4-2020

The Impact of Neurofeedback on Women Diagnosed with PTSD: A Multiple Case Study

Reema Abdulrahman Alhowaish

THE IMPACT OF NEUROFEEDBACK ON WOMEN DIAGNOSED WITH PTSD: A MULTIPLE CASE STUDY

A

DISSERTATION

Presented to the Faculty of the Graduate School of
St. Mary's University in Partial Fulfillment
of the Requirements
for the Degree of

DOCTOR OF PHILOSOPHY
in
Counseling

by
Reema Alhowaish
San Antonio, Texas
April 2020

THE IMPACT OF NEUROFEEDBACK ON WOMEN DIAGNOSED WITH PTSD:

A MULTIPLE CASE STUDY

APPROVED:

_____

Dana L. Comstock-Benzick, Ph.D.
Committee Chair

_____

Priscilla Reyna-Vazquez, Ph.D.
Committee Member

_____

Allen Novian Jr, Ph.D.
Committee Member

APPROVED:

_____

Leona Pallansch, Ph.D.
Dean College of Arts, Humanities, and Social Sciences

_____

Date

ACKNOWLEDGMENT

I believe that Allah (GOD) is always with me and guides me to achieve my goals. Without Allah's power, this accomplishment would not be possible. Allah, thank you for all of your favors I cannot enumerate.

My sincere gratitude to Saudi Arabia's King Salman ben Abdulaziz, for granting me the scholarship and the financial support to study in the United States. Without your generosity and financial support, I would not have been able to study abroad. I also extend my deepest thanks to my sponsor, King Abdulaziz University. Thank you for allowing me to go on sabbatical, and for providing me financial support to attain a doctoral degree.

My deepest love and appreciation to my mother, Lulu. Thank you for your constant support and for your prayers that helped me achieve my goal. To my father, Abdulrahman, my first teacher. Thank you for teaching me determination and self-confidence. To my husband Sami, thank you for being with me on this long journey. I will not forget the long hours we spent traveling between states to obtain admission into a doctoral program. Thank you for your effort. To my heart, my children for whom I sought to study in America. Sultan, Faisal, and Abdulrahman, the most beautiful gifts Allah has given me. Thank you for your love and support. To my three siblings, Khalid, Mona, and Bandar. Thank you for your love and kindness.

My genuine appreciation to Dr. Dana L. Comstock-Benzick, who was not only my dissertation chair, but the first source of support at St. Mary's University. Thank you, for your continued support, guidance, time, and effort.

My sincere gratitude to Dr. Allen Novian Jr, who I credit for everything I learned about neurofeedback. Thank you, for your encouragement and patience. It was your wonderful advice that led me to research women diagnosed with PTSD.

My deepest thanks to committee member Dr. Priscilla Reyna-Vasquez. Thank you for your willingness to help with this dissertation research. Also, my heartfelt gratitude to Kate Novian, Dr. Novian's wife. Without you, I would not have been able to use neurofeedback technology to treat clients.

My warm thanks to the clinic director who guided me in accessing the participants in this study and for providing me with the quantitative data. Without your help, this research would have not been possible.

My sincere gratitude to the three participants who shared their experiences to help other women with PTSD. Finally, my special thanks to all the people who contributed to the successful completion of this research.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

The Impact of Neurofeedback on Women Diagnosed With Ptsd: a Multiple Case Study

Reema Alhowaish

St. Mary's University, 2020

Dissertation Adviser: Dana L. Comstock-Benzick. PhD

The purpose of this study was to examine how women diagnosed with PTSD experienced neurofeedback (NFB) using quantitative and qualitative data. The quantitative data included pre- and post-test scores on the quantitative electroencephalogram (QEEG), the Davidson Trauma Scale, and the Inventory of Altered Self-capacities. The qualitative data illuminated participants' experiences with NFB and their observations about the changes that occurred during and after NFB. The participants in this study included three women who received at least 20 sessions of NFB to treat their PTSD. The results indicated that two participants achieved a significant reduction in their PTSD symptoms and improvements in their concentration, sustained attention, and ability to calm themselves down. The third participant observed limited reductions in her depression and anxiety symptoms and improvement in her concentration and sustained attention. Participants also shared that understanding NFB before beginning treatment would have helped them to acquire self-regulation skills. Results also implicated that negative effects could occur from overtraining and standardized NFB protocols. Recommendations were made for the use of individualized NFB protocols to address clients' unique symptoms and EEG patterns. Future studies should utilize mixed-method or qualitative methods to investigate the impact of NFB

combined with bottom-up approaches such as somatic experiencing therapy, trauma-sensitive yoga, and eye movement desensitization and reprocessing (EMDR). Recommendations were also made to investigate treating PTSD using new NFB protocols based on the triple network mode.

CHAPTER I

THE PROBLEM AND JUSTIFICATION OF THE STUDY

Post-traumatic stress disorder (PTSD) is a mental health disorder that can occur after exposure to a traumatic or life-threatening event (American Psychiatric Association, 2013). According to the fifth edition of the *Diagnostic and Statistical Manual of Mental Disorders* (American Psychiatric Association, 2013), PTSD is characterized by four main symptom clusters described as reexperiencing, avoidance, negative cognitions and mood, and alterations in arousal and reactivity associated with the traumatic event(s). In the *DSM-5*, PTSD was placed in a new diagnostic category named "Trauma and Stressor-related Disorders" (Pai, Suris, & North, 2017, p. 2).

Kessler et al. (2017) reviewed a survey conducted by the Mental health - World Health Organization in 24 countries (N = 68,894) on the types of trauma that were associated with PTSD. Kessler et al. (2017) noted that rape, sexual assault, being stalked, and the unexpected death of a loved one are the most common events types of trauma associated with PTSD. The most frequently reported traumatic events in the United States are physical and sexual assaults (52% lifetime prevalence) and accidents or fires (50%) (Shalev, Liberzon, & Marmar, 2017). The major PTSD-related issues facing American society are personal problems, social and economic burdens, the cost of medical care, disability compensation, and loss in productivity (Lake, 2015).

Pietrzak et al. (2014) utilized latent class analyses to evaluate predominant typologies of PTSD in a nationally representative sample of 2,463 adults in the United States. Pietrzak et al. found three predominant typologies of PTSD: dysphoric, anxious-reexperiencing, and high

symptom. Dysphoric is characterized by numbing and dysphoria symptoms. Anxious reexperiencing is characterized by hyperarousal, reexperiencing, and avoidance symptoms. The high symptom is characterized by elevations of all symptom clusters (Pietrzak et al., 2014). Pietrzak et al. stated that "the anxious-reexperiencing and high symptom classes were more likely to report sexual assault, physical assault, and military combat" (p. 102).

Due to the high rate of comorbidity between PTSD and other mental health disorders, PTSD is considered to be one of the most debilitating disorders for adults (van der Kolk et al., 2016). PTSD impacts an individual's health-related quality of life, impairing psychosocial and occupational functioning and compromising overall well-being (Armenta et al., 2018; Hunnicutt-Ferguson et al., 2018; Pagotto et al., 2015). PTSD has been associated with long-term neurobiological changes and comorbidities that can have profound effects on physical and mental health and chronic pain (Armenta et al., 2018; Mickleborough et al., 2011).

The prevalence of PTSD is higher among women, who have a greater overall risk (11–20%) for developing PTSD than men (4–8%) following trauma exposure (Irish et al., 2010; Kessler, Sonnega, Bromet, Hughes, & Nelson, 1995; Kimerling, Allen, & Duncan, 2018; Kobayashi, Sledjeski, & Delahanty, 2018). While men and women are both vulnerable to experiencing traumatic events, they differ markedly by the type of trauma that would result in PTSD (Kimerling et al., 2018). Women are more prone to experience sexual and intimate partner violence and various forms of childhood trauma (Kimberling et al., 2018). Women's coping styles are also "more emotion and avoidance- focused and less problem-centered than men" (Matud, 2004, p. 1412). Traditionally, the primary physiological responses for both males and females in the face of life-threatening situations have been either fight, flight, or freeze responses (Sapolsky, 2004; Taylor, 2006). However, women have an additional response that has been

coined "tend-and-befriend" that results in affiliation behaviors (Taylor, 2006, p. 273). Tending includes nurturant activities that enhance safety and reduce distress. The quality of social contacts and the release of oxytocin during stressful times are fundamental to understanding this stress response in women (Taylor, 2006).

Heim and Nemeroff (2009) found that sex differences, genetic variability, and developmental exposures to stress can influence neurobiological systems and impact one's risk for developing PTSD. Husky, Mazure, and Kovess-Masfety (2018) pointed out that gender is an important factor that affects the type and prevalence of psychological disorders and medical conditions. For example, women with severe PTSD are more likely to develop depression, have specific phobias, chronic back or neck problems, frequent headaches, and arthritis. On the other hand, men are more likely to suffer from comorbid substance use disorders and to report cardiovascular diseases and diabetes (Husky et al., 2018). Kobayashi et al. (2018) posited that various psychosocial and other factors contribute to one's vulnerability to traumatic stress and that the degree to which each factor affects risk for PTSD can vary by age and gender. Taking gender into account, Olff (2017) urged researchers to conduct single-sex studies to fully understand how gender and trauma relate changes in the brain and impact behavior.

Men and women differ with regard to the release of endogenous oxytocin. Oxytocin plays a role in how women cope with PTSD (Koch et al., 2014). Frijling (2017) suggested that oxytocin, associated with social support, fear, and stress responses, plays a sex-specific role in the stress response. Olff (2017) asserted that women have a more sensitized hypothalamus-pituitary axis than men, while men have a sensitized physiological hyperarousal system. Moreover, sex differences impact responses to trauma that, in turn, guide treatment choices.

For example, Frijling (2017) investigated the effects of utilizing intranasal oxytocin administration early after trauma for preventing PTSD symptoms. Frijling found sex differences in the way the amygdala reacts to emotional stimuli. Another potential sex-specific factor that impacts fear-related symptoms is the menstrual cycle (Nillni et al., 2015). Nillni et al. (2015) found that in the early follicular phase, days 2–6 of the menstrual cycle, women with PTSD reported more severe anxiety symptoms. Maddox et al. (2018) asserted that estrogen has an impact on the degree to which fear-related memories are formed or retrieved in women with PTSD.

Because traumatic experiences can result in chronic dysregulation in neurophysiology and maladaptive coping in stressful situations, psychological approaches to treating women with PTSD vary widely (Schottenbauer, Glass, Arnkoff, Tendick, & Gray, 2008). Some of the treatment approaches are cognitive behavioral therapy (CBT) (Hinton, Hofmann, Rivera, Otto, & Pollack, 2011; Monson et al., 2012), CBT-based exposure therapy (McLean & Foa, 2014; Mørkved et al., 2014), cognitive processing therapy (CPT) (Galovski, Blain, Mott, Elwood, & Houle, 2012), eye movement desensitization and reprocessing (EMDR) (Aranda, Ronquillo, & Calvillo, 2015; Hasto, & Vojtová, 2013; van der Kolk et al., 2007), trauma-sensitive yoga (Cramer, Anheyer, Saha, & Dobos, 2018; Emerson, Sharma, Chaudhry, & Turner, 2009; Nolan, 2016; Price et al., 2017), narrative exposure therapy (Mørkved et al., 2014), abreactive ego state therapy (Barabasz, 2013), and hypnotherapy (Kwan, 2006).

Psychotherapy is reported to reduce PTSD symptoms (Bradley, Greene, Russ, Dutra, & Westen, 2005; Kline, Cooper, Rytwinksi, & Feeny, 2018; Steenkamp, Litz, Hoge, & Marmar, 2015). However, 60% to 72% of clients retain their diagnosis of PTSD following psychotherapy (Boyd et al., 2018). About one-fifth of clients drop out of psychotherapy, and one-third of clients

who complete psychotherapy continue to have residual symptoms or relapse altogether (Boyd et al., 2018; Bradley et al., 2005; van der Kolk, 2015). Bradley et al. (2005) conducted a multidimensional meta-analysis of research studies published between 1980 and 2003 to determine the effect size of the use of psychotherapy for PTSD. Bradley et al. found that psychotherapy for PTSD resulted in large initial improvements from baseline but did not lead to complete symptom remission. Hasto and Vojtová (2013) stated that "psychotherapy involving the repeated presentation of traumatic memories caused re-traumatization, strengthened the memories' negative effects, and led to generalizing traumatic memories to other stimuli" (p. 95).

Van der Kolk (2015) reported that "top-down processing" strengthens the capacity of the neocortex, while "bottom-up processing" regulates the autonomic nervous system, which originates in the brain stem (p. 63). Van der Kolk (2015) further emphasized that utilizing approaches that use a combination of both top-down and bottom-up processing while treating both psychological and physiological symptoms gives individuals with PTSD the best possibility for recovery. In the same manner, Byrne, Harpaz-Rotem, Tsai, Southwick, and Pietrzak (2019) suggested that "trauma survivors with PTSD exhibiting anxiety provoking reexperiencing of symptoms may benefit from treatments focused on reducing hyperarousal, while those with dysphoric symptoms could benefit from treatments such as behavioral activation" (p. 267).

Due to the limitations of current mainstream approaches, neuroscience, and social scientists have worked to bridge the gap between the neurobiological underpinnings of trauma-related PTSD and clinical practice. Trauma-informed researchers and clinicians have moved away from traditional diagnostic and intervention methods towards the use of interdisciplinary and integrative approaches to treating PTSD utilizing new technologies (Gerin et al., 2016; Lake, 2015). The development of neuroscientifically informed treatments has the potential to advance

the comprehension of the mechanisms underlying PTSD and enhance current clinical interventions (Lake, 2015; Lanius, Frewen, Tursich, Jetly, & McKinnon, 2015).

Emerging neuroscience researchers have demonstrated that trauma resulting in PTSD involves disturbances in areas of the brain that operate within large-scale networks (Jiang et al., 2017; Fan et al., 2017; Menon, 2011). In turn, large-scale brain networks contribute to cognitive and affective dysfunction as well as aberrant brain connectivity, which is a core feature of psychiatric disorders (Menon, 2011; Reiter, Andersen, & Carlsson, 2016). Neuroscience researchers have also indicated that neuroplasticity, which is "the brain's ability to change and adapt its structure and function in response to environmental pressures, physiological changes, and experiences," is key to recovery from PTSD (Orndorff-Plunkett, Singh, Aragón, & Pineda, 2017, p. 22). Pascual-Leone, Amedi, Fregni, and Merabet (2005) emphasized that understanding normal psychological function or the manifestations of the disease is impossible without consideration of brain plasticity.

One of the progressive evidence-based interventions based on neuroplasticity is neurofeedback therapy (NFB) (Angelakis et al., 2007; Arnold & Jensen, 2018; Dias & Van Deusen, 2011; Frey, 2016; Friel, 2007; Hammond, 2011; Jones & Hitsman, 2018; Peniston & Kulkosky, 1991; Rostami & Dehghani-arani, 2015; Sterman & Egner, 2006; Sterman & Friar, 1972; Walker, 2009). NFB aims to enhance individuals' regulation of their brain activity. NFB is a noninvasive treatment approach that utilizes neuroimaging technology such as electroencephalography (EEG) or functional magnetic resonance imaging (fMRI) to modulate brain function through real-time monitoring of one's current brain state (Gapen et al., 2016; Gerin et al., 2016; Mills, 2012; Moss, 2009; Othmer & Othmer, 2009; Rance et al., 2018; Reiter et al., 2016; Saxby & Peniston, 1995; Trivedi, 2017).

NFB is a variant of biofeedback known as brain wave biofeedback, EEG operant-conditioning training technique, or electroencephalographic (EEG) biofeedback (Angelakis et al., 2007; Reiter et al., 2016; Vernon, 2005). Othmer and Othmer (2009) emphasized that "NFB is an intervention for regulating bidirectional arousal, hyperarousal, and hypoarousal of the central and autonomic nervous systems" (p. 25). NFB does not require the individual to discuss thoughts and emotions; rather, it trains directly on the levels of arousal within the brain to increase or decrease frequencies (Othmer & Othmer, 2009). Through operant conditioning, NFB can change "neuronal activation or connectivity patterns that operate in the central nervous system" (van der Kolk et al., 2016, p. 2).

A growing body of literature emphasizes that NFB has efficaciously treated a wide range of psychological and physical disorders such as epilepsy (Frey, 2016; Sterman & Egner, 2006; Sterman & Friar, 1972), attention deficit and hyperactivity disorder (ADHD) (Arnold & Jensen, 2018; Friel, 2007), traumatic brain injury (Nelson & Esty, 2012), anxiety (Jones & Hitsman, 2018), depression (Dias & Van Deusen, 2011), schizophrenia (Gruzelier et al., 1999), substance abuse (Rostami & Dehghani-arani, 2015), chronic fatigue syndrome (Hammond, 2001), and cognitive enhancement (Angelakis et al., 2007). Panisch and Hai (2018) stated that, "The demand for research of this nature [the influence of NFB on PTSD] has largely been driven by the success reported by mental health therapists in clinical anecdotes and case studies of individuals who failed to respond to other forms of treatment" (p. 2). Several existing studies have found the efficiency of NFB as both a stand-alone and adjunctive treatment for PTSD (Askovic, Watters, Aroche, & Harris, 2017; Panisch & Hai, 2018). Askovic et al. (2017) determined that NFB, by attending to underlying emotional instability and physiological arousal, would allow individuals to benefit from previously unsuccessful therapeutic interventions.

Although evidence-based studies demonstrate the efficacy of NFB in treating PTSD (Askovic et al., 2017; Gapen et al., 2016; Kelson, 2013; McReynolds, Bell, & Lincourt, 2017; Othmer & Othmer, 2009; Peniston & Kulkosky, 1991; Rastegar, Dolatshahi, & Dogahe, 2016; Smith, 2008; van der Kolk et al., 2016), few studies have investigated the impact of NFB on women with PTSD (Fisher, Lanius, & Frewen, 2016; Kluetsch et al., 2014). Further, there is a scarcity of NFB research that utilizes multiple case mixed-methods using qualitative and quantitative data. Case studies that include both quantitative and qualitative data cover the process and outcome of a phenomenon (Tellis, 1997).

Although it is commonly believed that case studies are qualitative in nature, there is a strong and essential common ground between utilizing qualitative and quantitative data depending on the phenomenon being studied (Yin, 2009). Some aspects of case study research may be viewed through a quantitative template (Elman, Garring, & Mahoney, 2016). Therefore, the purpose of this study is to address the gap in the literature by utilizing both quantitative and qualitative data in the context of a multiple-case study designed to examine the impact of NFB on women diagnosed with PTSD.

Statement of the Problem

Few studies have examined the impact of NFB on women diagnosed with PTSD (Fisher et al., 2016; Kluetsch et al., 2014). Most NFB studies on PTSD have been conducted on war veterans (Larsen & Sherlin, 2013). Male veterans were the only participants in early studies on NFB and PTSD (Panisch & Hai, 2018), and other studies on the efficacy of NFB on the treatment of PTSD included both male and female subjects (Gapen et al., 2016; Kluetsch et al., 2014; Mills, 2012; Valenzuela, 2016; van der Kolk et al., 2016).

Valenzuela (2016) emphasized how important it is for researchers to examine NFB outcomes that vary by age and gender. Currently, Fisher et al. (2016) are the only researchers that have investigated the impact of NFB on PTSD, which was done on one woman. Fisher et al. (2016) argued that case studies on NFB are long overdue. There is no research that illuminates women's perspectives on how they experienced NFB as a treatment for their PTSD. Trauma-based PTSD is a prevalent clinical issue for women in the United States that warrants special examination. Without an understanding of the ways in which women experience NFB, clinicians trained in this technique are unable to assure that their clients are receiving optimal care and treatment for their PTSD.

Research Questions

The purpose of this study was to examine how NFB impacted the recovery of women diagnosed with PTSD. Specifically, this research study examined the experiences of three women who received NFB therapy for PTSD at a university counseling center. The researcher utilized an explanatory multiple case study methodology due to the nature of the research questions that focused on *how* NFB was experienced. Yin (2009) stated that "'how questions' were more explanatory and deal with operational links that need to be traced over time, rather than mere incidence or frequencies" (p. 9). The processes of this multiple case study were based on Yin's (2009) description. Yin suggested that explanatory case studies should be utilized by researchers whose aim is to seek to explain causal links in real-life interventions that are too complex for survey or experimental research designs.

The researcher utilized existent data related to each participant's NFB experience. The researcher also asked individualized questions relevant to participants' pre- and post-test scores on Davidson Trauma Scale (DTS) (Davidson et al., 1997), and Inventory of altered self-

capacities (IASC) (Briere & Runtz, 2002). The researcher also shared observations of participants' quantitative electroencephalogram (QEEG) and asked them how their experiences matched noted shifts in brain patterns. The process for constructing individualized questions is described in Chapter 3. All data, both quantitative and qualitative, sought to answer the following research questions as they related to each case.

1. How did women, diagnosed with PTSD, experience neurofeedback therapy?
2. How did utilizing neurofeedback therapy impact the recovery of women diagnosed with PTSD?

Justification for the Study

Counselors and mental health professionals have a number of treatment options in treating PTSD. PTSD is a highly heterogeneous condition diagnosed by numerous combinations of symptoms (Byrne et al., 2019; Galatzer-Levy & Bryant, 2013). About PTSD, the DSM-5 (American Psychological Association, 2013) states,

> In some individuals, fear-based reexperiencing, emotional, and behavioral symptoms may predominate. In others, anhedonic or dysphoric mood states and negative cognitions may be most distressing. In some other individuals, arousal and reactive externalizing symptoms are prominent. While in others, dissociative symptoms predominate. Finally, some individuals exhibit a combination of these symptom patterns. (p. 274)

Bangasser, Eck, and Ordoñes Sanchez (2019) articulated how women with PTSD have additional risk factors that increase the heterogeneity and the uniqueness of their experience with this disorder. Women with PTSD have more hyperarousal symptoms such as concentration difficulties, disrupted sleep, and increased ruminations compared to men (Bangasser et al., 2019). Hyperarousal symptoms are key differences in the presentation of PTSD between the

sexes (Bangasser et al., 2019). Grupe, Wielgosz, Nitschke, and Davidson (2017) emphasized that individual differences in discrete symptom clusters are important factors to be considered when investigating the neurobiological mechanisms of PTSD.

Another heterogenic factor that affects NFB therapy on women with PTSD is the electroencephalogram (EEG) pattern (Hammond, 2010). EEG patterns are obtained through a Quantitative Electroencephalogram (QEEG). Conducting a QEEG involves obtaining data at 19 or more electrode sites simultaneously (Hammond, 2010). Although a QEEG provides reliable, objective data of the brainwave patterns, "there is heterogeneity in the EEG patterns that are associated with diagnostic categories and symptoms" (Hammond, 2010, p. 31). Therefore, a multiple case study methodology that combines qualitative and quantitative data is necessary to acquire a better understanding of how women report to experience NFB therapy for the treatment of PTSD. Moreover, a multiple case study methodology is also an ideal approach to utilize when researchers are interested in identifying factors that impede the recovery of women with PTSD (Hammond, 2010).

This study might have been the first multiple case study that examined qualitative and quantitative data to explore the impact of NFB on the recovery of women diagnosed with PTSD. This study filled gaps in the literature in an area that is not broadly covered in scholarly research (Fisher et al., 2016). The findings of this multiple case study will help counselors and mental health professionals to gain insight into important factors that impact the recovery of women with PTSD. The participants' descriptions of their experiences of neurofeedback therapy will aid counselors and mental health professionals better meet their needs by providing a psychoeducation component and a trauma-informed approach to treatment. Also, the findings of this study will help NFB practitioners acquire a comprehensive understanding of NFB protocols

that can be utilized to treat women with PTSD and other factors that may affect NFB outcome. Due to the nature of research that combines quantitative and qualitative data, this study created an opportunity to understand the impact of NFB therapy on PTSD from the perspectives of women who have experienced this type of treatment.

Limitations of the Study

One of the limitations of the study was that participants received NFB therapy at a university research clinic with different counselors-in-training. Because of this, the therapeutic rapport between the participant and their counselor could have affected the overall outcome of NFB therapy. Factors that affect the therapeutic rapport in psychotherapy are also important considerations in NFB therapy (Helfand, 2015). Another limitation to consider is that the qualitative data in this study is based on participant interviews that occurred after one year of NFB therapy concluded. As such, events can occur that unduly influence the outcome (Creswell, 2014). Despite these limitations, this study has notable strengths. This research was the first study to examine the impact of neurofeedback on women with PTSD utilizing multiple case studies that included both quantitative and qualitative data. Although case studies may not be generalizable to populations, Yin (2009) contended that case studies are generalizable to theory.

Definition of Key Terms

The following terms are described as they were used for the purpose of this study:

Afferent nerve. "From the Latin *affere*, 'to bring to.' The bundles of nerve fibers that convey information about the stimulus (sensory impulses) from tissues and organs to the central nervous system" (Corr, 2006, p. 67).

Amplitude. A measure of strength or size of the EEG signal that measured in microvolts (uV) (Demos, 2005).

Biofeedback. A process that utilizes instruments to measure a person's physiological functions, such as brain waves, heartbeat, breathing, muscle activity, and skin temperature, so that the person can learn how to regulate these processes. The purpose of this learning process is to improve health and performance (International Society for Neurofeedback and Research [ISNR] Board of Directors, 2008, n.d.).

Coherence. "A measure of how stable the frequency and/or phase relationship is between two neural sites; it reflects the amount of information that is shared between two sensors or channels" (Sitaram et al., 2017, p. 87).

Efferent nerves. "From the Latin *effere,* 'to bring forth.' The bundles of fibers that convey information away from the central nervous system to the effector cells called motor neurons" (Corr, 2006, p. 67).

Electroencephalography (EEG). "The measurement of the brain-generated electrical potential between locations on the scalp and/or with respect to a reference" (Thatcher, 2011, p. 496).

Frequency(ies). The number of waves produced in one second expressed in terms of Hertz (Hz) (Thompson & Thompson, 2003, p. 35).

International 10-20 system. "An internationally recognized method to describe and apply the location of scalp electrodes. The actual distances between adjacent electrodes are either 10% or 20% of the total front-back or right-left distance of the skull. Each site has a letter to identify the lobe and a number to identify the hemisphere location" (Ahmed, 2011, p. 56).

Neurofeedback. "The process of training the brain using electroencephalography (EEG) to modulate excitatory and inhibitory responses via self-regulation" (Shi et al., 2014, p. 3638).

Over-arousal (hyperarousal). "A condition in which some brain waves have too much power in amplitude and are overactive in certain areas of the brain, with a need to decrease their power and amplitude through neurofeedback training" (Monjezi, 2005, p. 8).

Post-traumatic stress disorder (PTSD). The development of characteristic symptoms following exposure to one or more traumatic events (American Psychiatric Association, 2013, p. 372).

Quantitative EEG (QEEG). "Is a technique in which EEG recordings are computer-analyzed to produce numbers referred to as 'metrics' (e.g., amplitude or power, ratios, coherence, phase, etc.) used to guide decision-making and therapeutic planning. The data is typically made up of raw numbers, statistics transformed into z-scores, and/or topographic images" (Collura, 2014, p. 2).

Stress. "The state of long-term (chronic) effects of exposure to aversive stimulation in which bodily reactions are maladaptive or inadequate in their ability to cope" (Corr, 2006, p. 620).

Trauma. An emotional response to a terrible event like an accident, rape, or natural disaster (American Psychological Association, 2019).

Under-arousal (Hypoarousal). "A condition that exists when some waves have too little power in amplitude and are underactive in certain areas of the brain, with a need to increase their powers and amplitude through neurofeedback training" (Monjezi, 2005, p. 8).

CHAPTER II

REVIEW OF THE LITERATURE

Early descriptions of post-traumatic stress disorder (PTSD) were often linked to returning war veterans (Berg, 2002; van der Kolk, Blitz, Burr, Sherry, & Hartmann, 1984). Over the decades, researchers have investigated the mechanisms of exposure to trauma that lead to PTSD (Akiki, Averill, & Abdallah, 2017; Aranda et al., 2015; Berg, 2002; Bradley et al., 2005; Byrne et al., 2019; Chen & Etkin, 2013; Frewen, Kleindienst, Lanius, & Schmahl, 2014; Hinton et al., 2011; Jokić-begić & Begić, 2003; Kimerling et al., 2018; Kluetsch et al., 2014; Koch et al., 2014; Rhodes, Spinazzola, & van der Kolk, 2016; Schottenbauer et al., 2008; Steenkamp et al., 2015; Trivedi, 2017; van der Kolk et al., 1984). In the early 1970s, feminist clinicians and researchers started studying the effects of sexual assault and domestic violence on women and documented how these experiences led to trauma and PTSD (Morris, 2015; Robb, 2006). Since then, PTSD has had a rich history that involved many scholars who contributed to the contemporary understanding of PTSD and its diagnostic criteria in the current *Diagnostic and Statistical Manual of Mental Disorder-5* (2013) (Figley, 1985; Herman, 1981, 1992; Miller, 1976; van der Kolk & Ducey, 1989; Wood, 1986).

The connectivity of the mind and body led contemporary clinicians and researchers to understand how PTSD involves the nervous system (Bonaz, Sinniger, & Pellissier, 2016; Bonnet et al.,2015; George et al., 2000; Kobayashi, 2011; Reggie & Parag, 2018; van der Kolk, 2015). One approach believed to mediate the impact of PTSD on the nervous system and regulatory system is neurofeedback (NFB) therapy (Fisher, 2014; Kluetsch et al., 2014; Sapolsky, 2004).

Due to the composite nature of PTSD and NFB therapy, this literature review will include (a) a brief history of the diagnosis of PTSD, (b) changes in PTSD criteria in the *Diagnostic and Statistical Manual of Mental Disorders-5* (American Psychiatric Association, 2013), (c) the physiology of PTSD and NFB, (d) the impact of trauma on the nervous system, and (e) NFB therapy.

A Brief History of the Diagnosis of PTSD

The inclusion of PTSD in the *DSM-5* was the result of collaborative lobbying efforts between leaders of the women's movement, activists against the Vietnam war, and psychological researchers (Morris, 2015; Penn & Penn, 1976; Robb, 2006; van der Kolk & Ducey, 1984). From a historical perspective, changes in psychiatric classifications resulted more from societal and theoretical processes rather than advances in science (Taylor & Vaidya, 2008). PTSD cannot be understood apart from its social, ideological, and political contexts (Morris, 2015). Young (1995), in the introduction to his book *The Harmony of Illusions: Inventing Post-Traumatic Stress Disorder*, stated,

> PTSD disorder is not timeless, nor does it possess an intrinsic unity. Rather, it is glued together by the practices, technologies, and narratives with which it is diagnosed, studied, treated, and represented and by the various interests, institutions, and moral arguments that mobilized the efforts and resources. (p. 5)

Although PTSD was first described in the third edition of the *Diagnostic and Statistical Manual of Mental Disorders (DSM III)*, the concept of post-traumatic stress disorder has a long history that was initially linked to soldiers returning from battle (Morris, 2015). In the first major epic, the *Tale of Gilgamesh*, it is written that exposure to war and death can leave chronic psychological symptoms among those involved (Sandars, 1972).

Over the centuries, many scholars contributed to our contemporary understanding of PTSD (Bourke, 2012; Bremner, 2002; Figley, 1985; Friedman, Resick & Keane, 2014; Hautzinger & Scandlyn, 2014; Herman, 1981, 1992; Olff, 2017; Miller, 1976; Morris, 2015; van der Kolk et al., 2007, 2014, 2016; van der Kolk & Ducey, 1989). This overview of the history of PTSD is integrative and includes descriptions of events and by noted pioneers who are credited with the inclusion of PTSD in the various editions of the *DSM*.

The term *trauma* is derived from the Greek term τραύμα, meaning "trauma wound" (Bourke, 2012, p. 26) or "bodily injury" (Kolaitis & Olff, 2017, p. 1). In the late 1800s, Emil Kraepelin, a German psychiatrist, used the term "fright neurosis" to describe anxiety symptoms following accidents or injuries (Friedman et al., 2014, p. 6). The first to record the severe impact of traumatic stressors on cognitions, feelings, and behaviors were poets, dramatists, and novelists, such as Homer, Charles Dickens, and William Shakespeare (Bremner, 2002; Friedman et al., 2014).

The emergence of a broader description of PTSD coincided with the American Civil War (Jones & Wessely, 2005). In 1871, Jacob Mendes da Costa, an American physician and surgeon, noted that after intense battles, some soldiers complained of cardiac symptoms including fatigue, shortness of breath, sweating, chest pain, and heart palpitations, while having no physical abnormalities of the heart or circulatory system (Bremner, 2002; Hautzinger & Scandlyn, 2014; Morris, 2015). Da Costa coined the phenomena "soldier's heart" (Hautzinger & Scandlyn, 2014, p. 100), and over time, soldier's heart was referred to as "Da Costa' syndrome" (Morris, 2015, p. 84).

In 1884, the German neurologist Hermann Oppenheim (as cited in Crocq & Crocq, 2000), "used the term 'traumatic neuroses' to describe the aftermath experienced by 42

individuals who had railway or workplace accidents. Although Oppenheim's diagnosis was subjected to criticism, his work became the basis of Freud's term 'war neurosis'" (p. 49).

In 1893, Sigmund Freud described traumatic hysteria as the dissociation that trauma induces, and "the pathogenic role of forgotten memories" (Crocq & Crocq, 2000, p. 49). According to Wilson (1994)," Freud very clearly describes the core PTSD symptom clusters listed in the *DSM-III-R* 70 years before the revision of the diagnostic category" (p. 685).

In 1915, military physicians described soldiers as having "shell shock" upon returning from World War I (Scott, 1990, p. 296). Although shell shock resulted from exposure to blasts, clinicians believed that the traumatic event by itself was not sufficient to produce distress and that soldiers with shell shock had psychiatric "weakness" or were seeking relief from work (Hautzinger and Scandlyn, 2014, p. 101). David Morris (2015), in his book *The Evil Hours*, said,

> The stigma associated with not doing one's duty meant a soldier was not "manly." Because "stigma reduction" became part of the medical culture within the military, the term shell shock was abandoned, and two new categories arose in its place: concussion and nervous shock. (p. 95)

In 1936, the Hungarian scientist Hans Selye (as cited in Cantor & Ramsden, 2014) suggested that many of the most common illnesses of humans are diseases of adaptation. Selye (as cited in Cantor & Ramsden, 2014) is quoted as describing the physiological stages of the "general adaptation syndrome" and explained the major role of the adrenal glands in adaptive responses (p. 47). During WWII and the Korean War respectively, the term "combat or battle fatigue" was used to describe soldiers' responses to traumatic experiences (Campise, Geller & Campise, 2006, p. 215).

In 1952, the American Psychiatric Association published the first edition of the *Diagnostic and Statistical Manual of Mental Disorders* (Cantor & Ramsden, 2014; Morris, 2015). The *DSM-I* (1952) included the diagnosis of "gross stress reaction," which was described as a diagnosis that was,

> justified only in situations in which the individual has been exposed to severe physical demands or extreme emotional stress, such as in combat or civilian catastrophe (fire, earthquake, explosion, etc.). In many instances, this diagnosis applies to previously more or less "normal" persons who have experienced intolerable stress. (p. 40)

In 1968, the second edition of the *Diagnostic and Statistical Manual of Mental Disorders* was published (Zelviene & Kazlauskas, 2018). In the *DSM-II*, the diagnosis of gross stress reaction was eliminated and combined with the diagnostic category of "adjustment disorders" to become a part of what was known as "transient situational disturbances" (Zelviene & Kazlauskas, 2018, p. 377). The only diagnostic criteria in this class that resembled a gross stress reaction was the symptom described as "fear associated with military combat and manifested by trembling, running and hiding" (American Psychiatric Association, 1968, p. 66).

The Veterans Administration (VA) hypothesized that any psychiatric issues occurring more than one year after the veteran's discharge could not be related to military service. Therefore, veterans lost any compensation when their traumatic symptoms were delayed (Wylie, 2004). The VA neglected to consider how war experiences were a form of "combat stress" and, as a result, did not fund research that examined the connection between war experiences as a form of trauma (Wylie, 2004, p. 3).

In 1978, van der Kolk (2015) began working at the VA in Boston, MA. As van der Kolk prepared to support his patients, he was not able to find a single book about war neurosis, shell

shock, battle fatigue, or any condition that could help him. However, in the Countway Library at Harvard Medical School, van der Kolk found a book titled T*raumatic Neurosis of War* that had been published in 1941 by a psychiatrist named Abram. Kardiner. Kardiner's assumption that "the nucleus of neurosis is a physioneurosis" guided van der Kolk's observations of his patients and his understanding that traumatic stress symptoms were not "all in one's head," but that they had a physiological basis that originates in the whole body's response to the main trauma (van der Kolk, 2015, p. 11).

During the 1970s, various social and feminist movements occurred that brought societal changes including laws regarding family abuse, marital rape, and mandatory reporting of child abuse (Figley, 1985). The feminist movement impacted the public's attitudes toward women and changed the services provided for women (Figley, 1985). According to Foster (2015), "Some of the major powerhouses of the U.S.'s second wave were Maya Angelou, Shulamith Firestone, and Karen DeCrow, as well as the feminist icon, Gloria Steinem" (p. 68).

Various feminist scholars produced writing and research that shifted the understanding of women's health, psychology, and civil rights (Figley, 1985). In 1973, the Boston Women's Health Book Collective published the first edition of *Our Bodies, Ourselves,* which helped create the second-wave women's health movement. The women's health movement started in the late 1960s (Foster 2015; Norsigian, 2019), when women's groups and providers of health services collaborated to legalize abortion. Then, the women's health movement addressed other health issues by establishing health centers controlled by women and creating self-help organizations that advocated policy changes (Norsigian, 2019). The Boston Women's Health Book Collective inspired the women's health movement by encouraging women to take ownership of their

bodies, learn about themselves, discuss their feeling about their bodies with their doctors, and challenge the medical field to improve the care of women (Norsigian, 2019).

According to Norsigian (2019), the Boston Women's Health Book Collective and the National Women's Health Network changed public consciousness about women's health needs and, as a result, the Office of Research on Women's Health was established. The efforts by the National Women's Health Network and the Boston Women's Health Book Collective resulted in successfully "advancing women's health research, service provision, and prevention programs in some areas such as ovarian and breast cancer, sexually transmitted infections, contraception, infertility, osteoporosis, and adolescent pregnancy" (Norsigian, 2019. p. 845).

It is noteworthy that activism against the Vietnam war had a great effect on the women's movement. In 1970, Jan Barry, leader of Vietnam Veterans Against the War, in collaboration with others including Robert Jay Lifton, a Yale professor who had served as an air force psychiatrist and his friend Chaim Shatan, a New York University psychoanalyst, formed a "rap group" (Morris, 2015, p. 141). In rap groups, women had a safe space to think about their place in the broader culture and to build the women's movement. As a result of this, the first rape crisis center opened in Manhattan in 1971 (Hinton & Good, 2015; Morris, 2015).

During the same period, Ann Burgess and Lynda Holmstrom (as cited in Morris, 2015), researchers at Boston college, conducted a study to investigate the psychological effect of rape by interviewing rape victims. Burgess and Holmstrom (as cited in Morris, 2015) found that post-rape symptoms included nightmares, sleeplessness, paranoia, exaggerated startle responses, and phobias related to the circumstance in which the victims were attacked. Post-rape symptoms were called "rape trauma syndrome" (Morris, 2015, p. 301). Burgess's and Holmstrom's (as

cited in Morris, 2015) research results, along with victims advocacy efforts, resulted in a shift in the diagnosis of PTSD.

In her 1992 book *Trauma and Recovery,* Judith Lewis Herman, a professor of psychiatry at Harvard University who is best known for her contributions to the understanding of trauma resulting from sexual abuse, stated,

> The systematic study of psychological trauma, therefore, depends on the support of a political movement. Indeed, whether such a study can be pursued or discussed in public is itself a political question. The study of war trauma becomes legitimate only in a context that challenges the sacrifice of young men in war. The study of trauma in sexual and domestic life becomes legitimate only in a context that challenges the subordination of women and children. Advances in the field occur only when they are supported by a political movement powerful enough to legitimate an alliance between investigators and patients and to counteract the ordinary social processes of silencing and denial. Three times over the past century, a particular form of psychological trauma has surfaced into public consciousness. Each time, the investigation of that trauma has flourished in affiliation with a political movement. The first to emerge was hysteria, the archetypal psychological disorder of women. Its study grew out of the republican, anticlerical political movement of the late nineteenth century in France. The second was shell shock or combat neurosis. Its study began in England and the United States after the First World War and reached a peak after the Vietnam War. Its political context was the collapse of a cult of war and the growth of an antiwar movement. The last and most recent trauma to come into public awareness is sexual and domestic violence. Its political context is the feminist movement in Western Europe and North America. Our contemporary

> understanding of psychological trauma is built upon a synthesis of these three separate lines of the investigation. (Herman, 1992, p. 9)

During the 1960s through the mid-1980s, the work of Herman and other noted researchers such as Carol Gilligan, Jean Baker Miller, and their colleagues supported the women's movement by constructing a theoretical and research-based foundation that altered perspectives on issues such as rape, incest, domestic violence, and trauma (Foster, 2015; Robb, 2006). For example, Herman proposed the concept of "complex PTSD" as a diagnosis for individuals exposed to prolonged, repeated trauma (Herman, 1992a, p. 1). Herman's books *Father-Daughter Incest* (1981) and *Trauma and Recovery (*1992) reflected her research on incest, trauma, sexual abuse, and posttraumatic stress (Robb, 2006).

Gilligan's work drew attention to the importance of conducting research on women (Foster, 2015). Gilligan argued that existing theories of moral development created from observations of white men. Psychologists have tended to regard male behavior as the "norm" and female behaviors as a deviation from that norm (Wood, 1986). In Gilligan's *In a Different Voice* (1982), she stated "When women do not conform to the standards of psychological expectation, the conclusion has generally been that something is wrong with the women" (p. 14).

Jean Baker Miller, a professor of psychiatry at Boston University and the director of the Stone Center for Development and Studies at Wellesley College, Wellesley, MA, served as the editor of *Psychoanalysis and Women* (1973). Miller's *Toward a New Psychology of Women* (1976), was the first book that provided an extensive critique of the classical psychoanalytic view of women (Robb, 2006). Miller illustrated how relational traits, traditionally associated with women, were not weakness, but rather strengths necessary for the survival of the human race (Robb, 2006).

Due to findings from studies and the emergence of social and feminist movements, the *DSM-III* included PTSD as an official diagnosis for the first time (Rosen & Frueh, 2010). The *DSM-III* classified PTSD as an anxiety disorder that could occur at any age. PTSD was defined as "the development of characteristic symptoms following a psychologically traumatic event that is generally outside the range of usual human experience" (American Psychiatric Association, 1980, p. 236). Examples in the *DSM-III* of events outside the range of "the usual human experience" included "rape, assault, military combat, natural disasters (floods, earthquakes), accidental man-made disasters (car accidents with serious physical injury, airplane crashes, large fires), or deliberate man-made disasters (bombing, death camps), and torture" (American Psychiatric Association, 1980, p. 236).

In 1987, a revision of the *DSM-III* was published in which significant changes in the four diagnostic criteria were made for PTSD: "First, the duration of symptoms must have lasted at least one month. Second, persistent avoidance of stimuli associated with the trauma and the numbing of general responsiveness (not present before trauma)" (American Psychiatric Association, 1987, p. 249). The fourth edition of *Diagnostic and Statistical Manual of Mental Disorders* (American Psychiatric Association, 1994) was published in 1994. A revision to the fourth edition of the DSM-IV was published in 2000, and there were no subsequent revisions to the diagnostic criteria of PTSD (American Psychiatric Association, 2000).

