

The Effects of Neurofeedback on the Parasympathetic and Sympathetic Nervous Systems: Three Case Studies

by

Richard C. Lill, LCSW; Nicholas L. DePace, MD; Joe Colombo, PhD, DNM, DHS

ABSTRACT

INTRODUCTION

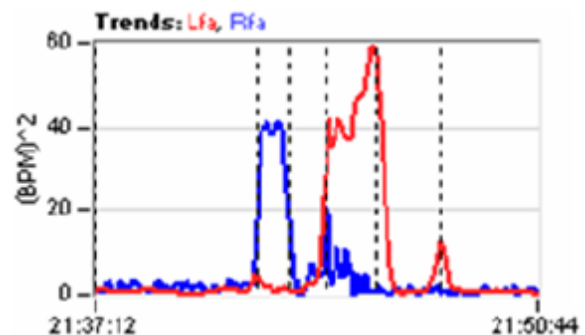
Parasympathetic and Sympathetic (P&S) nervous system monitoring (*aka.*, Cardio-Respiratory Monitoring) provides more information regarding an individual patient's clinical condition or wellness [1]. There are a number of pharmaceutical [1] and non-pharmaceutical [2] treatments and therapies available to treat any and all P&S (autonomic) disorders. However, there are still some patients that do not respond and continue to suffer P&S dysfunction. An option that has presented is Neurofeedback. Neurofeedback involves the retraining of the brain to restore balance, including balance between the P&S nervous systems, including the portions of the P&S nervous systems that are in the brain. For example, the “mathematical” (left) side of the brain is found to be Parasympathetically dominant and the right-side of the brain is Sympathetically dominant [ref Shaun's work]. Three patients that were resistant to all other autonomic treatments and therapies were referred to Neurofeedback are presented; two of whom survived COVID-19 infections.

METHODS

The patients reported here are from a single, suburban, cardiovascular and autonomic dysfunction clinic in the northeastern United States of America (Sicklerville, NJ, USA) where they were diagnosed with autonomic dysfunction and treated with little effect and ultimately referred to Neurofeedback therapy nearby (Toms River, NJ, USA). Detailed patient histories and physicals were taken as routine. Exclusion criteria included: pregnancy, nursing, or refusal of testing. All patients consented to testing and patient data were maintained according to HIPAA guidelines.

Cardio-Respiratory Monitoring

Each patient had the following tests: Vestibular testing; Mast Cell blood and urine work; Small Fiber Neuropathy (Sudomotor) testing; age- and symptom-specific cardiology testing; and serial Cardio-Respiratory Monitoring (*aka.*, P&S Monitoring; Physio PS, Inc., Atlanta, GA), which includes the Ewing challenges resulting in the Ewing Ratios (E/I Ratio, Valsalva Ratio, and 30:15 Ratio, respectively [3,4,5]). The blood and urine work were performed by third-party labs according to the patient's medical insurance policy.



The remaining tests are easily performed in the out-patient setting. P&S Monitoring includes LFa as the direct measure of Sympathetic (S) activity, RFa as the direct measure of Parasympathetic (P) activity, and Sympathovagal Balance ($SB=S/P$, measured at rest as the average of ratios, not the ratio of averages) [6]. P&S Monitoring includes: A) five-minute, initial resting baseline, B) one-minute, deep breathing challenge (breathing paced at 0.1 Hz; a strong Parasympathetic challenge), C) one-minute, baseline, D) 1:35 minute, Valsalva challenge (including one 15 second Valsalva maneuver followed by a series of 10-second Valsalva maneuvers; a strong Sympathetic challenge), E) two-minute, baseline, and F) a quick postural change (stand), followed by five-minutes of quiet standing (a challenge of the coordination between the two P&S systems, which also helps to differentiate causes of lightheadedness and dizziness). A plot of normal adult P&S responses to P&S Monitoring is displayed in the insert, right.

