The Application of Neurofeedback and the "Safe and Sound Protocol" in Recovery from 50 Years of Complex PTSD: A single case study of a refugee torture survivor

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Abstract

Objective: The study assessed the effects of 36 sessions of neuromodulation in the amelioration of 50 years of complex posttraumatic stress disorder (cPTSD) across a 16-month period.
Method: A case study was conducted with a refugee torture survivor following developmental and genocide war trauma. Neurofeedback and the Safe and Sound Protocol (SSP) were combined to reorganise overactivation of fear circuitry in the brain and autonomic nervous system (ANS). Neuromodulation and psychotherapy were integrated so the participant could reach ventral vagal state regulation.
Results: Pre and post brainwave and heart-rate variability data highlighted more synchronised EEG patterns and slower resting heart rate. Improved inhibitory control, sleep onset, and the slowing of beta brain waves were recorded whilst a reduction in avoidance and hypervigilance was observed. A significant reduction in cPTSD, depression, and anxiety symptoms were achieved to the point of extinction. These findings were robust across self-report and physiological marker measures.
Conclusion: Stabilisation of brainwave and ANS functioning was achieved in a brief amount of time compared with half a century of psychiatric disturbance. A combination of neuromodulation methods may be superior to singular neuromodulation treatment for cPTSD. Implications for refugee torture survivors and the fields of neuroscience and developmental trauma are discussed.

Keywords: Neurofeedback, Safe and Sound Protocol, neuromodulation, complex PTSD, torture survivor, refugee mental health, genocide, vagus nerve, polyvagal theory

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1. Introduction

This case study describes the case of Zeya1, a refugee torture and genocide survivor. Zeya presented to the NSW Service for the Treatment and Rehabilitation of Torture and Trauma Survivors (STARTTS) with treatment resistant cPTSD that had persisted for a period of 50 years. Zeya received a total of 36 sessions of neurofeedback and SSP treatment across a period of 16 months throughout the height of the COVID pandemic. Despite regular interruption to treatment due to lockdown restrictions, weekly therapeutic contact was maintained via telehealth when neurofeedback could not take place. As a result of neurofeedback, SSP treatment and trauma-informed counselling, Zeya's traumatic sequelae extinguished. Ventral vagal state regulation was achieved. Zeya remained asymptomatic of cPTSD, depression, and anxiety and quality of life returned for the first time in half a century.

2. Background

2.1. Refugee Trauma

One in five refugees report being a survivor of torture, a harmful form of social control currently practiced in more than 140 countries worldwide (Amnesty International, 2014; Steel et al., 2009). Its effects are so insidious that five out of every six torture victims are reported to have a lifelong mental disorder (van Ommeren et al., 2001). As defined by the United Nations Convention (United Nations High Commissioner for Refugees (UNHCR), 1951, 1967), refugees are forced to flee their country of origin due to inescapable threats to their life. Human-to-human perpetrated harm violates deeply held moral frameworks (Nickerson et al., 2015) with torture ranked as one of the most harmful life events one can experience (Abu Suhaiban et al., 2019). Lewis & Herman (1997, p.33) assert "when the force is that of nature, we speak of disasters. When the force is that of other human beings, we speak of atrocities".

Psychiatric disorders amongst refugee populations are disproportionately high compared with Australian prevalence rates for PTSD (5.7%) and depression (4.6%) (Australian Bureau of Statistics, 2020-2021). In one systemic review with a sample of more than 80,000 post-conflict affected persons, elevated PTSD prevalence (30.6%) and depression prevalence (30.8%) were reported (Steel et al., 2009). Disconcertingly, a recent study by Abu Suhaiban et al (2019) suggests PTSD can affect as many as 88.3% of torture survivors from the Middle East, Central Africa, Southeast Asia, and Southeast European regions. With torture increasing as a widespread phenomenon globally, higher volumes of refugees are resettling with pronounced mental health difficulties. Many will live functionally impaired lives with limited improvement in wellbeing (Abu Suhaiban et al., 2019). Factors such as torture severity, post-settlement stress, and a lack of appropriate treatment and long-term support are barriers to recovery (Abu Suhaiban et al., 2019; Blackmore et al., 2020). Research suggests narrative exposure therapy, cognitive behaviour therapy, and in vivo exposure can moderately reduce psychological distress and PTSD symptoms amongst refugee trauma survivors (Nickerson et al., 2011). However, reductions in trauma symptoms can be short lived and many will experience a return to baseline symptomatic levels. Further factors to consider are the possible effects of developmental and transgenerational trauma which may add to the complexity of cPTSD. Opaas & Varvin's (2015) study examining refugees with both childhood and human rights abuse histories found childhood trauma was significantly associated with arousal and avoidance symptoms, while war trauma was significantly related to reexperiencing PTSD symptoms. It is pertinent then to consider wider developmental and attachment related issues that may be concurrent with war and torture exposure as these could exacerbate and maintain cPTSD if not addressed (Punamäki et al., 2019).

2.2. Neurological and Physiological Markers of PTSD

Neuroimaging research suggests torture has unique and long-lasting effects on the brain, ANS, and neuroendocrinergic systems caused by cumulative stress exposure (Liddell & Bryant., 2018). Neuropsychiatric problems amongst torture victims are common, and deficits are often seen in the areas of sleep, perception, cognition, emotional and behavioural functioning, and somatic/bodily complaints (Liddell & Bryant., 2018). Further, refugees may demonstrate marked and prolonged difficulties with emotion regulation, self-identity and interpersonal functioning which are qualifying features for a diagnosis of cPTSD (International Statistical Classification of Diseases and Related Health Problems; 11th ed [ICD-11]). Individuals with PTSD exhibit brain changes that include reduced hippocampal and anterior cingulate volumes, decreased medial prefrontal cortex functioning, and increased amygdala function and stress hormone production (Bremner, 2006). Many EEG studies have demonstrated abnormal brainwave patterns amongst those living with PTSD exhibiting excessive beta (i.e., fast) and excessive delta/theta (i.e., slow) brainwave patterns (Begic et al., 2001; Giesbrecht et al., 2006). EEG markers of PTSD have also highlighted increased cortical activation and reduced alpha activity which suggests relaxed levels of alertness are hard to achieve for trauma victims (van der Kolk et al., 2016). Furthermore, refugee torture survivors have less spectral power in the low-frequency band of the left central executive network that suggests impairment in goal-directed behaviour and executive functioning (Liddell et al., 2022).

