Respiratory Sinus Arrhythmia Is an Intrapersonal and Interpersonal Moderator of the Negative Interpersonal Consequences of Brooding Rumination

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ABSTRACT

RSA Is an Intrapersonal and Interpersonal Moderator of the Negative Interpersonal Consequences of Brooding Rumination

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This dissertation examined the moderating role of self-regulatory capacity, as indexed by respiratory sinus arrhythmia (RSA), in mitigating the negative interpersonal consequences of rumination. Interpersonal emotion regulation theory suggests that the social context in which intrapersonal emotion regulation strategies are enacted will impact the outcomes of those strategies. Within this frame, RSA was examined as both an intrapersonal and interpersonal moderator of the negative interpersonal impact of rumination. In manuscript 1, it was found that greater rumination and lower RSA were associated with worse interpersonal outcomes, including more negative interpersonal behaviors, impaired support mobilization, and interpersonal stress. Therefore, the hypothesis that RSA acts as an intrapersonal regulatory factor associated with the negative interpersonal consequences of ruminating was supported. In manuscript 2, the association of rumination with marital conflict was attenuated when the romantic partner had higher RSA. Here, the reciprocal hypothesis was supported, in that romantic partners with greater self-regulatory capacity reduced the negative interpersonal impact of rumination within romantic relationships. Together, the findings suggest that rumination negatively impacts the social environment, that the social environment modulates the negative interpersonal consequences of rumination, and that greater RSA acts as both an intrapersonal and interpersonal

moderator of these effects.

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CONTRIBUTION OF AUTHORS

In collaboration with my supervisor, Dr. Jean-Philippe Gouin, and other members of the Stress, Interpersonal Relationships, and Health (SIHR) laboratory, I selected constructs and measures to include in the larger longitudinal datasets that were used in the current dissertation; calibrated and maintained psychophysiological recording equipment; collected data via in-person interviews, psychophysiological data recoding equipment, and online surveys; processed data directly and in a supervisory capacity; planned and conducted statistical analyses; and authored both manuscripts in close collaboration with my supervisor. Additional contributions of other coauthors are discussed below.

Manuscript 1

This manuscript draws findings from three ongoing longitudinal studies. I was directly involved in the selection of measures that would be appropriate in all three studies, however Dr. Wrosch, Dr. McGrath, and Dr. Dang-Vu and their respective teams also collaborated in the design of the larger experimental paradigms, and the collective resources of their labs contributed to data collection. I also worked closely with Dr. Morin, who contributed generously to my training and helped me to develop, analyze, and report the SEM model described in this manuscript. Dr. Morin, Dr. Wrosch, Dr. McGrath, Dr. Dang-Vu, and Sasha MacNeil also provided input on the final manuscript, which was submitted to Personality and Social Psychology Bulletin.

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Manuscript 2

The data for this study was collected prior to my entry in the PhD program. Chelsea da Estrela and Sasha MacNeil helped extensively with the data processing. They both contributed comments and feedback that improved the conceptual interpretation of the findings and provided input on the final manuscript. Additionally, reviewer comments contributed significantly to the quality of the manuscript, which was published in the Journal of Family Psychology.

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CHAPTER ONE: GENERAL INTRODUCTION

Interpersonal relationships represent an important context in which emotional experiences, regulation, and co-regulation unfold (Barthel, Hay, Doan, & Hofmann, 2018; Marroquín, 2011; Zaki & Craig Williams, 2013). Salient emotional experiences organize verbal and nonverbal communicative behaviors that elicit responses from the interpersonal environment, which may alter the trajectory of one's own affect or the affect of those around them. Thus, interpersonal emotion regulation processes are intertwined with the self-regulatory capacities and social skills of both individuals and members of their social circles, highlighting the importance of studying the consequences of individual emotion regulation strategies within the social context in which they occur. Broadly, interpersonal emotion regulation involves two distinct and related processes: the impact of the social environment on the consequences of intrapersonal emotion regulation, as well as the impact of intrapersonal emotion regulation on the social environment (Zaki & Craig Williams, 2013). For example, social environments that are perceived as supportive are associated with more adaptive intrapersonal emotion regulation, and social environments that are perceived as unsatisfactory (e.g. critical or disappointing) are associated with less adaptive intrapersonal emotion regulation (DeLongis & Holtzman, 2005; Holtzman, Newth, & Delongis, 2004). Similarly, social isolation is also associated with less adaptive intrapersonal emotion regulation, including negative cognitive biases, and related behavioural responses like hypervigilance (Cacioppo & Hawkley, 2009). Reciprocally, intrapersonal emotion regulation strategies also influence the social environment. For example, relative to cognitive reappraisal, the suppression of emotional expression during an interpersonal exchange has been associated with less self-reported engagement and more negative evaluations by a conversational partner (Butler et al., 2003; Richards, Butler, & Gross, 2003). In sum,

emotion regulation often involves an exchange between intrapersonal and interpersonal processes.

Rumination is an intrapersonal emotion regulation strategy involving repetitive, passive, self-focused cognition about the causes and consequences of one's experience of distress. It has been associated with increased risk of experiencing dysphoric mood, impaired instrumental behavior, and social functioning (Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008). A large body of work also suggests that brooding rumination is a transdiagnostic risk factors for a broad range of emotional disorders. It has been associated with increased risk for depression, post traumatic stress disorder, substance and alcohol abuse, insomnia, and eating disorders (reviewed in Watkins & Roberts, 2020). Watkins & Roberts (2020) suggest that, intrapersonally, rumination's maladaptive effects can be related to at least four possible mechanisms. First, rumination prolongs negative mood through a vicious cycle where habitually ruminating in response to negative mood increases self-focus and further exacerbates negative mood. Second, rumination interferes with problem-solving by making problems seem more abstract, and increasing pessimism about potential solutions. Third, rumination directly interferes with instrumental behaviours that could lift mood, like enacting solutions or engaging in pleasant distractions. Fourth, as rumination is theorized to be a form of abstract and internally oriented preoccupation, ruminators may be less sensitive to contextual cues in their environment like signals of potential reward, changing contingencies, or interpersonal reactions to their behavior, which may interfere with their interpersonal functioning. Together, these four negative effects of rumination are likely to maintain negative mood and promote behaviours that could lead to chronically stressful circumstances, including interpersonal stress.

Indeed, rumination is associated with a range of negative interpersonal behaviours including excessive reassurance seeking (Potthoff, Holahan, & Joiner, 1995; Stroud, Sosoo, & Wilson, 2018; Weinstock & Whisman, 2007), poor interpersonal problem-solving (Lyubomirsky & Nolen-Hoeksema, 1995), greater motivation to continue arguments (Carr, Schrodt, & Ledbetter, 2012), and aggression following interpersonal transgressions (Collins & Bell, 1997; Watkins, DiLillo, & Maldonado, 2015). In turn, rumination negatively affects interpersonal relationships and is associated with negative changes in relationship quality, including the perception of less emotional support (Nolen-Hoeksema & Davis, 1999), prospective decreases in satisfaction with personal, sexual, and social relationships (Pearson, Watkins, Kuyken, & Mullan, 2010), and more tension and withdrawal in romantic relationships (King & DeLongis, 2014). Further, brooding rumination has been associated with greater interpersonal stress, both cross-sectionally (Lam, Schuck, Smith, Farmer, & Checkley, 2003) and longitudinally (McLaughlin & Nolen-Hoeksema, 2012; Stroud, Sosoo, & Wilson, 2015; Stroud et al., 2018). However, not all studies have confirmed associations between brooding rumination and interpersonal stress (Hamilton et al., 2017, 2013; Shapero et al., 2013), motivating the current examination of possible moderators (Liu & Alloy, 2010).

The negative impact of rumination is also affected by the interpersonal context in which it occurs. For example, within the context of romantic couples, a partners' withdrawal in response to rumination promotes further rumination (King & Delongis, 2014; Cropley & Purvis, 2003), and it is theorized that interpersonal emotion regulation may assist some individuals exit ruminative cycles (Watson & Andrews, 2002; Delongis et al. 2010). Further, maladaptive responses within close relationships, such as co-rumination, strengthen the association between rumination and interpersonal stress generation (Bouchard & Shih, 2013; Rose, Glick, Smith,

Schwartz-Mette, & Borowski, 2017), and higher levels of social support attenuate the association between rumination and negative mood (Marroquín & Nolen- Hoeksema, 2015; Nolen-Hoeksema & Davis, 1999; Puterman, DeLongis, & Pomaki, 2010). Thus, unsupportive interpersonal contexts are associated with greater rumination and exacerbate the association between rumination and negative interpersonal behaviors, while supportive interpersonal contexts have the opposite effect.

Respiratory sinus arrhythmia (RSA) represents the magnitude of the oscillations in time intervals between consecutive heartbeats associated with the respiration cycle (Berntson et al., 1997). RSA occurs because cardiac activity is under tonic inhibitory control by the parasympathetic branch of the autonomic nervous system, which travels from the brain to the heart via the vagus nerve. Vagal inhibition of cardiac activity is gated during inhalation and resumes during exhalation, periodically increasing and decreasing heart rate. The magnitude of change in cardiac activity across the respiration cycle corresponds to the magnitude of parasympathetic vagal inhibition over the sinoatrial node of the heart. This parasympathetic output through the vagus nerve is modulated by brainstem nuclei that integrate input from cortical and limbic structures with input from sensory and visceral organs to coordinate cardiac activity with situational demands (Benarroch, 1993). RSA thus indexes vagally-mediated parasympathetic output to the heart, a component of the autonomic nervous system that regulates the "rest and digest" functions of the organism.

RSA has been conceptualized as a psychophysiological marker of self-regulatory capacity (Balzarotti, Biassoni, Colombo, & Ciceri, 2017; Smith, Deits-Lebehn, Williams, Baucom, & Uchino, 2020). Two theories indicate that greater self-regulatory capacity may assist individuals within interpersonal relationships. Porges' polyvagal theory (2003) is a phylogenetic

model that posits that, in addition to regulating physiological arousal, the autonomic nervous system also evolved to support social behaviors. Calm physiological states promoted by elevated RSA allow for social engagement responses instead of activation of a fight or flight response in certain contexts. Polyvagal theory asserts that common brain-stem nuclei that regulate cardiac activity also influence facial muscles and sensory organs that are required for social engagement. The coregulation of visceral states, facial muscles, and sensory organs allowed the coordination of somatic arousal, visual perception, audition, vocalization, and facial gestures. RSA is thus conceptualized as a biomarker of an integrated social engagement system supporting socially affiliative behaviors. Similarly, the neurovisceral integration model (Thayer & Lane, 2009) predicts the ability to effectively organize behaviors in response to situational demands is supported by greater concomitant prefrontal inhibition over limbic brain regions (e.g. amygdala) and related parasympathetic signaling toward the heart. The theory emphasizes that the tonic inhibitory influence of the frontal cortex within these neural circuits facilitates flexible organismic responding to situational demands, thereby supporting a range of self-regulation behaviors. Thus, these two complementary theories delineate that the capacity for self-regulation and social engagement may be rooted in a shared neurophysiological system, which can be indexed by resting levels of RSA.

As an intrapersonal marker of self-regulatory capacity, greater RSA is positively associated with performance on neuropsychological tests of executive functioning (Williams et al., 2019), persistence on a difficult task (Segerstrom & Nes, 2007), self-reported attention control (Balle et al., 2013), and more adaptive and flexible attention to negative emotional stimuli (Park, Van Bavel, Vasey, & Thayer, 2013). Greater RSA is also related to better emotional self-regulation, in that it is associated with less negative affect in response to stressors

(Fabes & Eisenberg, 1997; Gouin, Deschênes, & Dugas, 2014), faster emotional recovery following a stressor (Diamond & Hicks, 2005; Souza et al., 2007), and fewer stressor-related intrusive thoughts (Geisler & Kubiak, 2009; Gillie, Vasey, & Thayer, 2015). Thus, greater RSA is a marker of intrapersonal self-regulatory capacity, with a small and consistent meta-analytic effect across a variety of self-control tasks (Zahn et al., 2016).

Interpersonally, greater RSA is associated with better control of emotional facial expression (Tuck, Grant, Sollers, Booth, & Consedine, 2016), emotion recognition (Quintana, Guastella, Outhred, Hickie, & Kemp, 2012), self-reported empathy (Lischke et al., 2018), and the maintenance of self-reported affiliative social behaviors when experiencing negative affect (Gyurak & Ayduk, 2008). Further, greater RSA reduced the impact of depressive symptoms on observed negative affect during neutral social interaction (Connell, Hughes-Scalise, Klostermann, & Azem, 2011), and facilitated the de-escalation of observed negative affect following disagreement (Connell, McKillop, Patton, Klostermann, & Hughes-Scalise, 2015). Within close relationships, greater RSA also weakened the association between negative affect and negative social interactions (Diamond, Hicks, & Otter-Henderson, 2011; Switzer, Caldwell, da Estrela, Barker, & Gouin, 2018), and longitudinal decreases in marital quality (Ong et al., 2019). Thus, greater RSA is associated with a set of characteristics that promotes positive interpersonal functioning (Smith et al., 2020).

With respect to rumination, greater RSA may moderate at least two aspects of interpersonal emotion regulation. Greater RSA may assist the intrapersonal regulation of ruminators and help prevent the negative internal experience associated with ruminating from spilling over into overt negative interpersonal behaviours. In turn, this may positively impact interpersonal emotion regulation by improving access to social support and mitigating the

generation of interpersonal stress. Greater RSA may also impact interpersonal emotion regulation by enhancing the interpersonal abilities of supportive partners. Greater RSA in individuals that act as supportive figures to a person that is ruminating may assist the supporting individual in tolerating negative affect that is provoked by the ruminator's negative interpersonal behaviors (i.e. better intrapersonal regulation, for the supporting individual), and by improving their empathic accuracy and communicative behaviors to be more responsive to the needs of ruminating individuals and prevent the escalation of negative affect within the relationship. In two manuscripts, the current thesis will explore and expand upon the empirical basis for each of these aspects of the interpersonal regulation of rumination. The first manuscript examines RSA as an intrapersonal moderator of the negative impact that rumination has on interpersonal functioning by examining negative interpersonal behaviours, received social support, and interpersonal stress across three different study populations. The second manuscript examines RSA as an intrapersonal and interpersonal moderator of the negative interpersonal impact of rumination within romantic couples, and will elucidate the mutual contributions that each member of the dyads make to relationship conflict, and how the RSA of one dyad member may moderate the contributions of their partner. Thus, the current thesis is focused on the moderation of the negative interpersonal impact of rumination by greater self-regulatory capacity, as index by RSA, as both an intrapersonal moderator (preventing one's own negative affect from interfering with interpersonal functioning), as well as an interpersonal moderator (preventing another person's communicative behaviors from negatively impacting one's own interpersonal functioning). RSA is hypothesized to mitigate the negative impact that rumination has within the interpersonal emotion regulation framework, serving both intrapersonal and interpersonal functions.

CHAPTER TWO: MANUSCRIPT 1

Respiratory Sinus Arrhythmia Moderates the Interpersonal Consequences of Brooding Rumination

Caldwell, W., MacNeil, S., Wrosch, C., McGrath, J.J., Dang-Vu, T.T., Morin, A.J.S., Gouin, J.-P. Respiratory sinus arrhythmia moderates the interpersonal consequences of brooding rumination. *Personality and Social Psychology Bulletin* (submitted).

