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The Effect of Depression, Anxiety, and Stress on Heart Rate Variability
During Self-Critical and Self-Compassionate Exercises

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A thesis submitted to the faculty of
Brigham Young University
in partial fulfillment of the requirements for the degree of

Master of Science

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ABSTRACT

The Effect of Depression, Anxiety, and Stress on Heart Rate Variability During Self-Critical and Self-Compassionate Exercises

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The cognitions of individuals who experience symptoms of depression, anxiety, and stress have been well documented, but their physiological reactions have not. The present study examines the physiological reactions of individuals with elevated levels of depression, anxiety, and stress during a self-critical and self-compassionate writing exercise to see if there is a difference in comparison to healthy participants. This study is a secondary analysis of data that was collected from a randomized controlled trial where participants followed a protocol. This protocol consisted of a 5-minute baseline, a 10-minute breathing exercise or nature video, 5-minutes of a self-critical writing exercise, 5-minutes of a self-compassionate writing exercise, and a 10-minute recovery period. The individuals in the study were separated into different groups depending on their scores on a measure of depression, anxiety, and stress. The data were analyzed twice with two different grouping methods. One method compared individuals with mild to severe symptoms of depression ($n = 35$), anxiety ($n = 43$), and stress ($n = 33$) to healthy group ($n = 26$) and another method compared individuals with moderate to severe symptoms of depression ($n = 28$), anxiety ($n = 36$), and stress ($n = 24$) to 44 healthy individuals. In both methods, the participants with symptoms of depression, anxiety, and stress did not significantly differ from healthy participants on any measure of HRV. Overall, the results of this show that college students with symptoms of depression, anxiety, and stress physiologically react in a similar way to a self-critical and self-compassionate writing exercise.

Keywords: heart rate variability, self-compassion, self-criticism, depression, anxiety, stress

Table of Contents

ABSTRACT.....	ii
LIST OF TABLES.....	v
The Effect of Depression, Anxiety, and Stress on Heart Rate Variability During Self-Critical and Self-Compassionate Exercises.....	1
Current Study.....	3
Methods.....	3
Participants.....	3
Psychological Measures.....	4
Physiological Measures.....	5
Procedure.....	6
Statistical Analysis.....	7
Results.....	8
Manipulation Check.....	8
Assumption of Sphericity.....	9
Depression (Mild to Severe).....	10
Depression (Moderate to Severe).....	10
Anxiety (Mild to Severe).....	10
Anxiety (Moderate to Severe).....	11
Stress (Mild to Severe).....	11
Stress (Moderate to Severe).....	11

Healthy (Mild to Severe) 12

Healthy (Moderate to Severe)..... 12

Discussion..... 12

 Limitations 13

 Conclusion 15

References..... 16

LIST OF TABLES

Table 1. Summary Statistics of the DASS in comparison to the sample from Crawford & Henry (2003).....	7
Table 2. Means and Significance Values	9

The Effect of Depression, Anxiety, and Stress on Heart Rate Variability During Self-Critical and Self-Compassionate Exercises

Individuals with depression, anxiety and stress tend to react in maladaptive ways to stressors and have an attentional bias towards negative stimuli (Dalgleish & Watts, 1990). Researchers have found that individuals with symptoms of depression, anxiety, and stress are less self-compassionate (Sadeghi et al., 2017). Self-criticism is also more common in individuals with depression, anxiety, and stress (Trindade et al., 2019). These maladaptive patterns of thought have been well documented; however, the physiological response to stressors have not been well identified.

This study examined college students with elevated levels of depression, anxiety, and stress to observe if their physiological reaction to a self-critical and self-compassionate writing exercise differed from participants with no elevated levels of psychological distress. This study specifically observed measures of heart rate variability (HRV) as a way to measure an individuals' physiological adaptability and changes in their sympathetic and parasympathetic nervous system. The hypothesis for this study was that as individuals with symptoms of depression, anxiety, and stress engage in a self-critical and self-compassionate writing exercise, their physiological adaptability would decrease more and their sympathetic activation would increase more than those with no symptoms.

The autonomic nervous system plays a crucial role in our bodies' ability to adapt to its environment. HRV measures the beat-to-beat differences that exist in our hearts and many researchers have found that HRV is a measure of autonomic flexibility (Miyawaki & Salzman, 1991). High HRV (i.e., greater variability from one heartbeat to the next) is a positive indicator of a healthy autonomic nervous system. If an individual has low HRV or low variability from

beat to beat, their body is not able to adapt to its environment as effectively (Fujimura & Okanoya, 2012).

