HRV measurement not predictive of depression symptoms or improvement: a case report

Stephanie Burns*

ABSTRACT: The purpose of this study was to determine if HRV measurements could predict depression, predict depression treatment outcomes, and determine the resolution of depression symptoms for an individual. Ventral vagus nerve treatment for depression consisted of body techniques as well as the Safe and Sound Protocol (SSP). Symptoms of major depression were significantly improved after body techniques as well as the SSP. However, no significant differences were found for HR, RMSSD, LF, HF, and the LF/HF ratio. As such, HRV measurements for this client did not predict depression, predict treatment outcomes, nor determine the resolution of depression symptoms. This case highlights that the large differences found in the HRV measurement means of clients experiencing depression versus healthy controls make it very difficult for an individual treatment provider to predict a client's mental health status, predict a client's treatment outcomes, or determine if treatment was successful for their client. Additionally, it has been suggested that differences in HR and HF readings are superior indexes of within-subject differences. However, comparing HF and HR readings for this individual also did not predict treatment outcomes.

ABOUT THE AUTHOR
Stephanie T. Burns, Ph.D., LPC, NCC, is an Associate Professor at Western Michigan University in the Counselor Education and Counseling Psychology Department, where she is the Coordinator of the Clinical Mental Health Counseling Program. Dr. Burns is a Licensed Professional Counselor (LPC) in Michigan; a National Certified Counselor (NCC); and the chapter advisor for the Mu Beta Chapter of Chi Sigma Iota. She was co-chair of the Chi Sigma Iota Professional Advocacy Committee for six years and was the inaugural Edwin L. Herr Fellow for Excellence in Counseling Leadership and Scholarship. Her research areas of interest include adult trauma, student learning outcomes, counselor professional identity, ethical decision-making, the psychometrics of career interest inventories, counseling outcomes, counseling program evaluation, and supervision. Dr. Burns’ 2017 Journal article, “Evaluating Independently Licensed Counselors’ Articulation of Professional Identity Using Structural Coding,” won The Professional Counselor’s 2017 Research category of the Outstanding Scholar Award.

PUBLIC INTEREST STATEMENT
It has been suggested that depression is accompanied by higher heart rate variability (HRV) readings. Difficulties are experienced when counseling treatment providers attempt to use heart rate variability (HRV) measurements to determine their client’s current mental health status, predict treatment outcomes, or determine counseling treatment success. The difficulty occurs because of the large differences in HRV averages reported in studies comparing depressed individuals and healthy controls. Additionally, it is suggested that two HRV readings be considered before and after treatment to determine if treatment was successful for an individual. However, some clients experience treatment success with no changes in those readings. It is currently difficult for a counseling treatment provider to know how to use heart rate variability (HRV) readings in clinical practice with clients experiencing depression. This case study reports that while significant depression treatment outcomes were found, there were no significant changes in the client’s HRV readings.
1. Introduction
The autonomic nervous system (ANS) is reported to influence human emotions and behavior (Chang et al., 2012; Choi et al., 2019). Heart rate variability (HRV) measures such as heart rate (HR), root mean square of successive differences of normal-to-normal RR intervals (RMSSD), the HF (0.15−0.40 Hz) frequency, the LF (0.04−0.15 Hz) frequency, and the LF/HF ratio are established methods to measure the ANS (Chang et al., 2012; Choi et al., 2019; Stadler et al., 2019). Lower HRV measurements have been associated with poor self-regulation, less behavioral flexibility, depression, anxiety disorders, and post-traumatic stress disorder (Brown et al., 2018; Choi et al., 2019).

Meta-analyses document that LF readings do not significantly differ between clients experiencing depression versus healthy controls (Brown et al., 2018). However, meta-analyses suggested lower HF readings with a small to moderate effect size for clients experiencing depression when compared to healthy controls (Blanck et al., 2019; Brown et al., 2018). Additionally, meta-analytic correlations have found lower HF readings corresponded to increased depression severity (Blanck et al., 2019). Other researchers report that clients with higher HF readings at the beginning of 25 weeks of cognitive-behavioral therapy exhibited a stronger decline in depressive symptoms at the end of treatment (Blanck et al., 2019).

