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The Relationship Between Vagal Tone, A Marker of Parasympathetic Activity, and Pro-Social Behavior

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The Relationship Between Vagal Tone, A Marker of Parasympathetic Activity, and Pro-Social Behavior

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Abstract

Vagal tone, a measure of parasympathetic activity via the vagus nerve, is known to be associated with positive emotion because it promotes social engagement and self-soothing behavior. Heart rate variability (HRV), especially high frequency oscillation, is a direct measure of vagal tone, and has been used in previous studies to test the correlation between vagal tone and positive emotion. This study aims to determine if the two major oscillations of heart rate variability, high frequency (HF-HRV) and low frequency (LF-HRV) can predict pro-social behavior, which is classified as giving donations to charities. Baseline LF- and HF-HRV levels were recorded, and compared to how much each participant donated after watching several donation appeals by charities. Results showed there was no significant difference in either LF- or HF-HRV levels between donors and non-donors. A negative correlation was found between both LF and HF-HRV levels and donation behavior, contradicting research that predicts a positive correlation between the two variables. There was no significant effect of gender on donation amount. This research gives insight in to how physiological changes can affect psychological processes, such as emotional expression.

Introduction

Psychophysiology is a burgeoning field that investigates how physiological parameters can affect our observable behaviors. Research has been published that investigates the relationship between parasympathetic activity and positive emotional or behavioral response. The vagus nerve is the primary nerve through which bi-directional parasympathetic activity flows between the heart and brain. Afferent vagal nerves located in the brainstem lie in close proximity to the neural network that controls facial expression and vocalization. Due to this relationship, many scientists believe the vagus plays a role in emotional regulation. Heart rate variability, a measure of cardiac vagal tone, can provide insight into how physiological measures affect psychological behaviors. This thesis studies the relationship between vagal tone and pro-social behavior, and hypothesizes that a positive correlation exists between the two variables.

Historical Background

Cardiovascular Regulation and Autonomic Nervous System

The autonomic nervous system (ANS) provides homeostatic regulation of processes within the body by sending precise signals that properly adapt an organism to its external environment. The ANS consists of two divisions, parasympathetic and sympathetic, which work antagonistically to tightly control physiological changes in the body. The parasympathetic system is dominant during states of immobilization and rest in non-threatening situations. The sympathetic system works oppositely to initiate the fight or flight response during life-threatening or stressful periods (Silverthorn, 2012).

Parasympathetic influences on the heart occur when acetylcholine is released by the vagus, and binds to muscarinic cell receptors on post-ganglionic neurons at the sino-atrial node. These receptors respond by depolarizing receptor neurons and increasing K+ import into cardiac pacemaker cells. The resulting depolarization at the sino-atrial node, or pacemaker of the heart, causes diastolic depolarization and ventricular relaxation. Sympathetic influence on heart rate is facilitated by the release of epinephrine and norepinephrine, which bind to β-adrenergic receptors. Activation of these receptors initiates phosphorylation of membrane proteins by cyclic AMP, which increases calcium flow into the cell. This speeds up depolarization of the cardiac cells, causing heart rate to increase (Malik *et al*., 1996).

The vagus, or 10th cranial nerve, is a neural pathway that connects the brain to the heart, and is also the primary nerve through which parasympathetic signals travel. In mammals, the vagal nerve originates in the medulla oblongata of the brainstem, and has two main branches, each with separate functions. Activity from the vagus is asymmetrical, with most parasympathetic activity coming from the right branch. This branch, termed the "smart" vagus, originates from the nucleus ambiguous (NA) in the brainstem, and ends at the sino-atrial node of the heart. The right vagus is myelinated, which allows for rapid communication between the heart and brain through parasympathetic neurons. In contrast, the unmyelinated left vagus originates in the dorsal motor nucleus (DMNX) of the brainstem, and is termed the "vegetative" vagus because it does not have a major role in neural regulation of the heart (Porges, 1995).

The vagal brake tightly controls heart rate by mediating vagal tone to the heart. At rest, the vagus inhibits sympathetic activity, causing a decrease in heart rate and a calming effect. In contrast, when a threat to survival is present, vagal inhibition is released, causing sympathetic activity to increase. As a result, heart rate increases, initiating metabolism in the muscles, which allows the individual to effectively respond to the threat. This function of the vagal system is very efficient at regulating heart rate because it can cause rapid changes to sympathetic or parasympathetic activity, without having to activate the sympathetic-adrenal system (Porges, 2001).