Changes in Diagnostic Criteria for PTSD in the *DSM-5*

The *DSM-5* was published in 2013. PTSD was moved out of the anxiety disorders category and into a new chapter entitled "Trauma- and Stressor-Related Disorders" (Friedman, 2013, p. 757). In the *DSM-5,* children under the age of six have separate diagnostic criteria for PTSD. The *DSM-5* includes a new dissociative subtype for situations where PTSD is associated

with clinically significant symptoms such as depersonalization and/or derealization. The symptom "sense of a foreshortened future" was expanded to include negative expectations about one's self, others, or one's future (Friedman, 2013, p. 759). The American Psychiatric Association (2013) described the changes to PTSD in the *DSM-5* by stating,

> Compared to *DSM-IV*, the diagnostic criteria for PTSD in the *DSM-5* draw a clearer line when detailing what constitutes a traumatic event. Sexual assault is specifically included, for example, as is a recurring exposure that could apply to police officers or first responders. Language stipulating an individual's response to the event—intense fear, helplessness or horror, according to *DSM-IV*—has been deleted because that criterion proved to have no utility in predicting the onset of PTSD. *DSM-5* pays more attention to the behavioral symptoms that accompany PTSD and proposes four distinct diagnostic clusters instead of three. They are described as reexperiencing, avoidance, negative cognitions and mood, and arousal. Reexperiencing covers spontaneous memories of the traumatic event, recurrent dreams related to it, flashbacks or other intense or prolonged psychological distress. Avoidance refers to distressing memories, thoughts, feelings or external reminders of the event. Negative cognitions and mood represent myriad of feelings, from a persistent and distorted sense of blame of self or others to estrangement from others or markedly diminished interest in activities, to an inability to remember key aspects of the event. Finally, arousal is marked by aggressive, reckless or self-destructive behavior, sleep disturbances, hyper-vigilance or related problems. The current manual emphasizes the "flight" aspect associated with PTSD; the criteria for PTSD in the *DSM-5* also account for the "flight" reaction often seen. The number of symptoms that must be identified depends on the cluster. The *DSM-5* would only require that a disturbance

> continue for more than a month and would eliminate the distinction between acute and chronic phases of PTSD. (pp. 1-2)

The Physiology of PTSD and Neurofeedback

The human brain has extremely complex connectivity (Menon, 2011) that changes in response to a traumatic experience. This section focuses on explaining brain physiology as it relates to PTSD and neurofeedback (NFB) therapy with a particular emphasis on the nervous system. In order to identify how NFB therapy trains various functional brain regions associated with PTSD, it is important to first understand the international 10-20 system of electrode placement utilized during NFB sessions and the quantitative electroencephalography process. Therefore, in this section, the International 10-20 system is explained first, before moving on to the nervous system.

According to Thatcher (2011) the international 10-20 system is,

> the method that identifies the location on where scalp electrodes are placed during the recording of an electroencephalogram (EEG) or quantitative electroencephalogram (QEEG). EEG is the measurement of the brain-generated electrical potential between locations on the scalp and/or with respect to a reference. (p. 496)

The numbers 10-20 indicate the distance between electrodes as either 10% or 20% of the total front-back or right-left distance of the head.

Each site of the brain is designated by a corresponding letter to identify the lobe, and a number, to identify the hemisphere location as shown in Figure 1. The letters that identify the lobes are F (frontal lobe), T (temporal lobe), C (noting the central placement), P (parietal lobe), and O (occipital lobe) (Trans Cranial Technologies, 2012). Longo (2018) explained that “the midline is identified by the letter ‘z’ (zero), and those sites include Fpz, Fz, Cz, Pz, and Oz” (p.

99). The numbers that identify electrode placement on the right hemisphere are even numbers (2, 4, 6, 8), while odd numbers (1, 3, 5, 7) refer to electrode placements on the left hemisphere. Therefore, right hemisphere sites are all followed by an even number such as F4, C4, T4, P4, and O2, and the left hemisphere sites all have odd numbers such as F3, C3, T3, P3, and O1 (Trans Cranial Technologies, 2012). In most cases, a full quantitative electroencephalogram collects data from 19 locations on the scalp of the head (Longo, 2018).

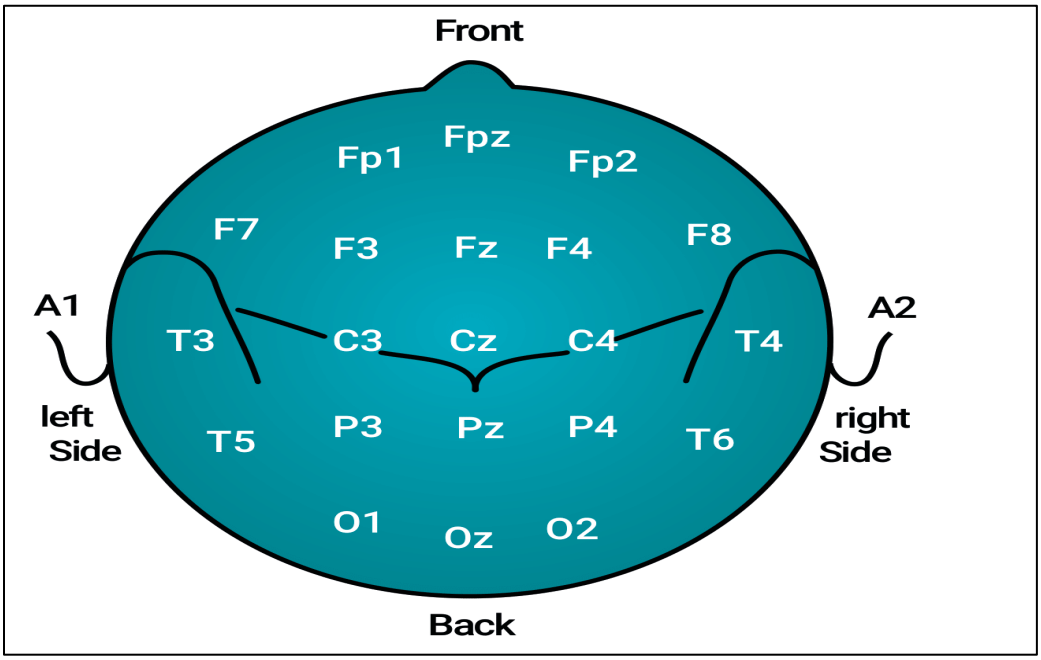

Figure 1. The International 10-20 system of electrode placement. Adapted from Thomas F. Feiner Institute for EEG-Neurofeedback (IFEN), by T. Feiner, 2017, *10-20 positions*. Copyright 2017 by the IFEN. Reprinted with permission.

The nervous system. This section focuses on the nervous system and addresses neurons; the central nervous system, which consists of the brain and the spinal cord (Fisher, 2014; Pinel & Edwards, 2008; Pinel, 2011); and the peripheral nervous system, which has two divisions, the somatic nervous system and the autonomic nervous system (Corr, 2006; Pinel, 2011). The somatic nervous system is responsible for interacting with the external environment, transfers

information from the sensory receptors (in skin, muscles, and joints) to the central nervous system, and sends motor signals from the central nervous system to muscles and glands (Corr, 2006). The autonomic nervous system consists of the sympathetic nervous system and the parasympathetic nervous system and is responsible for interacting with the internal environment and regulating the basic processes of the body such as the heart, blood vessels, digestive system, and genitalia. In addition, the social nervous system will be described based on the polyvagal theory (Porges, 1995). Although the enteric nervous system is separate from the peripheral nervous system, it will be described in this section because it plays a fundamental role in response to stress and trauma and its importance in understanding the role of the vagus nerve (VN) in the autonomic nervous system.

The neuron controls every aspect of the body and connects divisions of the nervous system (Corr, 2006). A neuron consists of a cell body (soma), axons, and dendrites. The structures of the neuron are illustrated in Figure 2. Dendrites are similar to trees in structure, as they are tapering extensions of a neuron that receives signals from other neurons and then transmits those signals toward the cell body (Fisher, 2014; Pinel, 2011).

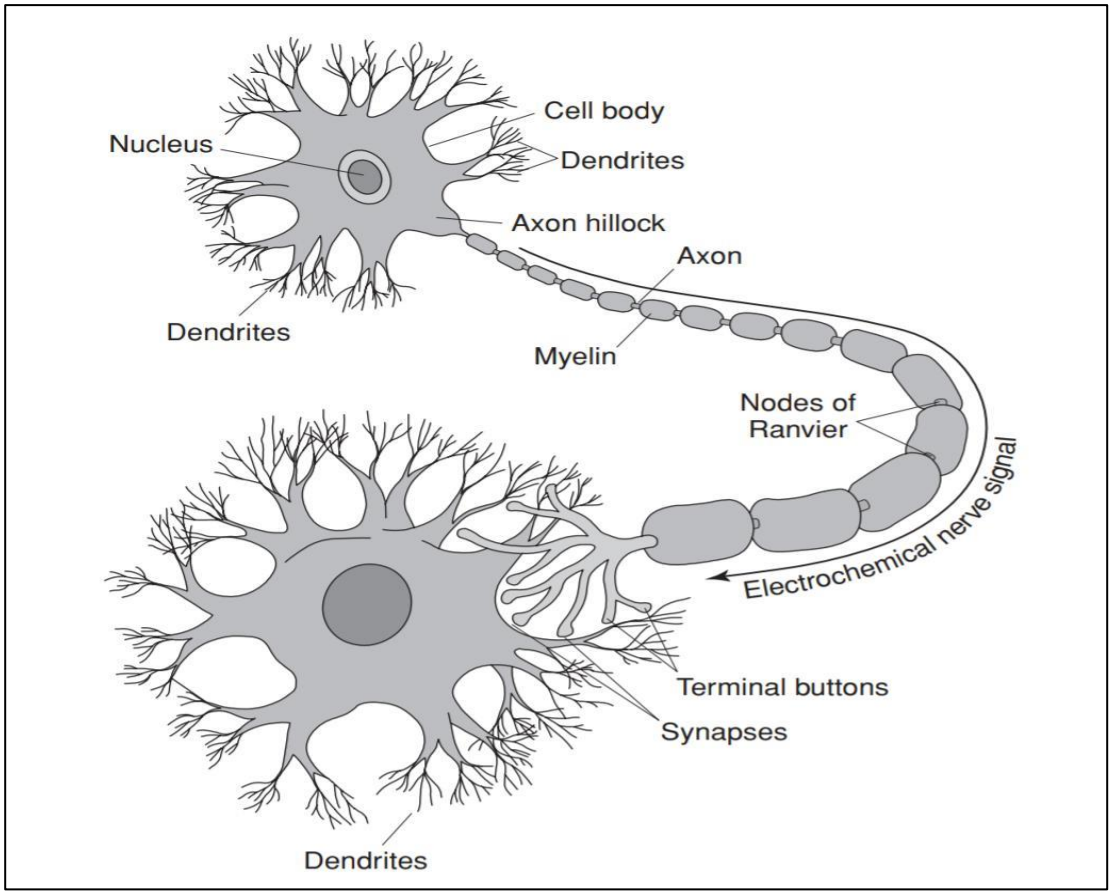

Figure 2. The structures within a neuron. Adapted from *Understanding Biological Psychology* (1st ed.), by J. Corr, 2006, p. 91. Copyright 2006 by Blackwell Publishing. Reprinted with permission.

Neurons communicate by passing messages at their synapses, which are gaps between each nerve cell. When chemical and electrical signals are strong enough, approximately 55 millivolts, neurotransmitters are released into the synapse (Corr, 2006). The electrical signal sent to the neuron and axon produces a chemical reaction in the synapse, which creates another electrical reaction in the dendrite (Wolfe, 2001). Therefore, all the information coming into the body and brain through the senses is realized and registered through synapses. Also, "each

reflex, behavior, emotion, or thought is produced through a discrete set of synapses" (Rothschild, 2000, p. 18).

The central nervous system. The central nervous system is made up of the brain and the spinal cord. For the purposes of this review, the various parts of the brain will be discussed in detail in this section.

The brain. The brain is located within the skull, which is composed of the facial bones and the cranium and protects the brain (Corr, 2006; Chapin & Russell-Chapin, 2014). The brain is the coordinating center for conscious experiences such as learning, memory, language, and reasoning (Chapin & Russell-Chapin, 2014). The brain also works to regulate homeostasis in the body (Betts et al., 2013; Chapin & Russell-Chapin, 2014; Demos, 2005). There are three major divisions of the brain including the forebrain, the midbrain, and the hindbrain. The forebrain consists of the cerebrum, thalamus, and hypothalamus. The midbrain, or limbic system, consists of the amygdala, the thalamus, and hippocampus. The hindbrain consists of the medulla oblongata (or medulla), the pons, the reticular formation, the locus coeruleus, the brainstem, and the cerebellum (Chapin & Russell-Chapin, 2014; Corr, 2006). Figure 3 illustrates the various components of the brain.

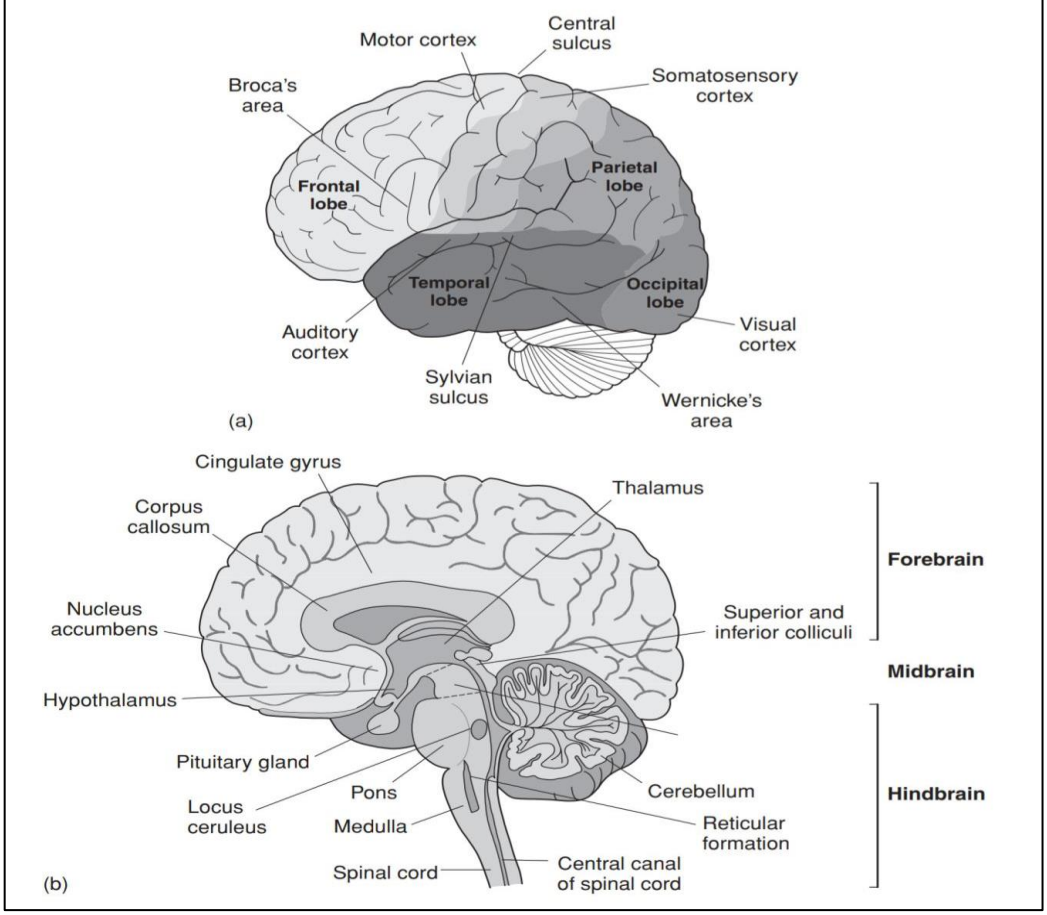

Figure 3. Brain structure, including the three major divisions of the brain: the forebrain, midbrain, and hindbrain. Adapted from *Understanding Biological Psychology*, by J. Corr, 2006, p. 75. Copyright 2006 by Blackwell Publishing. Preprinted with permission.

The forebrain is the largest part of the brain and is responsible for communication between the midbrain and cerebral cortex, and is made up of the cerebrum and parts of the limbic system, including the thalamus and the hypothalamus (Chapin & Russell-Chapin, 2014; Corr, 2006). The cerebrum is the largest part of the forebrain, consisting of clefts called sulci or fissures; the ridges formed along the sulci are gyri (Corr, 2006). The cerebrum includes the cerebral cortex and basal ganglia, which connect to the limbic system (Chapin & Russell-Chapin,

2014). The surface of the cerebrum, or the outer portion of the brain, is the cerebral cortex (Chapin & Russell-Chapin, 2014).

The cerebral cortex is made up of folded layers of nerve tissue about 1/8 inch (3mm) thick (Chapin & Russell-Chapin, 2014; Demos, 2005). About the cerebral cortex, Pinel (2011) stated,

> It is best to think of the cerebral cortex as a flat sheet of cells that just happens to be divided into lobes because pressure causes it to be folded in on itself at certain places during development. Thus, it is incorrect to think that a lobe is a functional unit, having one set of functions. (p. 67)

The cerebral cortex integrates information from the senses, manages emotions, retains memory, mediates thinking and emotional expression, and coordinates and organizes motor functions (Chapin & Russell-Chapin, 2014). The cerebral cortex is divided into a right and left hemisphere, which are connected by bundles of nerve fibers forming a bridge. This bridge, called the corpus callosum, carries information from one side of the brain to the other (Betts et al., 2013).

The right hemisphere helps to regulate attention, process emotions, and inhibit old habits. Right hemisphere-dominant neurotransmitters are serotonin (which slows down action) and noradrenaline (which speeds up action) (Chapin & Russell-Chapin, 2014, p. 56). The left hemisphere controls thinking and action and is the center for auditory verbal representation, speech, and recognition. The left hemisphere-dominant neurotransmitter is dopamine, which is responsible for reward-driven behavior. Each hemisphere is divided into four lobes: the frontal, parietal, occipital, and temporal lobes (Chapin & Russell-Chapin, 2014; Demos, 2005).

The frontal lobe is located at the anterior of the brain over the eyes. This lobe contains the olfactory bulb, which processes smells, and the motor cortex which is important for planning and implementing movement (Walpole, Davies, & Dann, 2011). The frontal lobe is responsible for immediate and sustained attention; executive functions, which include planning, anticipating consequences, and identifying choices; social skills and emotions; time management; expressing language; and inhibiting unwanted behavior (Chapin & Russell-Chapin, 2014; Demos, 2005, Fisher, 2014). The ventromedial prefrontal cortex is involved in adaptive emotional responding (Grupe et al., 2017). Parts of the frontal lobe coordinate voluntary movements and speech, memory, emotion, and many aspects of personality.

The parietal lobe is located at the top of the brain (Walpole et al., 2011) and is responsible for solving problems that are conceptualized by the frontal lobes. The parietal lobe is also involved in integrating raw sensory information and the perception of the physical body and motor functions, including touch, taste, temperature, and pain (Chapin & Russell-Chapin, 2014; Demos, 2005; Fisher, 2014; Walpole et al., 2011).

The temporal lobe, located on the sides of the head above the ears, is primarily involved in processing and interpreting sounds (Demos, 2005; Walpole et al., 2011). It also contains the hippocampus, a structure that processes memory formation. Therefore, the temporal lobe is involved in memory processes, especially verbal memories, the integration of new information, and the organization of hearing and smelling (Betts et al., 2013; Chapin & Russell-Chapin, 2014; Demos, 2005; Fisher, 2014).

Finally, the occipital lobe is located at the posterior of the brain (Walpole et al., 2011). This lobe is primarily involved in recognizing and identifying the visual world. The occipital lobe is responsible for visual memory, processing image construction, pattern recognition, and

recognizing colors and shapes and integrating them into complex visual understandings (Chapin & Russell-Chapin, 2014; Demos, 2005; Fisher, 2014).

The basal ganglia, or basal nuclei, are two groups of interconnected cerebral nuclei, one in each hemisphere (Pinel & Edwards, 2008). Basal ganglia regulate motivation and play important roles in movement control and posture (Betts et al., 2013; Pinel & Edwards, 2008).

The thalamus is the large, two-lobed structure that constitutes the top of the brain stem (Pinel & Edward, 2008). It is a collection of various nuclei that serve as reception centers for the cerebral hemispheres and is responsible for moderating all sensory information except smell by receiving, processing, and transmitting signals to the receptive visual, auditory, somatosensory, and motor cortex (Corr, 2006; Chapin & Russell-Chapin, 2014; Demos, 2005; Fisher, 2014; Pinel, 2011).

The hypothalamus is just below the thalamus and controls the endocrine and autonomic nervous systems (Demos, 2005; Pinel, 2011). The hypothalamus regulates the secretions of the pituitary gland by directing it through signals to release various hormones that affect other glands (Pinel, 2011). The hypothalamus coordinates eating, body temperature, sleep, and emotional responses (Pinel & Edward, 2008); activates the fight or flight response in the sympathetic nervous system and calms the body by activating the parasympathetic sympathetic nervous system (Demos, 2005); and manages complex behavior such as social interaction, learning, working memory, speech, language, and habit control (Chapin & Russell-Chapin, 2014).

The midbrain, or limbic system, is located within the brainstem between the forebrain and the hindbrain (Demos, 2005; Pinel, 2011). The limbic system regulates emotion; is involved in the regulation of fear and motivated behaviors including feeling, feeding, fighting, and sexual behavior; plays a role in memory formation and levels of arousal; and is involved in motivation

and reinforcing behaviors (Chapin & Russell-Chapin, 2014; Demos, 2005; Fisher, 2014; Pinel, 2011). The limbic system includes portions of the thalamus and hypothalamus, the hippocampus, amygdala, septal nuclei, anterior cingulate gyrus, pituitary gland, olfactory bulb, and fornix (Chapin & Russell-Chapin, 2014; Demos, 2005; Fisher, 2014; Pinel, 2011). For the purpose of this literature review, the main structures of the midbrain that are addressed include the hippocampus, amygdala, pituitary gland, and the cingulate gyrus.

The hippocampus is located at the medial edge of the cerebral cortex in the medial temporal lobe, and lies adjacent to the amygdala (Pinel, 2011; Pinel & Edward, 2008). The hippocampal structure plays a key role in the control of emotions, especially stress responses, fear conditioning, and declarative memory (Corr, 2006; Demos, 2005). The hippocampus and left temporal lobe work in the memory-making process (Chapin & Russell-Chapin, 2014; Demos, 2005; Fisher, 2014). The hippocampus allows an individual to compare the present situation with past memories (Chapin & Russell-Chapin, 2014). Individuals with trauma-related PTSD have a smaller hippocampus structure (Henigsberg, Kalember, Petrović, & Šečić, 2019).

The amygdala is the almond-shaped nucleus of the anterior temporal lobe (Pinel & Edward, 2008). The amygdala, or "the organ of fear," connects all areas of emotion, the dynamic nervous system, and the endocrine system (Bonnet et al., 2015, p. 2) and stores unconscious memories and egregious non-verbal memories (Demos, 2005). Therefore, a simple trigger in the environment, such as a particular smell, facial expression, hair color, or style of clothing could trigger a negative reaction driven by fear. During a traumatic affective experience, there is an increase in activation in the amygdala, which indicates that symptoms of PTSD are positively associated with amygdala activity (Henigsberg et al., 2019). Increased amygdala activity

coincides with decreased medial prefrontal cortex activity (Henigsberg et al., 2019). Nicholson et al. (2017) stressed that amygdala dysregulation is central to the pathophysiology of PTSD.

The pituitary gland is attached to the base of the hypothalamus by a thin stalk that contains neurons, blood vessels, and connective tissue (Corr, 2006). The pituitary gland releases hormones as signaled by the neurosecretory neurons of the hypothalamus. The pituitary gland "consists of two distinct lobes: (a) the anterior pituitary, which secretes growth hormones, gonadotropins, prolactin, thyroid-stimulating hormone, and adrenocorticotropic hormone, which is related to stress responses; and (b) the posterior pituitary, which regulates the secretion of the hormone oxytocin and arginine vasopressin" (Corr, 2006, p. 173).

The cingulate gyrus is located on the middle surface of the cerebral hemispheres, above the corpus callosum (Pinel, 2011), and divides the brain's right and left hemispheres (Demos, 2005). The cingulate gyrus has an extensive connection with the amygdala, thalamus, and frontal cortex (Kobayashi, 2011) and is involved in emotion, pain, and response selection. The cingulate gyrus also plays an important role in spatial information processing, which is essential in long-term memory formation (Kobayashi, 2011).

The anterior cingulate cortex inhibits the amygdala (Evans & Abarbanel, 1999). Stevens et al. (2017) found that during repeated presentations of fearful stimuli, decreased activation in the ventral anterior cingulate cortex predicted increases in PTSD symptoms. This finding emphasized that amygdala hyperreactivity predicts maintaining PTSD symptoms after a traumatic experience. Also, a failure to maintain ventral anterior cingulate cortex activation in response to fearful stimuli predicts poor recovery from PTSD. Shin et al. (2001) suggested that the reduction in the anterior cingulate cortex response may mediate symptoms such as distress and arousal in individuals with PTSD when exposed to trauma triggers.

The hindbrain regulates functions that are necessary for survival, including respiratory rhythm, sleep, motor activity, and wakefulness (Rogers, 2015). The hindbrain consists of the medulla oblongata (or medulla), pons, reticular formation, locus coeruleus, brainstem, and the cerebellum (Chapin & Russell-Chapin, 2014; Corr, 2006). For the purpose of this literature review, the medulla oblongata (or medulla), reticular formation, locus coeruleus, and the brainstem will be described.

The medulla is located in the upper spinal cord controls (Corr, 2006; Pinel, 2011). The medulla carries signals between the brain and the spinal cord and controls automatic and homeostatic activities such as breathing, swallowing, digestion and heart rate, circulation, and respiration (Corr, 2006; Pinel, 2011; Walpole et al., 2011). The medulla provides afferent (sensory) input to the locus coeruleus, which connects to several areas of the cortex associated with the pathophysiology of PTSD (Aston-Jones, Ennis, Pieribone, Nickell, & Shipley, 1986).

The reticular formation is a complex network of about 100 tiny nuclei. It is called the reticular formation because of its netlike appearance. The word “reticulum” means “little net;” the reticular formation is also called the reticular activating system because of its role in arousal (Pinel, 2011, p. 68). Pinel (2011) stated that,

> The reticular formation runs through the middle of the hindbrain and enters the midbrain; it receives sensory impulses (concerning sound) from higher brain centers and then passes these back up to the thalamus. This formation is vital for arousal and sleep. Also, the reticular formation is involved in a variety of functions such as sleep, attention, movement, the maintenance of muscle tone, and various cardiac, circulatory, and respiratory reflex. (p. 68)

Locus coeruleus is a Latin name that means “the blue spot” (Steinberg, 2015, p. 22). The blue color in the locus coeruleus is caused by melanin granules inside the neurons of the locus coeruleus (Carter et al., 2010). Neurons of the locus coeruleus are the main source of the hormone norepinephrine, also known as noradrenaline (Sara, 2009), which correlates with periods of wakefulness and arousal (Carter et al., 2010; Corr, 2006). Neurons in the locus coeruleus fire between 1–3 Hz during wakeful states and fire less during non–rapid eye movement sleep and are inactive during rapid eye movement sleep (Aston-Jones & Bloom, 1981). The locus coeruleus provides noradrenergic innervation to widespread areas of the forebrain (Aston-Jones & Bloom, 1981). Therefore, sensory vagal inputs have the potential to affect neuronal activity in those cortical areas that are innervated by noradrenergic locus coeruleus neurons (Hasselmo, Linster, Patil, Ma, & Cekic, 1997).

Naegeli et al. (2018) utilized psychophysiological recording and functional magnetic resonance imaging to determine whether behavioral and autonomic hyperresponsiveness to sudden sounds in patients with PTSD is associated with a hyperactive LC. Intermittent white noise bursts of 95 decibels were presented to determine if there was a link between PTSD and a hyperactive LC. Participants with PTSD showed more eye-blink reflexes, a higher heart rate, skin conductance, and pupil area responses to loud sounds as compared to participants with no PTSD (Naegeli et al., 2018).

The brainstem connects the brain with the spinal cord, where motor and sensory neurons are relayed to the body (Betts et al., 2013; Parvizi & Damasio, 2001). Neural pathways cross in the brainstem, allowing the left hemisphere of the cerebrum to control the right side of the body and the right hemisphere of the cerebrum to control the left side of the body (Betts et al., 2013). The brainstem is a fundamental center for processing data, serves as a crossway of information

and signal integration, and distributes commands from the brain in a way that contributes to smooth and efficient motor functions (Valls-Solé, 2015). Also, the brainstem controls important functions of the body including alertness, arousal, heart rate, breathing, blood pressure, swallowing, digestion, walking, and sensory and motor information integration (Betts et al., 2013).

The spinal cord. The spinal cord was described by Kalat (2014) as,

> the part of the CNS within the spinal column. The spinal cord communicates with all the sense organs and muscles except those of the head. The spinal cord is a segmented structure, and each segment has on each side a sensory nerve and a motor nerve. The entering dorsal roots (axon bundles) carry sensory information, and the exiting ventral roots carry motor information. (p. 48)

The peripheral nervous system. The peripheral nervous system carries information to and from the central nervous system (Walpole et al., 2011). The peripheral nervous system is further divided into two subsystems based on the control of voluntary and involuntary response: the somatic nervous system and the autonomic nervous system (Chapin & Russell-Chapin, 2014; Demos, 2005; Pinel & Edwards, 2008).

The somatic nervous system. The somatic nervous system contains 12 nerves with different important functions. However, the tenth cranial nerve, the vagus nerve, is explained here due to the fundamental role it plays in the expression and treatment of PTSD symptoms (Breit, Kupferberg, Rogler, & Hasler, 2018).

The vagus nerve (VN), the name of which is coined from the Latin word *vagus*, meaning "wandering," is the longest nerve in the human body (van Mersbergen, 2014, p. 68). The VN originates in the medulla oblongata, extends from the skull, and passes through the neck, thorax,

and down to the abdomen (Rosas-Ballina et al., 2011). The VN is an integrated neural system that involves bi-directional communication between the viscera and the brain (Porges, 2003).

The VN works in response to safety and is responsible for self-expression, orientation (turning the neck and head), listening, speaking, calling/asking for help, and communicating (Williamson, Porges, Lamb, & Porges, 2014). The VN regulates crucial bodily functions including mood, digestion, immune response, heart rate, vasomotor activity, and certain reflexional responses, such as coughing, sneezing, swallowing, and vomiting (Breit et al., 2018; Porges, 2003). The VN is connected to many body organs and serves as the entry point to various neuroendocrine and neurotransmitter systems (Reggie & Parag, 2018), and is thus considered the sixth sense of the body (Zagon, 2001).

Of all the neurons in the VN, 80% are afferent fibers that convey visceral, somatic, and taste perceptions to the brain from the head, neck, and thorax (Bonaz et al., 2016). The remaining 20% of neurons are efferent fibers (Bonaz et al., 2016). Efferent fibers represent 75% of all parasympathetic nerve fibers of the autonomic nervous system (Breit et al., 2018). The autonomic nervous system controls the release of acetylcholine (Bonaz et al., 2016; Breit et al., 2018; George et al., 2000; Porges, 2003).

The VN consists of two branches. The first branch of the VN is the dorsal vagal complex (DVC), which is the unmyelinated branch that sends signals “down” from the brain to the gut through efferent (motor) fibers (Porges, 2018. p. 53). The DVC is located in the medulla, originates from the dorsal motor nucleus, and connects to the stomach, spleen, liver, and kidneys, as well as the small and large intestines underneath the diaphragm (Porges, 2018; Tubbs, 2015). According to Porges (2018), “the DVC mediates immobility and energy conservation, in contrast

to active defensive strategies mediated by the sympathetic nervous system. The DVC branch primarily remains dormant until the human body faces a life-threatening situation" (p. 53).

The second branch of the VN is the ventral vagal complex (VVC), also known as the "social nervous system" (Porges, 2003, p. 124). The VVC is the myelinated VN branch that sends the signals up from the intestinal wall to the brain through afferent (sensory) fibers (Tubbs, 2015). The VVC originates in the nucleus ambiguous and connects to the heart, lungs, larynx, pharynx, and inner ear, as well as to the facial muscles around the mouth and eyes above the diaphragm (Porges, 2018). The VVC "regulates heart rate and is integrated into the regulation of facial muscles, middle ear muscles, larynx, and pharynx via special visceral efferent (motor) pathways resulting in a functional social engagement system" (Porges, 2018, p. 54).

The VVC is involved in the autonomic, endocrine, and limbic responses of the "inner medium" (Porges, 2018, p. 52). The VVC transfers a respiratory rhythm signal to the heart pacemakers, resulting in a rhythmic oscillation in heart rate at the frequency of spontaneous breathing, known as respiratory sinus arrhythmia (Porges, 2018). Therefore, Kemp et al. (2014) emphasized that measures of heart rate variability are reliable indicators of vagal activity.

When the vagal tone to the pacemaker is high, the VN acts as a restraint or brake, limiting the rate at which the heart is beating. When the VN is not working optimally, there is little or no inhibition of a high heart rate (Porges, 2007). In addition, heart rate variability measures indicating higher vagal activity were positively correlated with positive non-verbal behaviors (i.e., nonverbal indicators of social interest, positive feelings, and/or willingness to communicate) (Fernandes et al., 2017). The social engagement system can work efficiently when the fight or flight response is inhibited (Porges & Furman, 2011).

The VVC actively inhibits the sympathetic nervous system's influence on the heart and reduces hypothalamic-pituitary-adrenal axis activity (Porges, 2001). Therefore, the VVC is called the "smart vagus" because it is linked with the regulation of sympathetic fight or flight behaviors in the service of social affiliative behaviors (Beauchaine, Gatzke-Kopp, & Mead, 2006, p. 5).

Based on the neurophysiological distinction between the DVC and the VVC, each branch regulates a different adaptive behavioral strategy (Porges, 2009). Increases in vagal activity are associated with positive emotions, social connectedness, and longevity, while decreases in vagal activity are associated with depression, anxiety, cardiovascular disease, and mortality (Kemp et al., 2014).

The next section describes the autonomic nervous system. However, to understand the role of the VN in the autonomic nervous system, it is important to know that "the ENS [enteric nervous system] arises from neural crest cells of the primarily vagal origin and consists of a nerve plexus embedded in the intestinal wall, extending across the whole gastrointestinal tract from the esophagus to the anus" (Breit et al., 2018, p. 3). It is estimated that the human ENS contains about 100–500 million neurons, which is the largest accumulation of nerve cells in the human body (Furness, Callaghan, Rivera, & Cho, 2014; Schemann, 2005). The ENS has been described as "the second brain" or "the brain within the gut" due to its similarity to the brain with regards to structure, function, and chemical coding (Goldstein, Hofstra, & Burns, 2013, p. 3). The ENS regulates the relaxation and contraction of the intestinal wall and the major enteric processes, such as immune response, detection of nutrients and ions, and microvascular circulation (Furness et al., 2016).

The connection between the central nervous system and the ENS is called "the gut-brain axis" (Carabotti, Scirocco, Maselli, & Severi, 2015, p. 203). The gut-brain axis enables the bidirectional connection between the brain and the gastrointestinal tract, monitors the physiological homeostasis, and connects the emotional and cognitive areas of the brain with peripheral intestinal functions such as immune activation and entero-endocrine signaling (Carabotti et al., 2015). The gut-brain axis includes the brain, the spinal cord, the autonomic nervous system (sympathetic, parasympathetic, the enteric nervous system), and the hypothalamic-pituitary-adrenal (HPA) axis (Carabotti et al., 2015). The ventral vagal complex (VVC) is involved, through afferent pathways, in the activation and regulation of the HPA axis, which coordinates the adaptive responses of the organism to stressors of any kind (Tsigos & Chrousos, 2002).

In response to the environmental stress, the HPA axis becomes activated through the secretion of corticotropin-releasing factor from the hypothalamus (Tsigos & Chrousos, 2002). According to Breit et al. (2018),

> Corticotropin-releasing factor stimulates adrenocorticotropic hormone (ACTH) secretion from the pituitary gland. This stimulation, in turn, leads to cortisol release from the adrenal glands. Cortisol is a major stress hormone that affects many human organs, including the brain, bones, muscles, and body fat. (p. 3)

The communication between the VN and the ENS releases "the neurotransmitter acetylcholine through nicotinic receptors at the synaptic junction with smooth muscles, intrinsic nervous fibers, or secreting cells" (Bonaz et al., 2016, p. 5782). The vagus nerve releases acetylcholine as a response to stressful events like trauma or infection (Bonaz et al., 2016).

The autonomic nervous system. The autonomic nervous system (ANS) functions primarily at a subconscious level and is considered a balancing system in the body (Porges, 2003). The ANS controls involuntary movements in the body and regulates vital processes of internal organs including heart rate, breathing, hormone secretion, and digestion (Chapin & Russell-Chapin, 2014; Demos, 2005; Pinel & Edwards, 2008). Based on the region of the brain and spinal cord in which the autonomic nerves have their origin, the autonomic nervous system has two divisions: the sympathetic nervous system (SNS) and the parasympathetic nervous system (PNS).

The SNS contains autonomic fibers that exit the thoracic and lumbar segments of the spinal cord (Porges, 2003). The SNS allows the body to respond in the face of life-threatening situations; these responses are commonly known as fight or flight responses (Betts et al., 2013). Fight or flight responses prepare an organism's body for the physical strain required to fend off a predator or escape a potentially dangerous situation (Betts et al., 2013; Fisher, 2014; Pinel, 2011; Pinel & Edwards, 2008; Porges, 2003; Sapolsky, 2004; Walpole et al., 2011). Innervation of the SNS leads to a constriction of blood vessels, a dilatation of bronchioles, an increase in heart rate, and a constriction of intestinal and urinary sphincters (Breit et al., 2018).

The second division is the parasympathetic nervous system (PNS), which exits from the brainstem via the cranial nerves and the sacral segments of the spinal cord (Porges, 2003). The PNS decreases physiological arousal by slowing the heart rate, increasing intestinal activity, and relaxing the sphincter muscles (Betts et al., 2013; Fisher, 2014; Pinel, 2011; Pinel & Edwards, 2008; Porges, 2003; Sapolsky, 2004; Walpole et al., 2011). Innervation of the PNS causes the dilatation of blood vessels and bronchioles and the stimulation of salivary glands (Breit et al., 2018), which allows the body to rest and digest. The PNS works to restore the body to a calm

state in non-urgent, relaxed situations, and facilitates a return to homeostasis after the sympathetic nervous system no longer needs to be activated (Fisher, 2014; Pinel, 2011; Pinel & Edwards, 2008; Sapolsky, 2004; Walpole et al., 2011). This inhibitory process is important for self-regulation (Thayer & Lane, 2007; Thayer, Hansen, Saus-Rose, & Johnsen, 2009).

Both the SNS and the PNS receive impulses from the brain, but function concurrently to maintain internal balance. For example, the SNS increases heartbeat, while the PNS slows it down (Fisher, 2014; Pinel, 2011; Pinel & Edwards, 2008; Sapolsky, 2004; Walpole et al., 2011).

Based on the polyvagal theory, the third branch of the autonomic nervous system is the social nervous system, also called the "social engagement system" (Porges, 2009, p. 86). Polyvagal theory builds on the early findings by Paul Maclean (as cited in Porges, 2003), who studied emotion and recognized the fundamental role of the vagal afferents in the regulation of higher brain structures. Polyvagal theory emerged from Stephen Porges's (2018) research on heart rate patterns in human fetuses and newborns. Polyvagal theory explains important factors related to PTSD. The social nervous system and polyvagal theory are discussed in detail in the next section.

The Impact of Trauma on the Nervous System

In recent decades, the development of neuroimaging has facilitated a better understanding of the underlying mechanisms of psychopathologies including PTSD (Menon, 2011; Weng et al., 2018; Yuan et al., 2018). In order to understand the impact of trauma on the nervous system, neuroscientists have used a variety of neuroimaging techniques such as diffusion tensor imaging, functional magnetic resonance imaging (fMRI), resting-state functional magnetic resonance imaging, fMRI blood-oxygen-level-dependent, positron emission tomography, and magnetic

resonance spectroscopy (Biswal, 2012; Bressler & Menon, 2010; Hovsepian et al., 2019; Lanius et al., 2006; Lope-Piedrafita, 2018; Reiter et al., 2016).

Diffusion tensor imaging is an MRI technique that measures "the translational motion of water, providing information about its anisotropy (or lack of it) in different tissues" (Lope-Piedrafita, 2018, p. 103). FMRI measures brain activity by detecting changes in blood flow (Reiter et al., 2016). Resting-state functional magnetic resonance imaging is a method of fMRI that evaluates the regional interactions that occur in a resting or task-negative state when an explicit task is not being performed (Biswal, 2012). An fMRI blood-oxygen-level-dependent identifies the nodes of large-scale functional networks by relating the joint activation of brain areas to different cognitive functions (Bressler & Menon, 2010). Positron emission tomography is an imaging test that uses a radioactive drug (tracer) to reveal how tissues and organs are functioning (Lanius et al., 2006). Magnetic resonance spectroscopy displays the functional characterization of brain tissue on a biochemical level (Hovsepian et al., 2019).

Neuroimaging techniques have provided a comprehensive understanding of psychiatric and neurological disorders (Bressler & Menon, 2010; Chen, Cai, Ryali, Supekar, & Menon, 2016; Fan et al., 2017; Greicius, Supekar, Menon, & Dougherty, 2009; Menon, 2018; Sridharan, Levitin, Menon, 2008) that involve functional integration abnormality and aberrant connectivity in brain regions as a core feature (Lanius et al., 2006; Menon, 2011; Reiter et al., 2016). According to Powers et al. (2017), all the regions of the brain are part of a wide network that impact emotional experiences and responses, and none of these regions work independently of others.

Reiter et al. (2016) posited that PTSD is characterized by altered perception, cognition, and emotion processes that all rely on the functioning of large-scale brain networks, rather than

dysfunction in one specific area of the brain. These findings were in line with many resting-state functional magnetic resonance imaging studies that showed that various psychiatric conditions are indicated by a disruption of the coordinated activity between multiple brain networks (Fan et al., 2017; Luo et al., 2018; Menon, 2011). Based on the paradigm of multiple brain networks, supported by neuroimaging and psychophysiological studies, the impact of trauma on the nervous system is illustrated in the next section, which includes an overview of (a) the neurophysiological response to stress and trauma, (b) the triune brain, (c) polyvagal theory and the social nervous system, and (d) the triple network model.

The neurophysiological response to stress and trauma. When an individual faces a life-threatening event or experiences an extreme stressor, the brain's attention is fully focused on the threat, whether perceived or real. Such experiences can be physical or emotional in nature and can also include the reexperiencing of traumatic events (Chrousos & Gold, 1992). In the face of such threats, heart rate and respiration increase, and blood flow is redirected to the brain, heart, and muscles in a way that is designed to increase one's chances for survival (Chrousos & Gold, 1992). Hyperarousal and physiological symptoms become intense, due to high sympathetic activity coupled with low parasympathetic cardiac control. Also, respiratory abnormalities were present in PTSD (Blechert, Michael, Grossman, Lajman, & Wilhelm, 2007; Grupe et al., 2017).

The neurophysiological response to stress and trauma occurs based on the connection between the central nervous system, the autonomic nervous system, the enteric nervous system, and the hypothalamic-pituitary-adrenal (HPA) axis, which is called the brain-gut axis (Breit et al., 2018; Carabotti et al., 2015). According to Carabotti et al. (2015), "the BGA consists of bidirectional communication between the central and the enteric nervous system, linking emotional and cognitive centers of the brain with peripheral intestinal functions" (p. 203).

