliefs or expectations about oneself, others, or the world
    3. Persistent distorted cognitions about the cause or consequences of the traumatic event(s) that lead to blaming self or others
    4. Persistent negative emotional state (e.g., anger, guilt, fear)
    5. Markedly diminished interest in important activities
    6. Feelings of detachment from others
    7. Persistent inability to experience positive emotions (e.g., happiness, satisfactions, or loving feelings)

E. Marked alterations in arousal and reactivity associated with the traumatic event(s):
    1. Irritable behavior
    2. Reckless or self-destructive behavior
    3. Hypervigilance
    4. Exaggerated startle response

5. Problems with concentration
6. Sleep disturbance

F. Duration of symptoms is more than one month

G. The symptoms cause significant distress in social, occupational, or other important areas of functioning

H. The symptoms are not attributable to the effects of a substance or medical condition

Source: American Psychiatric Association, DSM-5, 2013

Table 5

Demographic Frequencies (N = 33)

Variable	*n*	%
Sex		
Male	26	78.8
Female	7	21.2
Age		
17 – 30	6	18.2
31 – 44	9	27.3
45 – 58	8	24.2
59 +	10	30.3
Groups		
Military background with PTSD	21	63.6
No military background with PTSD	12	36.4
IVA-2 CPT Measures		
Auditory Attention Quotient (AAQ)	33	100.0
Visual Attention Quotient (VAQ)	33	100.0
Auditory Response Control Quotient (ARCQ)	33	100.0
Visual Response Control Quotient (VRCQ)	33	100.0

Table 6

Paired sample one-tailed t-tests comparing Mean (SD) IVA-2 Attention Quotient scale scores between baseline and after 20 neurofeedback sessions. (N = 33)

IVA-2 Attention Scales	Baseline *M(SD)*	20 Sessions *M(SD)*	Score Change	*p* value	Cohen's *d*
Visual Attention Quotient Score (VAQ)	85(24)	97(18)	12	.000	.57
Auditory Attention Quotient Score (AAQ)	84(22)	94(16)	10	.002	.52

Note. A Bonferroni correction has been applied for multiple comparisons.

Table 7

Paired sample one tailed t-tests comparing Mean (SD) IVA-2 Response Control Quotient scale scores between baseline and after 20 neurofeedback sessions. (N = 33)

IVA-2 Response Control Scales	Baseline *M(SD)*	20 Sessions *M(SD)*	Score Change	*p* value	Cohen's *d*
Visual Response Control Quotient Score (VRCQ)	92(22)	96(18)	4	.184	.20
Auditory Response Control Quotient Score (ARCQ)	94(19)	97(14)	3	.166	.18

Note. A Bonferroni correction has been applied for multiple comparisons.

Table 8

MANCOVA Results

Predictor	*df*	Multivariate *F*	Wilks' λ	Partial η^2	*p* value
Group	1, 31	.592	.938	.062	.626
Time	1, 31	1.728	.944	.056	.199
Group * Time	1, 31	.045	.998	.002	.834

Note. A Bonferroni correction has been applied for multiple comparisons. Group = Military vs. Non-Military; Time = Pre- and Post-Treatment of 20 neurofeedback sessions