Because of the complexity of HRV, there are many measures that identify different aspects of HRV. The standard deviation of the interbeat intervals (IBI) of normal sinus beats (SDNN) is the most commonly used measure of HRV. SDNN is influenced by both the sympathetic nervous system (SNS) and parasympathetic nervous system (PNS) (Shaffer & Ginsberg, 2017). The low frequency band (LF) is influenced by baroreceptor activity as well as the PNS and the SNS (McCarty & Shaffer, 2015). The high frequency band (HF) is influenced primarily by the PNS (Grossman & Taylor, 2007). These measures of HRV can provide a more wholistic view of HRV by examining the parasympathetic and sympathetic activation.

It has been well established in the literature that individuals with higher levels of depression, anxiety, and stress have lower HRV (Kemp et al., 2012). Depression, anxiety, and stress can chronically increase an individual's sympathetic activation through persistent rumination (Woody et al., 2014). This chronic arousal can wear down the stress system by increasing cardiac load (Lampert et al., 2016). Individuals with depression, anxiety and stress may have greater difficulties adapting to the demands of their environment because of the rigidity in their HRV.

Another contributing factor to low HRV may be that individuals with high levels of depression may respond with greater distress to negative events relative to healthy controls (Wenzler et al., 2017). This population also tends to be more self-critical towards themselves and less self-compassionate (Yamaguchi et al., 2014). Similar trends are found with those who have clinically elevated levels of anxiety (Gilbert et al., 2008). Stevenson et al., (2019) noted that anxiety was related with less self-compassion, and others have found that anxiety is associated

with greater internalized shame (Benda et al., 2018). Similar findings were identified in the relationship of stress and self-criticism (López et al., 2015). The relationships between depression, anxiety, and stress to self-criticism and self-compassion have been identified, but researchers have yet examined the impact that these factors could have on HRV (Matos et al., 2017).

Current Study

The purpose of this study is to examine the relationship between depression, anxiety, stress, and HRV during a self-critical and self-compassionate writing exercise. Researchers have not yet studied the relationship between depression, anxiety, stress, self-critical thinking, self-compassionate thinking, and HRV. The first hypothesis for this study is that individual's with elevated scores of depression, anxiety, and stress on the Depression Anxiety and Stress Scale (DASS) will have lower SDNN, lower high frequency (HF) HRV, and higher low frequency (LF) HRV during a self-critical writing and self-compassionate writing exercise. Those with elevated scores of depression, anxiety, and stress tend to be more self-critical and less self-compassionate (Kaurin et al., 2018). Because this population tends to be more self-critical and less self-compassionate, their SDNN and HF HRV would decrease more during the self-critical writing exercise and increase less during the self-compassionate task.

Methods

Participants

A total of 96 undergraduate students volunteered for this study, however, only 84 (59 female) of the participant's data was included in the analysis because data was lost through mechanical errors in collecting the data. Upon interest in the study, the participants were

randomized into 3 different groups (e.g., biofeedback group, soothing rhythms breathing group, nature video group). The average age was 20.95 years old at the time of the study and the average years of education was 13.54 years. The participant's age ranged from 18 to 41 and 90.8% of the individuals in the study were white, 6.9% were Asian and 4% were Hawaiian or Pacific Islander. 16.1% of the participants rated their health as excellent, 49.4% very good, 29.9% good, and 4.6% fair.

Psychological Measures

The Depression, Anxiety, and Stress Scale (DASS) is a set of three self-report scales designed to measure the negative emotional states of depression, anxiety, and stress (Sinclair et al., 2012). The DASS is composed of 21 items with 7 items for each scale. The DASS was designed as a dimensional measure of general depression, anxiety, and stress. Reliability is very good with Cronbach's alphas of 0.91 for the depression scale, 0.84 for the anxiety scale and 0.80 for the stress scale. In comparison to similar measures, the DASS displayed validity in each scale. The depression scale assesses dysphoria, hopelessness, devaluation of life, self-deprecation, lack of interest/involvement, anhedonia, and inertia. The anxiety scale assesses general symptoms of anxiety including autonomic arousal, situational anxiety, and subjective experience of anxious affect. The stress scale is sensitive to levels of chronic non-specific arousal. It assesses difficulty relaxing, nervous arousal, and being easily upset/agitated, irritable/over-reactive and impatient. Subjects are asked to respond on a 4-point severity/frequency scale to rate the extent to which they have experienced each state over the past week. Scores for Depression, Anxiety and Stress are calculated by summing the scores for the relevant items. Because the DASS is not a diagnostic tool, mild symptoms of depression,

