Resilience to Stress

The Association of Perseverative Cognitions with Heart Rate Recovery after the repeated Montreal Imaging Stress Test, and the role of Trait Mindfulness.

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Abstract

Background: Stress recovery is important for one's health to prevent the psychological and physiological consequences of stress. Specifically, decreased cardiovascular recovery severely affects the individuals functioning, underlining the usefulness of understanding which factors affect heart rate recovery (HRR). Previous research suggests that state perseverative cognitions (PC; rumination and worry) have a negative, while trait mindfulness has a positive influence on stress, but little is known regarding HRR. Examining the association with HRR may help improve physiological stress recovery.

Current study: In the current study the relationship of state PC and trait mindfulness on HRR after a stress task were examined, as well as a moderation effect of trait mindfulness on the relationship of state PC and HRR. The aim was to increase the understanding of these factors' influence to help prevent the consequences of ineffective stress recovery.

Method: Secondary data of 46 participants was used from De Calheiros Velozo et al. (2021), who used the repeated Montreal Imaging Stress Task. Heart rate (HR) was measured prior, during, and after the task, and self-reports were filled in about trait mindfulness and state PC. The models included HRR (= HR during recovery-HR during stress) as the outcome variable while controlling for HR prior to the stress task. The predicting variables were PC and mindfulness, of which the latter was also a moderator in one of the three models.

Results: Results indicated that participants differed greatly regarding HR in all testing phases. PC and mindfulness were not significant predictors for HRR, and no moderation effect was found. All analysed models explained little of the variance in HRR.

Discussion: The results from the current study imply that state PC, and trait mindfulness do not have an influence on HRR after a stress task, which contradict previous research. Thus, this preliminary research would suggest that it is ineffective to take these factors into account when trying to improve HRR. However, the lack of variability and operationalisation of HRR indicated that the current results should be interpreted with caution. Future studies could use an alternative HRR variable, e.g., as a time-measure instead of a difference-measure, to enable better comparison with previous research. Additionally, with the low R^2 (<.13) additional factors should be examined to increase insights into factors affecting HRR with the intention to effectively prevent the adverse effects of stress.

Keywords: heart rate, heart rate recovery, rumination, worry, perseverative cognitions, mindfulness, rMIST, stress task

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The Association of Perseverative Cognitions with Heart Rate Recovery after the repeated Montreal Imaging Stress Test, and the role of Trait Mindfulness.

Stress recovery is crucial for a healthy lifestyle (Radstaak et al., 2011) and necessary to prevent the severe psychological and physiological consequences of chronic stress (Larsen & Christenfeld, 2009). Consequently, decreased physiological recovery increases the cumulative burden of stress, which damages the individuals functioning (Charney, 2004; Guidi et al., 2021; Larsen & Christenfeld, 2009). Moreover, as stress is strongly linked to decreased cardiovascular health (Pickering, 2001), research on factors associated with cardiovascular stress recovery, e.g., heart rate recovery (HRR), can aid in preventing the adverse effects by improving physiological recovery after stress. While previous studies have shown that mindfulness has a positive effect on stress, and perseverative cognitions have a negative influence, little is known about their association with physiological stress recovery. By studying mindfulness and perseverative cognitions and their association with HRR after a stress task the understanding of factors influencing stress recovery can be increased.

Stress Recovery

Stress recovery is the process during which a person’s strain level, which increases as a reaction to a stressor, returns to the pre-stress level (Craig & Cooper, 1992; Sonnentag et al., 2017). This includes homeostasis, i.e., the body’s process of self-regulation by maintaining stable physiological conditions, such as heart rate (HR). A decreased, i.e., anomalous and ineffective, recovery has damaging effects for the individual’s physiological and psychological functioning and long-term health (Charney, 2004; Guidi et al., 2021; Larsen & Christenfeld, 2009; Pickering, 2001).

Decreased recovery after stress is strongly linked to serious health conditions, such as cardiovascular diseases (Pickering, 2001), which emphasises the importance of understanding physiological stress recovery. Specifically, decreased cardiovascular recovery after stress predicts reduced cardiovascular health (Brosschot & Thayer, 2003; Verkuil et al., 2009) and is associated with e.g., hypertension (Stewart & France, 2001). Previous studies have shown that physiological reactions to laboratory stressors are valid and comparable to those experienced due to real-life stressors (Henze et al., 2017). In this context, HR measures are useful as it enables measuring homeostatic functioning (Kim et al., 2018). Moreover, the effect stress has on HR is associated with increased risk for obesity and mortality, for example, through withdrawal of sympathetic drive (Laguna et al., 2013), and psychological disorders, such as anxiety and depression (Berntson & Cacioppo, 2004). This further emphasizes the usefulness of examining and understanding factors that may be associated with efficient physiological, and particularly, heart rate recovery (HRR) to prevent negative prolonged effects of stress.

Perseverative Cognitions

The importance of stress recovery gives rise to the value of understanding influencing factors, such as perseverative cognitions (PC). PC is a frequently used concept in literature which includes two types of negative affective cognitions, namely worry and rumination (Brosschot et al., 2006). Rumination can be defined as repetitive, intrusive, negative cognitions, often regarding personal problems, while worry is considered a chain of future-oriented negative thoughts (Brosschot et al., 2006; Radstaak et al., 2011). Brosschot et al. (2006 and 2014) suggested the PC hypothesis, stating that rumination and worry extend the mental representation of a stressor, even without it being present. As a result, physiological activity associated with a stressful event is elicited and prolonged (Larsen & Christenfeld, 2009). Thus, momentary PC temporarily extend the stressor and the biological response to it or may even serve as a stressor itself without an external stressor present (Brosschot et al., 2006).

With the extended stress response, PC have a negative influence on numerous areas in life. Concretely, research showed negative effects on cognitive, motivational, affective, and behavioural aspects (see Clancy et al., 2016; Nolen-Hoeksema et al., 2008; Ottaviani et al., 2016). Besides the negative psychological influence (Roelofs et al., 2009; Larsen & Christenfeld, 2009), PC also affects the individual's physiology, e.g., increased blood pressure and cortisol levels (Ottaviani et al., 2016), resulting in negative long-term effects on somatic health (Brosschot et al., 2006; Ottaviani et al., 2016).

With state PC prolonging the stress activation and affecting cardiovascular and homeostatic functioning (Kim et al., 2018; Pieper et al., 2007), one may hypothesize an impact on HRR. Previous studies are mainly focused on rumination alone, i.e., excluding worry, and the association with physiological stress recovery, e.g., blood pressure and cortisol levels (Capobianco et al., 2018, Radstaak et al., 2011), but few examined PC. The studies that examined PC, i.e., Ottaviani et al. (2016; systematic review) and Verkuil et al. (2009), reported an association of PC with higher HR and lower heart rate variability, however, they did not assess HRR as a factor itself. As stress is often associated with decreased cardiovascular health (Pickering, 2001), the influence of PC in this area may be of value. To my knowledge, there is no previous research done to assess the impact of state PC, i.e., including both spontaneous worry and rumination, on HRR after stress.

