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Cognitive reappraisal increases heart rate variability in response to an anger provocation

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Abstract Adaptive self-regulatory responses to negative events are associated with good mental health, social functioning, and physical health. Two forms of emotion regulation that have received attention within the context of anger are cognitive reappraisal and expressive suppression. Research suggests that greater heart rate variability (HRV) is a physiological indicator of adaptive emotion regulation and decreased mental load. In the present experiment, we recorded HRV while 131 undergraduate women viewed an anger-inducing video of a fellow student arguing for a position counter to that of the participant on an important political issue. Immediately prior to viewing, participants were instructed to reappraise, suppress their emotions, or simply watch the video as normal. Participants in the reappraisal condition showed increased HRV whereas those in the suppression and control condition showed no such increase. These results provide support for increased HRV as a biological correlate of adaptive emotion regulation. One implication is that cognitive reappraisal might afford greater autonomic flexibility when an individual is confronted with anger-inducing events.

Keywords Anger · Reappraisal · Suppression · Heart rate variability · Emotion regulation

Introduction

Daily life offers ample opportunity to experience irritation, annoyance, and anger. Anger often occurs when the appraisal is made that one's goals are obstructed (Wranik and Scherer 2010). For instance, simply watching favorable political developments for the opposing party on the evening news can be quite anger-inducing for some. The manner in which we regulate our emotions during such events can have important implications for our social functioning, mental well-being, and even physical health (Gross 2001). Indeed, those who frequently experience anger and hostility are at risk for negative cardiovascular health including early mortality (Friedman and Booth-Kewley 1987; Kubzansky et al. 2005; Suls and Wan 1993). In the present research we instructed participants to regulate their emotional responses while listening to anger-inducing counter-attitudinal opinions on political issues that were important to them. One biomarker of adaptive emotion regulation and cardiovascular health is increased heart rate variability (HRV) (Appelhans and Luecken 2006; Hadase et al. 2004; La Rovere et al. 2003; Stein and Kleiger 1999). Our primary aim was to examine change in HRV as a function of adaptive versus maladaptive emotion regulation.

Individuals can employ a range of cognitive strategies when exposed to adverse emotional states. Gross' (1998, 2001) process model of emotion regulation differentiates emotion regulation strategies that are employed prior to (i.e., antecedent-focused) and following (i.e., response-focused) emotion-eliciting events. Reappraisal is an example of an antecedent-focused strategy, and entails adopting a neutral perspective on a situation prior to the event in order to attenuate its emotional impact. Reappraisal is an adaptive emotion regulation strategy because it prevents negative emotional and maladaptive cardiovascular responses from being fully elicited (Mauss et al. 2007; Memedovic et al. 2010; Ray et al. 2008). By comparison, suppression is response-focused because it is

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employed later in the emotion generative process (i.e., following the elicitation of a full emotional response). Suppression involves inhibiting all outward signs of emotional expression and is considered maladaptive in the sense that it can result in increased physiological reactivity and have no effect on anger or even increase it (Hosie et al. 2005; Memedovic et al. 2010; Quartana and Burns 2010).

There is evidence to suggest that reappraisal can modulate cardiovascular responding in some situations. In one study, participants who were verbally harassed by an experimenter were given an excuse for the experimenter's behavior beforehand or not, providing the former group with an opportunity to evaluate the situation less negatively (Stemmler 1997). Participants who were given the excuse had lower diastolic blood pressure in response to the harassment than participants who were not given the excuse. Similarly, using multiple measures of cardiovascular reactivity (but not HRV) Mauss et al. (2007) examined the effect of trait reappraisal on cardiovascular outcomes following provocation. Participants who were high in trait reappraisal reported less anger and more adaptive cardiovascular responses (i.e., increased cardiac output and ventricular contractility and decreased total peripheral resistance) relative to participants who were low in trait reappraisal.

Taking an experimental approach, Ray et al. (2008) instructed participants to recall an anger-inducing event and then to either reappraise or ruminate. Participants in the reappraisal condition reported less anger and had smaller increases in sympathetic reactivity than those in the rumination condition. More recently, Memedovic et al. (2010) examined the effects of trait reappraisal and suppression on self-reported anger and blood pressure following a direct anger provocation. Participants who were high in trait reappraisal demonstrated attenuated blood pressure and anger in response to the provocation, even when controlling for individual differences in negative emotionality. Trait suppression had no effect on either of these variables. Taken together, these findings provide preliminary evidence of the importance of emotion regulation strategies in determining the affective and physiological impact of encountering and recalling anger-eliciting events.