anxiety, and stress may not qualify them for a diagnosis of a mood or anxiety disorder but may represent the distress of an individual in a particular area (Sinclair et al., 2012).

The Survey of Positive and Negative Experience (SPANE) is a 12-item questionnaire that assesses positive and negative mood (Diener et al., 2010). Participants are asked to rate their experience during the past four weeks in terms of feeling positive, negative, good, bad, etc. Each question is rated on a 5-point scale, with 1 being 'Very Rarely or Never' and 5 being 'Very Often or Always'. Each scale contains 6 items. The positive and negative mood items have shown good reliability with Cronbach's alpha .87 for positive mood and Cronbach's alpha of .81 for negative mood. An exploratory factor analysis of the SPANE-P and SPANE-N showed 2 strong factors for positive emotions and negative emotions with eigenvalues of 3.69 for the SPANE-P and 3.19 for the SPANE-N (Diener et al., 2010). The SPANE-P had factor loadings that ranged from 0.58 to 0.81 while the SPANE-N had factor loadings that ranged from 0.49 to 0.78. The SPANE was used in this study as a manipulation check to evaluate whether the experimental conditions elicited the desired effects.

Physiological Measures

Heart rate variability biofeedback training followed the protocol established by Lehrer et al. (2013). Healthy breathing mechanics were taught, emphasizing diaphragmatic breathing at six breaths per minute (low and slow breathing), inhaling through the nostrils and exhaling slowly through pursed lips as if breathing out through a straw. Participants' respiration and HRV was measured via a NEXUS 4 biofeedback device (MindMedia, Herten, The Netherlands). This device uses a three lead ECG configuration and a strain gauge respiration belt to measure physiology continuously and provide real time feedback to the participant as they learn to be aware of, track, and moderate their physiological functioning. Interbeat interval data were

extracted in five-minute segments and cleaned for artifact using the Kubios program and measures of SDNN, HF HRV, LF HRV and LF/HF ratio were calculated (Tarvainen et al., 2014). The participants' systolic and diastolic blood pressure was also measured through a GE automated blood pressure machine. Blood pressure and heart rate data was collected at the middle and end of each phase of the study using a GE ProCare monitor.

Procedure

A total of 96 participants were recruited for participation in this study through undergraduate psychology courses at the university. Participants first completed an online survey measuring perceived levels of depression, anxiety, and stress, and then based on interest, participated in the experimental portion of the study. Participants were randomly assigned to either a heart rate variability biofeedback training group (n=33), a breathing instruction group (n=32), or a nature video control group (n=31). Exclusion criteria consisted of current engagement in mental health treatment, biofeedback, or use of medications that impact the cardiovascular system. All participation was voluntary and was approved by the Institutional Review Board.

During the experimental portion of the study, 3 electrodes from the ECG were placed on the participant, specifically on their collarbones and bottommost left rib. A respiration belt was also placed around the participant's stomach and a blood pressure cuff was wrapped around the participant's nondominant arm. After a 5-minute baseline was obtained, participants engaged in either 6 breath per minute breathing, soothing rhythm breathing, or watched a nature video for 10 minutes. To induce a stressful state, participants then wrote for 5 minutes about a time they felt intensely self-critical. Participants then wrote for 5 minutes about a time they felt self-compassionate, and the experiment ended with a 10-minute recovery period.

Statistical Analysis

In comparison to the normative data of the DASS, there were larger percentages of participants in the mild, moderate, severe, and extremely severe range in this study's sample. The specific percentages are presented in Table 1. To address this concern, the data was analyzed twice with two methods of defining the healthy comparison group. The first method put only participants with normal levels of depression, anxiety, and stress in the healthy group. The other method was created by putting individuals with mild symptoms of depression, anxiety, and stress in the healthy group as mild symptoms of depression, anxiety, and stress are fairly normative experiences (Smirnova et al., 2018).