The HPA axis has an essential role in responding to external and internal stimuli, including psychological stressors (Koch et al., 2014). When environmental stressors occur, the hypothalamus secretes corticotropin-releasing factor (Tsigos & Chrousos, 2002); this stimulates adrenocorticotropic hormone secretion from the pituitary gland, which stimulates the adrenal glands to secrete cortisol, the major stress hormone that affects many human organs including the brain, bones, muscles, and body fat (Breit et al., 2018). The vagal afferent pathways contribute to the activation and regulation of the HPA axis. The communication between the vagal nerve and the enteric nervous system releases the neurotransmitter acetylcholine through nicotinic receptors (Bonaz et al., 2016), which activates the secretion of adrenaline and regulates the adaptive responses of the organism to stressors of any kind (Tsigos & Chrousos, 2002).

Another line of research found that oxytocin release reduces cortisol release in the bloodstream and helps to reestablish homeostasis in the body by returning it to its pre-stress baseline (Donadon, Martin-Santos, & Osório, 2018). However, stressful experiences could change the functioning of the suprachiasmatic nucleus, which decreases the release of oxytocin (Nicolson, Davis, Kruszewski, & Zautra, 2010); this affects the HPA axis and leads to hypercortisolemia, which reduces coping and resiliency responses (Brown, Cardoso, & Ellenbogen, 2016).

Trivedi (2017) found discrepant results in terms of the activation and deactivation of various areas of the brain in individuals with PTSD. Cisler, Bush, James, Smitherman, and Kilts (2015) indicated that there are changes in the functional activity of four neuroanatomical regions, including the amygdala, hippocampus, ventromedial prefrontal cortex, and the dorsal anterior cingulate cortex in the brains of individuals with PTSD. Ressler (2019) found that the amygdala, along with the hippocampus and prefrontal cortex function, have been consistently shown to be

dysregulated in the brains of individuals with PTSD. Stevens et al. (2017) suggested that PTSD can cause heightened reactivity in the amygdala.

Van der Kolk (2006) found that the Broca's area, the center of expressive language, has decreased activity in individuals with PTSD, while the amygdala, insula, and right medial orbitofrontal cortex have increased activity. At the time of trauma, the deficiency of hippocampal function may lead to exaggerated associations between cues and the trauma (van der Kolk, 2006). A deficient association of the context and the trauma can potentially trigger a fear response when an individual is exposed to a single element similar to the environment in which one was traumatized (Acheson, Gresack, & Risbrough, 2012). Therefore, individuals with PTSD react as if the trauma were continuing to occur in real time (Fragedakis & Toriello, 2014).

PTSD also affects the sense of coherence, which is "the individual's feeling of confidence in both the predictability of their internal and external environment and their ability to cope with stressful and challenging situations in life" (Schäfer, Becker, King, Horsch, & Michael, 2019, p. 1). There is a negative association between symptoms of PTSD and one's sense of coherence. Individuals with higher symptom severity of PTSD symptoms have a lower sense of coherence levels (Schäfer et al., 2019).

The "triune brain" model. Paul MacLean (as cited in Cory, 2000), an American physician and neuroscientist, developed some of the most influential ideas in brain science. MacLean's concept of "the triune brain" emerged in 1949 and was refined over 30 years through animal experiments and studies in humans (Ploog, 2003, p. 489). Based on MacLean's studies of temporal lobe epilepsy in 1952, he introduced the term "limbic system" (Heimer, van Hoesen, Trimble, & Zahn, 2008, p. 6), which validated the biological perspective in the study of emotion (Porges, 2003). MacLean's concept of the triune brain provided important insight into

understanding human social behavior and communication from a neurobiological perspective (Ploog, 2003; Porges, 2003). Based on MacLean's triune brain model, Stephen Porges (1995), proposed polyvagal theory as a new way to conceptualization the role of the vagus nerves. Building upon the triune brain model, van der Kolk (2015), proposed the body-mind relationship, involving top-down and bottom-up processes, as a way of thinking about the impact of trauma on the nervous system.

The triune brain consists of three independent interactive brain structures (Chaudhuri & Buck, 1995). The first and the oldest part of the brain is the protoreptilianregion and responsible for survival (Chaudhuri & Buck, 1995, p. 133). The second is the paleomammalian or the old mammalian brain, which, with the protoreptilian brain, makes up the emotional brain. The third is the neomammalian brain or the neocortex. However, each brain structure is dependent on the network connectivity of all three systems (Cory, 2000; MacLean, 1990; Ploog, 2003; van der Kolk, 2015). The triune brain develops from the bottom up (van der Kolk, 2015), starting with the development of the protoreptilian brain in utero, followed by the development of the paleomammalian and the neomammalian brain.

The protoreptilian portion of the brain controls the vital functions of the body, such as circulation, heart rate, breathing, consumption, reproduction, and defensive behaviors throughout the entire life span (Cory, 2000; MacLean, 1990; van der Kolk, 2015). The protoreptilian brain is the most primitive part of the brain and is located in the hindbrain; it is responsible for all the behaviors the newborn needs to survive, such as eating, sleeping, crying, and expressing pain (van der Kolk, 2015). A disruption to any function in the body, such as sleep disturbances or sexual or physical abuse, results in disequilibrium in the whole organism. As such, individuals

with psychological disorders reported difficulties in sleep, appetite, digestion, and arousal (van der Kolk, 2015).

The paleomammalian portion of the brain is located in the limbic system (the midbrain). In humans, the development of the limbic system starts after a baby is born. The limbic system develops during the first six years of life and is shaped in response to an individual's experiences. An individual's emotional and perceptual map of the world is based on their experiences and relationships with their caregivers from the time they are born (van der Kolk, 2015). The protoreptilian brain and paleomammalian brain are collectively the "emotional brain" (van der Kolk, 2015, p. 57). The emotional brain establishes "the fight or flight response," which leads to automatic physiological reactions (van der Kolk, 2015, p. 57).

The neomammalian brain is the rational and cognitive brain (Cory, 2000, p. 387), located in the neocortex of the forebrain, and it develops after the protoreptilian and the paleomammalian brain (Cory, 2000; MacLean, 1990; Ploog, 2003; van der Kolk, 2015). The neocortex detects danger and organizes the individual's response through the five senses. Sensory information about the outside world converges in the thalamus before moving down to the amygdala and up to the frontal lobes (van der Kolk, 2015). The amygdala evaluates the new input based on feedback from the hippocampus, which connects the new input to past experiences. When the amygdala evaluates the new input as a threat, it triggers the hypothalamus, which, in turn, activates the adrenal glands to release cortisol and adrenaline (van der Kolk, 2015). Cortisol and adrenaline increase the heart rate, blood pressure, and rate of breathing. Then, the body returns to its normal state when the danger passes (van der Kolk, 2015).

Van der Kolk (2015) provided a simplified explanation about how the body responds to threat and trauma, and the connection between the limbic system brain and the neocortex. Van der Kolk explained that the amygdala acts as the "brain smoke detector," and the frontal lobes, specifically the medial prefrontal cortex (MPFC), as the "watchtower" (p. 62). The MPFC is located directly above the eyes. Based on past experience and supported by the hippocampus, the MPFC processes current input from the environment and predicts the most adaptive response (Euston, Gruber, & McNaughton, 2012). The MPFC enables individuals to observe the environment around them and predict what the result may be should they consciously choose a particular course of action (van der Kolk, 2015). However, in the face of intense emotions, the amygdala "is activated and blood flow to the MPFC decreases" (van der Kolk, 2006, p. 281).

Although the amygdala (smoke detector) and the MPFC (watchtower) work together to balance the rational and emotional brains (van der Kolk, 2006), when an individual's survival is at stake, the amygdala and MPFC function independently (van der Kolk, 2015). When the MPFC breaks down, an individual automatically goes into fight or flight mode the moment danger is detected (van der Kolk, 2015). The reaction does not follow a clear memory or details; rather, it is an inner knowing (Chapin & Russell-Chapin, 2014; Demos, 2005; Fisher, 2014).

Van der Kolk (2015) emphasized that understanding the top-down and bottom-up regulation is essential to comprehending and treating PTSD. Talk therapy is considered a top-down approach to treating PTSD, which aims to strengthen the capacity of the MPFC (watchtower) to monitor body sensations, reconnecting with other people, and allowing the clients to be attentive and in an effort to understand what is going on within their brains while processing trauma memories. Bottom-up approaches to treating trauma focus on the physical sensations that clients experience and aim to recalibrate the autonomic nervous system through

breath, movement, or touch, to allow the body to have experiences that viscerally contradict the rage, helplessness, or collapse that result from trauma. An additional approach to treating PTSD is by using technologies, such as neurofeedback (van der Kolk, 2015).

The polyvagal theory and the social nervous system. Polyvagal theory provides an expansive way of conceptualizing the autonomic nervous system to include target organs, afferent and efferent pathways, and the bidirectional communication between the heart and the central nervous system (Porges, 2007). According to the polyvagal theory, there is an ordered hierarchical link between the three subsystems of the autonomic nervous system. The social engagement system (the myelinated ventral branch of the vagus nerve) links behaviors related to social communication. The sympathetic nervous system is linked to mobilization, and the parasympathetic nervous system (the unmyelinated dorsal branch of the vagus nerve) is linked to immobilization (Porges, 2009; Porges & Furman, 2011). The three subsystems of the autonomic nervous system regulate adaptive behaviors in stages to respond to environmental cues such as safety, danger, and threats to one's life (Porges, 1995, 2001, 2003).

In the first stage, the social communication system sends messages via the vagus nerve that inhibits sympathetic nervous system activation of the heart rate by suppressing the hypothalamic-pituitary-adrenal (HPA) axis, which results in calm, prosocial responses (Porges, 2009). The social communication system is also linked to facial expressions, vocalizations, and listening (Porges, 2009). The second stage involves the activation of the sympathetic nervous system, responsible for activating fight or flight responses (Porges, 2009). When the fight or flight response is activated, the large muscles are ready to move and awareness of any pain or injury is reduced (Ogden, Pain & Fisher, 2006). During the flight response, individuals are able to escape from danger or run toward a person or place that can provide safety (Nijenhuis & van

der Hart, 1999). The third stage, according to Porges (2018), is responsible for "immobilization such as feigning death and behavioral shutdown [and] is dependent on the unmyelinated dorsal vagal complex" (p. 56). Immobilization is the adaptive response to feeling safe (Nijenhuis & van der Hart, 1999).

In this hierarchy of adaptive responses, the newest circuit is used first; if that circuit fails to provide safety, the older circuits are recruited sequentially (Porges, 2009). Porges and Furman (2011) explained the role of the vagus nerve in hypoarousal and hyperarousal and stated,

> Many functions of the body begin to slow down when the dorsal vagal system is activated, the heart rate decreases, breathing slows, and, in trauma, all this is often accompanied by fear and a sense of numbness and shutting down. This immobilizing hypoarousal can ensure survival, and it also stimulates endorphins that mediate pain. Increased sympathetic tone, without the fear, enables individuals to engage in highly stimulating activities such as sports, dance, energizing debates, or performances and feel high-arousal emotions, such as joy, elation, or excitement. Increased dorsal vagal tone, without the fear, allows us to enjoy low-arousal activities, such as relaxation, dreamy states, meditation, and yoga and low-arousal emotions, such as peaceful, calm, tranquil, and contemplative states. Traumatized people, however, often cannot enjoy either extreme of arousal because these extremes are coupled with fear. (p. 39)

The neural process that enables humans and other mammals to engage in social behaviors by distinguishing safe from dangerous contexts is called "neuroception" (Porges, 2009, p. 89). Porges (2009) described neuroception as a mechanism that mediates between the expression and

the disruption of prosocial behavior, emotional regulation, and a balanced response to one's environment. According to Porges (2009),

> In most individuals (i.e., those without a psychiatric disorder or neuropathology), the nervous system evaluates risk and matches the neurophysiological state with the actual risk of the environment. When the environment is appraised as being safe, the defensive limbic structures are inhibited, enabling social engagement and calm visceral states to emerge. In contrast, some individuals experience a mismatch and the nervous system appraises the environment as being dangerous even when it is safe. This mismatch results in physiological states that support the fight, flight, or freeze behaviors, but not social engagement behaviors. According to the theory, social communication can be expressed efficiently through the social engagement system only when these defensive circuits are inhibited. (p. 89)

Polyvagal theory offers a way to conceptualize why some individuals who have been exposed to trauma can have difficulties feeling connected and safe with others. For some traumatized individuals, their autonomic nervous system loses its resilience and remains in a defense state (Porges, 2018).

The triple network model. For a long time, it was thought that cognitive functions occurred in a single portion of the brain (Bressler & Menon, 2010). However, researchers now understand the brain as "a neuroanatomical structure of large-scale brain networks with complex connections that facilitate signaling pathways for specific cognitive functions" (Bressler & Menon, 2010, p. 278). There are different brain networks that are activated during an active task or resting state. However, the triple network is one of the more prominent networks in the brain (Menon & Uddin, 2010). According to Bressler and Menon (2010), "brain networks can be

defined based on structural connectivity or functional interdependence. The structural network organization of the brain is based on the anatomical linkage of its neurons" (p. 278). Vinod Menon (2011), one of the pioneers who contributed to the new large-scale network paradigm, particularly the triple network, summarized the developmental methodology that led to the shift of brain function and dysfunction studies. Menon (2011) stated that,

> researchers have turned their attention to investigations of how multiple brain regions interact over time. The distributed patterns of deficits observed in task-related activation paradigms have led to the suggestion that abnormal functional integration and aberrant connectivity is a core feature of psychiatric disorders. (p. 484)

Brain regions have unique fingerprints that distinguish one from another in terms of their connectivity, therefore giving each brain region a specific function (Passingham, Stephan, & Kötter, 2002). Brain networks can be characterized by brain regions (nodes) and the connections (edges) that link them together (Menon, 2011). Each region of the brain is considered to be a subnetwork of a large-scale network; this subnetwork consists of excitatory and inhibitory neuronal populations (nodes) and connecting pathways (edges) (Bressler & Menon, 2010; Menon, 2011).

Based on this large-scale functional network, which is a collection of interconnected brain areas that interact to perform circumscribed functions, the triple network's components can be identified as the central executive network (CEN), the default mode network (DMN), and the salience network (SN). The triple network is broadly involved in diverse cognitive and emotional processes (Fan et al., 2017; Greicius et al., 2009). In the triple network model, The SN mediates the interactions between the DMN and the CEN. The SN plays an important role in initiating

transient control signals that engage the CEN to mediate cognitive control processes while disengaging the DMN when a salient external stimulus is detected (Menon & Uddin, 2010). According to Sridharan et al. (2008), the CEN and SN show increased inactivation during stimulus-driven cognitive and affective information processing, however, the DMN shows decreased activation during tasks in which self-referential and stimulus-independent memory recall is not crucial. In the next section, the triple network's components (CEN, DMN, and SN) are illustrated first, followed by an overview of triple network studies on PTSD.

The central executive network. The central executive network (CEN) is a task-positive network that is located in the dorsolateral prefrontal cortex and the posterior parietal cortex (Menon, 2011). The CEN is activated when one is working on complicated cognitive tasks (Fan et al., 2017; Luo et al., 2018; Menon, 2011) and is largely involved in maintaining and manipulating information in working memory, attentional control, goal-directed behavior, decision making, problem-solving, inhibition, flexibility, and vigilance (Menon, 2011; Sripada et al., 2012; Luo et al., 2018). Central executive network disruption is widespread in virtually every major psychiatric and neurological disorder, including PTSD (Frewen, Thornley, Rabellino, & Lanius, 2017; Sripada et al., 2012; Weng et al., 2018).

The default mode network. The default mode network (DMN) shows increased activation during rest, compared to when an individual is performing a complex task (Shulman et al., 1997). The DMN deactivates during various attention-demanding tasks and activates during internally directed cognition and self-evaluation and in self-referential processing (Greicius et al., 2009; Menon, 2011; Raichle and Snyder, 2007; Shulman et al., 1997).

The DMN includes a collection of brain regions that are anchored in the medial prefrontal cortex and the posterior cingulate cortex, with prominent nodes in the medial temporal lobe and

the angular gyrus (Greicius et al., 2009; Raichle & Snyder, 2011). The DMN is described as a homogeneous system that is primarily responsible for many aspects of internally directed cognition. For example, the nodes in the posterior cingulate cortex, hippocampus, and angular gyrus have been typically associated with episodic memory, autobiographical memory, and semantic memory.

Episodic memory is defined as the ability to recall and recognize previously encountered objects, people, and events, and to discriminate them from those that were not experienced (Vannini et al., 2011). Zlomuzica et al. (2018) pointed out that individuals with PTSD have impairments in episodic memory formation and mental time travel, and difficulties in utilizing the content of episodic memories for solving problems in the present and planning future behaviors. Autobiographical memory encompasses the recollection of personal past events as well as factual knowledge about oneself (Spreng, Mar, & Kim, 2009).

According to St. Jacques, Botzung, Miles, and Rubin (2011), functional magnetic resonance imaging data of individuals with PTSD displayed greater recruitment of the amygdala/hippocampus during the construction of negative versus positive emotionally intense autobiographical memory. Semantic memory refers to knowledge about people, objects, actions, relations, self, and culture and is acquired through experience and related to internal thought (Binder, 2009). The DMN consists of an integrated system for diverse aspects of self-referential mental processes, which is defined from the neuroscientific perspective as "the experience of strongly relating to one's own person," such as the way an individual perceives pictures of close friends versus pictures of completely unknown people (Northoff et al., 2006, p. 441).

A major and consistent feature of disorders that alter episodic memory, autobiographical memory, and self-related mental processes are abnormalities in intrinsic functional connectivity

within the DMN (Menon, 2011), which plays an important role in self-directed thought. The disrupted connectivity may reflect a reduced ability to maintain a calm internal state due to increased arousal and the presence of intrusive and negative thoughts that are observed in PTSD (Abdallah et al., 2017; Akiki et al., 2018). The DMN, which controls internal thought and autobiographical memory, is hypoactive in PTSD patients during the resting state and is triggered when they are engaged in a task (Qin, & Northoff, 2011; Weng et al., 2018).

The salience network. The salience network (SN), also referred to as "ventral attention" and is an intrinsically connected large-scale network anchored in the dorsal anterior cingulate cortex and the anterior insula (Akiki et al., 2017, p. 2). The anterior insula has an important role in attentional processes and high-level cognitive control (Menon & Uddin, 2010). The SN is involved in the detection of personally salient internal and external stimuli that directs behavior/arousal and plays a crucial role in the triple network process through rapid detection of goal-relevant events and facilitation of access to appropriate cognitive resources (Chen et al., 2016; Seeley et al., 2007).

SN mediates the switching between the central executive network and the default mode network, which causes a change between externally oriented attention and higher-order cognitive processing (in the central executive network) and internal self-reflective functioning (in the default mode network). The purpose of this switching is to integrate and balance internal mental processes with external stimulus-driven cognitive and affective processes (Chen et al., 2016; Chen & Etkin, 2013; Menon, 2018; Menon & Uddin, 2010; Seeley et al., 2007).

Sridharan et al. (2008) investigated the mechanisms underlying the switching of brain networks in three different experiments. Sridharan et al. examined the switching process in an auditory event segmentation task, a visual attention "oddball" task, and a task-free resting state.

Using functional magnetic resonance imaging on 18 participants, Sridharan et al. observed a deactivation of the default mode network and activation of the central executive network and SN that comprised the right fronto insular cortex and anterior cingulate cortex. Sridharan et al. found that the right fronto-insular cortex contributed majorly to the switching between the central executive network and the default mode network across task paradigms and stimulus modalities, which causes both exogenous and endogenous cognitive control (Sridharan et al., 2008).

Chen et al. (2016) asserted that the SN has a unique spatiotemporal organization in the human brain, characterized by high temporal flexibility, spatiotemporal diversity, and node centrality. Chen et al. also noted the time-varying connectivity profiles of the SN were distinct from all other cognitive control systems. Chen's et al.'s result showed how the dynamic function of the SN enabled interactions with multiple functional systems that supported a wide range of cognitive processes.

The SN, together with its interconnected brain networks, contributes to a variety of complex brain functions, including communication, social behavior, and self-awareness through the integration of sensory, emotional, and cognitive information (Chen et al., 2016). Moreover, the SN is involved in the orientation of attention to the most homeostatically relevant (salient) of ongoing intrapersonal and extrapersonal events (Bressler & Menon, 2010).

Triple network studies on PTSD. The triple network model demonstrates how dysfunctional connections between the central executive network (CEN), the default mode network (DMN), and the salience network (SN) are often consistent with psychiatric disorders, including PTSD (Abdallah et al., 2017; Akiki et al., 2017; Bressler & Menon, 2010; Chen et al., 2016; Fan et al., 2017; Greicius et al., 2009; Menon, 2011; Sridharan et al., 2008). Alternatively, the symptoms of PTSD, such as cognitive dysfunction, altered self-referential processing, and

dysregulated arousal/interoceptive processing, have been related to disturbances in triple network connectivity (Sridharan et al., 2008). Triple network studies of PTSD concentrated on two pathways: aberrant functional organization between the triple networks and connectivity patterns within each network (Greicius et al., 2009; Sridharan et al., 2008; Weng et al., 2018).

Akiki et al. (2017) summarized studies on PTSD that utilized functional and structural neuroimaging by focusing on their relevance toward an emerging network-based neurobiological model of the disorder. Akiki et al. found PTSD is often present when the DMN and CEN are poorly connected and underactive, thereby resulting in an overactive and hyper connected SN.

Liu et al. (2017) compared 10 PTSD patients and 10 healthy survivors who experienced the same coal mining flood disaster to explore the alteration of triple network connectivity following this event. Liu et al. identified decreased connectivity in PTSD patients in the left middle frontal gyrus of the CEN, the left precuneus and bilateral superior frontal gyrus of the DMN, and the right anterior insula of the SN. The decreased connectivity in the left middle frontal gyrus of the CEN was associated with clinical severity (Liu et al., 2017).

Similarly, Weng et al. (2018) investigated the usefulness of observing neuroimaging biomarkers as a method for identifying individuals with PTSD. Participants were survivors of a devastating typhoon, out of which 27 were PTSD patients, 33 were trauma-exposed controls, and 30 were healthy controls without trauma exposure. By using functional magnetic resonance imaging, Weng et al. observed that within the CEN, enhanced positive connectivity from the left posterior parietal cortex to the left dorsolateral prefrontal cortex was indicative of PTSD and a reliable means of detecting effected individuals. Also, in the SN, there was a decreased causal flow from the right amygdala to the right insula and a lower transit value for the right amygdala in PTSD patients relative to trauma-exposed controls. Weng et al. suggested that altered

connectivity patterns in the triple network may reflect the occurrence of PTSD symptoms, providing a potential biomarker for detecting patients.

Chen and Etkin (2013) used resting-state functional magnetic resonance imaging along with a task-based assessment of posterior hippocampal/default-mode network function with 116 participants, including 17 with PTSD, 39 with a generalized anxiety disorder, and 60 healthy participants. Chen and Etkin sought to determine whether there is differential hippocampal network functioning in individuals with PTSD and generalized anxiety disorder. Chen and Etkin found that the posterior hippocampus and the associated default-mode network were different in individuals with PTSD as compared to the other groups.

Yuan et al. (2018) investigated the behavior and dynamic properties of resting state networks in individuals with combat-related PTSD, using a novel multimodal imaging approach: simultaneous electroencephalography and functional magnetic resonance imaging. Yuan et al. developed a strategy to integrate functional magnetic resonance imaging and electroencephalography by quantifying the fast temporal dynamics associated with the resting state networks to measure neurobiological brain activity among 36 veterans with combat-related PTSD and 20 combat-exposed veterans without PTSD. Yuan et al. found electroencephalography microstates (associated with the dorsal default mode network) were positively correlated with the severity of PTSD. The occurrence rate of the electroencephalography microstate for the anterior salience network was negatively correlated with hedonic tone or degree of pleasantness reported by veterans with PTSD as compared to veterans with no PTSD (Yuan et al., 2018).

In summary, the real-time connectivity and multivariate methods enabled modulation of patterns of neural activation, which may better represent the underlying neural function than

activity in single brain regions (Sitaram et al., 2017). Menon (2018) asserted that multimodal neuroimaging is a useful technology for providing new and complementary tools that contribute to the understanding of neural mechanisms of PTSD and neuropsychiatric disorders. Observations of distinct neural functioning patterns within individuals with PTSD have driven efforts to develop treatment interventions that target the functioning of intrinsic networks (Lanius et al., 2015). The results of triple network studies allow NFB practitioners and researchers to maximize the proficiency of NFB therapy and to provide new protocols to treat PTSD.

Neurofeedback Therapy

Neurofeedback (NFB) therapy emerged as an evidence-based therapy through interdisciplinary research collaborations in the fields of bioengineering, neuroscience, psychology, and computer science (Chapin & Russell-Chapin, 2013). The historical roots of NFB go back to 1924, when the German psychiatrist Hans Berger attached electrodes to a patient's scalp and detected small currents in the brain (Chapin & Russell-Chapin, 2013). In 1960, Sterman and Friar (as cited in Sterman, LoPresti & Fairchild, 2010) found that cats who had previously received sensorimotor rhythm training to produce 12-15 Hz activity were resistant to substance-induced epileptic seizures, which suggested that perhaps the human brain could be trained to regulate itself. In 1969, Joe Kamiya discovered that some individuals had the ability to control the alpha waves in their brains and spontaneously reported feeling relaxed (Nowlis & Kamiya, 1970). Feeling relaxed is consistent with maintaining alpha waves (Nowlis & Kamiya, 1970).

Sterman and Friar (1972) found that training in a sensorimotor rhythm range of 12 to 15 Hz resulted in a 23-year-old female being able to reduce her seizures and improve her sleep

(Sterman, 2000). This finding led to the first study that investigated the impact of NFB on Attention Deficit/Hyperactivity Disorder (ADHD) (Angelakis et al., 2007). Since then, NFB researchers have produced compelling evidence for NFB as an efficacious treatment for epilepsy, ADHD, and a wide variety of other disorders (Angelakis et al., 2007; Arnold, & Jensen, 2018; Dias & Van Deusen, 2011; Frey, 2016; Friel, 2007; Hammond, 2011; Huang-Storms, Bodenhamer-Davis, Davis, & Dunn, 2007; Jones & Hitsman, 2018; Peniston & Kulkosky, 1991; Rostami & Dehghani-Arani, 2015; Sterman & Egner, 2006; Walker, 2009).

In order to understand the process of NFB, the following subsection serves to define and describe biofeedback, behavioral theory, and neurofeedback. Following those descriptions and definitions, quantitative electroencephalography is explained. Finally, a summary of NFB studies on PTSD is presented.

Biofeedback. The Association for Applied Psychophysiology and Biofeedback (AAPB) defined biofeedback as,

> a process that enables an individual to learn how to change physiological activity for the purposes of improving health and performance. Precise instruments measure physiological activity such as brainwaves, heart function, breathing, muscle activity, and skin temperature. These instruments rapidly and accurately "feed back" information to the user. The presentation of this information—often in conjunction with changes in thinking, emotions, and behavior—supports desired physiological changes. Over time, these changes can endure without continued use of an instrument. (para. 2)

Frank, Khorshid, Kiffer, Moravec, and McKee (2010) explained the mechanism of feedback learning and positive reinforcement that occurs during biofeedback by stating,

> the biofeedback process is similar to learning to putt a golf ball. As the individual sees where the ball goes, the feedback helps to improve the next stroke. In biofeedback, the clinician explains what the biofeedback equipment is measuring and how it relates to the patient's physiology. Individuals undergoing biofeedback training must take an active role and practice in order to develop the skill. Rather than passively receiving treatment, the client is an active learner. It's like learning a new language. (p. 86)

In general, biofeedback is based on real-time feedback of voluntarily induced changes of certain physiological signals (Strehl, 2014); it utilizes specialized equipment, including sensors, amplifiers, digital encoders, and software filters to collect and convert physiological data into digitally readable signals. Proprietary software is then used to provide meaningful visual, auditory, and sometimes tactile cues or "rewards" to the individual creating the physiological signals (Gapen et al., 2016; Sterman, 2000).

Biofeedback training uses various modalities to provide a real-time assessment of physiological processes such as respiration, heart rate variability, muscle tension, and skin temperature (Wahbeh & Oken, 2013). Neurofeedback (NFB) is a sophisticated form of biofeedback, which is based on specific aspects of cortical activity (Vernon, 2005).

Behavioral theory and biofeedback. Biofeedback (BFB) is a form of operant conditioning (Sitaram et al., 2017). In 1937, Skinner (as cited in Staddon & Cerutti, 2003), coined the term "operant conditioning" in the context of reflex physiology to describe a behavior "controlled by its consequences" (p. 116). Staddon and Cerutti (2003) defined operant conditioning as "the study of reversible behavior maintained by reinforcement schedules" (p. 115). Sitaram et al. (2017) defined operant conditioning as "a process by which an organism learns a new association between two paired stimuli" (p. 92). Based on consequences' form,

strength, or frequency, the behavioral response is modified during operant conditioning (Yael et al., 2013). Demos (2005) stated that "the reinforcement comes only when the trainee emits the correct response" (p. 60).

In operant conditioning, "shaping" refers to "the successive approximation to a new behavior, especially skills" (Strehl, 2014, p. 2). For shaping to be successful, the final goals and the breakpoints on the way to the goals have to be defined (Strehl, 2014). Steele (2015) stated that "within Neurofeedback, shaping is done when the clinician rewards a small shift in the microvolt level of a particular frequency band and then, as the client is successful, changes the threshold to make the task a little more difficult" (p. 93). To make sure the feedback remains the same during the training, the BFB and NFB practitioner modify thresholds (Smith, 2008).

Operant conditioning is a type of associative learning (O'Donnell, Neumann, Duffy, & Paolini, 2019), "where two stimuli are paired systematically and each stimulus elicits the other stimulus" (Corr, 2006, p. 208). Associative learning has been explained in more depth from the neuroscience perspective. Donald Hebb (1994), a Canadian psychologist and pioneer of neuropsychology, stated that "any cells that are repeatedly active at the same time will tend to become 'associated,' so that activity in one facilitates activity in the other" (p. 70). Siegel (2012) stated that,

> With repeated activation, the state of mind becomes more deeply engrained, and the state is remembered. According to Hebb's approach as articulated by Carla Shatz, "Neurons that fire together wire together." Shatz also emphasizes how such neural assemblies reinforce their associations with the phrase "out of sync, lose your link." With associated and synchronized neural firing, the brain is more likely to activate this clustering of processes in the future as a cohesive state of mind. The mind as an emergent property of

> both the embodied nervous system and relationships has a self-reinforcing quality to its organization, which serves as the mechanism for such reinforcement. (p. 179)

During BFB treatment, operant conditioning of physiological responses utilizes a "reinforced stimulus" as a reward to encourage the individual to repeat the desired action (Demos, 2005; Staddon & Cerutti, 2003). Reinforcement comes only when the individual responds correctly (Demos, 2005; Strehl, 2014). BFB is based on clients learning how to objectively explore their pattern of physiological responses and to acquire skills that allow them to monitor, regulate, and make changes in their responses. BFB is used to reduce distressful thoughts due in part to sympathetic arousal, and to improve associated emotional distress (Frank et al., 2010; Sterman, 2000).

Although NFB is a form of BFB, NFB exclusively concentrates on the central nervous system, primarily the brain, while BFB concentrates on the peripheral nervous system (Schwartz & Andrasik, 2003). Also, the basic aspects of operant conditioning related to BFB are harder to access in NFB because there are no receptors to recognize the electrophysiological activity of the brain (Strehl, 2014). In NFB, the state of the brain can, at best, be reconstructed by cognitions and emotions (Strehl, 2014).

Neurofeedback. The main aim of neurofeedback (NFB) therapy is "to teach the individual what specific states of cortical arousal feel like and how to voluntarily activate such states" (Vernon, 2005, p. 348). The procedure necessitates that the individual learns to modify some aspect of their cortical activity, which may result in learning to increase or decrease the amplitude of a wave, frequency and/or coherence, or phase-lag (processing speed) between certain electrode sites (Demos, 2005; Vernon, 2005). The International Society for Neurofeedback and Research (2008) states that,

> Neurofeedback uses measuring and monitoring devices to provide moment-to-moment information to an individual on the state of their electrical activity in the brain. NFB is preceded by an objective assessment of brain activity and psychological status. During training, sensors are placed on the scalp and then connected to sensitive electronics and computer software that detect, amplify, and record specific brain activity. Resulting information is fed back to the trainee virtually instantaneously with the conceptual understanding that changes in the feedback signal indicate whether or not the trainee's brain activity is within the designated range. Based on this feedback, various principles of learning, and practitioner guidance, changes in brain patterns occur and are associated with positive changes in physical, emotional, and cognitive states. Often the trainee is not consciously aware of the mechanisms by which such changes are accomplished although people routinely acquire a "felt sense" of these positive changes and often are able to access these states outside the feedback session. (para. 1)

Initially, NFB was developed to address seizure disorders and epilepsy; however, its use has been expanded to address other complex cognitive and emotional issues (Othmer & Othmer, 2009). During NFB training, the practitioner can observe and measure the electrical patterns coming from the client's brain, much like a physician listens to the patient's heart from the surface of their skin (Hammond, 2011).

NFB sessions are designed individually to assist the client to gradually change and retrain their brainwave patterns. One or more electrodes are placed on the scalp on specific regions based on the client's symptoms, and two electrodes are placed on the ear lobes or behind each ear. Sensors are usually attached to the scalp using electrically conductive paste, which keeps the electrodes in place. Electroencephalography (EEG) amplifiers are usually built into NFB

software, which are connected wirelessly to the computer. Prior to every session, the practitioner sets the EEG software on the computer-based on the protocol designed for the client (Demos, 2005; Hammond, 2011; Trivdi, 2017). Each session usually lasts about 15 to 30 minutes once the equipment is attached. The typical length of treatment is 20-40 sessions or more (Demos, 2005; Hammond, 2011; Trivdi, 2017).

NFB training sessions involve playing games, watching videos, listening to auditory stimuli, or a combination of these. NFB software rewards the brain each time the brain wave levels are within the threshold of desired frequencies (Trivedi, 2017). The feedback takes different forms, such as auditory feedback, which is given through varying tones, or visual feedback, which is given in the form of rising and falling bars. The feedback indicates EEG activity in targeted frequency bands. For example, feedback in video games is provided through one's ability to move certain objects or being able to successfully get a paused movie to play (Meier, 2012).

During NFB sessions, brainwave frequencies are targeted to reduce symptoms associated with different psychiatric disorders (Hammond, 2011; Helfand, 2015). The brain waves are categorized based on their frequency range and are associated with observable behaviors (Peper & Shaffer, 2010). The frequencies of these brainwaves are measured in cycles per second or hertz. The measure of brainwave activity in NFB is often the amplitude of electrical activity for a specific brainwave, which is measured in microvolts (equal to one millionth of a volt). Helfand (2015) explained that "brainwaves generally operate between five and one hundred microvolts" (p. 7). The classic names of these brainwave "EEG bands" are delta, theta, alpha, beta, and gamma (Chapin & Russell-Chapin, 2014, p. 58).

Brainwave bands: definitions and functions. Understanding brainwave patterns is fundamental to practicing all modalities of neurofeedback (NFB) therapy. Therefore, brief descriptions of delta, theta, alpha, sensorimotor, beta, and gamma brainwave bands are provided below.

Delta. Delta frequencies range between 1 and 4 Hz. The delta frequency is the slowest, with the highest amplitude (magnitude) of waves (Chapin & Russell-Chapin, 2014). Delta waves are most commonly associated with a sleep state and are not a major component of the adult waking electroencephalogram, but are dominant in normal infants in the waking state until about six months of age (Angelakis, Lubar, Frederick, & Stathopoulou, 2002; Chapin & Russell-Chapin, 2014; Hammond, 2001; Thompson & Thompson, 2003). Delta waves are associated with learning disabilities and may be seen in people with brain damage (Angelakis et al., 2002; Chapin & Russell-Chapin, 2014; Hammond, 2001; Thompson & Thompson, 2003).

Theta. Theta frequencies range between 4 and 8 Hz (Chapin & Russell-Chapin, 2014; Hammond, 2001; Thompson & Thompson, 2003). At very slow levels, theta represents a relaxed state between sleeping and awakening. When individuals are drowsy or inattentive to external things and their mind is wandering, theta is present (Hammond, 2001; Thompson & Thompson, 2003). The high range of Hz in the theta frequency band is associated with creativity and spontaneity (Demos, 2005; Chapin & Russell-Chapin, 2014; Hammond, 2001; Thompson & Thompson, 2003). Theta is typically observed as symmetrical between the right and left hemispheres, and asymmetrical theta frequencies can indicate conditions of depression or anxiety (Demos, 2005; Chapin & Russell-Chapin, 2014; Hammond, 2001; Thompson & Thompson, 2003). Theta activity is related to distractibility, inattention, and poor impulse control, and high ratios of theta-to-beta power are often observed in children diagnosed with Attention

Deficit/Hyperactivity Disorder (ADHD) (Demos, 2005; Hammond, 2001; Thompson & Thompson, 2003).

Alpha. Alpha frequencies range between 8 and 12 Hz; they are slower and larger than other brain waves and are generally associated with feelings of calm and relaxation (Demos, 2005; Chapin & Russell-Chapin, 2014; Hammond, 2001; Thompson & Thompson, 2003). Alpha frequencies are particularly associated with the visual system and increase substantially during periods of visual inactivity. When an individual closes their eyes and imagines a peaceful setting, for example, alpha waves increase within 30 seconds (Demos, 2005; Chapin & Russell-Chapin, 2014; Hammond, 2001; Thompson & Thompson, 2003). Alpha frequencies occur in the back of the head. People who feel anxious and stressed may show a decrease in alpha frequencies (Demos, 2005; Hammond, 2011; Thompson & Thompson, 2003).

The sensorimotor rhythm. Sensorimotor rhythm (SMR) frequencies range between 12 and 15 Hz and overlap with the upper-alpha frequencies and the low-beta frequencies (Demos, 2005; Hammond, 2011; Thompson & Thompson, 2003). The SMR is so named because of its prominence in the sensorimotor cortex of the brain; these waves are called SMR only across the sensorimotor strip of the cortex and are called beta when found elsewhere (Demos, 2005; Hammond, 2011; Thompson & Thompson, 2003). SMR frequencies decrease during physical activity, appear to be associated with a calm mental state, and are observed in individuals who usually think before acting, which indicates an internal orientation (Demos, 2005; Hammond, 2011; Thompson & Thompson, 2003). Thompson and Thompson (2003) explained how “it is thus important to increase SMR frequencies in those who have problems with hyperactivity and/or impulsivity” (p. 39).

Beta. Beta frequencies range between 12 and 36 Hz. Beta waves represent wakeful, alert, externally focused, logical, problem-solving, and attentive states (Demos, 2005; Hammond, 2011, p. 305; Thompson & Thompson, 2003), but can also indicate anxious and tense states. An individual in a beta state is more typically externally oriented (Demos, 2005). The beta wave has distinct low and high frequencies. The beta wave can be further divided into low beta frequencies and high beta frequencies. Low beta frequencies range between 16 and 20 Hz and are associated with problem solving (Thompson & Thompson, 2003). Frequencies between 19-21 or 20-23 Hz, which may correlate with emotional intensity, are often present in anxious individuals (Demos, 2005; Hammond, 2011; Thompson & Thompson, 2003). High beta frequencies that range between 22 and 36 Hz are seen in worried and anxious individuals, who often feel stressed-out and hyper-vigilant (Thompson & Thompson, 2003).

Gamma. Gamma frequencies range between 38 and 50 Hz. Gamma activity is distributed evenly across the scalp. Gamma frequencies are associated with peak performance, problem-solving tasks, and creativity and are generally lower in individuals with learning disabilities (Demos, 2005; Hammond, 2011; Thompson & Thompson, 2003).

Everyone has some degree of each brainwave frequency, which are produced in different parts of the brain. Heterogeneity in electroencephalography patterns is associated with different diagnostic conditions such as Attention Deficit/Hyperactivity Disorder (ADHD), anxiety, or PTSD. In general, problematic theta, delta, and high beta waves inhibit the brain from being able to function efficiently when an individual needs to be alert and externally-focused. High beta frequencies also interfere with an individual's ability to stay calm and relaxed when needed (Monjezi, 2005, p. 34; Thompson & Thompson, 2003).

Although numerous studies indicated a positive influence of neurofeedback (NFB) therapy (Angelakis et al., 2007; Arnold & Jensen, 2018; Dias & Van Deusen, 2011; Frey, 2016; Friel, 2007; Hammond, 2011; Huang-Storms et al., 2007; Jones & Hitsman, 2018; Peniston & Kulkosky, 1991; Rostami & Dehghani-Arani, 2015; Sterman & Egner, 2006; Walker, 2009), negative effects can occur from inappropriate training (Matthews, 2008). Hammond and Kirk (2008) emphasized the importance of avoiding NFB overtraining by close observation of training responses. Matthews (2008) provided these tips to avoid the negative effects of overtraining,

> Patients who experience declines because of overtraining should be shifted to another, dissimilar protocol or away from training entirely for a few days or even a couple of weeks until the adverse response remits. It may be necessary to reverse the training effect with an appropriate contrasting protocol, but this probably will not be well tolerated in the same session at the same scalp location. It is recommended that during any hiatus from treatment, the therapist remains in close contact with the patient because the transient negative effect may frighten the patient. Such patients may be expected to display overtraining reactions to other protocols as well. Therefore, proceed cautiously and observe treatment response in the sessions. (p. 66)

Another sophisticated type of neurofeedback (NFB) is real-time functional magnetic resonance imaging neurofeedback, which is a neuromodulation technique that monitors the aspects of task-related changes in neural activation or brain connectivity. Investigators can offer feedback of simple or complex neural signals patterns back to the participant on a quasi-real-time basis" (Linden & Turner, 2016, p. 412).

NFB may produce effects on both the synaptic level by strengthening circuitry and may modulate abnormal brain oscillations directly (Ghaziri et al., 2013; Ros et al., 2013). Ghaziri et

al. (2013) observed microstructural changes in the white and grey matter after NFB training. Ros et al. (2013) found that alpha amplitude was able to significantly reduce after a single 30-minute training session.

Quantitative electroencephalography. The signal processing during neurofeedback (NFB) is based on a mathematical analysis of an individual's electroencephalogram (EEG) (Marzbani, Marateb, & Mansourian, 2016). The EEG is the measurement of the brain-generated electrical potential between locations on the scalp and/or with respect to a reference (Thatcher, 2011, p. 496). Quantitative electroencephalography (QEEG) is used in conjunction with other diagnostic procedures and testing and is not considered a stand-alone diagnostic tool (Longo, 2018).

The QEEG is a form of "EEG brain mapping" and is used to identify where individuals are experiencing abnormal brainwaves relevant to the symptoms they are trying to alleviate through NFB (Smith, Collura & Tarrant, 2014, p. 11). Using the QEEG, NFB practitioners design a protocol that assists the brain towards a more normative state (Smith et al., 2014).