The Polyvagal Theory

The polyvagal theory describes how the autonomic nervous system evolved to create new neural pathways that became associated with emotional expression and social behavior (Porges, 2001). The theory states that vagal pathways shifted from the older, more primitive dorsal motor nucleus of the vagus (DMNX) to the nucleus ambiguous (NA), which is located next to, and communicates with, nerves that control facial expression, head movement, and vocalization (Porges, 2007). Because of this connection, it is postulated that emotional expression is related to the regulation of cardiopulmonary activity (Porges, 1995). Porges called this relationship the "social engagement system" because this network of nerves is responsible for our ability to actively communicate and socially interact with others (Porges, 2007).

The polyvagal theory predicts that social engagement behavior is dependent on vagal regulation of heart rate. Individuals with a highly developed and fully functioning vagal nerve have shown faster response times to environmental demands, and recover more quickly from stress-inducing situations. Deficits in development of the vagal nerve are associated with reduced ability to communicate socially with others (Porges, 2007). Other research has shown that infants who have higher resting vagal tones are more facially expressive, show higher intrigue with novel events, and have greater competency in sustaining attention. In contrast, children with lower vagal tone were described as being ineffective at managing behavior in response to stress and showing higher levels of anger, hostility and anxiety (Diamond *et al.*, 2011). A study that tested the hypothesis of the polyvagal theory found that cardiac vagal tone was positively associated with the routine use of engagement coping strategies, and importantly these individuals actively seek social support (Geisler *et al.*, 2013). Research has investigated this association, with many studies testing whether vagal activity, measured through high frequency heart rate variability, can predict emotional and social behavioral state.

Vagal Control and Heart Rate Variability

Heart rate variability (HRV) is defined as the variation in time intervals between successive beats of the heart. This variability is due to changes in vagal efferent output as respiration occurs. During inspiration, vagal activity is inhibited, causing an increase in heart rate because parasympathetic activity is blocked. Upon exhalation, the "vagal brake" is released, causing heart rate to decrease as parasympathetic activity resumes. This phenomenon is termed respiratory sinus arrhythmia (RSA), and is used to measure vagal control of the heart. RSA at baseline levels determines cardiac vagal tone, which is the level of parasympathetic influence on the heart during normal, non-stressful conditions (Porges, 1995).

Autonomic control of the heart is measured at two different periodic oscillations, which are reflective of parasympathetic and sympathetic activity. Response latencies of the heart to autonomic control differ due to differences in the signaling cascade of the two divisions. Parasympathetic control has a fast acting response because muscarinic receptors are located in the membrane of post-ganglionic neurons, making agonist-receptor binding more efficient (Berntson *et al.*, 1997). Due to its fast response, parasympathetic influences have better control of producing rapid beat-to-beat changes to the heart (Thayer *et al*., 2012). Adrenogenic receptors are not located within the membrane of post-ganglionic neurons, meaning activation of a second messenger is required for signal transmission, and response time is much slower (Berntson *et al*., 1997). High frequency HRV (0.15-0.4 Hz) is characteristic of parasympathetic activity, while low frequency HRV (<0.10 Hz) is representative of sympathetic control due to its slower response time (Lane *et al.*, 2009).

Pharmacological inhibition of cardiac sympathetic synapses produces a decrease in low frequency heart rate variability (LF-HRV), providing evidence that the sympathetic system plays a large role in maintaining this cardiopulmonary oscillation (Bernston *et al*., 1997). Other research has shown that sympathetic activation and parasympathetic retraction cause heart rate variability to shift from HF to LF fluctuations, especially when investigating the effects of orthostatic tilt. Determining the effects of orthostatic tilt involves measuring heart rate during supine, sitting, and standing positions (Reyes del Paso *et al.*, 2013). Myocardial infarction, a known sympathetic stimulus, results in this shift as well (Bernston *et al*., 1997). Firing of sympathetic fibers abnormally increases after myocardial infarction due to the changes in geometry of the beating heart (Malik et al., 1996). However, sympathetically mediated changes in arterial blood pressure can lead to changes in parasympathetically mediated vagal-cardiac nerve traffic, suggesting that both branches of the autonomic nervous system interact to produce LF-HRV patterns (Bernston *et al*., 1997).

Other literature suggests that LF-HRV is more likely to reflect baroreflex arterial blood pressure variations, as both rhythms fall within the same low frequency bandwidth (Bernston *et al.*, 1997). This is supported by the fact that LF-HRV decreases when baroreflexes are disabled, and that LF-HRV is correlated with baroreflex sensitivity of HRV (Martelli *et al*., 2014). The LF/HF ratio is thought to be a measure of the balance of sympatho/vagal regulation on the heart (Malik *et al.,* 1996). Thus, LF-HRV cannot only be contributed to sympathetic neural activity because there are many other physiological parameters that affect this measure. It is more likely that there is an indefinite mixture of vagal and sympathetic influences acting on the low frequency component of HRV (Thayer *et al.,* 2012).

