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The Associations of Extraversion and Heart Rate Variability

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Abstract

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Heart rate variability as a measure of cardiovascular health and autonomic activity correlates with psychological resiliency but is not consistently related to trait extraversion, a strong predictor of emotional well-being. This study intends to clarify research findings about trait extraversion and heart rate variability by identifying the context and nature of the relationship between extraversion and physiological responses. As a secondary analysis of data from a study comparing biofeedback and compassionate breathing, extraversion scores were compared with heart rate variability data at three different points including prior to a stressor, during exposure to a stressor, and recovery to a stressor to determine the influence of extraversion on stress reactivity and stress recovery. In our sample population of 80 participants who were mostly young and in good health determined by self-report, the average extraversion score 79.14. Linear regression was used to compare differences at each time point and data was analyzed for significance at $p=.05$; a post-hoc power analysis revealed $\beta = .81$, $1 - \beta$. There were no significant findings between extraversion and heart rate variability at any time point. The results of this study support no relationship between extraversion, health, and stress-resiliency.

Keywords: heart rate variability, extraversion, stress reactivity

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The Associations of Extraversion and Heart Rate Variability

Heart rate variability (HRV) is a measure of cardiovascular health and autonomic activity that predicts morbidity and mortality (Ernst, 2013; Billman et al., 2015). High HRV is healthier than low HRV because it reflects adaptability of the cardiovascular system to internal and external stressors (McCraty & Shaffer, 2015). A number of studies and reviews have established HRV as a reasonable assessment of physiological and emotional health, especially in a research capacity (Joyce & Barrett, 2019; Lehrer et al., 2020; Perna et al., 2020). HRV is related to physiological and psychological health, reflecting a more adaptive way of interacting with the world. HRV predicts improved psychological resiliency and stress reactivity, (Shaffer et al., 2014; Lombardi & Stein, 2011; Kleiger et al., 1987), decreased depression and anxiety, (Kemp et al., 2012) as well as improved immune function and inflammation (Thayer et al., 2010). HRV interventions have led to improved physical and emotional outcomes (Coyle et al., 2020; Goessl et al., 2017; Economides et al., 2020).

Extraversion is a personality trait that refers to behavioral preferences for stimulating and high energy activity, as well as assertiveness in interpersonal relationships (Digman, 1990). Extraversion positively correlates with life satisfaction and happiness (Røysamb et al., 2018; DeNeve & Cooper, 1998). Many researchers conceptualize psychological well-being as having high autonomy, environmental mastery, personal growth, positive relations with others, purpose in life, and self-acceptance (Kállay & Rus, 2014). Extraverted traits relate to self-acceptance, environmental mastery, purpose in life, personal growth, and positive relations with others; but not high autonomy (Schmutte & Ryff, 1997). Extraversion is a strong predictor of emotional well-being.

Extraversion also contributes to physical well-being, however the relationship between physical health and extraversion is not direct (Finch et al., 2012). Extraversion relates to physical health through more direct pathways such as positive affect and socialization (Taylor et al., 2017; Fredrickson, 2001; Kinnunen et al., 2012). Likely through these pathways, several health outcomes seem affected by higher trait extraversion. Extraversion predicts cardiovascular health, improved sleep habits, increased physical activity, and mortality (Giannelou et al., 2018; Otonari et al., 2011; Rizzuto et al., 2017).

We do not fully understand the relationship of extraversion to stress regulation, even if some mechanisms such as positive affect have been identified as potential influences. Research on extraversion also has yet to consistently demonstrate a relationship between cardiovascular health and extraversion (Kim et al., 2018; Brouwer et al., 2015; Jonassaint et al., 2009; Coyle et al., 2020; Finch et al., 2012). Examining the relationship between extraversion and HRV may lead to a greater understanding of the emotional processing mechanisms associated with improved HRV and related improved autonomic balance and stress resiliency. Increases in extraversion related behavior and cognitions may be a key to reducing the effects of acute stress and improving cardiovascular health. This study proposes to add clarity to the potential relationship between extraversion and stress resiliency as well as between extraversion and cardiovascular health. This study will examine extraversion as a protective factor for physiological stress as assessed by HRV.

Heart Rate Variability, Health, and Wellbeing

As a measure of cardiovascular health, HRV can be used as a diagnostic tool for myocardial infarction, as well as an assessment measure for cardiovascular risk (Billman et al., 2015; Ernst, 2013). HRV measures oscillations in the beat-to-beat of heart rate (Ernst, 2013).

Reduced HRV predicts cardiovascular mortality, with lower HRV predicting increased risk of sudden death in cardiovascular patients (Kleiger et al., 1987; Lombardi & Stein, 2011). HRV is also related to all-cause mortality, due to its relationship with other physiological disease states (Thayer et al., 2010). HRV reduces in response to diabetes, smoking, obesity, work stress, hypertension, and heart failure (Billman et al., 2015).