Not all increases in cardiovascular activity are related to poor health. One such cardiovascular indicator is higher levels of high frequency HRV (Stein and Kleiger 1999). The interval between heart beats varies during normal sinus rhythm. Changes in this variability are of interest to psychologists because such changes can be reliably associated with psychological phenomena. Indeed, theory and research suggest that HRV, particularly the high frequency component, is a physiological indicator of one's capacity to effectively regulate one's emotions (Appelhans and Luecken 2006; Thayer and Lane 2000, 2009).

HRV is indicative of the flexibility of the interplay between the two divisions of the autonomic nervous system (ANS): the sympathetic nervous system (SNS) and the parasympathetic nervous system (PNS). The SNS is the excitatory system that increases physiological arousal including HR in response to stressful situations. The PNS is the inhibitory system that maintains a homeostatic low level of arousal in safe circumstances. High frequency HRV is thought to reflect predominantly PNS influence, whereas low frequency HRV reflects SNS influence.

Evolutionarily informed theories of HRV suggest that greater high-frequency HRV allows mammals to rapidly and effectively respond to important changes in the environment including social and emotional situations (Porges 2007; Thayer and Lane 2000, 2009). Indeed, greater high-frequency HRV reflects more adaptive, flexible responding to environmental demands. For instance, higher levels of resting HRV are associated with better self-reported emotion regulation (Fabes and Eisenberg 1997). By contrast, lower HRV (so-called "cardiac rigidity", see Appelhans and Luecken 2006) is associated with mental health problems, which are characterized by poor emotion regulation.

Because reappraisal is an adaptive form of emotion regulation, it should be associated with increased high frequency HRV relative to response-focused emotion regulation strategies such as suppression. In the only study to date that has investigated this hypothesis, undergraduate women viewed a disturbing film about the Hiroshima bombing and were asked to talk about it with another participant while either reappraising, suppressing, or responding as they normally would (Butler et al. 2006). Participants in the reappraisal condition showed the largest increase in high frequency HRV followed by participants in the suppression group. Participants in the control condition showed no change.

A second reason to expect that reappraisal should be associated with increased HRV concerns the degree of cognitive effort associated with each strategy. Relative to response-focused strategies such as suppression, reappraisal is believed to require less mental effort because it involves "cutting the emotion off at the pass" rather than managing the emotion after a full-blown response has occurred (Gross 2001; Richards and Gross 2000). Thus, for individuals engaged in reappraisal, the self-regulatory resources required for managing emotional responses are superfluous. Indeed, controlled processing and cognitive load decrease HRV (Aasman et al. 1987; Tattersall and Hockey 1995), whereas higher levels of HRV are associated with increased prefrontal cortical activity during emotional experiences and better executive functioning (Hansen et al. 2003; Jönsson and Sonnby-Borgström 2003; Lane et al. 2009; Thayer and Lane 2000). Moreover, Lane et al. (2009) reported that high frequency HRV while watching emotional film clips and autobiographical recall was correlated with activation in the dorsolateral prefrontal cortex (DLPFC). The DLPFC is thought to play a critical role in cognitive reappraisal (Ochsner and Gross 2008).

To our knowledge, only one study has examined HRV within the context of anger regulation. Leon et al. (2009) investigated the association between HRV and participants' perceptions of the degree to which another person was to blame for a hypothetical negative event (job dismissal). Among participants who were led to believe that another person intentionally caused them to lose their job, those with higher HRV made less extreme evaluations of the extent to which the other person was to blame relative to those with low HRV. Interestingly, there was no direct association between HRV and emotion, suggesting additional downstream mediators. The authors concluded that HRV is "…an index of prefrontal regulation of emotion, enhancing the cognitive appraisal of environmental demands in an adaptive manner" (Leon et al. 2009, p. 3).