Inhibition of parasympathetic neurons by administration of atropine abolished the high frequency component of heart rate variability, proving that HF-HRV is only a measure of parasympathetic influence (Pomeranz *et al*., 1985).

The Interaction between Vagal Tone and Positive Affect

HF-HRV represents an index of parasympathetic activity through vagal control, and therefore is often used as a measure of physiological and emotional arousal regulation (Gouin *et al.,* 2015). A study investigating stress and insomnia found that individuals with low HF-HRV were found to have longer-lasting elevations in heart rate and higher diastolic blood pressure, cortisol and tumor necrosis factor-α in response to emotional stressors (Gouin *et al*., 2015). Lower HF-HRV has also been associated with greater anxiety, depression, increased reported sleep disturbances, and other mental illnesses (Gouin *et al.*, 2015).

In contrast, higher HF-HRV has been an indicator of positive affect and health. Higher HF-HRV causes an increase in parasympathetic activity, soothing an individual that experiences an environmental stressor, and thus likely improving their emotional state (Cosley *et al*., 2010). Resting vagal tone is known to be associated with greater emotional expression, especially empathic concern (Oveis *et al.,* 2009). Recent research has studied the relationship between altruistic giving and heart rate variability (Barraza *et al.*, 2015). One study tested the effects cardiac vagal control, heart rate, and electrodermal activity had on charitable giving after participants watched a persuasive narrative asking for donation appeals (Barraza *et al*., 2015). The authors found that HF-HRV significantly predicted the decision to donate, and that both mean RR-intervals, or the distance between two QRS peaks, and HF-HRV decreased after watching the narrative. Interestingly, donors had higher baseline HF-HRV levels than non-donors, and while HF-HRV decreased in both groups, HF-HRV post-narrative was considerably higher for the donor group. This study concluded that mean R-R intervals were strongly correlated with concern (Barraza *et al*., 2015). These findings suggest that heart rate variability as an autonomic measure may play a role not only in emotional expression, but possibly also in philanthropic and unselfish acts of virtue.

Other research hypothesizes that there is an "upward spiral" relationship between vagal tone and positive emotion (Kogan *et al*., 2014). This theory states that individuals with higher vagal tone will have greater desire to engage in positive social behavior. The physical and emotional rewards received from these increased social opportunities will further increase vagal tone. Therefore, it is suspected that higher vagal tone is associated with greater overall health and happiness because individuals feel a higher sense of social connectedness (Kok and Fredrickson, 2010). This finding is related to a study that tested how compassion affects physiological measures, such as blood pressure, HRV, and cortisol level. Participants who were more compassionate exhibited lower blood pressure and cortisol levels, and particularly, higher HF-HRV measures (Cosley *et al*., 2010). Individuals with higher resting levels of vagal activity were found to have increased self-reports of traits associated with pro-sociality, including extraversion and agreeableness, after 6 months of their vagal activity evaluation (Oveis *et al.,* 2009). This is further evidence that individuals with higher HF-HRV may show greater positive affect, and therefore better well-being (Cosley *et al*., 2010).

Although increased vagal activity and pro-sociality are correlated, some research has shown that excessively high levels of vagal activity are associated with mania (Gruber, Harvey, & Purcell, 2011). Kogan *et al*. (2014), proposed the *quadratic vagal-activity-prosociality hypothesis*, which postulates that cardiac vagal tone and pro-sociality do not have a positive linear relationship. They believe that higher vagal activity is an adaptive response that encourages pro-sociality behavior; however, activity at elevated levels can result in socially maladaptive behavior. Therefore, there appears to be a threshold vagal activity that corresponds to positive emotion, with extremely high or low levels corresponding to negative social behaviors or emotions.

Brain Activity Specific to Emotional Expression Correlates with HF-HRV Activity

A few studies have measured neural activity in the brain and vagal tone simultaneously during emotional expression. The polyvagal theory predicts that vagal tone is related to positive emotion because of the close proximity of neural networks that control vagal activity and facial expression (Porges, 2001). One study measured emotion-specific regional cerebral blood flow (rCBF) independent of HF-HRV, then measured HF-HRV along with rCBF to investigate how rCBF varied while HF-HRV was being measured (Lane *et al*., 2009). The authors found that emotion-specific rCBF independent of HF-HRV localized brain activity to the prefrontal cortex. Further, when HF-HRV was measured simultaneously with rCBF, brain activity also located to the prefrontal cortex, indicating that HF-HRV and emotional expression are co-simultaneously active (Lane *et al*., 2009). The prefrontal cortex is an area of the brain important for establishing a representation of one's emotions (Lane *et al*., 1997). This correlation suggests that this cognitive function is likely linked to activation of nerves that control visceral smooth muscle, which implies that there is a connection between emotional expression and heart rate activity (Ongur *et al*., 1998).

