Published in final edited form as:
Cognit Ther Res. 2013 June ; 37(3): 613–619.

Differentiating Worry and Rumination: Evidence from Heart Rate Variability During Spontaneous Regulation

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Abstract

Worry is the defining feature of generalized anxiety disorder (GAD), and rumination is a central process in depression. GAD and depression are highly comorbid, and worry and rumination reflect similar perseverative cognitive processes. Prior studies have largely assessed these emotion regulation strategies at the trait level, which has resulted in a limited understanding of their phasic characteristics, including associated physiological processes. We addressed this limitation by examining the relationship between spontaneous state-level worry and rumination and heart rate variability (HRV)—a physiological measure of emotion regulation—in response to emotion-eliciting film clips. We found differential associations between worry and rumination in relation to HRV, such that, worry was more consistently associated with HRV across emotional contexts than rumination was. Findings highlight functional distinctions between worry and rumination that have implications for understanding their associations with mood and anxiety disorders and, more broadly, for theories of emotion regulation and psychopathology.

Keywords

Worry; Rumination; Heart rate variability; Spontaneous regulation; Emotion regulation strategies

Background

Worry is the hallmark feature of generalized anxiety disorder (GAD). Borkovec et al. (2004) have suggested that individuals with GAD utilize worry in an attempt to cognitively avoid processing of negative emotional stimuli and decrease physiological hyperarousal typically associated with exposure to emotional stimuli. Recent theoretical extensions of the

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avoidance approach have argued that worry is a regulatory strategy aimed at reducing distress arising from contrasting emotional (Newman and Llera 2011) and motivational states (e.g., Mennin and Fresco, in press). Given the substantial diagnostic overlap between GAD and depressive disorders (Watson 2009), it is not surprising that worry is strongly associated with rumination (e.g., Fresco et al. 2002; Segerstrom et al. 2000; Watkins 2008), another perseverative cognitive process that has been primarily conceptualized as repetitive thinking about past mistakes and failures and is a central feature of depressive disorders (e.g., Nolen-Hoeksema et al. 2008).

Indeed, both worry and rumination share core features, as they both consist of repetitive, negatively-valenced thought (Watkins 2008). However, the empirical evidence regarding the precise relationship between these processes is mixed, with some studies showing that they are indistinguishable (e.g., Segerstrom et al. 2000) and others demonstrating that they can be functionally differentiated (e.g., Fresco et al. 2002). One potential factor contributing to the mixed evidence might be that the vast majority of previous investigations of the relationship between these two processes have relied on trait level assessments utilizing self-report questionnaires. Indeed, the few studies consisting of experimental manipulations have shown that worry is more likely to generate feelings of anxiety, whereas rumination tends to induce feelings of depression (e.g., McLaughlin et al. 2007a, b). In order to further explore this possibility, we sought to examine the spontaneous state-level implementation of these processes in response to a standard emotion-eliciting paradigm. Specifically, given the conceptualization of affective processes as multi-modal phenomena (Bradley and Lang 2000), we evaluated the relationship between worry and rumination and a physiological process associated with flexible emotion regulation: heart rate variability (HRV), which is an index of brainstem-mediated parasympathetic influences on heart rate (e.g., Porges 2007). HRV is particularly germane to this investigation because there is an extensive literature showing that state worry is associated with blunted HRV (e.g., Hofmann et al. 2005; Llera and Newman 2010; Thayer et al. 1996), yet there are very few investigations that have examined the relationship between state rumination and HRV and these have produced equivocal results. For example, one study has shown that a rumination manipulation lead to lower HRV (Ottaviani et al. 2009) and another one that there was no relationship between trait rumination and HRV during an experimental baseline (Key et al. 2008).

Another potential confounding factor in the literature on worry and rumination pertains to the operationalization of these constructs, particularly in relationship to their temporal focus. Whereas worry has been consistently conceptualized as a future-oriented cognitive response to anticipated threat (e.g., Borkovec et al. 2004), rumination has been conceptualized with more heterogeneity. Specifically, different subtypes rumination have been described as focused on the past (Trapnell and Campbell 1999), depressive symptoms (e.g., Nolen-Hoeksema et al. 2008) or anger (e.g., Sukhodolsky et al. 2001). Heterogeneous operational definitions make it more difficult to delineate processes specific to rumination as opposed to concomitant worry, which may also be elevated at the state level in individuals who have trait levels of heightened perseveration. Thus, in the present study, we choose to focus on an operational definition of past-oriented rumination, which, theoretically, should have the greatest level of distinction with worry (i.e., future oriented).