Abstract

Brooding rumination is an intrapersonal emotion regulation strategy associated with negative interpersonal consequences. Resting respiratory sinus arrhythmia (RSA), a psychophysiological marker of self-regulatory capacity, may buffer the association between maladaptive emotion regulation and negative interpersonal behaviors. The current work examines the moderating effect of RSA on the association between brooding rumination and different negative interpersonal behaviors. Across three samples, individuals with lower RSA showed a stronger association between brooding rumination and more negative interpersonal behaviors and less support mobilization (Study 1; n = 154), higher levels of interviewer-rated interpersonal stress (Study 2; n = 42), and a stronger indirect association between brooding rumination and depressive symptoms via daily interpersonal stress (Study 3; n = 222). These findings highlight the negative social consequences of maladaptive intrapersonal emotion regulation strategies, particularly among individuals with lower self-regulatory capacity.

Introduction

Brooding rumination is an intrapersonal emotion regulation strategy involving repetitive, passive, self-focused cognition about the causes and consequences of one's experience of distress. It has been associated with increased risk of experiencing dysphoric mood, exhibiting negative interpersonal behaviors, and reducing social support availability (Nolen-Hoeksema et al., 2008). Greater capacity for self-regulation in interpersonal relationships, as indexed by respiratory sinus arrhythmia (RSA; Porges, 2003; Thayer & Lane, 2009), may mitigate the negative interpersonal consequences of rumination by limiting the extent to which it translates into negative interpersonal behaviors. The current investigation examined the buffering role of RSA in the associations between brooding rumination and negative interpersonal behaviors and social support mobilization (Study 1), chronic interpersonal stress (Study 2), and the daily stressful interpersonal pathway associated with depressive symptoms (Study 3).

Rumination, Negative Interpersonal Behaviors, and Interpersonal Stress

Emotion regulation is increasingly conceptualized as an interpersonal process, where attempts to influence the timing, experience, and expression of emotion involves exchanges between intrapersonal regulation and reactions from the social environment (Marroquín, 2011; Zaki & Craig Williams, 2013). Indeed, supportive social contexts are associated with more adaptive and effective intrapersonal emotion regulation (DeLongis & Holtzman, 2005; Holtzman et al., 2004), whereas social isolation may impair intrapersonal emotion regulation (Cacioppo & Hawkley, 2009). Reciprocally, intrapersonal emotion regulation strategies can also influence the social environment. For example, relative to cognitive reappraisal, the suppression of emotional expression during an interpersonal exchange has been shown to lead to less self-reported engagement and more negative evaluations by a conversational partner (Butler et al., 2003;

Richards et al., 2003). In sum, emotion regulation often involves an exchange between intrapersonal and interpersonal processes.

Nolen-Hoeksema et al. (2008) proposes brooding rumination enhances negative thinking, impairs problem-solving, and interfere with instrumental behaviors. These intrapersonal difficulties may spill-over into negative interpersonal exchanges as they lead to persistent urges to discuss upsetting material, to perceptions of insufficient social support, and tend to be associated with more negative social evaluations of the ruminating individual, leading to a reduction in social support over time (Nolen-Hoeksema, 2008). Empirically, brooding rumination increases the risk for various negative interpersonal behavior, including excessive reassurance seeking (Potthoff et al., 1995; Stroud et al., 2018; Weinstock & Whisman, 2007), poor interpersonal problem-solving (Lyubomirsky & Nolen-Hoeksema, 1995), greater motivation to continue arguments (Carr et al., 2012), and aggression following interpersonal transgressions (Collins & Bell, 1997; Watkins et al., 2015). Rumination is also associated with lower satisfaction with social support (Nolen-Hoeksema & Davis, 1999), and greater daily withdrawal within romantic couples (King & DeLongis, 2014). Thus, brooding rumination is an intrapersonal emotion regulation strategy that increases risk for negative interpersonal behaviour that may interfere with social support.

Converging evidence shows brooding rumination is also associated with the development of interpersonal stress. Brooding rumination has been associated with greater interpersonal stress, both cross-sectionally (Lam, Schuck, Smith, Farmer, & Checkley, 2003) and longitudinally (McLaughlin & Nolen-Hoeksema, 2012; Stroud, Sosoo, & Wilson, 2015; Stroud et al., 2018). Further, brooding rumination has been associated with negative changes in relationship quality, including the perception of less social support (Nolen-Hoeksema & Davis,

1999), more relationship conflict (Caldwell, da Estrela, Macneil, & Gouin, 2019; King & DeLongis, 2014), and prospective decreases in satisfaction with personal, sexual, and social relationships (Pearson, Watkins, Kuyken, & Mullan, 2010). However, not all studies have confirmed associations between brooding rumination and interpersonal stress (Hamilton et al., 2017, 2013; Shapero et al., 2013), and there is a paucity of studies examining the interaction between brooding rumination and possible moderators which may serve to increase, or curb, its effects (Liu & Alloy, 2010).

RSA and Interpersonal Functioning

As a psychophysiological marker of self-regulatory capacity (Balzarotti et al., 2017; Smith et al., 2020), RSA may be an important moderator of the association between brooding rumination and negative interpersonal consequences. RSA represents the magnitude of the oscillations in time intervals between consecutive heartbeats associated with the respiration cycle (Berntson et al., 1997). Cardiac activity is under tonic inhibitory control by the parasympathetic branch of the autonomic nervous system, which travels from the brain to the heart via the vagus nerve. Vagal inhibition of cardiac activity is gated during inhalation and resumes during exhalation, periodically increasing and decreasing heart rate. The magnitude of change in cardiac activity across the respiration cycle corresponds to the magnitude of parasympathetic vagal inhibition over the sinoatrial node of the heart. This parasympathetic output through the vagus nerve is modulated by brainstem nuclei that integrate input from cortical and limbic structures with input from sensory and visceral organs to coordinate cardiac activity with situational demands (Benarroch, 1993). RSA is thus considered a measure of vagally-mediated parasympathetic activity.

Two main conceptual models position RSA as a marker of self-regulation in interpersonal

relationships. Porges' (2003) polyvagal theory is a phylogenetic model that posits that in addition to regulating physiological arousal, the autonomic nervous system also evolved to support social behaviors. This theory states facial muscles and sensory organs required for social engagement are co-regulated with the autonomic nervous system to coordinate somatic arousal, visual perception, audition, vocalization, and facial gestures. Similarly, the neurovisceral integration model (Thayer & Lane, 2009) predicts the ability to effectively organize behaviors in response to situational demands is supported by greater concomitant prefrontal inhibition over limbic brain regions (e.g. amygdala) and related parasympathetic signalling toward the heart. Thus, these complementary conceptual models both predict the capacity for self-regulation in interpersonal contexts is rooted in a shared neurophysiological system that is indexed by resting levels of RSA.

Empirically, resting RSA has been associated with greater self-regulatory capacities (Balzarotti et al., 2017; Smith et al., 2020), like persistence on a difficult task (S. Segerstrom & Solberg Nes, 2007). Greater resting RSA has also been associated with different aspects of emotion regulation processes. Intrapersonally, RSA is related to less negative affect in response to stressors (Fabes & Eisenberg, 1997; Gouin et al., 2014), faster recovery (Diamond & Hicks, 2005; Souza et al., 2007), and regulation of negative intrusive thoughts (Gillie et al., 2015). Interpersonally, greater RSA is related to better control of emotional facial expression (Tuck et al., 2016), emotion recognition (Quintana et al., 2012), and self-reported empathy (Lischke et al., 2018). Importantly, resting RSA is also associated with the maintenance of affiliative behaviors, even when experiencing negative affect (Gyurak & Ayduk, 2008). Within close relationships, RSA weakened the association between negative affect and negative social interactions (Diamond, Hicks, & Otter-Henderson, 2011; Switzer, Caldwell, da Estrela, Barker, & Gouin, 2018) or decreases in marital quality (Ong et al., 2019), and reduced the impact of a marital

partner's brooding rumination on conflict within the couple (Caldwell et al., 2019). Greater RSA also reduces the impact of depressive symptoms on observable negative affect during neutral social interaction (Connell et al., 2011), and facilitates de-escalation of negative affect following disagreement (Connell et al., 2015). Consistent with this view of RSA as an index of self-regulatory capacity within interpersonal relationships, individuals with greater RSA may be better able to prevent the negative intrapersonal experience of brooding rumination from affecting their interpersonal behaviors.

Current Studies

Brooding rumination is theorized to enhance negative thinking, impair problem-solving, interfere with instrumental behavior, and erode social support. Empirically, brooding rumination also increases negative interpersonal behaviors and is associated with interpersonally stressful circumstances in some, but not all studies. This suggests the need to examine moderators of the negative interpersonal consequences of brooding rumination (Liu & Alloy, 2010). In the present research, we argue the link between negative internal experiences and social behaviors is stronger among individuals with lower self-regulatory capacity. More precisely, we propose higher levels of RSA, as an index of self-regulatory capacity, should enhance individuals' ability to maintain socially affiliative behaviors in the presence of brooding rumination, whereas lower levels of RSA should impede this ability. The current work aims to assess the role of RSA as a moderator of the negative interpersonal consequences of brooding rumination in three complementary studies. More precisely, these studies assessed the interaction between brooding rumination and RSA on negative interpersonal behaviors and support mobilization (Study 1), objectively rated chronic interpersonal stress (Study 2), and the stressful interpersonal pathway that mediates depressive symptoms (Study 3). The general hypothesis across studies is higher

levels of brooding rumination will be associated with worse negative interpersonal behaviors and consequences, and that RSA will moderate these associations such that individuals with lower RSA will exhibit a stronger association between brooding rumination and negative interpersonal behaviors and consequences.

Study 1: Introduction

Nolen-Hoeksema et al. (2008) hypothesized brooding rumination is associated with negative interpersonal behaviors that are counter-productive to social relationships. These negative interpersonal behaviors are hypothesized to represent maladaptive attempts to interpersonally regulate the negative intrapersonal experience of brooding (Nolen-Hoeksema et al., 2008). For example, brooding rumination may drive individuals to seek excessive reassurance to reduce prolonged negative affect (Joiner, Alfano, Metalsky, 1992), and could promote interpersonal aggression by negatively biasing cognition and tying up cognitive resources that may otherwise be used for social cognition (Tse & Bond, 2004). While theorized as part of the same maladaptive interpersonal style (Nolen-Hoeksema, 2008; Pearson, Watkins, & Mullan, 2011), these constructs have been examined independently. The current work integrates previous findings by relating brooding rumination to a broader set of negative interpersonal behaviors, and by verifying the moderating role of self-regulatory capacity on these associations.

Nolen-Hoeksema (2008) also theorized brooding rumination may interfere with social support. However, current empirical description is limited to between-person differences in perceived emotional support (Nolen-Hoeksema & Davis, 1999). Given ruminators' tendency to perceive problems as overwhelming, generate less effective solutions, and have low confidence in the efficacy of potential solutions (Nolen-Hoeksema, 2008), they may be even less likely to

seek instrumental support, compared to emotional support. The current analysis expands on previous findings by examining the impact of brooding rumination across both instrumental and emotional support, and by also considering the role of between-person and within-persons differences in rumination. To examine the within-person associations between rumination and support mobilization, daily ratings of rumination were compared against individuals' own average to examine whether daily deviations in rumination from that person's own average were related to perception of emotional or instrumental support mobilization. We hypothesize higher within-person levels of rumination will be associated with greater interference on instrumental support, relative to emotional support, and RSA would further moderate these associations.

Study 1 aimed to test whether RSA moderates the associations between rumination and negative interpersonal behaviors, and daily social support mobilization. A first model examined whether individual differences in RSA moderated the between-person associations between trait brooding rumination and negative interpersonal behaviors across participants. A second model examined whether trait brooding rumination and RSA moderated the daily within-person associations between state rumination and the mobilization of instrumental and emotional social support.

Study 1: Method

Participants

A sample of 153 female undergraduate students (mean age = 21.76, SD = 1.94) gave informed consent (IRB: 30000613) and participated in the study in exchange for course credit. Exclusion criteria were taking medication affecting cardiac functioning (e.g. beta blockers) and smoking more than one cigarette per day. Approximately 45% of the participants were in a committed relationship. The distribution of self-reported ethnicities was 59.5% White/Caucasian, 10.5% Middle Eastern, 7.2% Asian, 5.2% South Asian, 4.6% Black/African American, 2.6% Latino, and 10.5% others.

Measures

Brooding Rumination. Brooding rumination was assessed with the Ruminative Response Scale (Treynor, Gonzalez, & Nolen-Hoeksema, 2003). This instrument assessed the frequency individuals engage in moody pondering when they are feeling sad, down, or depressed (5 items; $\alpha = .84$; $M = 12.05$; $SD = 3.90$; e.g. "think about a recent situation, wishing it had gone better"). Items were rated on a 4-point Likert-type scale ranging from 1 – almost never, to 4 – almost always.

Negative Interpersonal Behaviors. Problems in interpersonal functioning were assessed using three measures. Excessive reassurance seeking was assessed with the relevant subscale from the Depressive Interpersonal Relationships Inventory (Metalsky, Joiner, Potthoff, et al., 1991). This subscale includes four items ($\alpha = .93$; e.g. "Do you frequently seek reassurance from the people you feel close to as to whether they really care about you?") rated on a 7-point Likert-type scale from 1 – not at all to 7 – very much. Salient interpersonal difficulties were assessed using the 32 items from the Inventory of Interpersonal Problems (Horowitz, Alden, Wiggins,

Pincus, 2000), all rated on a 5-point Likert-type scale from 0 - not at all to 4 - extremely. This instrument includes seven subscales (domineering/ controlling, vindictive/ self-centered, cold/distant, socially avoidant/ inhibited, non-assertive, over nurturant/over accommodating, exploitable/self-sacrificing, and intrusive/needy), used to obtain a single global score (α = .92). Finally, anxious expectations of rejection in ambiguous social contexts were assessed using the Rejection Sensitivity Questionnaire (Downey & Feldman, 2013). This instrument asked participants to respond to eight scenarios (α = .74; e.g. "you go to a party and notice someone on the other side of the room and then you ask them to dance") and to estimate their level of distress and the likelihood of rejection using two 7-point Likert-type scales. Within each scenario, the anticipated likelihood of rejection was reverse coded and then multiplied by that scenario's distress score to create a summary rejection sensitivity score. Scores from these three questionnaires were converted to z-scores and averaged (M = 0; SD = 2.32, α = .66). Higher scores indicated more negative interpersonal behaviors.

State Rumination. State rumination was assessed using the three-item mental capture subscale of the Perseverative Thinking Questionnaire (Ehring, Zetsche, Weidacker et al., 2011). Participants indicated the degree to which each statement corresponded to how they thought about past or future negative events on that day (e.g., "The same thoughts kept going through my mind again and again") using a 5-point Likert-type scale ranging from 0 – never, to 4 – always. An average of 3.57 (SD = 2.34) was reported and the internal consistency on day 1 of the daily diary period was good (α = .80). The intraclass correlation (ICC) was .50 across 14 days, indicating substantial between and within person variability.