HRV can also be used to assess physiological responsiveness to stress. Casad and Petzel (2018) found that in response to a social stress, female participant's resting HRV was lower. HRV is typically used as an assessment tool for acute stressors (Thayer et al., 2010; Coyle et al., 2020; Thayer et al., 2012). Physiological stress, as well as psychological stress, directly affect HRV (Billman et al., 2015). The relationship of HRV to stress may reflect its relationship to the autonomic nervous system.

HRV is correlated with psychological health. Improved emotional well-being predicts higher HRV (Mather & Thayer, 2019). Several mental disorders correlate with HRV (Berntson & Cacioppo, 2004; Beauchaine & Thayer, 2015; Jung et al., 2019). Those with MDD experienced lower HRV responses to stressors (Schiweck et al., 2019; Jung et al., 2019) and depression and generalized anxiety disorder correlate with lower baseline HRV (Kemp et al., 2012; Kemp & Quintana, 2013). Suicide attempters experienced increased anger and decreased HRV in response to a stress test compared to non-suicide attempters (Wilson et al., 2016). HRV interventions lead to improvements in mental disorders. Several studies have found that HRV biofeedback can reduce the symptoms of chronic depression and anxiety, as well as anger (Economides et al., 2020; Goessl et al., 2017; Shearer et al., 2016; Lehrer et al., 2020).

Two mechanisms contribute to stress resiliency: a) regulating emotional reactivity and stress response; and b) the ability to recover quickly from stressful experiences. These adaptive perceptions and responses to stressors are also considered HRV-related self-regulatory mechanisms. Therefore, HRV is a way to identify individual's ability to regulate their own mood (Holzman & Bridgett, 2017; Kim et al., 2018; Goessl et al., 2017). Higher resting HRV is related with better use of regulatory strategies and better emotional responding (Balzarottie et al., 2017; Perna et al., 2020). Holzman and Bridgett (2017) identified in a meta-analytic review that HRV has demonstrated reliability as a biomarker of top-down regulation, or emotional regulation that is directional from cognitive appraisal to autonomic and cardiovascular responding.

As a measure of self-regulatory capacity, HRV is additionally related to stress resiliency through quicker stress recovery (McCraty & Shaffer, 2015; Kim et al., 2018). HRV leads to better stress recovery via an increased capacity to down-regulate negative experiences (Balzarottie et al., 2017). HRV can also reflect individual ability to respond adaptively stressors and demands (Holzman & Bridgett, 2017). In a review by Perna et al. (2020), HRV is a marker for individual flexibility and adaptability to stressors. HRV correlates with psychological resiliency and indicates a greater ability to respond healthily to negative or challenging experiences.

Porges' developed the Polyvagal Theory to explain the vagal connection to self-regulation, suggesting a social engagement system in mammals where several physiological systems, focusing on the central nervous system, lead to a more complex interaction with the environment than 'fight, flight, and freeze' (Porges, 2018; Shaffer et al., 2014). Shaffer's application of Porges' theory, in which healthy autonomic functioning leads to successful emotional expression, communication, and self-regulation, indicate that measuring healthy autonomic nervous system activity through HRV is measuring healthy emotional and social behaviors.

Extraversion, Health, and Wellbeing

Extraversion is a personality trait reflecting an individual's relative response to positive stimuli, and encompasses traits such as propensity to warmth, assertiveness, gregariousness, activity, excitement seeking, and sensitivity to positive emotions (McCrae et al., 2000). Specific positive emotions related to extraversion include joy, contentment, pride, love, compassion, amusement, and awe (Shiota et al., 2006). Extraversion predicts social success, as well as increased optimism and positivity.

Extraversion and positive affect are strongly related, with extraversion accounting for positive affect in factor models, therefore positive affect is a key facet of the extraversion trait (DeNeve & Cooper, 1998; Steel et al., 2008; Smillie et al., 2015). Extraversion and positive affect are contributors to one's well-being. Extraverted behavioral and cognitive patterns that are related to positive living and increased well-being are learnable. McNiel and Fleeson (2006) demonstrated improved positive affect in participants who instructed to act extraverted. Other studies describe effective interventions that improve positive affect with extraversion related activities such as engaging in kind social acts and sharing positive experiences (Alden & Trew, 2013; Lambert et al., 2012). Specific interventions to increase positive affect through positive emotionality for anxious and/or depressed patients were effective (Taylor et al., 2017). Personality traits are conceptualized as stable, but it is important to note that extraversion is a personality trait repeatedly demonstrated to be approximately 50% heritable, with 50% developing out of psychosocial factors (Røysamb et al., 2018; DeNeve & Cooper, 1998; Wilt & Revelle, 2009). The mechanisms of wellbeing related to extraversion are learnable and can potentially increase an individual's ability to increase their own life satisfaction.