The primary aim of this brief report was to evaluate the relationship between HRV and state level worry and past-oriented rumination in response to emotion-eliciting film clips, which is a frequently used manipulation in the emotion regulation literature (e.g., Rottenberg et al. 2007). Importantly, worry and past-oriented rumination were not manipulated, but rather the extent to which participants spontaneously implemented each strategy was assessed, therefore increasing the ecological validity of this paradigm (see, Egloff et al. 2006). We first examined whether worry, rumination, and HRV would be characterized by contextual flexibility or inflexibility across emotional contexts, that is, in response to film clips primarily eliciting fear, happiness, or sadness. We then sought to examine the relationship between HRV and levels worry and rumination. Based on previous work, we expected worry to be negatively associated with HRV across emotional contexts (e.g., Hofmann et al. 2005; Llera and Newman 2010; Thayer et al. 1996); however, given the scarcity of research on rumination and HRV (c.f., Key et al. 2008; Ottaviani et al. 2009), our hypotheses regarding this relationship remained exploratory.

Method

Participants

Participants aged 22–65 were recruited via flyers placed in an urban community surrounding a large private university in the northeast United States as part of a larger investigation examining emotion regulation processes in individuals with a diagnosis of GAD or depression and healthy controls. Participants were required to have no history of heart conditions or diabetes, current substance abuse, or use of medications that directly affect cardiac functioning (e.g., beta blockers). They completed the Structured Clinical Interview for DSM-IV Disorders (SCID; First et al. 2002) to assess the presence of mood and anxiety disorders. Clinical interviews were conducted by advanced clinical psychology graduate students and post-baccalaureate research assistants. They were rigorously trained over a 6-month period in diagnostic interviewing with the SCID. As part of their training, students had to achieve reliability (with expert diagnosticians) in their diagnoses of patients in a departmental clinic or with individuals from the community. A total of 25 % of interviews were coded for each diagnosis by an additional rater (AA) who watched a video recording of the interview (for GAD and depressive disorders, κ's from .89 to 1; for other disorders, κ's from .70 to .85). Additional exclusion criteria consisted of the presence of a primary diagnosis of a disorder other than GAD or depression.

Sample Characteristics—A total of 68 individuals participated in the study. The mean age of the sample was 30.5 (SD = 10, range 22–61) and the majority of the sample (56.4 %) identified as Caucasian (8.4 % identified as Asian/Asian American, 9.9 % as African American, 7 % as Hispanic, 1.4 % as Native American, and the remaining 16.9 % identified as mixed race or other). A total of 38 participants had a diagnosis of GAD and 13 had a diagnosis of major depression.

Experimental Procedures

Film Clips—Participants were first asked to watch an emotionally-neutral film clip followed by three emotion-eliciting films, which have been extensively used in the emotion

regulation literature (e.g., Rottenberg et al. 2007). At the beginning of the task, participants were given the following set of instructions "Please watch the following clips as you normally would." Before each clip was presented, they were provided with this additional instruction "Please watch this film carefully." The film clips were selected to elicit a distinct discrete emotional state, ensuring contextual variability in the type of affective states experienced by participants: neutral (*Color Bars*; Rottenberg et al. 2007), fear (*Silence of the Lambs*), happiness (*Frequency*), and sadness (*Return to Me*). They were presented with Superlab 4.0.7 (Superlab, Cedrus, Inc. San Pedro, CA, USA) in a counterbalanced order.

Manipulation Check: Emotion Ratings—At the end of each film clip, participants were asked to rate the extent to which they experienced target and non-target emotions on a 9-point scale, raging from 0 (not at all) to 8 (extremely).

State Worry and Rumination—Before the experimental procedures, participants created a 0–100 worry visual analogue scale (WVAS) using anchors relevant to their own lives. They generated anchors of 0, 25, 50, 75, and 100 in terms of the degree of worry associated with five personal topics. Previous studies have used this scale as a state-level indicator of worry (e.g., McLaughlin et al. 2007b). Participants created a rumination visual analogue scale (RVAS) using the same procedure. Both worry and rumination were operationally defined to the participant as "talking a lot to ourselves about things that we are concerned about happening in the future" and "mulling things over in our heads about things that have happened to us," respectively. Following presentation of each of the film clips, participants were asked to rate the levels of state worry and rumination they felt during the film clips using these anchors as a guideline. Because WVAS and RVAS were skewed, we conducted transformation that would normalize the distribution (i.e., skewness statistic <2). For WVAS, the square root transformation worked best and for RVAS, it was the logarithmic transformation that resulted in a normal distribution.