Mindfulness

Another factor frequently mentioned in the context of stress is mindfulness. Mindfulness can be defined as the maintenance and effort of bringing one's attention to the present-moment, while practicing acceptance (*Mindfulness*, n.d.; Sala et al., 2020). Research on mindfulness has shown substantial positive effects on behaviour (Sala et al., 2020), and psychological health (Keng et al., 2011; Teper et al., 2013). Trait mindfulness is the innate capacity to be mindful and having an open and nonjudgmental attitude (Brown & Ryan, 2003). This disposition is associated with better self-regulation and adaptation, also concerning HR (Delizonna et al., 2009), and homeostasis (Sun et al., 2019). While there is support for the notion that mindfulness reduces stress reactivity (Brewer et al. 2009; Gard et al. 2012; Taylor et al. 2011), and Weinstein et al. (2009) found that mindfulness fosters effective stress processing, little is known about the influence of mindfulness on stress recovery. For that reason, Fogarty et al. (2015) studied physiological recovery as heart rate variability after emotional stress and results indicated that trait mindfulness predicts physiological recovery.

Furthermore, noticeable is the contradictory effect of mindfulness and PC on individuals. With mindfulness showing improvements in life domains that are negatively influenced by PC, the relationship between the two concepts may be interesting. Research suggests mindfulness to relate to less negative automatic thoughts and a greater ability to let go of those thoughts (Frewen et al., 2008) through eased disengagement of attention (Keng et al., 2011). Raes and Williams (2010) argue that mindful people may not ruminate less but are more aware when they do and are then able to disengage from it. When PC negatively effects HRR, and individuals with higher levels of trait mindfulness are better able to disengage from PC, one may hypothesize that the effect of PC on HRR differs with levels of mindfulness. Moreover, this would suggest, that individuals lower in trait mindfulness would not be able to be aware, and then let go, of intrusive thoughts, and thus, the extended stress response due to PC would result in decreased stress recovery compared to people higher in trait mindfulness. To my knowledge, there is no existing literature on the notion that mindfulness may lessen an association of PC on HRR.

Current study

The current study aims to increase insights into aspects concerning physiological stress recovery by examining state perseverative cognitions, i.e., worry and rumination, and trait mindfulness of individuals in relation to heart rate recovery after completing a laboratory stress task. The current study used the data from De Calheiros Velozo et al. (2021) to assess the research question: "*Are perseverative cognitions associated with heart rate recovery levels after a stress task, and what is the role of trait mindfulness?"*.

The following hypotheses (H) are formulated:

H_1: Individuals with higher levels of state PC show less HRR compared to individuals lower in PC.

H_2: Individuals higher in trait mindfulness show greater HRR compared to less mindful individuals.

H_3: Trait mindfulness moderates the association between state PC and HRR after stress, such that individuals reporting lower levels of trait mindfulness show a stronger association between PC and HRR than individuals reporting higher levels of trait mindfulness.

Methods

Design

A within-subjects laboratory study design was chosen. The collected data consisted of quantitative self-report data and continuous physiological measurements prior, during, and after the stress task. The data has been collected by De Calheiros Velozo et al. (2021) at the KU Leuven. Thus, the present study comprises a secondary data analysis.

Participants

De Calheiros Velozo et al. (2021) recruited the participants online and via flyers which were spread throughout the city. Participants signed the informed consent prior to the study and received a 30€ reward per session. The original study included two sessions one week apart. Fifty-Three people from the general community between the ages of 19 and 35 participated. They were included when they had sufficient command of the Dutch language to understand the informed consent and self-report measures. To eliminate bias, participants with an endocrine or cardiovascular disease were excluded, as were people who use medication ongoing with the exception for the birth control pill. Moreover, participants were excluded when illicit drugs were used within the past three months. People could not take part when they had allergies to conductive gels or certain patches, as these were used for certain measurements. Lastly, people who work night shifts were eliminated. The Sociaal Maatschappelijke Etische Commissie (SMEC) of KU Leuven ethically approved the study (De Calheiros Velozo et al., 2021).

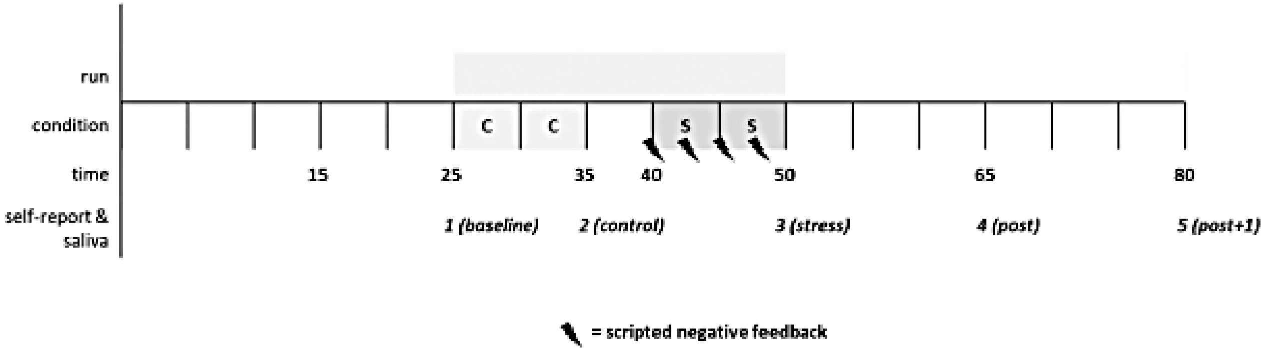
Procedure

After arriving at the laboratory and agreeing to the terms and conditions, the participants filled in the baseline questionnaire, which included items about demographics and trait mindfulness. The testing period consisted of a control period, a 5-minute break, and a one-time stress period. Afterwards, participants watched a neutral, muted video throughout a one-hour recovery phase. During the recovery phase, heart rate was measured continuously, and participants filled in the self-report, including PC items, in 15-minute intervals. Figure 1 shows the complete design.