In order to evaluate the activation processes and the network dynamics, NFB clinicians utilize QEEG metrics to identify connectivity between pairs of channels (Smith et al., 2014). These metrics most often include "amplitude asymmetry (a measure of the ratio of energy from one site to another), coherence (a measure of the amount of shared energy between network pairs), and phase (the metric used to determine the speed of information transfer)" (Smith et al., 2014, p. 12). The QEEG was described by Hammond (2011) as,

> an assessment tool to objectively and scientifically evaluate a person's brainwave function. The procedure usually takes about 60 to 75 minutes and consists of placing a snug cap on the head, which contains small electrodes to measure the electrical activity

> coming from the brain. This is done while the client is resting quietly with his or her eyes closed, eyes open, and sometimes during a task. Afterward, a careful process is used to remove as completely as possible artifacts that occurred when the eyes moved or blinked, from body movement, or tension in the jaw, neck, or forehead. The brainwave data that were gathered are then statistically compared to a sophisticated and large normative database that provides scientifically objective information on how the brain should be functioning at the client's age. This assessment procedure allows the professional to then determine in a scientific, objective manner whether a client's brainwave patterns are significantly different from normal, and if so, how and where they differ. (p. 307)

Quantitative electroencephalography studies on PTSD. Begić, Hotujac, and Jokić-Begić (2001) compared the quantitative electroencephalography parameters of 18 veterans with PTSD and 20 healthy non-veterans. The researchers observed power values of the particular frequency bands delta (1-3 Hz), theta (3.5-7 Hz), alpha 1 (7.5-9.5 Hz), alpha 2 (10-13 Hz), beta 1 (13.5-18 Hz), and beta 2 (18.5-30 Hz) on the regions Fp1, Fp2, F3, F4, F7, F8, C3, C4, T3, T4, T5, T6, P3, P4, O1, and O2. Theses regions are displayed in Figure 1. Begić et al. found that veterans with PTSD had increased theta activity over central regions and increased beta activity. Beta 1 (13.5-18 Hz) activity increased over the frontal, central, and left occipital sites for the F3, F4, C3, C4, and O1 regions and an increase in beta 2 (18.5-30 Hz) activity were observed over the frontal F3 and F4 regions. Begić et al. suggested that the increase in beta activity might have been due to global cortical hyperexcitability, prolonged wakefulness, or attention disturbances in the veterans with PTSD. Begić et al. also found no significant differences in delta and alpha activity between the PTSD and control group. These results point to the role of theta and beta rhythms as potential markers of PTSD.

In another attempt to investigate electroencephalography patterns, Jokić-Begić and Begić (2003) compared quantitative electroencephalography in combat veterans with and without PTSD. The experimental group was comprised of 79 combat veterans with PTSD, while the control group consisted of 37 veterans without PTSD. The findings showed that veterans with PTSD had decreased alpha and increased beta activity. These results suggest altered neurobiology in PTSD.

Neurofeedback studies on PTSD. Neurofeedback (NFB) therapy is not a new treatment method. Numerous researchers have investigated NFB for several decades to help clients to self-regulate their brainwave activity, reduce psychological symptoms, and increase performance by training brainwaves in specific brain locations (Marzbani et al., 2016; Orndorff-Plunkett et al., 2017; Strehl, 2014). Early NFB researchers focused on treating epilepsy (Lubar & Shouse, 1977; Sterman, 2000; Sterman & Egner, 2006; Walker, 2008) and Attention-Deficit/Hyperactivity Disorder (ADHD) (Cunningham & Murphy, 1981; Linden, Habib, & Radojevic, 1996; Sheer, 1975, 1977; Shouse & Lubar, 1979). Later studies were designed to investigate the influence of NFB on other disorders such as PTSD (Nelson & Esty, 2012; Peniston & Kulkosky, 1991), depression (Baehr & Baehr, 1997; Walker & Lawson, 2013), anxiety (Hammond, 2005), schizophrenia (Bolea, 2010; Gruzelier et al., 1999), substance abuse (Goldberg, Greenwood, & Taintor, 1976, 1977; Rostami & Dehghani-Arani, 2015; Watson, Herder, & Passini, 1978), chronic fatigue syndromes (Hammond, 2001), traumatic brain injury (Schoenberger, Shiflett, Esty, Ochs, & Matheis, 2001), fibromyalgia (Donaldson, Sella, & Mueller, 1998), and cognitive enhancement in the elderly (Angelakis et al., 2007).

Due to the scarcity of NFB research designed to investigate this treatment modality in women with PTSD, the next subsection includes the NFB studies conducted on veterans of both

sexes. Next, the two NFB studies that investigated the impact of NFB on women only are described.

Neurofeedback studies on veterans or both sexes. The early studies of Neurofeedback (NFB) therapy on PTSD were conducted on veterans by using various protocols (Othmer & Othmer, 2009; Peniston & Kulkosky, 1991; Smith, 2008). For more than three decades, Peniston and Kulkosky worked to develop electroencephalography (EEG) alpha-theta NFB with a substance abuse population. Peniston and Kulkosky (1991) investigated the effect of alpha-theta brainwave NFB therapy on 29 Vietnam combat veterans who had a history of chronic combat-related PTSD who were randomly assigned to an experimental and control group.

Peniston and Kulkosky (1991) used the Minnesota Multiphasic Personality Inventory to evaluate personality changes in all veterans. The control group received a traditional medical treatment that included psychotropic medications and combined individual and group therapy, while the experimental group received alpha-theta brainwave neurofeedback therapy. First, the experimental group received deep relaxation by skin temperature biofeedback that additionally incorporated autogenic phrases for a minimum of five sessions. The experimental group then received alpha-theta brainwave training at the O1 occipital site with a single electrode in a relaxed condition with eyes closed. Veterans in the experimental group reduced their medication dosages after treatment, and their Minnesota Multiphasic Personality Inventory T-scores on clinical scales decreased (Peniston & Kulkosky, 1991).

Smith (2008) conducted a study on 10 veterans with PTSD to determine if NFB would reduce depression and increase attention in participants. All participants completed the Hamilton Depression Rating Scale and the Test of Variables of Attention before and after treatment. The NFB training entailed two phases. In the first phase, veterans completed daily 30-minute bipolar

up-training protocols using C3-Fpz (15-18 Hz), C4-Pz (12-15 Hz), and theta (4-7 Hz) inhibition. In the second phase, the veterans completed 20 daily 30-minute sessions of alpha-theta training with eyes closed using Pz (Alpha 8-12 Hz and theta 5-8 Hz). In this phase, the alpha-theta training was followed immediately by 10 minutes of bipolar up-training using C3-Fpz (15-18 Hz), C4-Pz (12-15 Hz), and theta (4-7 Hz) inhibition. Smith found a reduction in PTSD and depression symptoms, as well as an increase in attention levels in all participants.

Othmer and Othmer (2009) studied frequency-based EEG training in which the reinforcement frequency was tailored to decrease symptoms in two military veterans with PTSD. Particular attention paid to arousal. Othmer and Othmer used infra-low frequency regions that narrowed the signal bandwidth down to .01 Hz. Each veteran received training on T3-T4 with a reward frequency of 9.5 Hz, which decreased gradually to .01 Hz. In the second phase of the treatment, an alpha-theta protocol was utilized. Both veterans showed a significant reduction in PTSD symptoms and increased their capacity for functioning in other domains.

Kelson (2013) conducted a pilot study utilizing Othmer's and Othmer's (2009) protocol to examine how EEG biofeedback impacted PTSD symptoms in veterans of different ages and races. Kelson utilized a demographic questionnaire and Likert-scale questionnaire tracking 23 symptoms of PTSD for both the experimental and control groups at the same weekly intervals. Kelson found a significant reduction in PTSD symptoms in the experimental group after 20 sessions of EEG biofeedback.

In a randomized waitlist control group trial, van der Kolk et al. (2016) assessed the efficacy of NFB to increase affect regulation and reduce PTSD symptoms in 52 male and female participants. Participants had histories of multiple trauma exposures and treatment-resistant PTSD. The protocol in this study was in the T4-P4 areas that inhibit the slow waves (2-6 Hz) and

inhibit the fast waves (22-36 Hz) while simultaneously increasing the power spectrum of the mid-range (10-13 Hz) starting point activity. Participants received NFB training for 12 weeks, twice a week, and completed four evaluations done as a baseline, and again after weeks 6, 12, and 16. The evaluations included the Traumatic Events Screening Inventory, the Clinician-Administered PTSD Scale, Davidson Trauma Scale, and Inventory of altered self-capacities. Van der Kolk et al. found significant reductions in PTSD symptoms in individuals with chronic PTSD, as well as increased affect regulation compared with the control group.

Gapen et al. (2016) investigated the influence of neurofeedback on multiple-traumatized individuals with treatment resistant PTSD using NFB protocols on either T4-P4 or T3-T4, rewarding 12-15 Hz with accompanying theta (4-7 Hz) and upper beta (22-36 Hz) inhibition. A total of 40 sessions of neurofeedback training twice a week were completed by 19 male and 15 female participants between 32-64 years of age. All participants received the mini-map EEG assessment that placed electrodes at O1, PZ, CZ, F3, F4, and FPZ. Participants completed the Stressful Life Events Screening Questionnaire, Davidson Trauma Scale, and Inventory of Altered Self-Capacities (Briere & Runtz, 2002) before and after treatment. These assessments measured the degree of difficulty participants had relating to others. Also, participants completed a checklist to rate over- and under-arousal symptoms and the changes that they noticed after NFB. Gapen et al. found that NFB significantly reduced PTSD symptoms.

Rastegar et la. (2016) applied NFB alpha-theta protocol in the PZ area of veterans with PTSD who were hospitalized in psychiatric wards. The experimental group received NFB while the control group did not receive NFB. There were 30 patients with half of the participants assigned to either the experimental or control group. All participants completed the continuous

performance test that measures attention deficits. The results showed that NFB training significantly increased sustained attention.

McReynolds et al. (2017) investigated the impact of NFB therapy on improving attention and reducing symptoms of PTSD in veterans. McReynolds et al. utilized z-score NFB therapy on 20 veterans (16 males, 4 females). Assessments included the General Well-Being Scale and the Visual and Auditory Continuous Performance Test-Version 2, which is software that helps clinicians test and evaluate both visual and auditory attention. The assessments were completed after 20 half-hour NFB sessions, and then again after 40 half-hour NFB sessions. Participants showed significant improvement in overall auditory attention, processing speed, focus, and on the Visual and Auditory Continuous Performance Test-Version 2. Furthermore, there was a significant correlation between the improvements in well-being and the increase in veterans' overall auditory attention and auditory processing speed.

Askovic et al. (2017) studied the impact of NFB as an adjunct to trauma-informed therapy in two male clients with chronic PTSD. Participants completed clinical interviews, symptom questionnaires, and the Visual Continuous Performance Task scale, which measures sustained attention, the ability to inhibit a response, and working memory. Also, resting-state EEG recordings and event-related potential measures were used as a part of the routine clinical evaluation pre- and post-NFB. The objective of the NFB protocol was to enhance either the Cz sensory motor rhythm or the Pz alpha activity to reduce symptoms of hyperarousal. Askovic et al. showed that both clients achieved a significant reduction in symptoms of PTSD and improvement in daily functioning after NFB therapy.

Neurofeedback studies on women with PTSD. A handful of studies investigated the impact of NFB on clinical disorders in women only. These studies included examinations of the

effectiveness of NFB on treating alcoholism (Hayner, 2005), bulimia (Santarpia, 2008), eating disorders (Schmidt & Martin, 2016), and in assisting overweight women to reduce their food cravings (Fattahi, Naderi, Asgari, & Ahadi, 2019). To date, there is only one case study that examined the impact of NFB therapy as an adjunct to psychotherapy on a single female with complex developmental trauma-related disorders. Fisher et al. (2016) illustrated the long-term treatment of "Bea," a survivor of repeated and complex developmental trauma, via trauma-focused psychotherapy combined with electroencephalography neurofeedback.

Fisher et al. (2016) described significant changes that Bea reported within the first 10 sessions of NFB therapy. Bea was able to stop all self-injurious behaviors, she was able to interrupt a trauma-related flashback, her nightmares became less frequent, her dissociative episodes virtually ceased, and her sleep improved. Bea stopped taking all medications after she completed weekly sessions for several months. Additionally, Bea went back to school and started a new career (Fisher et al., 2016).

The second study that investigated the impact of NFB on women was conducted by Kluetsch et al. (2014). Kluetsch et al. utilized a resting-state functional magnetic resonance imaging scan to determine if a single session of NFB training, aimed at the voluntary reduction of alpha rhythm (8-12 Hz) amplitude, would be related to differences in electroencephalography network oscillations and functional magnetic resonance imaging connectivity. The participants were 21 women with PTSD related to childhood abuse who received 30 minutes of electroencephalography NFB training preceded and followed by a resting-state functional magnetic resonance imaging scan. Immediately before and after NFB, participants completed Spielberger's State Anxiety Inventory and Thayer's Activation-Deactivation Adjective Checklist to measure state anxiety and arousal.

Kluetsch et al. (2014) found that alpha desynchronizing NFB was associated with decreased alpha amplitude during training, followed by a significant increase rebound in resting-state alpha synchronization. This rebound was linked to increased calmness, greater salience network connectivity within the right insula, and enhanced default mode network connectivity with the bilateral posterior cingulate, right middle frontal gyrus, and left medial prefrontal cortex. Kluetsch et al.'s findings explained the potential neurobehavioral mechanisms mediating the effects of NFB therapy on regulatory systems in PTSD.

A summary of neurofeedback studies on PTSD. The studies covered in this literature review are consistent with studies reviewed by Panisch and Hai (2018) and Reiter et al. (2016), which found a positive clinical effect in neurofeedback (NFB) therapy on treating PTSD symptoms. Panisch and Hai (2018) found that the studies related to PTSD in veterans did not include females (Kelson, 2013; Peniston & Kulkosky, 1991; Smith, 2008). The majority of NFB studies investigated the impact of NFB on male veterans (Kelson, 2013; McReynolds et al., 2017; Othmer & Othmer, 2009; Peniston & Kulkosky, 1991; Rastegar et al., 2016; Smith, 2008). Van der Kolk et al. (2016) and Gapen et al. (2016) conducted NFB research that included both males and females. The only two studies that investigated the impact of NFB on women only were Fisher et al. (2016) and Kluetsch et al. (2014).

Studies of individuals with PTSD revealed functional abnormalities in frontal, temporal, and parietal cortices linked to different electroencephalography frequency bands (Fisher et al., 2016). Although NFB studies on PTSD identified specific patterns of altered brain function in individuals with PTSD, heterogeneity exists (Reiter et al., 2016). Therefore, NFB researchers investigated different NFB protocols to treat PTSD symptoms. Some NFB studies on PTSD

utilized treatment protocols that were individualized to each participant, such as Fisher et al. (2016) and Reiter et al. (2016).

The studies covered in this literature review illuminated eight different NFB protocols that were used to treat PTSD including (a) an alpha-theta protocol (Peniston & Kulkosky, 1991), (b) a sensorimotor rhythm beta protocol (Kelson, 2013), (c) a unipolar protocol on CZ and PZ (Askovic et al., 2017), (d) a bipolar protocol on T4-P4 (van der Kolk et al., 2016), (e) an interhemispheric protocol on T3-T4 (Gapen et al., 2016), (f) a z-score protocol (McReynolds et al., 2017), (g) an infra-low frequency region protocol (Othmer & Othmer, 2009), and (h) a combination of more than one protocol (Fisher et al., 2016; Gapen et al., 2016; Smith, 2008). Smith (2008) used alpha-theta and bipolar protocols; Othmer and Othmer (2009) applied an infra-low frequency region protocol, then an alpha-theta protocol in two phases; and Gapen et al. (2016) utilized interhemispheric T3-T4 and bipolar T4-P4 protocols.

The results from NFB studies on PTSD (Askovic et al., 2017; Fisher et al., 2016; Gapen et al., 2016; Kelson, 2013; Kluetsch et al., 2014; McReynolds et al., 2017; Othmer & Othmer, 2009; Peniston & Kulkosky, 1991; Rastegar et al., 2016; Smith, 2008; van der Kolk et al., 2016), as well as the findings of gender difference studies (Frijling, 2017; Koch et al., 2014; Maddox et al., 2018; Matud, 2004; Nillni et al., 2015; Taylor, 2006), showed a significant need for conducting multiple case studies that use both qualitative and quantitative data to get an in-depth understanding of the NFB processes and the changes that occurred during and after NFB in women with PTSD.

CHAPTER III

RESEARCH METHODS

Research Design

The purpose of this study was to examine the impact of neurofeedback (NFB) therapy on women diagnosed with PTSD. The researcher utilized an explanatory multiple case study design and examined quantitative and qualitative data. This research produced implications for NFB therapists in their work with women with PTSD. The benefit of using multiple cases was that multiple realities and meanings could be captured (Cousin, 2005). Case study methodology investigates a real-life contemporary bounded system (a case) or multiple bounded systems (cases) over time, by collecting information from multiple sources and reports (Creswell, 2013).Yin (2009) defined a case study as,

> an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident. The case study inquiry relies on multiple sources of evidence, with data needing to converge in a triangulating fashion, and benefits from the prior development of theoretical propositions to guide data collection and analysis. (p. 18)

Eisenhardt and Graebner (2007) illustrated that a single-case study could help to describe an existing phenomenon, while multiple case studies can be a better ground for building theory because the phenomenon becomes more generalizable if it occurs in a number of cases. Researchers select cases based on the purpose of the research and the theoretical propositions about the topic of interest (Harrison, Birks, Franklin, & Mills, 2017). Individual case studies may produce a similar result (a literal replication) or produce a contradictory result (a theoretical replication) but for anticipatable reasons (Yin, 2018).

Yin (2009) stated,

> Researchers take into account three conditions to distinguish between methods, (a) the type of research questions posed, (b) the extent of control an investigator has over actual behavioral events, and (c) the degree of focus on contemporary as opposed to historical events. Therefore, every research method can be used for all three purposes, exploratory, descriptive, and explanatory, and there is a large overlap among them. (p. 6)

By meeting Yin's three conditions, this study utilized an explanatory multiple case study design due to the nature of the research inquiry, which focused mainly on "how" questions. Yin stated that "how and why questions are more explanatory and deal with operational links that need to be traced over time, rather than mere accident or frequencies" (p. 9). Researchers use explanatory case study when they seek to illustrate links between the case and its context in a real-life situation or to understand the reasons behind the phenomenon (Yin, 2009). This study utilized an explanatory case study model and aimed to illuminate the causal links between the symptoms that women with PTSD were experiencing NFB therapy, and the changes that occurred during and after NFB from the women's perspectives.

Yin (2009) refuted a common misinterpretation that posits that research methods should be organized hierarchically, which means that case studies are only appropriate for the descriptive phrase, and that experiences are the only way of doing explanatory case study. Although it is commonly believed that case studies are qualitative, some aspects of case study research may be viewed through a quantitative lens (Elman et al., 2016). Yin (2009) argued that quantitative data may be relevant to qualitative data due to its ability to cover the behavior or events that case study is trying to explain.

Assumptions and Rationale for Design

A case study can cover both process and outcomes because it can include both quantitative and qualitative data (Tellis, 1997). PTSD is complex and is expressed differently in individuals (Waddington et al., 2003). This was the case for the participants in this study, who were women diagnosed with PTSD as a result of a variety of life experiences and exposure to traumatic events. This study utilized explanatory multiple case studies that included both quantitative and qualitative data to answer questions designed to explain the assumed causal links in real-life interventions (Yin, 2009). According to Yin (2009), answering explanatory how and why questions are too complex for a survey or experimental strategies. In evaluation of language, the explanations would link program implementation with program effects (Yin, 2009).

Due to the mechanisms of NFB, and procedures that work directly on the levels of arousal within the brain to increase or decrease frequencies (Othmer & Othmer, 2007), the participants' responses to NFB therapy are varied. For example, all the participants in this study received the same NFB protocol. However, participants have different reactions toward the NFB training and typically respond to the signal with a shift in arousal, alertness, and vigilance (Othmer & Othmer, 2007). Therefore, in order to understand the changes that occurred during and after NFB from each participant's perspective, this research utilized a multiple case study design. Cousin (2005) proposed that multiple cases studies do not aim to analyze cases, but to define and to explore the cases, attempting to understand them.

The philosophical assumption of this study was ontology. Crotty (2003) defined ontology as "the study of being. It is concerned with 'what is,' with the nature of existence, with the structure of reality as such" (p. 10). According to Creswell (2013), ontological issues relate to the

nature of reality and its characteristics. In terms of ontological assumptions, the researcher "embraces the idea of multiple realities and reports them by using multiple forms of evidence in themes by using the actual words of different individuals and presenting different perspectives" (Creswell, 2013, p. 20). The interpretive framework of this research is based on a pragmatic worldview. Pragmatism "focuses on the outcomes of the research, the actions, situations, and consequences of inquiry" (Creswell, 2013, p. 28).

The research questions that guided this study were:

1. How did women diagnosed with PTSD experience neurofeedback therapy?
2. How did utilizing neurofeedback therapy impact the recovery of women diagnosed with PTSD?

To obtain the answers to these questions, the researcher interviewed participants utilizing the following prompts:

1. How did you experience neurofeedback treatment?
2. What kinds of changes did you observe in your symptoms during and after the neurofeedback treatment period?

Participants

One general guideline for sample size in qualitative research is to collect extensive detail about each individual studied (Creswell, 2013). According to Creswell (2013), in case study research, no more than four or five case studies should be included in a single study. Therefore, the sample size in this study was three participants, based on criterion sampling that meant "cases had met some prespecified criterion based on identifying explicit inclusion-exclusion on criteria" (Creswell, 2013, p. 350). The inclusion criteria for this study were English-speaking women at least 18 years of age, diagnosed with PTSD, who had received at least 20 sessions of

NFB therapy and had completed their treatment. Participants also had to have received a quantitative electroencephalography before and after NFB therapy. The participants also completed Davidson Trauma Scale (Davidson et al., 1997) and Inventory of altered self-capacities (Briere & Runtz, 2002) before and after treatment.

Participants in the study were identified as qualified for inclusion by the director of a university clinic. At the clinic, each participant had received at least 20 sessions of NFB for PTSD. Prior to the interviews, the researcher analyzed their deidentified assessment data.

Procedures

The clinic director briefed all qualified prospective participants about this study after they all completed their NFB sessions. All three prospective participants signed an Authorization to Release Confidential Records and Information form such that their deidentified assessments and information about their NFB therapy could be shared between the clinic and the researcher for a preliminary analysis. Following IRB approval (Appendix A), an email invitation was sent to prospective participants from the clinic on behalf of the researcher.

The body of the email included an invitation to participate, introduced the researcher, and explained the purpose of the study, procedures, risks and benefits, and included an overview of individuals' rights and choices in research with human subjects. The email also stated that participants would receive a $25 gift card at the time of the interview and contained a link to the Informed Consent. Interested prospective participants were instructed that they could click on the Qualtrics link in the body of the email, which would take them to the Informed Consent (Appendix B). At the end of the Informed Consent, prospective participants were advised that by leaving only their first name and their contact information they were consenting to (a) being

contacted by the researcher to set up an interview, and (b) having their assessments identified after the interview was scheduled.

To identify the assessments, the researcher contacted the clinic and provided the first name left by the respective participants. The clinic then examined the three clients' coded files and provided the researcher with only a single matching letter noted on the deidentified assessments for the respective volunteer participant. The original authorization forms releasing deidentified assessments are currently being kept in the clients' files at the clinic. Prior to the qualitative interview, each participant's assessments were reviewed such that the researcher could prepare questions unique to each participant's noted changes in her pre-post quantitative electroencephalogram, and responses on Davidson Trauma Scale (Davidson et al., 1997) responses, and Inventory of Altered Self-Capacities (Briere & Runtz, 2002).

The Role of the Researcher

I am from Saudi Arabia and was born and raised in a collectivistic culture where family and social support is a fundamental principle underlying the relationships between individuals. The participants in this study were American women who lived and grew up in an individualistic culture. One of the strongest predictors of PTSD in women is low social support (Guilaran, de Terte, Kaniasty, & Stephens, 2018). Although American women may be surrounded by social support, those with PTSD are more likely to report negative responses and poor support from family and friends (Andrews, Brewin, & Rose, 2003). During data collection, I reminded myself that the participants were from a different culture. I needed to carefully consider their point of view, become more aware of accepting our differences, and avoid any prejudice or assumptions.

Another factor I considered was language differences. My first language is Arabic. Although I can speak and understand English, there are some English phrases and metaphors that

I do not understand in conversation. Temple and Young (2004) explained that words and languages are wrought with values, and that the way researchers represent people who speak other languages is influenced by the way they see their social world. Therefore, I asked each participant what she meant if she used a phrase I did not understand due to the language barrier or cultural differences. Additionally, I used a reflexive journal to avoid bias, and I recorded my thoughts and feelings after each interview and during the data collection and analysis processes.

Data Collection Procedures

This multiple case studies research design utilized both quantitative and qualitative data. The qualitative data was obtained through participant interviews and was used to illuminate participants' experiences of NFB therapy, including their observations about changes that occurred during and after NFB therapy. The deidentified quantitative data was obtained from participants' files after they signed a release of information through the clinic. The quantitative data served to complement the qualitative data to show changes in participants' quantitative electroencephalograms, and responses on Davidson Trauma Scale (Davidson et al., 1997) and Inventory of Altered Self-Capacities (Briere & Runtz, 2002) before and after NFB therapy. The quantitative data included participants' pre- and post-quantitative electroencephalograms and their scores on Davidson Trauma Scale and Inventory of altered self-capacities.

Quantitative electroencephalography. The quantitative electroencephalogram is a form of brain mapping and is done prior to NFB training. Quantitative electroencephalography serves NFB practitioners by demonstrating which part of an individual's brain is over- or under-activated, which serves as a guide for NFB practitioners to set up a client's specific NFB protocols. The quantitative electroencephalogram of all individuals is compared to those drawn exclusively from nonclinical populations. In practice, this allows the NFB practitioner to

determine how a given individual deviates from the "normal" population in both direction and magnitude for various measures (Kanda, Anghinah, Smidth, & Silva, 2009; Thompson, 2018).

Davidson trauma scale. Davidson Trauma Scale (Davidson et al., 1997) is composed of 17 items corresponding to each of the 17 symptoms of the fourth edition of the *Diagnostic and Statistical Manual of Mental Disorders* (American Psychiatric Association, 1994). Items can be categorized as follows:

- Items 1- 4 and 17: Criteria B (intrusive reexperiencing)
- Items 5-11: Criteria C (avoidance and numbness)
- Items 12-16: Criteria D (hyperarousal)

For each item, the participant rates both frequency and severity during the previous week on a 5-point (0 to 4) scale for a total possible score of 136 points.

Inventory of altered self-capacities. Inventory of altered self-capacities is a 63-item standardized measure of disturbed functioning in relation to self and others. The seven scales of the inventory are interpersonal conflicts, idealization-disillusionment, abandonment concerns, identity impairment, susceptibility to influence, affect dysregulation, and tension reduction activities (Briere & Runtz, 2002). Interpersonal conflicts measures problems in relationships with others and a tendency to be involved in chaotic, emotionally upsetting relationships.

Idealization-disillusionment measures a predisposition to dramatically change one's opinions about significant others, generally from a very positive view to an equally negative one. Abandonment concerns measures a general sensitivity to perceived or actual abandonment by significant others and the tendency to expect and fear the termination of important relationships. Identity impairment measures difficulties in maintaining a coherent sense of identity and self-awareness across contexts. There are two subscales of identity impairment including self-

awareness and identity diffusion. Self-awareness indicates a lack of understanding of oneself and sense of identity, whereas identity diffusion evaluates the tendency to confuse one's feelings, thoughts, or perspectives with those of others.

Susceptibility to influence measures a proclivity to follow the directions of others without self-consideration and to accept uncritically others' statements or assertions. Affect dysregulation measures problems in affect regulation and control, including mood swings, problems in inhibiting the expression of anger, and an inability to easily regulate dysphoric states without externalization. There are two subscales of affect dysregulation: affect instability describes the actual phenomenon of rapidly changing mood, whereas affect skills deficits assesses the underlying deficits in affect control thought to underlie some affect dysregulation. Tension reduction activities measure the tendency to react to painful internal states with externalizing behaviors that distract, soothe, or otherwise reduce internal distress (Briere & Runtz, 2002).

All forms of qualitative data, according to Creswell (2013), are grouped into four basic types of information, including documents, observation, interviews, and audiovisual materials. In this study, the documents that were used included the participants' quantitative electroencephalograms, their answers and scores on Davidson Trauma Scale (Davidson et al., 1997) and Inventory of altered self-capacities (Briere & Runtz, 2002), and participants' responses provided during the interviews. The interview was face to face, semi-structured individual interview that was digitally recorded. Semi-structured interviews were utilized in this study because they are appropriate for exploring experiences and perceptions regarding complex and sensitive issues.

Interviews enabled probing for more information and clarification of responses (Barriball & While, 1994). Semi-structured interview techniques provided freedom to probe all unclear or ambiguous words and phrases with the flexibility to validate the meaning of participants' answers (Barriball & While, 1994). Probing enabled the researcher to explore and clarify inconsistencies within participants' responses and helped participants to recall information for questions involving memory (Smith, 1992). To help the participants respond to the research questions and describe their observations in more depth and detail, the researcher prepared sub-questions based on the participants' results on Davidson Trauma Scale and Inventory of Altered Self Capacities.

Data Analysis Procedures

Case study research can free researchers from "being constrained by restrictive rules. Data can be analyzed by utilizing a combination of procedures, such as examining, categorizing, tabulating, or combining narrative and numeric evidence" (Yin, 2018, p. 212). Adu (2019) emphasized that it is almost impossible to have a consensus among qualitative researchers on one appropriate qualitative analysis strategy for case study data because every case is unique, and the researcher works on data from multiple sources.

According to (Yin, 2018) if the researchers have a general strategy for analyzing the data, they can reduce the analytic difficulties. For this study, holistic and embedded analyses were utilized to understand the differences and the similarities between the cases, and to analyze the data both within and across situations (Yin, 2009). A holistic analysis examines the phenomenon as a whole. An embedded analysis draws conclusions about the phenomenon by investigating sub-units of the study object (Yin, 2009).

The analysis procedures in this study were undertaken through several steps. First, the researcher coded the interviews using structural coding, emotion coding, and values coding. Structural coding is a question-based code and "acts as a labeling and indexing device, allowing researchers to quickly access data likely to be relevant to a particular analysis from a larger data set" (Namey, Guest, Thairu, & Johnson, 2008, p. 141). The researcher utilized structural coding based on the main research questions. Structural coding was tailored for each participant based on her quantitative electroencephalogram and responses to Davidson Trauma Scale and Inventory of altered self-capacities taken before and after NFB therapy.

According to Saldaña (2015), emotion coding is appropriate to explore "intrapersonal and interpersonal participant experiences and actions" (p. 99). Saldaña stated that emotion coding and values coding "tap into the inner cognitive systems of participants. Emotion coding, quite simply, labels the feelings participants may have experienced. Values coding assesses a participant's integrated value, attitude, and belief systems at work" (p. 99).

Second, the researcher applied the methodology described by Creswell (2014) to analyze the data:

> (1) The researcher organizes and prepares the data for analysis. That involves transcribing the data, optically scanning material, typing up field notes. (2) The researcher reads or looks at all data. This first step provides a general sense of the information and opportunity to reflect on its overall meaning. What general ideas are participants saying? What is the tone of the ideas? What is the impression of the overall depth, credibility, and use of the information? (3) The researcher starts coding all of the data. (4) The researcher uses the coding process to generate a small number of themes and categories to build additional layers of complex analysis. For example, in case

> studies, themes are analyzed for each case and across different cases. (5) The researcher advances how the description and themes will be represented. (6) In the final step, the researcher interprets the findings or results. (pp. 197-200)

The researcher followed similar steps as those described by Creswell (2014) in his description of how to systematically analyze data. First, the researcher read the transcripts of the participants' interviews individually a few times. The researcher then applied structural coding and coded the themes based on the sub-questions for each participant in one Word file by organizing the data in three tables to facilitate the comparison between the three participants. While the researcher coded the themes, additional themes were added that were driven by the interview responses from the participants. Next, the researcher created three new Word files, one for each participant's transcript, which were reviewed separately line by line. Finally, notes were made on any final themes in the margins of each transcript, and then themes for each participant and across the three participants were categorized.

The researcher utilized the theoretical propositions strategy during data analysis. According to Yin (2018),

> The original objectives and design of the case study were based on such propositions, which in turn reflected a set of research questions and a review of the literature. The propositions would have shaped the researcher's data collection plan and therefore would have yielded analytic priorities. (p. 325)

Consistent with Yin's (2018) notion of theoretical propositions, the researcher reviewed the literature on the treatment of PTSD with NFB. Research indicated that NFB reduced symptoms of PTSD (Askovic et al., 2017; Gapen et al., 2016; Kelson, 2013; Othmer & Othmer,

2009; Smith, 2008; van der Kolk et al., 2016). The researcher's data collection strategies were consistent with those of prior studies.

The researcher also utilized pattern matching. Yin (2018) emphasized that,

> the researcher should consider using any of five analytic techniques, (1) pattern matching, (2) explanation building, (3) time-series analysis, (4) logic models, and (5) cross-case synthesis. The purpose of the analytic strategy is to give the researcher a sense of direction in analyzing the data. (p. 223)

based on Yin's (2018) description, the researcher identifyed and compared the patterns evident in the data against one or several hypothesized patterns that the researcher has previously observed in related literature (Yin, 2009). The logic of pattern matching is drawn from traditional hypothesis testing strategies, not from statistical hypothesis testing methods (Almutairi, Gardner, & McCarthy, 2014). Trochim (1989) illustrated the major differences between pattern matching and traditional hypothesis testing approaches by stating that "pattern matching encourages the use of more complex or detailed hypotheses and treats the observations from a multivariate rather than a univariate perspective" (p. 357). In this research, all participants' data was compared to the tenets of the findings of previous research. Accordingly, Yin implied that if the patterns from current data match with results from previous studies, the researcher can draw conclusions from those patterns.

Based on prior PTSD and NFB research, the researcher hypothesized the following patterns:

1. There will be a significant reduction of PTSD symptoms, such as depression, anxiety, flashback, nightmares, and dissociative episodes for those participants who received NFB

therapy (Askovic et al., 2017; Fisher et al., 2016; Gapen et al., 2016; Kelson, 2013; Othmer & Othmer, 2009; Smith, 2008; van der Kolk et al., 2016).

2. There will be a significant improvement in affect regulation capacities, auditory attention and auditory processing speed, sustained attention, and calmness and daily functioning in participants with PTSD who received NFB therapy (Askovic et al., 2017; Kluetsch et al., 2014; McReynolds et al., 2017; Smith, 2008; Othmer & Othmer, 2009; Rastegar et al., 2016; van der Kolk et al., 2016).
3. Women with PTSD are more likely to develop depression, have specific phobias, and even to report arthritis, chronic back or neck problems, and frequent or severe headaches (Husky et al., 2018).
4. Women's coping styles are more emotion- and avoidance-focused (Matud, 2004).

Qualitative Methods and Validity

Qualitative validity indicates that the researcher checks for the accuracy of the findings by employing certain procedures (Gibbs, 2007). In case study research, "the researcher can examine the quality of their emerging design in relation to four tests commonly used in social science research: construct validity, internal validity, external validity, and reliability" (Yin, 2018, p. 58). According to Yin (2009), case study researchers need to guarantee construct validity (through the triangulation of multiple sources of evidence, chains of evidence, and have key informants draft case study report), internal validity (through the use of analytic techniques such as pattern matching, explanation building, addressing rival explanations, and using logic models), external validity (through the use of replication logic), and reliability (through the use of case study protocols and developing case study databases).

External validity establishes the extent to which a study's findings can be generalized. Yin (2009) stated that qualitative case study results can be generalized to some broader theory. Generalization occurs when qualitative researchers study additional cases and generalize findings from the new cases. In this study, the researcher enhanced the construct validity by triangulating through multiple sources, which were all used as evidence for emergent themes. The researcher enhanced internal validity by establishing analytic techniques such as pattern matching.

CHAPTER IV

RESULTS

This chapter includes participants' narratives and descriptions changes in their Quantitative Electroencephalography (QEEG) brain maps, and changes in scores on the Davidson Trauma Scale (DTS) and the Altered Self-Capacities (IASC) scale before and after neurofeedback (NFB) therapy. Finally, the emergent themes from the data will be discussed. Participant demographics, the number of NFB sessions, and the duration of the participants' NFB sessions are presented in Table 1.

Table 1

Participant Demographics

Characteristic	Participant 1	Participant 2	Participant 3
Name	Ina	Sara	Cat
Age	32	47	56
Ethnicity	Caucasian	Hispanic	Caucasian
Education	Masters	Bachelor	Bachelor
Marital Status	Single	Married	Divorced
Type of Trauma	Developmental trauma after being exposed to child abuse	Developmental trauma after witnessing and being exposed to domestic violence	Raped twice
NFB Sessions	31	52	22
Duration of Treatment	8 months	16 months	6 months

Participant Narratives

Ina. At the time of the interview, Ina was 32 years old and identified as Caucasian. Ina's parents divorced when she was three years old. Ina's mother remarried, and she grew up living with her mother and stepfather in an Eastern European country. Ina's mother and stepfather

eventually had a son. Ina stated that she had been close to her half-brother growing up. Ina described her stepfather as "abusive." Ina explained, "I was exposed to all types of abuse, physical and verbal. He [step-father] abused me in my mother's presence or absence. He never touched my mother but abused my brother and me."

Although Ina suffered from her stepfather's abuse during her childhood, when she turned 16, she started defending herself against him which proved helpful. Ina said, "ultimately, he stopped abusing me physically, but he continued to abuse me verbally." At age 16, Ina graduated early from high school and left her family's home to attend a college in another Eastern European country. She described the time she left home by saying "It was my happiest time." At age 21, Ina came to the United States as an exchange student. Ina has since obtained two master's degrees and has remained in the United States.

A few years ago, Ina's brother committed suicide at the age of 16. She described this painful event by stating,

> This trauma affected me in many ways, and it is hard for me to summarize it in a few words. It is not surprising that my brother committed suicide. What I went through, it is a miracle that I survived. Symbolically enough, I was 16 when I left the family because I moved. He was 16 when he left the family because he died.

Ina mentioned that she was in therapy at the time her brother committed suicide. She added, "I have been in therapy all my life." Ina mentioned her therapy again when she talked about her romantic relationships.

> It is not easy to trust people; it took a long time. I was in relationships a few times. My most recent relationship did not end well. I had to do what I had to do with my stepfather. I defended myself physically. My ex-boyfriend became abusive for the first time after we

> were together for three years. That ended the relationship. I went to the police and reported it. I had the choice to continue with him because he never showed anything like that before, but I did not trust him anymore. Due to other things that happened in my life, my ex-boyfriend's abuse put me in a strange place for a while. I did not date for a year. I was scared. I went to a lot of therapy and worked a lot. My counselors gave me a lot of reassurance. Everything is getting to be okay; now, I am not scared.

Ina mentioned that she felt "burned out" due to the stressful issues in her job and the effort it took to go to school at the same time. Ina shared,

> I was dealing with some really bad burnout. I was doing school at the same time as I was working. I felt like the work that I had before was really stressful, and that me going to school did not make it easy. Back then, I would sometimes go to sleep and not wake up for 15 hours. I spent a few months on short-term disability leave because of a situation related to my PTSD. At that time, I was able to get a lot of rest, and I was able to get even more treatment.

As an attempt to reduce her PTSD symptoms, Ina was in therapy with different counselors who used various methods, such as cognitive behavior therapy (CBT), somatic experiencing, eye movement desensitization and reprocessing (EMDR), and neurofeedback (NFB). Ina summarized her therapy journey by stating,

> I had a couple of counselors who would only be doing cognitive behavior therapy, the 'CBT' as they called it, and I never really saw any improvement. I just was going and going and going until I found a counselor who specialized in the somatic experience, like how your body responds to stress and how your body becomes after you experience some kind of trauma in your life through however it came to you. To me, the only way to

> become a healthy person after a traumatic event is to work with someone who has a really good idea of how the body and mind are connected. One thing I really like about NFB and EMDR is that those kinds of treatments are oriented toward your body because you cannot use the cognitive-based therapy only to try to deal with somebody who is a trauma survivor.

Ina was in therapy before she started NFB, and her counselor helped her register her dog as an emotional companion, which helped her with her anxiety. Ina described her relationship with her dog by stating, "My dog is my emotional companion. It is good for me to have a dog. My dog travels with me everywhere. Having my dog around me has helped me a lot with my anxiety."

In addition, Ina's counselor suggested that Ina try NFB and told her about a university clinic that was conducting research on NFB that could provide it for free. Ina registered to receive NFB and, while waiting for the study to start, Ina began receiving EMDR therapy with a second counselor. Ina started receiving two months of EMDR therapy before starting NFB. Ina then received NFB therapy for 7 months. In total, Ina completed 31 NFB sessions.

At the time that Ina sought NFB, she was given Davidson Trauma Scale (DTS) and Inventory of Altered Self-Capacities scales (IASC). In addition, a quantitative electroencephalogram (QEEG) was done before beginning NFB. Ina then had subsequent QEEGs at the end of NFB. Ina also completed DTS and IASC at the end of NFB.

During the interview, the researcher discussed changes in Ina's symptoms, based on her pre- and post-scores on the DTS and the IASC, and shared changes in the QEEGs. The researcher asked Ina to elaborate her thoughts on changes in specific items on DTS and the IASC, which are noted in the next section. following,

Ina's scores on Davidson Trauma Scale (DTS). Ina began NFB therapy with a total score of 68 and ended the treatment with a total score of 22. Ina changed most on the avoidance and intrusive reexperiencing subscales, with decreases from 23 to 4 and from 30 to 9, respectively. Ina also dropped from 15 to 9 on the hyperarousal subscale.

Ina had changes on the painful images/memories of the traumatic event and on the intrusive reexperiencing subscales. Ina started the study rating painful images/memories of the trauma with a frequency of 3 (4 to 6 times in the last week) and a severity of 3 (markedly distressing). At the time of the follow-up, Ina rated painful images/memories of the trauma as a frequency of 2 (2 to 3 times in the last week) and severity of 1 (minimally distressing). When Ina saw changes in the subscale scores, she elaborated by stating,

> The flashbacks used to make me freak out. It was not just the flashback; it was the experience with the flashback, the triggers, and memories. During and after the NFB, the flashbacks and the experiences with the flashbacks became less and less pronounced, so I was able to look at those flashbacks, I could still look at it in the face, and maybe it made me feel uncomfortable, to a certain extent, but, at the same time, I knew what to do. I may need to take a break; I may just walk out, take my dog for a walk.

On the avoidance subscale, Ina initially reported a frequency of 2 (2 to 3 times in the last week) and a severity of 3 (markedly distressing) on the questions regarding avoiding thoughts about the traumatic event and avoiding situations that reminded Ina of the event. For both of these subscales, Ina reported a 0 for frequency (not at all) and severity as 0 (not at all distressing). Ina described how she experienced changes in both of these areas by stating,

> Before the NFB therapy, the most important impulse would be to just completely avoid the flashback and the experience with the flashback. However, after NFB, avoidance

> would not necessarily make me compelled to just kind of escape the situation altogether. I have more of an inventory of how to handle this, compared to how it was before.

Ina also had changes on the hyperarousal subscale that asked questions about physical symptoms when reminded of the event, such as sweating or a racing heart. For physical symptoms, Ina started the NFB with a frequency of 3 (4 to 6 times in the last week) and a severity of 4 (extremely distressing). After NFB, Ina rated physical symptoms a frequency of 1 (one time only in the past week) and a severity of 2 (moderately distressing). When the researcher asked Ina about her changes in hyperarousal, she stated,

> Before NFB, I was extremely disturbed, and I sometimes felt like the earth was just about to move from underneath my feet. However, I became able to control my levels of anxiety. Even in the most stressful situations, I can still stay present. I am certainly not going to be freaking out the same way I would be in the past.