Daily Mobilization of Instrumental and Emotional Support. Daily received instrumental and emotional support were assessed in reference to the following social entities: romantic

partners, best friends, other friends, family, and classmates or coworkers using a measure adapted from Otto et al. (2015) and Zautra, Affleck, Tennen, Reich, and Davis (2005). Participants responded to two questions, "Thinking about your social interactions today, which of the following individuals…" "did something concrete to help you deal with a problem?" and "listened to you and provided you with comfort?" Participants indicated if each social entity provided concrete help or comfort on that day. Participants could also select "No one" when appropriate. Each endorsed social entity was scored as 1, except for "No one," which was scored as 0. The sum of endorsed social entity represented daily received instrumental or emotional support (0 to 5 each day). An average of 1.18 (*SD* = 0.70) and ICC = 0.49 for emotional support, and an average of 0.67 (*SD* = 0.64) and ICC = 0.49 for instrumental support were reported across 14 days.

RSA. Cardiac data was collected using an ECG amplifier module within a Mindware Bionex 8-slot chassis (Mindware Technologies, Ltd., Gahanna, OH). ECG signals were recorded continuously using a sampling rate of 1000 Hz. Mindware HRV Analysis software, Version 3.1, was used to analyze ECG recordings, detect improbable interbeat intervals using a validated automated algorithm (Berntson, Quigley, Jang, & Boysen, 1990), and were then visually inspected and corrected when necessary. Fast Fourier Transformation was used to isolate the .15 to .40-Hz high frequency band of each 30-s epoch, which reflects the vagal-dependent parasympathetic influence on the heart, or RSA (Jarrin, McGrath, Giovanniello, Poirier, & Lambert, 2012). Resting RSA was estimated as the mean value (natural log) of each 30-s epochs within the 5-minute resting period (*M* = 6.84, *SD* = 1.04).

Procedures

All participants attended a laboratory session for RSA assessment. Upon arrival,

participants' electrodes were fitted in a Lead II configuration for the ECG recordings and they were seated in a comfortable chair. The research assistant then left the room and a computer screen prompted the participant to begin a 5-minute resting period where they were asked to sit upright, breathe normally, and relax as much as possible without falling asleep while cardiac activity was recorded. Participants remained seated for the duration of the task to limit the influence of postural changes on RSA measurement. Participants were asked to refrain from strenuous exercise and the consumption of caffeine, alcohol, and tobacco in the 2 hours prior to the laboratory session and all laboratory sessions were scheduled between 12 PM and 5 PM to attenuate exogenous and diurnal confounds. Following the session, participants completed a questionnaire assessing trait variables. Participants then filled out an electronic diary to assess daily state rumination, instrumental support, and emotional support every evening for 14 days. Participants completed an average of 12.45 entries (SD = 2.09).

Study 1: Results

Between-Person Analysis of Negative Interpersonal Behavior

To test the hypotheses that brooding rumination would be associated with negative interpersonal behaviors and higher levels of RSA would moderate this association, a hierarchical linear regression-based moderation model was estimated using the PROCESS macro (Preacher & Hayes, 2004) in SPSS version 20. Consistent with recent recommendations, analyses included resting heart rate as a covariate (de Geus, Gianaros, Brindle, Jennings, & Berntson, 2019). The results are reported in Table 1. In the main effects model, brooding rumination was significantly and positively associated with negative interpersonal behaviors. The main effect of RSA was not statistically significant. In the moderation model, the interaction between brooding and RSA significantly predicted negative interpersonal behaviors, and accounted for an additional 3.9% of the variance beyond that explained in the main effects model. As illustrated in Figure 1, simple slopes analyses indicated the effect of brooding on negative interpersonal behaviors was stronger when RSA was lower (b = .152, $p \leq .01$, 95% CI = .113 to .190) compared to when RSA was higher (b = .070, $p \leq .01$, 95% CI = .036 to .109).

Within-Person Analysis of Social Support Mobilization

The daily within-person associations between state rumination and the mobilization of instrumental and emotional support were examined using multilevel modeling in order to account for the hierarchical structure (i.e. days nested within people) and serial dependency of daily diary data (Bolger & Laurenceau, 2013). The model was adjusted for serial dependency using a first-order auto-regressive covariance structure (Affleck, Zautra, Tennen, & Armeli, 1999). Within-person differences in state rumination were calculated by subtracting each individual's own average state rumination across the daily diary period from each day's score to

create a person-mean centered state rumination variable (i.e. daily deviations from that person's own average, or group-mean centering). Further, a random effect was specified for the intercept and slope of the associations between support mobilization and person-mean centered state rumination. Cross-level interactions between person-mean centered state rumination, trait brooding rumination, and RSA were tested. Consistent with prior recommendations, associations were examined while controlling for the between-person centered (i.e., grand mean centering) average of state rumination (Howard, 2015), and resting heart rate (de Geus et al., 2019). The pseudo-R^2 method was used to quantify the proportion of random slope variance explained when cross-level interactions were added to the models (Snijders & Bosker, 1999). Statistical analyses were conducted using SAS PROC MIXED, version 9.4 (Cary, North Carolina, USA).

The results of the within-person analysis of emotional support are presented in Table 2. In the main effects model, the association between state rumination and emotional support mobilization was significant, showing higher levels of state rumination were associated with more mobilization of emotional support. However, the variance of the random slope reflecting the effects of state rumination on the mobilization of emotional support was not significant, suggesting little between-person variability in this association. Consistent with this, the results from the model including the interactions between state rumination, brooding, and RSA, revealed no statistically significant interaction between these variables in the prediction of emotional support mobilization.

The results of the within-person analysis of instrumental support are presented in Table 3. In the main effects model the association between state rumination and instrumental support mobilization was not statistically significant, suggesting a lack of between-person association between these variables. However, the variance of the random slope reflecting the effects of state

rumination on the mobilization of instrumental support revealed significant between-person variability in this association. Results from the models including the interactions between state rumination, brooding, and RSA and are also reported in Table 3. These results first revealed a significant two-way interaction between state rumination and trait brooding interaction in the prediction of instrumental support mobilization. This interaction is graphically depicted in Figure 2 and accounted for an additional 9.84% slope variance relative to the main effects model. Consistent with the prediction that brooding rumination interferes with the mobilization of instrumental support, simple slopes analyses indicated higher than average within-person levels of state rumination were associated with more instrumental support mobilization for individuals reporting lower levels of trait brooding rumination (b = .035, $p \leq .01$, 95% CI = .008 to .062), but not for individuals reporting higher levels of trait brooding rumination (b = -.008, $p > .05$, 95% CI = -.029 to .014). The two-way moderation model accounted for an additional 9.84% slope variance compared to the main effect model.

Finally, the three-way interaction model between state rumination, trait brooding rumination, and RSA was also statistically significantly associated with instrumental support mobilization. This interaction is graphically depicted in Figure 3. Simple slopes analyses indicated that at higher levels of RSA, higher levels of state rumination were associated with higher levels of instrumental support for participants reporting lower levels of trait brooding rumination (b = .074, $p \leq .01$, 95% CI = .036 to .111), but not for those reporting higher levels of trait brooding (b = -.010, $p > .05$, 95% CI = -.038 to .018). In contrast, at lower levels of RSA, no association was found between state rumination instrumental support mobilization, regardless of the level of trait brooding rumination. The three-way moderation model accounted for an additional 45.37% slope variance compared to two-way moderation. This indicates instrumental

support is better mobilized in response to state rumination for individuals with a combination of lower trait brooding rumination and higher RSA.

Study 1: Discussion

The results from this first study showed, at the between-person level, higher levels of brooding rumination were associated with more negative interpersonal behaviors, and this effect was attenuated for individuals with higher levels of RSA. This is consistent with the hypotheses that the prolonged negative affective experience associated with brooding rumination should promote negative interpersonal behaviors (Nolen-Hoeksema et al., 2008), and that RSA, as an index of self-regulatory capacity, can assist the individual in adaptively organizing their social behaviors within this context (Porges, 2003). Further, at the within-person level, higher levels of state rumination were associated with the mobilization of both emotional and instrumental support. However, trait brooding rumination and RSA selectively impacted the mobilization of instrumental support, and not emotional support, on days characterized by higher levels of state rumination. Higher levels of instrumental support mobilization were only reported for individuals who engaged in lower levels of trait brooding rumination and who displayed higher levels of RSA. This specific effect on instrumental support may reflect tendencies for ruminators to vent and portray problems them as unsolvable, which could interfere with the mobilization of instrumental, but not emotional, support. Together, this suggests individuals characterized by higher levels of brooding rumination and higher levels of RSA tend to engage in less negative interpersonal behaviors and to mobilize more instrumental support when they engage in higher levels of daily rumination.

Study 2: Introduction

These results from Study 1 suggest low RSA may put individuals, particularly those with tendencies for brooding rumination, at increased risk of experiencing interpersonal stress. The stress generation hypothesis posits individual vulnerabilities, like brooding rumination, may cause chronic interpersonal stress, in part, by way of their associations with negative interpersonal behaviors (Hammen, 2003). Empirical evidence suggests brooding rumination is associated with greater interpersonal stress, with both self-report (Lam et al., 2003; McLaughlin & Nolen-Hoeksema, 2012) and interviewer-rated measures (Stroud et al., 2015, 2018). Interviewer-rated measures offer a standardized assessment of chronic interpersonal stress across major interpersonal domains that are less tainted by the subjective experience of the respondent. Study 2 examined whether greater brooding rumination and lower RSA interact to predict greater interviewer-rated chronic interpersonal stress across relationship domains.

Study 2: Method

Participants

Participants were part of a convenient sample of 42 adults meeting DSM-5 criteria for an insomnia disorder (APA, 2013) (IRB: 30004339). Exclusion criteria included the presence of a chronic unstable medical condition, sleep disorders other than insomnia (e.g. sleep apnea syndrome with apnea-hypopnea index greater than 5/h), severe mental illness (e.g. psychotic disorders, bipolar disorders, or substance use disorder), excessive alcohol use (>10 drinks/week) or illicit drug use (>1/month), chronic use of a hypnotic medication, cognitive impairment (<26 on the MOCA; Nasreddine et al., 2005), or employment involving nightshifts in the past year or during the study. On average, participants were 52.29 years old (S.D. = 15.96), 81% were female, and 54.8% were married and living with their partner. About 83.3% of the sample self-reported their ethnicity as White/Caucasian, and 29.3% of the sample had a university degree or higher.

Measures

Brooding Rumination. Trait brooding rumination was assessed using the Ruminative Response Scale, as described in Study 1 (M = 10.00; SD = 2.38; α = .75).

Chronic Interpersonal Stress. Interpersonal stress was assessed using the chronic stress portion of the UCLA life stress interview (e.g. Adrian & Hammen, 1993; Hammen, 1991; Hammen, Adrian, Gordon et al., 1987). The interview questions assessed chronic stress over the previous 6 months across various life domains, including three interpersonal domains (social life, intimate relationships, and family relationships). Consistent with previous work, each domain was coded by the interviewer using pre-defined anchor points that were described in behavioral terms (e.g. is support mutual in this relationship?) using a 5-point ordinal scale. The average of

the three interpersonal domains was used in the current analysis (M = 1.68; SD = .61). Higher scores represent worse chronic interpersonal circumstances (e.g. more isolation, more conflict, less warmth and trust), which are assumed to be stressful. The interviews were conducted by six trained interviewers, and approximately 10% of the sample was re-rated by an independent coder to calculate inter-rater reliability (κ = .93).

RSA. Cardiac data were collected using an ECG amplifier via a Somnoscreen Stationary/Sleep Lab PSG and the Domino sleep diagnostic software suite (Somnomedics GmbH, Randersacker, Germany). ECG signals were recorded continuously using a sample rate of 512 Hz. Recording artifacts were manually edited and RSA was calculated using the procedure from Study 1 by two independent rating dyads (ICC = .97). Resting RSA was estimated as the mean value of each 60-s epoch within the 5-minute resting period (M = 5.41, SD = 1.25).

Procedure

In the morning following an overnight visit, participants were fitted with electrodes in a Lead-II configuration for ECG recording. RSA was assessed using a Somnoscreen (Somnomedics GmbH, Randersacker, Germany) polysomnographic device during a 5-minute resting period (see Study 1). Participants also completed a semi-structured assessment of chronic stress exposure.

Study 2: Results

Moderation Analysis

The hypothesis brooding rumination would be associated with chronic interpersonal stress and higher levels of RSA would will mitigate the effect was analyzed as in Study 1. The moderation analyses were estimated while controlling for resting heart rate (de Geus et al., 2019), age, and sex (coded as 0-male, 1-female). The results are reported in Table 4. In the main effects model, brooding rumination and RSA did not have significant main effects on interpersonal stress. However, the results from the moderation model revealed a statistically significant interaction between brooding and RSA in the prediction of chronic interpersonal stress, which accounted for an additional 6% of the variance beyond the main effects of brooding rumination and RSA. Simple slopes analysis, illustrated in Figure 4, show the effect of brooding rumination on chronic interpersonal stress was significant when RSA was low (b = .160, $p \leq .05$, 95% CI = .032 to .288) but not when RSA was high (b = .019, $p \geq .05$, 95% CI = -.088 to .125).

Study 2: Discussion

The findings from this second study suggest that the association between brooding rumination and interviewer-rated chronic interpersonal stress (Nolen-Hoeksema et al., 2008) was only significant amongst individuals with lower self-regulatory capacity (as indexed by RSA). The findings are consistent with prior empirical work (Lam et al., 2003; McLaughlin & Nolen-Hoeksema, 2012; Stroud et al., 2015, 2018) and shows greater capacity to self-regulate mitigates the impact of brooding rumination on chronic interpersonal stress (Porges, 2003). Importantly, the measure of interpersonal stress used in the present study was interviewer-rated, suggesting the interaction between RSA and brooding rumination is associated with more objective differences in interpersonal stress, separate from more subjective, perceptual differences in self-rated interpersonal stress that could be impacted by either brooding rumination or RSA.

Study 3: Introduction

According to the stress generation hypothesis, chronically stressful circumstances that develop from risk factors like brooding rumination increase risk for future depressive episodes (Hammen, 2003). Empirical work has demonstrated the generation of interpersonal stress is predictive of later depressive symptoms (Liu & Alloy, 2010). Importantly, interpersonal stress has been shown to mediate the association between brooding rumination (a risk factor for depression) and depression in young adults (Flynn, Kecmanovic, & Alloy, 2010). However, the link between interpersonal stress and less pathological forms of repetitive thoughts, like reflective pondering (Treynor et al., 2003), has not been empirically examined. Study 3 was designed to examine the hypothesis that the indirect association between brooding and reflective rumination and depressive symptoms, via greater interpersonal stress, is attenuated for individuals with higher levels of RSA. Here, we hypothesize that greater brooding (risk factor), will lead to greater interpersonal stress (mediator), which will lead to greater depressive symptoms; and that in a moderated mediation model, greater RSA will attenuate the indirect pathway by moderating the association between brooding and interpersonal stress.