The role of the ANS is heavily implicated in the onset and maintenance of PTSD. Research suggests decreased parasympathetic nervous system (PNS) activity is associated with poor emotion-regulation (Beauchaine, 2001). The vagus nerve, responsible for important visceral functions that include heart rate, respiratory rate, immune response, digestion, and vasomotor activity (Breit et al., 2018), extends itself from the base of the brainstem down through the body via the neck, thorax, and abdomen. It provides parasympathetic activation to the heart, resulting in a reduction in heart rate (Breit et al., 2018). Polyvagal theory, one of the first neuroscience informed psychological theories, describes the ANS as an adaptive system that perceives safety, danger, or life threat with the central and peripheral nervous systems carrying important signals between brain nuclei and the heart (Porges, 2001). Polyvagal theory argues the "freeze" response (i.e., immobilised survival behaviours) and the "fight or flight" response (i.e.,

[1] The participant has been de-identified to protect their anonymity.

mobilised survival behaviours) have further evolved towards a myelinated mammalian social engagement system, which can regulate cardiac output through the ventral vagal complex (Porges, 2009). It is argued that when our social brain is activated via innate social bonding and attachment behaviours (i.e., through facial cues and vocalisations), regulation of the ANS can ensue (Porges, 2009, p.1). Kozlowska et al (2015) builds further on polyvagal theory by suggesting there are a set of hard-wired, distinct neural pathways that activate or inhibit functions in the periaqueductal gray and sympathetic and vagal nuclei brain areas. Consequently, these patterns can lock individuals into a pattern of behaviour linked to the original trauma, a term Kozlowska et al (2015) coined the "defense cascade". The authors argue that processing and reinterpretation of traumatic memories can help to "unblock" the patient's original trauma response which can then abate physiological markers of ANS arousal as recovery is facilitated.

2.3. Heart Rate Variability

Other markers of physiological trauma can be seen in heart rate variability (HRV), the beat-to-beat interval that occurs between each heartbeat. Ge et al (2020) purports individuals with PTSD demonstrate lower HRV, lower vagal state, inflammation, and alterations in executive function and emotion regulation. HRV is therefore, a common measure of ANS activity (Malik et al., 2019). RMSSD, the square root of the mean squared differences of successive normal-to-normal RR intervals, is reflective of the extent of vagal modulation of the heart (Reardon & Malik., 1996). It reflects PNS activity and overall, HRV is viewed as a valid measure of heart and autonomic responsiveness (Malik et al., 2019). For Huskey et al (2015) recovery from cPTSD was associated with an increase in parasympathetic control and the lowering of resting heart rate.

2.4. Neurofeedback

Knowledge of the brain has expanded across neuroscience to help paint a complex paradigm of trauma and the pathophysiology of fear. One method that can correct such pathophysiology is neurofeedback, a biofeedback method that can shape neuronal connectivity in a non-invasive and targeted manner. During neurofeedback, scalp electrodes provide real time feedback on electrical brainwave activity through a brain-to-computer interface. Patients undergoing neurofeedback receive positive reinforcement through visual and audio stimuli (e.g., through a video game or watching relaxing images on a screen) when the brain produces stable EEG patterns. Neurofeedback works by assisting trauma survivors to address dysregulated brainwave activity (Fisher., 2014). It has been found to assist refugee trauma survivors regain normalised levels of cognitive control (Askovic et al., 2020). In a randomised control trial by van der Kolk et al (2016) neurofeedback was found to significantly improve PTSD symptoms and emotion regulation amongst adults with high levels of cumulative trauma exposure. Marzbani et al (2016) suggests patterns of electrical activity in the brain, known as brain waves, produce different amplitudes and frequencies. Neurofeedback can assist individuals to recover from PTSD as brainwaves become modified and rewarded when "normal" brainwave patterns are produced. Empirical literature suggests approximately 30 to 40 sessions of neurofeedback trained at twice weekly intervals, can consolidate new learning and positively shape neuronal pathways in the brain (van der Kolk et al., 2016; Marzbani et al., 2016). Brain training protocols placed on the temporal and parietal lobes such as T4-P4, and bipolar placements such as T3-T4 have yielded positive results in diminishing PTSD hyperreactivity (van der Kolk et al., 2016; Gapen et al., 2016). Standardised inhibit frequencies such as 4–7 Hz and 22–36 Hz for low and high inhibits, and a reward frequency of 12–15 Hz have been found to be effective in increasing alpha and decreasing beta brain rhythms (Jokić-begić & Begić., 2003).

Table 1. List of specific brainwave frequencies that can be targeted in neurofeedback treatment as cited in Marzbani et al (2016, p. 144). Each frequency range represents physiological functions and levels of consciousness.

Common Brainwave Frequencies	Frequency Range (Hz)	General Characteristics
Delta	1-4	Sleep, rejuvenation, complex problem solving, pre-consciousness
Theta	4-8	Creativity, insight, unconsciousness, meditative states, depression, anxiety, distractibility
Alpha	8-13	Alertness and peacefulness, readiness, meditation, deep relaxation
Lower Alpha	8-10	Recalling
Upper Alpha	10-13	Optimised cognitive performance
Sensorimotor Rhythm (SMR)	12-15	Mental alertness, physical relaxation
Beta	15-20	Thinking, focusing, sustained attention, tension, alertness, excitement
High Beta	20-32	Intensity, hyper-alertness, anxiety
Gamma	32-100	Learning, cognitive processing, problem solving, mental sharpness, high level brain activity

2.5. The Safe and Sound Protocol

Exposure to bombings, combat, air raids and gunfire can result in auditory sensitivities and vigilance to noise. Listening to cues for danger can help the brain and nervous system gauge if danger is near, however this can promote a constant state of hypervigilance often seen in traumatised refugees. A solution to this may be an adjunct treatment to neurofeedback, a neural exercise called the Safe and Sound Protocol (SSP) based on Polyvagal Theory. The SSP is an auditory music program developed to train the neural networks associated with the middle ear (Porges et al., 2014). It is theorised that the SSP can dampen competing sounds that are lower than human voice frequencies so individuals can re-attune their hearing to higher frequencies that activate the brain's

social engagement system (Porges et al., 2014). It is theorised that once this optimal state is restored, adjunct therapies like neurofeedback can be accelerated. The SSP can promote ventral vagal safety with improvements in auditory sensitivity, social connectivity, emotion and behavioural regulation, and attention reported. Research studies of the SSP are preliminary and have focused largely on children with neurodevelopmental disability, chronic pain, sensory and neurological issues (Porges et al., 2014; Rajabalee et al., 2022). Porges (2022) suggests contemporary mental health treatment often overlooks the body's biological needs by failing to acknowledge that perceptions of safety derive from internal physiological states and the underpinnings of the ANS. When faced with the complex mental health needs of post-conflict affected persons it may be that a combination of neural interventions may be more wholistic and beneficial than neurofeedback treatment alone. In peer reviewed research, neurofeedback has not been offered in adjunct with the SSP. Neurofeedback and the SSP are safe, non-invasive, and non-verbal approaches to trauma treatment that could be helpful when working with refugees with high levels of psychiatric comorbidity. The current case study explores how a combination of neuromodulation methods can restore optimal brainwave, physiological, and psychological functioning in a refugee torture survivor with cPTSD.