Neurofeedback

The Electroencephalogram (EEG) is largely comprised of four clinical frequencies that have been associated with certain (normal) and essential daily activities, such as: sleep, relaxed attention, and hyper-attention. The different frequencies are labeled [7]:

- Alpha – waveforms associated generally with a state of relaxation (8-12 Hz)
- Beta – the fastest of the waveforms correlated, which represent a state of mental, intellectual activity, outward focused attention; (12-35 Hz)
 - the lower end of this frequency band (e.g., Sensorimotor Rhythm or SMR) corresponds to a state of relaxed attentiveness (12-15 Hz);
 - the hyper-state of high-frequency beta brainwaves is as high as 35 Hz;
- Delta – the slowest of the waveforms correlated, which are associated with deep restorative sleep (0.5-3.5 Hz);
- Theta – waveforms represent a deeply relaxed, daydreaming state (4-8 Hz).

Each of these brainwave frequencies are always present to some degree in different parts of the brain [8]. EEG Biofeedback (*aka.*, Neurofeedback⁹) has been in use as a clinical intervention for well over 30 years. It has been stated in conference that 298 of 315 major studies have demonstrated success. Yet Neurofeedback remains underutilized. One reason for this has been the difficulty in obtaining quantitative measures of clinical outcomes. P&S Monitoring, however, provides quantitative measures. It is well known that the individual P&S branches are associated with the different frequencies and different portions of the brain [ref Shaun's work].

Cortical plasticity can be changed with computer brain interface (CBI) techniques. CBI provides visual or auditory feedback to alter neural activity. Lasting changes in cortical plasticity have been detected following Neurofeedback. Neurofeedback is a relatively user-friendly method to operantly condition brain activity and to reshape neural activity to relieve neuropathological symptoms, or improve neural and behavioral performance, in many areas [10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34]. Neuropathology research has shown that turning abnormal rhythms and frequencies (based on Quantitative-EEG, or QEEG³⁵) into normal (or relatively normal) rhythms and frequencies, turns abnormal psychological states into normal ones [36].

During amplitude training, protocols are decided based on the QEEG or Mini-Map, in addition to history and symptoms. History becomes imperative with these patients at this point in order to ensure success in training. After evaluation, a determination is made as to which protocol is most commonly going to reward the Sensory Motor Rhythm (SMR) Beta or Alpha rhythm, and finds the placement and frequency that works best for the patient, based on the Mini-Map or QEEG results. The three common modes of training are:



Neurofeedback therapy is like playing video games

Alpha-Training – In cases of low-Alpha (from head injuries or injuries causing reduced cognitive abilities), Neurofeedback rewards Alpha while inhibiting the other brainwaves. High-Alpha may cause over arousal (a state of wakeful relaxation).

Sensory Motor Rhythm (SMR, 12-15 Hz) Beta (15 – 18 Hz) Training – This is a common form of training where the reward frequencies will be 12-15 Hz on the right side to decrease arousal and 15-18 on the left side to increase arousal. In individuals who suffer from anxiety or an over aroused brain it is common practice to work on the right (Sympathetically dominant) hemisphere which should alleviate any anxiety symptoms. Success in any neurofeedback training will likely be determined by the client over the following 24-48 hours and any change will fade away. Training includes approximately 30 SMR/Beta training sessions (depending on severity) of 50-minutes each over a two month period. In SMR/Beta-training (visual, relaxed attention), the suppressed frequencies are Delta (2–5 Hz), Theta (5–8 Hz), and high Beta (18–30 Hz). SMR/Beta neurofeedback training focuses on the Sensory Motor Strip and has been demonstrated to reduce Anxiety, improve aspects of personality, and decrease stress-related and blood-based beta-endorphins [37].

Alpha-Theta or Alpha Neurofeedback Training – includes approximately 30 SMR training sessions (depending on severity) of 20-minutes each over a two month period. Alpha-theta neurofeedback training focuses on the Parietal brain cortex area, and has been demonstrated to improve mood, personality inventory scales, ability to focus, and ability to processes information, with demonstrated benefits for patients with PTSD and Addiction, and individuals training for Peak Performance.