The present research is the first to investigate the effects on HRV of instructing participants to reappraise or suppress their emotional reactions to an anger provocation. Accordingly, we instructed undergraduate women to engage in either reappraisal or expressive suppression in response to a pre-recorded speech in which a fellow student expressed a view on a controversial topic that was directly counter to the participants' own view. Participants in the control condition were told to watch as they normally would. We predicted that participants who reappraised would demonstrate an increase in high frequency HRV whereas participants in the suppression and control conditions would show no such increases in HRV.

Method

Participants and design

A total of 131 undergraduate women from the University of New South Wales (UNSW) participated in exchange for course credit ($M_{age} = 20.23$ years, $SD_{age} = 3.02$). We utilized an all female sample because research suggests that females have higher high frequency HRV (Jönsson and Sonnby-Borgström 2003), and because we wished to compare our results to prior work on emotion regulation and cardiovascular responses, which has relied on exclusively female samples (Butler et al. 2006; Mauss et al. 2007; Memedovic et al. 2010; Ray et al. 2008). Participants were randomly assigned to one of three emotion regulation conditions: reappraisal ($n = 42$), suppression ($n = 45$), or control, ($n = 44$). Participants were told that the study was examining controversial issues, mood, and cognitive performance.

Materials and procedure

Participants completed the experiment individually. They were asked for their height and weight, and this information was entered into a Polar^{TM} Watch heart rate (HR) monitor (model RS800CX). Participants were affixed with the Polar Watch chest strap around the chest, just below the chest muscles and the watch was placed on an adjoining table face down so that the participant could not see it. The Polar Watch records HR time series to an accuracy of within the larger of either ±1% or 1 bpm. Polar Watches are frequently used in psychophysiological research (e.g., Epstein et al. 2005; Sloan and Epstein 2005; van der Meij et al. 2010), and HR assessed with the Polar Watch is very strongly correlated with HR assessed via traditional ECG (Goodie et al. 2000).

Initial attitude assessment

Participants completed a questionnaire that indexed their opinions on a series of controversial issues (e.g., taking strong action to counter climate change, increasing immigration to Australia, and decreasing university fees). Attitudes were rated on a scale from 1(completely for) to 10 (completely against). After participants rated each question, the experimenter noted which of the three issues received the most extreme attitude rating. This information was used to determine the video that participants would watch (see below). If two of the three issues were rated equally strongly, a coin flip determined which video would be shown.

Baseline mood and HRV

Next, participants were presented with a 5 min slideshow of 20 neutral images to establish baseline HRV. The images were taken from websites and included stimuli such as landscapes and furniture. To ensure neutrality of the images, a separate sample of 10 individuals rated the valence of the images (1 = very negative, 5 = neutral, 9 = very positive). The mean valence of 5.20 ($SD = 0.36$), which did not differ from the scale neutral midpoint of 5.00, $t(9) = 1.77$, $p = .11$. A new image appeared every 5 s and the 20 images repeated themselves. Participants then completed a mood adjective checklist that contained 28 adjectives (e.g., angry, happy) as a measure of initial affect (Nowlis 1965). Participants rated the degree to which they felt each emotion at the time (1 = *not at all*, 7 = *very much so*). We computed the mean of the 8 anger-related items (i.e., angry, annoyed, frustrated, grouchy, hostile, irritable, offended, scornful; Cronbach's $\alpha = .91$).

Emotion regulation manipulation

Participants were next asked to construct an argument about their opinion on the controversial issue for which they indicated the most extreme attitude. They were given 3 min to write down reasons and arguments that supported their position on the issue. This was done to increase the saliency of participants' attitudes.

We created videos for each of the three target topics (climate change, immigration and university fees) as an Internet pretest ($N = 175$) indicated that these were the three most important political issues to UNSW students. The videos were 1 min long and matched to be counter-attitudinal to the participants' position. For example, if a participant said that they had strong views against increasing immigration to Australia, they were shown a video of someone who strongly argued in favor of increasing immigration.