3. Method

3.1. Case Introduction

Zeya is a 57-year-old refugee torture survivor who presented to STARTTS with cPTSD, depression, and anxiety. She was aged seven when civil war broke out in her native country. Zeya and her family were held captive over a seven-year period in a labour camp. She was forced to build bridges and roads for her captors and there was a constant stream of fear and mass killings throughout the genocide. Zeya experienced starvation, disease, sleep deprivation, exhaustion, and psychological and physical torture. Tragically, Zeya's mother was murdered in the genocide. Upon learning of her death, Zeya's father beat her into silence as her wailing would have led to their execution. This was symbolic of Zeya's trauma; it was a deeply conditioned response for her to suppress her psychological pain as the denial of her suffering was a mechanism that kept her alive. Her father too, was profoundly affected by the genocide. When bombs would fly overhead, Zeya expressed she could not go to him for comfort as she knew he would not hug her. Zeya described her father as a harsh and critical man who remained emotionally unavailable to her throughout her life.

The genocide came to an end and Zeya and her family was smuggled out of the country by boat. She resettled in Australia when she was 14 years old. She spoke no English, and she slept in a crowded one-bedroom house with 20 other refugees upon first arriving to the country. Zeya faced resettlement challenges common to refugees such as language and acculturation difficulties and the navigation of a new socio-political environment. Over time, Zeya learned to speak English, she attended high school, and she worked part-time as a seamstress to earn money for her father. She went on to study at university and in her 20's she married and had three children. It was when Zeya was in her early 20's, that her symptoms of PTSD had become unmanageable. Zeya reported severe dissociation, flashbacks, intrusive imagery, and nightmares of the genocide. She was afraid to fall asleep and her appetite reduced to the point that she weighed a mere 30 kilos. She received pharmacological and psychological treatment and she was placed on antidepressants which helped to keep her functional, however, her PTSD symptoms never fully relinquished. In 2021 during the height of the COVID pandemic, Zeya self-referred to STARTTS after learning of STARTTS neurofeedback clinic. A biopsychosocial approach to case formulation and treatment planning was utilised for Zeya. She presented to STARTTS almost 50 years after her exposure to genocide.

Upon meeting Zeya, she reported she was in a constant state of fear daily. Trauma re-experiencing and hypervigilant behaviours were triggered by daily events where she perceived her life was in danger. Her mind was preoccupied with safety behaviours and her quality of life was diminished. Zeya experienced longstanding gastrointestinal ulcers, reflux, asthma, sinus pain, allergies, body and somatic pain, headaches, vertigo, and irritable bowel problems resulting from exposure to chronic stress. Her medication levels for depression were subtherapeutic despite being on antidepressants for 35 years.

Zeya was exposed to multiple and cumulative traumatic events in her childhood due to war, imprisonment, and torture. In addition, she experienced developmental trauma whereby physical abuse, verbal abuse, and neglect were present in her home environment. Parenting in conditions of war and military violence is difficult, and for Zeya, she experienced attachment loss through the murder of her mother. Her surviving parent reportedly had PTSD, and her father displayed an avoidant attachment style towards her. Zeya reported feeling a heavy burden of responsibility to survive the horrors of war and to take care of her father; a promise she made to her mother in the camp. This resulted in lifelong parentification and a role-reversal in her child-parent dyad. Due to her multiple experiences of human-perpetrated harm, Zeya did not feel safe in the world, nor did she find safety in her relationships with others. During the genocide she repeatedly thought that she would die in the camp, and no-one would be there to witness the event. Zeya was the youngest child in captivity and was often forcibly separated from her family. She reported feeling a profound sense of aloneness.

Precipitating and perpetuating factors for her mental health were confounded by the COVID pandemic which reactivated primitive defense mechanisms of anger, and a preoccupation with dying and a lack of safety. Zeya reported high somatic re-experiencing of trauma through various bodily and somatic ailments. Her fear hyperactivity was observed through her "road rage" as she reported feeling trapped when driving on the highway as she perceived no means of escape. Zeya was afraid to go to the bathroom as she catastrophised she would collapse, and no-one would find her body. Zeya also became preoccupied with getting sick. She was fearful of catching COVID and she became fixated on food, such as raw meat and poor cooking preparation, as she feared food poisoning. Her fear of getting sick through ingestion directly related to trauma from the genocide. Hundreds of thousands of her countryman had perished from starvation, and Zeya recalled that as a child she would be forced to eat spiders, dog, insects, plants and poisonous figs to stay alive. Stomach pains, vomiting, dehydration, diarrhoea, and severe malnourishment were a daily occurrence. As an adult, Zeya experienced traumatic re-experiencing through chronic gastrointestinal issues, cramping and irritable

bowel syndrome (IBS). Preparing, cooking, and eating food for herself and her family had become a laboured task filled with multiple safety behaviours. When Zeya presented to STARTTS her goals were to address issues related to hypervigilance, anger, rumination, insomnia, and interpersonal difficulties. Protective factors included her psychological mindedness, good insight, resilience, adequate social support, resourcefulness, and high levels of motivation that were intrinsic to her recovery.

3.2. Prior Treatment

Zeya engaged in vast array of mental health treatment throughout the last 35 years across public and private health sectors. She received anxiety treatment as an out-patient at a local hospital, she saw numerous psychiatrists, psychologists and counsellors over the years, and she received pharmacological treatment that included benzodiazepine and antidepressant medication. In addition to this, she engaged with acupuncture and physiotherapy treatment to assist her with chronic body pain. She also sought Chinese herbal medicine treatment to address her numerous health complaints. In the years prior to the COVID pandemic Zeya privately funded approximately 80 sessions of transcranial magnetic stimulation (TMS) therapy over a three-year period. TMS is a neuromodulation procedure that stimulates magnetic fields in the brain to improve symptoms of depression and PTSD. Zeya had engaged in TMS treatment with a focus on bilateral training at the prefrontal cortex. Some improvement was reported with Zeya's concentration, mood, sleep and appetite however she reported she could no longer afford treatment. Zeya was titrating off TMS therapy and attending one session every fortnight when she self-referred to STARTTS. Despite years of various evidence-based therapies, Zeya's mental health difficulties remained chronic and treatment resistant. Zeya received seven months of counselling at STARTTS before her referral was escalated to the neurofeedback clinic. Some symptom improvement in her cPTSD was noted however, Zeya continued to live day-by-day crippled by terror that would not abate.