Another region of the brain located in the thalamus, called the periaqueductal gray area (PAG), was identified as a region that correlated emotion-specific cerebral blood flow and HF-HRV activity (Lane *et al*., 2009). The PAG is an area of the brain that is responsible for managing behavioral and visceral responses to stress and threat (Price, 1999). It is logical that the PAG is correlated with HF-HRV activity, as changes in vagal outflow to the heart are one of the physiological responses to stress. (Lane *et al*., 2009). Evidence that regions of the brain that regulate emotional arousal and HF-HRV are activated simultaneously strengthens the inter-connectedness between physiological (HF-HRV) and psychological (emotion) systems.

Current Research and Predicted Results

This research investigates the relationship between cardiac vagal tone and feelings of positive affect, which was measured through level of donation behavior. In particular, this study tests whether baseline levels of heart rate variability can predict the degree of altruistic behaviors by the participants. In this experiment, two indicators of heart rate variability, high frequency (HF), low frequency (LF) at rest were measured. Although HF-HRV is most representative of vagal tone, LF-HRV may also have some parasympathetic influences, therefore both parameters will be looked at to determine the effect parasympathetic activity has on pro-social behavior.

Three separate tests were ran to analyze how heart rate variability affects donation behavior. The first was a t-test, which compared the difference in HF-HRV values between donors and non-donors. I hypothesized that the vagal tone of donors would be higher because they would show greater positive affect, and therefore donate more money. The second test I ran was a correlation to determine if heart rate variability could predict the magnitude of pro-social behavior. It was predicted that participants with higher baseline vagal tone, or HF-HRV activity, would exhibit greater charitable behaviors. In other words, individuals with higher HF-HRV levels would feel greater desire to help others in need, and therefore would give larger donations. In contrast, individuals with lower HF-HRV levels would give little to no donations because these individuals would feel less empathy and concern towards the charities. The relationship between LF-HRV and donation behavior could not be predicted because it is not completely known how LF-HRV affects vagal activity.

Methods

Data Collection

Dr. Jorge Barraza at the Claremont Graduate University collected the data used in this study. A total of 66 participants were recruited for the study; however, I chose to use a smaller subset of 29 participants. The randomly chosen sample consisted of 10 males and 19 females, creating a total sample size of 29 overall. Participants ranged in age from 18 to 43; however, the majority of the sample was younger than 30 (89.7%). For my thesis, I only used a subset of the total participants because it took significant time to clean the raw data I was given so that they could be accurately analyzed.

Participants were first asked to take an online survey, which asked them to consider their beliefs and attitudes towards charitable behavior. Participants were then attached to ECG equipment to obtain baseline heart activity levels. Three ECG leads were placed on the participant, one below the right collarbone, and two were placed over the ribs. Baseline ANS measures were recorded for five minutes. A second physiological variable, skin conductance, was measured to see how changes in electodermal activity affected emotional expression and predicted donations. While heart rate was being recorded, participants reviewed and rated several donation appeals by various charity organizations. The original experiment conducted by Barraza tested the effect changes in vagal tone had on the amount donated; however, for my project I only analyzed whether baseline HF-HRV levels, or resting vagal activity, could predict charitable giving.

After reviewing the charity appeals, participants were asked to write down the emotions they associated with each stimulus, such as concern, distress, or anger, and how strongly they felt each one. Participants were told that they would be given an additional fifteen dollars if they evaluated the charity appeals. At the end, participants were asked if they wanted to donate part of their earnings to any of the five charities. If the participants decided to donate money, the total sum of the money they decided to give to any of the five charities was subtracted from their original thirty dollars. The participants were aware that the sum of their donations would go to the charities on their behalf.

ECG Cleaning

Before HF-HRV values could be extracted from the data, the ECG readings had to be cleaned for errors such as background noise and signal loss. ECG data were collected by AcqKnowledge® software. Each waveform was manually inspected to ensure that any large deviations, or amplitude abnormalities, in the reading were smoothed. The baseline portion, or the participants' heart rate at rest, was the only part of the reading used in this experiment. After cleaning in AcqKnowledge, the ECG waveforms were ran through an algorithm using MatLab®; artifacts in the data were removed manually. Finally these values were ran through a software program called Kubios® to extract the baseline HF-HRV values of each participant. All data were log transformed to validate the assumption of normality required for t-tests, correlations, and regression models. SPSS was used to run the statistical tests.