As such, it is often proposed that HRV measurements can determine if an individual experiences mental health symptoms as well as predict mental health treatment outcomes. However, a review of research studies documenting HRV measurements between clients experiencing depression and healthy controls reported wide-ranging differences in both groups’ mean scores. For example, Choi et al. (2019) reported that depressed clients had an average RMSSD of 34.55, LF of 283.93, HF of 227.64, and LF/HF ratio of 2.68 while healthy controls had an average RMSSD of 43.83, LF of 319.05, HF of 287.12, and LF/HF ratio of 1.88. However, Chang et al. (2012) suggested that depressed clients had an average RMSSD of 22.23 (lower by 12.32), LF of 324.31 (higher by 40.38), HF of 255.44 (lower by 27.8), and LF/HF ratio of 1.76 (lower by 0.92) while healthy controls had an average of RMSSD of 27.68 (lower by 16.15), LF of 544.18 (higher by 225.13), HF of 385.04 (higher by 97.92), and LF/HF ratio of 1.62 (lower by 0.26). The large differences between the means of the two studies for clients experiencing depression and healthy controls make it very difficult for an individual treatment provider to predict the mental health status of their client, predict mental health treatment outcomes for their client, or determine if treatment was successful for their client. Further, a 10-year longitudinal study of adults found low HRV readings preceded the experience of any depressive symptoms and that current depressive symptoms did not predict future continued low HRV readings (Jandackova et al., 2016).

Additionally, a few studies have suggested that HRV measurements can be used to determine successful mental health treatment by looking at within-person HRV changes during treatment for depression. Lin et al. (2021) studied 58 individuals experiencing depression who were treated with tDCS and observed an increase in HF and LF activity one month after treatment. Shinbo et al. (2020) found that 30 workers experiencing major depressive disorder who received treatment experienced lower HR and higher HF scores as compared to their pre-treatment baseline. Blanck et al. (2019) found that HF readings over the course of 25 counseling sessions were unrelated to reductions in depressive symptoms experienced by clients at the end of treatment. Their findings suggested that clients can be successfully treated for depression and not have significant changes in their HRV readings (Blanck et al., 2019).
Grossman and Taylor (2007) state that, when properly measured, a strong within-subject relationship exists between HF and cardiac vagal tone. They also report that HF is only roughly correlated with within-subject variations in cardiac vagal tone. Grossman and Taylor (2007) further suggest that HR may be an equivalent or superior index of within-subject differences in cardiac vagal tone as compared to HF. They suggest both variables be used whenever predicting within-subject differences in cardiac vagal tone. Additionally, they caution that between-subject associations may be relatively weak (Grossman & Taylor, 2007). As HRV measurements are being used to differentiate between depressed clients and healthy controls, methods have been proposed to help individuals overcome depressive symptoms by treating the parasympathetic (PNS) branch of the ANS. Polyvagal Theory (PVT) suggests a neurophysiological structure for understanding the nervous system’s anatomic and functional connections of the human brain and body (Kolaczk et al., 2019). PVT acknowledges the commonly known fight or flight system that is activated by the sympathetic nervous system and the lesser-known vagal system of immobilization and disassociation that is activated by the parasympathetic system (Geller & Porges, 2014). PVT suggests the nervous system perpetually monitors and evaluates risk in the environment due to the basic human need for safety and relationship with others (Williamson et al., 2014). Cortical areas of the body detect safety or danger cues, which shift physiological states. These profound physiological changes are generally beyond our awareness (Geller & Porges, 2014). PVT recognizes both top-down (from the brain to the body) and bottom-up (from the body to the brain) signals that regulate a person’s physiological state (Geller & Porges, 2014). These shifts are communicated interpersonally through changes in facial muscles, eye contact, vocal features, and body posture (Geller & Porges, 2014).