For the stress period, the study used a stress induction task, namely the repeated Montreal Imaging Stress Test (rMIST). This stress task, being a modified version of the MIST (see Dedovic et al., 2009), consists of a series of arithmetic tasks while pressuring the participants to elicit stress. This was done by having two participants (or one participant and one confederate) ‘compete’ against each other while receiving negative feedback on their performance, stimulating a socio-evaluative threat. For optimal results, the participants needed to be manipulated about the study’s purpose and were not debriefed until after the second session, during which a different protocol was applied to avoid repetition bias (see De Calheiros Velozo et al. (2021) for details).

Figure 1

rMIST single-run design used for Study 1



Note: R= rest, C=control, S=stress. Time is depicted in minutes starting at the arrival. From "The repeated Montreal Imaging Stress Test (rMIST): Testing habituation, sensitization, and anticipation effects to repeated stress induction." by J. De Calheiros Velozo, et al. Copyright 2021 by Psychoneuroendocrinology. The original figure included 'study 2' which is not included in the current study.

Measures

Baseline questionnaire

Before the testing period a baseline questionnaire was filled in, which included demographics, such as age, gender, nationality, marital status, work, and education as well as various scales to assess resilience, (subclinical) psychopathology, trait mindfulness, cognitive coping style, childhood adversity, and stressful life events. For the current study trait mindfulness was of interest.

Mindfulness

To assess trait mindfulness, the Five Facet Mindfulness Questionnaire (FFMQ) by Bear et al. (2006) was used. The questionnaire includes 39 items to assess five facets, namely observing, describing, acting with awareness, nonjudging, and nonreactivity, and has been shown to have good psychometric properties (Bear et al., 2006). The FFMQ mean score variable was obtained by first recoding reversed items (see Bear et al., 2006), and then computing the average score of all items. Scores can range from 1 till 5, with higher final scores indicating higher levels of trait mindfulness. The mindfulness scale with the current sample had a high reliability (α= .90).

Perseverative cognitions

PC data was obtained during the recovery phase. The self-report included three items, of which one was a categorical item, i.e., “Right now, the focus of my thoughts is on the future, present, past”. As the focus of the current study is on PC and not focused on worry or rumination separately, this item was excluded from the analyses. The other two contain a 7-point-Likert Scale. The first measures state rumination and is formulated as “Right now, I keep thinking about my feelings and problems”. The second is “Right now, I worry”. To obtain the average score per participant, the variable for PC was computed by calculating the mean of the rumination and worry items. Higher PC scores indicate higher levels of spontaneous perseverative cognitions. The PC scale with the current sample had an acceptable level of reliability (α= .62).

Heart rate

Heart rate was measures continuously using an electrocardiography (ECG) at lead type II locations (De Calheiros Velozo et al., 2021). To simplify data use, the ECG signal was digitized at 1000hz and computed to a ‘mean heart rate per 5 minutes’ variable**.** The HR mean for each testing phase, i.e., HR control, HR stress, HR recovery, was computed per participant. For HR during the recovery phase one measure point was included, i.e., the first 5 minutes of the recovery phase. For the final analyses, a HRR variable was needed that represents the relative recovery per participant. HRR was computed using the following equation: $HRR = \bar{x}\ (HR\ stress) - \bar{x}\ (HR\ recovery)$. Larger values indicate a greater difference between HR during stress and HR during recovery, which in the current study represents greater recovery. Moreover, positive values indicate a decreased HR during recovery compared to the HR during the stress task, so negative values indicate that the HR increased during the recovery period.

Data Analysis

To test the hypotheses, the data from the study done by De Calheiros Velozo et al. (2021) was used, which had to be prepared first. Meaning, that the data file from the baseline questionnaire and the laboratory data were merged based on the participant's ID. Moreover, participants with missing data were excluded, e.g., participants whose heart rate measures were incomplete. De Calheiros Velozo et al. (2021) collected data on two days, however, in the context of the current study only data from the first day, i.e., the first session, was used.

Statistical analyses were performed using SPSS software with the PROCESS application. PROCESS is a macro tool for moderation, mediation, and conditioning analyses (Hayes, 2018) that applies an integrated bootstrap approach, which is a resampling procedure to construct a dataset with replacement, i.e., simulated samples (Muralidhar, 2003). The advantage of using the bootstrapping approach is that it can be used with smaller samples. Nevertheless, one should keep in mind that smaller samples make it more difficult to compute valid confidence intervals (Haukoos & Lewis, 2005). Another advantage is that the bootstrap approach allows for more accurate inferences as the data does not need to be normally distributed (Hesterberg, 2011).

To analyze the data, the variables *HR_control, HRR, mindfulness,* and *PC* were computed as described in the ‘measures’ section. Apart from visual data presentations, multiple regressions, and descriptive analyses, analyses to test normality assumptions were performed. The normality of the sample was tested by performing a Shapiro-Wilk’s test ($p < .05$), a visual inspection of their histograms, normal Q-Q, and box plots. Moreover, to assess whether the rMIST successfully elicited stress, i.e., that recovery after stress was measurable, a pairwise comparison t-test was performed. To assess whether individuals higher in state PC have a decreased HRR (*H_1*), a linear regression was performed using *PC* as the independent variable (IV) and *HRR* as the dependent variable (DV). To assess whether individuals higher in mindfulness show greater HRR (*H_2*), a linear regression was performed using *mindfulness* as the IV and *HRR* as the DV. To assess whether mindfulness has a moderating effect on PC and HRR (*H_3*), PROCESS was used. The moderator analysis included *PC* as the IV, *mindfulness* as the moderator variable, and *HRR* as the DV. All analyses controlled for HR during the control period (*HR control*) by using it as a covariate.

Results

Sample description

From the 53 participants in the original dataset seven participants were excluded due to missing data, e.g., no HR measures during baseline (N= 5), no heart rate measures during the control phase (N= 1), or no HR measures during the recovery phase (N= 1). As a result, the data set for analyses included N=46. Participants in the dataset ranged from 19 to 35 years old, M_{age}= 23.91. In table 1 the participant's demographics are presented.

In table 2 descriptive statistics of the variables are presented. The participants varied the most in HR during the stress phase, M= 78.25 (SD= 13.08), ranging from 52.62 to 124.23 bpm. The mean HR during the recovery phase was the lowest, with M= 73.02 (SD= 9.10). Pairwise comparisons showed a significant HR difference between the control and stress phase, t= 3.96, p< .001, as well as between the stress and recovery phase, t= 4.51, p< .001, indicating a significant increase in HR during the stress task and a decrease during the recovery.

In figure 2, the mean HR during the control, the stress, and the recovery phase is shown with error bars and figure 3 shows the frequency of the HRR values. In figure 4 and 5 the frequency of PC and mindfulness values are presented. Noticeable is that only few participants had higher levels of state PC, e.g., only three participants indicated state PC levels above 3.8 out of the possible 7. Additionally, only few participants had lower levels of mindfulness, i.e., only three participants indicated trait mindfulness levels below 2.5.