Results

The first question I wanted to investigate was whether there was a significant difference in HF-HRV values between donors and non-donors. Participants who did not donate were placed in the non-donor group (n=16), while participants that gave high donations, defined as amounts greater than ten dollars, were placed in the donor group (n=13). A two sample independent t-test was run, using donor status as the independent variable, and heart rate variability as the dependent variable. I used a t-test because I wanted to see if there was a difference between groups using a categorical, nominal variable. Participants who donated money show slightly higher log-transformed HF-HRV levels (mean ±SE=3.00±0.134) than those that did not donate (mean±SE=2.81±0.134); however the difference was not significant (Figure 1a, t=-1.092, df=27, p=0.284). The same trend is seen between donors and non-donors when LF-HRV values are examined; again the difference is not significant (Figure 1b, t=-0.556, df=27, p=0.583).

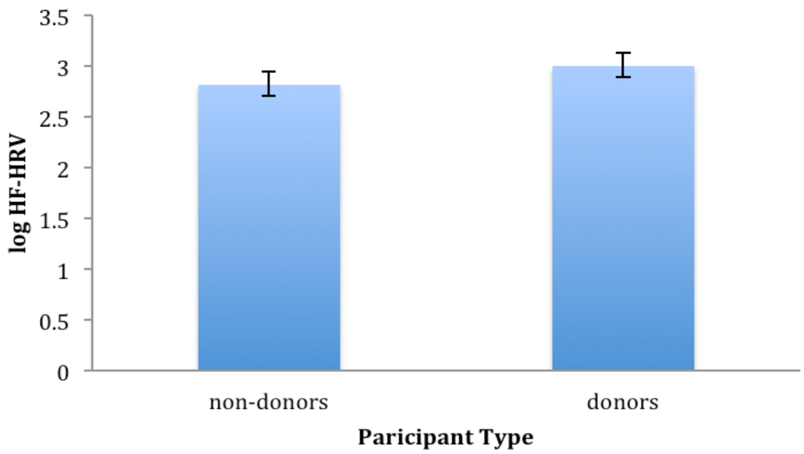

Figure 1a: Mean ± SE log value of high-frequency heart rate variability (HF-HRV) among participants who did or did not donate ($n_{non\text{-}donor}$=16, n_{donor}=13, n_{total}=29).

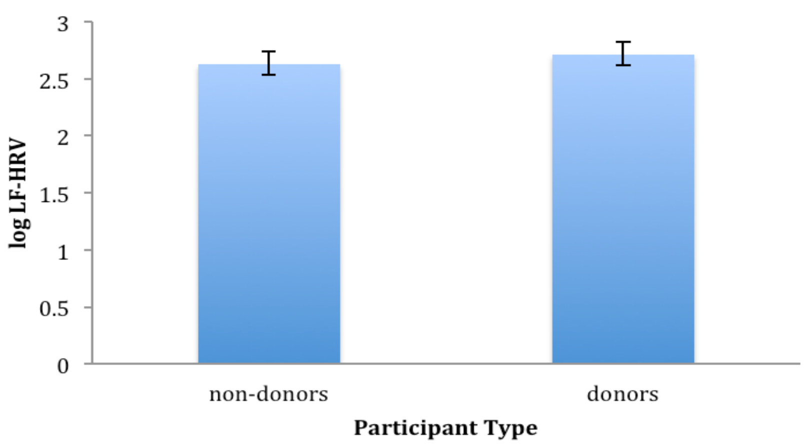

Figure 1b: Mean ± SE log value of low-frequency heart rate variability (LF-HRV) among participants who did or did not donate ($n_{non\text{-}donor}$=16, n_{donor}=13, n_{total}=29).

The second test I ran was a Pearson's correlation to determine if HF-HRV activity could predict the magnitude of pro-social behavior, which was represented by amount each participant donated. A correlation was used because I was comparing two numerical values that were both continuous, amount donated and HF-HRV. Only the donor group (n=13) was used because there was a range of values to test.

HF-HRV and donation amount show a negative, linear relationship among participants who donated; however, the correlation was not significant (Figure 2a, Pearson's correlation, $r = -0.449$, $p = 0.124$). The trend shows that as HF-HRV values increased, donation amount decreased; however, one cannot say that HF-HRV significantly predicted donation amount.

I also wanted to test the association between low-frequency heart rate variability (LF-HRV) and magnitude of donation amount. LF-HRV was initially thought to be associated with sympathetic activity; however new evidence indicates that this parameter is more closely associated to the regulation of blood pressure by the baroreflex, and most likely has parasympathetic influences (Reyes del Paso et al., 2013). Although LF-HRV is not a direct marker of vagal activity, it can still be used to see if there is a trend between LF-HRV and pro-social behavior, or donation amount.