Study 3: Method

Participants

Participants were drawn from a larger project on individuals undergoing chronic caregiving stress given that they are at the heightened risk for depressive symptoms (Lovell, Moss, & Wetherell, 2012). Mothers of adolescents with (n = 125) and without (n = 97) developmental disorders (total n = 222) gave their informed consent (IRB: 10000544) to participate a study on caregiving stress and health. Exclusion criteria included chronic medical conditions, regular use of anti-inflammatory medication, major mental illness (e.g. schizophrenia, bipolar disorder, or substance misuse), or being pregnant or nursing at the time of the study. Mothers were recruited through advertisements via school boards, social service centers, community organizations, as well as general advertisements in local newspapers. On average, mothers were 46.83 (SD = 6.03) years old, and had an adolescent that was 15.89 (SD = 2.5) years old. About 72.5% of the participants were Caucasian, 30.6% had a university degree, and 52.5% had a household family income below CAN$ 60,000. Approximately 76.2% were married or in a common-law relationship.

Measures

Rumination. Rumination was assessed with the Ruminative Response Scale (Treynor et al., 2003). This questionnaire incorporates two 5-item subscales assessing brooding rumination (described in Study 1; α = .77; M = 10.98; SD = 3.28) and reflection (e.g. "go someplace alone to think about your feelings"; α = .78; M = 10.92; SD = 3.20).

Interpersonal Stress. On seven consecutive evenings, participants responded to the question (adapted from the Daily Inventory of Stressful Events; Almeida et al. 2002), "how much stress or tension did you experience in your interactions with the following people?"

followed by a 4-point Likert-type scale from 0 - not at all to 3 - extremely for each interpersonal domain: family, friends, partner, and coworkers. The mean score across seven days was taken to reflect interpersonal stress in each relationship domain. Participants completed an average of 5.06 (*SD* = 1.96) days. Average interpersonal stress reported was 1.51 (*SD* = .42) and scale score reliability was satisfactory (α = .88).

***Depression*.** Depressive symptoms were measured using the Center for Epidemiological Studies Depression Scale (CES-D; Radloff, 1977). This 20-item scale assesses depressive symptoms over the previous week. Responses were provided on a 4-point Likert-type scale from 1- rarely or none of the time (less than 1-day) to 4 - most or all of the time (5-7 days). The CES-D includes four subscales assessing depressed affect (7 items, e.g., "I felt depressed"), low positive affect (4 items, reverse coded, e.g., "I was happy"), somatic complaints (7 items, e.g., "I did not feel like eating; my appetite was poor"), and interpersonal problems (2 items, e.g., "I felt that people dislike me"). In the present study, we rely on a total depression score encompassing the first three subscales (α = .90; *M* = 15.49; *SD* = 10.22). The interpersonal problems subscale was not included in the CESD total score to reduce conceptual overlap between the estimates of interpersonal stress and depression.

***RSA*.** Cardiac data were collected using a mobile chest belt and digital inter-beat interval recorder (Polar RS800CX; Finland, Kempele). Interbeat intervals were recorded continuously using a sampling rate of 1000 Hz. Timing artifacts were corrected in CardioEdit software (2007) using integer arithmetic (i.e. adding or dividing). Porges et al.'s (1980) moving polynomial approach was used to extract RSA using CardioBatch software (2007). Resting RSA was estimated as the mean value (natural log) of all 30-s epochs within the 5-minute resting period (*M* = 5.63, *SD* = 1.34).

Procedure

Participants first completed an online questionnaire assessing rumination and depressive symptoms. Next, all participants completed an online daily diary assessing interpersonal stress at the end of 7 consecutive days. During an in-person morning visit to the participants' homes or at the university laboratory, participants were fitted with a chest belt hardwired with a digital inter-beat interval recorder (Polar RS800CX; Finland: Kempele). They completed a 5-minute resting period during which they were asked to sit upright, relax, and breathe normally without speaking to assess resting RSA.

Analyses

Analyses were conducted using the MPlus 8.3 statistical package (Muthén & Muthén, 2019). Confirmatory factor analysis (CFA) and structural equation modeling (SEM) were used to examine whether higher levels of interpersonal stress mediated the relation between brooding rumination and depressive symptoms, and whether RSA moderated this indirect pathway. This was accomplished in three steps.

First, a measurement model was used to verify the measurement structure of our theoretical constructs. A higher order CFA model was used in order to estimate a global (i.e. higher-order) depression factor defined by three (negative affect, low positive affect, somatic complaints) first-order factors (Morin et al., 2011). To account for the ordered categorical nature of the four point scales used to assess brooding, reflection, and depression, this model was estimated using a robust weighted least square estimator (WLSMV; Finney & DiStefano, 2013). Given that latent interaction effects cannot yet be estimated using WLSMV (Marsh, Hau, Wen, Nagengast, & Morin, 2013), factor scores, estimated in standardized units ($M = 0$; $SD = 1$), were extracted from this measurment model for the main analyses. Although factor scores are unable

to completely control for unreliability, they still afford a partial control for measurement error (Skrondal & Laake, 2001), in addition to preserving the underlying nature of the measurement model (i.e., including the higher-order structure of the CESD). Due to its different rating method, interpersonal stress was still estimated as a latent variable in the predictive models, maintaining a complete control for unreliability.

Second, a structural model was estimated to examine the indirect association between brooding and depressive symptoms via interpersonal stress. Direct effects of brooding and self-reflection on depression were also incorporated in the model. Mothers' caregiving status (coded as -1 and 1) was used as a covariate to control for the impact of chronic caregiving stress on interpersonal relationships and depressive symptoms. The mediator role of interpersonal stress was assessed via the estimation of indirect effects, estimated as the product of the two coefficients forming the mediation chain (MacKinnon, Lockwood, & Williams, 2004), implemented in Mplus via the MODEL INDIRECT function. The statistical significance of these indirect effects was calculated using bias-corrected bootstrapped 95% confidence intervals (CIs based on 5000 bootstrap samples; Cheung & Lau, 2008).

Third, a second structural model was estimated to test whether this indirect pathway was moderated by RSA via tests of interactions (calculated as the product of the predictor and the moderator; Marsh, Hau, Wen, Nagengast, & Morin, 2013). This model was similar to the previous one and included RSA observed scores as an additional predictor. Simple slope analyses were implemented in Mplus via the model CONSTRAINT function (Hayes & Preacher, 2013).

Both predictive models were estimated via the Robust Maximum Estimator (MLR), which provide standard error and tests of model fit that are robust to non-normality. For all

models, acceptable model fit was determined by CFI and TLI values exceeding .90 or RMSEA values below .08, whereas excellent model fit was reflected by values exceeding .95 or RMSEA values below .06 (Hu & Bentler, 1999; Marsh, Hau, & Grayson, 2005; Yu, 2002).

Study 3: Results

The results from the measurement model, depicted in Figure 5, revealed the latent measurement model achieved an excellent level of fit to the data (χ^2 = 674.361, p < .01; RMSEA = .047; CFI = .954; and TLI = .950) and resulted in well-defined factors. The first predictive model achieved an excellent level of fit to the data (χ^2 = 20.415, p = .20; RMSEA = .035; CFI = .982; and TLI = .972). The results from this model, reported in Table 5 (left), revealed a significant positive association between brooding rumination and interpersonal stress, and a negative association between reflective rumination and interpersonal stress. Significant direct associations were observed between caregiving status, interpersonal stress and brooding rumination, and depression. The indirect effect of brooding rumination on depression via interpersonal stress was also significant (estimate = .074, *SE* = .036, p ≤ .05, bootstrapped 95% C.I. = .019 to .197). This indirect pathway accounted for approximately 10.4% of the total effect of brooding on depression, via interpersonal stress. The indirect effect of reflective rumination on depression via interpersonal stress was not significant (estimate = -.051, *SE* = .030, p > .05, bootstrapped 95% C.I. = -.158 to -.008).

The results from the final moderated mediation are reported in Table 5 (right). These results show the interaction between RSA and brooding rumination was a significant predictor of interpersonal stress, supporting the moderating role of RSA in the relation between brooding rumination and interpersonal stress. Simple slope analyses suggest the positive effect of brooding rumination was not significant at high levels of RSA (*b* = .083, *SE* = .049, p > .05, bootstrapped 95% CI = -.008 to .209), but was significant at low levels of RSA (estimate = .242, SE = .068, p ≤ .01, bootstrapped 95% CI = .116 to .418). When these simple slopes are considered within the context of the indirect relation between brooding and depression, mediated by interpersonal

stress, the results further show the indirect effect is not statistically significant at higher levels of RSA (estimate = .038, SE = .028, $p > .05$, bootstrapped 95% CI = -.001 to .164), but was significant at lower levels of RSA (estimate = .111, $SE = .050$, $p \leq .05$, bootstrapped 95% CI = .029 to .291).

Study 3: Discussion

The results from study 3 revealed a positive indirect effect of brooding rumination on depression via daily interpersonal stress. This indirect effect was moderated by RSA, such that the effect of brooding rumination via interpersonal stress became non-significant for individuals with higher levels of RSA. These results thus supported the stress generation model of depression, suggesting brooding rumination is associated with depressive symptoms via its associations with interpersonal stress (Hammen, 2003). These results replicate prior work showing interpersonal stress mediates the association between rumination and depression (Flynn et al., 2010) in an adult community sample. Furthermore, the indirect path from brooding rumination to depression via interpersonal stress was moderated by RSA, showing higher levels of RSA mitigated the negative interpersonal consequences of brooding rumination. The results thus support the conceptualization of RSA as an index of self-regulatory capacity within interpersonal relationships (Porges, 2003), and the importance of self-regulatory capacity in attenuating the interpersonal stress pathway through which brooding rumination increases depressive symptoms.

Discussion

The current research examined the moderating role of RSA in the association between brooding rumination and negative interpersonal behaviors, support mobilization, and interpersonal stress. Higher levels of RSA were found to reduce the strength of the associations between brooding rumination and negative interpersonal behaviors and daily support mobilization (Study 1), interviewer-ratings of chronic interpersonal stress (Study 2), and the strength of the stressful interpersonal pathway associated with greater depressive symptoms (Study 3). Together, the findings suggest the capacity to self-regulate within interpersonal relationships, as indexed by RSA, is an important individual difference variable that mitigates the negative interpersonal consequences of brooding rumination, an intrapersonal emotion regulation strategy.

Increasing evidence shows intrapersonal emotion regulation impacts interpersonal processes (Zaki & Craig Williams, 2013). Previous work has demonstrated maladaptive and adaptive coping strategies tend to have opposing effects on interpersonal outcomes (Butler et al., 2003; Richards, Butler, & Gross, 2003). Conceptualizing brooding rumination as a maladaptive emotion regulation strategy, our findings converge in demonstrating it is associated with negative interpersonal behaviors (Study 1), reduces the mobilization of instrumental social support (Study 1), and increases interpersonal stress (Studies 2 and 3). Thus, these findings extend prior work indicating that ruminating in response to negative mood appears to negatively impact the availability of interpersonal resources, and generate interpersonal stress.

Brooding rumination has been associated with a host of maladaptive interpersonal behaviors (Nolen-Hoeksema et al., 2008) and impoverished social support resources (King & DeLongis, 2014; Nolen-Hoeksema & Davis, 1999). Previous work suggests ruminators perceive

less emotional support (Nolen-Hoeksema & Davis, 1999), and elicit more withdrawal behaviors from their partner when they ruminate (King & DeLongis, 2014). The current work considers social support across relationships and differentiates emotional and instrumental support. In doing so, it adds nuance to previous findings by demonstrating that while state rumination is associated with an increase in both instrumental and emotional support, instrumental support is selectively reduced among individuals with greater brooding rumination (Study 1). Brooding rumination may interfere with instrumental support because it is associated with perceiving problems as overwhelming, excessive venting about negative emotion, generating less effective solutions, reducing confidence in the efficacy of potential solutions, and reducing instrumental behaviors (Nolen-Hoeksema, 2008). By contrast, rumination may promote excessive emotional support mobilization that can turn into co-rumination without eventually leading to instrumental support mobilization (Nolen-Hoeksema & Davis, 1999; Nolen-Hoeksema et al., 2008; Horn & Maercker, 2016). Interpersonally, these findings suggest brooding rumination selectively decreases ability to mobilize instrumental support. Thus, convergent with other work, brooding rumination likely exacerbates negative mood by reducing support and increasing interpersonal stress (Study 2 and 3; Lam et al., 2003; McLaughlin & Nolen-Hoeksema, 2012; Stroud et al., 2015, 2018).

Supporting the conceptualization that RSA acts as a self-regulatory resource within interpersonal contexts (Porges, 2003; Thayer & Lane, 2009), greater RSA buffered the negative interpersonal consequences of brooding rumination, whether it was conceptualized as negative interpersonal behaviors (Study 1), interviewer-rated chronic stress (Study 2), or subjectively reported daily stress (Study 3). Greater RSA may assist individuals to resist urges to perform negative interpersonal behaviors that are associated with negative affect and depressed mood

(e.g. Diamond et al. 2011; Connell et al., 2011, 2015; Switzer, Caldwell, da Estrela, Barker, & Gouin, 2018). The current research also suggests some of the inconsistent findings linking rumination to interpersonal stress generation (Hamilton et al., 2017, 2013; Shapero et al., 2013) may be partially explained by individual self-regulatory capacity.

Finally, Study 3 supports a stress generation model of depression, which predicts that individual vulnerabilities, like brooding rumination, are associated with depressive symptoms via interpersonal stress (Hammen, 2003). The findings converge with prior work showing interpersonal stress and negative interpersonal behaviors mediate the association between brooding rumination and depressive symptoms (Flynn et al., 2010; Stroud et al., 2018). Furthermore, this stressful interpersonal pathway was moderated by RSA. Individuals with greater RSA are better able to limit the effects of this maladaptive intrapersonal emotion regulation strategy on interpersonal behaviors. These findings highlight the importance of self-regulatory capacity in preventing the spill-over of brooding-related negative affect into interpersonal exchanges, which may prevent a cascade of inter-related interpersonal stress and depressive symptoms.

Strengths and Limitations

The use of different assessment methods (questionnaires, daily diary, and psychophysiological data), with the aim of reducing common method variance, is a strength in the current analysis. Further, the impact of rumination and RSA converge across diverse measures of interpersonal functioning and replicate in different convenience sample populations (healthy, at-risk, and clinical) increasing the potential generalizability of the findings. The major limitation is that each analysis was cross-sectional, precluding conclusions regarding the directionality of the associations. The stress generation hypothesis suggests greater rumination-

related interpersonal stress generation will be associated with increased risk for depression over time (Hammen, 2003), and thus longitudinal models are needed to assess individual trajectories in interpersonal stress and depressive symptoms. Nonetheless, when reverse causality models were evaluated, RSA did not moderate the association between negative behaviors and rumination (Study 1), or chronic interpersonal stress and rumination (Study 2), lending some support for the proposed directionality. Likewise, models assessing reverse causality in Study 3 showed interpersonal stress did not mediate the association between depressive symptoms and rumination, and RSA did not moderate the indirect effect. Further, we highlight two limitations associated with the sample populations. Given potential gender differences in the frequency (Johnson & Whisman, 2013) and negative interpersonal effect (McLaughlin & Nolen-Hoeksema, 2012) of rumination, we note female samples used in Studies 1 and 3 are a limit to the generalizability of the findings. Additionally, while convenience samples showed consistency in the effects, more targeted sample selection would further increase generalizability. Future work should also characterize the specific self-regulatory processes related to higher RSA that buffer the association between brooding rumination and negative interpersonal behaviors.

