



## The autonomic phenotype of rumination

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### ABSTRACT

Recent studies suggest that ruminative thoughts may be mediators of the prolonged physiological effects of stress. We hypothesized that autonomic dysregulation plays a role in the relation between rumination and health. Rumination was induced by an anger-recall task in 45 healthy subjects. Heart rate variability (HRV), baroreflex sensitivity (BRS), and baroreflex effectiveness index (BEI) change scores were evaluated to obtain the autonomic phenotype of rumination. Personality traits and endothelial activation were examined for their relation to autonomic responses during rumination. Degree of endothelial activation was assessed by circulating soluble intercellular adhesion molecule-1 (sICAM-1). Vagal withdrawal during rumination was greater for women than men. Larger decreases in the high frequency component of HRV were associated with higher levels of anger-in, depression, and sICAM-1 levels. BRS reactivity was negatively related to trait anxiety. BEI reactivity was positively related to anger-in, hostility, anxiety, and depression. Lower BEI and BRS recovery were associated with lower social desirability and higher anger-out, anxiety, and depression. Findings suggest that the autonomic dysregulation that characterizes rumination plays a role in the relationships between personality and cardiovascular health.

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## 1. Introduction

### 1.1. The role played by personally-relevant tasks

Recent research has highlighted the importance of the emotional nature of laboratory tasks in the study of cardiovascular reactivity (Linden and Rutledge, 1998). Glynn et al. (2002) found that the emotional vs. nonemotional nature of a task affected the cardiovascular response during and after the task. Only stressors with an emotional component, as assessed by poststress self-reports, have been associated with blood pressure (BP) elevations and delayed recovery, and the effects are independent of the original reactivity evoked by the task.

Personally-relevant recall tasks were found to be associated with more pronounced cardiovascular activation than other emotional tasks (Merritt et al., 2006), such as the viewing of film clips of higher emotional valence (Waldstein et al., 2000). Moreover, tasks evoking negative affect have been associated with the highest cardiovascular effects (Brosschot and Thayer, 2003). In fact, although immediate physiological responses to positive and negative emotional events may be of the same magnitude, physiological responses that follow negative events have a longer duration (Brosschot and Thayer, 1998; Linden et al., 1997; Neumann et al., 2001). Laboratory results are

consistent with ambulatory research supporting the notion that the greater the intensity of the negative emotional state the greater the cardiovascular effects (Shapiro et al., 2001).

The Anger Recall Interview is an effective tool for evaluating the accompanying physiological effects of a negative emotional event long after its occurrence (Ironson et al., 1992). Tasks requiring vocalization, however, pose methodological issues in the evaluation of autonomic responses (Suarez et al., 2004); for example, Girdler et al. (1990) found significant hemodynamic increases elicited by vocalization alone in the absence of emotional content. To avoid this confounding factor, the present study used a non-verbal version of the anger recall task (Ottaviani et al., 2006). The task required participants to “ruminate” on causes and consequences of a recalled episode in which they felt intense anger or rage. The potency of simply thinking about an anger-provoking event in determining cardiovascular activation has been previously demonstrated (Waldstein et al., 2000). Embodied cognition theories provide evidence that active thought simulates the affective properties of concepts in the emotional system; for example, the embodiment of anger might involve tension in muscles used to strike, innervation of certain facial muscles to form a scowl, and increases in blood pressure and peripheral resistance (Niedenthal, 2007).

“Rumination” is the theoretical construct commonly used to characterize the cognitions and negative affect evoked by stressful or anger-provoking events (Rusting and Nolen-Hoeksema, 1998). Gerin et al. (2006) suggested that prolonged anger may promote ruminative thoughts, and increased autonomic arousal may prolong

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anger, with these two processes operating as a feed-forward process. This hypothesis is consistent with the findings of slower recovery following an emotional stressor (e.g., Glynn et al., 2002). Moreover, the availability of a distracter after anger provocation has been shown to reduce the negative effects of rumination on recovery (Rusting and Nolen-Hoeksema, 1998; Schwartz et al., 2000).

### 1.2. Rumination and the autonomic nervous system

Two recent theoretical reviews (Brosschot and Thayer, 2004; Thayer and Siegle, 2002) revealed the association of worry and rumination with the activity of several physiological systems, including the cardiovascular system. We refer to “autonomic dysregulation” to indicate reduced parasympathetic and/or increased sympathetic nervous system effects on heart rate, and we hypothesized that this condition may play a role in the relation between ruminative thoughts and cardiovascular health. That cardiac vagal tone may serve as an index of emotional regulation has been well addressed by Porges’ polyvagal theory (2007), and has now been tested in several laboratories (Movius and Allen, 2005; Rottenberg et al., 2005; Thayer and Lane, 2000).