Ina's scores on the Inventory of Altered Self- Capacities (IASC) scale. Ina's scores reduced from a total score of 199 to a total of 124. The subscales that demonstrated the largest differences were affect dysregulation, idealization-disillusionment, and abandonment concerns. For the affect dysregulation subscale, Ina's ratings declined from 25 to 16. On the idealization-disillusionment subscale, her scores changed from 26 to 14. On the abandonment concerns subscale, Ina's scores dropped from 29 to 14.

Ina showed a change in affect dysregulation on a question asking whether or not the respondent was having a hard time calming down once upset. Before NFB Ina rated this area as a 4 (often in the last six months), and after treatment she rated this area as a 2 (once or twice in the last six months). When the researcher asked Ina about this shift in her ability to calm herself

down, she stated that the "NFB helped me better understand how to just calm myself down. It is almost like a type of skill that I would not otherwise know."

An example of a question on the idealization-disillusionment subscale relates to the experience of looking up to people and then being disappointed. Before NFB, Ina rated this item as a 4 (often in the last six months), and after treatment she rated this as a 2 (once or twice in the last six months). When the researcher asked Ina about this question, she said "I had a really good relationship with my grandfather. He was my role model and that is why I imagined myself being with a man. It is not easy to trust people; it took a long time."

Ina's Quantitative Electroencephalogram (QEEG) brain maps. The brain map (Figure 4) was created while Ina had her eyes open utilizing z-scored absolute power. The pre-NFB brain map showed an excess of alpha (8 to 12 Hz) brainwaves in P3-Pz areas, which is indicative of difficulties related to attention and sustained attention. In addition, alpha activity (8 to 12 Hz) is implicated in emotional processing, which indicates difficulties with emotional regulation, or traits of either depression or anxiety. The post-NFB brain map showed little change in Ina's alpha activity (8 to 12 Hz), but a shift occurred to the midline structures to the left parietal (Pz) and right occipital cortex (O2).

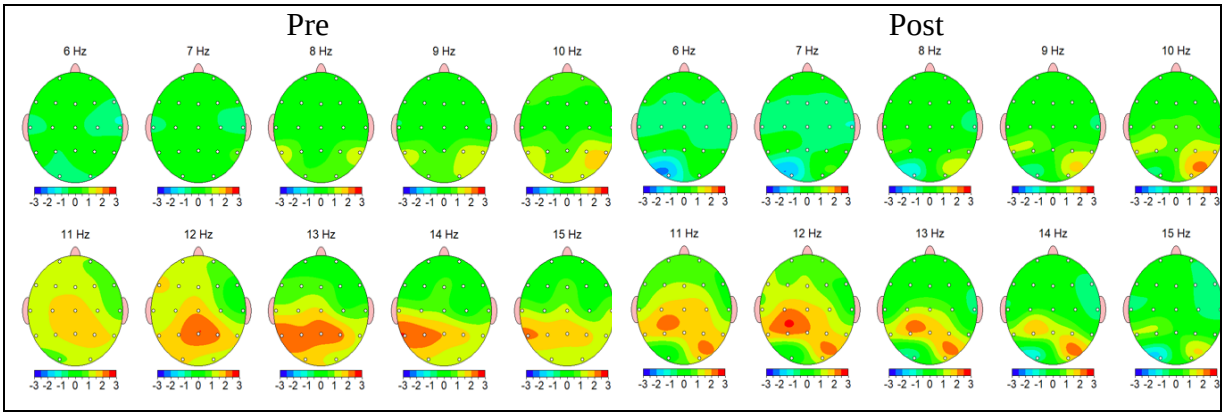

Figure 4. Ina's Brain Map - Eyes Open - Alpha (8- 12 Hz)

The brain map was also done while Ina's eyes were open utilizing z-scored absolute power as shown in Figure 5. This pre-NFB brain map showed an excess of beta (21 to 30 Hz) in the Pz, P3, and P4 areas, which is related to anxiety and is associated with somatic symptoms. In the post-NFB brain map, a net reduction was shown in the occipital beta, which indicates a significant improvement in somatic symptoms.

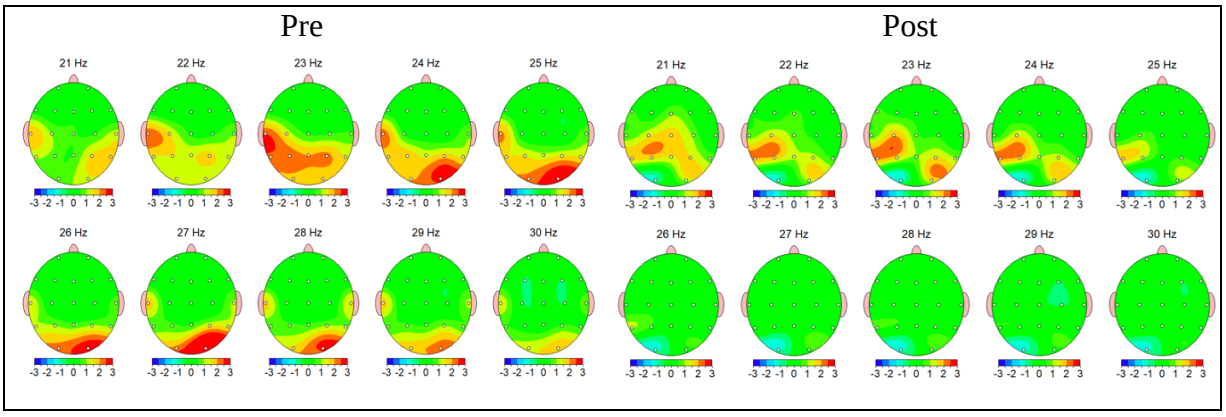

Figure 5. Ina's Brain Map – Eyes Open – High-Beta (21- 30 Hz)

The changes in Ina's QEEGs were compatible with the changes in scores on the DTS and the IASC. The descriptions of Ina's observed changes following NFB therapy also fit with the changes in her scores on the DTS and the IASC. In short, Ina described an improved ability to calm herself down and to reduce her anxiety.

Sara. At the time of the interview, Sara was 47 years old and identified as Hispanic. She was born and raised in the United States. Before Sara was born, her parents lived in a Latin American country, where her five older siblings were born. Sara's family subsequently immigrated to the United States due to Sara's father's work at a church.

Sara's parents did not complete their educations. When Sara talked about her parents, she stated that "My parents, roughly, can read." Sara's father was a pastor, and throughout Sara's

childhood, she lived close to the church community, which she said, “Strengthened my connection to God.” When Sara talked about her depression, she said that “I did not commit suicide due to my religious beliefs. I love the people in the church. They treat me with love and kindness. My relationship with them made me love my religion, but not my father.”

Sara’s recalled how, when her mother was pregnant, she was suffering from severe depression. Before Sara was conceived, her mother had not planned on having more children. Her mother did not choose abortion because of the family’s religious beliefs. Sara explained, “My mother told my younger sister and me that she did not want us. We were neglected. My mother was not in the picture.”

Sara’s father was responsible for the house and children. When Sara described her life with her father, she said, “My father was abusive. I witnessed tremendous violence and a large amount of blood.” In addition, Sara was verbally abused. Sara shared,

> When I would wear any clothes that girls my age would wear, such as short pants, my father would call me a whore and force me to change. I learned to lie to avoid his verbal abuse. For example, I wore a dress, and then when I went out of the house, I changed my dress and wore a skirt.

Sara eventually finished high school, completed a college degree, and secured work in a good position. When the researcher asked her about her achievements, Sara stated,

> I appreciate what my parents did when they immigrated to the United States and gave me the opportunity to learn. My tuition was paid for because my father was a pastor. This would not have happened if I had not lived in the United States.

Sara described her feelings toward her parents by stating, "When my father died, I forgave him. He did what he thought was good to raise me and my siblings. My priority now is to take care of my 83-year-old mother."

When Sara was 20, she married for the first time. She was married for four years and then separated for three years before asking for a divorce due to her husband's abusive behaviors. Sara remarried when she was 34. Sara described her current marital life by stating,

> When I was 34, I married my husband and we have one child. Although we have been married for 13 years and we love each other and enjoy doing things together, my husband is a narcissistic, manipulative person and abuses me verbally. You know what, there was verbal abuse on his part and on my part and I always felt that the two of us were participating. So, I made a choice to stay in my marriage.

Sara's childhood experiences and her husband's verbal abuse affected her emotions, sleep, and dreams, and triggered her anxiety and flashbacks. Sara described these symptoms by stating,

> Before I got NFB therapy, I used to be sad and cry all the time. I just felt so helpless, victimized, and overwhelmed, not knowing what to do. My body never relaxed. My body never got over the trauma. I did have flashbacks, very much so, and very poor sleep, that kind of vigilance where you are just still concerned.

For her symptoms, Sara was in therapy with a counselor who provided cognitive behavior therapy (CBT) for two years. Sara described going to therapy during that time about once every one or two months. Sara received a few NFB sessions in private practice before starting NFB at the university clinic. After Sara completed NFB therapy at the clinic, she went back to her previous counselor for more CBT. After doing more CBT, Sara started doing eye

movement desensitization and reprocessing (EMDR) with a new counselor. In total, Sara completed a total of 52 NFB sessions over eighteen months period at the clinic.

Before Sara began NFB therapy at the clinic, she was given Davidson Trauma Scale (DTS) and Inventory of altered self-capacities scales (IASC). Sara also did a quantitative electroencephalogram (QEEG) before NFB. Sara also completed the assessments and a second QEEG at the end of her NFB sessions.

During the interview, the researcher shared with Sara changes in her scores on the DTS and IASC. The researcher also shared changes in the QEEGs Sara did before and after her NFB sessions. When Sara began NFB, she struggled with sadness, anxiety, concentration, and an inability to sustain attention. After reviewing Sara's assessments, the researcher asked Sara how she experienced changes noted in her assessments and the QEEGs.

Sara's scores on Davidson Trauma Scale (DTS). Before Sara began NFB therapy, she had a total score of 72 on the DTS. At the end of NFB her score was 23. The reduction in her final overall score was noted on all three subscales. For the intrusive reexperiencing subscale, Sara's score dropped from 19 to 4. For avoidance, her score changed from 23 to 9, and for hyperarousal, her score went from 30 to 10.

For the intrusive reexperiencing subscale, Sara had changes on several questions. One question was about the degree to which she felt the traumatic event was reoccurring. Prior to NFB, Sara reported the frequency of feeling the event reoccurring as 2 (2 to 3 times in the last week) and the severity as 2 (moderately distressing). After NFB, she reported a 0 for frequency (not at all) and a 0 for severity (not at all distressing).

For the question regarding physical symptoms when reminded of the event, such as sweating or a racing heart, Sara rated the frequency of the physical symptoms as 3 (4 to 6 times

in the last week) and the severity of physical symptoms as 4 (extremely distressing). After NFB, Sara rated frequency as 0 (not at all) and severity as 0 (not at all distressing).

While Sara had rated the reexperiencing of the traumatic event as a 0 for frequency and severity after NFB, she clarified that the "flashbacks were better, but had not all gone. I still have flashbacks and fear, so that is why I think that the anxiety did not change. There was something else that was bigger." Sara was also dissatisfied regarding the reduction of her physical symptoms and stated,

> I was just so shocked that my thoughts kind of changed, but nothing changed in me physically. My body continued to do the same thing. What is it telling me? Even though I was taking different steps in my mind and doing different things intentionally, my body continued to do the same exact thing causing very bad anxiety. My body was not chilling out, but my thoughts were much more collected and in control.

Sara's reduction in the subscale on hyperarousal was noted in one question relating to feeling jumpy or being easily startled. Before NFB, Sara rated the frequency as 3 (4 to 6 times in the last week), and severity as 4 (extremely distressing). After NFB, Sara rated the frequency as 1 (once only in the last week) and severity as 0 (not at all). However, Sara was dissatisfied with this level of reduction and stated she was unable to "have a normal conversation without screaming and yelling if I was upset."

Sara's scores on Inventory of altered self-capacities (IASC) scale. Prior to NFB, Sara's total score on the IASC was 200. After 52 sessions of NFB, her score was 162. The subscales with the most noted reductions were in susceptibility to influence and interpersonal conflicts, with a reduction in scores being 24 to 13, and 29 to 19, respectively.

For the susceptibility to influence subscale, the two questions that exemplified Sara's progress were about being talked into doing something that you really did not want to do and wishing you were not so easily led by others. Sara's ratings on these items dropped from 3 (sometimes in the last 6 months) to 1 (never happened). Sara described her experience of these changes by stating,

> Before NFB, I felt that I must explain myself all of the time, almost apologetically. Now, I try to hold back being so accommodating because it is easy to be needy. Now, I try to gather more information or see how I can work with someone versus is this person just manipulating me? Do I realize, okay, kind words and all of a sudden, "Oh, I will do anything for you." Now I realize that, sometimes, people use kind words to manipulate others. Therefore, I am slower to respond until after I have examined the situation.

For the interpersonal conflicts subscale, the largest change was on the question related to getting into a fight, which dropped from 4 (often) to 1 (never happened). The item on conflict in relationships shifted from 4 (often) to 2 (once or twice in 6 months), and the item on becoming upset with a friend or lover reduced from 5 (very often) to 3 (sometimes in the last 6 months).

The biggest change in score was the response to the question about getting into a fight. During the interview, Sara had described her current husband as abusive. She also stated that she had come to recognize her part in their arguments to such a degree that she had chosen to stay in the marriage. Sara attributed other changes in the interpersonal conflicts subscale as relating to her ability to place boundaries with her husband and others. Sara described her experience by stating,

> I came up with my own idea to place boundaries and start setting limits. I thought my husband was the only person manipulating me or being hurtful, but I was so focused on

> this relationship or overwhelmed by it, that I did not see it in the other areas where it was occurring. I was overcompensating in different areas and what I found when I was able to no longer experience trauma from my husband was that I was able to see other areas where, okay, manipulation does occur, but I was just ignoring it. It was happening and I do not even see it. All of my energy was in one area instead of realizing that this trauma could be in other situations as well. Once I saw these situations, I had the opportunity to see other things where I could improve. It was the same type of concept; it is better to have boundaries. It is better to stop being so accommodating to others or to the boss.

It is also worth noting two subscales on which Sara's scores stayed the same or increased. For the subscale related to affect skills deficits, Sara's initial score was 10, and after NFB it was 11. For the subscale concerning tension reduction activities, Sara's score remained 11 before and after NFB. The subscale on affect skills deficits related to how well an individual can control intense emotions, such as anger and the degree to which these feelings are externalized. Individuals with high scores in this subscale are thought to have problems with mood swings. The subscale tension reduction specifically relates to how individuals externalize their reactions to painful situations (Briere, 2002).

Sara's Quantitative Electroencephalogram (QEEG) brain maps. Sara's brain maps, conducted before and after NFB, were done while her eyes were open utilizing z-scored absolute power and are shown in Figure 6. Before starting NFB at the clinic, Sara's brain map showed an excess of alpha brainwaves (12 Hz) over the frontal Fz, F3, F7, F4, F8, parietal Pz, P3, P4, and midline Cz, C3, C4 areas. This activity is indicative of attention issues and difficulty with sustained attention. Additionally, the excess of alpha brainwaves over the frontal Fz, F4, F8 and

right temporal cortex T4, T6 areas is associated with emotional issues, such as anxiety and depression.

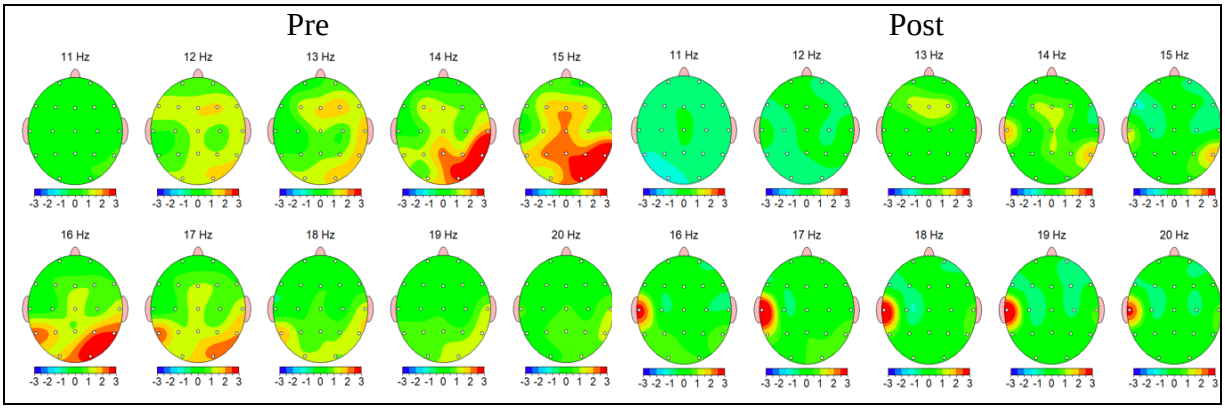

Figure 6. Sara's Brain Map - Eyes Open - Alpha (8- 12 Hz) and Beta (13- 17 Hz)

The activity was slightly elevated in Sara's first QEEG, but was entirely normalized in the second, which is indicative of a reduction in anxiety and depression, and improvement in attention. In addition, there is an excess of beta in the posterior cortex Pz, P3, P4 areas, which is associated with anxiety and physical symptoms. After NFB, a net reduction could be seen in the occipital O2 beta area, which means that there was a significant improvement in physical symptoms. However, activity in the temporal component T3 area persisted, which indicates that symptoms of anxiety persisted.

Changes in the QEEG following NFB were compatible with changes in scores on the DTS and the IASC. Such as some reduction in avoidance, flashbacks, anxiety, and hyperarousal. However, Sara considered these changes inadequate because her body continued to react intensely. In addition, Sara mentioned that she did not receive feedback about her QEEG before or after NFB sessions, which made her feel frustrated. Of learning about changes in her QEEG, Sara stated,

> I appreciate that you shared this information with me. This is the first time that I received feedback about my brain map. My job is in problem-solving, I am always looking for solutions, so by not having that closure of someone doing analysis and telling me follow-up information, I was not able to improve.

Cat. At the time of the interview, Cat was 56 years old and identified as Caucasian. She was raised in a conservative, religious family. At age 29, Cat got married. She was married for 25 years before she got divorced. During her marriage, she had three children. Cat sought NFB therapy after experiencing many traumatic events. Cat described being raped at age 16, and again at age 18. Cat also described trauma related to her mother's sudden passing after being diagnosed with a brain tumor.

Cat described her mother's death by stating, "I used to say the worst week of my life was the week that my mom was diagnosed with a brain tumor and I lost my job." About 10 years after her mother passed away, Cat witnessed her husband fall 30 feet from a building. Cat's husband was in a coma for 12 days and suffered permanent hearing loss as a result of the fall. She described this accident by saying,

> I watched it happen. I watched him fall. Well, I looked away as he hit. I think I did that on purpose because I knew something was going to hit. My husband was in a coma for 12 days. When he woke up, he had lost 95% to 98% of the fluid in both ears. So, he became deaf as well as having all of the traumas from the brain injury. The good thing was that the base of his skull was where the fractures occurred, so he didn't have any of the shearing. The major mood swings and all of that kind of stuff was not an issue because his brain swelled that all opened up. As the swelling went down, the base of the skull kind of got back to where it was supposed to be. It has been a long time. My husband

> spent almost half of his life deaf, which has been very, very interesting for the family in general, me, and him. His deafness has had a lot of play in my life as well as dealing with having watched his accident.

After 25 years of marriage, Cat's husband decided to divorce her, which affected her emotionally and made her frustrated. Cat explained this shift in her marital life by stating,

> I get frustrated and angry because my husband has a head injury and doesn't think he needs any help. He is doing everything on his own. He didn't work for five years; I supported the family for five years on my own with three small children and a man who could not work. However, now he does it all by himself. He got himself back together.

Cat's first major trauma occurred when she was raped at age 16. After the attack, she blocked it out for 20 years. About remembering the assault, she shared,

> It was four o'clock in the morning. I am up, and I am nursing the baby, my second daughter. She was two and a half months old. While I am looking at her, and for no apparent reason, I had a flash of my first attacker. Just in my face, and his face was here [Cat put her hand close to her face]. In my flashback, he was on top of me. The next thing I knew, I was looking at it from behind. "NO! I don't want to be here" is how I felt, and then I saw things from somewhere else because, even during the attack, I don't remember it physically. I remember it like I was looking at it from somewhere else.

Two years later, when Cat was 18, she was raped by an extended family member. Cat became pregnant as a result of this rape. Cat chose to terminate the pregnancy. Terminating the pregnancy affected her in many ways. Cat stated, "I terminated that pregnancy at that point, and that was harsh. That was another thing I had to deal with." Additionally, Cat shared that she did not tell any of her family members about her pregnancy.

Both assaults affected Cat during her life emotionally and psychologically. Cat only sought counseling after remembering her first assault 20 years later. She stated,

> When I remembered my first assault, I went to the rape crisis center for one year. I was on Prozac for a year and a half, and I was not ready to deal with it [talking about the trauma]. I could not discuss it [the rape] at that point in time. I could not deal with the ramifications, so I stopped.

After Cat stopped going to the rape crisis center, she continued on with her life being busy with her family and children. Cat stated, "I just kind of plugged along, being angry, and suffering from PTSD, but not realizing it at that time." Then, 17 years after stopping counseling, her husband told her he wanted a divorce. Cat's husband's decision to end their marriage shifted her thoughts, feelings, and attention. Cat described these changes by stating,

> When my now ex-husband decided that he wanted to divorce, I realized that I needed to get myself taken care of. I needed to take care of me. That is when I had to deal with what happened to me in the past. So, this the first time that I took it upon myself to deal with the issues. It was the best thing I have ever done.

To seek treatment for her past traumas, Cat chose to get counseling at a local community counseling center. Cat stated, "My counselor told me to try NFB and EMDR, and said she felt those things would be good for me." Cat's community counselor told her about the clinic that was offering free NFB, and Cat found another counselor who treated trauma using EMDR. Cat pursued both the NFB and EMDR treatments, while she continued to see her community counselor every other week. Cat received bi-weekly NFB and completed 22 sessions over six months. During this same time, Cat received EMDR with a third counselor every other week.

When Cat arrived at the NFB clinic, she was suffering from anxiety, anger, insomnia, flashbacks, nightmares, and a lack of sustained attention. Before NFB, Cat was given Davidson Trauma Scale (DTS) and Inventory of Altered Self-Capacities (IASC) scales. Cat also did a quantitative electroencephalogram (QEEG) before her first NFB session. After NFB, Cat completed the DTS and IASC assessments again, and she also had QEEG. During the interview, the researcher shared changes in Cat's scores on the DTS and the IASC. Cat was also shown changes in her QEEGs before and after NFB. Cat was asked to share her experiences of NFB, and to describe how she experienced changes in herself during the treatment.

Cat's scores on Davidson Trauma Scale (DTS). Prior to starting NFB therapy, Cat's overall score on the DTS was 38. At the end of Cat's NFB, her overall score on the DTS was 2. Cat had reductions on all three of the subscales including avoidance, hyperarousal, and intrusive reexperiencing. The scores on those subscales changed from 26 to 0, 5 to 2, and 7 to 0, respectively.

An example of Cats' her improvement on the avoidance subscale was noted on questions related to avoiding thoughts about the traumatic event and avoiding situations that remind an individual about the traumatic event. For avoiding thoughts about the traumatic event, Cat went from a frequency of 4 (every day) and a severity of 1 (mildly distressing) to a frequency of 0 (not at all) and severity of 0 (not at all distressing). When the researcher Cat how she experienced a reduction in avoidance, she said,

> Due to the stigma of the two assaults and having had terminated a pregnancy, I always felt like, if I thought about it, if I dealt with it, if I dwelled on it, then people were going to know, and they were going to look at me differently. So, I would avoid it. I just blocked it out myself. I was raised in a very conservative household and was taught that

> "Good people don't get themselves into situations where those types of things will happen." I was raised to believe that "it [rape] was the girl's fault." That had been running through my mind. I was blaming myself for a lot of stuff.

Cat had avoided thinking about the two assaults to avoid feeling bad about herself. However, after NFB and EMDR, Cat's avoidance decreased. She described that decrease by stating, "Thanks to being able to be safe in myself, to be calm, and know that I am in control of my thoughts and through NFB and EMDR as well, I can talk about things."

As Cat stated, "It is okay," she smiled. Cat spoke in a soft and encouraging manner as if she were speaking to a younger version of herself.

An example of Cat's improvement on the hyperarousal subscale was found on the question about trouble falling or staying asleep. Cat went from a frequency of 3 (4 to 6 times in the last week) and a severity of 2 (moderately distressing) to a frequency of 1 (one time only in the last week) and a severity of 0 (not at all distressing). Cat described the changes in her sleep by stating, "Before NFB, I didn't sleep for a very long time. I didn't sleep well. After NFB therapy, I learned to play a little bit of music in the background and it was much easier to fall asleep and I stay asleep."

Cat's scores on Inventory of altered self-capacities (IASC). After NFB, Cat's score on the IASC went from 184 to 91. Cat had noted reductions on the tension reduction, affect dysregulation, abandonment concerns, interpersonal conflicts, and identity impairment subscales. On the tension reduction subscale, Cat's score dropped from 23 to 10. For affect dysregulation, the score went from 21 to 9. The abandonment scored changed from 18 to 9. Reductions on the interpersonal conflicts and identity impairment subscales changed from 21 to 10, and 25 to 12, respectively.

An example of Cat's lowered score on the tension reduction subscale was on the question about using sex as a way to stop feeling bad. Cat's scores on this question went from 5 (very often in the last 6 months) to 1 (never happened in the last 6 months) after the NFB therapy. Cat described her feelings toward her sexual relationship with her husband by saying,

> It was a conflict because I wanted to love my husband and show him that love, but I didn't want the sex because the sex reminded me of this horrible thing that had happened to me. I wanted to enjoy sex, but I didn't want to want sex. I wanted to enjoy the feelings, but I didn't want to want the act. The act reminded me of rape; the feelings reminded me of the love I had for my husband. The thought of wanting to have sex was so foreign to the person I was because, every time, my association was with the act of rape.

Cat described the insight she gleaned after NFB by stating,

> Thinking back and looking at our relationship, because of where I came from, it was always more of a power thing. My husband was in control. He wants sex, he gets sex. However, after NFB, I came to terms with the fact that what I do I do to please myself. I am doing it for me.

An example of the reduction in the on the affect dysregulation subscale score was noted on the questions about moods changing rapidly. Before NFB, Cat rated this item as 4 (often), and afterward she rated it as 1 (never happened). Cat described her experience of this change by saying,

> When I got anxious or hypersensitive, I would go from being loud and screaming and crazy to being withdrawn. It just depended on the situation. My ex-husband would say, "She is a crazy woman; you will never know what you are going to get" [laugh]. NFB has helped me to understand and feel, and my feelings have meaning. What I feel has

substance. I mean that the feeling that I feel is important. I can calm down and, knowing that I need to calm down, the feelings that I was feeling that made me anxious or made me upset are important.

Cat's Quantitative Electroencephalogram (QEEG) brain maps. Cat's first brain map was obtained before NFB, and was done with her eyes open utilizing z-scored absolute power. The pre-treatment brain map shown in Figure 7 indicates an excess of theta (6-7 Hz), and more predominantly marked in alpha (12 Hz), over the temporal cortices in the T3 area. Activity in this area is indicative of anxiety, difficulties with emotional processing, and a dissociative state. Also, the brain map showed an excess of theta and alpha brainwaves that indicate difficulties in attention.

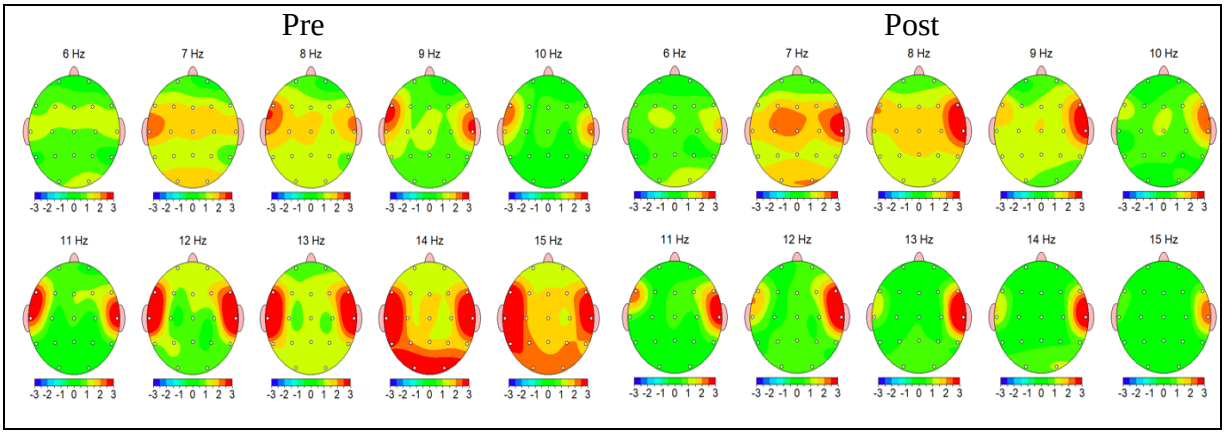

Figure 7. Cat's Brain Map - Eyes Open - Theta and Alpha (6-12 Hz)

After NFB, Cat's QEEG, post brain map, showed changes predominantly over the right temporal lobe T4 area, which indicates significant improvements in anxiety and emotional processing. In addition, the excess of alpha was far less present, which meant a reduction of dissociative symptoms.

In the brain map shown in Figure 8, the pre-treatment evaluation showed an excess of beta activity over the posterior Pz, P1, P2 and temporal cortices T3, T4, T5, T6 areas, touching the frontal cortex Fz, F3, F4, F7, F8 area through a number of frequencies. Beta activity is indicative of anxiety, feelings of agitation or irritability, and sleep issues, such as difficulty falling asleep or very light sleep with frequent waking.

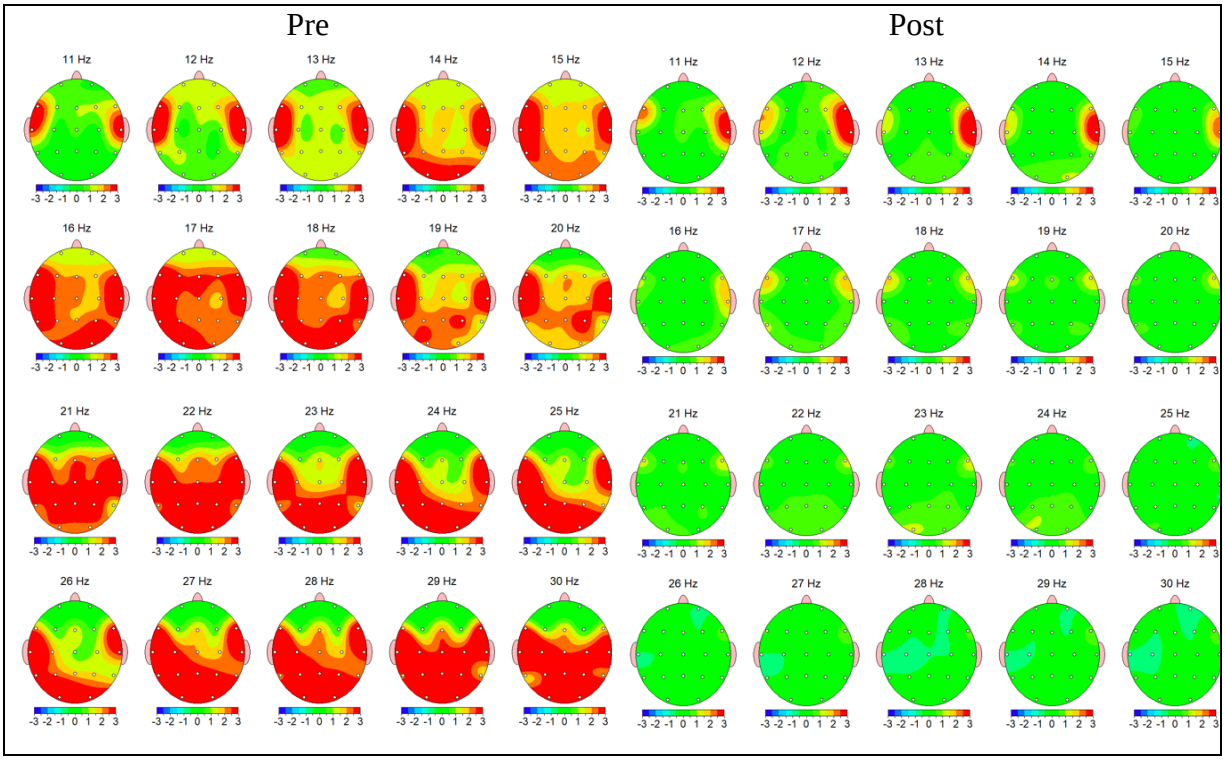

Figure 8. Cat's Brain Map - Eyes Open - Beta (13- 30 Hz)

In the post-NFB QEEG, the beta activity was absent, which means there was a reduction in anxiety, specifically less physical symptoms as shown in a reduction of activity in the occipital Oz, O1, O2 areas. The QEEG also indicated reductions in intrusive thoughts (mid-line frontal Beta Fz), ruminations (left frontal region F3, F7), anxious feelings (right frontal region F4, F8), and emotional sensitivity (parietal, sensorimotor, temporal cortices). Changes in Cat's QEEG

brain maps were compatible with changes in her scores on the DTS and the IASC. Cat's experiences of the changes in her symptoms, such as the improvement in her attention and the reduction in her anxiety and emotional dysregulation. When Cat saw her brain maps, she described her concentration and sustained attention by stating,

> At that point in time, before I received NFB therapy, I was very easily distracted. I was either very focused on something or very scattered. It depended on the situation and what I was doing, whether it was a focus or avoidance. After NFB, my concentration is improving. I still tend to get a little distracted, but not bad as I did.

Presentation of the Data and Results of the Analyses

This section provides a presentation of the three participants' responses and the themes based on the two main research questions:

> RSQ1: How did women diagnosed with PTSD experience neurofeedback therapy?
>
> RSQ2: How did utilizing neurofeedback therapy impact the recovery of women diagnosed with PTSD?

Participants' responses were sorted into five overarching themes and subthemes (Table 2) as they related to each research question. The main themes include perspective on neurofeedback, personal perspective on self, participants' needs during neurofeedback therapy, changes in symptoms and overall well-being, and acquired skills. Due to the use of holistic and embedded analyses, the data included similarities and differences between the cases.

Table 2

Themes and Subthemes

Research Question (RSQ)	Themes	Subthemes
RSQ1: How did women diagnosed with PTSD experience neurofeedback therapy?	Perspective on neurofeedback	
	Personal perspective on self	
	Participants' needs during NFB	
RSQ2: How did utilizing neurofeedback therapy impact the recovery of women diagnosed with PTSD?	Changes in symptoms and overall well-being	Sleep Dreams/Nightmares Flashbacks Avoidance Concentration Acceptance Objective Evaluation Feelings
	Acquired skills	Ability to Calm Journaling Relationship Cognitive reframing

Research question one (RSQ1): "How did women diagnosed with PTSD experience neurofeedback therapy? To glean responses to the first research questions, the researcher began the interview by asking, "How did you experience neurofeedback therapy?" Three themes emerge from participants' responses that included (a) participants' perspective on NFB, (b) participants' perspective on herself during and after receiving NFB therapy, and (c) participants' needs during NFB therapy.

Theme 1-1: participants' perspectives on neurofeedback. This theme refers to each participant's impressions about the characteristics, features, and disadvantages of NFB based on their experience as a client who has undergone NFB therapy to treat PTSD symptoms.

Ina described her impression of NFB as a type of exercise that helped her learn how to consciously calm herself down. Ina stated,

> NFB has to be done regularly. It is a short process. It doesn't take a lot of time. Twenty to 30 minutes could work really well. The thing that I really like about NFB is that it is a self-regulation method that worked well for me. I enjoyed it the most. NFB helped me to better understand how to just calm myself down. I would certainly describe NFB as some type of experience that I had that was efficient and, if I had a chance to do it again, I would continue doing so.

Sara described her perspectives on NFB as,

> A very slow process. It was two times a week for several months, about 20 weeks straight that I participated in, one hour for each session. NFB is a very slow process, but it is important to have a very positive, good outcome. I committed to the process, and I could gradually see the difference in the first month after 8 to 10 sessions of receiving NFB. I felt that NFB was helpful because I used to be a lot sadder and cried all the time. With NFB, I was not so sad. I felt that there was progress in that I was not so anxious. Instead, I felt that there were things that I could do to help myself since I started doing NFB.

Sara described her experience of NFB therapy by stating,

> I had the experience that NFB was very good, yet it was incomplete. Even though I knew "Okay, things are better," My body continued to do the same bad stuff it was doing before. My body still had a memory of something bigger than itself controlling it or running the show.

In contrast to Sara's experience, Cat stated "I found a wonderful way to focus and become more in tune with myself. NFB has helped me be able to find that calm space in myself, and I am able to think more clearly." Cat also described NFB by stating,

> NFB gave me a place to start to heal. I found NFB to be very helpful in my everyday life, as well as dealing with trauma and dealing with everything that I have gone through and dealing with people in general in my life. NFB helped so much. Due to NFB, everything has been so much easier to deal with because I am coming from a place of calm. I went twice a week for NFB therapy. Within the first month, I was noticing changes and finding myself easier to calm down. Being able to be calm is the most important thing that I think can happen.

Theme 2-1: personal perspective. This theme refers to each participant's perception and impression of herself before and after receiving NFB therapy. Ina described her personal perspective of herself by stating,

> I see myself as a person who has more skills to deal with the traumatic events that happened to me in the past. I was able to control my levels of anxiety. Another thing that I noticed because I meditate is that the experience with NFB helped me easily get into this meditative state if I needed to. I can confidently describe the kind of feeling that I may be dealing with.

When Sara described herself before and after receiving NFB therapy, she stated,

> When I received NFB, I noticed that I was starting to get different ideas related to things I don't like. Then, I started to think, "Well, this is what can happen" and I started to think outside the box. I was just starting to kind of create the scenarios and be more specific in my own life. I used to feel helpless and overwhelmed, not knowing what to do; however, after NFB, I can set these things in place and started feeling that it is not such a big issue, you can go ahead and try to tackle it in little pieces. That is how I was able to start thinking differently. I could step through it instead of feeling that "This is too big. This is

too much. I am suffering." After six weeks in the program, I started feeling much more curious and think differently. I started considering other ways of looking at things.

Cat described her perspective of herself before and after receiving NFB therapy by stating,

> I am a much calmer person overall because I am closer to that calm state all of the time now. Everything is much calmer, so I don't have to go quite so far. I can just stay closer to that alpha state of being in control, letting everything go, and being calmer. Before NFB, I used to cry when I got angry or anxious, but I don't do that anymore. I know that I am in control of my thoughts, and it was not my mistake. Now, I am so much more comfortable in myself. I now understand that it is in my brain and in my mind to calm myself. I don't have to have any outside stimulus. I still use my NFB. It takes a little bit longer to do it without the music, without my outside stimulus, but I still use the practice. I mean I cannot hook myself up, but it is so much quicker and I can do it myself and I am a much nicer person. Now, I see myself as more complete.

Theme 3-1: participants' needs during NFB therapy. This theme refers to each participant's stated needs as a client during NFB therapy. All three of the participants explained their needs from different perspectives. For example, Ina stated,

> When I was signing up for the NFB therapy, I knew it is going to be a bunch of different practitioners because it was a research procedure, but if I was to receive NFB from a clinician in private practice, I would certainly like to receive it from one person.

Sara described her needs as a client receiving NFB therapy in more detail by talking first about her need for accurate information about the impact of NFB and its limitation so that she could build reasonable expectations. Sara shared,

What I found difficult was, in NFB, that the practitioners talked to me as if NFB is a very good program or premise to base healing on and is the format from which you will see the best results. That is not true simply because, while it is, definitely, one application, it is not believable to say that it is the only application. I was disappointed that it did not fix all of my issues as it was presented to be a cure all and sustainable. You are just not going to need anything; you are just going to be cured and it is permanent.

Sara described her second need for feedback and progress evaluation by saying,

I would like the practitioner to provide more ongoing transparency of what we started with, where we are at, and where we are trying to be. This is what we are expecting to see. Is there something going on, which is why you are not improving. There should be, for the practitioner, some kind of five-point survey that I fill out where I can gauge, periodically, whether we are on track. If the practitioners could have just shown me the brain maps and said, "This is where we see trauma. This is what your brain maps look like. This is what a good brain map looks like. This is our progress, or this is what your brain is doing in the session. This is what we are hoping to achieve at the end of the session" then that would be helpful. There was none of that correlation occurring. That is why it was hard to measure. I was just going in there with an, "I hope this works" attitude, just being very desperate, wanting it to work. That was my motivation. I would say NFB is a wonderful tool or thing to do, but only if you have someone who is really going to share where you are at; what you should expect to see; and, if you are not seeing it, then other things that are issues. I would say it is good to do NFB with someone who is aware of NFB and what things you can do to make the best use of NFB. Maybe that

could be my personality, I am a person who does a lot of research as it is, so I need to know details.

Sara concluded describing a need for psychoeducation from the practitioner treating trauma-related PTSD. Sara elaborated by explaining,

> I would say for another individual looking to do NFB, definitely do it, but also be in session with someone who knows what NFB is so that you can get the best of talk therapy or maybe someone who can also talk to you if your trauma is just that much bigger than NFB can interrupt or address. During NFB therapy, the practitioners would tell me, "Find a counselor, find a counselor, find a counselor," but they didn't say how or what type of counselor. They didn't explain, "Look, childhood trauma is just so deep that, in order for you to have any marked results or progress, you need to maybe consider these options." I wish there could have been even a handout with a disclaimer saying these are some ideas where if it is so deep that you feel you must continue to check, consider EMDR, consider talk therapy. There was none of this [psychoeducation] on how to enrich the situation to make better improvements. That is why I was disappointed and why I continued to search for something, anything to sleep better, anything to stop me from feeling anxious and from asking, "Why is my body still so scared?" Even though I knew not to be scared in my thoughts, it was like my body did not trust that. That is what pissed me off and that is why I continued to search for a cure for depression and anxiety. That is why I went to EMDR.

In a similar vein, Cat identified two needs she had during NFB. First was her need to understand what NFB was and how it works by stating,

> At first, when I started NFB, I had no idea. I didn't know where I started and where I finished. When I started the NFB sessions, I had the practitioner hide the bars on the screen because it was distracting me. It was so distracting because I didn't know what NFB was. Then, finally, I knew what we were trying to do and what I needed to do. Then, the practitioner could keep the bars on the screen and it didn't distract me as much because I could center myself or let my mind do whatever it was trying to figure out; what I needed to do to get that equilibrium, whether I needed to think this or not think that or just kind of let go. It's important to know what NFB is. Let me know where I start because it is very difficult to express what you do or don't do to get to that state. I thought that I was going to have a session where the practitioner went through and said, "This is where you start and this is where you end," but that never happened.

The second was Cat's need for receiving feedback about her brain map results and her progress during the NFB sessions. Cat stated,

> The first time I have seen anything about my brain map results is now with you [the researcher]. I was like "You have got that information? Cool! I would love to see that." If I had seen that red, red always means wrong, there is something wrong. I got to get that information. That kind of unknown left me hanging. I knew NFB worked. I knew NFB helped. I had no idea what NFB was doing. I had no idea where I was beforehand and where I was at the end. I mean even a slight change, something to indicate that this is what a brain looked like before NFB and this is what a brain can look like after NFB. That is what I needed.

Research question two (RSQ2): "How does utilizing neurofeedback therapy impact the recovery of women diagnosed with PTSD?" Participants' responses revealed main themes

including changes in symptoms and overall well-being and acquired skills. The researcher noted some overlap between these two themes. Occasionally, a fine line existed between the first and second themes. For the purposes of this study, any subtheme related to positive improvement in any aspect of participants' overall well-being was included in the first theme, while any improvement in the participant's abilities or skills that help her deal with her trauma were included in the second theme.