Conclusion

The current investigation suggests the negative interpersonal consequences of brooding rumination are attenuated by greater self-regulatory capacity, as indexed by RSA. The findings offer a nuanced picture of how the interaction between rumination and self-regulation may impact both negative interpersonal behaviors and social support mobilization. Clinically, the findings are consistent with previous recommendations that interventions targeting social skills, social problem-solving, and repairing damaged social relationships would be particularly beneficial for individuals that ruminate, especially among those with lower self-regulatory capacities (Nolen-Hoeksema et al., 2008). Future studies should extend these findings using longitudinal study designs.

Table 1

Moderation of the Association between Negative Interpersonal Behaviors and Brooding Rumination by RSA (Study 1)

		95% C.I.			95% C.I.	
Variables	b	lower	upper	b	lower	upper
Intercept	-1.032	-2.265	.200	.227	-.529	.984
HR	-.002	-.012	.009	-.003	-.013	.007
Brooding	.110**	.083	.137	.112**	.086	.139
RSA	-.023	-.129	.083	-.021	-.124	.083
Brooding x RSA				-.038**	-.063	-.013

Note. * $p \leq .05$; ** $p \leq .01$; RSA = resting respiratory sinus arrhythmia; HR = resting heart rate

Table 2

Between- and Within-Person Effects of State Rumination on Daily Perceived Emotional Support (Study 1).

		95% C.I.			95% C.I.			95% C.I.	
	b	lower	upper	b	lower	upper	b	lower	upper
Fixed Effects									
Between-Person									
Intercept	1.187	1.076	1.298	1.187	1.076	1.298	.871*	.027	1.715
State Rumination (GMC)	.001	-.047	.049	.000	-.053	.053	.001	-.054	.056
Brooding				.001	-.031	.033	.003	-.029	.036
RSA							-.036	-.149	.077
HR							.004	-.007	.016
Brooding x RSA							-.008	-.036	.020
Within-Person									
State Rumination (PMC)	.020*	.001	.039	.023*	.003	.042	.025*	.005	.045
Cross-Level Interactions									
State Rumination (PMC) x Brooding				-.003	-.008	.003	-.003	-.008	.002
State Rumination (PMC) x RSA							-.002	-.021	.018
State Rumination (PMC) x Brooding x RSA							-.002	-.007	.004
		95% C.I.			95% C.I.			95% C.I.	
	estimate	lower	upper	estimate	lower	upper	estimate	lower	upper
Random Effects									
Intercept	.416**	.326	.551	.416**	.326	.551	.413**	.323	.548
Slope	.002	.000	.041	.002	.001	.033	.002	.000	.064
Autoregressive structure	.118**	.062	.174	.119**	.063	.175	.119**	.063	.176

Note. * $p \leq .05$; ** $p \leq .01$; GMC = grand-mean centered; RSA = resting respiratory sinus arrhythmia; HR = resting heart rate; PMC = person-mean centered.

Table 3

Between- and Within-Person Effects of State Rumination on Daily Perceived Instrumental Support (Study 1).

		95% C.I.			95% C.I.			95% C.I.	
	b	lower	upper	b	lower	upper	b	lower	upper
Fixed Effects									
Between-Person									
Intercept	.667**	.566	.769	.666**	.566	.767	.679	-.086	1.443
State Rumination (GMC)	.033	-.011	.076	.050*	.002	.097	.046	-.003	.096
Brooding				-.026	-.054	.003	-.023	-.053	.007
RSA							-.039	-.141	.064
HR							.000	-.010	.010
Brooding x RSA							-.006	-.032	.019
Within-Person									
State Rumination (PMC)	.01	-.007	.026	.014	-.003	.031	.017*	.000	.033
Cross-Level Interactions									
State Rumination (PMC) x Brooding				-.005*	-.010	-.001	-.006**	-.010	-.001
State Rumination (PMC) x RSA							.015	-.001	.030
State Rumination (PMC) x Brooding x RSA							-.005*	-.009	.000
		95% C.I.			95% C.I.			95% C.I.	
	estimate	lower	upper	estimate	lower	upper	estimate	lower	upper
Random Effects									
Intercept	.355**	.279	.467	.348**	.273	.458	.350**	.275	.461
Slope	.002*	.001	.012	.002	.001	.013	.001	.000	.210
Autoregressive structure	.147**	.090	.204	.147**	.090	.204	.136**	.079	.193

Note. * $p \leq .05$; ** $p \leq .01$; GMC = grand-mean centered; RSA = resting respiratory sinus arrhythmia; HR = resting heart rate; PMC = person-mean centered.

Table 4

Moderation of the Association between Chronic Interpersonal Stress and Brooding Rumination by RSA (Study 2)

		95% C.I.			95% C.I.	
Variables	b	lower	upper	b	lower	upper
Intercept	3.565*	.197	6.452	3.089	-.529	.984
Brooding	.069	-.019	.162	.089	-.007	.186
RSA	-.132	-.334	.146	-.084	-.327	.159
Brooding x RSA				-.057*	-.111	-.002
HR	-.021	-.057	.014	-.017	-.055	.021
Age	-.001	-.015	.015	.004	-.012	.019
Sex	-.178	-.681	.305	-.203	-.749	.343

Note. * $p \leq .05$; ** $p \leq .01$; RSA = resting respiratory sinus arrhythmia; HR = resting heart rate.

Table 5

Mediation and Moderated Mediation Models of the Association between Depression and Brooding Rumination, via Interpersonal Stress, Moderated by RSA (Study 3)

	Mediation					Moderated Mediation			
				95% Bootstrapped C.I. of Unstandardized Estimate				95% Bootstrapped C.I. of Unstandardized Estimate	
Variables	b	S.E.	β	lower	upper	b	S.E.	lower	upper
Outcome: Interpersonal Stress									
Caregiving status	-.022	.035	-.055	-.099	.042	-.031	.037	-.113	.034
Brooding	.158**	.045	.357**	.072	.263	.163**	.048	.075	.287
Reflection	-.109*	.046	-.247*	-.220	-.027	2.676	3.063	-3.010	10.819
RSA						-.03	.027	-.098	.019
RSA*Brooding						-.06*	.026	-.127	-.01
HR						-2.532	2.799	-9.962	2.596
Outcome: Depression									
Caregiving status	.125**	.042	.139**	.039	.207	.125**	.042	.042	.213
Interpersonal Stress	.470*	.196	.211*	.122	1.101	.458*	.204	.107	1.32
Brooding	.636**	.07	.647**	.498	.783	.634**	.07	.476	.775
Reflection	.024	.063	.024	-.113	.149	.026	.063	-.105	.154
Correlation									
Brooding with Reflection	.537**	.063	.651**	.424	.664	.537**	.063	.422	.660

Note. * $p \leq .05$; ** $p \leq .01$; Brooding, reflection, and depression are factor scores generated from the measurement model; Interpersonal stress is a latent variable; Model 1 represents the path coefficients for the indirect effects model; Model 2 represents the path coefficients for the moderated indirect effect model; Unstandardized coefficients (b), standard errors (S.E.), and standardized coefficients (β) are presented; 95% C.I. using 5000 bootstrapped samples; RSA = Respiratory sinus arrhythmia.

Figure 1. Between-person interaction of brooding rumination by respiratory sinus arrhythmia (RSA) on negative interpersonal behavior (Study 1). Low and high represent +/- 1 SD of the mean.

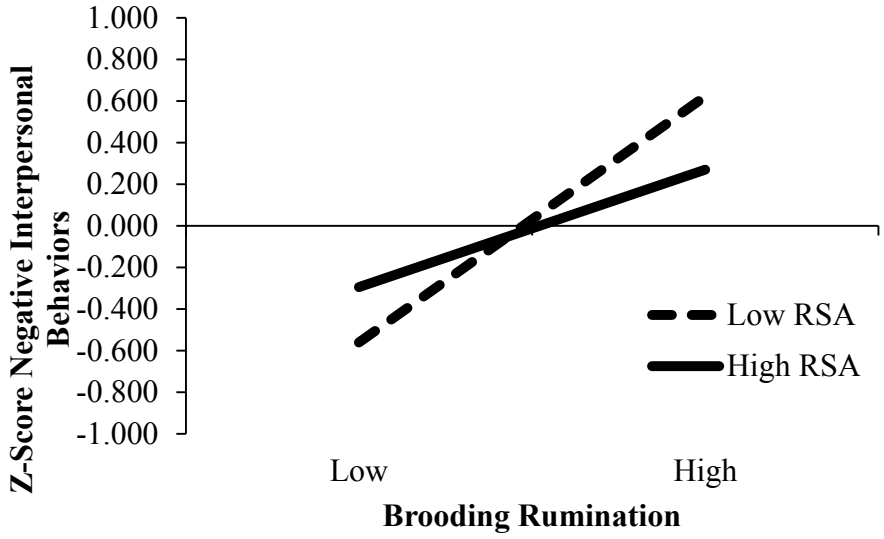


Figure 2. Interaction of brooding rumination and person-mean centered state rumination on daily perceived instrumental support (Study 1). Low and high represent +/- 1 SD of the mean

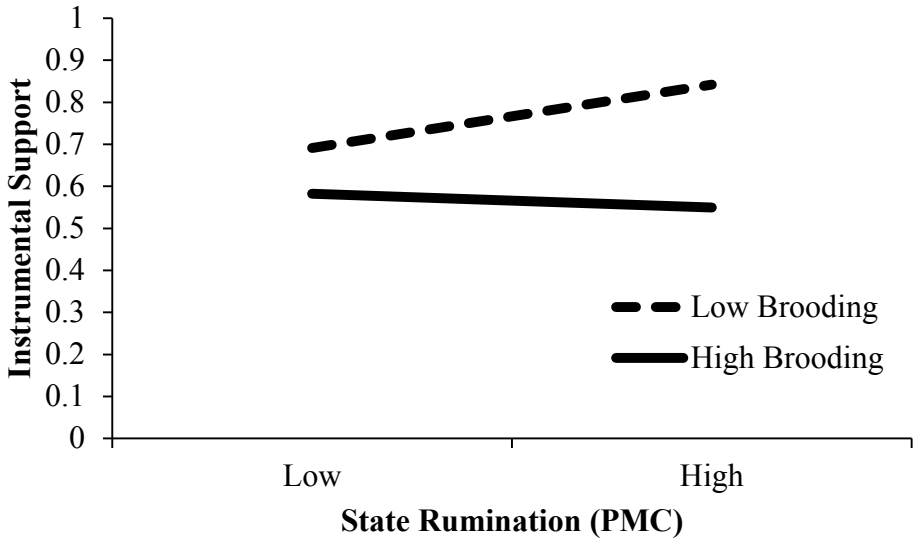


Figure 3. Interaction of brooding rumination, respiratory sinus arrhythmia (RSA), and person-mean centered state rumination on daily instrumental support (Study 1). Low and high represent +/- 1 SD of the mean.

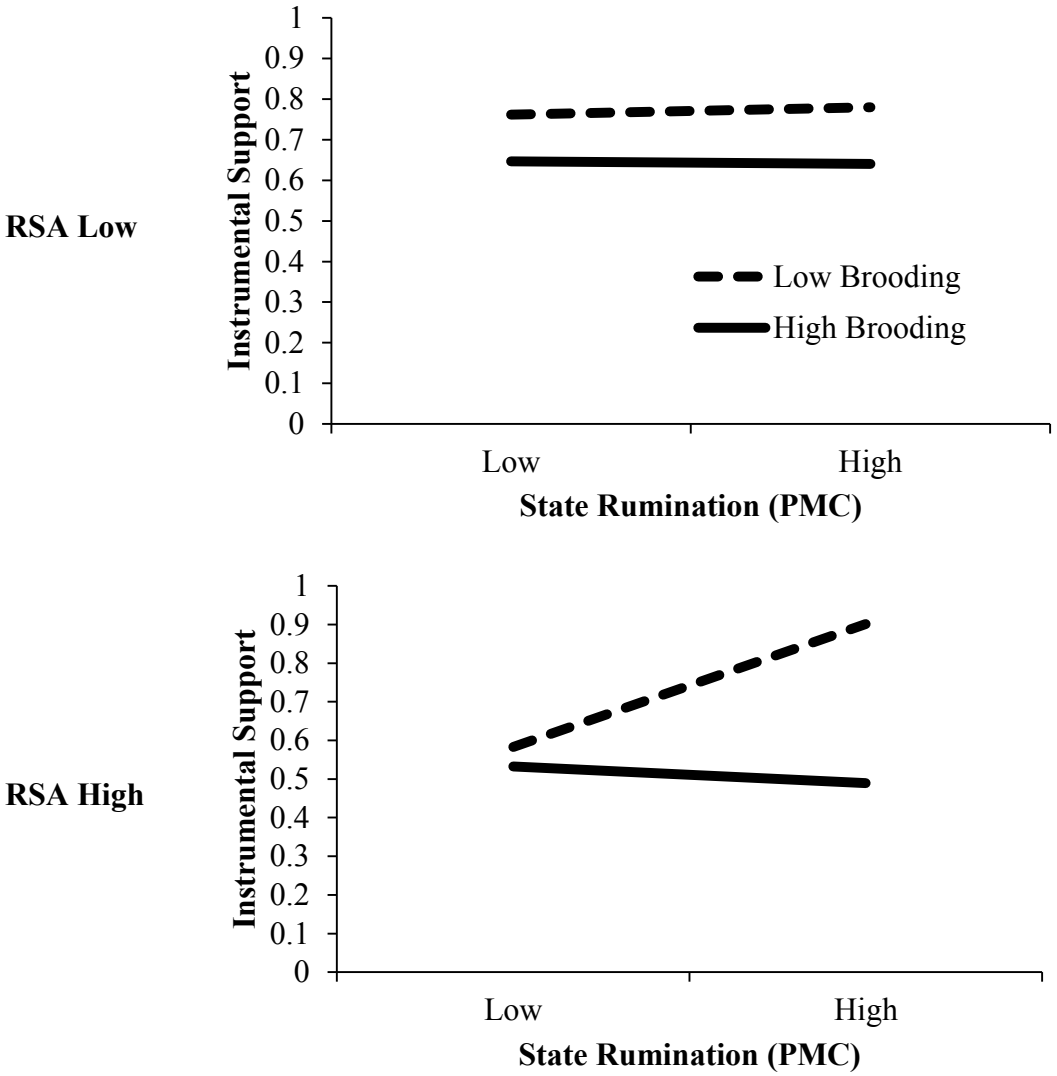


Figure 4. Interaction between brooding rumination and respiratory sinus arrhythmia (RSA) on chronic interpersonal stress (Study 2). Low and high represent +/- 1 SD of the mean.