Low frequency heart rate variability and donation amount showed a significant negative correlation (Figure 2b, Pearson's correlation, $r=-0.668$, $p=0.013$). Unlike HF-HRV, LF-HRV values could significantly predict magnitude of donation amount, with higher LF=HRV values giving lower donations (Figure 2b).

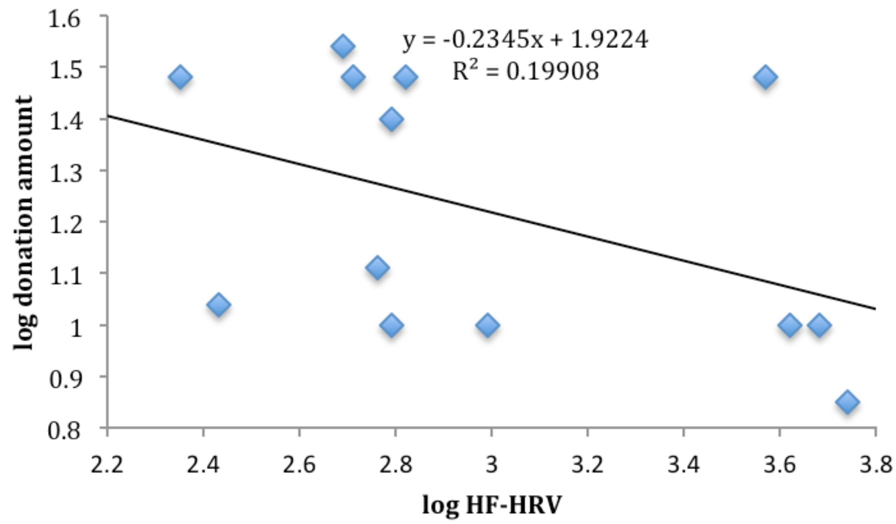

Figure 2a: The relationship between HF-HRV levels and total amount donated. All values represent log 10 transformations (n=13).

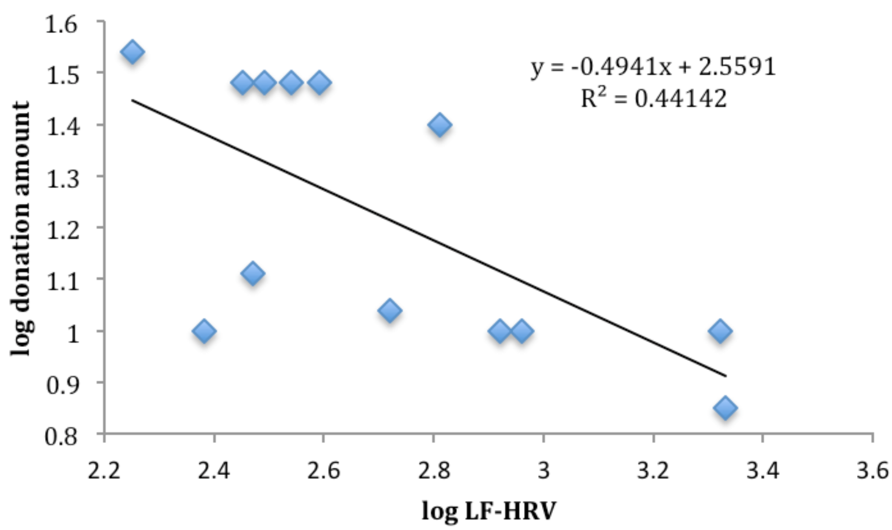

Figure 2b: The relationship between LF-HRV values and donation amount. All values represent log 10 transformations (n=13).

Finally, I wanted to test if gender affected the relationship between HF-HRV and donation amount. A regression model was used to analyze this effect. In my regression model, HF-HRV, which is numerical and continuous, acted as the independent variable, donation amount (numerical, continuous) was the dependent variable, and gender was entered as a covariate.

A general linear regression model was used to determine how gender (covariate) affected the relationship between HF-HRV and amount donated (Figure 3a). Overall, the regression model did not show significant results (Figure 3a, F=3.612, df=1,13, p=0.066). There was no significant effect of gender on amount of money donated to the charities; however, women on average donated more than men (Figure 3a, F=3.754, df=1,13, p=0.081). HF-HRV significantly predicted donation amount, regardless of gender (Figure 3a, F=6.665, df=1,13, p=0.027). There was no significant interaction between the effects of HF-HRV levels and gender on donation amount (Figure 3a, F=0.337, df=1,13, p=0.576).