Following the 3 min argument construction period, participants were told that they were going to be shown a pre-recorded interview of a person who held the opposite opinion on the controversial issue that was most important to them. This person was referred to as their "video partner". In reality, the people in the video were actors from a local dramatic arts college. They were asked to evaluate the argument that was given by the video partner by applying a set of instructions, which were specific to the emotion regulation condition. The instructions were modeled from prior research on reappraisal and suppression (e.g., Butler et al. 2006; Gross 1998; Ray et al. 2008). Participants in the *reappraisal* condition were told:

> It is possible that what he/she says may offend and upset you. However, regardless of what your partner may say, we would like you to test out your ability to manage your emotional reactions. Therefore, it is very important that you try to adopt a neutral attitude as you watch the video. To do this, we would like you to view the video with the detached interest of an impartial observer or a mediator of a debate. In other words, as you watch the video, try to think about what your partner is saying objectively and analytically, rather than as personally, or in any way emotionally relevant to you. So, watch and listen to the video carefully, but please try to think about what you are seeing and hearing in such a way that allows you to maintain a neutral mood.

Participants in the *suppression* condition were told:

> It is possible that what he/she says may offend and upset you. However, regardless of what your partner may say, we would like to see how well you can control your facial expressions. Therefore, it is very important that you try to adopt a neutral facial expression as you watch the video. To do this, we would like for you to keep your facial muscles from moving. In other words, as you watch the video, try to keep a straight face by keeping the muscles around your neck, your chin, your lips, your cheeks, your eyes, and your forehead very still. So, watch and listen to the video carefully, but please try to keep your facial muscles still so that you don't make any expressions at all. Therefore, if you have any feelings while you are viewing the video, try to behave in such a way that a person watching you would not know that you are feeling anything.

Participants in the *control* condition were told "You will now view the video of your partner's speech." Following delivery of the instructions, the experimenter started the video and left the room. HRV was recorded while participants watched the video.

Post-video questionnaires and end of study HRV

In order to assess the effectiveness of the video in inducing anger, participants completed a second mood adjective checklist following the video (8 anger items, Cronbach's $\alpha = .90$). In order to ascertain the efficacy of the emotion regulation manipulation, participants answered one question regarding the extent to which they reappraised (i.e., "I tried to reconsider the event from an objective perspective")[1] and three questions that assessed suppression (i.e., "I felt emotions but tried to hide them", "I tried to keep a neutral facial expression", and "I tried to hide my emotional responses"; Cronbach's $\alpha = .89$). Two minutes of HRV were recorded following completion of the questionnaires (i.e., approximately 5 min after watching the video) during which the participant sat quietly alone. Finally, participants were probed for suspicion, fully debriefed, and thanked.

HRV assessment

As an index of HRV, we relied on the widely utilized root mean square of successive differences (RMSSD). This time domain measure is highly correlated with frequency domain measures of the high frequency component of the respiratory frequency range and thus considered to reflect vagal influence (i.e., PNS activity; Mendes 2009; Goedhart et al. 2007). In order to accurately obtain HRV data for the baseline period, during the video, and post-video phase,

[1] Participants also completed a second manipulation check item for reappraisal (i.e., "I thought about the positive aspects of the event") but this did not form a reliable composite with the "objective perspective" item ($\alpha = .53$). We therefore relied on the latter item as it accurately captures the essence of cognitive reappraisal.

electronic markers were inserted manually on the Polar watch by the experimenter following each of the above mentioned portions of the study (i.e., baseline, during video, end of study). RMSSD and average HR data for the three phases were later retrieved for each participant using Polar ProTrainer 5 software (Version 5.35.165). Each dataset was visually inspected for abnormal fluctuations (e.g., erroneous interbeat intervals; see Goedhart et al. 2007) and software-assisted error correction was conducted.

Statistical analyses

All analyses were conducted in SPSS 18. We relied on one-way ANOVAs with the experimental condition as the independent variable to check the efficacy of the manipulations. We then conducted within-group *t*-tests to examine changes in self-reported anger from baseline as a result of viewing the counterattitudinal video. We conducted parallel analyses with the HRV data and additional between-groups analyses in order to compare the relative magnitude of HRV change between the groups. We also examined correlations between HRV and self-reported anger. Finally, we examined HR change within and between groups.