RESULTS

PATIENT 1, Female, dob: 01/04/2001

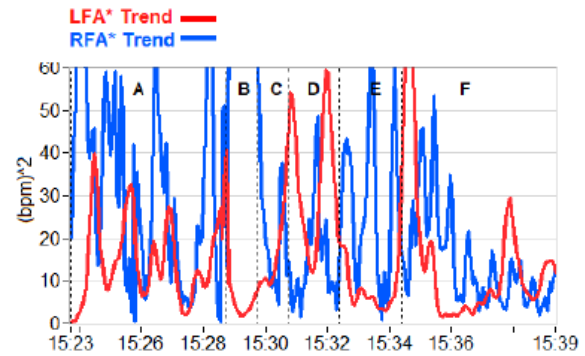
Baseline Test. 07/25/2022; Age 21, Ht. 5’4”, Wt. 153#. Patient 1 reports lightheadedness, near-Syncope, palpitations, fatigue, brain-fog, difficulty finding words, memory difficulties,

paresthesias, nausea, difficulty standing, shortness of breath, hyperhidrosis, cold hands and feet, heat intolerance, depression, anxiety, and constipation.

At rest, Patient 1 demonstrates normal Heart Rate (HR) and elevated Blood Pressure (BP), high P&S activity (see section A of her Trends plot, right) and low-normal Sympathovagal Balance (SB = 0.48; indicating resting Parasympathetic Excess, PE).

Her deep breathing challenge response (section B) is normal. Her Valsalva challenge Sympathetic

response (section D) is borderline low indicating possible Small Fiber Disorder (SFD) and the Valsalva BP response is weak indicating Baroreceptor Reflex (BRR) disorder. She reported lightheadedness during Valsalva. Upon standing, she demonstrates (1) alpha-Sympathetic Withdrawal (SW) with (2) a 3/1 mmHg drop in BP and (3) a trend towards tachycardia, together indicating Postural Orthostatic Intolerance; and (4) an instantaneous Sympathetic Excess (SE³⁸, see section F), indicating (pre-clinical) Syncope. PE with stand SE indicates Vasovagal Syncope (VVS). She reported lightheadedness during stand. Her elevated resting BP is compensatory for her postural change abnormalities and should normalize as her stand response normalizes [39].



A plot of her baseline P&S responses to P&S Monitoring is displayed in the P&S Trends plot (insert), above, right. Comparing Patient 1's baseline Trends plot with the normal adult Trends plot in Methods, it is obvious that there is too much P&S activity, especially while resting: at the baselines (sections A, C & E of the trends plot) and during quiet standing (the later portion of section F of the Trends plot). This excess activity is responsible for her symptoms. This excess activity is responsible for her symptoms. Given her sensitivity to medications, she was referred to Neurofeedback.

Neurofeedback Baseline 09/20/2022. At initial evaluation Patient 1 completed (1) an arousal assessment to help in guiding the training based on symptoms, (2) a mini-map (Table 1) to objectively help guide training, and (3) a history intake. Based on the findings it was determined that T4-P4 would be the most appropriate training protocol. Symptoms reported on the arousal assessment included: under arousal- poor concentration, inattentive, distractibility, frequent day dreaming, spaciness/fogginess, forgetful, confused thinking, depression/low mood, sensitive/feelings easily hurt, low self-esteem, frequent waking at night, not feeling rested after sleep, likes caffeine, dislikes alcohol, overarousal, busy mind/many competing thoughts, impulsivity, fidgety, easily bored, risk seeker, agitated, aggressive, angry depression, anxious/fearful, feeling overwhelmed, low emotional awareness, heart palpitations, unstable arousal, chronic fatigue, wakes during night/light sleeper, sleep walking, hot flashes, psychiatric illness in family w/ hospitalization, PMS symptoms, and poor eye contact. She additionally reported having anxiety since she was in 1st grade. Patient 1 was prescribed Klonopin at the start of neurofeedback training.