HRV—HRV during the film clips was assessed with a Biopac ECG100C amplifier (Biopac Systems Inc, Santa Barbara, CA, USA) and two pre-gelled Ag–AgCl 1 cm disposable electrodes in a modified Lead II configuration. The electrocardiogram (EKG) was recorded with a sampling rate of 1,000 Hz. This EKG signal was imported into QRSTool and CmetX (Allen et al. 2007) for semi-automatic R-peak detection and calculation of the cardiac parameters of interest. CmetX was utilized to estimate various metrics of heart rate variability, including the standard deviation of the interbeat interval (IBI) series (SNDD), the root mean square of the successive differences between IBIs (RMSSD), the mean absolute successive IBI difference (MSD), the proportion of consecutive IBI differences higher than 50 ms (pnn50), the log of the variance of the IBI series (log HRV) and the natural log of the band-limited (.12–40) variance of the IBI time series (logRSA). Because all of these measures are highly correlated with each other (r's>.70 in this sample) and we did not have an a priori rationale for choosing one in particular, we standardized and averaged all 6 metrics into a standardized HRV score. Given that the standardized HRV measure was skewed, we conducted a logarithmic transformation (skewness statistic <2). Data were manually checked by research assistants and double-checked by the first author;

segments in which the waveforms included excessive noise were removed from the analyses.

Results

Manipulation Check

Each of the three emotional film clips elicited higher levels of the target emotion than the non-target emotions (*p*'s <.01 for Bonferroni-adjusted comparisons). Interestingly, when comparing the target emotions elicited during each film clip (i.e., fear during the fear film clip, happiness during the happy film clip, and sadness during the sad film clip), we found a significant main effect, F [2, 128] = 11.61, $p < .01$, $\eta_p^2 = .15$ and Bonferroni-adjusted comparisons reveal that sadness to the sad film clip was higher than fear to the fear clip (*mean difference* = 1.23, $p < .01$) and happiness to the happy clip (*mean difference* = 1.19, $p < .01$). We return to this difference in intensity in the next section.

Worry, Rumination, and HRV Across Film Clips

We examined the values of WVAS, RVAS, and composite HRV across emotional contexts (i.e., film clips). We predicted WVAS across the four film clips and found a significant main effect, F [3, 195] = 4.16, $p < .01$, $\eta_p^2 = .06$. Bonferroni-adjusted post hoc comparisons reveal that WVAS was lower during the neutral film than the sadness film (*mean difference* = −1.10, $p < .05$). We also found a main effect for RVAS across the four film clips, F [3, 192] = 3.68, $p < .05$, $\eta_p^2 = .05$). Bonferroni-adjusted post hoc comparisons reveal that RVAS was lower during the fear film than the sadness film (*mean difference* = −.51 $p < .05$). Lastly, we found a non-significant effect of standardized HRV across the four film clips, F [3, 165] = .32, ns, $\eta_p^2 = 0$. See Table 1.

Relationships Between HRV and Worry and Rumination Across Film Clips

We next predicted the relationship between standardized HRV and WVAS and RVAS across film clips in a series of regression analyses.

Fear Film Clip

Predicting WVAS: In Step 1, we predicted WVAS during the fear film clip with WVAS during the neutral film clip and the fit of the model was significant, R^2 = .149, F [1, 67] = 15.56, $p < .01$, as this variable was a significant predictor, t [67] = 3.95, $\beta = .43$, $p < .01$. In Step 2, we entered standardized HRV during the fear film clip and the fit of the model increased significantly, $R^2\Delta = .13$, F [1, 66] = 12.28, $p < .01$, as this variable significantly (negatively) predicted WVAS during the fear film clip, t [66] = −3.50, $\beta = -.36$, $p < .01$.

Predicting RVAS: In Step 1, we predicted RVAS during the fear film clip with RVAS during the neutral film clip and the fit of the model was significant, R^2 = .46, F [1, 66] = 58.86, $p < .01$, as this variable was a significant predictor, t [66] = 7.67, $\beta = .69$, $p < .01$). In Step 2, we added standardized HRV during the fear film clip and the fit of the model did not

increase significantly, $R^2\Delta = .02$, F [1, 65] = 2.30, ns, as this variable did not significantly predict RVAS during the fear film clip, t [65] = −1.51, $\beta = -.14$, ns.