The relationship between extraversion and health is unclear. Some researchers indicate that no direct relationship between extraversion and physical health (Finch et al., 2012). Yet, extraversion as a personality trait may influence healthier patterns of cognition and behavior that affect physical health. In studies of the relationship between extraversion and physical health, extraversion predicts certain healthier activities. Extraversion is related to increased physical activity, and healthier sleep habits (Otonari et al., 2011). Extraversion also relates to subjective positive rating of physical health and the reduced effect of painful daily symptoms (Mikulaskova & Babincak, 2015; Zhang & Zheng, 2019) . Extraversion has demonstrated an inverse relationship with plaque formation in the heart and Parkinson's disease (Giannelou et al., 2018; Santangelo et al., 2018). In a particularly robust finding looking at geriatric population's mortality, extraversion predicted a reduction in mortality (Rizzuto et al., 2017). In many ways, extraversion seems to demonstrate a clear positive relationship with health.

However, extraversion is also related to specific negative health outcomes. Extraversion has been related to increased smoking, alcohol use, and higher BMI (Otonari et al., 2011; Munafo et al., 2007; Wimmelmann et al., 2018). These behaviors each negatively affect health and contribute to decreased mortality and lower quality of physical health. The relationship of extraversion and physical health is more complex than a direct univariate model.

Extraversion includes more facets than positive affect and emotionality. Sensation seeking is considered an essential element to the definition of extraversion in research (McCrae & John, 1992). The effect of positive affect on health is strongly positive, however sensation seeking behaviors relate to negative health outcomes (Kinnunen et al., 2012). These contrasting facets within extraversion is potentially an underlying reason for mixed findings about the relationship of extraversion and health. In an analysis of the healthiest personality types, extraversion contributed to the health most successfully when paired with conscientiousness, a trait describing diligence and prudence (Kinnunen et al., 2012; McCrae & John, 1992). Extraversion may be most closely related to physical health when other behaviors moderate sensation seeking, or impulsive-related traits.

Extraversion and Heart Rate Variability

Previous literature has identified some connections between extraversion and cardiovascular health. Extraversion predicted lower heart rate and higher heart rate variability (Soliemanifar et al., 2018). The observed relationship between extraversion and physiological differences may be stronger in stressful situations. Higher extraversion leads to improved HRV in reaction to and recovery from a stressor. Jonassaint et al. (2009) found decreased systolic blood pressure and heart rate in stress tasks for those scoring higher on extraversion. In a review by Soliemanifar et al. (2018), extraversion was related to lower cortisol reactivity and lower cardiovascular reactivity to stress; they also found low extraversion linked to higher epinephrine and BP.

Stressful conditions with a social element demonstrate even stronger relationships between extraversion and cardiovascular health. Bibbey et al. (2013) proposed that since extraversion relates to social adaptability, more physiological differences are observable in social situations. Adolescents who scored higher on extraversion demonstrated lower cortisol reactivity in socially demanding situations (Evans et al., 2016). In stressful social conditions, individuals with higher extraversion demonstrated improved HR and BP, reacting less strongly to the stressor, and recovering more effectively (Lu et al., 2018).

However, studies examining the relationship between cardiovascular health and extraversion do not consistently find physiological differences. Jonassaint et al. (2009) found no baseline relationship with extraversion. Gallagher et al. (2018) and Bibbey et al. (2013) observed that extraversion negatively correlated with perceived life-events stress, though not with physiological measures. Shepherd et al. (2015) and Silvia et al. (2014) found no significant correlations between extraversion and baseline HRV. Brouwer et al. (2015) observed no significant differences in HRV and HR by extraversion in reactivity to a stress game, despite significant baseline HRV and HR correlations to extraversion.

Current Study

The lack of consensus in research findings on extraversion and HRV indicates need for further studies. This study intends to clarify research findings by identifying the context and nature of the relationship between extraversion and physiological responses. Specifically, this study examines three different contexts of the physiology to identify where extraversion may or may not correlate. To address this gap in knowledge, I first hypothesize that heart rate variability measurements of standard deviation of normal to normal heart beat intervals (SDNN), average heart rate (Mean HR), and ratios between low- and high- frequency domains by absolute power (LF/HF ms^2) and natural logarithm transformed values of absolute power (LF/HF log) will be significantly higher at baseline in individuals who scored with higher extraversion. I next hypothesize that HRV measurements of SDNN, Mean HR, LF/HF ms^2, LF/HF log will be less reactive to a psychological stressor. My final hypothesis is that those higher in extraversion will show a faster HRV recovery, based on SDNN, Mean HR, LF/HF ms^2, LF/HF log, from a psychological stressor.