Table 1

Descriptive Statistics about the participants' demographics (N=46).

Variable		N	%
Gender	female	40	87%
	male	6	13%
Nationality	Belgian	39	84.8%
	Dutch	3	6.6%
	Greek	1	2.2%
	missing	3	6.5%
Employment status	employed	18	39.1%
	unemployed	27	58.7%
	missing	1	2.2%
Marital status	single	10	21.7%
	in a relationship	28	60.9%
	married & living together	7	15.2%
	missing	1	2.2%

Table 2

Descriptive Statistics for the mean HR variables, FFMQ scores, and PC scores (N=46).

Variable	range	Mean	SD	Variance
HR control	51.03 – 97.82	73.92	9.74	94.93
HR stress	52.62 – 124.23	78.25	13.08	171.214
HR recovery	54.53 – 96.19	73.02	9.09	82.68

HRR	-5.97 – 32.72	5.22	7.85	61.56
PC	1.33 - 5	2.77	0.82	1.55
Mindfulness	1.77 – 4.26	3.38	.53	.28

Figure 2

Mean Heart Rate during the different testing phases, with Error Bars (95% Confidence Intervals).

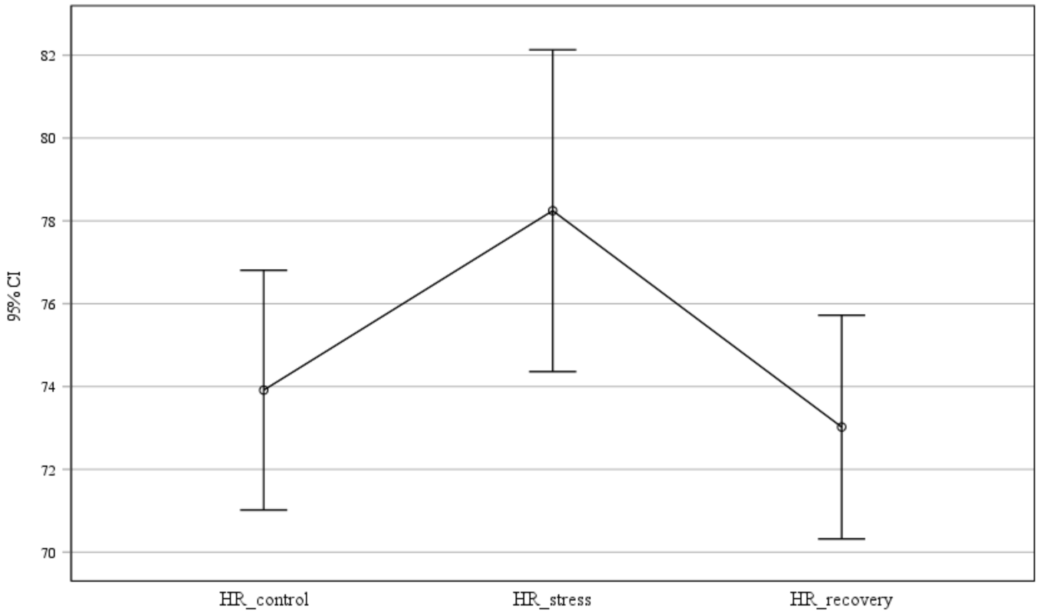


Figure 3

Frequency of Heart Rate Recovery values with normality curve.

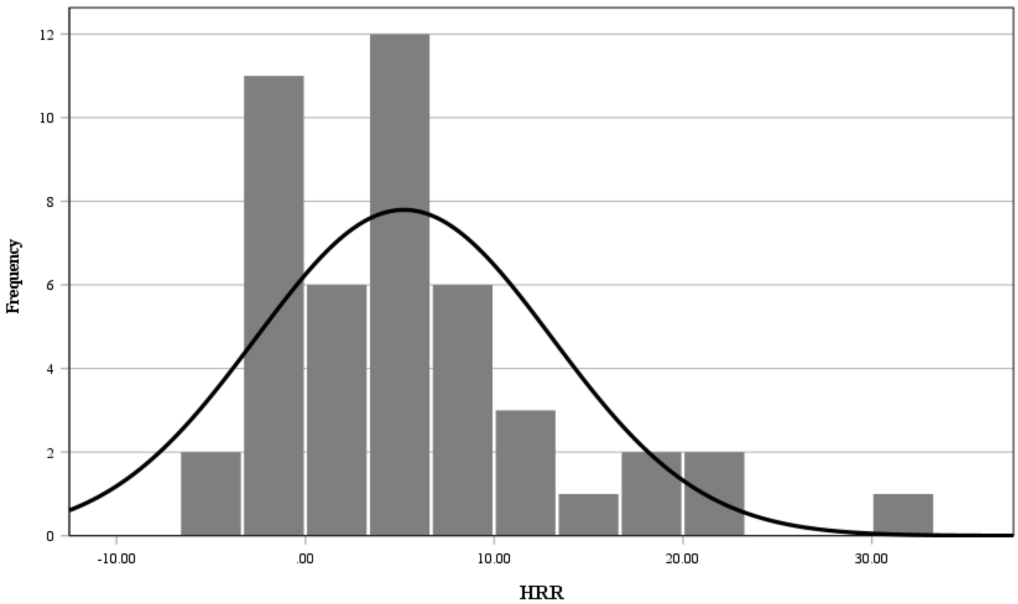


Figure 4

Frequency of PC values.