Results

Manipulation checks

One-way ANOVAs revealed main effects of emotion regulation condition on self-reported reappraisal, $F(2, 128) = 5.37$, $p = .006$, $MSE = 20.23$, $d = .59$, and suppression, $F(2,128) = 13.08$, $p = .000007$, $MSE = 46.73$, $d = .91$. As expected, follow-up directional *t*-tests revealed that participants in the reappraisal condition ($M = 6.17$, $SD = 1.72$) reported reappraising to a greater extent than participants in the suppression condition ($M = 5.42$, $SD = 2.15$), $t(85) = 1.78$, $p = .04$, $d = .38$, and control condition ($M = 4.80$, $SD = 1.92$), $t(84) = 3.49$, $p = .006$, $d = .75$. Also as expected, participants in the suppression condition ($M = 5.23$, $SD = 1.95$) reported engaging in suppression more than participants in the reappraisal condition ($M = 4.29$, $SD = 1.98$), $t(85) = 2.22$, $p = .02$, $d = .48$, and control condition ($M = 3.18$, $SD = 1.73$), $t(87) = 5.24$, $p = .01$, $d = 1.11$. Although these manipulation checks may be susceptible to demand effects, these results suggest an effective emotion regulation manipulation.

Self-reported anger

There were no differences between the groups in anger at baseline, $F(2,128) = 0.30$, $p = .74$, $MSE = 0.31$, $d = .20$.

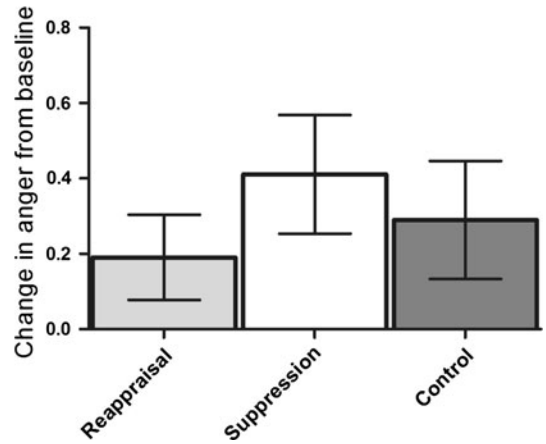

Fig. 1 Mean change (and standard errors) in self-reported anger as a result of viewing the counterattitudinal video from baseline as a function of emotion regulation condition

However, as expected participants reported an increase in anger from baseline after watching the video in the suppression condition, $t(44) = 2.61$, $p = .01$, $d = .39$, and a marginally significant increase in the control condition, $t(43) = 1.85$, $p = .07$, $d = .28$, but no significant increase in anger in the reappraisal condition, $t(41) = 1.68$, $p = .10$, $d = .26$. These results are shown in Fig. 1 (see also Table 1).

Heart rate variability

There were no differences in RMSSD between the groups at baseline, $F(2,128) = 0.51$, $p = .60$, $MSE = 170.78$, $d = .18$. Comparing HRV changes within the experimental groups revealed a significant increase in HRV among participants in the reappraisal condition, $t(41) = 2.69$, $p = .01$, $d = .44$, but not among participants in the suppression condition, $t(44) = 1.55$, $p = .13$, $d = .23$, or control condition, $t(43) = 0.89$, $p = .38$, $d = .14$. By the end of the study, participants' HRV had returned to baseline levels. Figure 2 displays these results (see also Table 1).

Additional directional between-group contrasts revealed that the HRV change was greater in the reappraisal condition than the control condition, $t(128) = 1.81$, $p = .04$, $d = .37$. HRV change in the suppression condition was not significantly different from HRV change in the control, $t(128) = 0.59$, $p = .28$, $d = .06$, and reappraisal conditions, $t(128) = 1.24$, $p = .11$, $d = -.18$.

We also examined correlations between HRV and self-reported anger following the video within groups. In the control condition, there was a negative correlation between HRV and anger while watching the video, $r = -.30$, $p = .046$. We discuss this finding in more detail below. The correlations between HRV and anger were not

Table 1 Means and standard deviations for self-reported anger, heart rate variability (HRV), and heart rate (HR) as a function of experimental condition

	Reappraisal ($n = 42$)		Suppression ($n = 45$)		Control ($n = 44$)	
	M	*SD*	*M*	*SD*	*M*	*SD*
Baseline anger	1.74	0.95	1.72	0.86	1.87	1.18
Anger after video	1.93	1.02	2.13	0.98	2.16	1.10
Baseline HRV	38.12	21.86	34.90	16.26	34.45	16.51
HRV change score	6.19	14.95	3.65	15.83	1.40	10.37
Baseline HR	81.95	12.30	83.07	12.16	85.46	14.15
HR change score	−2.26	4.21	0.89	14.47	−1.91	5.69