Table 1. Summary Statistics of the DASS in comparison to the sample from Crawford & Henry (2003).

Group	Normal	Mild	Moderate	Severe	Extremely Severe
Depression	54.8% (81.7%)	15.1% (6.2%)	19.4% (6.3%)	7.5% (2.9%)	3.2% (2.9%)
Anxiety	47.3% (94.4%)	10.8% (2.0%)	18.3% (3.8%)	9.7% (2.0%)	14% (2.9%)
Stress	61.3% (80.2%)	10.8% (8.4%)	17.2% (5.9%)	9.7% (3.5%)	1.1% (2.0%)

Percentages in parentheses are the normative percentages of the DASS in a non-clinical sample as seen in Crawford & Henry (2003).

Participants were divided into groups based on their responses on the DASS. Participants with no elevated reports of depression, anxiety and stress were placed in a "healthy" group while the other participants were included in groups that they were high in (e.g., depression, anxiety, stress). Of the participants in the data set, 35 participants mild to severe in depression were compared to 26 individuals with no significant mental health issues as reported by the DASS. 43 participants indicated mild to severe levels of anxiety were compared to 26 healthy individuals. 33 individuals with mild to severe levels of stress were compared to 26 healthy people. There

was significant overlap of participants from one group to the next. Many of the participants belonged to multiple groups which violates the assumption of independence. To address this violation, another group was created which compared those in the healthy group (26 participants) to 58 individuals with mild to severe levels of depression, anxiety, and stress.

In the second grouping method, 28 individuals with moderate to severe symptoms of depression, 36 individuals with moderate to severe symptoms of anxiety, 24 individuals with moderate to severe symptoms of stress, and 47 individuals with moderate to severe symptoms of either depression, anxiety, or stress were compared to 44 healthy participants. The data was analyzed with SPSS using a repeated measures analysis of variance approach examining participants HRV before, during, and after the self-critical and self-compassionate writing exercise to see if there were any difference between any of the groups compared to the healthy group (IBM SPSS Statistics, Version 26).

Results

Manipulation Check

Because of the subjective nature of a self-critical and self-compassionate writing exercise, the SPANE was given to monitor positive and negative mood immediately after each section of the protocol. The majority of the findings were not significantly different when comparing the depression, anxiety, or stress group in comparison to the healthy group on measures of positive and negative mood during either the self-critical or self-compassionate exercise. There were statistically significant differences between the anxiety and stress group in comparison to the healthy group in negative mood during the self-compassionate writing exercise. For all groups, the self-critical writing exercise led to a decrease in positive mood and

an increase in negative mood while the self-compassionate exercise led to an increase in positive mood and a decrease in negative mood. The means and significance values are summarized in

Table 2.

Table 2. Means and Significance Values

Self-Critical, Positive Mood	Means	Significance Values
Depression	12.30	0.161
Anxiety	13.21	0.475
Stress	12.89	0.360
Healthy	14.12	0.353
Self-Compassionate, Positive Mood		
Depression	21.51	0.149
Anxiety	21.83	0.314
Stress	21.78	0.117
Healthy	22.81	0.206
Self-Critical, Negative Mood		
Depression	15.60	0.067
Anxiety	15.89	0.052
Stress	15.54	0.074
Healthy	13.42	0.087
Self-Compassionate, Negative Mood		
Depression	8.44	0.081
Anxiety	8.63	0.042*
Stress	8.94	0.013*
Healthy	7.56	0.076

Items significant at the 0.05 level are marked with *

Assumption of Sphericity

In the repeated measures ANOVA analysis, Mauchley's test of sphericity was violated in all of the comparisons as each analysis had a $p < 0.05$. Because of this violation, the Greenhouse-Geisser epsilon was used as the significance values for all of the analyses were below 0.75. These rules of thumb are recommended by Field and Howell (Field, 2013; Howell, 2002).

Depression (Mild to Severe)

In the repeated measures ANOVA, no significant differences were found in the time by condition comparisons for high frequency (HF) HRV $F(4.48, 264.349) = 1.046, p = 0.395$, low frequency (LF) HRV $F(3.155, 186.138) = 1.108, p = 0.37$, or SDNN $F(2.858, 168.615) = 1.423, p = 0.205$. There was also no significant differences in the between subjects portion of the analysis with HF HRV $F(1, 59) = 0.611, p = 0.438$, LF HRV $F(1, 59) = 0.710, p = 0.403$, and SDNN $F(1, 59) = 0.028, p = 0.869$.