Reduced heart rate variability (HRV), an index of parasympathetic activity, has been specifically associated with both increased risk of hypertension (Schroeder et al., 2003; Singh et al., 1998) and trait anger rumination (Neumann et al., 2001) or worry (Pieper et al., 2007). According to the Task Force guidelines (1996), the high frequency component of HRV (HF-HRV) reflects parasympathetic activity, and the low frequency component of HRV (LF-HRV) is proportional to sympathetic activity but influenced by parasympathetic tone. The interpretation of LF-HRV as primarily an index of sympathetic tone has been commonly derived by the calculation of the ratio of LF- to HF-HRV. However, the sympathovagal balance concept has been criticized (Berntson et al., 1997; Eckberg, 1997). Although HF-HRV and baroreflex sensitivity (BRS) are correlated, BRS has been shown to be a better predictor of parasympathetic tone during parasympathetic blockade (Reyes del Paso et al., 1996). In their review, Barron and Lesh (1996) concluded that HRV and BRS are both powerful independent predictors of future arrhythmic events. La Rovere et al. (2001) further confirmed that the analysis of vagal reflexes significantly adds to the prognostic value of HRV. An additional measure of baroreflex control of heart rate that recently emerged as clinically relevant for daily life BP regulation is the baroreflex effectiveness index, BEI (Di Rienzo et al., 2001). BEI measures the number of times the baroreflex is effective in overcoming the non-baroreflex influences that regulate the sinus node (Di Rienzo et al., 2001). A reduction of the BEI may occur in conjunction with an increase in BRS (Di Rienzo et al., 2001). Thus, the number of times the baroreflex inhibits the sinus node (the baroreflex ‘gating’ mechanism) may be taken as another measure of its effectiveness in controlling the circulation (Davydov et al., 2007). The present study assessed sympathetic and parasympathetic activity by examining HRV, BRS, and BEI measures. To our knowledge, this is the first study linking the rumination process with baroreceptor functioning.

### 1.3. Rumination and personality

A substantial body of findings has suggested rumination as a likely candidate for a moderating variable in the established relation between dispositional response styles (e.g., anger-expression style, hostility, depression) and cardiovascular diseases (Iribarren et al., 2000; Sykes et al., 2002). In fact, rumination appears to have a unique relationship to depression even after statistically controlling for other negative cognitive styles (Flett et al., 2002; Nolen-Hoeksema et al., 1994; Spasojevic and Alloy, 2001). Given the high comorbidity between depression and anxiety, rumination might be expected to increase risk for anxiety disorders as well as depression. Indeed,

longitudinal prospective studies have found that people prone to ruminate also have higher levels of general anxiety and post-traumatic stress symptoms (Abbott and Rapee, 2004; Fresco et al., 2002; Harrington and Blankenship, 2002; Kocovski et al., 2005; Muris et al., 2005; Nolen-Hoeksema, 2000; Segerstrom et al., 2000). In addition to depression and anxiety, greater levels of dispositional hostility have been shown to prolong cardiovascular recovery after an anger recall task (Neumann et al., 2004). Moreover, harassment produces increases in rumination only among high hostile individuals (Suarez et al., 1993).

Among the personality traits that have been linked to rumination tendencies, defensiveness has been recently considered to test whether this trait would be associated with reduced negative affect during rumination (Thomsen et al., 2004). The authors demonstrated that scoring high on defensiveness did not reduce the negative affect experienced by high ruminating participants. Finally, rumination has been recently proposed as a separate dimension in a new model of anger expression (Hogan and Linden, 2004). Thus, we decided to consider the link between rumination and the following personality characteristics: depression, anxiety, hostility, defensiveness, and anger.

### 1.4. Gender differences in autonomic responses during rumination

The literature does not provide insight into whether the tendency to ruminate differs between genders. Lawler et al. (1998) reported gender-related differences in hemodynamic reactivity to the anger recall interview, with men responding with larger increases in cardiac output and women showing larger increases in total peripheral resistance. Furthermore, Hogan and Linden (2004) showed that higher ambulatory BP is associated with higher avoidance in women and lower assertion in men, thus demonstrating gender differences in the cardiovascular consequences of different anger response styles. Thayer et al. (1994) found that men tended to use active distraction to regulate negative emotions, whereas women tended to use rumination. Moreover, Nolen-Hoeksema et al. (1999) postulated the greater tendency to ruminate that characterized women in their sample as a possible explanation for gender differences in depression rates. However, Glynn et al. (2002), and Suarez et al. (2004) reported that the cardiovascular reactivity evoked by the anger recall interview did not vary as a function of gender. Given these different findings, a further aim of this study was to examine gender differences in the autonomic response patterns during a rumination task.

### 1.5. Rumination and endothelial activation

It is known that the autonomic nervous system reacts more rapidly than the hypothalamic–pituitary–adrenal axis, but it is also known that the autonomic activity induced by a stressor affects inflammatory processes (Isowa et al., 2004; Mills et al., 2003). We focused on circulating levels of an inflammatory biomarker that is linked with the pathophysiology of several cardiovascular diseases (Amar et al., 2006; Malik et al., 2001; Zee et al., 2007). Soluble intercellular adhesion molecule 1 (sICAM-1) is a marker of endothelial activation and dysfunction (Preston et al., 2002), is associated with degree of atherosclerosis (see Blankenberg et al., 2003 for a review), and is a potent predictor of cardiovascular disease, including risk of future myocardial infarction (Constans and Conri, 2006; Ridker et al., 1998). In this study we used resting levels of sICAM-1 as a trait marker of each participant’s endothelial activation and tested if it is related to autonomic activity during rumination.

Consistent with previous literature, we hypothesized that the arousal associated with rumination plays a critical role related to vulnerability to diseases by enhancing and prolonging concomitant physiological activation in subjects with specific dispositions, such as

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