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ORIGINAL PAPER

Self-compassion Modulates Heart Rate Variability and Negative Affect to Experimentally Induced Stress

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Abstract

Self-compassion has increasingly been recognized to buffer stress and promote emotional health. However, few studies have examined the influences of self-compassion on physiological stress response. The current study aimed to investigate the impact of self-reported self-compassion on physiological stress response and negative affect induced in a laboratory setting. Healthy male participants ($N = 34$, Asians) were grouped into high ($N = 17$, age: mean = 19.65, SD = 0.59) or low ($N = 17$, age: mean = 19.71, SD = 0.82) self-compassion groups based on the Self-Compassion Scale. They were subjected to the Trier Social Stress Test, with electrocardiography recorded and negative affect assessed by the Positive and Negative Affect Schedule. Results demonstrated that self-compassionate individuals showed higher vagally mediated heart rate variability (vmHRV) at baseline (CI = [0.30, 0.91], $p = 0.01$). Interestingly, self-compassionate individuals demonstrated higher vmHRV to an acute stressor after an anticipated decrease in vmHRV (CI = [0.02, 0.67], $p = 0.04$). Moreover, self-compassionate individuals reported less negative affect in response to stress (CI = [− 8.29, − 0.42], $p = 0.03$). Our results demonstrate the role of self-compassion in the flexible adjustment of physiological and psychological responses to stress.

Keywords Self-compassion · Stress · Emotion · Heart rate variability

Introduction

A growing body of evidence has examined the health-promoting influences of self-compassion. Self-compassion is broadly described as treating oneself with kindness and concern when one is experiencing negative life events (Neff 2003a, b). Specifically, self-compassion is defined as being composed of three components: self-kindness (i.e., being kind towards oneself when encountering pain and shortcomings), common humanity (i.e., considering personal suffering as part of the shared human experience), and mindfulness (holding painful thoughts and feelings in mindful awareness without avoiding or exaggerating them). In general, literature has shown that self-compassion is positively associated with emotional well-being (Neff et al. 2007b; Zessin et al. 2015), while negatively associated with the experience of life stress and negative affect (Diedrich et al. 2014; Ying and Han 2009; Zhang et al. 2016). Moreover, recent evidence has suggested that self-compassion can protect emotional well-being against stressful events in daily life (Barlow et al. 2017; Kyeong 2013; Terry et al. 2013), as well as acute stress induced in laboratory settings (Johnson and O'Brien 2013; Leary et al. 2007; Neff et al. 2007a).

To date, few studies have examined the influences of self-compassion on physiological stress systems, in which self-compassion is demonstrated to be associated with lower physiological stress responses (Bluth et al. 2016; Breines et al. 2014, 2015; Pace et al. 2009). A recent study further found that self-compassion is positively associated with vagally mediated heart rate variability (vmHRV) (Svendsen et al. 2016).

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HRV is a physiological phenomenon of variation between heartbeats. In stress and health research, HRV has been demonstrated as a biomarker of self-regulatory mechanisms that may be involved in promoting health (Holzman and Bridgett 2017; Thayer et al. 2012). Findings from Svendsen et al. (2016) therefore suggested that self-compassionate individuals are able to physiologically adapt emotional responses to stressful events with more flexibility. Moreover, this argument is consistent with the evidence which shows that brief training in self-compassion can enhance HRV during stress anticipation (Arch et al. 2014).

However, Svendsen et al. (2016) only assessed the relationship between self-compassion and vmHRV in resting state, which makes it difficult to extend their findings to stressful situations. Life distress is one of the major threats to health, which also provides the context for self-compassion to act according to the definition. Examining the benefits of self-compassion in the context of stress therefore bears more significance, which may help illuminate the associations between self-compassion, stress response, and health outcomes. To this end, the current study examined the association between self-compassion and vmHRV in response to a social-evaluative threat. Specifically, healthy individuals were divided into high (HSC) and low self-compassion (LSC) group according to the reported self-compassion (Neff 2003a), and subjected to the Trier Social Stress Test (TSST) (Kirschbaum et al. 1993). We hypothesized that HSC would demonstrate higher HRV and lower negative affect than LSC to the TSST stress.