Theme 1-2: changes in symptoms and overall well-being. This theme refers to participants' observations of how NFB impacted their PTSD symptoms. This theme refers to participants' observations of how NFB impacted their PTSD symptoms and their overall well-being. Changes in symptoms and overall well-being were noted in the areas of sleep, dream and nightmares, flashbacks, avoidance, concentration, acceptance, objective evaluation, and feelings that included sadness, anxiety, and self-worth.

Sleep. This subtheme refers to each participant's observations about her sleep before and after NFB therapy, including difficulty falling and/or staying asleep and sleeping for a long time. Two of the participants (Ina and Cat) spoke about the improvements in their sleep. Ina described her sleep before she started NFB therapy by saying,

> I would sometimes go to sleep, and I would not wake up for the next 15 hours. After NFB therapy, if I am not more stressed out than regular, I sleep fine. I don't have any problems falling or staying asleep.

In the same vein, Cat said that "as the treatment progressed, my sleep was much easier. I would say, within two to three months of starting NFB, I was sleeping better, and it is just gotten better since." Sara reported that she did not have any improvements in her sleep. "I noticed I had no change at that time with my rest, and that was very frustrating during NFB."

Dreams and nightmares. This subtheme refers to any disturbing dreams or nightmares that woke participants from their sleep, regardless of whether the dream was related to the participants' trauma. Of the three participants, Ina reported that she never had nightmares. While, Sara and Cat had nightmares. Sara and Cat described the types of dreams and nightmares they had as well as the changes they noticed after the NFB therapy. Sara described dreaming about bad situations and facing difficulty by stating,

> There was a period of time where I dreamed things that were very bad situations or "GOSH, I have to work on this?!" So, each situation was a struggle that I just couldn't seem to get ahead or take care of. Those dreams were not about my problems. For example, I would have a dream that my parents were in a damaged mobile home that needs repairs. I was picturing situations that had problems that I had to work on but couldn't improve. Now, I don't dream about those things.

According to Cat,

> I would wake up afraid, but not know why. I would realize that I had been asleep and had a nightmare. I don't remember what it was. During the NFB therapy, the nightmares slowed down a lot, and they have progressively stayed away and gotten better.

Flashbacks. Flashbacks refer to the recurrence of disturbing images, smells, sounds, or pain related to the initial incident (Dunleavy & Kubo Slowik, 2012). Ina and Cat both stated that they observed a gradual reduction in their flashback symptoms during NFB therapy, and both stopped having flashbacks after completing their NFB therapy. According to Ina,

> Before NFB, the most important impulse would be to completely avoid the flashbacks, but, through this time, as the flashbacks and the experiences with the flashbacks became

> less and less pronounced, I was able to look at those flashbacks and the triggers of the flashbacks in the face.

Similarly, Cat said "Since I remembered the first assault, the flashbacks happened for a while. Once I started NFB, I have not had a flashback in probably two years maybe." Although Ina and Cat described reductions in flashbacks following NFB, Sara was still struggling to a degree. Sara explained, "I did have flashbacks, very much so, and there's been no change in the flashbacks. I guess because the trauma was so recent, I did not see any improvement until I started placing boundaries." Although Sara had some reductions in her flashbacks, she remained concerned about ongoing hyperarousal and anxiety. About NFB, Sara shared, "I feel that NFB introduced me to healing, but I was still hungry to get rid of what got me there. I would say that EMDR helped with the flashbacks" (Sara started her EMDR after completing NFB).

Avoidance. Avoidance refers to participants' efforts to avoid internal distressing memories, thoughts, and/or feelings or external reminders (e.g., people, places, conversations, activities, objects, situations) that arouse distressing memories, thoughts, and/or feelings about the traumatic event(s). Ina described changes that indicated a connection between her flashback and avoidance behaviors, and explained how she now faces the triggers and flashbacks,

> I do find myself more able to embrace whatever situation that may come up. Situations that were just really distressful before are less now. I am not avoiding doing things or going into situations, especially if there is something that I really worked through.

Cat avoided everything that made her think of the two assaults and the pregnancy termination to protect herself from feeling worse about herself. She always thought about the way people would look at her if they know that she terminated the pregnancy. However, Cat described changes related to avoidance by stating, "I am so much more comfortable in myself

that I don't have anxiety about dealing with what happened to me, talking about it and being open. It is part of me, and it is okay."

Concentration. The concentration subtheme refers to participants' ability to focus on the task at hand while ignoring distractions. All three of the participants reported improvements in their concentration during and after NFB therapy. Ina stated,

> After the NFB and right now, it is easier for me to concentrate. I have more control when I just need to empty my mind out, and just really look at one thing. I feel like I became a good listener, too, because it's easier for me to kind of be in the moment, present, after the NFB and EMDR treatment. So, they certainly complimented each other in a great way.

Sara described her concentration and sustained attention by stating, "I had very poor concentration, and it was very bad. During and after NFB, my concentration was much better at my job." In the same vein, Cat described the improvement in her concentration by stating,

> At that point-of-time, [before NFB] I was either very, very focused on something or scattered. It depended on the situation and what I was doing, whether it was focus or avoidance. I tended to get tunnel vision, so if I was focused on something, the attention would be there, and I would pay attention to nothing else. I was very easily distracted, but, after NFB, my concentration improved. I still tend to get a little distracted, but not nearly as bad as it was before.

Acceptance. The acceptance subtheme refers to each participant's acknowledgment and assent related to negative emotion and/or situation. Ina described how she always looks at the positive side of her trauma and considers herself fortunate to have gotten treatment. Ina said that she left her family when she was 16 and did not commit suicide as her brother, stating, "With

what I went through, it is a miracle that I survived." In addition, Ina described her healing process and stated, "I was fortunate enough to make it post-traumatic growth."

Sara spoke about acceptance from a different perspective when she spoke about her anxiety symptoms. She stated,

> I don't know if my anxiety changed so much. I can't see my anxiety as less. I am just able to work through it now with my choice to be autonomous, with my choice to see how I can help me, and with my choice to journal. I think, maybe, it was an acceptance of, "I'm here. Ok, I don't want to see I'm anxious. I hate being anxious. How do I help myself? What would I do to myself?"

Cat spoke of acceptance in relation to her history and shared,

> Dealing with the trauma, dealing with whatever happened to you, is so important. You have to get past it; not get past but get through it. You do not really get past something; you get through it. Being able to deal with the ramifications and the personal acceptance of what has happened, and how that is has affected you and changed you. From my experience, there is nothing, nothing better than being able to now talk about and deal with the horrible things that happened. People look at me and they said this and this and this, "All of these things happened to you and you are laughing! And you are smiling! And you are happy! How?" That is just what NFB and EMDR have done, looking back and taking care of me finally. After almost 40 years, I am finally to the point where I am happy, and I am able to function. Now, I have to figure out what I want to do with the rest of my life. My grandmother died the day after her 101st birthday. I've got a long time to go. [laugh]

Ability to objectively evaluate the environment and people. This subtheme refers to participants' ability to objectively evaluate how safe they were in different situations and/or with different kinds of people. All three of the participants observed improvement in this area. Ina shared how she gradually noticed an increase in her ability to be fully present in a situation, enabling her to notice more about what might indicate safety or danger. She stated,

> I have seen some improvement in being able to just kind of navigate the situation. If something is less triggering, then, of course, I am going to be able to observe more. Colors are going to be brighter. Tunes or melodies are going to be more vibrant because my senses are open more than before. It is such a gradual type of change.

Sara also noticed a change in her ability to objectively evaluate situations and stated, "I felt more relaxed, not so scared. I felt less scared when I was with people." In the same manner, Cat observed major improvements that allowed her to work alone with men. She stated,

> When I was younger, and before NFB, I always noticed when I was outnumbered by men. If there were more men in a room than women, I was not comfortable. I felt threatened regardless of whether I was. I felt threatened in a church full of people if there were more men than women. After NFB, I dealt with everything based on how I felt about what I saw versus what the true situation was. Now, at work, I am the only girl. My manager and direct supervisor are men. There are three male folks on the other side of the store doing their thing. Before NFB, when I first started my work, it was really rough but, as I started going through NFB, I started realizing that my boss and supervisor were not out to get me. They were not threatening me physically or in any way. After NFB, I had no problems because I knew what to expect. I knew what our relationship was.

Feelings. Feelings are defined as "the mental representation of the physiologic changes that occur during an emotion" while emotion is "any bioregulatory reactions that aim at promoting, directly or indirectly, the sort of physiological state that secures survival and well-being" (Damasio, 2004, p. 52). Feelings, in this section, refer participants' physiologic changes that occur as they experience different emotions and process thoughts related to their PTSD. These feelings include sadness and crying, anxiety, and changes in self-worth. Sara and Cat described experiencing intense bouts of sadness and tearfulness. Crying, anxiety, and thoughts about their self-worth.

Sara and Cat observed gradually becoming less sad and tearful. Sara explained how her crying decreased slightly during and after NFB,

> I used to be sadder and cry all the time. I only knew either to cry, cry, cry as I was trying to work through something, or scream and yell, and the conversation was over. I could not even have a conversation. I just felt so helpless and victimized.

During NFB therapy, Sara's crying did not decrease to her desired level, which made her frustrated. However, it did make her think about why she cried and why her behavior changed during stressful situations. After Sara feels reactive, she now asks herself, "What possessed me all of a sudden? Why have I gone from competent, logical talking and normal banter to 'I need to be excused'? It was just odd." In addition, Sara did not accept that she could not control herself and not cry. Sara explained, "This [crying] happened with everyone, even at my job and that was just not acceptable. It could be with anyone. I just had to have a difficult conversation with something I deemed personal."

Cat described how she used to cry in a way similar to her mother. Cat explained,

> When my mother got angry with me as a child, she would break down and cry. As I get older, I started doing the same thing. I cried when I got angry or anxious, but after NFB and EMDR, I learned how to calm myself down before I got to the point where break into tears.

All three of the participants reported changes in their anxiety but in different ways. Ina described reductions in her anxiety and increases in her ability to manage it. Ina explained,

> Before I had the NFB therapy, any stressful situation almost felt like the end of the world. However, after multiple sessions of NFB, I was able to solidify the skills and become consciously able to, just at least for 10 minutes, set my mind in a place where I would not be worried. NFB is ingrained in my day-to-day life.

In a different vein, Sara attributed the reduction in her anxiety to skills that she acquired. She stated,

> The anxiety got better because I could take small steps to help myself. I would now look at a situation and ask, “What is happening? What about it don't I like? What are my choices? What can I do about it?” Then, I would ask, “What is the worst possible consequence? Are you okay with that possible consequence?”

Although Sara mentioned that her anxiety got better, it did not decrease to her desired level, which caused her frustration. She stated that,

> NFB was presented to me as if it was a permanent cure, but my body is still doing the same exact thing. Nobody warned me of that. That's the part that I was like, “What happened? Was their tool broken?” The body needs to cure as well. It is like the body continued to do what it had always done and that's why NFB pissed me off. I felt it was inconclusive. I felt incomplete or like I didn't do enough because my body did not at all

> get interrupted from its maladapted choices to continue doing what it does. It's like "Dammit. I wanted to fix that trauma."

Although Sara was frustrated and dissatisfied with the reduction level of her anxiety, she shared,

> Thanks to NFB, I feel more secure with my own situation because I just don't feel so scared. The anxiety is there, but I don't feel so scared. I feel like I could do something about it. I could journal. I could take small steps to help myself, or just break it down.

Cat described how she used to "block the feelings" that made her anxious or upset. About NFB she explained,

> NFB has helped me be able to find that calm space in myself. I realized that these feelings are important and, when I get to that point of a hypersensitivity type of feeling, I have to calm down. I say "Oh, I have that. There is the reason behind my anxiety," and I can deal with that anxiety, deal with those reasons in a constructive way because I have become calm about whatever it was. Those feelings have validity, and I can deal with them.

All three of the participants observed improvements in their self-worth. Ina stated that after NFB, she was able to see herself as "a confident, successful woman who achieved her goals despite the obstacles and trauma that she faced." Ina added, "If I could summarize my experience with PTSD, I would say I was fortunate enough to make it post-traumatic growth." Along the same line, Sara talked about her self-worth by giving an example from her marriage. Sara described how the improvement in her self-worth affected her decision to set boundaries with her husband, which, in turn, decreased marital conflict. Sara stated,

> My husband would call to say horrible things in the morning while I was at work, and I did not realize that it had gone on for years. So, I chose to no longer take the phone calls

> in the morning at all. Then he said, “Please call me back,” and I said, “Please text.” I was much more consistent in realizing my value and knowing that this is what I need. It was relevant whether my husband liked it or not. So, to me, even cutting off the calls in the morning caused a remarkably good improvement, but it was like the tip of the iceberg of things I needed to do to change. Boundaries have made a world of difference by allowing me to take care of myself. My attitude is that I need to be more empowered than I have been before. I must have some sanity and self-worth. I needed to just start to take care of myself.

Cat described her self-worth before NFB by stating, “My self-worth was in the toilet, so I avoided everything having to do with thinking about the two assaults because I didn't want to feel worse about myself.” However, Cat became more confident after NFB, and her perspective about her self-worth changed, which affect her feelings as well. Cat stated, “From my experience, there is nothing better than being able to talk about and deal with the horrible things, and you are laughing, and you are smiling, and you are happy now.”

Theme 2-2: acquired skills. This theme refers to any improvement in the participant’s abilities or skills that help her deal with her trauma as well as her thoughts, feelings, and body responses in order to improve her relationships with others. The subthemes for acquired skills include the ability to calm down, journaling, relationships and interactions with others, and cognitive reframing. Cognitive reframing includes skills such as breaking problems into manageable components, not feeling like a victim, and integrated views of self and experiences.

Ability to calm down. This subtheme refers to participants' abilities to calm down. All three participants described being better able to deal with uncomfortable feelings and

experiences. Recover from negative emotions. Ina described her ability to calm herself by stating,

> The fact that I can calm myself down consciously is something that worked well for me. Self-regulation is a side of NFB that I certainly enjoyed the most. I found more ways to express things, even if it was something that was uncomfortable for me or something that made me angry, in a calmer fashion.

Similarly, Sara mentioned that she has the ability to take small steps to help herself or break down what causes her fears and anxiety.

> I think I didn't feel the need to defend myself so often or people please so often. I noticed that I'm trying to be much more present. When I am getting anxious, talking fast, and trying to over-explain myself, I try to slow down and take into account what is happening and what I can do to help myself. That is how I changed my anxiety. I noticed that I calmed down, and my fear reduced. I am less scared. I can exhale a little better. I feel safer.

Cat described a shift in her ability to deal with negative feelings and anxiety instead of blocking them. Cat explained,

> Before NFB, when I would calm down, I would block those [negative] feelings and not deal with them. After NFB and EMDR, when I get to that point of the hypersensitivity type feeling, I have to calm down. "Okay, I can now deal with this feeling. I got upset because of A, B, C." There is a reason behind my anxiety, and I can deal with those reasons in a constructive way because I have become calm. Those feelings have validity, and I can deal with them. Also, I have much better coping mechanisms related to my

anger. When I start getting frustrated or angry, I can bring myself down to a calmer state much easier and much quicker, and it is much nicer for the rest of the world.

Journaling. Although journaling is not a technique associated with NFB, Ina and Sara applied it during their treatment. Ina mentioned journaling and the positive impact it had by stating,

> I have had a tendency to journal ever since I can remember, but I've never really done it regularly. Journaling was part of my treatment in NFB and EMDR and my general therapy. [Journaling] is one of the healthy ways to process my feelings, so I have always done journaling, but I only started doing it regularly in the last two years or so at the same time when I started the NFB therapy. I could be in a very upset state, but I could still be very aware of a trigger and I could still write it down or do the audio journaling. I could stop myself consciously, whatever I am doing, and sit down and document it. I am doing this over and over again a lot, so, at this point, what I learned is that doing this type of exercise helps me make the triggers less intense.

Along the same line, Sara described her experience with journaling by stating,

> I started journaling more in order to kind of trust myself as being my own friend. I think journaling allowed me to transfer that energy of anxiety into, "How do I help myself? What would I do to myself?" I was still anxious, but now I try to journal.

Relationships and interactions with others. This subtheme refers to participant's relationships and interactions with others. Ina noted that the better able she was able to identify what she was feeling, the more her interactions with others improved. She described the benefits of self-awareness by stating,

> [Self-awareness] is directly and proportionally related to the way I could express myself in a relationship because the better we express our own selves to ourselves, the more likely we are to do better when we deal with other people.

Ina explained the changes she observed after NFB by stating, “I became more willing to open my mind to an opportunity to express myself a bit more.” In addition, Ina spoke about her improved ability to make eye contact with others. “I would be looking at someone for some time, but, then, I would become uncomfortable. Right now, I may still experience some kind of discomfort, but I can make eye contact for longer amounts of time compared to before.”

Sara noted some behaviors and feelings that she needs to change in her relationships with others. She explained,

> I was still so needy and pining for approval and acceptance in all other areas, not just my husband. I asked myself, “Why were those core maladapted choices still present?” NFB didn't change me, and that's what needed to be changed. Why am I still needy? Why do I still seem to be codependent knowing how hurtful and unhelpful it is. It's not good, yet I keep doing it. My body was still, by memory, wanting that validation that it never got as a kid. So, even if my husband didn't give it to me and even though I set boundaries and he's no longer being abusive, my body still needed to be a child, validated like a child, loved like a child. The childhood hurt was still hurting. However, I now transferred that neediness, that wanting acceptance, that validation into other relationships. I found that I needed to set boundaries in place and be strong for myself by myself.

Then, Sara explained the change that she observed by stating, “I think I didn't feel the need to defend myself so often or people please so often. I noticed that I was trying to be much more present.”

Cat spoke about the positive changes that she observed by stating, "NFB just helps so much. I found a wonderful way of dealing with people in general and men especially. I found it to be much easier dealing with the people in my life." Then, Cat described her interactions with people, in particular her ability to make eye contact with others,

> I used to not make eye contact with men. Now, I do. Since both of my attackers were older than me, I never had problems with younger people. Due to this issue, I would not look at people in their eyes if they were my age or older. I did not look men in the eye, but now I do [laugh]. Now it does not matter. I feel like everybody else.

Cognitive reframing. This subtheme refers to participants' strategies to change the ways they looked at situations, people, and/or relationships by identifying irrational or maladaptive thoughts, finding more positive alternatives, and looking at situations from different perspectives. The cognitive reframing subtheme includes breaking problems down into manageable parts, not feeling like a victim, and integrative views of self and experiences.

All three participants described having acquired an ability to break down overwhelming feelings into smaller parts that helped them manage feeling overwhelmed. Ina described her strategy by stating,

> I could say I am overwhelmed, and this is why, X, Y, and Z. If I feel like I am overwhelmed, I could come up with a list of triggers, exactly what happened. I am more willing to sit down and say "Okay, I have something that doesn't make me feel great, let us explore mentally." That is an example of some of the inner mental dialogue that I would have when something like this would happen. I am certainly not going to be freaking out the same way I would in the past.

In the same vein, Sara stated,

> I starting to think "out of the box," so I can set these things [that are bothering Sara] in place and realize this [solution] can happen. You can go ahead and try to tackle it in little pieces. That's how I was able to start thinking differently. I could step through it instead of feeling like "This is too big. This is too much. I'm suffering." I could break my thoughts down into smaller pieces, take small steps, and see improvements in those little things.

Cat stated, "When I get anxious, I think about the reasons behind my anxiety, and I can deal with those reasons without becoming an emotional wreck."

Not feeling like a victim was described by participants as feeling they had autonomy over the ways they could relate to others. Sara and Cat used to have a feeling of helplessness, passivity, and a loss of control. Sara believed her husband was verbally abusive, but then gleaned some insight into how she was a part of their dysfunctional interactions. Sara stated, "I noticed there was verbal abuse on his part and on my part, and I always felt that the two of us were participating." Sara described the change in her thinking by stating,

> I do not want to give 100% blame to my husband. While I do believe he is very much an abusive, hurtful individual with severe insecurities, I do not think there needs to be a victim and a perpetrator. I believe both need to be looked at as responsible and unhealthy because I see now the extent of my unhealthy choices based on selecting an individual so broken or damaged when I, too, clearly had severe trauma and suffering before ever even seeing this individual. I believe that the individual who is hurting or with depression or with anxiety also has many, many maladapted choices in his/her life regardless of who else is around. I'm not excusing that behavior. I am just saying the individual also has bad behaviors, and one is not worse than the other. We always want to create a bad guy and a

> good guy, and it is not about that. It is just these choices that are not working for yourself and others. If you have a broken leg, then you go to the doctor to get a cast. I believe thoughts are the same way. If they are not working, then let us work on that and make them better, healthier thoughts.

After being raped twice, Cat's trauma spilled over into her marriage, namely their sexual relationships. About sex, Cat felt that her husband was in control and like she did not have a choice in their sexual relationship, which left her feeling like a victim. Cat explained,

> I was thinking that, in our relationship, it is more empowering for my husband. He is the husband. If he wants sex, he gets sex. I let it happen because whether I wanted it or not, he is my husband, and that is what is expected. I do not want to, but, if I do not, then he will pester me, and then we will have a fight, and I do not want to have a fight. It is just easier to give in. As I got better, mentally, I realized it was not a victim thing. I am not a victim. I am a participant if I want to be. Whether I want to be with my husband is up to me. That realization changed the dynamic in our marriage for the better for me, but worse for my husband. I finally found that I am blocking the enjoyment because of the past. I came to terms with the fact that what I do to please myself, I am doing for me. It does have things to do with my partner, but, if I do not enjoy it, then that is on me. Whether he enjoys it, that is on him.

Participants described experiencing an integration between conflicting thoughts, feelings and bodily sensations. Sara was disappointed in the incongruence between her thoughts and her body's physical responses by stating,

> Even though I said "Okay, things are better. I can trust." My body didn't believe it. I was still not sleeping. I still was worried. I still had anxiety. Even though I knew not to be scared in my thoughts, it's like my body didn't trust that.

Sara described her inner conflict by giving an example of there being two people inside her. She explained,

> There is Sara that I want to portray to the world and Sara that really is happening in secret. I feel like they are more the same person now. Before, I felt like the secret person had a whole other world and the person you see at work or out at the grocery store was a different Sara. Now, I feel like the two are much more together.

Cat used to blame herself for the two assaults and the termination of the pregnancy after the second rape. She said, "I knew it was not my fault, but it is one of those things where your brain knows that it is not your fault, but your emotions are still saying, 'You could have, should have, would have.'" After NFB, Cat's self-blame decreased, and she experienced more congruence between accepting what happened to her and not blaming herself. Cat described this congruence by stating, "After NFB, I realized that I did the best that I could in the situations I was in. I survived and that made me who I am because of my experiences. I am good, and I can deal with that."

Cat also described more consistency between her sexual needs and desires, and her ability to express and own her feelings in her marriage. Cat explained,

> It was a conflict because I wanted to love my husband and show him that love, but I did not want the sex because the sex reminded me of this horrible rape that had happened to me. I have realized that sex is good, and it is okay to want it because it is not to make me feel good about myself, actually, it is to enjoy. It has nothing to do with how I am feeling

about myself; it is for my enjoyment. I am going to have sex for fun not because, "Oh, I am sad, I want to feel better."

Discussion of the Results

For this research, pattern matching was utilized to analyze the data by "matching the collected data with a pattern defined prior to the data collection" (Yin, 2018, p. 352). Therefore, this section presented a brief summary of the research findings that included a discussion of the pattern matching.

The researcher asked two general research questions to understand how (a) participants experienced NFB, and (b) how NFB impacted their PTSD. The participants all emphasized that it is important for NFB providers to explain NFB, how it works, and how clients can observe their cognitive and physical responses while receiving NFB. Participants expressed feeling that understanding NFB was important to achieving the maximum benefits. According to Vernon (2005), the main aim of NFB therapy is to teach the individual "what specific states of cortical arousal feel like and how to voluntarily activate such states" (p. 348). Therefore, when clients understand how NFB works, they can gradually acquire the self-regulation skills needed to reduce their symptoms. Cat stated, "I didn't know what NFB was. So, finally, I knew that this is what we are trying to do, that is what I need to do. Got it."

Ideally, clients should be able to apply the self-regulation skills they acquire from NFB outside of the sessions. For example, Ina described NFB as a type of "exercise" which helped her acquire the skills she needed to learn how to calm herself down. Cat described how she still uses NFB by stating,

> I still use my NFB. It takes a little bit longer to do it without the music, without my outside stimulus, but I still use the practice. I cannot hook myself up, but it is so much quicker, and I can do it myself.

Sara never fully gleaned an understanding of NFB, and stated, "It is good to do NFB with someone who is aware of NFB and what things you can do to make the best use of NFB."

Participants perspectives on NFB were compatible with studies that demonstrated how NFB helps clients learn to regulate their cortical activity, which is accomplished by learning to increase or decrease the amplitude of a wave, frequency and/or coherence, or phase-lag (processing speed) between certain electrode sites (Demos, 2005; Vernon, 2005).

Participants shared a variety of ways that NFB impacted their PTSD. All three participants observed an improvement in their concentration and a reduction in their PTSD symptoms, such as sadness, anxiety, flashbacks, nightmares, and avoidance. However, the participants' symptoms varied, and each participant had different levels of reduction related to their symptoms. For example, Ina observed a decrease in her flashbacks and anxiety and her avoidance behavior stopped. Cat described significant changes in her PTSD. For example, Cat's disturbing dreams, nightmares, and flashbacks stopped. Cat also became less anxious and tearful. Sara observed that her disturbing dreams and nightmares stopped, however, she did not feel her flashbacks, anxiety, and depression were sufficiently reduced.

The reduction of the three participants' symptoms showed a close resemblance to the findings of a case study by Fisher et al. (2016). Fisher et al. reported a reduction in the participant's PTSD symptoms after receiving NFB. The participants in this study reported improvements in their PTSD similar to the findings of other researchers (Askovic et al., 2017;

Gapen et al., 2016; Kelson, 2013; Othmer & Othmer, 2009; Smith, 2008; van der Kolk et al., 2016).

Also, the participants' answers were consistent with the findings of Byrne et al. (2019) and Galatzer-Levy and Bryant (2013) that indicated PTSD is a highly heterogeneous condition diagnosed by numerous combinations of symptoms. Also, with Reiter et al. (2016) that found that NFB studies on PTSD identified specific patterns of altered brain function in individuals with PTSD. However, heterogeneity exists.

Participants reported variations in the reduction of the PTSD after NFB. For example, Sara had 52 NFB sessions. However, she had limited improvements to her PTSD symptoms. Sara's limited results could be attributed to standardized NFB protocols or to overtraining. Hammond (2010) found that optimal treatment outcomes require individualized protocols based on the client's QEEG. Additionally, Hammond and Kirk (2008) and Matthews (2008) emphasized the importance of avoiding NFB overtraining by close observation of training responses.

Van der Kolk's (2015) suggestion that "top-down processing" strengthens the capacity of the neocortex, while "bottom-up processing" regulates the autonomic nervous system, could explain Sara's limited results from NFB (p. 63). Accordingly, Sara may find more reduction in her PTSD utilizing combined top-down and bottom-up forms of treatment (van der Kolk, 2015). Sara may have had better NFB results had she been informed about NFB and understood her QEEGs and targeted goals of the protocol.

Participants reported improvements in their overall well-being that included improvements in concentration and attention. Improved attention and concentration following

NFB were found in studies conducted by McReynolds et al. (2017), Rastegar et al. (2016), and Smith (2008).

All three of the participants reported that after NFB therapy, they felt more able to calm themselves down, which is compatible with the results presented by Askovic et al. (2017). Askovic et al. (2017) found NFB to be an adjunct to trauma-informed therapy in reducing symptoms of hyperarousal and PTSD. Additionally, Kluetsch et al. (2014) found that alpha desynchronizing NFB was associated with decreased alpha amplitude during training, followed by a significant increase rebound in resting-state alpha synchronization. About the rebound, Kluetsch et al., 2014 stated it "was linked to increased calmness; greater salience network connectivity with the right insula; and enhanced default mode network connectivity with bilateral posterior cingulate, right middle frontal gyrus, and left medial prefrontal cortex" (p. 123). The findings of this study explained the potential neurobehavioral mechanisms mediating the effects of NFB therapy on the regulatory systems related to PTSD.

CHAPTER V

SUMMARY, IMPLICATIONS, AND RECOMMENDATIONS

This chapter presents a summary of the research findings related to the impact of neurofeedback (NFB) on women diagnosed with post-traumatic stress disorder (PTSD). Implications for clinical practice and counselor educators, and recommendations are also discussed.

Summary

This study was designed to fill several gaps in the literature. The first gap was that the majority of the research on the impact of NFB on PTSD focused on male veterans or both males and females despite established data indicating that gender affects the behavioral responses to trauma (Taylor, 2006). The release of endogenous oxytocin plays a sex-specific role in the stress response and coping strategies related to PTSD (Frijling, 2017; Koch et al., 2014; Matud, 2004). The second gap was a dearth of qualitative research designed to take an in-depth look at how NFB impacts women with PTSD. The third gap was a paucity of multiple case studies that illuminate how NFB impacts the recovery of women with PTSD by utilizing quantitative and qualitative data. This study was designed to bridge those gaps.

There were two reasons for choosing a multiple case study approach. First, a multiple case study that included both quantitative and qualitative would cover both processes and outcomes and reveal an in-depth understanding of how women experienced NFB. This method also illuminated how the participants experienced changes in their PTSD symptoms. Second, a multiple case study is generalizable to theory.

This multiple case study utilized both qualitative and quantitative data. Qualitative interviews revealed how women with PTSD experienced NFB and gleaned their perceptions of

how this method impacted their PTSD. The quantitative data complemented the qualitative data and consisted of pre- and post-test scores on the Quantitative electroencephalogram (QEEG), Davidson Trauma Scale (DTS) (Davidson et al., 1997), and Inventory of Altered Self-Capacities (IASC) (Briere & Runtz, 2002). Both the qualitative and quantitative data were used to seek answers to the following research questions:

1. How did women diagnosed with PTSD experience neurofeedback therapy?
2. How does utilizing neurofeedback therapy impact the recovery of women diagnosed with PTSD?

The participants in this study were English-speaking women at least 18-years-old who had been diagnosed with PTSD. Participants had completed their treatment and had received 20 or more NFB sessions at a university clinic. The participants also received QEEG, DTS, and IASC assessments before and after NFB.

This study utilized both holistic and embedded analyses to understand the differences and similarities between the cases. To code the interview data, the researcher used a structural question-based code, emotion coding, and values coding. During the analysis, the researcher utilized theoretical propositions and pattern matching techniques. The emergent themes included participants' perspectives on NFB, changes in how they saw themselves during and after NFB therapy, and their needs during NFB sessions. Themes also related to participants' observations of changes in their symptoms and overall well-being, and the skills that they acquired during and after NFB therapy.

Of the three participants, two achieved a significant reduction in their PTSD symptoms, such as flashbacks, nightmares, avoidance, sadness, and anxiety, as well as improvement in their concentration, sustained attention, and ability to calm themselves down. The third participant

reported being disappointed in the limited reduction in her depression and anxiety, but her concentration and sustained attention improved.

The researcher found that understanding the NFB process is an essential part of treatment. Participants shared that knowing about NFB would have likely helped them in acquiring the skills of self-regulation. NFB is based on the operant conditioning of physiological responses, and participants stated that knowing about this process would have been helpful. The researcher found that negative effects can occur from overtraining via standardized NFB protocols and noted that protocols should be set to address clients' specific needs and the results of their EEG patterns.

Implications

PTSD is a complex disorder that has comorbidity with other mental health issues, especially for women. Consistent with the literature reviewed in Chapter 2 of this dissertation, participants experienced a wide range of traumatic events that resulted in PTSD. The participants also had some variation in the severity of their symptoms. Prior to seeking NFB, several of the participants had sought other therapies including counseling and EMDR in different points in their recovery. An important implication of this study is to consider how prior therapies might prepare, or not, individuals for NFB. At least one participant credited EMDR for helping her find the courage to deal with her past trauma by seeking NFB.

The variations in participants' QEEGs were indicative of the range of individuals' experiences with PTSD. These variations have implications for NFB practitioners to apply NFB protocols appropriate to the client's symptoms and initial brain map, and to then modify protocols based on the client's feedback. Client feedback might include emotional or physical

changes. One participant, who had 52 sessions of NFB, with limited results, suggests the possibility of overtraining.

One implication of this study is that seeking client input on how they are responding to NFB is especially important when treating women with PTSD. Participant responses implied that adding a psychoeducation component prior to implementing NFB protocols would have helped them to understand the process. The participants in this study described some of the symptoms of their trauma-related PTSD as feelings of helplessness, poor communication, and as not understanding they had choices in their lives and relationships.

Discussing the results of clients' assessments and QEEGs creates an opportunity for increased communication and partnership with their NFB practitioner. A collaborative approach to setting goals and monitoring progress is consistent with empowering women who have experienced trauma via sexual assault or childhood abuse. Participants' experiences of NFB suggest that a trauma-informed approach to providing NFB to women seeking treatment for trauma-related PTSD is warranted.

Recommendations for NFB Practitioners, Educators, and Supervisors

The recommendations in this section are based on the emergent themes in this study. First, participants stated they needed information and clarification about NFB processes. Participants stated that understanding the NFB process would have likely helped them to effectively notice their cognitive and physical responses to NFB. For participants, understanding how to monitor their progress would have likely prepared them to better acquire self-regulation skills and to apply them in everyday life. Therefore, it is recommended that NFB practitioners take the time to explain NFB to their clients using language that makes understanding the process accessible to a wide variety of individuals.

Second, participants stated they needed feedback from their NFB providers about any observations they were making about the changes occurring in the sessions. Participants stated this feedback would have helped them to understand how they were progressing, or not. At least one participant shared she struggled to know what was expected of her during NFB and described it taking some time before she became aware she was in a productive flow during her initial sessions. Therefore, it is recommended that NFB practitioners provide feedback.

Feedback can be used with clients to (a) orient them as to their goals before each session, (b) provide a rationale for changes in protocols, and (c) debrief them during and at the end of the session. Based on participants' responses, it is recommended that clients provide feedback to their NFB practitioners as to any shifts in their symptoms between sessions.

Participants also expressed a need to be informed of the results of their QEEG assessments prior to staring NFB. The participants in this study were very interested in the results of their QEEGs taken before and after NFB. While many NFB practitioners in private practice do discuss their clients' QEEGs with them, it is recommended that all clients, regardless of setting, be provided with an explanation of their QEEGs before starting NFB protocols.

There are potential negative side effects when standardized NFB protocols are used, because they have been prescribed, or because the NFB practitioner has insufficient training. This is especially important while treating PTSD in women with trauma related to sexual assault or childhood abuse. For example, all three of the participants in this study received the same protocol (P4-T4). Ina and Cat observed significant improvements in their symptoms, while Sara observed improvement in her cognitive processes and thoughts and felt less sad and tearful. At the time of the interview, Sara continued to experience some anxiety and depression, as well as some agitation in her body. Of the three participants, Sara received the most neurofeedback

sessions, completing 52 sessions. Therefore, it is recommended that NFB providers and researchers (a) choose protocols that are individualized to address each client's unique QEEG brain map and symptoms, (b) monitor each client's responses during a session, and (c) change the protocol based on the client's responses to avoid overtraining or harming their clients. NFB educators and supervisors should closely monitor their supervisees' competencies such that they can assure NFB is provided with a high level of proficiency, and that no harm is done to clients.

Several participants shared that they used journaling during neurofeedback. Participants shared that getting their shifting thoughts and feelings on paper helped them to further process issues related to their unique experiences. It is recommended that NFB practitioners treating women for PTSD consider incorporating creative methods such as journaling to keep clients engaged in monitoring shifts in their thoughts and feelings between NFB sessions.

It is also recommended that NFB practitioners treating clients with trauma-related PTSD provide mechanisms they can use to calm themselves during and outside the session. Specifically, NFB practitioners could share mindfulness, grounding, and breathing techniques. Collectively, all of the recommendations in this section are consistent with providing a trauma-informed approach to the delivery of NFB. It recommended that NFB practitioners utilize the Adverse Childhood Experience (ACE) scale in their intakes with individuals seeking NFB for trauma or PTSD. Also, it is recommended that NFB educators and supervisors incorporate trauma-informed approaches into their trainings with students.

Recommendations for Further Research

To determine how women diagnosed with trauma-based PTSD experienced NFB, this mixed-method multiple case study utilized quantitative data and qualitative interviews. The quantitative data included participants' quantitative electroencephalogram (QEEG), and their

scores on Davidson Trauma Scale (DTS), and Inventory of altered self-capacities (IASC). The QEEG, DTS, and the IASC were done before and after NFB.

Although the DTS and IASC scores indicated a decrease in PTSD symptoms, some of the participants' responses in the qualitative interviews were incompatible with changes in assessment scores. In the interviews, participants often provided valuable context to some of the noted changes in their assessments after NFB. For example, the post-test for Sara's DTS showed a significant reduction in her PTSD symptoms; however, Sara shared in the interview that she still had anxiety and tension in her body. Overall, Sara was satisfied with changes in her thinking, but still complained of feeling the trauma in her body.

Regarding context, Cat's IASC scores related to the question "using sex as a way to stop feeling bad" could be understood as an indication that Cat stopped doing this behavior. Cat clarified her response to that question by explaining how she used to agree to have sex with her husband to avoid marital conflict because she believed her husband was in control, and she was a victim. After NFB, Cat realized that she had the ability to exercise choice in her sexual relationship with her husband. The qualitative interviews provided clarity and context to assessment questions. Without clarity and context, researchers are unlikely to accurately interpret the impact of NFB.

Therefore, it is recommended that NFB researchers continue to utilize mixed-method case study research to investigate the impact of NFB on women diagnosed with trauma-related PTSD. This type of research will help build an understanding of the factors that contribute to effective and ineffective NFB therapy. In order to identify the obstacles that prevent clients from receiving the maximum benefits of NFB, future research should be conducted on individuals who report that they did not experience sufficient changes in symptoms. Researchers should

avoid relying exclusively on assessment data in determining which clients benefitted from neurofeedback. Future researchers should utilize surveys or interviews with NFB clients to identify who is not satisfied with the results of NFB.

The participants in this study all started NFB after having experienced other forms of therapy including talk therapy, cognitive behavioral therapy, and EMDR. Therefore, it was not possible to determine the true effectiveness of NFB outside of the context of other forms of therapy. Future research should carefully present clients' prior treatments such that NFB practitioners and educators have a greater understanding of the impact of NFB as it relates to prior forms of therapy.

The limited improvement of Sara's symptoms indicates the need for investigations on combinations of top-down and bottom-up approaches to the treatment of trauma related PTSD. Combinations of top-down and bottom-up approaches to treating trauma could include integrating or alternating NFB with EMDR, biofeedback, somatic approaches, and trauma-sensitive yoga. Lastly, future research should examine participants' experiences of NFB that incorporate trauma-informed procedures, trauma psychoeducation, feedback, and discussions of assessments and changes in assessments during and after NFB.

REFERENCES

Abdallah, C. G., Wrocklage, K. M., Averill, C. L., Akiki, T., Schweinsburg, B., Roy, A., . . . Scott, J. C. (2017). Anterior hippocampal dysconnectivity in posttraumatic stress disorder: A dimensional and multimodal approach. *Translational Psychiatry*, *7*(2). https://doi.org/10.1038/tp.2017.12

Acheson, D. T., Gresack, J. E., & Risbrough, V. B. (2012). Hippocampal dysfunction effects on context memory: Possible etiology for posttraumatic stress disorder. *Neuropharmacology*, *62*(2), 674–685. https://doi-org.sdl.idm.oclc.org/10.1016/j.neuropharm.2011.04.029

Adu, P. (2019). *A step-by-step guide to qualitative data coding*. London: Routledge. https://doi.org/10.4324/9781351044516

Ahmed, K. S. (2011). Wheelchair movement control VIA human eye blinks. *American Journal of Biomedical Engineering*, *1*(1), 55-58. https://doi.org/10.5923/j.ajbe.20110101.09

Akiki, T. J., Averill, C. L., & Abdallah, C. G. (2017). A network-based neurobiological model of PTSD: Evidence from structural and functional neuroimaging studies. *Current Psychiatry Reports*, *19*(11). https://doi.org/10.1007/s11920-017-0840-4

Akiki, T. J., Averill, C. L., Averill, L. A., Wrocklage, K. M., Scott, J. C., Schweinsburg, B., . . . Abdallah, C. G. (2018). Default mode network abnormalities in posttraumatic stress disorder: A novel network-restricted topology approach. *Neuroimage*, *176*, 489-498. https://doi.org/10.1016/j.neuroimage.2018.05.005

Almutairi, A. F., Gardner, G. E., & McCarthy, A. (2014). Practical guidance for the use of a pattern-matching technique in case-study research: A case presentation. *Nursing & Health Sciences*, *16*(2), 239-244. https://doi.org/10.1111/nhs.12096

American Psychiatric Association. (1952). *Diagnostic and statistical manual of mental disorders* (1st ed.). Washington, D.C.: American Psychiatric Association.

American Psychiatric Association. (1968). *Diagnostic and statistical manual of mental disorders* (2nd ed.). Washington, D.C.: American Psychiatric Association.

American Psychiatric Association. (1980). *Diagnostic and statistical manual of mental disorders* (3rd ed.). Washington, D.C.: American Psychiatric Association.

American Psychiatric Association. (1987). *Diagnostic and statistical manual of mental disorders* (3rd ed., revised). Washington, D.C.: American Psychiatric Association.

American Psychiatric Association. (1994). *Diagnostic and statistical manual of mental disorders* (4th ed.). Washington, D.C.: American Psychiatric Association.

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). Washington, D.C.: American Psychiatric Association.

American Psychological Association. (2019). *Trauma*. Retrieved from https://www.apa.org/topics/trauma

Andrews, B., Brewin, C. R., & Rose, S. (2003). Gender, social support, and PTSD in victims of violent crime. *Journal of Traumatic Stress*, *16*(4), 421-427. https://doi.org/10.1023/A:1024478305142

Angelakis, E., Lubar, J. F., Frederick, J., & Stathopoulou, S. (2002). The role of slow-wave electroencephalographic activity in reading. *Journal of Neurotherapy*, *5*(3), 5-25. https://doi.org/10.1300/J184v05n03_03

Angelakis, E., Stathopoulou, S., Frymiare, J. L., Green, D. L., Lubar, J. F., & Kounios, J. (2007). EEG neurofeedback: A brief overview and an example of peak alpha frequency training for cognitive enhancement in the elderly. *The Clinical Neuropsychologist, 21*(1), 110-129. https://doi.org/10.1080/13854040600744839

Aranda, B. D. E., Ronquillo, N. M., & Calvillo, M. E. N. (2015). Neuropsychological and physiological outcomes pre- and post-EMDR therapy for a woman with PTSD: A case study. *Journal of EMDR Practice and Research, 9*(4), 174-187. https://doi.org/10.1891/1933-3196.9.4.174

Armenta, R. F., Rush, T., LeardMann, C. A., Millegan, J., Cooper, A., Hoge, C. W., Millennium Cohort Study team. (2018). Factors associated with persistent posttraumatic stress disorder among U.S. military service members and veterans. *BMC Psychiatry, 18*(1). https://doi.org/10.1186/s12888-018-1590-5

Arnold, L. E., & Jensen, P. S. (2018). What is the evidence for neurofeedback for ADHD? *Journal of the American Academy of Child & Adolescent Psychiatry, 57*(10), S281-S282. https://doi.org/10.1016/j.jaac.2018.07.663

Askovic, M., Watters, A. J., Aroche, J., & Harris, A. W. F. (2017). Neurofeedback as an adjunct therapy for treatment of chronic posttraumatic stress disorder related to refugee trauma and torture experiences: Two case studies. *Australasian Psychiatry, 25*(4), 358-363. https://doi.org/10.1177/1039856217715988

Aston-Jones, G., & Bloom, F. E. (1981). Activity of norepinephrine-containing locus coeruleus neurons in behaving rats anticipates fluctuations in the sleep-waking cycle. *Journal of Neuroscience, 1*(8), 876-886. https://doi.org/10.1523/JNEUROSCI.01-08-00876.1981

Aston-Jones, G., Ennis, M., Pieribone, V. A., Nickell, W. T., & Shipley, M. T. (1986). The brain nucleus locus coeruleus: Restricted afferent control of a broad efferent network. *Science, 234*(4777), 734-737. https://doi.org/10.1126/science.3775363

Baehr, E., & Baehr, R. (1997). The use of brainwave biofeedback as an adjunctive therapeutic treatment for depression: Three case studies. *Biofeedback, 25*(1), 10-11.