3.3. Diagnosis

Zeya was diagnosed with PTSD and post-natal depression 35 years ago. When she presented to STARTTS Zeya still met diagnostic criteria for PTSD (2.65 >2.5 clinical threshold on the HTQ-R), major depressive disorder (2.4 >1.75 clinical threshold on HSCL-D), and she was on the cusp for anxiety disorder (1.7 >1.75 clinical threshold on HSCL-A). Other differential diagnoses included complex grief, somatoform disorder, sleep disorder, borderline personality disorder, and panic disorder. As defined by the ICD-11, cPTSD refers to individuals who have experienced prolonged and chronic trauma that has led to complex reactions and impairment in day-to-day functioning. It includes not only the core symptoms of PTSD, but additional disturbances in areas of emotion regulation, self-identity and relationship difficulties which were evident in Zeya's presentation. An ICD-11 diagnosis of cPTSD was preferred over a Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5) as Zeya's PTSD symptoms were enduring, extreme and treatment resistant.

3.4. Recruitment

A participant was recruited from STARTTS neurofeedback clinic. Informed consent for use of clinical and EEG data for research purposes was obtained at the baseline EEG assessment. Participation in the neurofeedback program was voluntary. Certified interpreters were available for all treatment sessions if required. Psychological treatment provided to the client adhered to the Australian Psychological Society's Code of Ethics. Inclusionary criteria included adult refugees (18-70 years of age) from any cultural background, ethnicity, religion or visa status. Clients must have been in Australia for at least 12-months prior to neurofeedback treatment and they were required to attend twice weekly sessions to reshape neuronal networks. Exclusionary criteria included psychotic disorders, neurological disorders, untreated substance abuse, and active risk of harm issues i.e., suicidality, domestic or family violence issues etc.

3.5. Equipment

i. Neurofeedback equipment included EEGer software and license, Windows laptop, spare monitor screen, a neurofeedback amplifier, sensors, and 10/20 paste and nu gel to prep the scalp prior to electrode placement.
ii. The Safe and Sound Protocol equipment was comprised of headphones and an MP3 player with special frequencies embedded in the music supplied by Unyte Integrated Listening Systems.
iii. Heartmath HRV biofeedback dongle and software were used in the study to measure heart rate. Kubios software was used for HRV analysis.
iv. WinEEG software for quantitative EEG analysis was used in the study. Results were analysed via an endorsed QEEG Diplomat trained in EEG analysis.

4. Assessment

Assessment measures used at STARTTS neurofeedback clinic can be seen in Table 2. Collected at baseline was Zeya's refugee and developmental trauma history as seen in Table 3 below.

Table 2. List of assessment measures collected at baseline, mid and post treatment.

Assessment	Description
Clinical Interview	Assessment of client's presenting issues, developmental history, refugee trauma history, and current health and lifestyle factors.
Harvard Trauma Questionnaire (HTQ-R) (Mollica et al., 1992)	A cross-cultural questionnaire measuring trauma exposure and PTSD related symptoms widely used in refugee mental health research.
Hopkins Symptom Checklist – Depression (HSC-D) (Mollica et al., 1987)	A cross-cultural questionnaire measuring symptoms of depression widely used in refugee mental health research.
Hopkins Symptom Checklist – Anxiety (HSC-A) (Mollica et al., 1987)	A cross-cultural questionnaire measuring symptoms of anxiety widely used in refugee mental health research.
DASS-21 (Lovibond & Lovibond., 1995)	Three self-report scales that measure the states of depression, anxiety, and stress.
World Health Organization Wellbeing Index (WHO-5) (Topp et al., 2015).	A brief five item self-report measure of current mental wellbeing.
Digit Span (Wechsler., 2008)	A cognitive subtest examining attention and working memory from the Wechsler Adult Intelligence Scale – IV.
STARTTS Arousal Questionnaire (Fisher., 2014)	An internal instrument to assess for symptoms of ANS over-arousal, under-arousal and unstable arousal as defined through categories of; sleep symptoms, emotional and behavioural symptoms, pain, and body-related symptoms, and immune, endocrine and ANS symptoms.
Heart Rate Variability biofeedback assessment (Lehrer & Gevirtz., 2014)	Heart rate data was recorded as a measure of cardiorespiratory function.
Quantitative Electroencephalogram (EEG)	Resting-state EEG activity for eyes open and eyes closed conditions measuring brainwave activity.

Table 3. Zeya's scores for the ACE and HTQ-E questionnaires highlight severe childhood trauma and refugee trauma exposure, suggesting the cause of Zeya's cPTSD was due to harm from both war and home environments.

Assessment	Description
Adverse Childhood Experiences (ACE) questionnaire	Zeya's ACE score was 8/10. This suggests the presence of significant child maltreatment, abuse and adverse events from her childhood.
Harvard Trauma Questionnaire Events scale (HTQ-E) (Mollica et al., 2004)	A checklist of 16 potentially traumatic events (PTE) common to many refugees. Zeya directly experienced: -Lack of food and water -Ill health and lack of medical care -Lack of shelter -Imprisonment -Serious physical injury/assault -Combat -Brainwashing -Enforced isolation from others -Being close to death/life threat -Forced separation from family -Murder of family or friends -Unnatural death of family or friends -Murder of strangers -Disappearance or kidnapping -Torture Zeya's PTE score of 15/16 highlights a dose response effect of cumulative refugee trauma.

5. Treatment

Neuromodulation and psychotherapy treatment was provided by a registered forensic psychologist and clinical psychology candidate with certified training in neurofeedback, the SSP, and a range of evidence-based psychological interventions. Where possible, the patient attended twice weekly sessions of neuromodulation however continuous training was interrupted by the COVID pandemic and multiple, extended COVID lockdowns across Australian states. Due to the pandemic, the neurofeedback clinic was closed intermittently as recommended by NSW Health guidelines. When this occurred, weekly telehealth psychological treatment took place. An emphasis was placed on in vivo exposure, CBT and other psychology interventions. Zeya completed a total of 10 sessions of SSP and 26 sessions of neurofeedback across a 16-month period. In comparison when not affected by COVID

restrictions, such treatment could be completed in approximately five months. A general treatment timeline can be viewed in the table below.