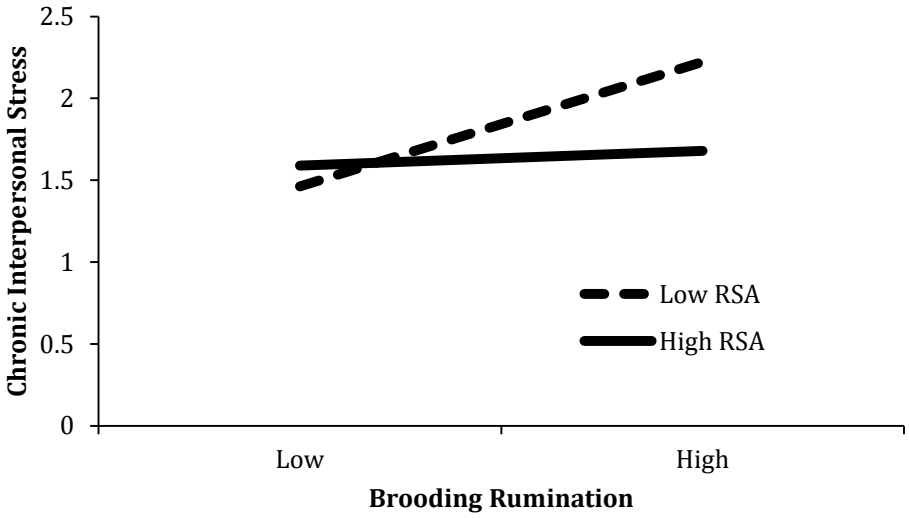
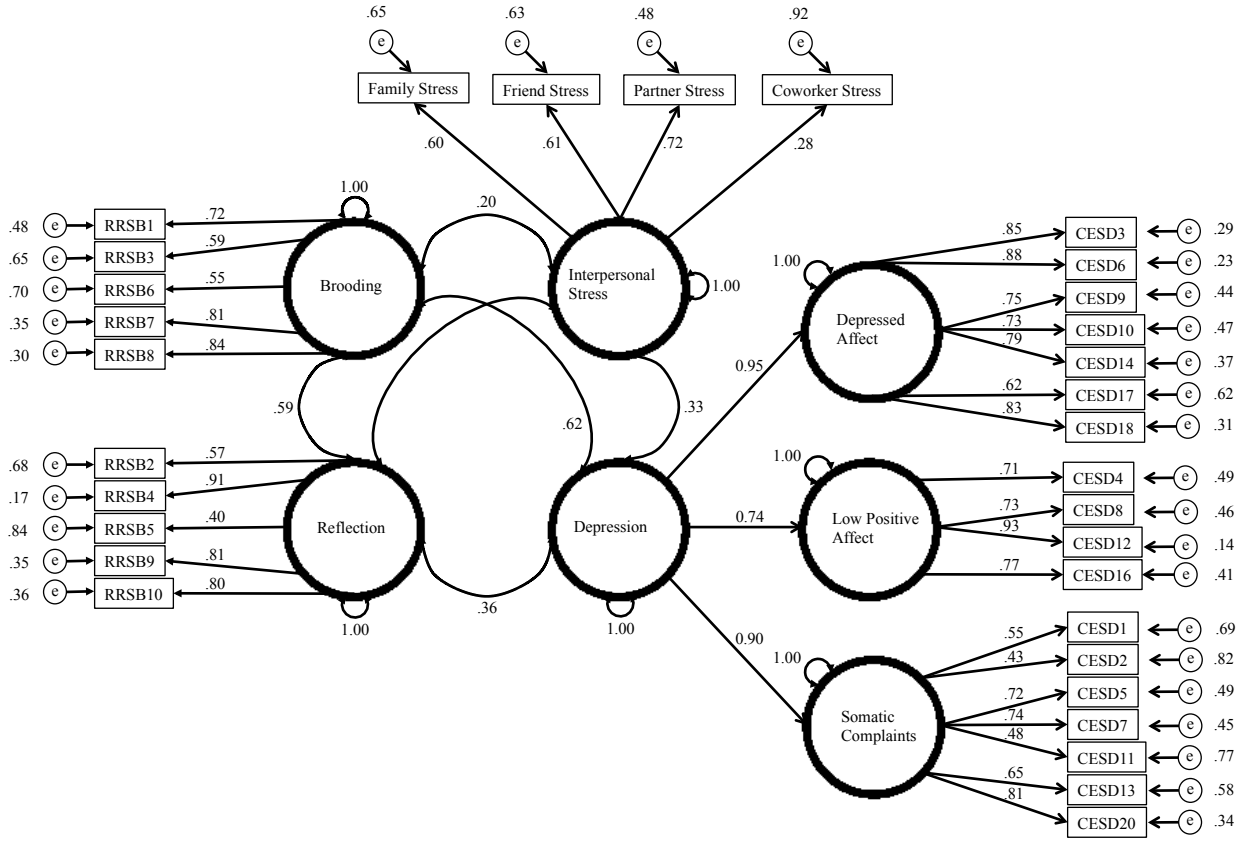


Figure 5. Measurement model with standardized uniquenesses, disturbances, factor loadings, factor variance, and higher order factor correlations.

Note. Circles represent latent variables, rectangles represent latent indicators, double headed arrows represent correlations, single headed arrows represent factor loadings, and small circles marked by an *e* and linked with an arrow represent items uniquenesses. All factor loadings significant at $p \leq .01$. All correlations depicted in the model were significant at $p \leq .01$. Non-significant correlations are not depicted.



CHAPTER THREE: MANUSCRIPT 2

Association Between Romantic Partners' Rumination and Couples' Conflict Is Moderated by Respiratory Sinus Arrhythmia

Caldwell, W., da Estrela, C., MacNeil, S., & Gouin, J.-P. (2019). Association between romantic partners ' rumination and couples ' conflict is moderated by respiratory sinus arrhythmia. *Journal of Family Psychology*, *33*(6), 640–648.

Interim Discussion

The findings from manuscript 1 confirm the negative interpersonal consequences of brooding rumination, including negative interpersonal behaviors, reduced instrumental support, and greater interpersonal stress. The association between rumination and each negative interpersonal outcome was mitigated by greater RSA. Together, the findings support hypotheses about the negative interpersonal consequences of rumination (Nolen-Hoeksema et al., 2008), and the conceptualization of RSA as a marker of intrapersonal self-regulatory capacity in social relationships (Porges, 2003; Thayer & Lane, 2009). These findings support the general hypothesis that greater RSA interacts with rumination to prevent its negative internal experience from spilling over into negative interpersonal behaviors that negatively impact social environments and reduce opportunities for interpersonal emotion regulation. However, the primary limitation in examining the interpersonal regulation of rumination from an individual perspective is that the coping and self-regulatory capacities of the other individuals within their

social network were unavailable and that interpersonal outcomes are fundamentally dyadic phenomena (Duncan, Kanki, Mokros, & Fiske, 1984). Manuscript 2 uses a dyadic design and data-analytic strategy in a sample of romantic couples to examine the mutual contributions of each couple members' brooding rumination as they contribute to conflict within the relationship, and whether RSA acts as an intrapersonal or interpersonal moderator of these associations.

Abstract

Close relationships are an important social context in which emotional experiences, regulation, and coregulation unfold. This interpersonal emotion regulation process is likely intertwined with the self- regulatory capacities and social skills of each individual dyad member. This study aimed to examine whether respiratory sinus arrhythmia (RSA), a physiological marker related to self-regulation, moderates the impact of rumination, a maladaptive emotion regulation strategy, on couples' conflict. A dyadic, longitudinal design examined the association among RSA, rumination, and couples' conflict in a sample of 83 cohabiting romantic partners raising young children. At baseline, rumination and RSA from each romantic partner were assessed. Couples' conflict was reported at 3 time points over the following 12 months. Actor–partner interdependence modeling examined the mutual contributions of each couple member's rumination to couples' conflict, as well as the moderating impact of RSA. Results indicated that rumination from both members of the dyad were independently associated with couples' conflict across the 12-month period. Furthermore, RSA moderated the association between one's partner's rumination and couples' conflict, such that high actor RSA attenuated the positive association between partner's rumination and couples' conflict. The findings highlight the

interdependent nature of emotion regulation within close relationships, and the impact of RSA on interpersonal emotion regulation processes.

Introduction

Close relationships represent an important social context in which emotional experiences, regulation, and coregulation unfold (Zaki & Craig Williams, 2013). Salient emotions may trigger verbal and nonverbal communicative behaviors that serve as signals for supportive partners, whose responses may alter the trajectory of their own and/or their partner's affect (Zaki & Williams, 2013). This interpersonal emotion regulation process is intertwined with the self-regulatory capacities and social skills of each individual dyad member (Verhofstadt, Ickes, & Buysse, 2010), highlighting the importance of understanding the consequences of individual emotion regulation strategies within their social context. Rumination is an emotion regulation strategy that is characterized by repetitive, passive, self-focused cognition about the causes and consequences of emotional distress (Nolen-Hoeksema et al., 2008). In addition to exacerbated dysphoria, rumination has been associated with behaviors that promote social friction (Nolen-Hoeksema & Davis, 1999), and is theorized to erode social support (Nolen-Hoeksema et al., 2008). Given that romantic partners often act as a primary source of social support (Gariépy, Honkaniemi, & Quesnel-Vallée, 2016), they represent an important social context in which rumination occurs. In this dyadic context, the self-regulatory capacities of either partner may then moderate the impact of rumination within the relationship. Respiratory sinus arrhythmia (RSA) is hypothesized to index a neurophysiological system that supports self-regulation and affiliative behaviors (Porges, 2003; Thayer & Lane, 2009), and may influence the maladaptive interpersonal consequences of rumination. The goal of this study is to examine the mutual contributions of both partners' rumination to couples' conflict, and to examine the moderating effect of RSA.

Rumination and Social Functioning

Nolen-Hoeksema et al. (2008) posited that rumination is associated with the degradation of interpersonal relationships due to its associations with maladaptive social behaviors. Examples of maladaptive behaviors linked to rumination include excessive reassurance seeking (Stroud et al., 2018; Weinstock & Whisman, 2007); excessive concern about the emotions of others (Nolen-Hoeksema & Jackson, 2011); poor interpersonal problem solving (Lyubomirsky & Nolen-Hoeksema, 1995); greater motivation to continue arguments (Carr et al., 2012); and revenge-seeking and aggressive behaviors following interpersonal transgressions (Collins & Bell, 1997; Watkins et al., 2015). Mounting evidence also suggests that greater rumination is cross-sectionally associated with interpersonal stress (Lam et al., 2003), and prospectively predicts interpersonal stress generation (McLaughlin & Nolen-Hoeksema, 2012; Stroud et al., 2015, 2018) and decreased relationship satisfaction over time (Pearson et al., 2010). Daily rumination is also associated with concurrent partner ratings of marital tension and withdrawal (King & DeLongis, 2014), highlighting the negative impact of rumination on the social environment. Furthermore, maladaptive responses within close relationships, such as co-rumination, increased the strength of the association between rumination and interpersonal stress generation (Bouchard & Shih, 2013; Rose et al., 2017). Conversely, higher levels of social support attenuate the association between rumination and negative mood (Marroquín & Nolen-Hoeksema, 2015; Nolen-Hoeksema & Davis, 1999; Puterman, DeLongis, & Pomaki, 2010), indicating that responses from the social environment may moderate the impact of rumination.

RSA, Self-Regulation, and Social Behavior

RSA has been conceptualized as a biomarker associated with self-regulation and social behaviors. It represents the magnitude of the oscillations in time intervals between consecutive heartbeats associated with respiration (Berntson et al., 1997). The heart is under tonic inhibitory

control by the parasympathetic nervous system. The parasympathetic output travels from the brain to the heart via the vagus nerve. This vagal inhibition fluctuates during the respiration cycle. It is gated during inhalation, and resumes during exhalation, creating increases and decreases in heart rate across the respiratory cycle. The magnitude of the change in heart rate associated with the respiratory cycle reflects the magnitude of vagal inhibition and its related level of parasympathetic activity. Importantly, the brain stem nuclei regulating the vagus nerve are themselves influenced by a network of cortical, limbic, and brain stem structures that integrate input from sensory organs, visceral afferents, and cortical structures to coordinate cardiac activity with situational demands (Benarroch, 1993). Thus, RSA has been conceptualized as an indicator of the parasympathetic output of an integrated neurophysiological system supporting self-regulation and affiliative behaviors (Porges, 2003; Thayer & Lane, 2009). Porges' polyvagal theory is a phylogenetic model positing that the neural circuits regulating the autonomic nervous system also evolved to support social behaviors (Porges, 2003). Polyvagal theory cites that common brain-stem nuclei that regulate cardiac activity also influence facial muscles and sensory organs that are required for social engagement. The coregulation of visceral states, facial muscles, and sensory organs allowed the coordination of somatic arousal, visual perception, audition, vocalization, and facial gestures. RSA is thus conceptualized as a biomarker of an integrated social engagement system supporting affiliative behaviors.

In a complementary theory, the neurovisceral integration model (Thayer & Lane, 2009), the ability to effectively organize behavior in response to situational demands is supported by greater tonic prefrontal inhibition over limbic brain regions (e.g., amygdala), which is concomitant with greater parasympathetic signaling toward the heart. The theory emphasizes that the tonic inhibitory influence of the frontal cortex within these neural circuits facilitates flexible

organismic responding to situational demands, thereby supporting a range of self-regulation behaviors. Thus, these two complementary theories delineate that the capacity for self-regulation and social engagement may be rooted in a shared neurophysiological system, which can be indexed by tonic RSA.

Empirical evidence supports the hypothesis that tonic RSA assessed during resting wakefulness is a physiological trait that has been related to greater capacity for self-regulation, broadly defined (reviewed in Balzarotti et al., 2017). For example, greater RSA at rest has been associated with less negative affect in response to naturalistic stressors (Fabes & Eisenberg, 1997; Gouin et al., 2014) as well as faster emotional and physiological recovery following the cessation of emotional laboratory stressors (Diamond & Hicks, 2005; Souza et al., 2007). Furthermore, greater RSA at rest has been associated with more effective suppression of negative intrusive thoughts during a laboratory task, which mediated the association between RSA and negative emotion (Gillie et al., 2015).

Empirical evidence also supports associations between tonic RSA and affiliative behaviors. RSA has been associated with the ability to control the facial expression of certain emotions (Tuck et al., 2016), and better emotion recognition (Quintana et al., 2012). Importantly, RSA at rest has been associated with the maintenance of affiliative behaviors, even in the context of elevated negative affect. During adolescent–parent interactions, greater adolescent or parent RSA at rest weakened the relationship between maternal depressive symptoms and observed negative affect (Connell et al., 2011), and were related to de-escalating patterns of negative affect among dyads when a parent reported more depressive symptoms (Connell et al., 2015). Similarly, developmental increases in adolescent RSA at rest predicted increases in adolescent warmth during conflict with a parent (Diamond & Cribbet, 2013). Greater RSA at rest also

weakened the association between rejection sensitivity and hostile conflict behaviors and attenuated the association between negative dyadic coping and depressive symptoms in romantic couples (Gyurak & Ayduk, 2008; Switzer et al., 2018). Similarly, in a daily diary study of married couples, men with greater RSA at rest showed a weaker relationship between their own daily ratings of negative affect and their partners' ratings of negative interactions (Diamond et al., 2011), suggesting that RSA was associated with less spill-over of negative affect into marital exchanges. Thus, greater tonic RSA may enhance social engagement by preventing the escalation of negative affect into negative social behaviors.