Responses to threat, safety, and uncertainty with others or the environment produce physiological states that constrain psychological processes (Flores & Porges, 2017). PVT recognizes three involuntary ordered and behaviorally linked autonomic subsystems that produce adaptive domains of behavior based upon cues of safety or danger. The order begins with social communication (facial expression, vocalization, listening), then moves to defensive mobilization (fight or flight behaviors), and can ultimately lead to defensive immobilization (fainting, social withdrawal, and disassociation); (Geller & Porges, 2014). Chronic defensive mobilization or immobilization responses can result in a deterioration of mental and physical health, unhealthy interpersonal relationships, and an acceleration of the aging process (Williamson et al., 2014). These changes can be found in heart rate variability (HRV) measures. For example, reduced low-frequency baseline (rest) HRV is related to coronary artery disease, and lower nighttime standard deviation of RR intervals is linked to increased stroke risk (Williamson et al., 2014).

Use of the ventral vagal pathway results in high cardiac vagal tone. This increases attention regulation, productive affective processing, and productive flexibility when adapting and responding to others and the environment (Sullivan et al., 2018). Individuals with a strong ventral vagal tone can rapidly engage and disengage with others or the environment to facilitate self-soothing behaviors, cooperation with others, inner calm, and accurately reading verbal and nonverbal communication (Flores & Porges, 2017).

Polyvagal Theory (PVT) suggests that deficits in behavioral and psychological functioning are caused by reductions in the ventral vagal functioning of the autonomic nervous system (ANS), which leads to higher HRV readings that culminate in mobilization or immobilization responses that are coupled with auditory hypersensitivities (Porges et al., 2013). This structure may account for a connection between depression and the ANS. Porges et al. (2013) suggested that the entire ANS can be treated by focusing on any one aspect of the ANS. Porges postulates that exercising the middle ear muscles to reduce middle ear muscle tension would not only improve auditory processing performance but also would improve HRV readings, which would result in improved behavioral responses (Porges et al., 2013). He created the Safe and Sound Protocol (SSP), which uses computer altered vocal music that exaggerates the features of human prosody to relax the middle ear muscles so that they no longer deflect the
frequencies of the human voice. A study using the SSP with individuals experiencing autism demonstrated significantly higher RSA readings coupled with improvement in the ability to successfully complete auditory processing tasks (Porges et al., 2014). Additionally, Rosenberg has suggested that there are body techniques that can be performed in order to restore the functioning of the ventral vagal nerve in order to improve depression symptoms (Stadler et al., 2019). The purpose of this study was to determine if HRV measurements could predict depression, predict treatment outcomes, and determine the resolution of depression symptoms for an individual being treated for depression using only techniques specifically designed to restore ventral vagal nerve functioning.

2. Methods
The client was a 40-year-old White woman diagnosed with Histamine Intolerance (HI), Mast Cell Activation Syndrome (MCAS), and Major Depressive Disorder (MDD). She weighed 110 pounds. Her HI, and MCAS were well controlled by taking progesterone at three times the dosing for a traditional birth control prescription, diamine oxidase at 18 grams, and ketotifen fumarate at 3 grams per day. Additionally, successful treatment of her HI, and MCAS required a very limited and strict diet, which included only being able to drink filtered water. As such, the client eats and drinks the same thing every day, 365 days of the year. As estrogen triggers the release of histamine, high doses of progesterone have been prescribed for over five years and menstruation ceased five years ago.

Most females experience a follicular phase where progesterone levels are low while estrogen levels are dominant, which results in lower resting pulse rates, respiratory rates, and HRV readings (Stadler et al., 2019). Additionally, most females follow with a luteal phase that has high progesterone levels while estrogen levels are low, which results in higher resting pulse rates, respiratory rates, and HRV readings (Stadler et al., 2019). Because this client takes high doses of progesterone daily, any hormonally driven HRV changes over a typical menstrual cycle did not interfere with HRV readings. Two years before treatment, three medications (escitalopram at 20 mg, bupropion at 450 mg, and trazodone at 50 mg) were titrated up to maximum dosages to attempt to control MDD symptoms. However, the medications made no impact and her symptoms worsened during the two-years prior to the 42 days of treatment.