Happiness Film Clip

Predicting WVAS: In Step 1, we predicted WVAS during the happiness film clip with WVAS during the neutral film clip and the fit of the model was significant, $R^2 = .16$, F [1, 64] = 13.48, $p < .01$, as this variable was a significant predictor, t [64] = 3.67, $\beta = .42$, $p < .01$. In Step 2, we added standardized HRV during the happiness film clip and the fit of the model increased significantly, $R^2\Delta = .05$, F [1, 63] = 4.22, $p < .05$, as this variable negatively predicted WVAS during the happiness film clip, t [64] = −2.05, $\beta = -.23$, $p < .05$.

Predicting RVAS: In Step 1, we predicted RVAS during the happiness film clip with RVAS during the neutral film clip and the fit of the model was significant, $R^2 = .30$, F [1, 63] = 27.46, $p < .01$, as this variable was a significant predictor, t [63] = 5.24, $\beta = .55$, $p < .01$. In Step 2, we added standardized HRV during the happiness film clip and the fit of the model did not increase significantly, $R^2\Delta = .01$, F [1, 62] = .61, ns, as this variable did not predict RVAS during the happiness film clip, t [62] = .78, $\beta = .08$, ns.

Sadness Film Clip

Predicting WVAS: In Step 1, we predicted WVAS during the sadness film clip with WVAS during the neutral film clip and the fit of the model was significant, $R^2 = .20$, F [1, 66] = 17.73, $p < .01$, as this variable was a significant predictor, t [66] = 4.21, $\beta = .46$, $p < .01$. In Step 2, we added standardized HRV during the sadness film clip and the fit of the model did not increase significantly, $R^2\Delta = .03$, F [1, 65] = 2.71, ns, as this variable was not a significant predictor of WVAS during the sadness film clip, t [65] = –1.65, $\beta = -.18$, ns.

Predicting RVAS: In Step 1, we predicted RVAS during the sadness film clip with RVAS during the neutral film clip and the fit of the model was significant, $R^2 = .21$, F [1, 65] = 17.36, $p < .01$, as this variable was a significant predictor, t [65] = 4.17, $\beta = .46$, $p < .01$. In Step 2, we added standardized HRV during the sadness film clip and the fit of the model did not increase significantly, $R^2\Delta = .02$, F [1, 64] = 1.63, ns, as this variable did not predict RVAS during the sadness film clip, t [64] = −1.28, $\beta = -.14$, ns.

Because this sample was part of a larger investigation examining emotional processes in individuals with a diagnosis of GAD or depression and healthy controls, we re-ran all of these analyses entering GAD and MDD diagnosis and as Table 2 shows, neither of them were significant predictors over and above our hypothesized relationships.

Discussion

In this brief report, we present findings from an investigation examining differences in the functional characteristics of worry and rumination in relation to a physiological marker of emotion regulation (i.e., HRV). In line with previous work showing differentiation of these constructs at the trait level (e.g., Fresco et al. 2002), our findings suggest that that worry and rumination can be functionally differentiated at the state-level.

We found that all three constructs of interest, namely worry, rumination, and HRV were largely insensitive to contextual variations, with the only differences stemming from levels of worry being higher during the sadness than the neutral film clip and levels of rumination being higher during the sadness than the fear film clip. This is particularly important given recent work relating inflexible responses across context to psychological dysfunction (e.g., Rottenberg et al. 2005). Also, it is important to keep in mind the sadness film clip elicited higher levels of its target emotion (i.e., sadness) than the other two film clips. Therefore, it is possible that this higher intensity could account for the two differences found in levels of worry and rumination and worry across contexts. Of note, it was also during the sadness film clip that worry did not have an association with HRV. Thus, it might be important for future work to more systematically manipulate changes in valence and intensity across emotional contexts.

In contrast to the similarities in the fluctuations of worry and rumination across emotional contexts, these two processes had different relationships to HRV: whereas worry negatively predicted HRV during the fear and happiness film clip, rumination was not associated with HRV in any of the emotional contexts. This suggests that the relationship between perseverative regulation strategies, such as worry and rumination, and cardiovascular functioning might be nuanced. It is possible that the association between HRV and worry is stronger because state worry might be more reflective of a strong threat state (e.g., Thayer et al. 2000). Threat states may produce a cardiac defensive response that, in part, involves decreasing flexibility in the parasympathetic nervous system as one orients to this possible threat (Ramirez et al. 2010). In contrast, rumination may be less strongly associated to changes in cardiac functioning since its content is less reflective of future uncertain orientation but is, rather, more of a maladaptive form of self reflection, which is often focused on the past (e.g., Nolen-Hoeksema et al. 2008; McLaughlin et al. 2007a, b). However, the paradigm utilized in this investigation was not intended to directly assess or elicit threat; thus it will be important for future investigation to closely examine the relationship between worry, rumination, and cardiovascular responding across emotional contexts that might vary in the amount of threat they elicit.