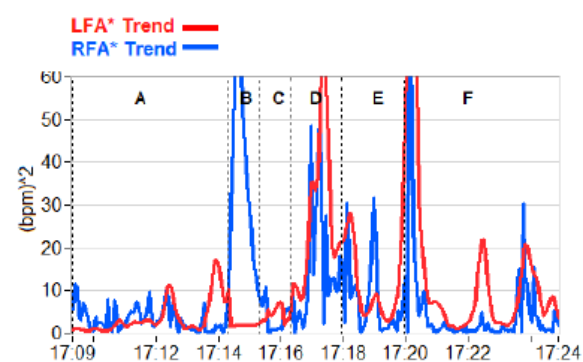
Neurofeedback retest correlating with PhysioPS 05/11/2023- Patient 1 attended 30 trainings 1x weekly at T4-P4. At this time Patient 1 reports the following symptoms on her arousal

assessment. Under arousal- dislikes alcohol effects, over arousal- impulsive, dislikes caffeine, unstable arousal- hot flashes, psychiatric illness in family, PMS Symptoms, Poor Eye contact.

9/20/2022	CZ (mv)	PZ (mv)	PZ E/C (mv)
4-8 Hz	14.6	12.4	12.9
8-12 Hz	8.4	8.3	9.6
12-18 Hz	6.9	7.2	9.3
22-36 Hz	8.0	8.1	9.2

Table 1: Patient 1 baseline mini-map showing excess activity in 4-8 Hz at CZ (14.6 mV) and PZ (12.4 mV), low activity in 8-12 Hz at CZ (8.4 mV) and PZ (8.3 mV) and elevated activity in 22-36 Hz. The activity in 4-8 Hz is the dominant pattern with a Theta/Beta Ratio of 2.11 and a Posterior Dominant Rhythm (PDR) of 8 mV. We additionally do not see the expected 50% increase in activity in the 8-12 Hz frequency at PZ with eyes closed.

Follow-up Test. 05/11/2023; Age 22, Ht. 5'4", Wt. 160#. Patient 1 reports continued hyperhidrosis, dimmed vision, but with many P&S symptom improvements.



At rest Patient 1 demonstrates continued normal HR, normalized BP, and normalized P&S activity (see section A of her Trends plot, left) and SB have (SB = 1.02). Her deep breathing challenge response remains normal (section B). Her Valsalva challenge Sympathetic response remains low indicating possible Small Fiber Disorder (SFD) (section D) and BP response remains weak indicating BRR disorder. She no longer reports lightheadedness during Valsalva. Upon standing

(section F), the SW has been relieved, and her standing BP & HR responses have normalized; however, the SE persists, but she no longer reports lightheadedness during stand. Her normalized resting BP is a response to her partially normalized stand responses. Overall her follow-up P&S responses to P&S challenges show that her P&S activity has settled significantly and is much more calm, tending towards normal (see Methods).

5/11/2023	CZ (mv)	PZ (mv)	PZ E/C (mv)
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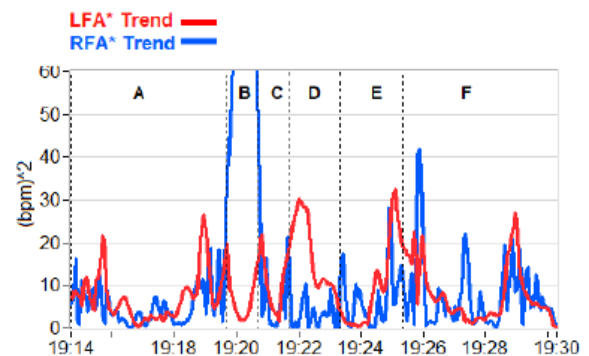
4-8 Hz	12.7	12.0	12.7
8-12 Hz	8.2	7.9	10.0
12-18 Hz	7.6	7.3	9.8
22-36 Hz	6.6	6.4	7.4

Table 2: Patient 1 follow-up mini-map. After Neurofeedback training, Patient 1 demonstrates decrease in 4-8 Hz activity at CZ and PZ, and increase in 8-12 Hz activity at PZ, but decrease at CZ, increase in 12-18 Hz activity at both CZ and PZ, and decrease in 22-36 Hz activity at both CZ and PZ. Patient 1 demonstrated a decrease in Theta/Beta Ratio from 2.11 to 1.67. Ultimately when looking at change in her activity there is a demonstrated improvement in regulation as seen in her P&S responses and improvements in symptoms.