The client reported that her use of medications and supplements remained the same each day of the 42 days of treatment, as well as the week of follow-up six months later. Additionally, the client kept the same full-time work schedule over those 42 days of treatment as well as the one-week follow-up six months later and did not report any unusual physical, mental, or psychological stressors during those times. The client took HRV readings on the same device every day 5 minutes after waking up in the morning and before ingesting anything using Camera HRV (A.S. M.A. B.V, 2019) for 42 days during treatment and then one week six months later. The same protocol was performed every morning that the client took an HRV reading. Once the client woke up that morning, she sat up in bed and took the phone off the nightstand. She then opened Camera HRV on the phone and waited for 5 minutes to pass after waking up. After the 5 minutes had passed, the client placed her left middle finger on the camera and took a 5-minute HRV reading.

Camera HRV is a form of photoplethysmography (PPG) where HRV readings are taken using a smartphone (Plews et al., 2017). Camera HRV captures video at a 30 Hz frame rate and immediately averages the red, green, and blue (RGB) channels over the entire frame (Altini, n.d.). Then it converts from RGB to hue, saturation, and value (HSV) color space calculations. Next, the intensity of the hue value is filtered using a fourth-order Butterworth band pass filter and frequency pass band between 0.1 and 10 Hz (Plews et al., 2017). This step removes DC signal components (such as movement and pressure) and high-frequency noise while preserving the AC component. Lastly, cubic spline interpolation up-samples the signal from 30 to 180 Hz, which ensures sufficient resolution. Further,
Camera HRV uses a peak detection algorithm to determine peak-to-peak intervals, which is based on a slope inversion algorithm. Peak-to-peak intervals are corrected for artifacts in two ways before features extraction as the signal can be easily disrupted by motion or ectopic beats (Altini, n.d.). First, consecutive RR intervals are eliminated if they differ by more than 75% from a previous interval. Second, RR intervals within less than 25% of the 1st quartile and within more than 25% of the 3rd quartile are removed as they are considered outliers (Plews et al., 2017). These two correction techniques avoid over-correcting with individuals who have very high beat-to-beat variability.

The Symptom Checklist-90-Revised (SCL-90-R) (Derogatis, 1994) was used to track current, point-in-time changes in MDD symptoms. The nine Primary Symptom Dimensions Scales include Somatization (SOM), Obsessive–Compulsive (O-C), Interpersonal Sensitivity (I-S), Depression (DEP) Anxiety (ANX), Hostility (HOS), Phobic Anxiety (PHOB), Paranoid Ideation (PAR), and Psychoticism (PSY). The three Global Indices of Distress include the Global Severity Index (GSI), Positive Symptom Distress Index (PSDI), and the Positive Symptom Total (PST). The client took the SCL-90-R a week before treatment began, two weeks after the 42-day treatment protocol had ended, and six months after treatment.

Ventral vagus nerve treatment consisted of body techniques as well as the SSP. All 42 days of treatment began by taking morning HRV readings. The first fourteen days of treatment included performing 5 minutes of ujjayi breath. Additionally, the basic exercise, neuro-fascial release technique, half-salamander exercise, half-salamander variation, full salamander, SCM exercise for a stiff neck, twist and turn exercise for the trapezius, four-minute natural facelift part 1, four-minute natural facelift part 2, and the massage for migraines were performed as outlined by Rosenberg (2017). The SSP is a five-day auditory intervention that intensifies each successive day and is designed to improve ventral vagal functioning. Days eight through 42 of treatment consisted of listening to one-hour of the SSP (Integrated Listening Systems, 2019), which resulted in the client listening from day one to day five of the SSP programming seven times in a row.

3. Results
An ANOVA could not be run because the normality assumption was violated. A Friedman test was run to determine if there were differences in HR, RMSSD, LF, HF, and the LF/HF ratio for all six weeks of treatment as well as one-week six months later (Table 1). There were no statistically significant differences found for HR, RMSSD, LF, HF, and the LF/HF ratio: HR $\chi^2(6) = 7.16, p = 0.31$; RMSSD $\chi^2(6) = 11.51, p = 0.06$; LF $\chi^2(6) = 6.18, p = 0.40$; HF $\chi^2(6) = 3.74, p = 0.71$; and the LF/HF ratio $R \chi^2(6) = 7.41, p = 0.29$.