Parenting Young Children: A Stressful Developmental Transition

The consequences of rumination and RSA may be particularly salient during stressful life events. Parents of young children report a normative increase in psychosocial stress associated with the demands and time constraints required for childcare, increased strain between parents, and greater work–family conflict (Umberson, Pudrovska, & Reczek, 2010). Longitudinal increases in marital conflict and decreases in marital quality are also reported in this context (Crohan, 1996; Keizer & Schenk, 2012). Furthermore, given that each dyad member is part of the social context in which his or her partner's emotion regulation strategies unfold, this developmental transition provides an ideal context in which to examine the mutual contributions of each partner's rumination and the moderating role of tonic RSA. We hypothesize that greater rumination in either partner will be associated with greater couples' conflict, and that either partner's tonic RSA could moderate this effect, with higher RSA attenuating the association between rumination and couples' conflict.

Method

Participants

The study sample included 84 cohabiting, heterosexual couples. To be included in the study, couples were required to be the legal guardian of a child under the age of 7. Children with neurodevelopmental disorders were oversampled (21.70% of dyads) in order to increase the range of parenting challenges within the sample. Participants were recruited via online advertisements as well as through schools and support groups for parents of children with developmental disabilities. Participants were excluded if they were pregnant or nursing, had a chronic medical condition, or took prescribed medication on a regular basis to limit the impact of these confounding factors on RSA. Participants had a mean age of 34.60 (*SD* = 4.70) and were primarily White (55.36%). The majority of couples had one or two children (92.90%), had been together for an average of 9 years (*SD* = 4.32), and had an average household income of $55,000 (*SD* = $8,900) CAD.

Procedure

Participants first completed online self-report questionnaires assessing couples' conflict and rumination. Then, they participated in a laboratory visit to assess RSA. Participants were asked to refrain from consuming caffeine, alcohol, or tobacco, or engaging in vigorous exercise in the two hours prior to the laboratory session, as these behaviors can impact RSA assessment (Berntson et al., 1997). During the laboratory visit, couples were seated side by side in comfortable chairs and fitted with snap electrodes in a lead II configuration for electrocardiograph (ECG) recording. They first underwent a resting wakefulness period followed by a few experimental tasks to assess tonic RSA across different situations. Participants were asked to remain seated, limit movement and postural changes, and breathe normally throughout

the recording period in order to limit factors that may confound the association between tonic RSA and cardiac vagal tone (Berntson et al., 1997). Specifically, both members of each couple simultaneously underwent a 5-min seated and silent resting period where participants were instructed to "breathe normally and relax as much as possible without falling asleep"; a 5-min questionnaire about their child's behavior problems; a marital interaction task in which each dyad member was instructed to take turns leading a 7-min discussion about "the most difficult aspect of raising young children and how it has impacted your relationship with your partner," as well as how they would like their partner "to change regarding the way they raise your child," a procedure adapted from Roberts, Tsai, and Coan (2007); and a 5-min silent and seated recovery period. A retractable curtain separated the participants during the resting baseline and recovery periods to prevent interaction between partners. During the marital interaction, participants were prompted to continue the discussion during the 7-min duration. When self-reported affect on visual analogue scales following the marital interaction was compared to baseline, the mean level of negative affect reported (anxiety, worry, sadness, anger, shame) decreased after the marital interaction ($t = 3.705$, $p < .001$), and the level of happiness reported did not change ($t = -.344$, $p < .731$), suggesting this was, on average, an affectively neutral or positive dyadic interaction.

Subsequently, couples' conflict was reassessed using online questionnaires 6 months and 12 months later. Eight dyads did not provide data at Time 2, and 3 dyads did not provide data at Time 3. One dyad did not provide a report of couples' conflict at all three time points, and was therefore removed from the current analysis. The final sample size for this study was 83 couples. This study received approval from the Concordia Human Research Ethics Committee. Both members of each couple provided written informed consent prior to participation. Each couple received $100 CAD following the completion of the study.

Measures

Couples' conflict. Couples' conflict was assessed with the Test of Negative Social Exchange (TENSE; Ruehlman & Karoly, 1991) adapted for romantic couples (Repetti, 1989). A total score of the 19 items was used to assess the degree to which each participant reported that their partner ridiculed them, was hostile, was insensitive, or interfered with their goals. Responses were rated on a 9-point Likert- type scale from *not at all* to *frequently*. Internal consistency for the total score was excellent with a range of $\alpha = .92$ to .94 across the three time points in the current sample.

Rumination. Rumination was assessed with the brooding sub-scale of the Ruminative Response Scale (Treynor et al., 2003). The 5-item subscale assesses the frequency that individuals engage in moody pondering when they are feeling sad, down, or depressed (e.g., "think about a recent situation, wishing it had gone better"). Responses were rated on a 4-point Likert-type scale from *almost always* to *almost never*. Internal consistency for the brooding subscale was moderate ($\alpha = .75$).

Respiratory sinus arrhythmia. Cardiac activity was measured as part of the 60-min laboratory visit described above. Data were collected using an ECG amplifier module within a Mindware BioNex 8-slot chassis (Mindware Technologies, Ltd., Gahanna, OH). Interbeat intervals were recorded continuously using a sam- pling rate of 1000 Hz. The ECG recordings were analyzed using MindWare HRV Analysis software, Version 3.1. Physiologically improbable interbeat intervals were identified using a validated automated algorithm (Berntson, Quigley, Jang, & Boysen, 1990), and were visually inspected and corrected when necessary. Less than 1% of beats were edited for each participant. The high-frequency component of the heart rate variability spectrum that falls within the plausible range of respiration, corresponding

to RSA, was extracted using a Hamming windowing function, followed by Fast Fourier Transformation using a .15–.40-Hz frequency band. The natural log of each 30-s epoch of the recording was computed to isolate vagal-dependent parasympathetic influences on the heart. RSA was calculated by averaging the RSA value for each 30-s epoch (Berntson et al., 1997) across all task periods[1] as a marker of overall cardiac vagal tone[2].

Data Analytic Strategy

Using the multilevel modeling strategy outlined in Kenny, Kashy, and Cook (2006), we fit a dyadic growth curve model to estimate the trajectory of couples' conflict over the 1-year study period. This approach allows for a correlation between partners' reports and accounts for nonindependence across time. Next, we tested for a gender interaction effect to determine whether males or females differed in their reported trajectories of couples' conflict over time. Given that there was no significant change in couples' conflict over time, the random effect was estimated to be near 0, and no gender interaction effects were detected, the average couples' conflict across the three time points was predicted in subsequent analyses (see results below). Next, a series of actor–partner interdependence (APIM) models (Kenny et al., 2006) estimated the associations between actor and partner rumination and actor–reported couples' conflict. The moderating impact of actor and partner RSA and potential gender differences among these

[1] Repeated measures ANOVA and pair-wise comparisons between the different tasks suggest that resting, marital interaction, and recovery elicited statistically equivalent RSA, but RSA suppression was detected while completing the questionnaire relative to the other three conditions (RSA suppression relative to baseline = -.54, $t = 8.96$, $p < .001$).

[2] All analyses were repeated using RSA calculated over the 5-minute resting period and RSA level during the marital interaction, which showed an identical pattern of results as the averaged RSA value across all tasks. Additionally, RSA reactivity (RSA at rest–RSA during task) to the questionnaire and marital interaction task were tested as moderators, in separate models, but no significant interaction effects with actor or partner rumination were detected.

associations were then estimated (see Figure 6). This analytic strategy, which uses multilevel modeling, was selected because it accounts for within-couple dependency in the data structure. In this analysis, the multilevel structure comprises individuals at level 1, nested within dyads at level 2. Thus, each dyad member is treated as a repeated measure. A heterogeneous compound symmetry covariance structure was selected for the current analysis because it allows for the estimation of unique variance of each dyad member, while constraining the covariance between dyad members to be equal. Given the substantial literature indicating sex differences in the tendency to ruminate (Nolen-Hoeksema et al., 2008), a gender moderation approach was chosen to explicitly test for potential sex differences in the data.

In an APIM model, the main effects of actor and partner rumination with actor-reported couples' conflict were first estimated (Table 7, Model 1). In the APIM model, all individual data was arranged in a pairwise dataset with every individual's and their partner's reported rumination and conflict on every line. Next, we tested whether the strengths of these relationships were moderated by actor or partner RSA (Table 7, Model 2). Here, there are four possible moderation effects predicting actor's reported couples' conflict: (1) actor rumination moderated by actor RSA, (2) actor rumination moderated by partner RSA, (3) partner rumination moderated by actor RSA, and (4) partner rumination moderated by partner RSA. Subsequent moderation models tested whether these associations significantly differ by gender (women coded as 1, men coded at -1; Table 7, Model 3). Following statistically significant interactions, simple slopes analyses were conducted by plotting the change in strength of the relationship between rumination and couples' conflict at two levels of the moderator, RSA (1 *SD* above and below the mean). All continuous variables were centered. RSA was normally distributed, but couples' conflict showed a slight negative skew, which was corrected using a square-root

transformation. The pattern of results did not change substantially when transformed variables were used. Therefore, the untransformed analyses are presented for greater interpretability. SAS PROC MIXED was used to perform multilevel modeling with maximum likelihood estimation, and the alpha level was set at $p < .05$.

Results

First, a growth curve model indicated couples' conflict did not change significantly over one year in the current sample (b = .52, t = 1.63, p = .11), and that the variability in the trajectory of couples' conflict was estimated to be near 0. Next, the main effect of gender and interaction effect of time*gender were added to the model but the interaction effect was not significant (b = .03, t = .07, p = .94). Therefore, we used the mean couples' conflict score of each dyad member across the three time points to characterize negative marital interactions over one year. Table 6 presents the descriptive statistics, including the means and *SD*, and Pearson's bivariate correlations among couples' conflict, rumination, and RSA. There was a strong intraclass correlation on couples' conflict (*ICC* = .71), suggesting a high degree of agreement between romantic partners regarding the frequency of negative marital interactions. In contrast, rumination (*ICC* = .25) and RSA (*ICC* = .01) were not strongly correlated within couples. For both men and women, there were significant positive correlations between couples' conflict and their own and their partner's rumination, as well as significant positive correlations between actor- and partner-reported couples' conflict. There were no significant bivariate associations with RSA.

Table 7 presents the APIM models of actor and partner rumination predicting the mean actor-reported couples' conflict across one year. Model 1 shows significant main effects of both actor and partner rumination. Actor and partner rumination were independently associated with couples' conflict, such that greater actor and partner rumination were both associated with more couples' conflict. In Model 2, actor and partner RSA were added as moderators. No significant main effects of actor or partner RSA on couples' conflict were detected. However, there was a significant interaction between actor RSA and partner rumination. No other significant

interactions were detected. The fit statistics indicate that including the interaction terms substantially improved the model fit compared to Model 1. When the interaction was decomposed, actors with lower RSA had a significant positive linear association between partner rumination and actor-reported couples' conflict ($b = 1.45$, $SE = .33$, $t = 4.39$, $p < .0001$), but the association was not significant for actors with higher RSA ($b = .26$, $SE = .36$, $t = .73$, $p = .46$). In sum, both actor and partner rumination contribute to actor-reported couples' conflict, but the association between partner rumination and actor-reported couples' conflict is moderated by actor RSA. Figure 6 depicts the interaction between partner's rumination and actor's RSA predicting couples' conflict. In Model 3, gender was added as a third moderator. While the level of couples' conflict that was reported was marginally greater for males than females, the association between actor and partner rumination and actor-reported couples' conflict was not significantly moderated by gender. Furthermore, there were no significant three-way interactions among actor or partner rumination, actor or partner RSA, and gender. All models were also estimated after adjusting for participant age and length of the relationship. Covariates did not substantially change the pattern of results, and so the unadjusted models were reported for parsimony.

Discussion

The current investigation examined the interdependence among romantic partners' rumination and couples' conflict as well as the moderating effects of RSA and gender. Each couple member's rumination was independently associated with couples' conflict. There were no main effects of actor or partner RSA on couples' conflict. Actor RSA moderated the association between partner rumination and couples' conflict, but not the association between actor rumination and couples' conflict. Partner RSA did not moderate the associations between rumination and couples' conflict. None of these associations were moderated by gender. These results indicate that when actor RSA was higher, there was a smaller association between partner rumination and actor-reported couples' conflict. These findings provide further evidence that rumination is associated with impaired social functioning and highlight the role of the social context in moderating these outcomes. Furthermore, our findings suggest that RSA may modulate interpersonal emotion regulation processes.

The findings support the hypothesis that rumination is associated with greater interpersonal stress and deleterious consequences for close relationships (McLaughlin & Nolen-Hoeksema, 2012; Stroud et al., 2015). Both actor and partner rumination had independent effects on the perception of couples' conflict, showing that the maladaptive emotion regulation strategies of each partner impacted the other partner's perception of couples' conflict. Our findings expand upon previously established associations between daily rumination and partner-rated marital tension (King & DeLongis, 2014) by providing evidence that each partner's rumination is an important predictor of couples' conflict. Rumination may be associated with greater couples' conflict through several mechanisms, including poorer social problem-solving abilities (Lyubomirsky & Nolen-Hoeksema, 1995), greater revenge seeking and aggressive

behaviors (Collins & Bell, 1997; Watkins et al., 2015), or greater motivation to continue arguing (Carr et al., 2012). More broadly, rumination enhances negative moods, and disrupts problem-solving and instrumental behaviors (Nolen-Hoeksema et al., 2008), which may also provide more opportunities for disagreement.

The finding that greater actor RSA weakened the association between partner rumination and actor-reported couples' conflict is consistent with theory that links RSA to self-regulatory capacity and social behaviors (Porges, 2003; Thayer & Lane, 2009). This could be because greater RSA confers less negative emotional reactivity (Fabes & Eisenberg, 1997; Gouin et al., 2014) to the stressful interpersonal behaviors associated with rumination (Carr et al., 2012; Collins & Bell, 1997; Lyubomirsky & Nolen- Hoeksema, 1995; Nolen-Hoeksema & Jackson, 2011; Stroud et al., 2018; Watkins et al., 2015; Weinstock & Whisman, 2007). Similarly, individuals with greater RSA may have greater capacity to prevent the negative affect that is initiated by their ruminating partners' negative interpersonal behaviors from spilling over into their own communicative behaviors (Connell et al., 2011; Diamond et al., 2011; Switzer et al., 2018). This capacity may be particularly relevant for partners of individuals who ruminate, as rumination is also associated with aggression following interpersonal transgression (Collins & Bell, 1997; Watkins et al., 2015) and greater motivation to pursue arguments (Carr et al., 2012). Furthermore, individuals who ruminate tend to seek out social support more often, but perceive more criticism and less emotional support from their social networks (Nolen-Hoeksema & Davis, 1999), and also dwell excessively on the emotional states of others (Nolen-Hoeksema & Jackson, 2011). Partners with greater RSA may respond to the needs of individuals who ruminate more effectively, as they demonstrate better emotion recognition (Quintana et al., 2012), better empathic accuracy (Côté et al., 2011), and greater control over emotive facial expressions (Tuck

et al., 2016). Thus, there are several potential mechanisms through which greater RSA can prevent couples' conflict associated with a partner's rumination.