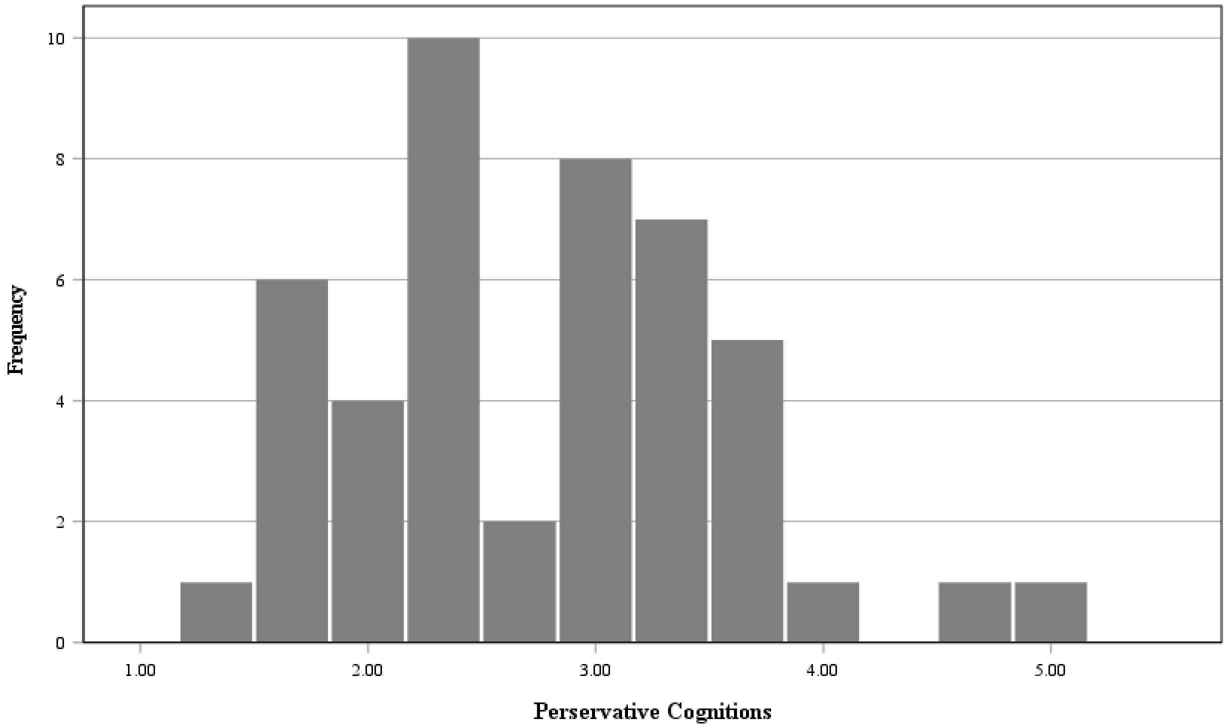
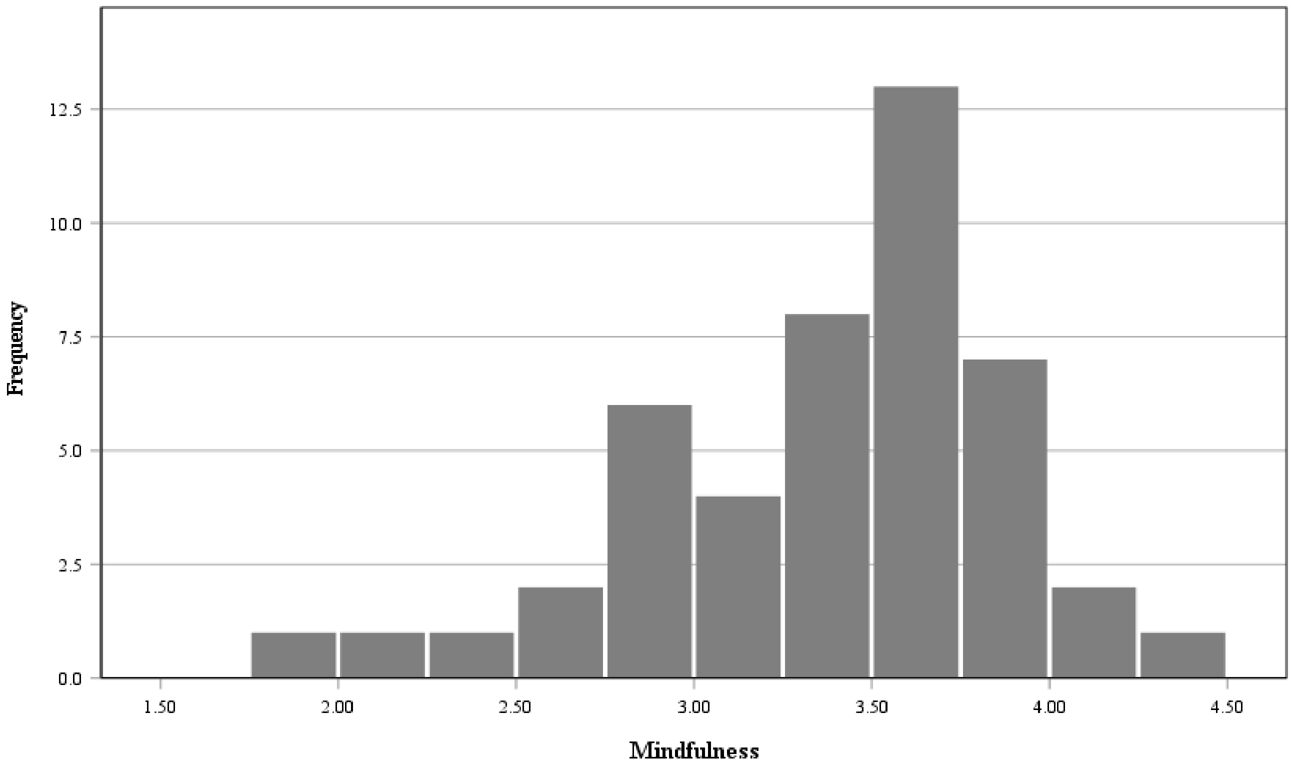


Figure 5

Frequency of mindfulness values.



Assumption testing

Normality tests were performed and indicated that mindfulness, PC, and HR control were approximately normally distributed. *HRR* was not normally distributed as skewness and kurtosis scores exceeded the acceptable *z*> 1.96 (see Table 3). Although, excluding the outliers improved the Shapiro Wilks score, it was not a significant change. Moreover, as a bootstrap approach was used for the analyses, meaning normality is not required to be met (Hesterberg, 2011), no further measures to reach normality for HRR were performed.

Table 3

Overview of Normality Testing (N=46).

Variable	Shapiro-Wilk	*p*-value	Skewness (*SE*= .35)	Kurtosis (*SE*= .69)
HRR	.88	<.001	1.45	2.52
Mindfulness	.92	.004	-1.07	1.12
PC	.96	.08	.43	- .05
HR control	.98	.83	.13	.54

Perseverative Cognitions and Heart Rate Recovery

To test the effect of PC on HRR, a regression analyses was performed. First, PC was not a significant predictor for HRR, β= - .01 (SE= .92), *t*(45)= - .09, *p*= .93. The PC-HRR model was not significant, *F*(2, 45)= 2.27, *p* = .12, and PC explained 10% of the variance in HRR, R^2= .10. The correlation of PC with HRR also was not significant, *r*= .03, *p*= .42. In figure 6, the variables are represented in a scatter plot, indicating a negligible negative association in this sample.

Mindfulness and Heart Rate Recovery

Another linear regression was performed to assess the relationship between mindfulness and HRR, with HR control as a covariate. The model was insignificant, *F*(2, 45)= 2.72, *p* = .08, and explained little of the variance in HRR, R^2= .11. Mindfulness had a positive effect on HRR, β= 1.31 (SE= 2.17), t(45)= .90, p= .37. The association of mindfulness with HRR was low, r= .07, p= .32. In figure 7 the variables are represented in a scatter plot.