From a methodological standpoint, a strength of this investigation resides in the assessment of naturally occurring, or spontaneous, implementation of worry and rumination rather than providing participants with specific instructions regarding what regulation strategies to use. This less frequently adopted approach (c.f., Egloff et al. 2006) provides researchers with the opportunity to study the selection and use of strategies in a way that maximizes its ecological validity. In addition, we sought to maximize the idiographic nature of the assessment by asking participants to anchor their levels of worry and rumination to their everyday experiences.

One of the important limitations of this investigation is the lack of assessment of additional regulation strategies that participants might have used in response to the film clips. Therefore, one extension of this work would consist of examining what other strategies, adaptive or maladaptive, occur in tandem with worry and rumination (e.g., Aldao and Nolen-Hoeksema 2012). In addition, we focused on a specific marker of physiological emotion regulation, so it will be important for future work to examine other physiological

mechanisms associated with emotional processes, such as the startle response. Although our state-level measure of worry have been successfully used in previous investigations (McLaughlin et al. 2007b), it will be necessary to conduct further psychometric work. Of particular importance will be the anchoring of worry and rumination to varying experimentally-derived temporal contexts, given that worry has been conceptualized as future-focused and rumination as past-focused (e.g., Trapnell and Campbell 1999). In addition, given that our definition of rumination did not explicitly state negative events as its target, it is possible that some participants might have reported on their mulling over of positive events. Lastly, because this sample was part of a larger investigation, it was not originally recruited for the purposes of these analyses, which might have resulted in limited power to test our effects. Needless to say, it will be crucial for future work to recruit larger clinical samples of individuals diagnosed with GAD and depression (see Hofmann et al. 2010).

Conclusion

This investigation constituted a novel approach to the study of the complex relationship between worry and rumination. Whereas the spontaneous occurrence of these emotion regulation strategies in response to emotion-eliciting film clips was characterized by comparable levels of inflexibility across emotional contexts, worry was more consistently (negatively) associated with HRV across such contexts. Such findings build upon a large body of work examining the relationship between worry and HRV (e.g., Hofmann et al. 2005; Llera and Newman 2010; Thayer et al. 1996) and underscore the importance of adopting a multi-modal approach to the study of the relationship among constructs that show little differentiation in one given domain. We hope that future investigations continue to examine the spontaneous use of worry and rumination in response to contexts that more broadly vary in their emotional characteristics. Such work will hopefully lead to a more sophisticated understanding of the mechanisms by which worry and rumination are perpetuated and eventually result in more targeted psychosocial interventions.

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Table 1

Means and standard deviations (SDs) for WVAS, RVAS, and Standardized HRV

	Neutral	Fear	Happiness	Sadness
WVAS				
Raw	18.94 (23.76)	24.83 (27.73)	22.44 (26.46)	28.42 (26.08)
Square root transformed	3.65 (2.59)	4.24 (2.82)	3.97 (2.79)	4.71 (2.71)
RVAS				
Raw	19.13 (25.88)	19.97 (25.20)	26.07 (230.00)	28.63 (27.48)
Log transformed	3.60 (2.70)	3.71 (2.70)	4.26 (3.01)	4.64 (2.86)
Standardized HRV				
Raw	0 (.93)	0 (.90)	0 (.92)	0 (.92)
Log transformed	.58 (.50)	.59 (.46)	.59 (.46)	61 (.39)

Raw values for standardized HRV have a mean of 0 and a SD or approx. because they represent the average of the 6 standardized metrics of HRV

Table 2

Standardized coefficients predicting worry and rumination during the film clips

	Fear	Happiness	Sadness
WVAS during film clips			
Step 1			
WVAS neutral film clip	.43**	.42**	.46**
Step 2			
Standardized HRV			
Emotional film clip	−.36**	−.23*	−.18
Step 3			
GAD diagnosis	−.15	−.07	.01
MDD diagnosis	.10	.11	.14
RVAS during film clips			
Step 1			
RVAS neutral film clip	.69**	.55**	.46**
Step 2			
Standardized HRV			
Emotional film clip	−.14	.08	−.14
Step 3			
GAD diagnosis	−.07	.07	−.11
MDD diagnosis	−.01	−.03	−.01

** $p < .01$,

* $p < .05$