FIGURES

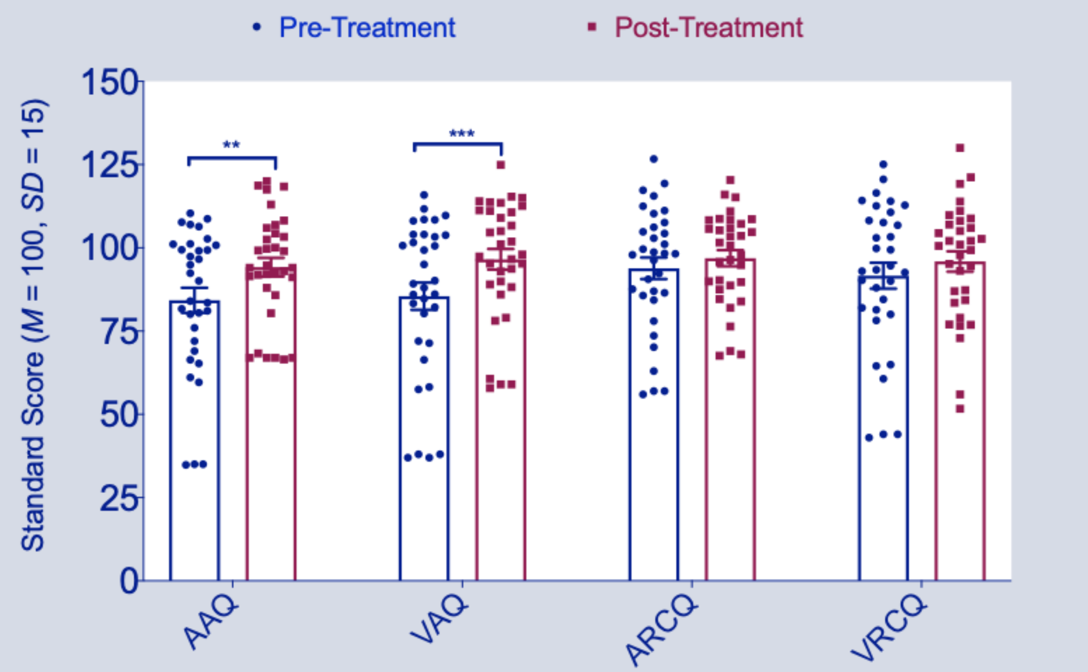

Figure 1. Visual and auditory attention and response control scale score changes between baseline and after 20 neurofeedback sessions
$^{**}p < .01$, $^{***}p < .001$ denotes statistical significance between pre- and post-treatment

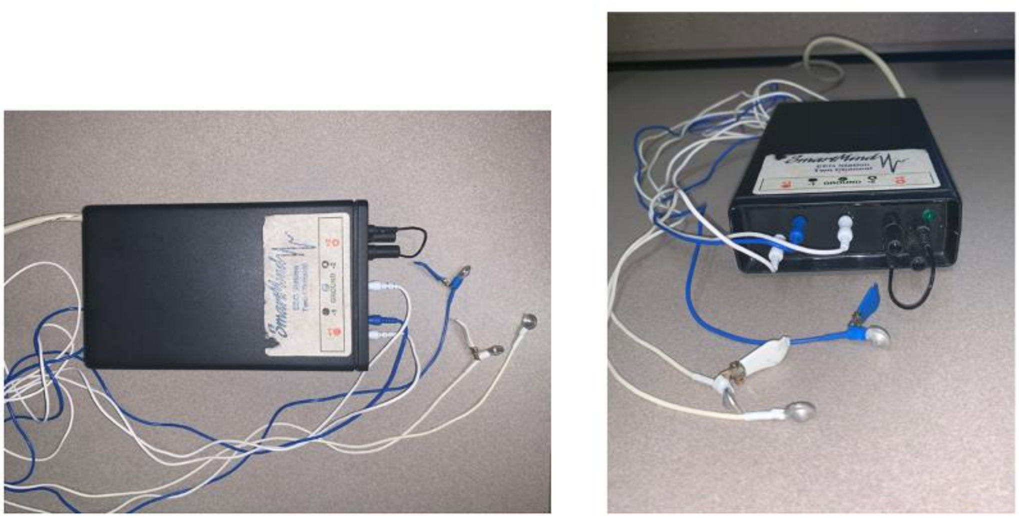

Figure 2. SmartMind 3 two-channel EEG station (BrainTrain, Inc., North Chesterfield, VA)

APPENDIX A

Description of IVA-2 visual and auditory primary scales

Attention Scales	**IVA-2 Description of Primary Attention Scales**
Vigilance	Measure of inattention as evidenced by two different types of errors omission
Focus	Reflects the total variability of mental processing speed for all correct responses
Speed	Reflects the average reaction time for all correct responses
Response Control Scales	**IVA-2 Description of Primary Response Control Scales**
Prudence	Measure of impulsivity and response inhibition as evidenced by three different types of errors of commission
Consistency	Measures the general reliability and variability of response times and is used to help measure the ability to stay on task
Stamina	Compares the mean reaction times of correct responses during the first 100 trials to the last 100 trials; this score is used to identify problems related to sustaining attention and effort over time

Source: (Sandford & Sandford, 2015)

APPENDIX B

Description of IVA-2 visual and auditory global composite measures

IVA-2 Measures	IVA-2 Description of Measures
AAQ Auditory Attention Quotient	Based on equal measures of auditory Vigilance, Focus, and Speed scales
ARCQ Auditory Response Control Quotient	Derived from auditory Prudence, Consistency, and Stamina scales
VAQ Visual Attention Quotient	Based on equal measures of visual Vigilance, Focus, and Speed scales
VRCQ Visual Response Control Quotient	Derived from visual Prudence, Consistency, and Stamina scales

Source: (Sandford & Sandford, 2015)