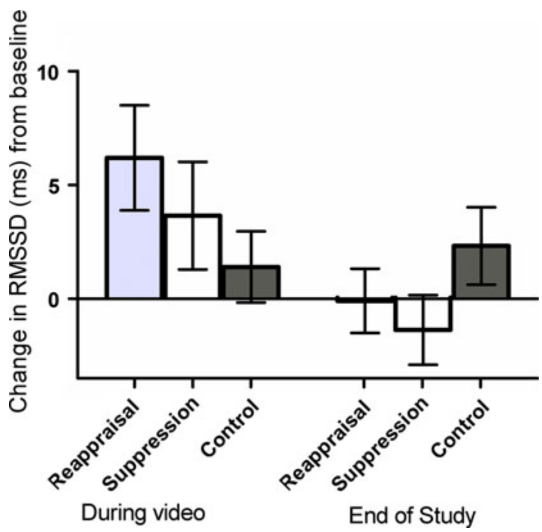

Fig. 2 Mean change (and standard errors) in heart rate variability from baseline as a function of emotion regulation condition. The dependent measure is the root mean square of successive differences (RMSSD) in ms

significant in the reappraisal, $r = -.01$, $p = .96$, or suppression conditions, $r = -.10$, $p = .50$.

Heart rate

We also analyzed HR with the expectation that if vagal activity is higher during reappraisal, HR should decrease. Table 1 reports the descriptive data. There were no differences in HR between the groups at baseline, $F(2,128) = 0.83$, $p = .44$, $MSE = 138.56$, $d = .20$. As expected, HR changes among the experimental groups revealed a significant decrease in HR among participants in the reappraisal condition, $t(41) = 3.48$, $p = .001$, $d = -.54$, but not among participants in the suppression condition, $t(44) = 0.41$, $p = .68$, $d = .07$. Unexpectedly, there was also a significant decrease from baseline in the control condition, $t(44) = 2.23$, $p = .03$, $d = -.36$. There were no differences between the groups in the magnitude of HR change, $F(2,128) = 1.49$, $p = .23$, $MSE = 131.66$, $d = .29$.

Discussion

In the present research, when exposed to an anger-inducing, opposing political perspective, women who were induced to reappraise showed increased high frequency HRV. No such increases were observed for those in the suppression or control conditions. These findings offer a physiological correlate of adaptive emotion regulation and support reappraisal as an adaptive means of managing emotion-laden social situations. These data contribute to a growing awareness of high frequency HRV as a biomarker of effective emotion regulation (Appelhans and Luecken 2006; Thayer and Lane 2009) and are consistent with both the polyvagal perspective (Porges 2007) and the neurovisceral integration model of HRV (Thayer and Lane 2000, 2009). Both theories emphasize that increases in HRV reflect application of the "vagal brake", which supports positive active engagement with the environment. This is consistent with the notion of reappraisal as an active and adaptive means of cognitively changing our response to emotional situations.

Our results are consistent with the only prior study to have evaluated the effects of reappraisal and suppression on HRV (Butler et al. 2006). Although the largest increase in HRV was seen for participants in the reappraisal condition, Butler et al. (2006) reported a small but significant increase in suppression relative to controls. By contrast, we found no significant increase in HRV in the suppression condition, although the direction was consistent with the findings reported by Butler et al. (2006). The reason for this discrepancy is uncertain. In their study, participants viewed a movie about the Hiroshima bombing and then discussed the film with another participant. One possibility is that the active social engagement inherent in their experiment led to increased HRV even among participants in the suppression condition. Another possibility is that suppression can also increase HRV, albeit to a lesser degree than reappraisal. Our between-group analyses showed that the increase in HRV was greater in the reappraisal condition than in the control condition, but the increase in the suppression condition fell in between that of the reappraisal and control conditions. Although the equivocal results for the suppression condition may be due to the fact that statistical power was greater to detect within-person change than between-group differences (Berntson et al. 2005), nonetheless, future research might identify moderating influences of suppression-induced HRV change in order to determine the specificity of HRV change with different forms of emotion regulation.