Table 4. SSP treatment is typically used as a priming intervention before a main intervention. At STARTTS neurofeedback clinic, the SSP is administered at pre, mid and post treatment so repeated activation of ventral vagal state regulation can take place. See below for Zeya's original treatment plan.

Stage 1	Stage 2	Stage 3
Five hours of the SSP "Core" program	Five hours of the SSP "Core" program	Five hours of the SSP "Core" program (optional)
1 to 20 sessions of neurofeedback training *twice weekly	1 to 20 sessions of neurofeedback training *twice weekly	
Adjunct psychotherapy	Adjunct psychotherapy	

Zeya demonstrated an immediate, and positive response to neuromodulation treatment. She did not need as many sessions as planned to reach a level of robust recovery. Treatment sessions typically lasted an hour and were split into 30 mins of psychotherapy and 30 mins of neurofeedback per session. COVID safety best practice guidelines were implemented as directed by NSW Health including the sterilisation of neurofeedback and SSP equipment, and social distancing requirements. The text box below highlights evidence-based psychotherapy Zeya engaged in whilst having concurrent neuromodulation treatment.

Text box. 1. Adjunct Psychotherapy that supported Zeya's recovery from cPTSD.

- *Psychoeducation*
- *Trauma informed CBT*
- *DBT*
- *Narrative therapy*
- *Mindfulness*
- *Grounding exercises*
- *Diaphragmatic breathing and tapping exercises*
- *Graded exposure*
- *In Vivo exposure to target avoidance and safety behaviours that perpetuated the maintenance of cPTSD symptoms*
- *Grief processing*
- *Social skills; more effective communication in relationships*
- *Boundary setting*
- *Roleplays*
- *Attachment; repair and reconnection*
- *Co-regulation with children and father*

The last stage of in vivo exposure centred around the upcoming 50th anniversary of Zeya's mother's death. She had never been buried, nor was her body ever found again. For the first time in 50 years Zeya planned a burial ceremony for her mother. Zeya and her family performed appropriate death rituals to acknowledge the passing of family in the genocide. Zeya was able to process her anger and loss, and she was offered a sense of healing with her father, children and cultural community who were involved in the proceedings. This final act of exposure offered Zeya a sense of closure. Attachment repair, reconnection of social bonds, and a ventral vagal state of safety was achieved as Zeya completed the final stage of her recovery. This time she was not alone, and she was surrounded by family, friends, and community to assist her with her grief. Collectively, they honoured the dead and their healing as genocide survivors was symbolic and life-affirming of their survivorship and resilience. This last therapeutic event was key to unlocking Zeya's defense cascade. After the event, her residual cPTSD and arousal symptoms diminished to the point of extinction. The table below showcases Zeya's treatment schedule.

Table 5. Zeya's treatment plan. By the 4th session of neurofeedback there was a 75% symptom improvement in anger, rumination, hypervigilance, sleep, and quality in her close relationships. This suggests evidence that the SSP may have been successful in accelerating the effects of neurofeedback treatment given her prior history of being treatment-resistant and remaining symptomatic of cPTSD.

Neurofeedback Protocols	Frequency range (reward)	Training sessions	Duration	Rationale	Brain area	Training Schedule
SSP	n/a	5	5 hours of Core program	Calm trauma response, reduce auditory sensitivities, and anxiety	Vagus nerve stimulation, brain stem, ANS function	5 sessions in a period of 1.5 weeks

T3-T4	SMR hertz) Alpha hertz)	(12-15 (10-13	9	10 to 14 mins	Assists with headaches, panic, anxiety, nightmares, and general stabilisation of symptoms	Temporal lobe: Calming of the amygdala, bilateral placement to improve connectivity between left and right hemispheres, stabilising effect	2 month break in treatment re: COVID lockdown. Psychotherapy focus Zeya successfully decreased antidepressant medication for the first time in 30 years.
T4-P4	SMR hertz)	(12-15	12	9 to 18 mins	Assists with anger, emotional reactivity and improved sensory and perceptual body integration	Temporal lobe: Calming of the amygdala, increased sensory and body integration	4.5 month break in treatment re: COVID lockdown. Psychotherapy focus
SSP	n/a		5	5 hours of Core program	Calm trauma response, reduce auditory sensitivities, and anxiety	Vagus nerve stimulation, brain stem, ANS function	5 sessions in a period of 2.5 weeks
C3-C4 *Note: C3-C4 and FZ-A2 were combined as two protocols in a single treatment session.	SMR hertz)	(12-15	6	8 to 15 mins	Assists with headaches, panic, anxiety, nightmares, and general stabilisation of symptoms	Sensory motor cortex, cerebral cortex, bilateral placement to improve connectivity between left and right hemispheres, stabilising effect	Concurrent in vivo exposure
FZ-A2	SMR hertz)	(12-15	3	4 to 5 mins	Enhance inhibitory abilities, executive functioning, and attention. Fear reduction.	Anterior Cingulate Cortex, higher level functions e.g., attention, impulse control, decision-making, emotions, and fear response.	Concurrent in vivo exposure

6. Results and Discussion

When Zeya self-referred to STARTTS she met diagnostic criteria for cPTSD, major depression, and an anxiety disorder (unspecified). She struggled daily with hypervigilance and fear-based thoughts regarding the belief "I might die". Zeya was preoccupied with germs and catching COVID. She feared food poisoning and enclosed spaces where she perceived she had no escape. She was afraid to be on her own. Simple tasks such as preparing family meals or going to the restroom which occurred multiple times a day were dominated by safety behaviours to appease her fear. Zeya's scores in the HTQ-R and HSCL-25 as seen in Figure 1, showcase a resolute score of 1.0 indicating zero clinical symptoms or concerns post treatment. Zeya's trauma/PTSD symptoms, and depression and anxiety symptoms fell within "normal" functioning. Furthermore, at the time of the post assessment, Zeya tested positive with COVID. It is possible her score of 1.25 ("normal" functioning) was mildly elevated due to her being ill at the time of the assessment. However, despite her previous fears of dying, this event did not reactivate fear circuitry in her brain. Her recovery from cPTSD continued to be robust.