Method

Participants

The Self-Compassion Scale (Neff 2003a) was administrated in a class of 85 male undergraduate students in the Southwest Petroleum University, Chengdu, China (age: mean = 19.67, SD = 0.73). Those who reported self-compassion scores within the upper and lower 27% of scores in the total sample (range = 2.21–4.62, mean = 3.52, SD = 0.41) were invited to participate in this study according to "The 27 Percent Rule" (Kelley 1939). This resulted in 23 potential participants in each self-compassion group. The final sample included 17 participants in the high self-compassion group (HSC: mean = 3.96, SD = 0.24; age: mean = 19.65, SD = 0.59) and 17 participants in the low self-compassion group (LSC: mean = 3.04, SD = 0.27; age: mean = 19.71, SD = 0.82), with six individuals in each group decided not to take part in. All the participants were screened using the Mini International Neuropsychiatric Interview (MINI) and were free from medication, neurological or psychiatric personal history (Sheehan and Lecrubier 2006). This study was approved by the local ethics committee in the Southwest University, Chongqing, China. All the participants signed the consent form after the experiment had been explained to them. They were reimbursed RMB 10 *Yuan* for taking part in this study.

Procedure

The 26-item Self-Compassion Scale was first used to measure individual differences in self-compassion, which consists of six subscales: self-kindness, self-judgment, common humanity, isolation, mindfulness, and over-identification (Neff 2003a). Participants indicated how they would act toward themselves in difficult times using a five-point Likert scale (from 1 "never" to 5 "almost always"). A total self-compassion score was created by calculating the means for the six subscales after reversing the coding responses to the negatively worded items. SCS has been demonstrated to show well-established psychometric characteristics with an internal consistency of 0.92 (Neff 2003a). Chen et al. (2011) reported the Cronbach's alpha (0.83) and test–retest reliability (0.89) of the Chinese version.

During the testing day, participants were first asked to relax for 10 min when they arrived at the laboratory. Then they were set up for the ECG recording (see below "Heart Rate and Heart Rate Variability"). Participants then underwent TSST (Kirschbaum et al. 1993). In brief, participants first relaxed themselves (5 min, "baseline"), then prepared for a research assistant job interview (5 min, "anticipation"), and delivered a talk in front of a consistent judge (5 min, "talking"), and then relaxed (5 min, "recovery").

The judge acted neutrally throughout the TSST talking stage. Right after the TSST anticipation, the experimenter told the participant that the speech would be audio recorded to evaluate his or her performance. All the participants agreed to be recorded. Then the judge pretended to start the recording, which was actually not recording, and asked the participant to start. In the first time when the participants finished the speech in less than 5 min, the judge told the participant "You still have some time left. Please continue!" From the second time on should the participant finish before the 5 min were over, the judge first remained quiet for a few seconds and then asked him or her to continue the speech. In the end of the TSST protocol, participants were debriefed of this study.

Measures

Heart Rate and Heart Rate Variability

Heart rate was continuously monitored using a heart rate belt (HRM-2110H, http://zencro.com/). The chest belt has built-in electrodes that detect the heartbeats while they are against bare skin. Heartbeats were received by a smartphone through Bluetooth 4.0 transmitter. Participants wore the belt with the

sensor box placed in the middle of their chest and then adjusted the belt to fit. They were instructed not to move heavily during testing.

Heart rate and inter-beat-interval (IBI) series were acquired with the Pan-Tompkins algorithm (Pan and Tompkins 1985). Artifacts were visually checked and corrected if necessary according to published guidelines (Berntson et al. 1997). We calculated the root mean square of successive differences (RMSSD), measured in milliseconds, as a measure of vmHRV. In order to fit the assumptions of linear analyses (Ellis et al. 2008), RMSSD values were natural log-transformed (i.e., lnRMSSD). lnRMSSD has been demonstrated to be a stable and valid measure of vmHRV (Li et al. 2009; Thayer and Sternberg 2010). We then checked the normality of the lnRMSSD scores in different combinations of our two factors (i.e., group and TSST stage) with Shapiro-Wilk test. None of the normality tests was violated ($p_s > 0.05$). In the four TSST stages, heart rate and lnRMSSD values were averaged across 5 min for each participant.

Negative Affect

Negative affect was acquired right after the TSST talking stage. Negative affect was assessed using the negative affect items (10 items) of the Positive and Negative Affect Schedule (PANAS) (Watson et al. 1988). Each item was rated on a Likert scale of 1 *(not at all)* to 5 *(extremely)*. The time instruction was given as "at the present moment." A total score of negative affect was calculated by summing the scores in negative items. Positive affect was also collected (HSC: mean = 29.53, SD = 7.20; LSC: mean = 27.24, SD = 5.60). PANAS was reported to show good psychometric properties, with the Cronbach's alphas ranging from 0.84 to 0.87 for the negative affect and from 0.86 to 0.90 for the positive affect. The Chinese version of PANAS was reported of a Cronbach's alpha of 0.83 for the negative affect and 0.85 for the positive affect (Huang et al. 2003).