Changes in 11 out of 12 SCL-90-R scales demonstrated that the client experienced significantly fewer MDD symptoms two weeks after the 42 days of treatment: SOM (Pre T58, Post T45, Change $-13$), O-C (Pre T74, Post T37, Change $-37$), I-S (Pre T71, Post T47, Change $-24$), DEP (Pre T81, Post T46, Change $-35$), ANX (Pre T68, Post T45, Change $-23$), HOS (Pre T60, Post T49, Change $-11$), PHOB (Pre T44, Post T44, Change 0), PAR (Pre T69, Post T54, Change $-15$), and PSY (Pre T62, Post T44, Change $-18$), GSI (Pre T70, Post T54, Change $-16$), PSDI (Pre T75, Post T46, Change $-29$), and PST (Pre T64, Post T43, Change $-21$). The PHOB scale was at its lowest possible reading for both the pre-test and post-test. Additionally, two weeks after treatment, the client was taking progesterone at three times the dosing for traditional birth control prescription, diamine oxidase at 18 grams, and ketotifen fumarate at 3 grams per day. However, the trazodone dosage was cut to 25 mg while the escitalopram and bupropion were slowly titrated and discontinued, and the client reported no depressive symptoms.

Six months after treatment, the client was taking progesterone at three times the dosing for traditional birth control prescription, diamine oxidase at 18 grams, and ketotifen fumarate at 3 grams per day. Trazodone was still at 25 mg, and the client reported no depressive symptoms despite not taking any other psychotropic medications. SCL-90-R scale scores six months later demonstrated the
|                  | HR     | RMSSD  | LF     | HF     | LF:HF  |
|------------------|--------|--------|--------|--------|--------|
| M Week 1 Body Only | 78.44  | 44.50  | 234.80 | 389.76 | 0.63   |
| SD Week 1        | 3.19   | 13.62  | 86.15  | 104.45 | 0.26   |
| Var Week 1       | 10.20  | 185.41 | 0.74   | 1.09   | 0.70   |
| Minimum Week 1   | 74.39  | 28.24  | 143.94 | 196.67 | 0.38   |
| Maximum Week 1   | 83.73  | 67.87  | 373.09 | 500.41 | 1.13   |
| Ra Week 1        | 9.34   | 39.63  | 229.15 | 303.74 | 0.75   |
| M Week 2 Body and SSP | 77.80  | 33.71  | 350.23 | 452.31 | 0.83   |
| SD Week 2        | 6.80   | 5.89   | 95.36  | 166.73 | 0.22   |
| Var Week 2       | 46.25  | 34.70  | 0.91   | 2.78   | 0.05   |
| Minimum Week 2   | 70.04  | 23.88  | 221.38 | 225.97 | 0.48   |
| Maximum Week 2   | 90.12  | 40.50  | 536.76 | 683.54 | 1.13   |
| Ra Week 2        | 20.08  | 16.61  | 315.38 | 457.57 | 0.66   |
| M Week 3 SSP Only | 79.03  | 38.33  | 306.24 | 491.43 | 0.60   |
| SD Week 3        | 5.33   | 4.54   | 125.79 | 101.08 | 0.15   |
| Var Week 3       | 28.37  | 20.61  | 1.58   | 1.02   | 0.02   |
| Minimum Week 3   | 71.44  | 32.25  | 141.30 | 348.31 | 0.35   |
| Maximum Week 3   | 87.24  | 43.52  | 466.11 | 609.43 | 0.76   |
| Ra Week 3        | 15.80  | 11.27  | 322.81 | 261.12 | 0.42M  |
| Week 4 SSP Only  | 83.00  | 36.80  | 421.17 | 630.23 | 0.69   |
| SD Week 4        | 4.87   | 11.61  | 373.30 | 469.52 | 0.25   |
| Var Week 4       | 23.73  | 134.89 | 13.94  | 22.04  | 0.06   |
| Minimum Week 4   | 75.83  | 18.39  | 208.96 | 227.01 | 0.42   |
| Maximum Week 4   | 89.81  | 55.76  | 1,256.62 | 1,624.48 | 1.18   |
| Ra Week 4        | 13.98  | 37.37  | 1,047.66 | 1,397.47 | 0.76M  |