Bangasser, D. A., Eck, S. R., & Ordoñes Sanchez, E. (2019). Sex differences in stress reactivity in arousal and attention systems. *Neuropsychopharmacology: Official Publication of the American College of Neuropsychopharmacology, 44*(1), 129-139. https://doi.org/10.1038/s41386-018-0137-2

Barabasz, A. (2013). Evidence based abreactive ego state therapy for PTSD. *American Journal of Clinical Hypnosis, 56*(1), 54-65. https://doi.org/10.1080/00029157.2013.770384

Barriball, K. L., & While, A. (1994). Collecting data using a semi-structured interview: A discussion paper. *Journal of Advanced Nursing, 19*(2), 328-335. https://doi.org/10.1111/j.1365-2648.1994.tb01088.x

Beauchaine, T. P., Gatzke-Kopp, L., & Mead, H. K. (2006). Polyvagal Theory and developmental psychopathology: emotion dysregulation and conduct problems from preschool to adolescence. *Biological Psychology, 74*(2), 174–184. doi:10.1016/j.biopsycho.2005.08.008

Begić, D., Hotujac, L., & Jokić-Begić, N. (2001). Electroencephalographic comparison of veterans with combat-related post-traumatic stress disorder and healthy subjects. *International Journal of Psychophysiology, 40*(2), 167-172. https://doi.org/10.1016/S0167-8760(00)00153-7

Berg, S. H. (2002) The PTSD diagnosis: Is it good for women? *Affilia, 17*(1), 55-68. https://doi.org/10.1177/0886109902017001004

Betts, J. G., Desaix, P., Johnson, E., Johnson, J., Korol, O., Kruse, D., . . . Yong, K. A. (2013). *Anatomy & Physiology*. Rice University. Houston, Texas. Retrieved from https://openstax.org/details/books/anatomy-and-physiology

Binder, J. R., Desai, R. H., Graves, W. W., & Conant, L. L. (2009). Where is the semantic system? A critical review and meta-analysis of 120 functional neuroimaging studies. *Cerebral Cortex, 19*(12), 2767-2796. doi:10.1093/cercor/bhp055

Biswal, B. B. (2012). Resting state fMRI: A personal history. *Neuroimage, 62*(2), 938-944. https://doi.org/10.1016/j.neuroimage.2012.01.090

Blechert, J., Michael, T., Grossman, P., Lajtman, M. & Wilhelm, F. H. (2007). Autonomic and Respiratory Characteristics of Posttraumatic Stress Disorder and Panic Disorder. *Psychosomatic Medicine, 69*(9), 935-943. doi: 10.1097/PSY.0b013e31815a8f6b.

Bolea, A. S. (2010). Neurofeedback treatment of chronic inpatient schizophrenia. *Journal of Neurotherapy, 14*(1), 47-54. https://doi.org/10.1080/10874200903543971

Bonaz, B., Sinniger, V., & Pellissier, S. (2016). Anti-inflammatory properties of the vagus nerve: Potential therapeutic implications of vagus nerve stimulation. *The Journal of Physiology, 594*(20), 5781-5790. https://doi.org/10.1113/JP271539

Bonnet, L., Comte, A., Tatu, L., Millot, J. L., Moulin, T., & Medeiros de Bustos, E. (2015). The role of the amygdala in the perception of positive emotions: An "intensity detector." *Frontiers in Behavioral Neuroscience, 9*. https://doi.org/10.3389/fnbeh.2015.00178

Bourke, J. (2012). Sexual violence, bodily pain, and trauma: A history. *Theory, Culture & Society, 29*(3). https://doi.org/10.1177/0263276412439406

Boyd, J. E., Lanius, Ruth A., & McKinnon, Margaret C. (2018). Mindfulness-based treatments for posttraumatic stress disorder: A review of the treatment literature and neurobiological evidence. *Journal of Psychiatry & Neuroscience, 43*(1), 7-25. https://doi.org/10.1503/jpn.170021

Bradley, R., Greene, J., Russ, E., Dutra, L., & Westen, D. (2005). A multidimensional meta-analysis of psychotherapy for PTSD. *The American Journal of Psychiatry*, *162*(2), 214-227. https://doi.org/10.1176/appi.ajp.162.2.214

Breit, S., Kupferberg, A., Rogler, G., & Hasler, G. (2018). Vagus nerve as modulator of the brain-gut axis in psychiatric and inflammatory disorders. *Frontiers in Psychiatry, 9*. https://doi.org/10.3389/fpsyt.2018.00044

Bremner, J. (2002). *Does stress damage the brain?: Understanding trauma-related disorders from a mind-body perspective.* New York, NY: W.W. Norton & Company.

Bressler, S. L., & Menon, V. (2010). Large-scale brain networks in cognition: Emerging methods and principles. *Trends in Cognitive Sciences, 14*(6), 277-290. https://doi.org/10.1016/j.tics.2010.04.004

Briere, J., & Runtz, M. (2002). *The Inventory of Altered Self-Capacities (IASC) a standardized measure of identity, affect regulation, and relationship disturbance*. *Assessment*. Odessa, FL: Psychological Assessment Resources.

Brown, C. A., Cardoso, C., & Ellenbogen, M. A. (2016). A meta-analytic review of the correlation between peripheral oxytocin and cortisol concentrations. *Frontiers in Neuroendocrinology, 43*, 19-27. https://doi.org/10.1016/j.yfrne.2016.11.001

Byrne, S. P., Harpaz-Rotem, I., Tsai, J., Southwick, S. M., & Pietrzak, R. H. (2019). Latent typologies of *DSM-5* PTSD symptoms in U.S. military veterans. *Psychiatry Research, 273*, 266-273. https://doi.org/10.1016/j.psychres.2018.12.094

Campise, R. L., Geller, S. K., & Campise, M. E. (2006). Combat stress. In C. H. Kennedy & E. A. Zillmer (Eds.), *Military psychology: Clinical and operational applications* (pp. 215-240). New York, NY: The Guilford Press.

Cantor, D., & Ramsden, E. (2014). *Stress, shock, and adaptation in the twentieth century*. Rochester, NY: University of Rochester Press.

Carabotti, M., Scirocco, A., Maselli, M. A., & Severi, C. (2015). The gut-brain axis: Interactions between enteric microbiota, central and enteric nervous systems. *Annals of Gastroenterology: Quarterly Publication of the Hellenic Society of Gastroenterology*, *28*(2), 203. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/25830558

Carter, M. E., Yizhar, O., Chikahisa, S., Nguyen, H., Adamantidis, A., Nishino, S., . . . De Lecea, L. (2010). Tuning arousal with optogenetic modulation of locus coeruleus neurons. *Nature Neuroscience, 13*(12), 1526-1533. https://doi.org/10.1038/nn.2682

Chapin, T., & Russell-Chapin, L. (2014). *Neurotherapy and neurofeedback: Brain-based treatment for psychological and behavioral problems.* New York, NY: Routledge.

Chaudhuri, A., & Buck, R. (1995). An exploration of Triune Brain effects in advertising. *Advances in Consumer Research, Vol. 22* (pp. 133-138). Provo, UT

Chen, A. C., & Etkin, A. (2013). Hippocampal network connectivity and activation differentiates post-traumatic stress disorder from generalized anxiety disorder. *Neuropsychopharmacology: Official Publication of the American College of Neuropsychopharmacology*, *38*(10), 1889-1898. https://doi.org/10.1038/npp.2013.122

Chen, T., Cai, W., Ryali, S., Supekar, K., & Menon, V. (2016). Distinct global brain dynamics and spatiotemporal organization of the salience network. *PLoS Biology, 14*(6). https://doi.org/10.1371/journal.pbio.1002469

Chrousos, G. P., & Gold, P. W. (1992). The concepts of stress and stress system disorders: Overview of physical and behavioral homeostasis. *JAMA, 267*(9), 1244-1252. https://doi.org/10.1001/jama.1992.03480090092034

Cisler, J. M., Bush, K., James, G. A., Smitherman, S., & Kilts, C. D. (2015). Decoding the traumatic memory among women with PTSD: Implications for neurocircuitry models of PTSD and real-time fMRI neurofeedback. *PLoS ONE, 10*(8), 1-17. https://doi.org/10.1371/journal.pone.0134717

Collura, T. F. (2014). *Technical foundations of neurofeedback*. New York, NY: Routledge.

Corr, P. J. (2006). *Basic psychology: Understanding biological psychology.* Oxford, UK: Blackwell Publishing.

Cory, G. A., Jr. (2000). From Maclean's Triune Brain concept to the conflict systems neurobehavioral model: The subjective basis of moral and spiritual consciousness. *Zygon: Journal of Religion & Science, 35*(2).https://doi.org/10.1111/0591-2385.00283

Cousin, G. (2005). Case study research. *Journal of Geography in Higher Education, 29*(3), 421-427. https://doi.org/10.1080/03098260500290967

Cramer, H., Anheyer, D., Saha, F. J., & Dobos, G. (2018). Yoga for posttraumatic stress disorder- A systematic review and meta-analysis. *BMC Psychiatry, 18*(1). https://doi.org/10.1186/s12888-018-150-x

Creswell, J. W. (2013). *Qualitative inquiry and research design: Choosing among five approaches.* Thousand Oaks, California: SAGE Publications.

Creswell, J. W. (2014). *Research design: Qualitative, quantitative, and mixed methods approaches* (4th ed). Thousand Oaks, California: SAGE Publications.

Crocq, M. A., & Crocq, L. (2000) From shell shock and war neurosis to posttraumatic stress disorder: A history of psychotraumatology. *Dialogues in Clinical Neuroscience, 2*(1), 47-55.

Crotty, M. (2003). *The foundations of social research: Meaning and perspective in the research process* (2nd ed.). London, UK: Sage Publications.

Cunningham, M., & Murphy, P. (1981). The effects of bilateral EEG biofeedback on verbal, visuospatial and creative skills in LD male adolescents. *Journal of Learning Disabilities, 14*(4), 204-208. https://doi.org/10.1177/002221948101400406

Davidson, J. R. T., Book, S. W., Colket, J. T., Tupler, L. A., Roth, S., David, D., . . . Feldman, M.E. (1997). Assessment of a new self-rating scale for post-traumatic stress disorder. *Psychological Medicine, 27,* 153-160. https://doi.org/10.1017/s0033291796004229

Demos, J. N. (2005). *Getting started with neurofeedback*. New York, NY: W.W. Norton & Co.

Dias, A. M., & Van Deusen, A. (2011). A new neurofeedback protocol for depression. *The Spanish Journal of Psychology, 14*(1), 374-384. https://doi.org/10.5209/rev_SJOP.2011.v14.n1.34

Donadon, M. F., Martin-Santos, R., & Osório, F. L. (2018). The associations between oxytocin and trauma in humans: A systematic review. *Frontiers in Pharmacology, 9.* https://doi.org/10.3389/fphar.2018.00154

Donaldson, C. C. S., Sella, G. E., & Mueller, H. H. (1998). Fibromyalgia: A retrospective study of 252 consecutive referrals. *Canadian Journal of Clinical Medicine, 5*(6), 116-127.

Dunleavy, K., & Kubo Slowik, A. (2012). Emergence of delayed posttraumatic stress disorder symptoms related to sexual trauma: patient-centered and trauma-cognizant management by physical therapists. *Physical Therapy, 92*(2), 339-351. https://doi.org/10.2522/ptj.20100344

Eisenhardt, K. M., & Graebner, M. E. (2007). Theory building from cases: Opportunities and challenges. *Academy of Management Journal*, *50*(1), 25-32. https://doi.org/10.5465/amj.2007.24160888

Elman, C., Gerring, J., & Mahoney, J. (2016). Case study research: Putting the quant into the qual. *Sociological Methods & Research, 45*(3), 375-391. https://doi.org/10.1177/0049124116644273

Emerson, D., Sharma, R., Chaudhry, S., & Turner, J. (2009). Trauma-sensitive yoga: Principles, practice, and research. *International Journal of Yoga Therapy, 19*(1), 123-128. https://doi.org/10.17761/ijyt.19.1.h6476p8084l22160

Euston, D. R., Gruber, A. J., & McNaughton, B. L. (2012). The role of medial prefrontal cortex in memory and decision making. *Neuron*, *76*(6), 1057–1070. doi:10.1016/j.neuron.2012.12.002

Evans, J. R., & Abarbanel, A. (1999). *Introduction to quantitative EEG and neurofeedback*. San Diego, CA: Academic Press.

Fan, J., Zhong, M., Gan, J., Liu, W., Niu, C., Liao, H., . . . Zhu, X. (2017). Altered connectivity within and between the default mode, central executive, and salience networks in obsessive-compulsive disorder. *Journal of Affective Disorders, 223*, 106-114. https://doi.org/10.1016/j.jad.2017.07.041

Fattahi, S., Naderi, F., Asgari, P., & Ahadi, H. (2019). Neuro-feedback training for overweight women: Improvement of food craving and mental health. *Neuroquantology*, *15*(2), 232-238. https://doi.org/10.14704/nq.2017.15.2.1067

Fernandes, R. A., Fiquer, J. T., Gorenstein, C., Razza, L. B., Fraguas, R., Jr, Borrione, L., . . . Brunoni, A. R. (2017). Nonverbal behaviors are associated with increased vagal activity in major depressive disorder: Implications for the polyvagal theory. *Journal of Affective Disorders*, 209, 18–22. https://doi.org/10.1016/j.jad.2016.11.010

Figley, C. R. (1985) *Trauma and its wake: The study and treatment of post-traumatic stress disorder.* New York, NY: Brunner/Mazel.

Fisher, S. (2014). *Neurofeedback in the treatment of developmental trauma: Calming the fear-driven brain* (Kindle Edition). New York, NY: W. W. Norton & Company.

Fisher, S. F., Lanius, R. A., & Frewen, P. A. (2016). EEG neurofeedback as adjunct to psychotherapy for complex developmental trauma-related disorders: Case study and treatment rationale. *Traumatology*, *22*(4), 255-260. https://doi.org/10.1037/trm0000073

Foster, J. E. (2015). Women of a certain age: "Second wave" feminists reflect back on 50 years of struggle in the United States. *Women's Studies International Forum*, 50, 68–79. https://doi-org.sdl.idm.oclc.org/10.1016/j.wsif.2015.03.005

Fragedakis, T. M., & Toriello, P. (2014). The development and experience of combat-related PTSD: A demand for neurofeedback as an effective form of treatment. *Journal of Counseling & Development, 92*(4), 481-488. https://doi.org/10.1002/j.1556-6676.2014.00174.x

Frank, D. L., Khorshid, L., Kiffer, J. F., Moravec, C. S., & McKee, M. G. (2010). Biofeedback in medicine: Who, when, why and how? *Mental Health in Family Medicine, 7*(2), 85-91. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2939454/

Frewen, P., Kleindienst, N., Lanius, R., & Schmahl, C. (2014). Trauma-related altered states of consciousness in women with BPD with or without co-occurring PTSD. *European Journal of Psychotraumatology, 5*(1). https://doi.org/10.3402/ejpt.v5.24863

Frewen, P., Thornley, E., Rabellino, D., & Lanius, R. (2017). Neuroimaging the traumatized self: fMRI reveals altered response in cortical midline structures and occipital cortex during visual and verbal self- and other-referential processing in women with PTSD. *European Journal of Psychotraumatology, 8*(1). https://doi.org/10.1080/20008198.2017.1314164

Frey, L. (2016). Impact of sensorimotor rhythm neurofeedback on quality of life in patients with medically- refractory seizures. *Neuroregulation, 3*(1), 3-6. https://doi.org/10.15540/nr.3.1.3

Friedman, M. J. (2013). Finalizing PTSD in *DSM-5*: Getting here from there and where to go next. *Journal of Traumatic Stress, 26*(5), 548-556. https://doi.org/10.1002/jts.21840

Friedman, M. J., Resick, P. A., & Keane, T. M. (2014) *Handbook of PTSD, (2nd ed): Science and practice*. New York, NY: The Guilford Press.

Friel, P. N. (2007). EEG biofeedback in the treatment of attention deficit hyperactivity disorder. *Alternative Medicine Review: A Journal of Clinical Therapeutic, 12*(2), 146-151. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/17604459

Frijling, J. L. (2017). Preventing PTSD with oxytocin: Effects of oxytocin administration on fear neurocircuitry and PTSD symptom development in recently trauma-exposed individuals. *European Journal of Psychotraumatology, 8*(1). https://doi.org/10.1080/20008198.2017.1302652

Furness, J. B. (2016). Integrated neural and endocrine control of gastrointestinal function. In Stuart Brierley and Marcello Costa (Eds.), *Enteric Nervous System: 30 Years Later* (pp. 159-173). https://doi.org/10.1007/978-3-319-27592-5_16

Galatzer-Levy, I. R., & Bryant, R. A. (2013). 636,120 ways to have posttraumatic stress disorder. *Perspectives on Psychological Science: A Journal of the Association for Psychological Science*, *8*(6), 651-662. https://doi.org/10.1177/1745691613504115

Galovski, T. E., Blain, L. M., Mott, J. M., Elwood, L., & Houle, T. (2012). Manualized therapy for PTSD: Flexing the structure of cognitive processing therapy. *Journal of Consulting and Clinical Psychology*, *80*(6), 968-981. https://doi.org/10.1037/a0030600

Gapen, M., van der Kolk, B, Hamlin, E., Hirshberg, L., Suvak, M., & Spinazzola, J. (2016). A pilot study of neurofeedback for chronic PTSD. *Applied Psychophysiology and Biofeedback*, *41*(3), 251-261. https://doi.org/10.1007/s10484-015-9326-5

George, M. S., Sackeim, H. A., Rush, A. J., Marangell, L. B., Nahas, Z., Husain, M. M., . . . Ballenger, J. C. (2000). Vagus nerve stimulation: A new tool for brain research and therapy. *Biological Psychiatry, 47*(4), 287-295. https://doi.org/10.1016/S0006-3223(99)00308-X

Gerin, M. I., Fichtenholtz, H., Roy, A., Walsh, C. J., Krystal, J. H., Southwick, S., & Hampson, M. (2016). Real-time fMRI neurofeedback with war veterans with chronic PTSD: A feasibility study. *Frontiers in Psychiatry, 7.* https://doi.org/10.3389/fpsyt.2016.00111

Ghaziri, J., Tucholka, A., Larue, V., Blanchette-Sylvestre, M., Reyburn, G., Gilbert, G., . . . Beauregard, M. (2013). Neurofeedback training induces changes in white and gray matter. *Clinical EEG And Neuroscience*, *44*(4), 265-272. https://doi.org/10.1177/1550059413476031

Gibbs, G. R. (2007) Analyzing qualitative data. In U. Flick (Ed.) *The SAGE Qualitative Research Kit* (pp. 17-20). Thousand Oaks, CA.

Gilligan, C. (1982). *In a different voice*: Psychological theory and women's development. Cambridge, MA: Harvard University Press.

Goldberg, R. J., Greenwood, J. C., & Taintor, Z. (1976). Alpha conditioning as an adjunct treatment for drug dependence: Part I. *International Journal of Addiction, 11,* 1085-1089. https://doi.org/10.3109/10826087609058830

Goldberg, R. J., Greenwood, J. C., & Taintor, Z. (1977). Alpha conditioning as an adjunct treatment for drug dependence: Part II. *International Journal of Addiction, 12,* 195-204. https://doi.org/10.3109/10826087709027219

Goldstein, A., Hofstra, R., & Burns, A. (2013). Building a brain in the gut: Development of the enteric nervous system. *Clinical Genetics*, *83*(4), 307-316. https://doi.org/10.1111/cge.12054

Greicius, M. D., Supekar, K., Menon, V., & Dougherty, R. F. (2009). Resting-state functional connectivity reflects structural connectivity in the default mode network. *Cerebral Cortex, 19*(1), 72-78. https://doi.org/10.1093/cercor/bhn059

Grupe, D., Wielgosz, J., Nitschke, J., & Davidson, R. (2017). Respiratory sinus arrhythmia and ventromedial prefrontal function in veterans with posttraumatic stress symptoms. *Biological Psychiatry, 81*(10). https://doi.org/10.1016/j.biopsych.2017.02.026

Gruzelier, J., Hardman, E., Wild, J., Zaman, R., Nagy, A., & Hirsch, S. (1999). Learned control of interhemispheric slow potential negativity in schizophrenia. *International Journal of Psychophysiology, 34*(3), 341–348.

Guilaran, J., de Terte, I., Kaniasty, K., & Stephens, C. (2018). Psychological outcomes in disaster responders: A systematic review and meta-analysis on the effect of social support. *International Journal of Disaster Risk Science, 9*(3), 344-358. https://doi.org/10.1007/s13753-018-0184-7

Hammond, C. & Kirk, L. (2008). First, do no harm: Adverse effects and the need for practice standards in neurofeedback. *Journal of Neurotherapy, 12*(1), 79-88. https://doi.org/10.1080/10874200802219947

Hammond, D. C. (2001). Treatment of chronic fatigue with neurofeedback and self-hypnosis. *NeuroRehabilitation, 16*(4), 295-300. https://doi.org/10.3233/NRE-2001-16415

Hammond, D. C. (2005). Neurofeedback with anxiety and affective disorders. *Child and Adolescent Psychiatric Clinics of North America, 14*(1), 105-123. https://doi.org/10.1016/j.chc.2004.07.008

Hammond, D. C. (2010). The need for individualization in neurofeedback: Heterogeneity in QEEG patterns associated with diagnoses and symptoms. *Applied Psychophysiology and Biofeedback, 35*(1), 31-36. https://doi.org/10.1007/s10484-009-9106-1

Hammond, D. C. (2011). What is neurofeedback: An update. *Journal of Neurotherapy 15*(4), 305-336. https://doi.org/10.1080/10874208.2011.623090

Harris, S. (2017). *An investigation of the effects of neurofeedback training on attention deficit-hyperactivity disorder (ADHD) symptoms, depression, anxiety, and academic self-efficacy in college students*. (Doctoral dissertation.) Retrieved from Electronic Theses and Dissertations. (Accession Order No. 5378) https://stars.library.ucf.edu/etd/5378

Harrison, H., Birks, M., Franklin, R., & Mills, J. (2017). Case study research: Foundations and methodological orientations. *Forum: Qualitative Social Research, 18*(1). Retrieved from http://www.qualitative-research.net/index.php/fqs/article/view/2655/4079

Hasselmo, M. E., Linster, C., Patil, M., Ma, D., & Cekic, M. (1997). Noradrenergic suppression of synaptic transmission may influence cortical signal-to-noise ratio. *Journal of Neurophysiology, 77*(6), 3326-3339. https://doi.org/10.1152/jn.1997.77.6.3326

Hasto, J., & Vojtová, H. (2013). Posttraumatic stress disorder: Bio-psycho-social aspects, eye movement desensitization and reprocessing and autogenic training in persistent stress: Case study, part 1. *European Journal of Mental Health, 8*(1), 81-101. https://doi.org/10.5708/EJMH.8.2013.1.5

Hautzinger, S. J., & Scandlyn, J. (2014). *Beyond post-traumatic stress: Homefront struggles with the wars on terror*. Walnut Creek, CA: Routledge. Retrieved from http://sdl.edu.sa/middleware/Default.aspx?USESDL=true&PublisherID=AllPublishers&BookURL=https://sdl.idm.oclc.org/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=asn&AN=113444906&site=eds-live

Hayner, C. B. (2005). *The design of a treatment program for women alcoholics utilizing neurofeedback.* (Doctoral dissertation.) Retrieved from ProQuest Dissertations and Theses Global. (Accession Order No. 3150896) https://search-proquest-com.sdl.idm.oclc.org/docview/305349794?accountid=142908

Hebb, D. O. (1949). *The Organization of Behavior*. Hoboken, NJ: John Wiley & Sons.

Heim, C., & Nemeroff, C. B. (2009). Neurobiology of posttraumatic stress disorder. *CNS Spectrums, 14* (Suppl 1), 13-24. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/19169190

Heimer, L., Van Hoesen, G. W., Trimble, M., & Zahn, D. S. (2008). The limbic system: A concept in perpetual search for a definition. In L. Heimer, G. W. Van Hoesen, M. Trimble, & D. S. Zahm (Eds.), *Anatomy of neuropsychiatry: The new anatomy of the basal forebrain and its implications for neuropsychiatric illness* (pp. 1-13). Amsterdam, The Netherlands: Academic Press.

Helfand, D. (2015). *Clients' experiences and the therapeutic relationship during neurofeedback training*. (Doctoral dissertation.) Retrieved from ProQuest Dissertations and Theses Global. (Accession Order No. 3711615) https://search-proquest-com.sdl.idm.oclc.org/docview/1707929254?accountid=142908

Henigsberg, N., Kalember, P., Petrović, Z. K., & Šečić, A. (2019). Neuroimaging research in posttraumatic stress disorder – Focus on amygdala, hippocampus and prefrontal cortex. *Progress in Neuropsychopharmacology & Biological Psychiatry*, *90*, 37-42. https://doi.org/10.1016/j.pnpbp.2018.11.003

Herman, J. (1981). Father-daughter incest. *Professional Psychology*, *12*(1), 76-80. https://doi.org/10.1037/0735-7028.12.1.76

Herman, J. (1992). *Trauma and recovery*. New York, NY: BasicBooks.

Herman, J. L. (1992a). Complex PTSD: A syndrome in survivors of prolonged and repeated trauma. *Journal of Traumatic Stress*, *5*(3), 377-391. https://doi.org/10.1002/jts.2490050305

Hinton, D. E., & Good, B. J. (2015) *Culture and PTSD: Trauma in global and historical perspective*. Philadelphia, PA: University of Pennsylvania Press, Inc.

Hinton, D. E., Hofmann, S. G., Rivera, E., Otto, M. W., & Pollack, M. H. (2011). Culturally adapted CBT (CA-CBT) for Latino women with treatment-resistant PTSD: A pilot study comparing CA-CBT to applied muscle relaxation. *Behaviour Research and Therapy, 49*(4), 275-280. https://doi.org/10.1016/j.brat.2011.01.005

Hovsepian, D. A., Galati, A., Chong, R. A., Mazumder, R., DeGiorgio, C. M., Mishra, S., & Yim, C. (2019). MELAS: Monitoring treatment with magnetic resonance spectroscopy. *Acta Neurologica Scandinavica, 139*(1), 82-85. https://doi.org/10.1111/ane.13027

Huang-Storms, L., Bodenhamer-Davis, E., Davis, R., & Dunn, J. (2007). QEEG-guided neurofeedback for children with histories of abuse and neglect: Neurodevelopmental rationale and pilot study. *Journal of Neurotherapy, 10*(4), 3-16. https://doi.org/10.1300/J184v10n04_02

Hunnicutt-Ferguson, K., Wyka, K. E., Peskin, M., Cukor, J., Olden, M., & Difede, J. (2018). Posttraumatic stress disorder, functional impairment, and subjective distress in World Trade Center disaster workers. *Journal of Traumatic Stress, 31*(2), 234-243. https://doi.org/10.1002/jts.22268

Husky, M. M., Mazure, C. M., & Kovess-Masfety, V. (2018). Gender differences in psychiatric and medical comorbidity with post-traumatic stress disorder. *Comprehensive Psychiatry, 84*, 75-81. https://doi.org/10.1016/j.comppsych.2018.04.007

International Society for Neurofeedback and Research [ISNR] Board of Directors. (2010, June 11). Neurofeedback Overview. Retrieved from https://isnr.org/neurofeedback-introduction

Irish, L. A., Fischer, B., Fallon, W., Spoonster, E., Sledjeski, E. M., & Delahanty, D. L. (2010). Gender differences in PTSD symptoms: An exploration of peritraumatic mechanisms. *Journal of Anxiety Disorders, 25*(2), 209-216. https://doi.org/10.1016/j.janxdis.2010.09.004

Jiang, Y., Duan, M., Chen, X., Chang, X., He, H., Li, Y., . . . Yao, D. (2017). Common and distinct dysfunctional patterns contribute to triple network model in schizophrenia and depression: A preliminary study. *Progress in Neuropsychopharmacology & Biological Psychiatry, 79* (Pt. B), 302-310. https://doi.org/10.1016/j.pnpbp.2017.07.007

Jokić-begić, N., & Begić, D. E. (2003). Quantitative electroencephalogram (qEEG) in combat veterans with post-traumatic stress disorder (PTSD). *Nordic Journal of Psychiatry, 57*(5), 351-355. https://doi.org/10.1080/08039480310002688

Jones, M., & Hitsman, H. (2018). QEEG guided neurofeedback treatment for anxiety symptoms. *Neuroregulation, 5*(3), 85-92. https://doi.org/10.15540/nr.5.3.85

Jones, E., & Wessely, S. (2005). *Shell shock to PTSD: Military psychiatry from 1900 to the Gulf War*. Hove, UK: Psychology Press.

Kalat, J. W. (2014) *Biological psychology* (12th ed.) South Melbourne, Australia: CENGAGE.

Kanda, P., Anghinah, R., Smidth, M. T., & Silva, J. M. (2009). The clinical use of quantitative EEG in cognitive disorders. *Dementia & Neuropsychologia*, *3*(3), 195-203. https://doi.org/10.1590/S1980-57642009DN30300004

Kelson, C. Y. (2013). *The impact of EEG biofeedback on veterans' symptoms of posttraumatic stress disorder (PTSD).* (Doctoral dissertation.) Retrieved from ProQuest Dissertations and Theses Global. (Accession Order No. 3603174) https://search.proquest.com/docview/1492137060?pq-origsite=gscholar

Kemp, A. H., Brunoni, A. R., Santos, I. S., Nunes, M. A., Dantas, E. M., Carvalho de Figueiredo, R., . . . & Thayer, J. F. (2014). Effects of depression, anxiety, comorbidity, and antidepressants on resting-state heart rate and its variability: An ELSA-Brasil cohort baseline study. *American Journal of Psychiatry*, *171*(12), 1328-1334. https://doi.org/10.1176/appi.ajp.2014.13121605

Kessler, R. C., Aguilar-Gaxiola, S., Alonso, J., Benjet, C., Bromet, E. J., Cardoso, G., . . . Florescu, S. (2017). Trauma and PTSD in the WHO world mental health surveys. *European Journal of Psychotraumatology*, *8*. https://doi.org/10.1080/20008198.2017.1353383

Kessler, R. C., Sonnega, A., Bromet, E., Hughes, M., & Nelson, C. B. (1995) Posttraumatic stress disorder in the national comorbidity survey. *Archives of General Psychiatry, 52*(12), 1048-1060. https://doi.org/10.1001/archpsyc.1995.03950240066012

Kimerling, R., Allen, M. C., & Duncan, L. E. (2018). Chromosomes to social contexts: Sex and gender differences in PTSD. *Current Psychiatry Reports, 20*(12), 1-9. https://doi.org/10.1007/s11920-018-0981-0

Kline, A. C., Cooper, A. A., Rytwinksi, N. K., & Feeny, N. C. (2018). Long-term efficacy of psychotherapy for posttraumatic stress disorder: A meta-analysis of randomized controlled trials. *Clinical Psychology Review, 59,* 30-40. https://doi.org/10.1016/j.cpr.2017.10.009

Kluetsch, R. C., Ros, T., Théberge, J., Frewen, P. A., Calhoun, V. D., Schmahl, C., . . . Lanius, R. A. (2014). Plastic modulation of PTSD resting-state networks and subjective wellbeing by EEG neurofeedback. *Acta Psychiatrica Scandinavica, 130*(2), 123-136. https://doi.org/10.1111/acps.12229

Kobayashi, I., Sledjeski, E. M., & Delahanty, D. L. (2018). Gender and age interact to predict the development of posttraumatic stress disorder symptoms following a motor vehicle accident. *Psychological Trauma: Theory, Research, Practice, And Policy, 11*(3), 328-336. https://doi.org/10.1037/tra0000366

Kobayashi, Y. (2011). Cingulate gyrus: Cortical architecture and connections. *Brain and Nerve, 63*(5), 473-82. https://doi.org/10.11477/mf.1416100906

Koch, S. B. J., van Zuiden, M., Nawijn, L., Frijling, J. L., Veltman, D. J., & Olff, M. (2014). Intranasal oxytocin as strategy for medication-enhanced psychotherapy of PTSD: Salience processing and fear inhibition processes. *Psychoneuroendocrinology*, *40*, 242-256. https://doi.org/10.1016/j.psyneuen.2013.11.018

Kolaitis. G., & Olff. M. (2017) Psychotraumatology in Greece, *European Journal of Psychotraumatology*, *8*(4), 135-175, Retrieved from http://sdl.edu.sa/middleware/Default.aspx ?USESDL=true&PublisherID=AllPublishers&BookURL=https://sdl.idm.oclc.org/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=asn&AN=124365924&site=eds-live

Kwan, P. (2006). The application of hypnosis in the treatment of a woman with complex trauma. *Australian Journal of Clinical and Experimental Hypnosis, 34*(2), 204-215.

Lake, J. 2015. The integrative management of PTSD: A review of conventional and CAM approaches used to prevent and treat PTSD with emphasis on military personnel. *Advances in Integrative Medicine, 2*(1), 13-23. https://doi.org/10.1016/j.aimed.2014.10.002

Lanius, R. A., Frewen, P. A., Tursich, M., Jetly, R., & McKinnon, M. C. (2015). Restoring large-scale brain networks in PTSD and related disorders: A proposal for neuroscientifically-informed treatment interventions. *European Journal of Psychotraumatology, 6*(1), 1-12. https://doi.org/10.3402/ejpt.v6.27313

Lanius, U., Lanius, R. A., Bluhm, R., & Pain, C. (2006). A review of neuroimaging studies in PTSD: Heterogeneity of response to symptom provocation. *Journal of Psychiatric* Research, *40*(8), 709-729. doi:10.1016/j.jpsychires.2005.07.007

Larsen, S., & Sherlin, L. (2013). Neurofeedback: An emerging technology for treating central nervous system dysregulation. *The Psychiatric Clinics of North America, 36*(1), 163-168. https://doi.org/10.1016/j.psc.2013.01.005

Linden, M., Habib, T., & Radojevic, V. (1996). A controlled study of the effects of EEG biofeedback on cognition and behavior of children with attention deficit disorder and learning disabilities. *Biofeedback & Self-Regulation, 21*(1), 35-49. https://doi.org/10.1007/bf02214148

Linden, D. E., & Turner, D. L. (2016). Real-time functional magnetic resonance imaging neurofeedback in motor neurorehabilitation. *Current opinion in neurology, 29*(4), 412. Retrieved from http://sdl.edu.sa/middleware/Default.aspx?USESDL=true&PublisherID=AllPublishers&BookURL=https://sdl.idm.oclc.org/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=edswsc&AN=000379207400003&site=eds-live

Liu, Y., Li, L., Li, B.,Feng, N., Li, L., Zhang, X., . . . Yin, H. (2017). Decreased triple network connectivity in patients with recent onset post-traumatic stress disorder after a single prolonged trauma exposure. *Scientific Reports, 7*(1). https://doi.org/10.1038/s41598-017-12964-6

Longo, R. (2018). *A consumer's guide to understanding QEEG brain mapping and neurofeedback training*. Bloomington, IN: iUniverse.

Lope-Piedrafita, S. (2018). Diffusion tensor imaging (DTI). In M. L. García Martín & P. López Larrubia (Eds.), *Preclinical MRI* (pp. 103-116). Methods in Molecular Biology, vol 1718. https://doi.org/10.1007/978-1-4939-7531-0_7

Lubar, J. F., & Shouse, M. N. (1977). Use of biofeedback in the treatment of seizure disorders and hyperactivity. In B. B. Lahey & A. E. Kazdin (Eds.), *Advances in Clinical Child Psychology* (pp. 204-251). Boston, MA: Springer. https://doi.org/10.1007/978-1-4613-9799-1_6

Luo, X., Chen, G., Jia, Y., Gong, J., Qiu, S., Zhong, S., . . . Wang, Y. (2018). Disrupted cerebellar connectivity with the central executive network and the default-mode network in unmedicated bipolar II disorder. *Frontiers in Psychiatry, 9*. https://doi.org/10.3389/fpsyt.2018.00705

MacLean, P. D. (1990). *The Triune Brain in evolution: Role in paleocerebral functions*. New York, NY: Plenum Publishing Corp.

Maddox, S. A., Kilaru, V., Shin, J., Jovanovic, T., Almli, L. M., Dias, B. G., . . . Smith, A. K. (2018). Estrogen-dependent association of HDAC4 with fear in female mice and women with PTSD. *Molecular Psychiatry, 23*(3), 658-665. https://doi.org/10.1038/mp.2016.250

Marzbani, H., Marateb, H. R., & Mansourian, M. (2016). Neurofeedback: A comprehensive review on system design, methodology and clinical applications. *Basic and Clinical Neuroscience, 7*(2), 143-158. https://doi.org/10.15412/J.BCN.03070208

Matthews, T. (2008). Neurofeedback overtraining and the vulnerable patient. *Journal of Neurotherapy, 11*(3), 63-66. https://doi.org/10.1080/10874200802126290

Matud, M. P. (2004). Gender differences in stress and coping styles. *Personality and Individual Differences, 37*(7), 1401–1415. https://doi.org/10.1016/j.paid.2004.01.010

McLean, C. P., & Foa, E. B. (2014). The use of prolonged exposure therapy to help patients with post-traumatic stress disorder. *Clinical Practice, 11*(2), 233-241. https://doi.org/10.2217/cpr.13.96

McReynolds, C., Bell, J., & Lincourt, T. (2017). Neurofeedback: A noninvasive treatment for symptoms of posttraumatic stress disorder in veterans. *Neuroregulation, 4*(3-4), 114-124. https://doi.org/10.15540/nr.4.3-4.114

Meier, M. (2012). *LORETA neurofeedback and spatial cognition in healthy participants* (Doctoral dissertation.) Retrieved from ProQuest Dissertations and Theses Global. (Accession Order No. 1531565) https://search.proquest.com/openview/a217dea 298e1e1b65ecbb2cb01855f24/1?pq- origsite=gscholar&cbl=18750&diss=y

Menon, V. (2011). Large-scale brain networks and psychopathology: A unifying triple network model. *Trends in Cognitive Sciences, 15*(10), 483-506. https://doi.org/10.1016/j.tics.2011.08.003

Menon, V. (2018). The triple network model, insight, and large-scale brain organization in autism. *Biological Psychiatry, 84*(4), 236-238. https://doi.org/10.1016/j.biopsych.2018.06.012

Menon, V., & Uddin, L. Q. (2010). Saliency, switching, attention and control: A network model of insula function. *Brain Structure & Function, 214*(5-6), 655-667. https://doi.org/10.1007/s00429-010-0262-0

Mickleborough, M. J. S., Daniels, J. K., Coupland, N. J., Kao, R., Williamson, P. C., Lanius, U. F., . . . Lanius, Ruth A. (2011). Effects of trauma-related cues on pain processing in posttraumatic stress disorder: An fMRI investigation. *Journal of Psychiatry & Neuroscience, 36*(1), 6-14. https://doi.org/10.1503/jpn.080188

Miller, J. B. (1973). *Psychoanalysis and women: Contributions to new theory and therapy*. Brunner/Mazel.

Miller, J. B. (1976). *Toward a new psychology of women*. Boston, MA: Beacon Press.

Mills, Z. L. (2012). *Neurofeedback experiences of clients with hyperarousal symptoms associated with PTSD.* (Doctoral dissertation.) Retrieved from ProQuest Dissertations and Theses. (Accession Order No. 3544522) https://search.proquest.com/docview/1225888554?accountid=142908

Monjezi, S. (2005). *A qualitative study of diabetic peoples' experience of neurofeedback training and its effect on their quality of life*. (Doctoral dissertation.) Retrieved from Proquest Dissertations and Theses. (Accession Order No. 3175014) http://search.ebscohost.com/login.aspx?direct=true&db=cat03837a&AN=SMU.b1420395&site=eds-live&scope=site

Monson, C. M., Fredman, S. J., Macdonald, A., Pukay-Martin, N. D., Resick, P. A., & Schnurr, P. P. (2012). Effect of cognitive-behavioral couple therapy for PTSD: A randomized controlled trial. *JAMA, 308*(7), 700-709. https://doi.org/10.1001/jama.2012.9307

Mørkved, N., Hartmann, K., Aarsheim, L. M., Holen, D., Milde, A. M., Bomyea, J., & Thorp, S. R. (2014). A comparison of narrative exposure therapy and prolonged exposure therapy for PTSD. *Clinical Psychology Review, 34*(6), 453-467. https://doi.org/10.1016/j.cpr.2014.06.005

Morris, D. J. (2015) *The evil hours: A biography of post-traumatic stress disorder*. Boston, MA: Houghton Mifflin.

Moss, D. (2009). Advances in the use of biofeedback and neurofeedback-back with post traumatic stress disorder, part II. *Biofeedback, 37*(1),1-2. https://doi.org/10.5298/1081-5937-37.2.41

Naegeli, C., Zeffiro, T., Piccirelli, M., Jaillard, A., Weilenmann, A., Hassanpour, K., . . . Mueller-Pfeiffer, C. (2018). Locus coeruleus activity mediates hyperresponsiveness in posttraumatic stress disorder. *Biological Psychiatry, 83*(3), 254-262. https://doi.org/10.1016/j.biopsych.2017.08.021

Namey, E., Guest, G., Thairu, L., & Johnson, L. (2008). Data reduction techniques for large qualitative data sets. In G. Guest & K. M. MacQueen (Eds.), *Handbook for team-based qualitative research* (pp. 119-136). Lanham, MD: Rowman Altamira.

Nijenhuis, E. R. S., & van der Hart, O. (1999). Forgetting and reexperiencing trauma: From anesthesia to pain. In J. Goodwin & R. Attias (Eds.), *Splintered reflections: Images of the body in trauma* (pp. 39–65). Basic Books. National Institute of Clinical Excellence (NICE). (2005). *Posttraumatic stress disorder: The management of PTSD in adults and children in primary and secondary care*. Leicester, UK: Gaskell. Retrieved from http://www.nice.org.uk/guidance/CG26/chapter/1-guidance.