Methods

Participants

A randomized controlled trial consisting of 94 college students provided data for this analysis. This study uses secondary data from a study “Integrating Breathing Techniques Into

Psychotherapy to Improve HRV: Which approach is Best?", which investigated the effects of different stress reduction techniques on heart rate variability (Steffen et al., 2021). Of the 94 participants, only 80 contributed data to this analysis due to incomplete questionnaires or incomplete heart rate variability recordings. There were 56 females and 24 males, with the age range between 17 and 41, with a mean age of 21. The mean education level was 13.41 years. 90% participants identified as white (n=72), 7.5% identified as Asian (n=6), and 2.5% identified as Hawaiian or Pacific Islander (n=2). 85% of participants were single/never married (n=68), 15% were married (n=12). Participants' self-reported quality of health was "excellent", n =11, "very good" n = 41, "good", n = 24, and "fair", n = 4. None of the participants reported poor health (See Figure 1). The participants recruited indicate the generalizability of this study constrained to mostly young, single, white, and healthy participants.

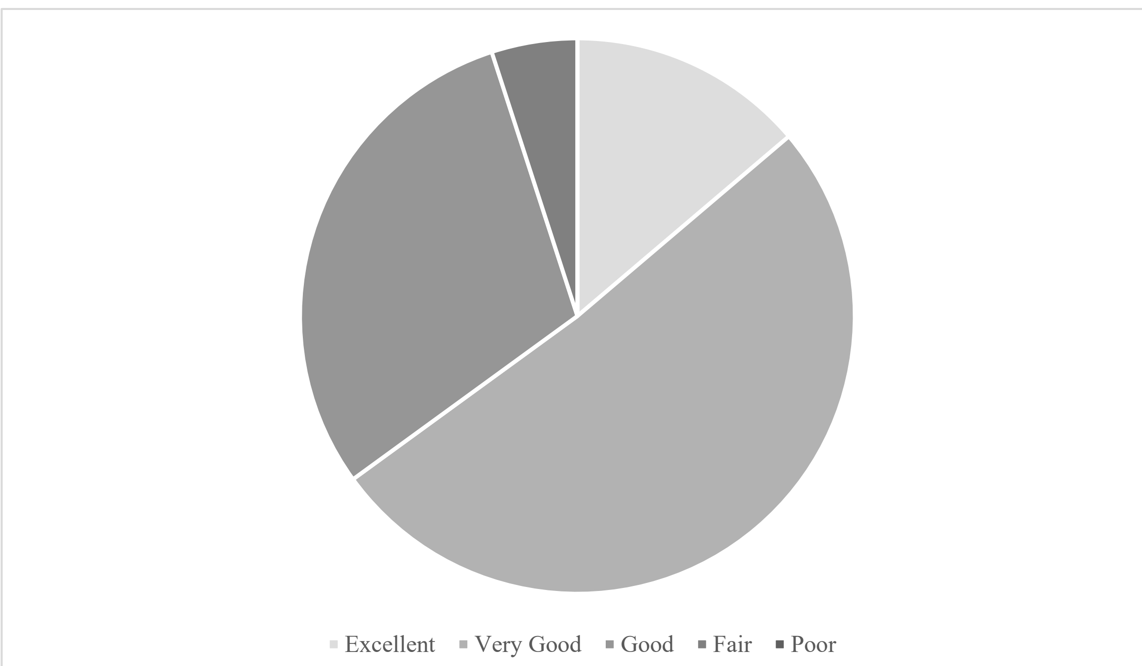

Figure 1 Self Reported Health Quality

A university institutional review board approved this study and all participants read and provided informed consent before starting the study.

Assessment Tools

Psychological Measures

Extraversion was measured using the short form of the International Personality Item Pool – Neuroticism, Extraversion & Openness (IPIP – NEO – 120). This assessment is used to measure the personality scales of Neuroticism, Extraversion, Conscientiousness, Openness, and Warmth (DeNeve & Cooper, 1998). Higher levels of a trait indicate a stronger behavioral pattern aligned with the trait. This shortened measure stemmed from the full International Personality Item Pool using ~600,000 respondents with Cronbach alpha reliability ranging from .87 - .90 (Johnson, 2014). The total of a trait score can be reported in several ways including the sum of the individual facet scores, the average of the facet scores, and the average Likert response. For the purposes of this study, extraversion will be reported as the total sum of responses and facets. Variability in extraversion mean scores between populations is expected.

Physiological Measures

BioTrace+ Nexus 4 measured heart rate variability. The heart rate variability factors were mean HR, SDNN, LFms, HFms, LF log, and HF log.