Patient 2, Male, dob: 06/21/1997

Baseline Test. 02/03/2021; Age 23, Ht. 6'3", Wt. 200#. Patient 2 reports lightheadedness, dizziness, presyncope, fatigue, history of tachycardia upon standing, anxiety, shortness of breath, palpitations, chest pain, numbness and tingling (paresthesia) in hands and feet, cold and heat intolerance; and a prescription for Finasteride 1 mg QD.

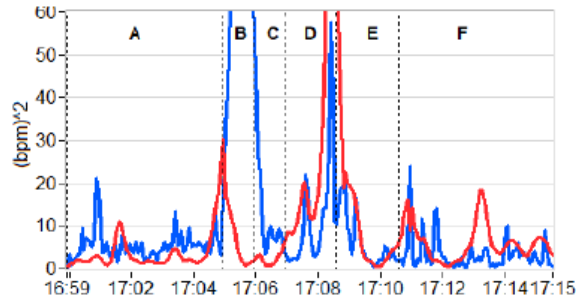
At rest Patient 2 reports normal HR, high BP, P&S activity within normal limits (see section A of trends plot, insert, right) and normal SB (=1.40). His deep breathing challenge response (section B) is normal, however, he reports shortness of breath. His Valsalva challenge Sympathetic response (section D) is low indicating Small Fiber Disorder (SFD) with a normal BP response. His reported shortness of breath normalized during Valsalva. Upon standing, he demonstrates (1) SW with (2) a weak BP response indicating Orthostatic Intolerance (OI); (3) PE (section F) and (4) an instantaneous SE (section F), indicating (pre-clinical) VVS. He did not demonstrate tachycardia during stand. His high resting BP is compensatory for his postural change abnormalities (OI & VVS).



A plot of his baseline P&S responses to P&S Monitoring is displayed in the P&S Trends plot (insert), above, right. Comparing Patient 2's baseline Trends plot with the normal adult Trends plot in Methods, it is obvious that there is too much P&S activity, especially while resting: at the baselines (sections A, C & E of the trends plot) and during quiet standing (the later portion of section F of the Trends plot). This excess activity is responsible for her symptoms. Given her sensitivity to medications, she was referred to Neurofeedback.

Follow-up Test 1: 11/12/2021; Age 24, Ht. 6'3", Wt. 200#. Patient 2 reports no improvement, in fact he reports additional symptoms, including: hypohidrosis, coat hanger pain, constipation, nausea, difficulty sleeping, brain-fog, difficulty finding words, memory difficulties, light sensitivity, incomplete and frequent urination, s/p concussion, s/p COVID-19 virus, and migraine headaches.

At rest Patient 2 continues to report normal HR, high BP, normal P&S activity (see section A of trends plot, insert, left), now low-normal SB



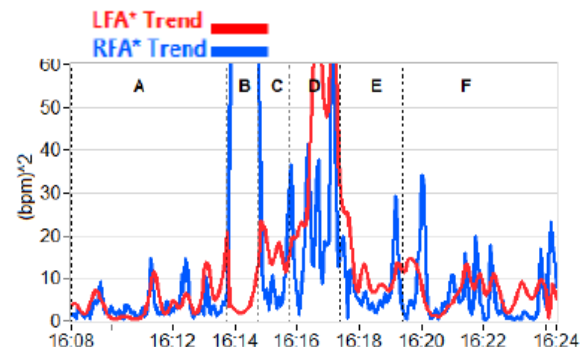
(=0.60) indicating resting PE. His deep breathing challenge response (section B) remains the same. His Sympathetic response to Valsalva (section D) improved, however, due to PE upon Valsalva.