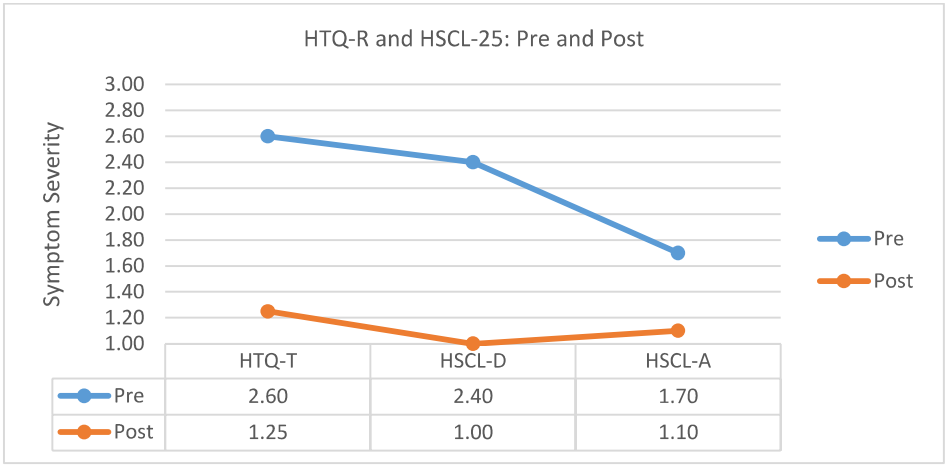


Figure 1. Zeya's scores on the HTQ-R and HSCL-25, gold standard measures that indicate refugee psychopathology, demonstrate a return to normal functioning for the first time in 50 years.

At baseline, Zeya reported chronic difficulties with emotional and behavioural symptoms, sleep difficulties, pain and body symptoms, and ongoing immune and endocrine issues. Prior to neuromodulation Zeya endorsed 50 problematic symptoms on any given day related to difficulties with overarousal (e.g., nightmares, panic attacks, hypervigilance, restlessness), under-arousal (e.g., hopelessness, helplessness, frequent waking at night, tension headaches and chronic body pain), and unstable arousal (e.g., tinnitus, irritable bowel syndrome, asthma, menopausal hot flushes). Post neuromodulation treatment, cPTSD and ANS dysregulation that had been present for half a century extinguished.

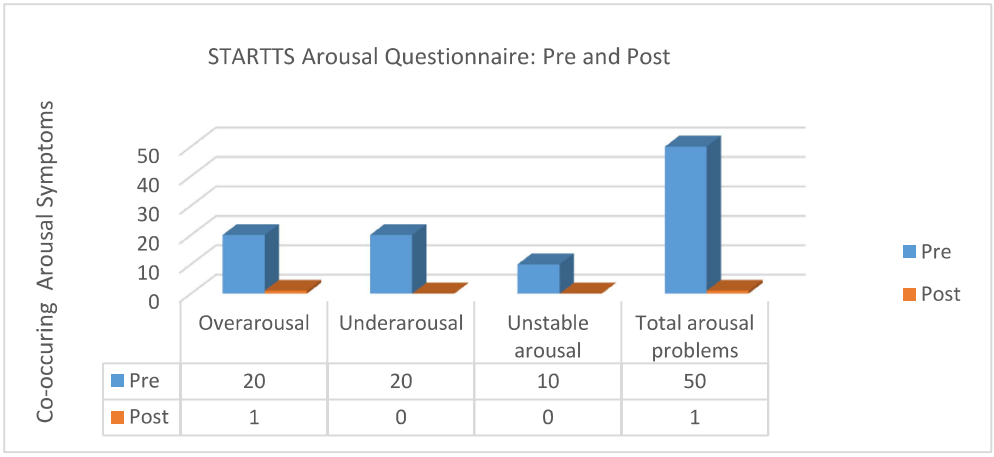


Figure 2. Zeya's chronic issues with ANS arousal and dysregulation self-corrected as a result of treatment.

Changes in HRV which reflect vagal tone and PNS activity in the body, suggest positive changes in Zeya's autonomic and cardiac function as a result of treatment. The decrease in Zeya's heart rate over time (see data below in Table 6) may be suggestive of a greater parasympathetic influence on her heart which correlate with the extinction of her cPTSD symptoms. Prior research studies have demonstrated that an increase in vagal tone can decrease heart rate, and it is hypothesised that this is likely to have occurred. Patients with SDNN values of <50 ms are generally classified as unhealthy, with Zeya's pre HRV scores indicating SDNN values between 41-46 in eyes open and closed conditions. Her post treatment scores of 66-67 SDNN suggest her heart and respiratory functioning have improved from baseline. HRV studies suggest a RMSSD value of 13–48 ms is generally present in healthy adults with Zeya's baseline falling just within this range. Her post treatment RMSSD values of 69-74 ms reflect a more adaptive heart to brain axis and positive changes in Zeya's physiology.

Table 6. Zeya's HRV scores highlight a decrease in resting heart rate which can occur when there is greater PNS activity.

	Eyes Open Pre	Eyes Open Post	Eyes Closed Pre	Eyes Closed Post
Heart rate (bpm) Heart rate in beats per minute	72	57	69	57
SDNN (ms) Standard deviation of NN intervals	41.11	67.1	46.02	65.9
RMSSD (ms) Root mean square of successive RR interval differences	40.53	69.4	49.07	74.7

Zeya's difficulties with depression, anxiety, and stress (i.e., the stress scale in the DASS-21 reflecting non-specific problems in arousal) changed from 'severe' to 'normal' functioning post treatment. These findings were correlated with refugee specific questionnaires used in the study. In addition, Zeya's feelings of wellbeing increased two-fold as a result of neuromodulation. Her digit span data suggests a mild improvement in attention and working memory capacity. Her occupation in a managerial role working with data afforded Zeya excellent verbal short-term and working memory. When compared with other refugee and trauma survivors, Zeya's prefrontal cortex and higher thinking skills appear to be reasonably intact which is surprising given her trauma history. It may also be evidence of her prior TMS treatment having had a positive effect on her frontal lobe regions, despite her arousal issues remaining chronic until SSP and neurofeedback treatment commenced

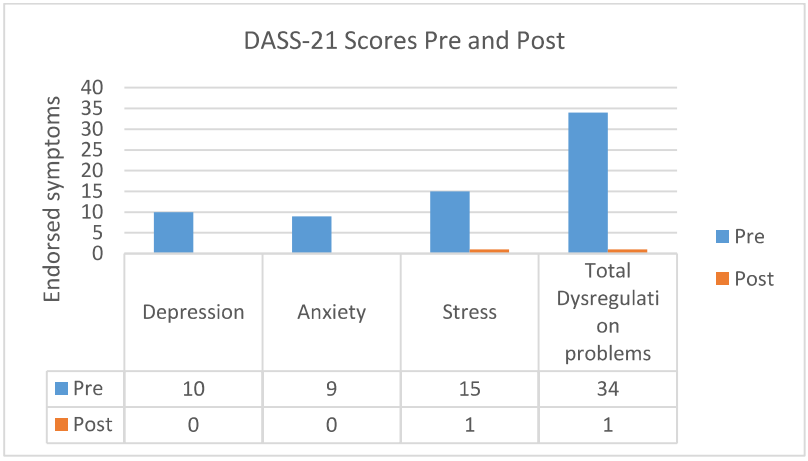


Figure 3. Zeya's DASS-21 scores further confirm the client's recovery as robust across multiple assessment instruments.