HRV Measurement

Metrics that provide information about HRV include SDNN, LF, HF, and HR. SDNN is the standard deviation of normal-to-normal intervals; increasing when HRV is large and irregular, which is associated with better outcomes and stress resiliency (Kim et al., 2018; Billman et al., 2015). The interpretation of low-frequency band (LF) and high-frequency band (HF) represent different intensities of spectral components.

Procedure

The participants for this study first answered an extensive online survey administered with Qualtrics and accessed through Brigham Young University's research participation program. This survey included the IPIP – NEO – 120 questions. Following the survey, participants indicated their interest in participating in the lab portion of the study. The lab portion of the study necessitated ~ 40 minutes of participant time in the lab in which the subject was attached to electrodes, a respiration sensor, and a blood pressure cuff. Participants were randomized into experimental groups related to the primary study from which the data was collected.

The primary study compared HRV differences in groups with a paced breathing intervention, a compassion focused therapy breathing intervention, and a controlled group which watched a nature video. All participants then engaged in expressive writing first focusing on self-critical thoughts and then focusing on self-compassionate thoughts. After each segment of the study: baseline, intervention, critical writing, compassionate writing, recovery, (See Table 1), and the participants completed a questionnaire to assess stress and affect. Participants had their blood pressure and heart rate measured twice per segment of the study. This secondary analysis of data compared HRV differences in the baseline, level of change to stressor, and level of change in recovery, by extraversion score rather than by experimental groups.

The stressor for this study was the self-critical period, in which participants spent time writing about a time they felt self-critical. Bibbey et al. (2013) propose that emotional stressors demonstrate differences in stress physiology for extraverts more strongly than other stressors. Emotional provoking tasks may potentially moderate increased stress regulation in extraverts (Jonassaint, et al., 2009). The stressor is emotionally evocative, and we predict it will lead to stronger effects of HRV mediated by extraversion.

Data Collection and Correction

The data collected into the BioTrace+ system was analyzed in five-minute segments, and then processed and analyzed through the Kubios software. Several variables such as subject movement, electrode adhesion, etc., impacted the collection of HRV data from human subjects, which is typical for this equipment (Rincon Soler et al., 2018). Kubios corrects for these artifacts using threshold correction, comparing every beat interval to a local mean beat-to-beat (RR) Beats exceeding the selected threshold are noted as artifacts. These artifacts are then corrected, or excluded from the analysis, which is done through a Kubios algorithm (Tarvainen et al., 2020). The data from this study was corrected at medium RR-Threshold. SDNN, Mean HR, and RMSSD were collected in the Time-Domain. AR results for power (ms2) LF and HF, and power (log) LF and HF were collected in the Frequency domain.

Statistical Analysis

The data was imported into SPSS 27 and extraversion scores were determined by summing the related responses to extraversion questions in the IPIP-NEO-180 (Appendix A) and appropriate items were reverse scored (Johnson, 2014). Descriptive statistics were calculated. There was no standardization of extraversion scores or comparison to national means because IPIP-NEO-120 norms are recommended to be assessed within a study's own sample, as norms develop locally and relate to personality differences among others in that population (Goldberg, 2019).

Linear regression was used to explore each of the hypotheses. The first regression series, to investigate possible differences in resting HRV and extraversion scores, looked at the relationship between each HRV measurement (Mean HR, SDNN, LF/HF ms^2, and LF/HF log) as dependent variables with extraversion as the independent variable at the baseline interval of the study.

The next series of regression analyses investigated the if there were differences in HRV response to a stressor among extraversions scores. Each HRV measurement (Mean HR, SDNN, LF/HFms^2, and LF/HF log) collected at the time of the stressor event was analyzed as a dependent variable with extraversion and related baseline HRV measurements as independent variables.

The final series of regression analyses were designed to investigate differences in recovery from the stressor event among extraversion scores. HRV data (Mean HR, SDNN, LF/HFms^2, and LF/HF log) at the recovery period was compared as a dependent variable to extraversion scores and HRV scores at the stressor event as independent variables.

The data was analyzed for a significance of $p=.05$. A post-hoc power analysis revealed $\beta = .87$, $1- \beta$ and an expected effect size as small as 0.15.

Results

The mean of extraversion scores was 79.14, with a range of 57 to 97 and standard variation of 7.362. This study's averaged extraversion score by facet is 13.19 and by Likert scale and facet is 2.638. The distribution of extraversion scores was determined to be within normal range; kurtosis was .392 and skewness was -.179 (See Figure 2).