Upon standing, he demonstrates (1) no change in HR, (2) a drop in systolic BP, (3) both indicating masked SW continuing to indicate OI; with continued (4) PE (section F) and (4) an

instantaneous SE (section F), indicating (pre-clinical) VVS. His continued high resting BP is compensatory for his postural change abnormalities (OI & VVS). All demonstrating that he is not responding to treatments and therapy. COVID-19 set him back, causing more PE, especially with stress (simulated by the Valsalva maneuver). Correction to dosing regimen was made in an attempt to effect relieve from autonomic dysfunction.

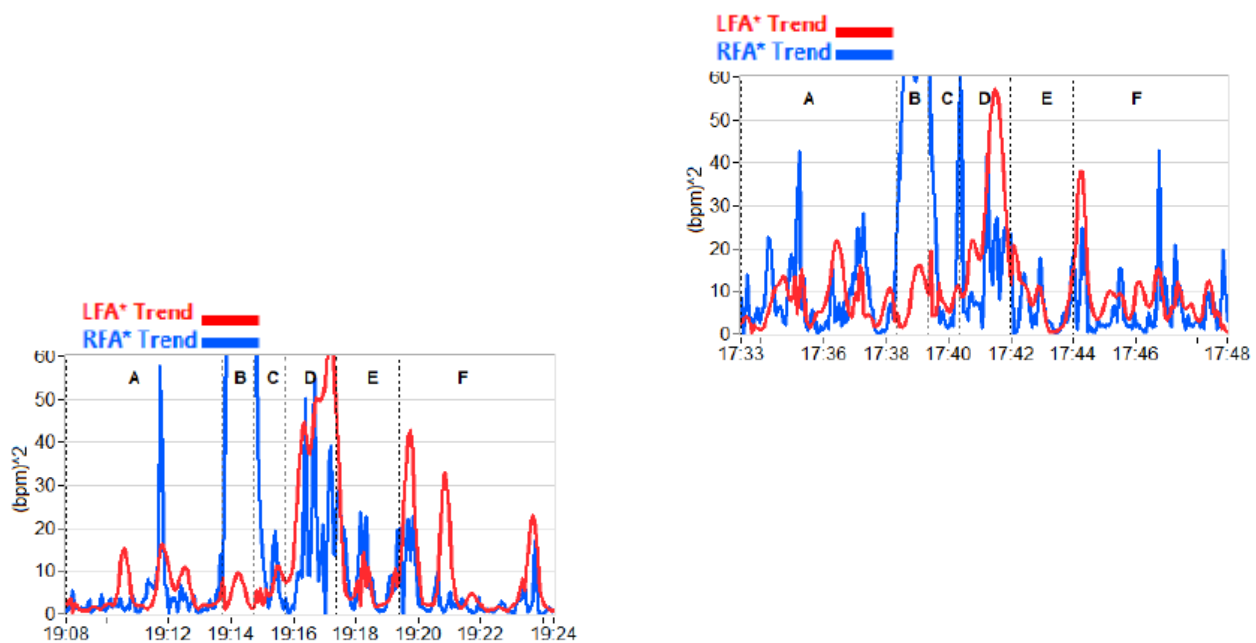
Follow-up Test 2: 03/11/2022; Age 24, Ht. 6'3", Wt. 200#. Patient 2 reports hardly any improvement, in fact he reports worsening hypohidrosis, coat-hanger pain, cold hands & feet, and heat & cold intolerance, with no changes in lightheadedness, brain-fog, difficulty finding words, memory difficulties, paresthesias, nausea, with difficulty standing, dimmed vision, palpitations, and only slight improvement in fatigue, light sensitivity, depression, and anxiety.

At rest his only change is a more normal SB (=1.38). There was little change in his breathing responses, and his abnormal stand responses did not change significantly (see Trends plot, right; compare with previous Trends plot). All demonstrating that he is not responding to treatments and therapy, his oral vasoactive strength was increased with little effect. He was referred to Neurofeedback.