Data Analyses

Aside from the normality test (see above "Heart Rate and Heart Rate Variability"), a series of tests were performed to check the assumptions of using a mixed ANOVA. Specifically, Levene's test for homogeneity of variances and Mauchly's Test of Sphericity were performed separately in SPSS (version 22, SPSS Inc.). Results validated the use of mixed ANOVA ($p_s > 0.05$). Two-way repetitive ANOVAs were performed on heart rate and lnRMSSD. Group (HSC, LSC) was specified as the between-subject factor and TSST stages (baseline, anticipation, talking, and recovery) were specified as the within-subject factor. Post-hoc *t* tests were conducted with Bonferroni correction to further explore the significant main and interaction effect of group and TSST stages, and the α-level was set to 0.05. Further, independent sample *t* test was performed to examine the group difference in negative affect aroused by the TSST. In the heart rate and lnRMSSD analyses, we did not control the baseline as the current study was not focusing on the different influences of baseline physiological activity on stress response in high and low self-compassion group.

Results

Heart Rate

Two-way ANOVA revealed the main effect of TSST stage on heart rate ($F_{(3, 96)} = 83.11$, $p = 0.0001$, $\eta_p^2 = 0.72$), but no main effect of group ($F_{(1, 32)} = 0.23$, $p = 0.64$, $\eta_p^2 = 0.01$) or the interaction effect of group × TSST stage ($F_{(3, 96)} = 0.78$, $p = 0.51$, $\eta_p^2 = 0.02$). Post-hoc tests showed that TSST anticipation had higher heart rate than TSST baseline (CI = [6.89, 16.50], $p = 0.0001$). TSST talking produced higher heart rate than TSST anticipation (CI = [4.44, 12.65], $p = 0.0001$) and baseline (CI = [14.83, 25.65], $p = 0.0001$). TSST recovery showed lower heart rate than TSST anticipation (CI = [− 15.90, − 8.22], $p = 0.0001$) and talking (CI = [− 25.64, − 15.57], $p = 0.0001$), but no difference to TSST baseline (CI = [− 2.32, 1.58], $p = 0.99$) (Fig. 1 and Table 1).

Heart Rate Variability

Two-way ANOVA revealed a main effect of group on lnRMSSD ($F_{(1, 32)} = 8.41$, $p = 0.007$, $\eta_p^2 = 0.21$), an interaction effect of group × TSST stage ($F_{(3, 96)} = 3.52$, $p = 0.02$, $\eta_p^2 =$

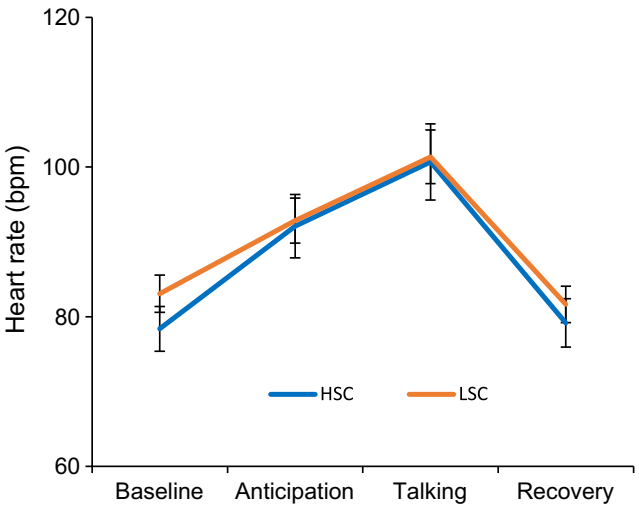

Fig. 1 Heart rate response to TSST in high ($n = 17$) and low ($n = 17$) self-compassion groups. Data represent the mean and the standard error of the mean (SEM). HSC high self-compassion, LSC low self-compassion, bpm stands for beat-per-minute

Table 1 Mean (SEM) of heart rate, lnRMSSD, and negative affect by the function of group and TSST stage. *SEM* standard error of the mean, *HSC* high self-compassion, *LSC* low self-compassion, *lnRMSSD* natural log-transformed root mean square of successive differences, *TSST* Trier Social Stress Test

	HSC ($n = 17$)				LSC ($n = 17$)			
	Baseline	Anticipation	Talking	Recovery	Baseline	Anticipation	Talking	Recovery
Heart rate	78.39 (2.99)	92.09 (4.22)	100.66 (5.09)	79.17 (3.22)	83.06 (2.49)	92.83 (3.01)	101.36 (3.57)	81.65 (2.43)
lnRMSSD	3.47 (0.12)	3.07 (0.1)	3.35 (0.12)	3.26 (0.12)	2.86 (0.09)	2.99 (0.11)	3.01 (0.11)	2.95 (0.09)
Negative affect	19.18 (0.88)				23.53 (1.72)			