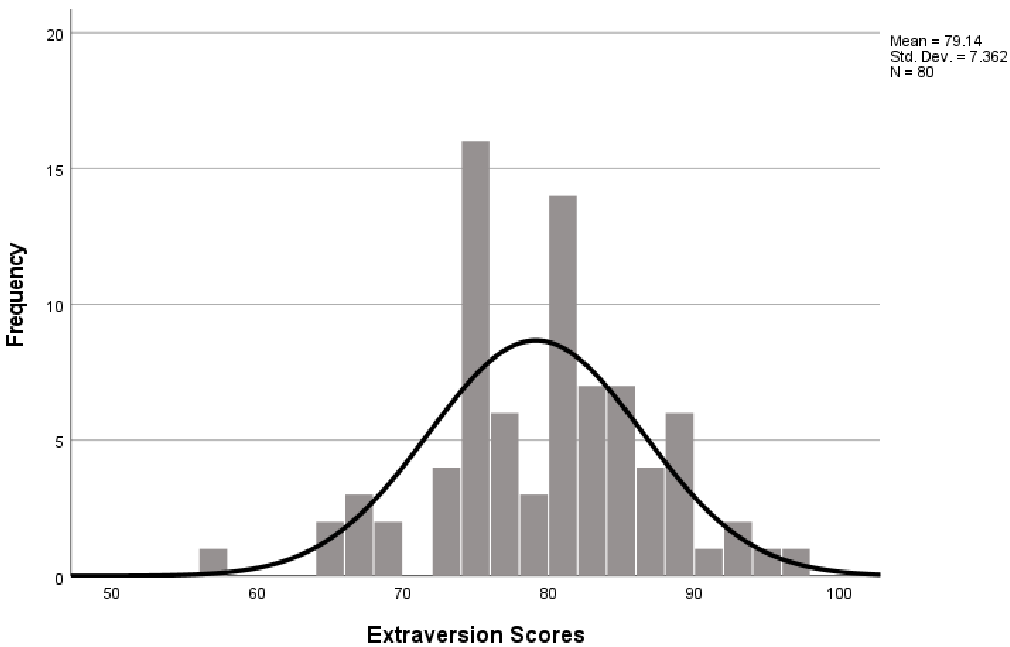

Figure 2 Distribution of Extraversion Scores

Hypothesis 1

A linear regression model was run to examine the relationship between HRV metrics at baseline with extraversion score. Extraversion did not significantly predict HRV at baseline.

Table 1 Descriptive Statistics of HRV Measurements at Baseline

	Minimum	Maximum	Mean	Std. Deviation
SDNN	17.55	106.67	50.1686	18.88810
Mean HR	47.17	106.84	75.2376	10.57615
LF/HF ms^2	.35	13.34	1.7364	1.92075
LF/HF log	.86	1.62	1.0491	.13464

Linear Regression

None of the coefficients for the HRV metrics demonstrated any statistical significance. The SDNN β of .168 was not statistically significant (p=.563; t = .581). The Mean HR β of -0.187 was not statistically significant (p = .25; t = -1.159). The LF/HF ms2 β of -.008 was not statistically significant (p=.783; t = -.276). The LF/HF log βof -.001 was not statistically significant (p=.678; t = -.416). There were no correlations between the extraversion score and baseline HRV; thus, this hypothesis was not supported.

Hypothesis 2

A multiple regression model examined changes in HRV at a self-critical stressor with extraversion score and baseline HRV in order to identify if extraversion score influenced reactivity to stress. While baseline HRV significantly predicted HRV during the self-critical stressor, extraversion was not related to HRV during the self-critical stressor.

Table 2 Descriptive Statistics of HRV Measurements at Self-Critical Stressor

	Minimum	Maximum	Mean	Std. Deviation
SDNN	17.94	123.24	46.3617	18.81931
Mean HR	47.34	96.91	74.8923	9.49111
LF/HF ms^2	.36	11.17	2.1547	1.97522
LF/HF log	.88	1.72	1.0971	.14801

*Compare to baseline data in Hypothesis 1.

Linear Regression

Extraversion score did not significantly predict SDNN, Mean HR, LF/HF ms^2, or LF/HF log during a self-critical stressor. While baseline HRV did statistically significantly predict reactivity at a critical stressor, extraversion did not demonstrate a relationship to SDNN, Mean HR, LF/HF ms^2, or LF/HF. For SDNN at critical stressor, the extraversion β was -.122, p = .495, t=.261; the baseline SDNN β was .794, p < .0005, t = 11.491. For mean HR at a self-critical stressor, the extraversion β was .039, p = .558, t = .588; the baseline mean HR β was .807, p

< .0005, t = 17.574. For LF/HF ms^2 the extraversion β was .002, p = .911, t = .112; the baseline LF/HF ms^2 β was .756, p < .0005, t = 9.509. For LF/HF log during a self-critical stressor, the extraversion β was .000, p = .774, t = .288; the baseline LF/HF log β was .86, p < .0005, t = 10.996. There were no statistically significant relationships with extraversion and HRV reactivity to a self-critical stressor; this hypothesis was not supported.