Figure 6

Scatter plot of HRR and PC with Regression line.

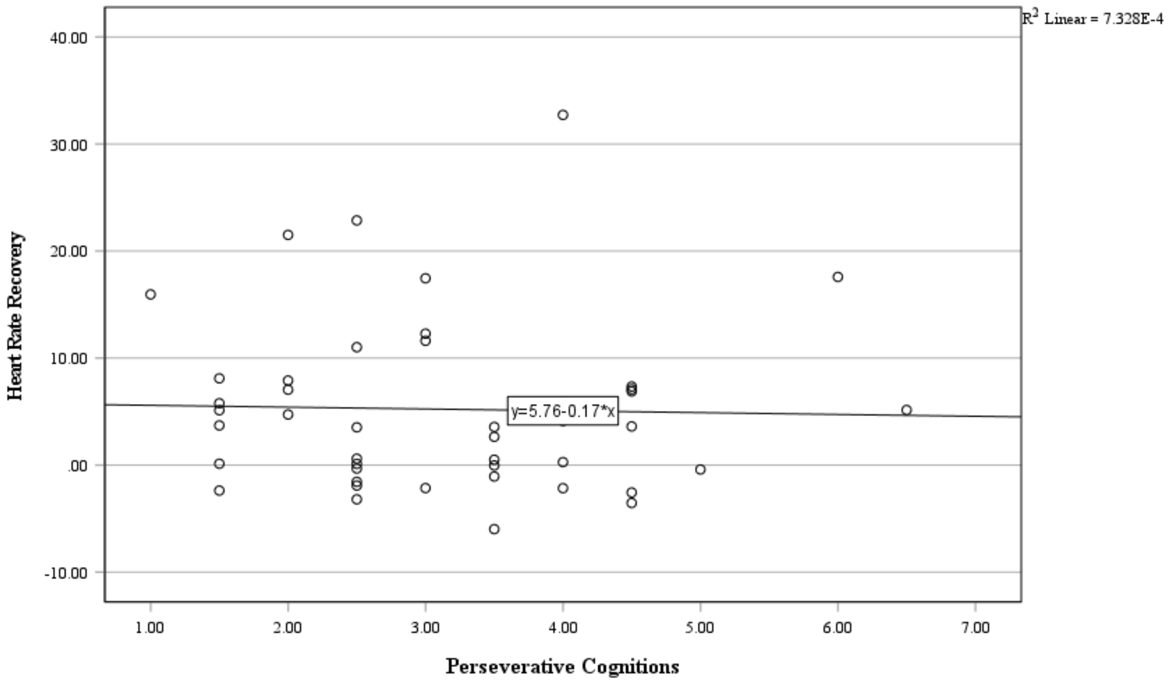
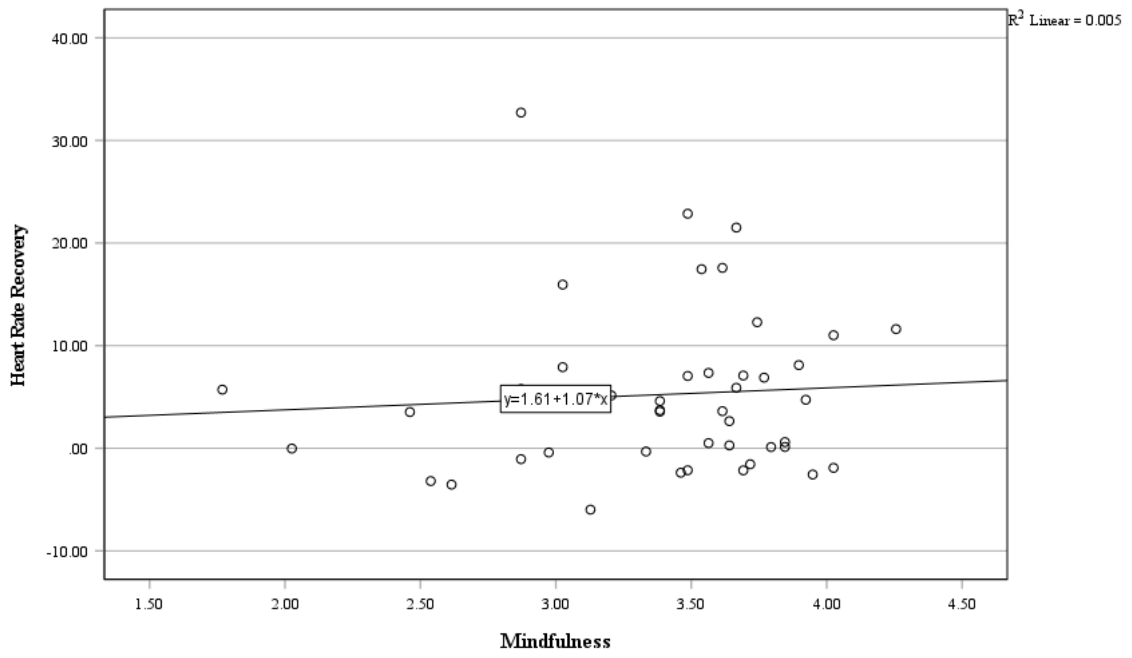


Figure 7

Scatter plot of HRR and Mindfulness with Regression line.