0.10), but no main effect of TSST stage ($F_{(3,\ 96)} = 1.38$, $p = 0.25$, $\eta_p^2 = 0.04$). Post-hoc tests showed that HSC showed higher lnRMSSD than LSC in TSST baseline (CI = [0.30, 0.91], $p = 0.01$), talking (CI = [0.02, 0.67], $p = 0.04$), and recovery stage (CI = [0.01, 0.61], $p = 0.04$). But two groups showed no difference in TSST anticipation stage (CI = [− 0.23, 0.38], $p = 0.62$) (Fig. 2 and Table 1).

Negative Affect

Independent t test revealed that HSC reported less negative affect than the LSC group ($t_{(32)} = -2.25$, $p = 0.03$, CI = [− 8.29, − 0.42]) (Fig. 3 and Table 1).

Discussion

Self-compassion has been shown to be related to higher regulatory vmHRV in resting state (Svendsen et al. 2016). Built on the literature, the current study demonstrated that self-compassion is associated with higher vmHRV and less negative affect when faced with a social-evaluative threat. Our data further highlight the role of self-compassion in adjusting physiological and emotional response to life stress.

Heart rate data showed the efficacy of stress manipulation in this study. Specifically, heart rate significantly increased from the TSST baseline to the anticipation and talking stage, and then it went down to the baseline level in the TSST recovery stage. These results suggest the efficacy of the TSST protocol (Kirschbaum et al. 1993), which induced a social-evaluative threat to the participants in this study. However, HSC and LSC groups showed comparable changes of heart rate across the TSST stages. Though it is surprising, it is consistent with a previous study conducted with the same protocol (Bluth et al. 2016). In this sense, self-compassion may not reflect changes in heart rate.

We further observed that HSC showed higher vmHRV than LSC in the TSST baseline stage. This finding replicates Svendsen et al. (2016) result, which found that trait self-compassion is positively associated with resting vmHRV. Though there are some inconsistencies (Gentzler et al. 2009; Sturge-Apple et al. 2016), recent evidence has demonstrated the role of HRV in the "top-down" regulation of physiological and behavioral response to aversive or uncertain situations. One meta-analysis found a significant positive relationship between HRV and self-regulation across a range of paradigms, i.e., emotion regulation, executive functioning, and effortful control (Holzman and Bridgett 2017). In another meta-analysis, the authors demonstrated that HRV may serve as a proxy for flexible control over behavioral response to uncertainty (Thayer et al. 2012). In affective and emotional research, our

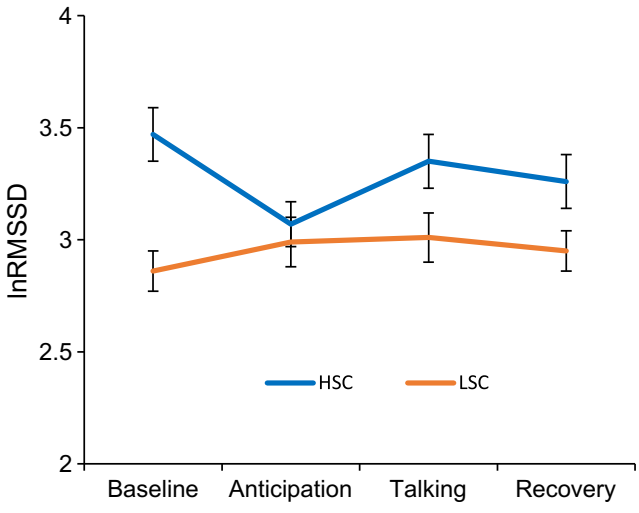

Fig. 2 Heart rate variability to TSST high ($n = 17$) and low ($n = 17$) self-compassion groups. Data are shown with the mean and the SEM. HSC high self-compassion, LSC low self-compassion, lnRMSSD natural log-transformed root mean square of successive differences