The regression model that tested how gender affected the relationship between low frequency HRV (LF-HRV) and amount donated showed significant results (Figure 3b, F=6.233, df=1,13, p=0.014). Donation amount was significantly different across genders (Figure 3b, F=5.960, df=1,13, p=0.037). LF-HRV was found to significantly predict donation amount, regardless of gender (Figure 3b, F=8.868, df=1,13, p=0.016). The interaction between gender and LF-HRV levels on donation amount was found to be significant (Figure 3b, F=5.527, df=1,13, p=0.043).

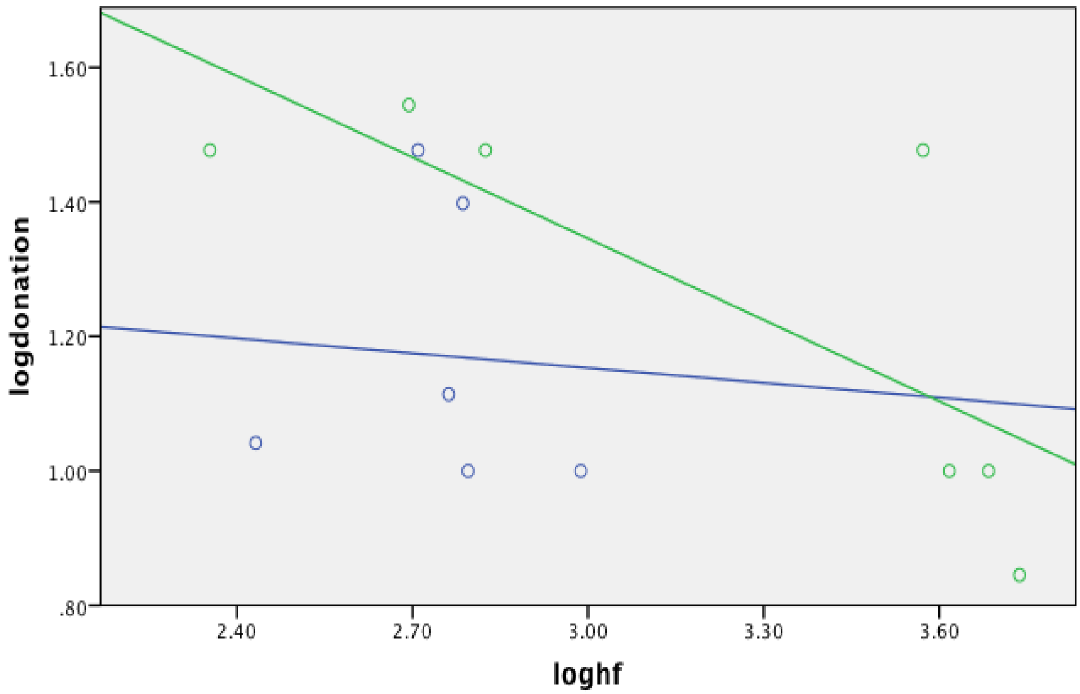

Figure 3a: Relationship between HF-HRV levels and total amount donated, separated by gender (blue=male, n=6, green-female, n=7). All values represent log 10 transformations.