Table 3 Coefficients of Extraversion and Baseline HRV to Stressor HRV

Coefficient	Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
SDNN – Stressor					
Extraversion	-.122	.177	-.048	-.686	.495
SDNN – Baseline	.794	.069	.796	11.491	.000
Mean HR – Stressor					
Extraversion	.039	.066	.030	.588	.558
Mean HR – Baseline	.807	.046	.899	17.574	.000
LF/HF – Stressor					
Extraversion	.002	.021	.009	.112	.911
LF/HF ms^2 – Baseline	.756	.080	.735	9.509	.000
LF/HF – Stressor					
Extraversion	.000	.001	.020	.288	.774
LF/HF log – Baseline	.860	.078	.782	10.996	.000

Hypothesis 3

A multiple regression model examined changes in HRV at recovery from a stressor and potential correlations with extraversion score and HRV data at the stressor. While stressor HRV showed consistent correlation to HRV at recovery, extraversion was not related to HRV at the self-critical stressor.

Table 4 Descriptive Statistics of HRV Measurements at Recovery

	Minimum	Maximum	Mean	Std. Deviation
SDNN	18.99	118.01	57.3202	21.76111
Mean HR	45.59	97.58	71.9443	8.80260
LF/HF ms^2	.28	12.47	1.9008	1.77271
LF/HF log	.85	1.38	1.0563	.10935

*Compare to Self-Critical Stressor data in Hypothesis 2.

Linear Regression

Extraversion score does not statistically significantly predict SDNN, Mean HR, LF/HF ms2, or LF/HF at recovery. HRV at the stressor did affect HRV at recovery. The relationship for extraversion and SDNN at recovery was not statistically significant; the β of extraversion was (.080), p = .682, t = .411; the stressor SDNN β was .944, p < .0005, t = 12.440. The relationship between extraversion and Mean HR at recovery was not statistically significant; t*he* extraversion β at recovery was -.004, p = .945, t = -.069; the stressor mean HR β was .861, p < .0005, t = 21.8. The relationship between extraversion LF/HF ms^2 at recovery was not statistically significantly; the extraversion β was .000, p = .774, t = .288; the stressor LF/HF ms^2 β was .86, p < .0005, t = 10.996. The relationship between extraversion and LF/HF log at recovery was not statistically significant; the extraversion β was -.001, p = .666, t = 6.560; the stressor LF/HF log coefficient was (.442), p < .0005, t = 6.560. There were no statistically significant relationships with extraversion and HRV at recovery; this hypothesis was not supported.

Table 5 Coefficients of Extraversion and Stressor HRV to Recovery HRV

	Unstandardized Coefficients		Standardized Coefficients		
Coefficient	B	Std. Error	Beta	t	Sig.
SDNN – Recovery					
Extraversion	.080	.194	.027	.411	.682
SDNN – Stressor	.944	.076	.817	12.440	.000
Mean HR – Recovery					
Extraversion	-.004	.051	-.003	-.069	.945
Mean HR – Stressor	.861	.039	.928	21.800	.000
LF/HFms^2 - Recovery					
Extraversion	-.011	.025	-.045	-.436	.664
LF/HFms^2 – Stressor	.359	.094	.400	3.832	.000
LF/HF log – Recovery					
Extraversion	-.001	.001	-.040	-.434	.666
LF/HF log – Stressor	.442	.067	.598	6.560	.000

Discussion

The hypotheses of this study were that extraversion would correlate with higher HRV at baseline, at a stressor, and at recovery. The study found no significant findings between extraversion and HRV. Extraversion did not predict any changes in HRV at baseline, in reaction to a self-critical stressor, and in recovery from a self-critical stressor. The results of this study suggest that there is not a relationship between HRV and extraversion in young, healthy college students. The lack of significant findings supports the inconsistency found in the relationship between extraversion and HRV in the research literature, instead demonstrating that effects of extraversion on health are related to specific stressors (e.g. social) and population types (e.g. older adults). These results also indicate that there is not an actual relationship between extraversion and stress resiliency in either stress reactivity or stress recovery in young, healthy individuals.

The results of this study are similar to several previous findings. Jonassaint et al. (2009), Gallagher et al. (2018), Bibbey et al. (2013), Shepherd et al. (2015), and Silvia et al. (2014) observed no relationship between baseline HRV and extraversion. Jonassaint et al. (2009) excluded participants with a family history of heart problems and hypertension and participants had an average BMI 24.53 and average age 27.3. Gallagher et al. (2018) excluded participants with cardiovascular disease, immune disorder, and pregnancy and participants had an average BMI of 23.7 and average age 21.65. Shepherd et al. (2015) reported that all participants were non-smokers and were in excellent health with an average age of 35. Silvia et al. (2014) had a population sample with an average BMI of 24 and an average age of 19. Additionally, Brouwer et al. (2015) observed no relationship between HRV and extraversion in reaction to a stressor. Brouwer et al. (2015) reported all participants were healthy and had an average age of 27.43.