Depression (Moderate to Severe)

This different grouping method did not yield any significant differences in the time by conditions comparisons or the between subjects comparisons. In the time by condition comparisons HF HRV had a $F(4.586, 307.394) = 0.409, p = 0.827$, the LF HRV had a $F(3.063, 205.230) = 0.863, p = 0.463$, and the SDNN had a $F(2.9, 194.3) = 0.123, p = 0.942$. In the between subjects analysis HF HRV had a $F(1, 67) = 0.896, p = 0.347$, the LF HRV had a $F(1, 67) = 0.160, p = 0.691$, and the SDNN had a $F(1, 67) = 0.001, p = 0.977$.

Anxiety (Mild to Severe)

No significant findings were observed in the time by condition comparison of those with clinically elevated levels of anxiety to a healthy group. The HF HRV had a $F(4.429, 296.755) = 1.921, p = 0.076$, the LF HRV had a $F(2.936, 196.725) = 1.059, p = 0.387$, and the SDNN had a

$F(2.764, 185.199) = 1.801, p = 0.098$. No significant findings were found in the between subjects comparison as well. The HF HRV had a $F(1, 67) = 0.072, p = 0.79$, the LF HRV had a $F(1, 67) = 0.126, p = 0.724$, and the SDNN had a $F(1, 67) = 0.26, p = 0.873$.

Anxiety (Moderate to Severe)

This different grouping method for the anxiety group did not yield any significant differences in the time by conditions comparisons or the between subjects comparisons as well. In the time by condition comparisons HF HRV had a $F(4.623, 360.587) = 0.948, p = 0.445$, the LF HRV had a $F(2.981, 232.489) = 0.430, p = 0.731$, and the SDNN had a $F(2.708, 211.260) = 0.108, p = 0.944$. In the between subjects analysis HF HRV had a $F(1, 78) = 0.020, p = 0.887$, the LF HRV had a $F(1, 78) = 0.198, p = 0.658$, and the SDNN had a $F(1, 78) = 0.585, p = 0.447$.

Stress (Mild to Severe)

The time by condition comparison of individuals with clinically elevated levels of stress to healthy individuals yielded no statistically significant results with HF HRV having a $F(4.472, 254.905) = 1.686, p = 0.124$, LF HRV with a $F(3.14, 178.997) = 0.957, p = 0.454$, and SDNN with a $F(2.929, 166.929) = 1.587, p = 0.15$. The between subjects comparison did not have any significant results as well: HF HRV $F(1, 57) = 0.32, p = 0.574$, LF HRV $F(1, 57) = 0.613, p = 0.437$, SDNN $F(1, 57) = 0.031, p = 0.861$.

Stress (Moderate to Severe)

This different grouping method for the stress group did not yield any significant differences in the time by conditions comparisons or the between subjects comparisons as well. In the time by condition comparisons HF HRV had a $F(4.452, 293.830) = 0.788, p = 0.546$, the LF HRV had a $F(2.937, 193.841) = 1.197, p = 0.312$, and the SDNN had a $F(2.732, 180.288) =$

0.373, $p = 0.754$. In the between subjects analysis HF HRV had a $F(1, 66) = 0.327$, $p = 0.570$, the LF HRV had a $F(1, 66) = 0.048$, $p = 0.827$, and the SDNN had a $F(1, 66) = 0.000$, $p = 0.984$.

Healthy (Mild to Severe)

In the time by condition comparison of healthy participants to those with clinically elevated levels of either depression, anxiety, and or stress no significant differences in HRV were found: HF HRV $F(4.372, 358.475) = 1.92$, $p = 0.76$, LF HRV $F(2.975, 243.949) = 1.576$, $p = 0.152$, SDNN $F(2.768, 226.973) = 2.64$, $p = 0.055$. The between subjects comparison also yielded no significant results with HF HRV $F(1,82) = 0.363$, $p = 0.548$, LF HRV $F(1,82) = 0.903$, $p = 0.345$, and SDNN $F(1,82) = 0.113$, $p = 0.738$.