Neurofeedback baseline 03/22/2022: At initial Neurofeedback evaluation, Patient 2 completed an arousal assessment to help in guiding the training based on symptoms, a mini-map (Table 3) to objectively help guide training, and a history intake. The following symptoms were reported in the initial arousal assessment. Under arousal- poor concentration, inattentive, distractibility, frequent day dreaming, spaciness/fogginess, forgetful, confused thinking, lack of motivation, depression/low mood, lethargy, sensitive/ feelings easily hurt, tends to introversion, excessively shy, frequent waking at night, not feeling rested after sleep, sleep >9 hours/night, dislikes

alcohol. Overarousal- Busy mind/many competing thoughts, impulsive, fidgety, hyperactive, easily bored, agitated, angry depression, anxious/fearful, tense, feel overwhelmed, frequent tension headaches, teeth grinding or clenching, holds resentments, difficulty falling asleep, sensory overload, heart palpitations, dislikes caffeine, likes alcohol effects. Unstable arousal-history of head injuries, chronic fatigue, wakes during the night-light sleeper, frequent nightmares, hot flashes- not related to menopause, poor eye contact. Based on findings it was determined that training at C3-C4 would be the most optimal protocol



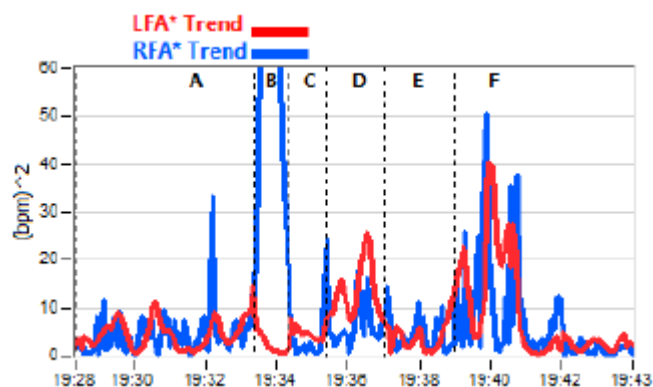
3/28/2022	CZ (mv)	PZ (mv)	PZ E/C (mv)
4-8 Hz	14.1	13.8	19.7
8-12 Hz	13.1	17.5	28.7
12-18 Hz	8.9	11.6	17.2
22-36 Hz	7.9	7.3	8.6

Table 3: In Patient 2's initial mini-map demonstrates excess 4-8, 8-12, 12-18, and 22-36 at CZ and PZ. At PZ E/C his 4- 8 by slightly more than 50%. His Theta Beta Ratio is 1.58 indicating overarousal. **Follow-up Test 3:** 09/22/2022; Age 25, Ht. 6'3", Wt. 205#. Again, Patient 2 reports hardly any improvement. At rest there is no significant change from the previous test

(see Trends plot, left; compare with previous Trends plot, above, right). Similarly with the breathing and stand challenges. All demonstrating that he is not responding to treatments and therapy, including second line treatments to affect the same results. One last treatment change to attempt to effect relieve was prescribed. Another oral vasoactive medication was prescribed.

Follow-up Test 4: 03/23/2023; Age 25, Ht. 6'3", Wt. 200#. Again, Patient 2 reports hardly any improvement, worsening sensitivity to light and now tension headaches. Overall his latest Trends plot (see Trends plot, right) shows more activity rather than less confirming any lack of improvement. At rest, while his P&S activity levels are still within normal limits, they are higher and high resting BP is 10/5 mmHg higher. No significant changes in his breathing challenges, and his stand challenge also shows more activity rather than less. All demonstrating that he is still not responding to treatments and therapy. He was recommended a second Neurofeedback training,

Neurofeedback retest correlating with Physio PS: Patient 2 Completed another arousal assessment and another mini-map was conducted. The following symptoms were reported: Under-arousal- spaciness/fogginess (less often), lethargy (less often), frequent waking at night, sleep >9 hours/night (less often), Dislikes the effects of alcohol, Overarousal- Busy mind/many competing thoughts, fidgety, Easily bored, Agitated, Tense, Feel overwhelmed, Teeth grinding or clinching, Dislikes Caffeine. Unstable Arousal- history of head injury, Chronic Fatigue (less often), Frequent nightmares.