The larger study from which the current data were derived demonstrated that HRV decreased from baseline to stressor and increased from stressor to recovery, implying that the stressor was significant, and recovery did occur (Steffen et al., 2021). However, the stressor used may not have been a sufficiently socially related stressor, which Bibbey et al. (2013) suggest may be necessary for demonstrating a relationship between extraversion and physiological stress responsiveness. Self-criticism as a stressor may not pull for the same social responsiveness that extraversion may protect against. However, there are studies demonstrating a relationship between extraversion and stress resiliency even in a non-social stress task, which is in direct contrast to the results of this study (Jonassaint et al., 2009; Soliemanifar et al., 2018).

Limitations.

The study design is somewhat limited as a secondary analysis of data. The original study design did include the continuous measuring of HRV, time-dependent collection of BP data, and three different intervals relevant to this study's research question: (a) baseline, (b) stressor event consisting of self-reflective criticism, and (c) recovery from the stressor.

As the study was a secondary analysis of data, the hypotheses did not guide the development of study design. However, the power of our study ($\beta = .87$) is an appropriate power to detect true significance. To reach a stronger power of .95 we would have needed 27 additional participants. As a secondary analysis, there may have been to additional noise in the data from the original study design (collection of BP, intervention testing, respondent fatigue with questionnaires completed at the same time as the IPIP-NEO Short) that were not related to the specific research questions. The study design testing different stress-reduction interventions may have limited the stress reactivity as well.

An additional limitation may have been the population sample which was self-selected by those who were willing to come for an in-person portion of the study. This self-selection process may have reduced the number of individuals who scored low on extraversion included in the study. The population tested was also primarily young (mean = 21) and healthy (See Figure 1). This population sample limits the generalizability of results and may not yet demonstrate significant differences in lifestyle-related health measures. Another limitation related to population sample as a convenience sample from college students. University experience positively correlates with the increase of extraverted behaviors (Kassenboehmer et al., 2018). This population of university students may have less variability in extraversion by trending towards the upper level. There may have been statistical effects of having a narrower range of extraversion scores that made findings less accurate.

Other samples of extraversion scores in the literature measured through the IPIP-NEO 120 and transformed to reflect total extraversion score include: $M = 82.14$, SD = 14.16 in a US sample of 320,128 ages 19 – 69; $M = 83.04$ in a US sample of 633 undergraduates; $M = 83.18$, SD = 9.32 in an Argentine study of 230 undergraduates; $M = 58.69$ in US undergraduates preparing for teaching; and $M = 83.76$, SD = 9.84 in a US sample of 400 undergraduates (Kajonius & Johnson, 2018; Donnellan & Burt, 2016; Trogolo & Medrano, 2012; Sanderson & Kelley, 2014; Witt et al., 2009). Comparing this study's mean total score of 79.14, with a standard variation of 7.362; the standard variation is within expected range and the mean is slightly lower than the majority. However, variability in sample population scores is normative.

Further Research.

Though significant differences between HRV and extraversion were not found in this population, further research may help to clarify the inconsistency in literature. Several studies of physiological correlates to extraversion were able to identify significant effects of stress response by looked at changes in salivary cortisol rather than HRV (Soliemanifar et al., 2018). Repeating this study using salivary cortisol as a measure of stress responsiveness and recovery may exhibit significant effects.

A study that used a more extreme social stressor, for example participants being told they were giving a speech to a panel of judges, may show greater differences in a population based on extraversion, since extraversion is hypothesized to be a protective factor to social stress. A study that assesses HRV over a longer period, like a 24-hr period, may demonstrate differences in extraversion more clearly. A longer look at HRV for participants in which they control/direct their own activities may demonstrate overall improved daily HRV relating to emotional regulation and self-selection of activities that are protective. In conjunction with a daily log of behaviors, this study may provide more insight to a potential relationship between extraversion and HRV. A meta-analysis that compares the results of this study and others looking at the effects of extraversion on HRV may also help clarify the inconsistency of research findings.

Conclusion

This study examined the relationship between extraversion and HRV at baseline, during a stressor, and during recovery. The results of this study found no significant differences among extraversion scores and HRV at baseline, during a self-critical stressor, and at recovery. There was no support for a relationship between extraversion, health, and stress-resiliency. Future studies can build on these findings by examining stressor type (i.e., social stressors) and different physiological parameters (i.e., cortisol).

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