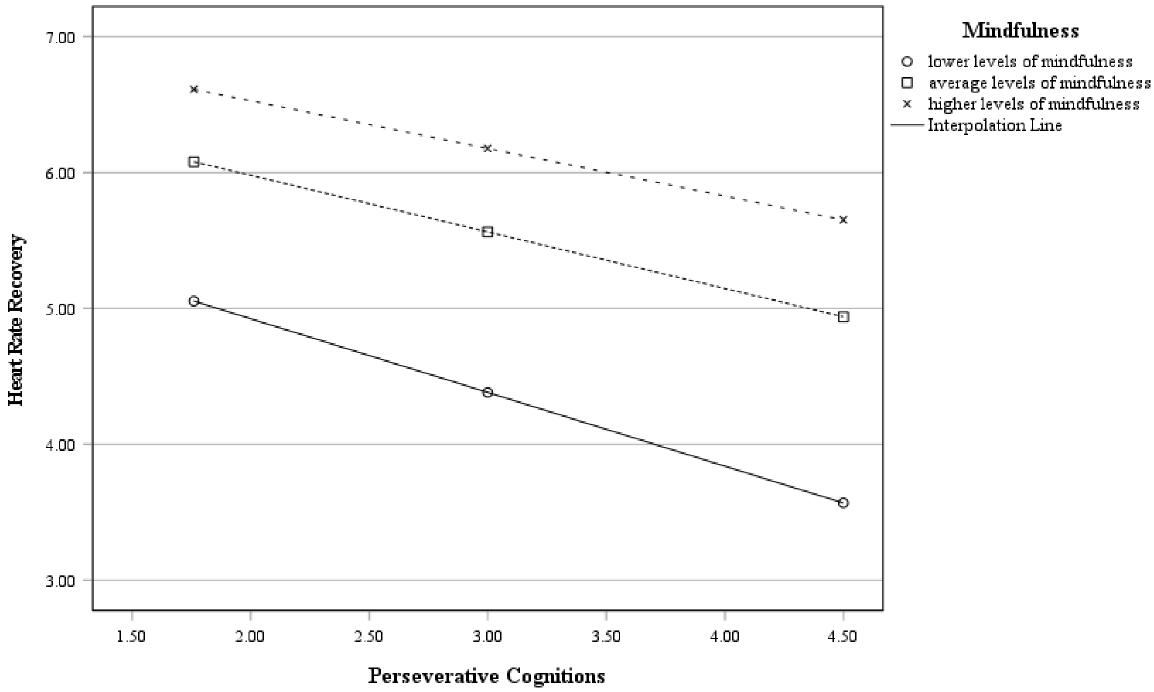


Perseverative Cognitions, Mindfulness, and Heart Rate Recovery

To test the interaction of mindfulness on the relationship of PC and HRR, a moderation analysis using PROCESS was performed, while controlling for *HR control*. Results indicated that PC and mindfulness were not significant for HRR, $F(4, 41) = 1.35$, $p = .27$. Generally, the model explained 12% of the variance in HRR, $R^2 = .12$, with a relatively high mean square error, $MSE = 59.70$. The interaction effect of PC and Mindfulness was negative, but not significant, $\beta = -1.50$ (SE= 3.45), $t(41) = -.44$, $p = .67$, and the addition of the interaction affect barely improved the model, $F(1, 41) = .190$, R^2 change= .004. In figure 8, HRR and PC are shown relative to three different levels of mindfulness produced by the PROCESS application. The trend shows, that, overall, higher levels of PC indicate less HRR for all levels of mindfulness. Although the mindfulness regressions are close to parallel, the lower level of mindfulness shows the steepest slope, indicating that lower levels of mindfulness and increasing levels of state PC appear to have the strongest trend effect on HRR compared to other levels of mindfulness.

Figure 8

Graph showing HRR and PC relative to the level of mindfulness.



Note: Graph output after PROCESS analysis. Lower levels of mindfulness represent the 16th percentile, average levels represent the 50th percentile, and higher levels of mindfulness indicate scores of the 84th percentile. Caution with the interpretation of the graph as the HRR window is limited and no error bars are presented.

Discussion

In an effort to gain insights into factors influencing physiological recovery, the current study focused on the associations of state perseverative cognitions (PC) and traitmindfulness with heart rate recovery (HRR) after the repeated Montreal Imaging Stress Task. Results indicated that state PC are not associated with HRR, and that trait mindfulness does not play a role. Thus, contrary to expectations, linear regressions showed no indication that individuals with higher levels of state PC show less HRR (H_1), nor did it support the notion that individuals with higher levels of trait mindfulness show greater HRR compared to less mindful individuals (H_2). Last, the interaction of trait mindfulness on the relationship between PC and HRR was examined, showing no moderation effect. Therefore, no differences between individuals with lower or higher levels of trait mindfulness were found regarding the association of PC with HRR, opposing H_3.

Perseverative Cognitions

Current results are not in line with previous findings supporting the PC hypothesis (see Brosschot et al., 2006). For example, a preceding study indicated that the effect of PC on stress recovery after a social stress test could be found on physiological but not self-report indices (Capobianco et al., 2018). Granted that in Capobianco et al.'s (2018) research the negative effect of state PC on recovery was greatest 30 minutes into the recovery, which exceeds the recovery time examined in the current study. Moreover, Brosschot (2010) summarized that in at least 15 additional studies a prolonged activity, i.e., delayed recovery, due to PC, was negatively associated with at least one cardiovascular measurement, including heart rate. The current study, however, examined HRR as the difference between two HR measures, rather than assessing HRR as a time measure. This means that whereas other studies talk about delayed and prolonged HRR, the current study can merely state HRR as being greater or weaker. This difference in operationalisation should be kept in mind when comparing results with previous studies.

Importantly, I focused on the umbrella term PC rather than worry and rumination separately. Current results differ from numerous findings supporting an association of delayed stress recovery with the two variables after emotional laboratory stressors (see Brosschot, 2010). Moreover, Key et al. (2008) differentiated between state and trait rumination and found that state rumination was associated with reduced HRR for people lower in trait rumination, but no association was found between state rumination and HRR for individuals high in trait rumination. Additionally, they highlighted the notion that as rumination can become habitual, it may be difficult for individuals to identify when they are ruminating (Key et al, 2008). This may explain why in the current sample only few participants reported higher levels of state PC. Additionally, there was no data available about the individual’s level of trait rumination, which as Key et al. (2008) argue may influence state rumination. In this regard, Brosschot et al. (2010) explained that the physiological reaction may be influenced by unconscious PC. The notion of unconscious PC still needs to be empirically researched. Nevertheless, more recent research of Brosschot et al. (2014) highlight that prolonged physiological activity does not just occur after a stressor, but also before stressors due to PC. Worry, i.e., anticipating stress, can cause a strong physiological reaction even when the feared situation never occurs. Brosschot et al. (2014) argue that “conventional stress studies do not only seldom measure PC but also typically fail to measure stressors that have not (yet) happened [...] missing apotentially large source of stress responses” (Brosschot et al., 2014, p. 180). Thus, while the findings presented here are not in line with previous results, researchers have suggested explanations, e.g., unconscious PC, prior elicted physiological reactions, or habitual PC.