9/14/2023	CZ (mv)	PZ (mv)	PZ E/C (mv)
4-8 Hz	12.3	11.7	17.3
8-12 Hz	11.2	14.0	24.5
12-18 Hz	8.3	10.6	16.0
22-36 Hz	6.7	6.9	8.5

Table 4: In patient 2's follow up mini-map the patient demonstrated improvement in 4-8, 8-12, 12-18 and 22-36. His Theta:Beta ratio adjusted to 1.48 closer to the ideal 1.5. **Follow-up Test 5:** 09/21/2023; Age 25, Ht. 6'3", Wt. 200#. This time, Patient 2 reports significant improvement in symptoms, mostly with lingering, yet reduced brain-fog, lightheadedness, and tension headaches. Overall, his latest Trends plot (see insert, left) shows less activity, confirming the improvement in symptoms. At rest, while his P&S activity levels are more normal for his age, and his resting BP is normal. His stand challenge shows less activity, but still higher than normal responses. He was referred back to the autonomic clinic. Now that his brain's P&S systems are more balanced, he is returning to the clinic to balance the rest of his P&S nervous systems.

DISCUSSION

Patient 1 demonstrated improvements in both P&S Monitoring and in their EEG Mini-map. Patient 1's improvement resulted in a decrease in number of medications being taken, and overall improved function and quality of life.

Patient 2 was not able to demonstrate the same improvement in symptoms reported and P&S monitoring. However, he demonstrated improvement in his arousal reports. Patient 2's improvements due to the first Neurofeedback session where Patient 2 reported going out with friends for the first time in 6 months. Within a month he began attending classes in-person, and went to his commencement, and other activities he avoided previously. His symptoms that were debilitating at first, improved to where he was working as a personal trainer, leading high intensity classes. As in this case, it is not uncommon for patients to report a lack of improvement because they are basing the measurement on their condition prior to P&S dysfunction. Patient 2 did not report improvement in symptoms even though his behavior reflected it.

Through the utilization of EEG's, QEEG's and Mini-maps, Neurofeedback has been shown to positively affect the regulation of the Central Nervous System. In doing so it makes sense it would then affect the Peripheral Nervous System, including the P&S Nervous Systems; thus, positively affecting the functioning of vital organs and organ systems. Neurofeedback has demonstrated improvements in P&S functioning primarily by decreases in symptoms or testing that measures P&S functioning. P&S monitoring provides objective evidence that Neurofeedback does cause changes in autonomic functioning.

In modern medicine, symptoms are evaluated in order to come to a diagnosis. We propose that in some cases the diagnosis that is given may be a symptom. This may explain why so many people see so many specialists for various conditions. What is not considered by these specialists is that there is one common denominator, the P&S Nervous Systems. P&S Monitoring provides information on the functioning of the two branches independently and simultaneously. With this more information, we can identify why multiple vital organs are behaving in such dysregulated ways.

Until now there has been a divide between the areas of Psychology and Medicine. Although there are respects given and referrals made primarily within fields of Psychology, between psychiatry and psychology or social work, it is not until Psychology and Medicine work more collaboratively that greater benefits will be realized.

CONCLUSION

A correlation can be seen between Neurofeedback and P&S Monitoring in the diagnosis and ailments that both have help, including Migraines, PTSD, Depression, Anxiety, Traumatic Brain Injuries among others. If both these practices are capable of making improvements on their own, it only makes sense that when utilized together they would provide optimal outcomes and Neurofeedback may speed the healing process of Dysautonomia when combined with other proven therapies. The two sample cases provide motivation for further research into the benefits of Neurofeedback for patients suffering autonomic dysfunction: a common cause of a spectrum of symptoms in patients suffering a wide variety of ailments.

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⁹ This is not HRV-Biofeedback

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