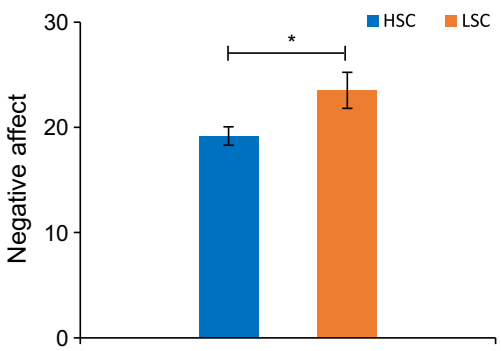

Fig. 3 Negative affect in response to TSST in high ($n = 17$) and low ($n = 17$) self-compassion groups. Data represent the mean and the SEM. HSC high self-compassion, LSC low self-compassion. *means $p < 0.05$

data therefore suggest that self-compassionate individuals may have higher adaptive emotion regulation abilities over life events. This is also consistent with the findings in which self-compassion was associated with greater emotional regulation and less experienced negative affect (Allen and Leary 2010; Diedrich et al. 2016; Finlay-Jones et al. 2015; Neff et al. 2005; Sirois et al. 2015).

Our data also demonstrate decreased vmHRV in HSC group from baseline to the anticipation of a social-evaluative threat. This is consistent with the evidence in which anticipating a social-evaluative threat was shown to increase heart rate and blood pressure but reduce HRV in HSC group (Bluth et al. 2016). In the current TSST protocol, participants were immediately told that they would perform a job interview in front of a judge. This unexpected event may thus create a threat to self-esteem and self-integrity even for individuals with high self-compassion. This could be seen from a rapid increase in heart rate but a decrease in vmHRV in HSC group. Therefore, our data suggest that an unexpected stressor may "temporarily" disrupt the ability to regulate physiological response among self-compassionate individuals.

Interestingly, HSC group bounced back from anticipated vmHRV decrease during TSST talking stage, though the LSC group showed no change of vmHRV. Moreover, these effects extended to the TSST recovery stage. A growing body of evidence has demonstrated that self-compassion is able to tranquilize the physiological stress response. For example, self-compassion is associated with lower stress response as measured in salivary alpha-amylase (Breines et al. 2015) and plasma concentrations of interleukin-6 (IL-6) (Breines et al. 2014), as well as lower plasma glucose concentration (i.e., glycated hemoglobin) after a self-compassion training program (Friis et al. 2016). Moreover, self-compassion has been shown to activate the parasympathetic nervous system that is involved in the adjustment of psychophysiological response (Gilbert and Irons 2005). Experimentally induced self-compassion (i.e., repeating soothing phrases while looking at the mirror) and self-compassion training resulted in higher HRV while undergoing a psychosocial threat (Arch et al. 2014; Petrocchi et al. 2017). Built on these findings, our data further demonstrated that self-reported self-compassion was associated with higher vmHRV and less negative affect during the social-evaluative threat. Moreover, this effect was observed after an anticipated decrease in vmHRV. These results together suggest the capability of self-compassionate individuals in flexibly adjusting physiological and psychological responses to stress.

Limitations

There are some limitations in this study. Results in the present study are not able to demonstrate the causality between self-compassion, vmHRV, and negative affect. It is unclear if self-compassion causally increases HRV and decreases negative affect, or if those who are naturally less influenced by stress are more likely to report self-compassion. Moreover, the current study did not experimentally manipulate the level of self-compassion, in which future studies should build on to further investigate the influences of self-compassion on psychophysiological stress response. Further, this study used a modified version of TSST, which might not create a stressor as intense as one evoked by the classic TSST. This should be considered when interpreting the findings. Another limitation is that a power analysis was not conducted to determine the sample size and our sample sizes were relatively small in each self-compassion group. We only assessed male young adults. Currently, there is not enough evidence of the relationship between self-compassion and HRV. Most of the studies are performed among young adults (but see Bluth et al. 2016). Moreover, only female participants were recruited in a well-controlled training study (Arch et al. 2014). Future investigations are therefore warranted to examine the influences of self-compassion on HRV in bigger and more diverse samples. We also did not preregister the study as of the study nature; this should be done in future trials of self-compassion intervention.

In conclusion, this study aimed to examine the role of self-reported self-compassion in modulating vmHRV and emotional response to an acute stressor. Our data demonstrated that self-compassion is associated with higher regulatory vmHRV and less negative affect to a social-evaluative stressor after an initial decrease of anticipated vmHRV. These results particularly suggest the flexibility of self-compassionate individuals in adjusting the physiological and psychological responses to life stress.

Author Contributions XL contributed to study design, data collection, data analysis, and manuscript preparation. LQ contributed to data collection and manuscript preparation. XC contributed to study design, data analysis, and manuscript preparation.

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Compliance with Ethical Standards

Ethical Statement All procedures performed in studies involving human participants were in accordance with the ethical standards of the local ethics committee in the Southwest University and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

Conflict of Interest The authors declare that they have no conflict of interest.

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