Mindfulness

To my knowledge there is little research on HRR and mindfulness. Generally, Sünbül and Güneri (2019) found a significant but low direct association of mindfulness and resilience, which stress recovery can be considered part of (Montpetit et al., 2010). Koerten et al. (2020) found that in a perfectionistic sample mindfulness of any kind aids cardiovascular recovery after failure-related stressors. Concerning heart rate variability, Fogarty et el. (2015) studied mindfulness and physiological recovery in the context of emotional stress and found that “rather than dampening the emotional response, mindfulness appears to facilitate recovery following initial reactivity to stressors” (Fogarty et al., 2015, p. 8). Other research focused on mindfulness and stress reactivity. In this regard, Skinner et al. (2008) found that individuals higher in mindfulness were less reactive to a mildly stressful task in terms of heart rate and blood pressure. While stress reactivity and recovery are distinct processes, Larsen and Christenfeld (2009) argue that it can be difficult to separate them during laboratory studies because “the actual experience of stress—and resulting physiological reactivity—can continue well after the event has ended” (p.4). In the case of the current study, it may be that some individuals were still in the reactivity phase, despite the stressor not being present. It is possible, therefore, that HRR differences due to different levels of mindfulness may not be distinguishable from the initial reactivity during (part of) the recovery phase. As a result, some participants might have had significantly different levels of HRR in a later stage of recovery. In this regard, stricter inclusion criteria regarding the recovery measures may make a difference, e.g., by assuring the individual is recovering, meaning that the HR decreased during the included recovery measurements.

It should be kept in mind, that the association of PC and HRR was insignificant, and no moderation effect of mindfulness was found. Although, to my knowledge, there is no previous research on the interaction of state PC and trait mindfulness on HRR, Brosschot et al. (2010) stated that “mindfulness is the exact opposite of perseverative cognition.” (p. 413). This would suggest a balanced influence on a dependent variable. Additionally, despite visual results indicating a miniscule positive association of trait mindfulness with HRR in the current sample, it also showed the lack of participants with lower levels of trait mindfulness. Thus, the current result may be explained by the fact that the sample did not include individuals with higher levels of state PC and lower levels of trait mindfulness, e.g., the lack of variability within these factors should be kept in mind. Overall, results indicated that the analyzed models explained very little of the variance in HRR suggesting that additional factors play an important role.

Heart Rate Recovery

Some general points regarding the HRR measure in the current study should be kept in mind. First, pairwise comparisons showed significant changes in HR between the different phases, i.e., control, stress, and recovery phase, and thus, the study supports the notion that psychosocial stress tasks are associated with increased heart rates (Brugnera et al., 2018). Nevertheless, some participants’ recovery phase in the current study would fall outside of the HRR definition, which implicated a decrease in HR during the recovery phase after HR increased during the stress task. This may be explained by a delayed reactivity to the stress task, or that individuals did not respond to it. Alternatively, as data was collected in a laboratory setting, the Hawthorne Effect, i.e., the influence of being observed, or anticipated stress prior to measurement/ session, may have been induced.

Second, contrarily to previous studies, the current study examined HRR as a difference-variable. As the operationalization of HRR is not standardized, researchers differ in the way they assess it, and thus, caution should be applied when comparing studies on HRR. Notwithstanding, Crosswell et al. (2017) also examined HRR by computing the mean change from HR during the stress task and recovery period, i.e., as a difference-variable, to examine the overall recovery pattern. Nevertheless, Brosschot and Thayer (2003) highlight the importance of studying stress more in the context of recovery, and specifically, "including more measures of duration of physiological responses—such as prolonged activation recovery measures" (Brosschot & Thayer, 2003, p.185), i.e., HRR as a time-measure. Moreover, with HRR as a time-measure more information can be implied from the data, e.g., beyond decreased, ineffective, or greater recovery. Questions concerning the occurrence and types of fluctuations during the recovery period, the 'starting' point of recovery, or the extent to which factors influence the recovery phase could be answered. These points can be kept in mind for future studies.

Study Strengths and Limitations

One strength of the current study is the use of secondary data from the laboratory, meaning the data was collected in a controlled environment. Furthermore, well researched scales were used, such as the FFMQ which increased the validity of the mindfulness values. However, this was not the case for the state PC items. The current study had one item for rumination and one item for worry. Future studies could use a validated PC scale such as the 'perseverative thinking questionnaire' (PTQ; Ehring et al., 2011). Additionally, although the sample is small and limited regarding the diversity in nationalities and ages, the current sample was included based on their health, i.e., no diseases, medication, etc.. This was a way to reduce possible confounding factors and allow for generalizable interpretations for a healthy population.

Moreover, it should be kept in mind that the individuals differed greatly in HR. In this regard, an inclusion criterion could have been that the participants should have a higher HR during the stress task and a decreasing HR during recovery to get more valid HRR results. Due to the sample size and the scope of this research, this criterion was not included, highlighting that the HRR values should be interpreted with caution.

Directions for Future Research and Study Implications

Taking the limitations into consideration, future studies could use a different measure for stress recovery, e.g., HRR as a time-measure instead of the difference-measure used in the current study. This may be done by assessing HR prior to and during the task, then measure the time it takes for the participants' HR to go from the highest HR during stress to their prior HR. Moreover, to increase reliability and allow for better comparison between studies, a more standardized measure of HRR should be applied. Furthermore, as only the first five-minute HR recovery measure was used, future studies could assess more or longer recovery time frames to compare and examine whether the factors may play a role in later stages of HRR. Another way to measure physiological recovery could be Heart Rate Variability, which is frequently used.

Additionally, as the variables explained very little of the variance in HRR, future research could focus on other factors that may influence it. While the results of the current study suggest that PC and mindfulness do not significantly influence HRR, the interaction of PC and mindfulness was not yet examined. Furthermore, it may be interesting to examine whether the results differ when trait PC is assessed rather than state PC, or by assessing the interaction of trait and state as Key et al. (2008) suggested. With the means of finding variables that influence stress recovery, ambulatory studies and research in daily life may also give additional insights into PC and HRR.

Despite the mentioned limitations, the current research enhanced our understanding of the association of state PC, and trait mindfulness with HRR. This way, it can be seen as a first step towards examining PC and mindfulness in the context of physiological stress recovery, which have not been directly linked before. These preliminary studies are important, as research on influential factors for HRR is needed to effectively design interventions that aid stress recovery. Thus, contrary to previous studies, the current findings imply that trait mindfulness and state PC do not need to be considered when aiming to improve HRR. As a result, more research is needed to gain insights into stress recovery to be able to successfully reduce adverse effects of stress and increase healthy lifestyles through effective, complete recovery.

Conclusion

The aim of this paper was to increase the understanding of factors, such as state perseverative cognitions and trait mindfulness, and their influence on physiological stress recovery. The results from the current study imply that state perseverative cognitions do not have an influence on the individuals heart rate recovery after a stress task, and that trait mindfulness does not have a positive effect on heart rate recovery either, i.e., mindfulness does not play a significant role. Nevertheless, the current study provides preliminary findings about state perseverative cognitions and trait mindfulness and their effect on heart rate recovery. Future studies could measure heart rate recovery as a time-variable rather than a difference-variable and assess additional factors to further increase our understanding of physiological stress recovery.

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