Healthy (Moderate to Severe)

This different grouping method for the healthy group did not yield any significant differences in the time by conditions comparisons or the between subjects comparisons as well. In the time by condition comparisons HF HRV had a $F(4.526, 402.847) = 0.727$, $p = 0.590$, the LF HRV had a $F(3.079, 274.046) = 0.680$, $p = 0.569$, and the SDNN had a $F(2.80, 249.244) = 0.176$, $p = 0.902$. In the between subjects analysis HF HRV had a $F(1, 89) = 0.110$, $p = 0.741$, the LF HRV had a $F(1, 89) = 0.000$, $p = 0.987$, and the SDNN had a $F(1, 89) = 0.169$, $p = 0.682$.

Discussion

This study was examining the relationship between heart rate variability, depression, anxiety, and stress during a self-critical and self-compassionate writing exercises. The first hypothesis was that individuals with clinically elevated levels of depression, anxiety, and stress would have lower SDNN, HF HRV, and higher LF HRV during the self-critical writing exercise and the self-compassionate exercise. The results of this study found no support for this

hypothesis as there were no significant differences in HRV between participants with no symptoms of depression, anxiety, or stress in comparison to those with these symptoms during the self-critical and self-compassionate exercises. These results suggest that individuals with depression, anxiety, and stress do not physiologically react differently during a self-critical and self-compassionate time.

There are many reasons that a significant difference was not found in this particular sample. This sample consisted of young and healthy college students who tend to have higher SDNN than older individuals overall (Umetani et al., 1998). Also, differences in measures and HRV are more prominent in individuals with severe depression, anxiety, and stress while this sample consisted of mostly mild cases (Bassett, 2016). It is possible that there is an effect, but the interaction of mild symptoms and young age could have hidden this relationship.

Young college students with symptoms of depression, anxiety, and stress physiologically reacted in a similar way throughout the study protocol. It is possible that persistent patterns of depression, anxiety, and stress over many years can produce differences in measures of HRV as this population ages. These findings of no statistically significant differences in young college students implies that there is still time to intervene before an individual's symptoms of depression, anxiety, and stress begin to take a toll on their physical body. Early intervention in mental disorders has been helpful in decreasing the likelihood of individuals progressing to a more severe case (Polanczyk, 2014). Additionally, early intervention can help decrease the physiological consequences that are associated with depression, anxiety, and stress.

Limitations

There are a couple limitations with this study. First, the participants in this study consisted of young and healthy college students. Many of the differences in HRV between those with depression and anxiety tend to exist in older populations (Kemp et al., 2012). As mentioned in the statistical analyses portion of the methods section, many of the participants in the depression, anxiety, and stress group were not exclusively in that group. Many individuals were in multiple groups which could have clouded the analysis and violated the assumption of independence. If the data were analyzed with only the participants that were solely in one group there would only be about 3 to 5 participants per group. This problem is especially challenging due to the high comorbidity of depression and anxiety (Aina & Susman, 2006). To address this violation, another comparison group was created that included all of the participants with mild to severe and moderate to severe levels of depression, anxiety, and stress. In this group that examined distress across many domains, no significant differences were found, supporting the findings from the other comparisons.

Another limitation is that the DASS is a dimensional measure of depression, anxiety, and stress and is not used as a diagnostic tool (Sinclair et al., 2012). Because of the structure of the DASS, it is unclear whether the participants with symptoms of depression, anxiety, or stress would have met the criteria for a diagnosis of a mood disorder or an anxiety disorder. The DASS detects the presence of depressive, anxious, or stress symptoms and their severity. It is possible that the participants in this study may have these symptoms, however, these symptoms may not persist for the needed duration for a diagnosis of a depressive or anxiety disorder.

Looking forward, future studies can be conducted to examine these hypotheses in a population with a diagnosis of a mood or anxiety disorder. It is possible that there is still a

relationship between these variables, however, this study was not able to identify those differences given the discussed limitations.

Conclusion

Overall, individuals with symptoms of depression, anxiety, and stress did not have a different physiological response during a self-critical and self-compassionate writing exercise. No significant difference were found in any of the HRV measures analyzed (e.g., SDNN, HF HRV, LF HRV). This study had a couple limitations that could have clouded the relationship that may or may not exist. Future studies can further explore these hypotheses in a sample of individuals with a clinical diagnosis of a mood disorder or anxiety disorder.

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