Nelson, D., & Esty, M. (2012). Neurotherapy of traumatic brain injury/post-traumatic stress symptoms in oef/oif veterans. *The Journal of Neuropsychiatry and Clinical Neurosciences, 24*(2), 237-240. https://doi.org/10.1176/appi.neuropsych.11020041

Nicholson, A. A., Friston, K. J., Zeidman, P., Harricharan, S., McKinnon, M. C., Densmore, M., . . . Lanius, R. A. (2017). Dynamic causal modeling in PTSD and its dissociative subtype: Bottom-up versus top-down processing within fear and emotion regulation circuitry. *Human Brain Mapping*, *38*(11), 5551-5561. https://doi.org/10.1002/hbm.23748

Nicolson, N. A., Davis, M. C., Kruszewski, D., & Zautra, A. J. (2010). Childhood maltreatment and diurnal cortisol patterns in women with chronic pain. *Psychosomatic Medicine*, *72*(5), 471-480. https://doi.org/10.1097/PSY.0b013e3181d9a104

Nillni, Y. I., Pineles, S. L., Patton, S. C., Rouse, M. H., Sawyer, A. T., & Rasmusson, A. M. (2015). Menstrual cycle effects on psychological symptoms in women with PTSD. *Journal of Traumatic Stress*, *28*(1), 1-7. https://doi.org/10.1002/jts.21984

Nolan, C. R. (2016). Bending without breaking: A narrative review of trauma-sensitive yoga for women with PTSD. *Complementary Therapies in Clinical Practice*, *24*, 32-40. https://doi.org/10.1016/j.ctcp.2016.05.006

Norsigian, J. (2019). Our Bodies Ourselves and the women's health movement in the United States: Some reflections. *American Journal of Public Health*, *109*(6), 844-846. https://doi.org/10.2105/AJPH.2019.305059

Northoff, G., Heinzel, A., de Greck, M., Bermpohl, F., Dobrowolny, H., & Panksepp, J. (2006). Self-referential processing in our brain—A meta-analysis of imaging studies on the self. *Neuroimage*, *31*(1), 440-457. https://doi.org/10.1016/j.neuroimage.2005.12.002

Nowlis, D. P., & Kamiya, J. (1970). The control of electroencephalographic alpha rhythms through auditory feedback and the associated mental activity. *Psychophysiology*, *6*(4), 476-484. https://doi.org/10.1111/j.1469-8986.1970.tb01756.x

O'Donnell, A. W., Neumann, D. L., Duffy, A. L., & Paolini, S. (2019). Learning to fear outgroups: An associative learning explanation for the development and reduction of intergroup anxiety. *Social and Personality Psychology Compass, 13*(3). https://doi.org/10.1111/spc3.12442

Ogden, P., Pain, C., & Fisher, J. (2006). A sensorimotor approach to the treatment of trauma and dissociation. *Psychiatric Clinics of North America, 29*(1), 263-279. https://doi.org/10.1016/j.psc.2005.10.012

Olff, M. (2017). Sex and gender differences in post-traumatic stress disorder: An update. *European Journal of Psychotraumatology, 8*. https://doi.org/10.1080/20008198.2017.1351204

Orndorff-Plunkett, F., Singh, F., Aragón, O. R., & Pineda, J. A. (2017). Assessing the effectiveness of neurofeedback training in the context of clinical and social neuroscience. *Brain Sciences, 7*(8). https://doi.org/10.3390/brainsci7080095

Othmer, S. F., & Othmer, S. (2007). Interhemispheric EEG training; Clinical experience and conceptual models. In J. R. Evans (Ed.)., *Handbook of neurofeedback: Dynamics and clinical applications* (pp. 109-136). Boca Raton, FL: CRC Press.

Othmer, S., & Othmer, S. (2009). Post-traumatic stress disorder-The neurofeedback remedy. *Biofeedback, 37*(1), 24-31. https://doi.org/10.5298/1081-5937-37.1.24

Oxford English Dictionary (2nd ed.). (1989). Oxford, UK: Oxford University Press.

Pagotto, L. F., Mendlowicz, M. V., Coutinho, E. S. F., Figueira, I., Luz, M. P., Araujo, A. X., & Berger, W. (2015). The impact of posttraumatic symptoms and comorbid mental disorders on the health-related quality of life in treatment-seeking PTSD patients. *Comprehensive Psychiatry, 58,* 68-73. https://doi.org/10.1016/j.comppsych.2015.01.002

Pai, A., Suris, A. M., & North, C. S. (2017). Posttraumatic stress disorder in the *DSM-5*: Controversy, change, and conceptual considerations. *Behavioral Sciences, 7*(1). https://doi.org/10.3390/bs7010007

Panisch, L. S., & Hai, A. H. (2018). The effectiveness of using neurofeedback in the treatment of post-traumatic stress disorder: A systematic review. *Trauma, Violence, & Abuse, 1*(1524838018781103). https://doi.org/10.1177/1524838018781103

Parvizi, J., & Damasio, A. (2001). Consciousness and the brainstem. *Cognition, 79*(1), 135-160. https://doi.org/10.1016/S0010-0277(00)00127-X

Pascual-Leone, A., Amedi, A., Fregni, F., & Merabet, L. B. (2005). The plastic human brain cortex. *Annual Review of Neuroscience, 28*(1), 377-401. https://doi.org/10.1146/annurev.neuro.27.070203.144216

Passingham, R. E., Stephan, K. E., & Kötter, R. (2002). The anatomical basis of functional localization in the cortex. *Nature Reviews Neuroscience, 3*(8), 606-616. https://doi.org/10.1038/nrn893

Peniston, E. G., & Kulkosky, P. J. (1991). Alpha-theta brainwave neurofeedback for Vietnam veterans with combat-related post-traumatic stress disorder. *Medical Psychotherapy, 4*, 47-60.

Penn, B. P., & Penn, N. E. (1976). The women's movement: Historical perspectives and current trends. *Psychiatric Annals, 6*(2), 12-21.

Peper, E., & Shaffer, F. (2010). Biofeedback History: An Alternative View. *Biofeedback*, *38*(4), 142–147. Retrieved from https://www.aapb-biofeedback.com/doi/abs/10.5298/1081-5937.46.4.80

Pietrzak, R. H., Southwick, S. M., Tsai, J., El-Gabalawy, R., Sareen, J., & Neumeister, A. (2014). Typologies of posttraumatic stress disorder in the U.S. adult population. *Journal of Affective Disorders*, *162*, 102–106. https://doi.org/10.1016/j.jad.2014.03.024

Pinel, P. J. (2011). *Biopsychology*. Boston, MA: Pearson Education Inc.

Pinel, P. J. & Edwards, M. (2008). *A colorful introduction to the anatomy of the human brain: A brain and psychology coloring book.* Boston, MA: Pearson.

Ploog, D. W. (2003). The place of the Triune Brain in psychiatry. *Physiology & Behavior, 79*(3), 487-493. https://doi.org/10.1016/s0031-9384(03)00154-9

Porges, S. W. (1995). Orienting in a defensive world: Mammalian modifications of our evolutionary heritage: A polyvagal theory. *Psychophysiology, 32*(4), 301-318. https://doi.org/10.1111/j.1469-8986.1995.tb01213.x

Porges, S. W. (2001). The polyvagal theory: Phylogenetic substrates of a social nervous system. *International Journal of Psychophysiology, 42*(2), 123-146. https://doi.org/10.1016/S0167-8760(01)00162-3

Porges, S. W. (2003). The polyvagal theory: Phylogenetic contributions to social behavior. *Physiology & Behavior*, *79*(3), 503-513. https://doi.org/10.1016/s0031-9384(03)00156-2

Porges, S. W. (2007). The polyvagal perspective. *Biological Psychology, 74*(2), 116-143. https://doi.org/10.1016/j.biopsycho.2006.06.009

Porges, S. W. (2009). The polyvagal theory: New insights into adaptive reactions of the autonomic nervous system. *Cleveland Clinic Journal of Medicine, 76*(2), 586-590. https://doi.org/10.3949/ccjm.76.s2.17

Porges, S. W. (2018). *Clinical applications of the polyvagal theory: The emergence of polyvagal-informed therapies* [Kindle Edition]. New York, NY: W.W. Norton & Co.

Porges, S. W., & Furman, S. A. (2011). The early development of the autonomic nervous system provides a neural platform for social behaviour: A polyvagal perspective. *Infant & Child Development, 20*(1), 106-118. https://doi.org/10.1002/icd.688

Powers, A., Stevens, J. S., van Rooij, Sanne J. H., Ely, T. D., Fani, N., Jovanovic, T., . . . Bradley, B. (2017). Neural correlates and structural markers of emotion dysregulation in traumatized civilians. *Social Cognitive and Affective Neuroscience, 12*(5), 823-831. https://doi.org/10.1093/scan/nsx005

Price, M., Spinazzola, J., Musicaro, R., Turner, J., Suvak, M., Emerson, D., & van der Kolk, B. (2017). Effectiveness of an extended yoga treatment for women with chronic posttraumatic stress disorder. *Journal of Alternative and Complementary, 23*(4), 300-309. https://doi.org/10.1089/acm.2015.0266

Qin, P., & Northoff, G. (2011). How is our self related to midline regions and the default-mode network? *Neuroimage, 57*(3), 1221-1233. https://doi.org/10.1016/j.neuroimage.2011.05.028

Raichle, M. E., & Snyder, A. Z. (2007). A default mode of brain function: A brief history of an evolving idea. *Neuroimage, 37*(4), 1083-1090. doi:10.1016/j.neuroimage.2007.02.041

Raichle, M. E., MacLeod, A. M., Snyder, A. Z., Powers, W. J., Gusnard, D. A., & Shulman, G. L. (2001). A default mode of brain function. *Proceedings of the National Academy of Sciences, 98*(2), 676-682.

Rance, M., Walsh, C., Sukhodolsky, D. G., Pittman, B., Qiu, M., Kichuk, S. A., . . . Hampson, M. (2018). Time course of clinical change following neurofeedback. *Neuroimage, 181*, 807-813. https://doi.org/10.1016/j.neuroimage.2018.05.001

Rastegar, N., Dolatshahi, B. & Dogahe, E. R. (2016). The effect of neurofeedback training on increasing sustained attention in veterans with posttraumatic stress disorder. *Journal of Practice in Clinical Psychology, 4*(2), 97-104. https://doi.org/10.15412/J.JPCP.06040204

Reggie, E. V., & Parag, G. (2018). Is the vagus nerve our neural connectome? *ELife, 7*. https://doi.org/10.7554/eLife.35592

Reiter, K., Andersen, S. B., & Carlsson, J. (2016). Neurofeedback treatment and posttraumatic stress disorder: Effectiveness of neurofeedback on posttraumatic stress disorder and the optimal choice of protocol. *The Journal of Nervous and Mental Disease, 204*(2), 69-77. https://doi.org/10.1097/NMD.0000000000000418

Ressler, K. (2019). From the neural circuits of fear to the neurobiology of PTSD. *Biological Psychiatry, 83*(9). Retrieved from http://sdl.edu.sa/middleware/Default.aspx?USESDL=true&PublisherID=AllPublishers&BookURL=https://sdl.idm.oclc.org/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=edswsc&AN=000432466300096&site=eds-live

Rhodes, A., Spinazzola, J., & van der Kolk, B. (2016). Yoga for adult women with chronic PTSD: A long-term follow-up study. *The Journal of Alternative and Complementary Medicine*, *22*(3), 189-196. https://doi.org/10.1089/acm.2014.0407

Robb, C. (2006). *This changes everything: The relational revolution in psychology*. New York, NY: Farrar, Straus and Giroux.

Rogers, K (2015). Hindbrain anatomy. *Encyclopaedia Britannica*. Retrieved from https://www.britannica.com/science/hindbrain#accordion-article-history

Ros, T., Théberge, J., Frewen, P. A., Kluetsch, R., Densmore, M., Calhoun, V. D., & Lanius, R. A. (2013). Mind over chatter: Plastic up-regulation of the fMRI salience network directly after EEG neurofeedback. *Neuroimage, 65*, 324-335. https://doi.org/10.1016/j.neuroimage.2012.09.046

Rosas-Ballina, M., Olofsson, P., Ochani, M., Valdés-Ferrer, S., Levine, Y., Reardon, C., . . . Tracey, K. (2011). Acetylcholine-synthesizing T cells relay neural signals in a vagus nerve circuit. *Science, 334*(6052), 98-101. https://doi.org/10.1126/science.1209985

Rosen, G. M., & Frueh, B. C. (2010) *Clinician's guide to posttraumatic stress disorder*. Hoboken, NJ: John Wiley & Sons.

Rostami, R., & Dehghani-Arani, F. (2015). Neurofeedback training as a new method in treatment of crystal methamphetamine dependent patients: A preliminary study. *Applied Psychophysiology and Biofeedback, 40*(3), 151-161. https://doi.org/10.1007/s10484-015-9281-1

Rothschild, B. (2000). *The body remembers: The psychophysiology of trauma and trauma treatment* (Vol. 1). New York, NY: W.W. Norton & Co.

Saldaña, J. (2015). *The coding manual for qualitative researchers*. Thousand Oaks, CA: SAGE Publications.

Sandars, N. K. (1972). *The epic of Gilgamesh*. London, UK: Penguin Classics.

Santarpia, S. M. (2008). *The effect of neurofeedback on symptom reduction in women with bulimia nervosa*. Retrieved from ProQuest Dissertations and Theses Global. (Accession Order No. 3337327). https://search-proquest-com.sdl.idm.oclc.org/docview/304381649?accountid=142908

Sapolsky, R. (2004). *Why zebras don't get ulcers: The acclaimed guide to stress, stress-related diseases, and coping* (3rd ed.). New York, NY: Holt Paperbacks.

Sara, S. J. (2009). The locus coeruleus and noradrenergic modulation of cognition. *Nature Reviews Neuroscience, 10*(3), 211-223. https://doi.org/10.1038/nrn2573

Saxby, E., & Peniston, E. G. (1995). Alpha-theta brainwave neurofeedback training: An effective treatment for male and female alcoholics with depressive symptoms. *Journal of Clinical Psychology, 51*(5), 685-693. https://doi.org/10.1002/1097-4679(199509)51:5<685::aid-jclp2270510514>3.0.co;2-k

Schäfer, S. K., Becker, N., King, L., Horsch, A., & Michael, T. (2019). The relationship between sense of coherence and post-traumatic stress: A meta-analysis. *European Journal of Psychotraumatology, 10*(1). https://doi.org/10.1080/20008198.2018.1562839

Schemann, M. (2005). Control of gastrointestinal motility by the "gut brain" – The enteric nervous system. *Journal of Pediatric Gastroenterology and Nutrition, 41*(1), S4-S6. Retrieved from https://doi.org/10.1097/01.scs.0000180285.51365.55

Schmidt, J., & Martin, A. (2016). Neurofeedback against binge eating: A randomized controlled trial in a female subclinical threshold sample. *European Eating Disorders Review, 24*(5), 406-416. https://doi.org/10.1002/erv.2453

Schoenberger, N. E., Shiflett, S. C., Esty, M. L., Ochs, L., & Matheis, R. J. (2001). Flexyx neurotherapy system in the treatment of traumatic brain injury: An initial evaluation. *Journal of Head Trauma Rehabilitation, 16*(3), 260-274. https://doi.org/10.1097/00001199-200106000-00005

Schottenbauer, M. A., Glass, C. R., Arnkoff, D. B., Tendick, V., & Gray, S. H. (2008). Nonresponse and dropout rates in outcome studies on PTSD: Review and methodological considerations. *Psychiatry, 71*(2), 134-168. https://doi.org/10.1521/psyc.2008.71.2.134

Scott, W. J. (1990) PTSD in the *DSM-III*: A case in the politics of diagnosis and disease. *Social Problems, 37*(3), 294-310. https://doi.org/10.2307/800744

Seeley, W. W., Menon, V., Schatzberg, A. F., Keller, J., Glover, G. H., Kenna, H., Reiss, A. L., . . . Greicius, M. D. (2007). Dissociable intrinsic connectivity networks for salience processing and executive control. *The Journal of Neuroscience: The Official Journal of the Society for Neuroscience*, *27*(9), 2349-56. https://doi.org/10.1523/JNEUROSCI.5587-06.2007

Shalev, A., Liberzon, I., & Marmar, C. (2017). Post-traumatic stress disorder. *The New England Journal of Medicine, 376*(25), 2459-2469. https://doi.org/10.1056/NEJMra1612499

Sheer, D. E. (1975). Biofeedback training of 40-Hz EEG and behavior. In N. Burch & H. I. Altshuler (Eds.), *Behavior and Brain Electrical Activity* (pp. 325-362). Boston, MA: Springer. https://doi.org/10.1007/978-1-4613-4434-6_15

Sheer, D. E. (1977). Biofeedback training of 40-Hz EEG and behavior. In J. Kamiya et al. (Eds.), *Biofeedback and Self-Control 1976/1977: An Annual Review* (pp. 325-362). Chicago, IL: Aldine.

Shi, X., Chen, C., Xia, W., Xiaojuan, G., Li, Y., & Jiacai, Z. (2014). Working memory training using EEG neurofeedback in normal young adults. *Bio-Medical Materials & Engineering*, *24*(6), 3637-3644. https://doi.org/10.3233/BME-141191

Shin, L. M., Whalen, P. J., Pitman, R. K., Bush, G., Macklin, M. L., Lasko, N. B., . . . Rauch, S. L. (2001). An fMRI study of anterior cingulate function in posttraumatic stress disorder. *Biological psychiatry*, *50*(12), 932-942.

Shouse, M. N., & Lubar, J. F. (1979). Operant conditioning of EEG rhythms and Ritalin in the treatment of hyperkinesis. *Biofeedback & Self-Regulation*, *4*(4), 299-311. https://doi.org/10.1007/bf00998960

Shulman, G. L., Corbetta, M., Buckner, R. L., Fiez, J. A., Miezin, F. M., Raichle, M. E., & Petersen, S. E. (1997). Common blood flow changes across visual tasks: I. increases in subcortical structures and cerebellum but not in nonvisual cortex. *Journal of Cognitive Neuroscience*, *9*(5), 624-647. doi:10.1162/jocn.1997.9.5.624

Siegel, D. J. (2012). *The developing mind: How relationships and the brain interact to shape who we ar*e (2nd ed.). New York, NY: Guilford Press.

Sitaram, R., Ros, T., Stoeckel, L., Haller, S., Scharnowski, F., Lewis-Peacock, J., . . . Birbaumer, N. (2017). Closed-loop brain training: The science of neurofeedback. *Nature Reviews Neuroscience*, *18*(2), 86-100. https://doi.org/10.1038/nrn.2016.164

Smith, L. (1992). Ethical issues in interviewing. *Journal of Advanced Nursing*, *17*(1), 98-103. https://doi.org/10.1111/j.1365-2648.1992.tb01823.x

Smith, M. & Collura, T. F. & Tarrant, J. (2014). *EEG/ERP Analysis: Methods and Applications*. Retrieved from https://www.researchgate.net/publication/281109725_Neurofeedback

Smith, W. D. (2008). *The effect of neurofeedback training on PTSD symptoms of depression and attention problems among military veterans.* (Doctoral dissertation.) Retrieved from ProQuest Dissertations and Theses Global. (Accession Order No. 3315214) https://search-proquest-com.sdl.idm.oclc.org/docview/193497792?accountid=142908

Spreng, R. N., Mar, R. A., & Kim, A. S. N. (2009). The common neural basis of autobiographical memory, prospection, navigation, theory of mind, and the default mode: A quantitative meta-analysis. *Journal of Cognitive Neuroscience, 21*(3), 489-510. doi:10.1162/jocn.2008.21029

Sridharan, D., Levitin, D. J., & Menon, V. (2008). A critical role for the right fronto-insular cortex in switching between central-executive and default-mode networks. *Proceedings of the National Academy of Sciences of the United States of America*, *105*(34). https://doi.org./10.1073/pnas.0800005105

Sripada, R. K., King, A. P., Welsh, R. C., Garfinkel, S. N., Wang, X., Sripada, C. S., & Liberzon, I. (2012). Neural dysregulation in posttraumatic stress disorder: Evidence for disrupted equilibrium between salience and default mode brain networks. *Psychosomatic Medicine*, *74*(9), 904-911. https://doi.org/10.1097/PSY.0b013e318273bf33

Staddon, J. E. R., & Cerutti, D. T. (2003). Operant conditioning. *Annual Review of Psychology, 54,* 115-44. https://doi.org/10.1146/annurev.psych.54.101601.145124

Steele, P. (2015). *The theoretical underpinning of Adlerian psychology and neurofeedback: A model for integration.* (Doctoral dissertation.) Retrieved from ProQuest Dissertations and Theses Global. (Accession Order No. 3663799) Retrieved from https://search-proquest-com.sdl.idm.oclc.org/docview/1707108541?accountid=142908

Steenkamp, M. M., Litz, B. T., Hoge, C. W., & Marmar, C. R. (2015). Psychotherapy for Military-Related PTSD: A Review of Randomized Clinical Trials. *JAMA: Journal of the American Medical Association*, *314*(5), 489. https://doi.org/10.1001/jama.2015.8370

Steinberg, E. (2015). *Neural mechanisms of sleep and anesthesia* (Doctoral dissertation.) Retrieved from Imperial College London. (Accession Order No. 31601) https://doi.org/10.25560/31601

Sterman, M. B. (2000). Basic concepts and clinical findings in the treatment of seizure disorders with EEG operant conditioning. *Clinical EEG and Neuroscience, 31*(1), 45-55. https://doi.org/10.1177/155005940003100111

Sterman, M. B., & Egner, T. (2006). Foundation and practice of neurofeedback for the treatment of epilepsy. *Applied Psychophysiology and Biofeedback, 31*(1), 21-35. https://doi.org/10.1007/s10484-006-9002-x

Sterman, M. B., & Friar, L. (1972). Suppression of seizures in an epileptic following sensorimotor EEG feedback training. *Electroencephalography and Clinical Neurophysiology*, *33*(1), 89-95. https://doi.org/10.1016/0013-4694(72)90028-4

Sterman, M. B., LoPresti, R. W., & Fairchild, M. D. (2010). Electroencephalographic and behavioral studies of monomethyl hydrazine toxicity in the cat. *Journal of Neurotherapy, 14*(4), 293-300. https://doi.org/10.1080/10874208.2010.523367

Stevens, J. S., Kim, Y. J., Galatzer-Levy, I. R., Reddy, R., Ely, T. D., Nemeroff, C. B., . . . Ressler, K. J. (2017). Amygdala reactivity and anterior cingulate habituation predict posttraumatic stress disorder symptom maintenance after acute civilian trauma. *Biological Psychiatry*, *81*(12), 1023-1029. https://doi.org/10.1016/j.biopsych.2016.11.015

St. Jacques, P. L., Botzung, A., Miles, A., & Rubin, D. C. (2011). Functional neuroimaging of emotionally intense autobiographical memories in post-traumatic stress disorder. *Journal of Psychiatric Research, 45*(5), 630-637. https://doi.org/10.1016/j.jpsychires.2010.10.011

Strehl, U. (2014). What learning theories can teach us in designing neurofeedback treatments. *Frontiers in Human Neuroscience, 8*. https://doi.org/10.3389/fnhum.2014.00894

Taylor, M. A., & Vaidya, N. A. (2008) *Descriptive psychopathology: The signs and symptoms of behavioral disorde*rs. Cambridge, UK: Cambridge University Press.

Taylor, S. E. (2006). Tend and befriend: Biobehavioral bases of affiliation under stress. *Current Directions in Psychological Science, 15*(6), 273-277. https://doi.org/10.1111/j.1467-8721.2006.00451.x

Tellis, W. M. (1997). Introduction to case study. *The Qualitative Report, 3*(2), 1-14. Retrieved from https://nsuworks.nova.edu/tqr/vol3/iss2/4

Temple, B., & Young, A. (2004). Qualitative research and translation dilemmas. *Qualitative Research*, *4*(2), 161-178. https://doi.org/10.1177/1468794104044430

Thatcher, R. W. (2011). Neuropsychiatry and quantitative EEG in the 21st century. *Neuropsychiatry*, *1*(5), 495-514.

Thayer, J. F., Hansen, A. L., Saus-Rose, E., & Johnsen, B. H. (2009). Heart rate variability, prefrontal neural function, and cognitive performance: The neurovisceral integration perspective on self-regulation, adaptation, and health. *Annals of Behavioral Medicine, 37*, 141-153. https://doi.org/10.1007/s12160-009-9101-z

Thayer, J. F., Lane, R. D. (2007). The role of vagal function in the risk for cardiovascular disease and mortality. *Biological Psychology, 74,* 224-242. https://doi.org/10.1016/j.biopsycho.2005.11.013

The Association for Applied Psychophysiology and Biofeedback. (2020, February 11). About Biofeedback. Retrieved from https://www.aapb.org/i4a/pages/index.cfm?pageid=3463#:~:text%20=%E2%80%9CBiofeedback%20is%20a%20process%20that,muscle%20activity%2C%20and%20skin%20temperature.

Thomas F. Feiner Institute for EEG-Neurofeedback (IFEN), T. (2017). The International 10-20 system of electrode placement [brochure]. Munich, Germany: Feiner.

Thompson, C. (2018). *The hermeneutics of quantitative electroencephalography (QEEG).* (Doctoral dissertation.) Retrieved from ProQuest Dissertations and Theses Global. (Accession Order No. 10788866) https://search-proquest-com.sdl.idm.oclc.org/docview/2071953746?accountid=142908

Thompson, M., & Thompson, L. (2003). *The neurofeedback book: An introduction to basic concepts in applied psychophysiology* (2nd ed). Wheat Ridge, CO: Association for Applied Psychophysiology and Biofeedback.

Trans Cranial Technologies. (2012). *10/20 System Position.* Wanchai. Hong Kong. Retrieved from http://chgd.umich.edu/wp-content/uploads/2014/06/10-20_system_positioning.pdf

Trivedi, N. (2017). *Efficacy of neurofeedback interventions for PTSD and/or substance dependence.* (Doctoral dissertation.) Retrieved from ProQuest Dissertations and Theses Global. (Accession Order No. 10259680) https://search-proquest-com.sdl.idm.oclc.org/docview/1885069115?accountid=142908

Trochim, W. M. (1989). Outcome pattern matching and program theory. *Evaluation and Program Planning*, *12*(4), 355-366. https://doi.org/10.1016/0149-7189(89)90052-9

Tsigos, C., & Chrousos, G. (2002). Hypothalamic-pituitary-adrenal axis, neuroendocrine factors and stress. *Journal of Psychosomatic Research, 53*(4), 865-871. https://doi.org/10.1016/s0022-3999(02)00429-4

Tubbs, R. S. (2015). *Nerves and nerve injuries: Vol 1: History, embryology, anatomy, imaging, and diagnostics*. London, UK: Academic Press. Retrieved from http://www.elsevier.com/books/nerves-and-nerve-injuries/tubbs/978-0-12-410390-0

Valenzuela, E. M., III. (2016). *Clinical efficacy of neurofeedback training in reducing post-traumatic-stress-disorder symptomology* (Unpublished doctoral dissertation). The Chicago School of Professional Psychology, Chicago, IL.

Valls-Solé, J. (2015). Neurophysiological studies of brainstem functions and reflexes: Publications from the Brainstem Society Meeting. Berlin, March 2014. *Clinical Neurophysiology, 126*(10), 1869-1870. https://doi.org/10.1016/j.clinph.2015.07.013

van der Kolk, B. A. (2006). Clinical implications of neuroscience research in PTSD. *Annals of the New York Academy of Sciences, 1071*(1), 277-293. https://doi.org/10.1196/annals.1364.022

van der Kolk, B. A. (2015). *The body keeps the score: Brain, mind, and body in the healing of trauma*. New York, NY: Viking.

van der Kolk, B., Blitz, R., Burr, W., Sherry, S., & Hartmann, E. (1984). Nightmares and trauma: A comparison of nightmares after combat with lifelong nightmares in veterans. *The American Journal of Psychiatry, 141*(2), 187-190. https://doi.org/10.1176/ajp.141.2.187

van der Kolk, B. A., & Ducey, C. P. (1989). The psychological processing of traumatic experience: Rorschach patterns in PTSD. *Journal of Traumatic Stress, 2*(3), 259-274.

van der Kolk, B. A., Hodgdon, H., Gapen, M., Musicaro, R., Suvak, M. K., Hamlin, E., & Spinazzola, J. (2016). A randomized controlled study of neurofeedback for chronic PTSD. *PLoS One, 11*(12). https://doi.org/10.1371/journal.pone.0166752

van der Kolk, B. A., Spinazzola, J., Blaustein, M. E., Hopper, J. W., Hopper, E.K., Korn, D. L., & Simpson, W. B. (2007). A randomized clinical trial of eye movement desensitization and reprocessing (EMDR), fluoxetine, and pill placebo in the treatment of posttraumatic stress disorder: Treatment effects and long-term maintenance. *Journal of Clinical Psychiatry, 68*(1), 37-46. https://doi.org/10.4088/jcp.v68n0105

van der Kolk, B. A., Stone, L., West, J., Rhodes, A., Emerson, D., Suvak, M., & Spinazzola, J. (2014). Yoga as an adjunctive treatment for posttraumatic stress disorder: A randomized controlled trial. *Journal of Clinical Psychiatry*, *75*(6), e559-65. https://doi.org/10.4088/JCP.13m08561

Van Mersbergen, M. (2014). Viva La Vagus! *Choral Journal*, *55*(3), 61. Retrieved from https://www.researchgate.net/profile/Miriam_Van_Mersbergen2/publication/266376150_Viva_La_Vagus/links/56e97fdb08ae95bddc29e48a.pdf

Vernon, D. J. (2005). Can neurofeedback training enhance performance? An evaluation of the evidence with implications for future research. *Applied Psychophysiology & Biofeedback, 30*(4), 347-364. https://doi.org/10.1007/s10484-005-8421-4

Vannini, P., O'Brien, J., O'Keefe, K., Pihlajamäki, M., Laviolette, P., & Sperling, R. A. (2011). What goes down must come up: Role of the posteromedial cortices in encoding and retrieval. *Cerebral Cortex,* 21(1), 22-34. https://doi.org/10.1093/cercor/bhq051

Waddington, A., Ampelas, J. F., Mauriac, F., Bronchard, M., Zeltner, L., & Mallat, V. (2003). Post-traumatic stress disorder (PTSD): The syndrome with multiple faces. *Encephale, 29*(1), 20-27. https://doi.org/ENC-2-2003-29-1-0013-7006-101019-ART3

Wahbeh, H., & Oken, B. S. (2013). Peak high-frequency HRV and peak alpha frequency higher in PTSD. *Applied Psychophysiology and Biofeedback, 38*(1), 57-69. https://doi.org/10.1007/s10484-012-908-z

Walker, J. E. (2008). Power spectral frequency and coherence abnormalities in patients with intractable epilepsy and their usefulness in long-term remediation of seizures using neurofeedback. *Clinical EEG and Neuroscience, 39*(4), 203-205. https://doi.org/10.1177/155005940803900410

Walker, J. E. (2009). Anxiety associated with post-traumatic stress disorder: Post Traumatic Stress Disorder—The Role of Quantitative Electro- encephalograph in diagnosis and in guiding neurofeedback training to remediate the anxiety. *Biofeedback, 37*(2), 67-70. https://doi.org/10.5298/1081-5937-37.2.67

Walker, J. E., & Lawson, R. (2013). FP02 beta training for drug-resistant depression—A new protocol that usually reduces depression and keeps it reduced. *Journal of Neurotherapy, 17*(3), 198-200. https://doi.org/10.1080/10874208.2013.785784

Walpole, B., Davies, A., & Dann, L. (2011). *Biology for the IB diploma*. Cambridge, UK: Cambridge University Press.

Watson, C. G., Herder, J., & Passini, F. T. (1978). Alpha biofeedback therapy in alcoholics: An 18-month follow-up. *Journal of Clinical Psychology, 34*(3), 765-769. https://doi.org/10.1002/1097-4679(197807)34:3<765::aid-jclp2270340339>3.0.co;2-5

Wilson, J. P. (1994). The historical evolution of PTSD diagnostic criteria: From Freud to DSM-IV. *Journal of Traumatic Stress, 7*(4), 681-698. https://doi.org/10.1007/BF02103015

Weng, Y., Qi, R., Zhang, L., Luo, Y., Ke, J., Xu, Q., . . . Lu, G. (2018). Disturbed effective connectivity patterns in an intrinsic triple network model are associated with posttraumatic stress disorder. *Neurological Sciences: Official Journal of the Italian Neurological Society and of the Italian Society of Clinical Neurophysiology 40,* 339–349. https://doi.org/10.1007/s10072-018-3638-1

Williamson, J. B., Porges, E. C., Lamb, D. G., & Porges, S. W. (2014). Maladaptive autonomic regulation in PTSD accelerates physiological aging. *Frontiers in Psychology, 5*. https://doi.org/10.3389/fpsyg.2014.01571

Wolfe, P. (2001). *Brain matters: Translating research into classroom practice.* Alexandria, VA: Association for Supervision and Curriculum Development.

Wood, J. T. (1986). Different voices in relationship crises: "An extension of Gilligan's Theory." *The American Behavioral Scientist, 29*(3), 273-301. https://doi.org/10.1177/000276486029003003

Wylie, M.S. (2004). The limits of talk: Bessel van der Kolk wants to transform the treatment of trauma. *Psychotherapy Networker, 28,* 30-41. Retrieved from https://www.psychotherapynetworker.org/magazine/article/818/the-limits-of-talk

Yael, A., Choi, J., DeSaix. J., Jurukovski. V., Wise, R., Rey, C., . . . Natarajan, S., (2013). *Biology* (2nd ed.). Rice University. Houston, Texas. Retrieved from https://openstax.org/details/books/biology-2e

Yin, R. K. (2009). *Case study research: Design and methods* (4th ed.). Thousand Oaks, CA: SAGE Publications.

Yin, R. K. (2018). *Case study research: Design and methods* (6th ed.). Thousand Oaks, CA: SAGE Publications.

Young, A. (1995). *The harmony of illusions: Inventing post-traumatic stress disorder*. Princeton, NJ: Princeton University Press.

Yuan, H., Phillips, R., Wong, C. K., Zotev, V., Misaki, M., Wurfel, B., . . . Bodurka, J. (2018). Tracking resting state connectivity dynamics in veterans with PTSD. *NeuroImage: Clinical, 19,* 260-270. https://doi.org/10.1016/j.nicl.2018.04.014

Zagon, A. (2001). Does the vagus nerve mediate the sixth sense? *Trends in Neurosciences*, *24*(11), 671-673. doi:10.1016/S0166-2236(00)01929-9

Zelviene, P., & Kazlauskas, E. (2018). Adjustment disorder: current perspectives. *Neuropsychiatric disease and treatment*, *14*, 375–381. doi:10.2147/NDT.S121072

Zlomuzica, A., Woud, M. L., Machulska, A., Kleimt, K., Dietrich, L., Wolf, O. T., . . . Margraf, J. (2018). Deficits in episodic memory and mental time travel in patients with post-traumatic stress disorder. *Progress in Neuropsychopharmacology & Biological Psychiatry*, 83, 42-54. doi:10.1016/j.pnpbp.2017.12.01

Appendix A

IRB Approval

ST MARY'S UNIVERSITY

October 17, 2019

Reema Alhowaish
Dept. of Counseling
St. Mary's University

DELIVERED BY EMAIL TRANSMISSION

Dear Ms. Alhowaish:

The IRB has approved the study, Alhowaish (Comstock, faculty sponsor), The impact of Neurofeedback on women diagnosed with PTSD: a multiple case study. If research participants have any questions about their rights as a research subject or concerns about this research study please contact the Chair, Institutional Review Board, St. Mary's University at 210-436-3736 or email at IRBCommitteeChair@stmarytx.edu.

Dan Ratliff, Ph.D.
IRB Chair
St. Mary's University

The proposal is determined to meet criteria for exemption under 45 CFR 46.104(d)(2), the use of surveys and interviews with de-identified, minimal risk data. Exempt research does not require IRB review or renewal for five years (2022). However, IRB requests a closure report when the data collection is completed, or, if active data collection continues, a summary report of the sample size at the May IRB meeting of each academic year.

Exempt research can proceed with an abbreviated consent process in which the subjects are informed of the purpose and duration of the survey, and with no signature for informed consent. The approval stamp must be visible in the information about the study provided to potential subjects.

The IRB reviewer indicated that your informed consent document identifies yourself as LPC-I, which is an illegal form of identification according to the LPC regulations. Please change the designation to LPC-Intern.

DEPARTMENT OF COUNSELING AND HUMAN SERVICES ■ ONE CAMINO SANTA MARIA ■ SAN ANTONIO, TEXAS 78228-8527
OFFICE: (210) 438-6400 ■ FAX: (210) 438-6441

The IRB has approved the study, Alhowaish (Comstock, faculty sponsor), The impact of Neurofeedback on women diagnosed with PTSD: a multiple case study. If research participants have any questions about their rights as a research subject or concerns about this research study please contact the Chair, Institutional Review Board, St. Mary's University at 210-436-3736 or email at IRBCommitteeChair@stmarytx.edu.

Dan Ratliff, Ph.D.
IRB Chair
St. Mary's University

Appendix B

Electronic informed consent

Informed Consent

Dear prospective participant,

Thank you for your interest in participating in this research study titled, "The Impact of Neurofeedback on Women Diagnosed with PTSD: A Multiple Case study. My name is Reema Alhowaish, and I am a doctoral student at St. Mary's University. I am doing this dissertation research as a part of the requirements for my doctoral degree in Counselor Education and Supervision.

The purpose of this study is to understand how women with PTSD experienced Neurofeedback (NFB). I am especially interested in how you experienced NFB, and how you experienced subsequent changes in the symptoms of your PTSD.
Your participation in the research will involve an in-person interview with the researcher, which will be between 1 to 1 ½ hours long, and a possible 20-minute follow-up phone call.

The interview will take place at a mutually agreed upon location that provides minimal interruptions. During the interview**,** you will be asked about how you experienced neurofeedback. You will also be asked for your feedback about some of the changes that were noted on the assessments you completed before and after neurofeedback. For research purposes, all interviews will be audio recorded. The audio recording will then be transcribed by the researcher. Information gathered from the interviews will be included in the doctoral dissertation. Your identity will remain anonymous and I will use only a pseudonym in my results. No identifying information will appear anywhere in the results of the study.
I do not anticipate any risks related to your participation in this study as you will be asked questions about the treatment and assessments you have already completed. The benefits of your participation include the opportunity to share information that neurofeedback clinicians and

programs can use to provide the best possible services for the women they treat for PTSD in the future.

You have several options about participating in this study. You may choose to participate. You may choose not to participate. Should you choose to participate in this study, you may choose to withdraw at any time should you change your mind by not coming to the interview. You can even stop the interview after it is started. Regardless of the choice you make, you will remain in good standing with the Sarabia Family Counseling Center. You will receive a $25 VISA gift card to compensate you for TRAVEL expenses at the time you arrive at the interview location.

If you have any questions or concerns about this research study or if any problems arise, please contact the Principal Investigator, Reema Alhowaish, ME, LPC-I, Doctoral Candidate, at email: ralhowasih@mail.stmarytx.edu, or to the dissertation advisor, Dr. Dana Comstock, Professor in the Department of Counselor Education and Supervision, who can be reached at phone number (210-438-6400)

If you have any questions about your rights as a research subject or concerns about this research study please contact the Chair, Institutional Review Board, St. Mary's University at 210-436-3736 or email at IRBCommitteeChair@stmarytx.edu. ALL RESEARCH PROJECTS THAT ARE CARRIED OUT BY INVESTIGATORS AT ST. MARY'S UNIVERSITY ARE GOVERNED BY THE REQUIREMENTS OF THE UNIVERSITY AND THE FEDERAL GOVERNMENT

If you agree to participate in this study, please provide your first name and preferred method(s) of contact information and submit this consent form by clicking NEXT at the end of this form.

First name:

Email:

phone number:

By providing your contact information and clicking "NEXT" you are consenting to (a) the researcher will call or email you to arrange for an interview and, (b) the researcher to identify your individual assessments in preparation for the interview.

REEMA ABDULRAHMAN ALHOWAISH

Email: r.h32@hotmail.com

Department of Psychology, Kin Abdul-Aziz University- Jeddah- KSA

St Mary's University-San Antonio- Texas

EDUCATION:

- Ph.D. in Counselor education and supervision- concentration on Neurofeedback.

  St. Mary's University, San Antonio, TX. USA. Defense Completed 3/16/2020
- Master's degree in counseling psychology with a grade of excellence and second honor.

  Umm Al Quora University, Makkah, the kingdom of Saudi Arabia. 2011
- Bachelor in Islamic studies with a grade of excellent and honors. King Abdulaziz University, Jeddah, the kingdom of Saudi Arabia. 2001

WORK EXPERIENCE:

Place of Work	Date	Position
Administration of Education in Jeddah	1992-2000	Teacher
Administration of Education in Jeddah	2000-2011	Educational Supervisor
King Abdul Aziz University in Jeddah	2011-2020	Lecturer - Psychology Department

LICENSE:

Texas State Licensed Professional Counselor-I intern (LPC-I) - 2018

CLINICAL EXPERIENCE SAUDI ARABIA:

1. Internship in Al Amal hospital for drug addiction treatment for 10 weeks.

CLINICAL EXPERIENCE USA:

1. Family life center in St. Mary's University.
2. Communities in Schools.
3. Barbra Jorden community center- extraordinary counseling center.

TEACHING EXPERIENCE- UNDERGRADUATE CLASSES.

1. Criminal psychology.
2. Developmental Psychology.
3. Physiological psychology.
4. Social Psychology.

RESEARCH:

1. "Self-Automatic Judgment, Aggression & Hostility among a group of battered women in shelter house and non-battered in Jeddah province." The Master's thesis
2. Components of Family Compatibility from the Kuwaiti families' point of view and the extent of practicing such components and their relation to certain demographic and social variables, research series of Kuwaiti Ministry of Endowments & Islamic Affairs, Kuwait.2008
3. Using social media platforms to address social phobia in Saudi Arabian women. 60th annual professional growth conference 2016. Dallas, Texas
4. Using Social Media Platforms to Inform Arabic Societies on the Use of Neurofeedback. The 25th Annual ISNR Conference 2017. Mashantucket. CT.

TRAINING:

1. Cognitive behavior therapy.
2. Training course for employees dealing with cases of abuse and neglect.
3. Family therapy intensive training 35 hours.
4. Mental health disorder classification.

5. Cognitive behavior thereby with PTSD
6. Interview techniques in psychotherapy.
7. Relaxation techniques.
8. Play therapy and psychodrama, 24 hours.
9. Solution focused brief therapy intensive training, 50 hours.
10. Clinical hypnosis, 40 hours.
11. Intensive cognitive behavior therapy for depression.
12. Operation military counseling.
13. Sensory integration and the management of anxiety in children.
14. Basic training Eye Movement Desensitization and Reprocessing (EMDR).
15. EMDR therapy protocol for early care and ongoing traumatic stress.
16. EMDR therapy training for pain protocol.
17. Feeling State Addiction Protocol.
18. The neurobiology of attachment in paly therapy.
19. QEEG certification didactic course, 24 hours.
20. Second QEEG certification didactic course, 24 hours.
21. Introductory level training in Hakomi mindful somatic psychology.
22. Internal family system.
23. Crisis response teams and critical incident first responder perspective.
24. Analytical Hypnotherapy.

MEMBERSHIP:

1. Counseling academic and professional honor society international (Chi Sigma lota)
2. International Society for Neurofeedback & Research (ISNR)

CONFERENCE:

1. The third regional conference for the Prevention of Child Abuse & Neglect, 2009, Riyadh.
2. The fifth Conference of Psychiatry, Jeddah, 2009
3. The sixth Conference of Psychiatry, Jeddah, 2010
4. Texas counseling association conference, the 58th Professional Growth Conference, Dallas, TX. 2014.
5. Texas counseling association conference, the 59th Professional Growth Conference, Corpus Christi, TX. 2015.
6. Texas counseling association conference, the 60th Professional Growth Conference, Dallas, TX. 2016.
7. International Society for Neurofeedback & Research (ISNR) 25th annual conference, Mashantucket, CT. 2017.
8. International Society for Neurofeedback & Research (ISNR) 26th annual conference, Mashantucket, CT. 2018.
9. International Society for Neurofeedback & Research (ISNR) 27th annual conference, Denver, CO. 2018.