(Continued)
|                          | HR  | RMSSD | LF    | HF    | LF:HF |
|--------------------------|-----|-------|-------|-------|-------|
| **SD Week 5**            | 4.35| 15.20 | 266.89| 627.46| 0.38  |
| **Var Week 5**           | 18.92| 231.13| 7.12  | 39.97 | 0.14  |
| **Minimum Week 5**       | 70.82| 26.33 | 132.21| 299.97| 0.22  |
| **Maximum Week 5**       | 82.64| 68.12 | 905.80| 2,001.57| 1.32 |
| **Ra Week 5**            | 11.82| 41.79 | 773.59| 1,701.60| 1.10 |
| **M Week 6 SSP Only**    | 80.87| 28.13 | 203.90| 292.39| 0.71  |
| **SD Week 6**            | 8.46 | 5.79  | 63.72 | 94.66 | 0.19  |
| **Var Week 6**           | 71.84| 33.57 | 0.41  | 0.90  | 0.04  |
| **Minimum Week 6**       | 74.96| 20.80 | 87.63 | 176.37| 0.50  |
| **Maximum Week 6**       | 99.30| 35.53 | 263.90| 436.15| 0.98  |
| **Ra Week 6**            | 24.34| 14.73 | 176.27| 259.78| 0.48  |
| **M Week Six Months Later** | 77.08| 36.48 | 224.62| 327.35| 0.99  |
| **SD Week Six Months Later** | 6.01 | 22.80 | 126.34| 338.56| 0.59  |
| **Var Week Six Months Later** | 36.15| 519.75| 1.60 | 11.46| 0.35  |
| **Minimum Week Six Months Later** | 65.90| 19.69 | 113.92| 100.40| 0.42  |
| **Maximum Week Six Months Later** | 83.00| 84.82 | 464.36| 1,053.62| 2.17  |
| **Ra Week Six Months Later** | 17.10| 65.12 | 350.44| 953.22| 1.74  |
client held the gains reported two weeks after treatment: SOM (Post T45, Six Months T45, Change 0), O-C (Post T37, Six Months T37, Change 0), I-S (Post T47, Six Months T50, Change +3), DEP (Post T46, Six Months T42, Change –4), ANX (Post T45, Six Months T45, Change 0), HOS (Post T49, Six Months T49, Change 0), PHOB (Post T44, Six Months T44, Change 0), PAR (Post T54, Six Months T54, Change 0), and PSY (Post T44, Six Months T45, Change 0), GSI (Post T54, Six Months T42, Change –12), PSTD (Post T46, Six Months T46, Change 0), and PST (Post T43, Six Months T41, Change –2). The significant reduction in GSI by 12 points six months later suggested that the client perceived a much lower intensity of internal distress six months after treatment as compared to two weeks after treatment ended.

4. Discussion
It has been suggested that HRV readings can tell a tremendous amount about an individual’s mental and physical wellbeing. When viewed through the lens of PVT, depression treatment should result in a strong ventral vagal tone that promotes enhanced physiological and behavioral state regulation. This allows individuals to engage and disengage rapidly with others or the environment to facilitate self-soothing behaviors, cooperation with others, inner calm, and accurately reading verbal and nonverbal communication (Flores & Porges, 2017). Individuals experiencing depression may benefit from neural exercises such as the SSP, focusing on slow steady exhalations, social play (such as team sports, group drumming, choral singing, improvisational music with others), singing, chanting, playing a wind instrument, rocking back and forth, being in nature, yoga, or meditation to engage the ventral vagal nervous system (Geller & Porges, 2014).

If HRV readings are to be used by treatment providers with clients experiencing depression to determine treatment success, then treatment providers need clear guidelines on exactly what HRV measurements they are looking for and what those exact measurements mean for treatment with individual clients. This case highlights that the large differences found in the HRV measurement of clients experiencing depression versus healthy controls in published studies make it very difficult for an individual treatment provider to predict a client’s mental health status, predict a client’s treatment outcomes, or determine if treatment was successful for the client. Further, this case suggests that within-person HR and HF reading differences also cannot always predict successful treatment. This case suggests the need to develop HRV parameters that can be used by treatment providers when working with individual clients to determine treatment success.