The present study also speaks to the issue of whether high frequency HRV in most indicative of emotion regulation or mental effort within the context of anger regulation. Because antecedent-focused reappraisal is thought to involve the recruitment of minimal mental resources, and mental effort is associated with decreases in HRV, it is possible that that the increase in HRV observed in the reappraisal condition was due to either of these processes or perhaps both of them. However, we believe our data are most consistent with the notion that HRV was indicative of emotion regulation. The nature of our baseline task lends weight to this interpretation. Because the heart is typically under strong vagal control at rest, if the observed increase in HRV in the reappraisal condition was due to reduced mental load, one would assume that reappraisal is less effortful than passively watching neutral images. Although we did not explicitly assess the exertion of mental effort, this possibility seems unlikely. Furthermore, because suppression is thought to be relatively effortful, one might expect a decrease in HRV in the suppression condition. Our data for the suppression group, coupled with the findings of Butler et al. (2006), suggest that HRV increases are indicative of emotion regulation (albeit it to a lesser extent during suppression relative to reappraisal).

Some previous research has investigated resting HRV as a trait (e.g., Beauchaine 2001; Leon et al. 2009). In the present research, the control condition would provide a test of this hypothesis, as the responses of participants in this condition were uncontaminated by the reappraisal or suppression instructions. That is, HRV of participants in the control condition reflected the outcome of the habitual emotion regulation strategies that participants naturally adopt when confronted with an anger-eliciting event. Although we did not find a significant correlation between anger and resting HRV, higher HRV while watching the video was associated with decreased anger. This suggests a possible "trait reactivity" effect such that individuals who demonstrated the largest increase in HRV while watching an irritating video reported experiencing the least amount of anger. Indeed, cardiovascular reactivity to laboratory tasks is moderately stable over time (Swain and Suls 1996).

The present research has implications for physical health. It is possible that HRV can account for the adaptive cardiovascular responding observed in prior research on reappraisal and anger (Mauss et al. 2007; Memedovic et al. 2010; Ray et al. 2008). Low HRV is related to poor cardiovascular health and early mortality (La Rovere et al. 2003; Liao et al. 2002; Hadase et al. 2004). By allowing increased autonomic flexibility, reappraisal could provide individuals with an increased capability to view anger-inducing events as non-threatening. Such an account is consistent with Mauss et al.'s (2007) finding that induced reappraisal created a cardiovascular challenge response as opposed to a threat response. Future longitudinal research could examine the possibility of reappraisal as a protective factor in cardiovascular disease outcomes.

The present research was limited to some extent. First, we relied on RMSSD as a measure of high frequency HRV. Although there is evidence that RMSSD is highly correlated with the high frequency component of the respiratory frequency (Goedhart et al. 2007), other investigators have suggested that more specific power spectral analyses of the high frequency component should be utilized (Berntson et al. 2005). Indeed, the RMSSD statistic is not a pure measure of PNS activity, as the RMSSD can include some low frequency components reflecting SNS influences (Berntson et al. 2005).Thus, some caution is warranted in interpreting our results. Second, we did not assess or control for respiratory influences on HRV and thus cannot rule out the possibility that the experimental conditions differed in respiration rate and/or depth. Nonetheless, research suggests that the RMSSD statistic is robust to changes in breathing patterns (Penttilä et al. 2001). Third, although our sampling approach was consistent with previous studies that have examined the effect of emotion regulation on anger and have the advantage of controlling for gender variability in cardiac responses (Butler et al. 2006; Mauss et al. 2007; Memedovic et al. 2010; Ray et al. 2008), future research should evaluate the effects of trait suppression on anger in mixed gender samples. Fourth, our study used a very mild anger induction. It remains to be seen whether reappraisal can increase HRV in response to more extreme provocation. Finally, including a measure of SNS activation would have allowed inferences regarding PNS/SNS balance during anger regulation.

Despite these limitations, the present work advances our understanding of HRV as an adaptive indicator of effective emotion regulation, especially in the context of an anger-inducing event. Future research might explore reappraisal training on long-term changes in HRV. Suggestive evidence is provided by research reporting increased HRV following the successful treatment of depression (Balogh et al. 1993). Thus incorporating reappraisal into an anger treatment intervention might not only facilitate mental health, but cardiovascular health as well.

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