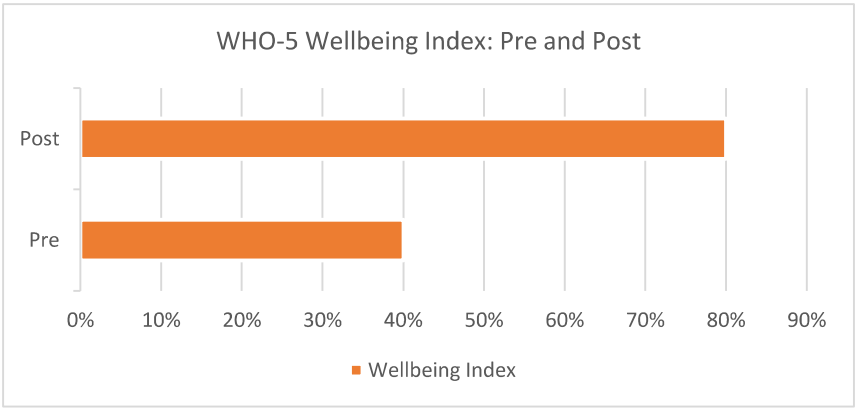


Figure 4. Zeya's Wellbeing Index doubled post treatment

Table 7. Zeya showed mild improvement in her executive functioning post treatment. Her baseline scores are well above the mean and highlight Zeya's cognitive strengths in verbal short-term memory and working memory.

	Pre	Post
Digit Span Forward (raw)	11 (mean 6.8)	12 (mean 6.8)
Digit Span Backward (raw)	6 (mean 4.8)	6 (mean 4.8)
Digit Span Sequencing (raw)	6 (mean 5.7)	7 (mean 5.7)

Furthermore, changes in QEEG brainwave patterns as a direct result of neuromodulation treatment can be seen in the Diagram 1. In summary, the main findings from Zeya's baseline EEG indicated the participant had a desynchronised EEG with mu and left frontotemporal transients. Her EEG pattern was classified as low voltage fast, with frontal lobe asymmetry and poorly defined alpha, suggesting difficulties with inhibitory control. Main findings from her post EEG assessment indicate improvements in temporal lobe functioning, sleep onset, and slower brainwave rhythmic activity. Slower activity in the beta range from fast to slower frequencies and a shift from left frontal asymmetry to a right frontal asymmetry (reversal of frontal asymmetry) suggest changes in the power distribution of alpha, mu, and beta (see Diagram 2 and 3). This suggests Zeya can now demonstrate situationally appropriate arousal levels and improvements in arousal regulation, inhibitory control, mood, and memory capabilities were evident. Less over and under activation has resulted in Zeya being able to produce more stable brain frequencies that reflect a calm level of alertness.

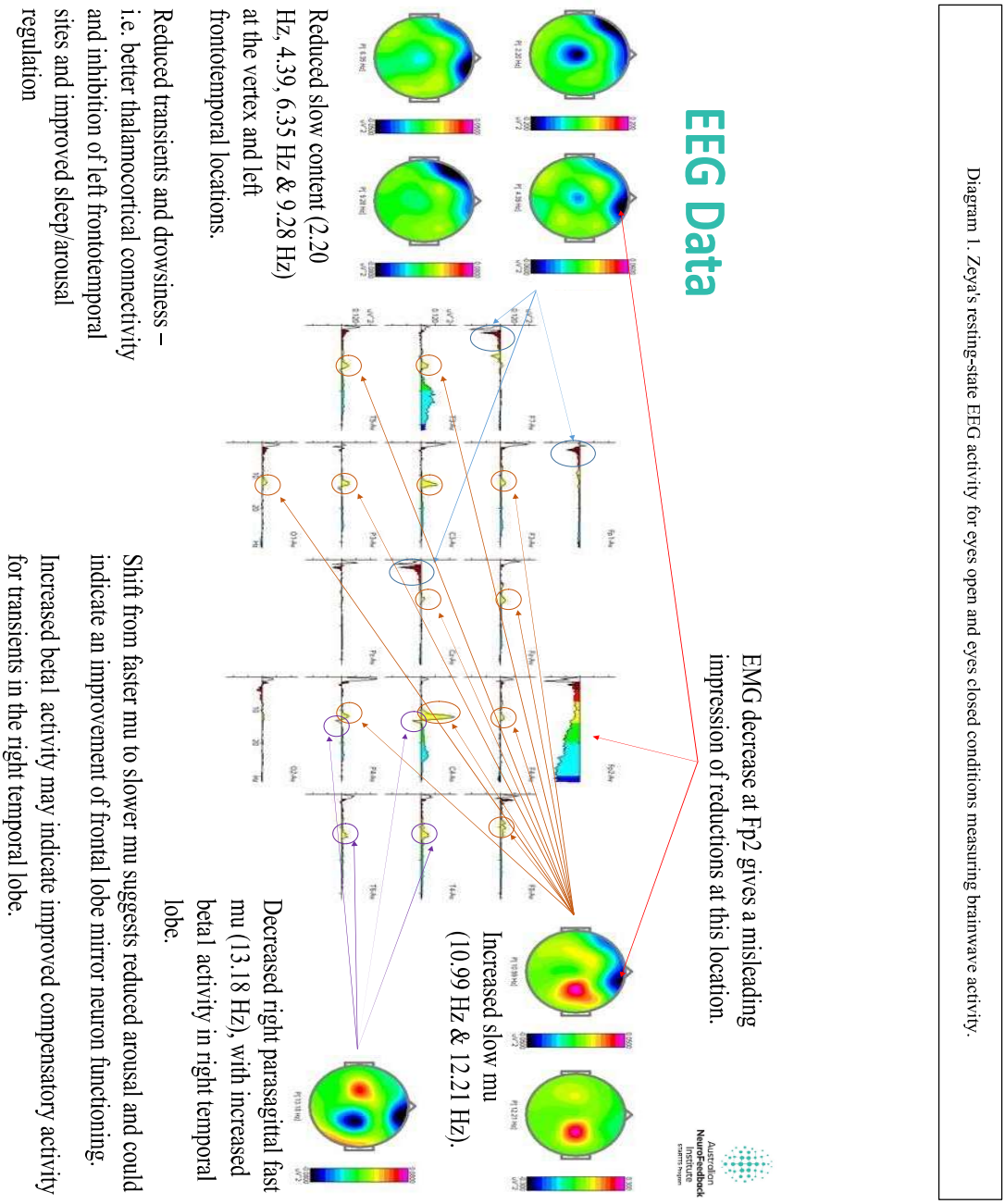


Diagram 1. Zeya's resting-state EEG activity for eyes open and eyes closed conditions measuring brainwave activity.