First, initial HRV measurements for this client overwhelmingly placed her with healthy controls found in between-person studies. Before treatment on the first day, the client’s HRV readings were: RMSSD 29.75, LF 373.09, HF 329.22, and LF/HF Ratio 1.13. According to Choi et al. (2019), this client would only classify with depressed clients for the RMSSD reading. Chang et al. (2012) data suggests this client would classify with depressed clients for the LF reading. Before the treatment, this client scored a T81 on the DEP scale, signaling a significant amount of depression in the clinically diagnosable range. Further, her pre-treatment GSI scale of T70 suggested that the depression made a significant negative impact on her life. However, only one out of four HRV readings of depressed clients by Choi and Chang classified her as depressed and those classifications were made in each study by two different HRV measurements. Second, the client’s HRV measurements did not predict therapeutic outcomes because her initial HRV measurements placed her with healthy controls found in between-person studies. It is hard to say that when a majority of HRV scores fall into healthy control ranges that these same HRV scores could then suggest that this client would benefit significantly from treatment.

Third, overwhelmingly, the client’s HRV measurements did not significantly change before treatment started, while treatment occurred, and six months later. The one-week averages of her HRV measurements six months after treatment were: RMSSD 36.48, LF 224.62, HF 327.36, and LF/HF ratio 0.99. Choi et al. (2019) data suggests she would classify with the depressed clients for
both RMSSD and LF measurements. According to Chang et al. (2012) readings, she would classify with the depressed clients for the LF measurement. If treatment providers use between-person studies to determine cutoff values for successful treatment, this client's results will imply that treatment was not successful. However, six months after treatment, her scores on the SCL-90-R DEP scale dropped another 4 points, and the GSI scale dropped another 12 points as compared to her scores two weeks after treatment. These SCL-90-R scores placed her even further below the clinically depressed range and more with healthy normal individuals. Her HRV readings did not significantly change after the vagal nerve treatment using body techniques and the SSP, which reduced her symptoms of depression initially after treatment as well as six months later. Additionally, the scores suggested by Grossman and Taylor (2007) for within-person differences measurements did not predict therapeutic outcomes for the client because HF and HR scores were never significantly different. The outcomes for this client support Blanck et al. (2019), who reported that HF readings were unrelated to reductions in depressive symptoms at the end of treatment and that clients can be successfully treated for depression and not have significant changes in their HRV readings.

5. Limitations
The limits of this study include a single female subject. Additionally, this client takes high doses of progesterone daily, which likely resulted in higher resting pulse rates, respiratory rates, and HRV readings. Therefore, it is hard to understand how all her HRV measurements throughout this study were impacted by taking high levels of progesterone. As such, patients of other genders, ages, ethnicities, medical diagnoses, mental health diagnoses, and symptom severities could have different results. Lastly, results may have been different if consecutive RR intervals were eliminated if they differed by more than 30% from a previous interval.

6. Conclusions
When viewed through the lens of PVT, individuals experiencing depression experience a weak ventral vagal tone that reduces physiological and behavioral state regulation, limits the effectiveness of self-soothing behaviors, increases strained relationships, raises inner turmoil, and leads to inaccurately reading verbal and nonverbal cues (Flores & Porges, 2017). This case reports the successful six-month treatment of Major Depressive Disorder (MDD) using two ventral vagal nerve treatments for a female client who is only able to eat and drink the same thing every day, 365 days of the year. As HRV readings are reported to tell a tremendous amount about an individual's mental and physical well-being, HRV measurements were taken during the 42 days of treatment as well as one week six months after treatment. HRV measurements did not predict the client's MDD, potential for successful MDD treatment, or successful MDD treatment outcome. Additionally, it has been suggested that differences in HR and HF readings are superior indexes of within-subject differences. However, comparing HF and HR readings for this individual also did not predict treatment outcomes.

Author details
Stephanie Burns
ORCID ID: http://orcid.org/0000-0002-7718-6021
1 Counselor Education and Counseling Psychology, Western Michigan University, Kalamazoo, USA.

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