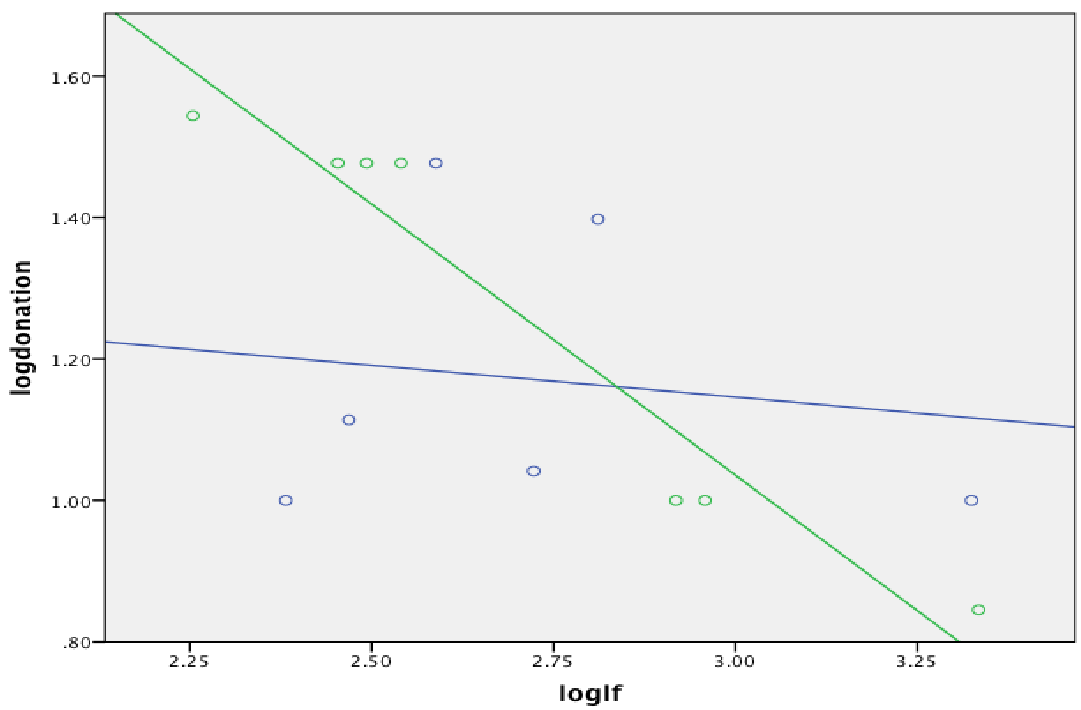

Figure 3b: Relationship between LF-HRV levels and total amount donated, separated by gender (blue=male, n=6, green-female, n=7). All values represent log 10 transformations.

Discussion

Interpreting Results

There was no significant difference in HF-HRV activity between individuals who decided to donate and those who did not, although donors showed slightly higher activity (Figure 1a). This may show that resting vagal activity may not be able to predict whether an individual expresses pro-social behavior. There may also be significant impact from sympathetic influences on the decision to donate; however, this effect could not be measured because it is hard to interpret the level of sympathetic activity that contributes to heart rate variability.

Contrary to hypotheses, high frequency heart rate variability negatively predicted amount donated; however, the difference was not significant (Figure 2a). It was expected that this relationship would be positively correlated due to the plethora of research that has associated higher vagal tone with better health and positive emotion (Barraza et al., 2015). The negative association may be attributable to the participants who had the highest vagal tones, which therefore skews the distribution to the right (Figure 2a). Research has shown that excessively high vagal activity may not be beneficial to positive health and emotion, instead causing more stressful, manic states (Kogan et al., 2014). This may provide reason for why the individuals with the highest HF-HRV activity donated the least amount of money.

The regression model showed that HF-HRV levels significantly predicted donation amount, but gender did not (Figure 3a). This shows that HF-HRV could predict amount donated across separate genders; however, gender alone cannot predict whether an individual decides to donate. HF-HRV significantly affected donation amount when it was part of the regression model; however, HF-HRV did not significantly affect donation in a simple correlation test.

Women showed a stronger negative linear relationship between HF-HRV and donation amount than men did (Figure 3). Women also donated on average higher amounts than man did. There is evidence that women report greater attention to their emotions, and particularly have a greater ability to recognize, express, and interpret emotional information (Barrett et al., 2000). Women also have a better recollection of momentary emotional events because they mark their autobiographical memories with greater detail than do men (Seidlitz and Diener, 1998). Its likely that men did not recognize as strong of emotions associated with the charity appeals, and therefore donated less because these appeals held less emotional meaning for them.

Similar patterns were seen when low frequency HRV levels were compared to donation behavior, across all three tests (Figure 1b, 2b, and 3b). Unlike HF-HRV, LF-HRV levels showed a significant negative correlation with donation amount (Figure 2b). In the regression model, gender was able to significantly predict donation amount, regardless of LF-HRV levels. Further, there was a significant interaction between gender and LF-HRV on donation amount (Figure 3b). Interpretation of the low frequency band has been a controversial topic in the literature. Past research has correlated LF-HRV with sympathetic activity; however, others believe that it is more likely this component has both sympathetic and vagal influences (Paso del Reyes et al., 2013). My results show that LF-HRV may play a significant role in the relationship between vagal tone and pro-social behavior; however, it is hard to know whether this effect comes from sympathetic or parasympathetic influences.

Conclusions and Future Research

Overall, my results do not support the hypothesis that higher vagal tone is associated with greater well being, which was measured through pro-social behavior. Instead, the trend of the data shows a negative association. However, the significance of these results is weak due to the very small sample size, thus the pattern may not represent that of the entire population. The sample size for the correlation and regression analyses is especially small because it included only the participants who donated, which was half of the original sample size. This severely limits the power of my results. With a larger sample size the differences I saw between donors and non-donors and pro-social behavior may have been statistically significant.

It would be interesting to test if the correlation between HF-HRV and pro-social behavior differed significantly with a larger sample size; especially when the relationship is compared across genders. For future studies, I would like to test how other covariates affect vagal tone, and therefore affect the relationship with giving behavior. Some possible covariates to test within participants would be their total weekly exercise, general diet, sleeping behavior, and whether they suffer from any mental illnesses. All of these factors could play a role in the regulation of vagal tone, which could subsequently have an effect on emotional expression and social behavior.

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