Diagram 2. Left frontal symmetry was observed in Zeya's Eyes Open pre-treatment EEG. Frontal brain symmetry represents trait markers seen in the presence of psychopathology and acute emotional reactivity. Beta brain waves are often associated with hyperarousal and high ruminative states.

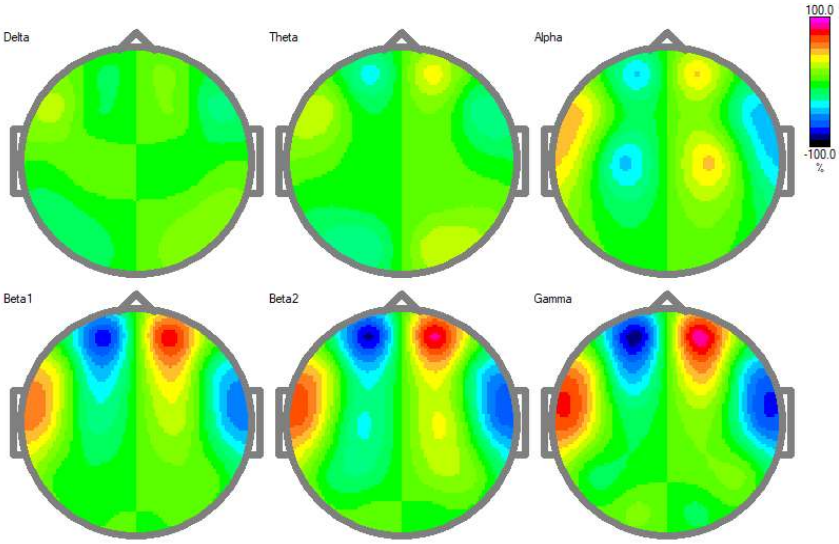
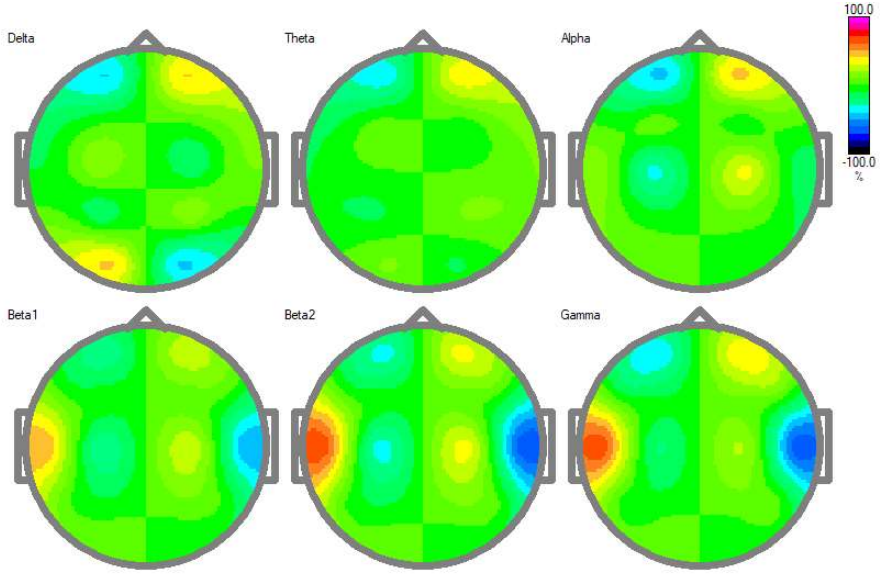


Diagram 3. A trend to right frontal symmetry was noted in Zeya's Eyes Open post-treatment EEG. The shift in frontal asymmetry from the left hemisphere to the right, and associated reduction in slow content, increased the stability of sleep sub-stage transitions, and reduced vertex slowing suggests improvements in arousal regulation that corroborates Zeya's self-report measures.



7. Conclusion

This case study is the first of its kind (known to authors) to combine two neuromodulation methods, the SSP and neurofeedback, in a treatment regime for a refugee torture survivor with cPTSD. The application of 36 sessions of neuromodulation served to simultaneously regulate dysfunctional brainwave activity and address imbalances of the ANS that act as maintaining factors of cPTSD. The SSP and neurofeedback worked as distinct yet complimentary neuromodulation methods by stimulating the vagus nerve as a means of calming the central and peripheral nervous systems, whilst also reorganising the neural circuitry of torture. Changes in physiological and vagal state regulation allowed Zeya to engage more effectively with adjunct psychotherapy. Psychotherapy assisted Zeya to safely process deeply suppressed trauma reactions that had somatically, neurologically, and psychologically locked Zeya into a permanent defense cascade. When brainwave and autonomic dysregulation stabilised to more normal and adaptive patterns of functioning, Zeya was able to make sense of her experiences and reinterpret the events in a new manner. Attachment repair and reconnection took place; and activation of the client's "social brain" played an important role in healing from complex trauma.

For the first time in half a century, neural circuitry that maintained Zeya's cPTSD extinguished and a reduction in complex avoidance and hypervigilant behaviours were observed. Changes in brainwave functioning showed improvements in inhibitory control, sleep onset, and the slowing of beta brain waves. The lowering of resting heart rate may suggest greater vagal modulation of the heart and increased PNS influence. A reduction in cPTSD, depression, and anxiety symptoms were achieved to the point of

extinction in a relatively brief amount of time compared with 50 years of neuropsychiatric disturbance. These findings were robust across self-report and physiological marker measures. Future direction in this area requires greater randomised control trial research, neuroimaging research, longitudinal research, cross-sectional research, and larger scale heterogeneous sample groups to make conclusive statements regarding treatment efficacy. A combined neuromodulation approach in the treatment of cPTSD is certainly promising and may in fact, be more superior, than singular neuromodulation methods. This has implications that extend far beyond the refugee trauma field, and into the areas of neuroscience, developmental trauma, early childhood development and beyond as we learn of new methods that may extinguish lifelong cPTSD sequelae.

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