These findings intersect with a growing body of evidence that highlights the role of the interpersonal context in emotion regulation (Zaki & Williams, 2013). Indeed, the social context can modulate the impact of deleterious maladaptive emotion regulation strategies (Puterman et al., 2010). For instance, Marroquín and Nolen-Hoeksema (2015) observed that greater trust and intimacy within one's romantic relationship buffered the association between maladaptive emotion regulation strategies and depressive symptoms. Similarly, the present findings suggest that individuals with greater RSA are better able to prevent the negative behaviors associated with their partner's maladaptive emotion regulation from spilling into their romantic relationship. Rumination may also fuel a vicious cycle of marital tension and avoidance, where rumination and marital tension become more strongly associated when marital partners withdraw from each other (King & DeLongis, 2014). Individuals with lower RSA who exhibit less self-regulation in the face of interpersonal stress may have difficulty disengaging from this negative interpersonal pattern (Diamond et al., 2011; Porges, 2003). Future research should focus on elucidating the specific behaviors of high RSA individuals that buffer the negative interpersonal consequences of their partner's brooding rumination.

The current investigation did not find a significant bivariate association between RSA and trait rumination. This is consistent with meta-analytic evidence indicating that the association between RSA and perseverative cognition, including rumination, is stronger with state measures compared to trait measures (Ottaviani et al., 2015). Relatedly, while actor RSA weakened the association between partner rumination and actor-reported couples' conflict, actor RSA did not impact the association with actor rumination, and partner RSA did not impact the

association between either actor or partner rumination and actor-reported couples' conflict. One explanation for this pattern of results may be that the skills and abilities required to personally disengage from rumination are different than those that are required to regulate a ruminating partner. Given the modest sample size relative to the number of interaction effects tested, future work could attempt to replicate the specificity of the actor and partner moderation effects, while simultaneously attempting to elucidate the related interpersonal mechanisms. Likewise, we did not find gender differences in the associations among rumination, RSA, and couples' conflict, or the interactions between rumination and RSA. Meta-analytic evidence suggests that rumination is slightly more common in women than men (Johnson & Whisman, 2013), and one study indicates that rumination leads to more problematic communication with peers for adolescent girls than boys (McLaughlin & Nolen-Hoeksema, 2012). However, other studies indicate that the dysphoria and interpersonal behaviors associated with rumination are probably similar across genders (Lyubomirsky & Nolen-Hoeksema, 1995; Michl, McLaughlin, Shepherd, & Nolen-Hoeksema, 2013; Weinstock & Whisman, 2007). Further research into sex-specific effects of rumination on interpersonal stress is warranted, as most data have focused primarily on actor effects (King & DeLongis, 2014; McLaughlin & Nolen-Hoeksema, 2012; Stroud et al., 2015). Thus, while rumination may be sex-linked, the current data suggest that the social consequences of rumination within close relationships appear similar for men and women.

In the current study, potential respiratory influences on the RSA metric were not assessed. Some have argued that changes in respiration may attenuate the association between RSA and cardiac vagal control (Grossman & Taylor, 2007). Potential concern about the lack of statistical or experimental control of respiration when calculating RSA may be mitigated in the current sample because we did not detect an average change in RSA between the resting period

and the discussion task, and RSA during both of these periods moderated the partner effect of rumination on couples' conflict. These results are consistent with the meta-analytic findings that positive or neutral social interactions do not cause reliable changes in RSA (Shahrestani, Stewart, Quintana, Hickie, & Guastella, 2015). Furthermore, prior work indicates that under seated, resting conditions, RSA estimates of vagal tone are significantly affected by differences in spontaneous respiratory rate (Lewis, Furman, McCool, & Porges, 2012). Additionally, statistical adjustment for respiration did not change the strength of the association between RSA and children's social functioning in a meta-analysis (Graziano & Derefinko, 2013). Furthermore, unexpectedly, phasic change in RSA was observed during the completion of the child behavior questionnaire. This may reflect the increased cognitive load during this task (Overbeek, Van Boxtel, & Westerink, 2014). RSA reactivity was not associated with rumination or couples' conflict. This lack of association may be due to the fact that the functional consequences of RSA reactivity may vary as a function of the task used to elicit phasic RSA changes (Fortunato, Gatzke-Kopp, & Ram, 2013; Rottenberg, Salomon, Gross, & Gotlib, 2005).

The major strengths of the current investigation were the dyadic design in combination with actor–partner interdependence modeling. Both were critical in characterizing the interdependence of couple members' mutual contributions to couples' conflict. Although changes in couples' conflict over time were assessed, they were stable across the one-year study period in the current sample. Thus, the most important limitation of the current analysis is that it is cross-sectional, so causality between rumination and couples' conflict cannot be established. It is also possible that greater couples' conflict is associated with greater rumination in each couple member, and actors' RSA decreased the association between couples' conflict and partners' ruminative responses. This alternative interpretation of the present findings is consistent with

data and theory indicating rumination is a response to stress (Lyubomirsky, Layous, Chancellor, & Nelson, 2015), and empirical data showing lower RSA catalyzed negative conflict behaviors, such as hostility, which are interpersonally stressful (Gyurak & Ayduk, 2008; Sloan et al., 1994; Smith et al., 2011). Furthermore, the findings are unable to clarify the timing, fluctuation, or duration of the associations between rumination and the trajectory of couples' conflict over time, as well as the moderating impact of RSA. Future work could use a longer follow-up period to better understand how these findings contribute to developmentally normative trajectories of marital conflict, which have already been documented in the literature (Crohan, 1996). We also note limits to generalizability, as the sample comprised only parents of young children. While this context was selected to expound the significance of emotion regulation, it is imperative that future work replicate these findings in more representative samples.

The study results also suggest several other future research directions. The current work has focused on trait measures of rumination and vagal regulation. Both polyvagal theory and the neurovisceral integration model point to mechanisms by which RSA is hypothesized to moderate the association between rumination and couples' conflict. Potential mechanisms include better empathic accuracy, executive functioning, or greater self-regulation (broadly defined) that may promote greater perceived partner responsiveness and more effective strategies to deal with the partner's maladaptive emotion regulation strategies and their associated negative interaction patterns (Reis, 2012). Furthermore, state levels of rumination and RSA are more strongly associated than trait measures (Ottaviani et al., 2016), yet the social consequences of moment-to-moment associations of RSA with situation-specific rumination have not yet been described. Longitudinal and dyadic daily diary data could be used to delineate the specific behaviors that underlie the associations observed in the current study across different social contexts.

Concomitant physiological recordings could also clarify the significance and timing of state measurements of rumination and RSA to couples' conflict.

The current investigation found that both couple members' tendencies to engage in rumination contributed to greater couples' conflict, and that actor RSA moderated the association between partner- and actor-reported couples' conflict. The findings highlight the interdependent nature of maladaptive emotion regulation strategies and the role of the romantic partner in modulating the consequences of maladaptive emotion regulation strategies within close relationships. The findings also suggest that RSA may influence interpersonal emotion regulation processes.

Table 6

Descriptive statistics and Pearson's correlations

	1	2	3	4	5	6
1. Actor Conflict	-	.270*	-.162	.570**	.255*	-.103
2. Actor Rumination	.356**	-	-.075	.332**	.172	-.134
3. Actor RSA	-.119	-.101	-	-.026	-.07	.065
4. Partner Conflict	.570**	.255*	-.103	-	.356**	-.119
5. Partner Rumination	.332**	.172	-.134	.270*	-	-.101
6. Partner RSA	-.026	-.07	.065	-.162	-.075	-
Mean (SD) Men	19.65 (10.16)	10.21 (2.77)	6.09 (0.97)	17.53 (11.15)	11.24 (3.4)	6.54 (0.82)
Mean (SD) Women	17.53 (11.15)	11.24 (3.4)	6.54 (0.82)	19.65 (10.16)	10.21 (2.77)	6.09 (0.97)

** $p < 0.01$; * $p < 0.05$

Note. Correlations for men are presented below the diagonal and correlations for women are presented above the diagonal. Actor effects represent the participant's own rating, whereas the partner effects represent the participant's spouse's rating.

Table 7

Actor and partner effects of rumination, respiratory sinus arrhythmia, and gender on couples' conflict.

	Model 1		Model 2		Model 3	
Fixed Effects	*b*	*SE*	*b*	*SE*	*b*	*SE*
Intercept	18.91***	0.93	18.35***	0.94	18.46***	1.06
Actor Rumination	0.91***	0.24	0.87***	0.24	0.87***	0.27
Partner Rumination	0.95***	0.23	0.86***	0.24	0.80***	0.26
Actor RSA			-0.74	0.85	-0.66	0.91
Partner RSA			0.34	0.86	0.041	0.90
Actor Rumination*Actor RSA			-0.06	0.27	0.16	0.29
Partner Rumination*Actor RSA			-0.64*	0.27	-0.78*	0.32
Actor Rumination*Partner RSA			-0.36	0.28	-0.41	0.32
Partner Rumination*Partner RSA			-0.97	0.27	-0.11	0.29
Gender					-1.18^{t}	0.61
Actor Rumination*Gender					-0.35	0.29
Partner Rumination*Gender					0.09	0.28
Actor RSA*Gender					-0.76	0.91
Partner RSA*Gender					-0.14	0.91
Actor Rumination*Actor RSA*Gender					0.23	0.28
Partner Rumination*Actor RSA*Gender					-0.20	0.31
Actor Rumination*Partner RSA*Gender					-0.25	0.31
Partner Rumination*Partner RSA*Gender					-0.12	0.28
Fit Statistics	Estimate		Estimate		Estimate	
AIC	1205.6		1198.6		1190.6	
BIC	1212.9		1205.9		1197.9	

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; t $p < 0.1$

Figure 6. Actor-partner interdependence model of rumination predicting couples' conflict and the moderation effects of respiratory sinus arrhythmia (RSA) and gender.

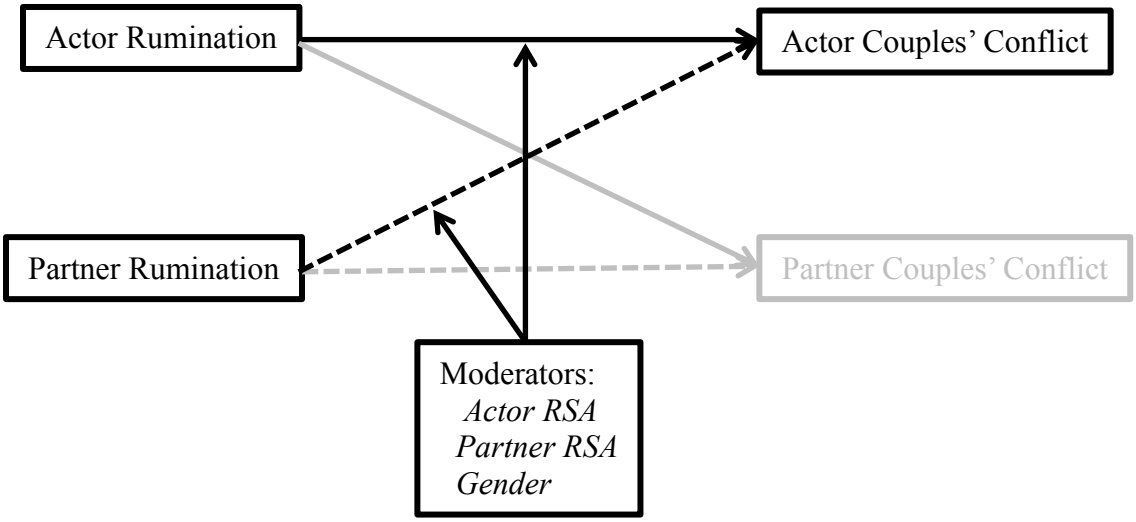
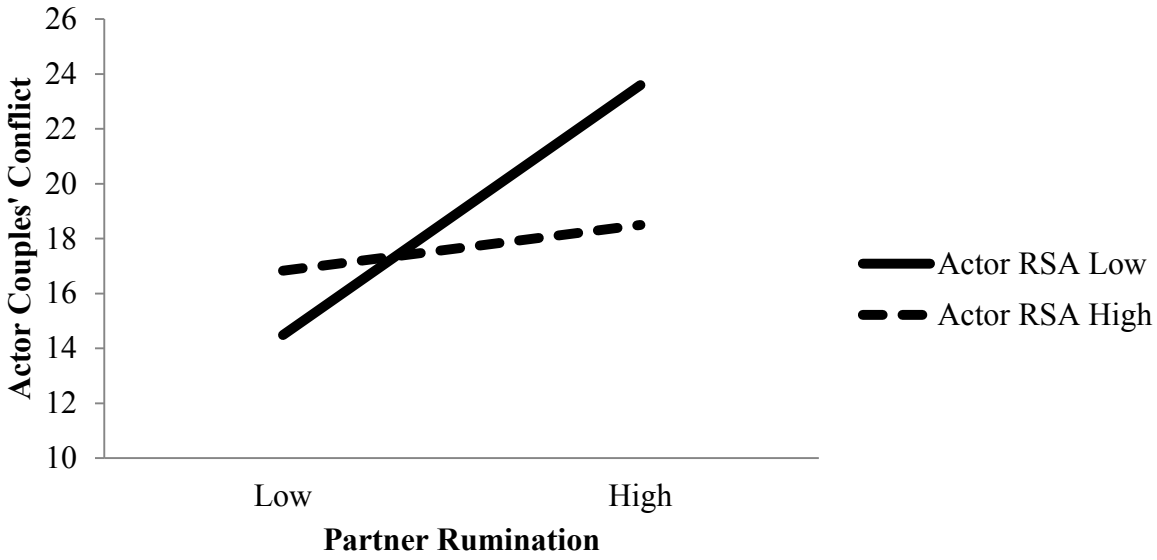


Figure 7. The association between partner-rated rumination and actor-rated couples' conflict as a function of actor respiratory sinus arrhythmia (RSA*)*.



CHAPTER FOUR: GENERAL DISCUSSION

Interpersonal emotion regulation involves two distinct and related processes: the impact of the social environment on the consequences of intrapersonal emotion regulation, as well as the impact of intrapersonal emotion regulation on the social environment (Zaki & Craig Williams, 2013). Findings from this dissertation highlight the negative interpersonal impact of rumination, and further shows that respiratory sinus arrhythmia (RSA) acts as an intrapersonal and interpersonal moderator of these effects. Across two manuscripts, the findings show that rumination is associated with a host of negative interpersonal behaviors and poor functioning. Greater RSA was shown to moderate the associations between rumination and negative interpersonal behavior, support mobilization, interpersonal stress; and the association between a ruminating partners' level of rumination and couples' conflict. Broadly, findings from this dissertation confirms the robust negative impact of rumination on interpersonal functioning, and provides novel findings and convergent evidence that RSA, a marker of self-regulation in interpersonal relationships, mitigates these effects.

Increasing evidence shows that emotion regulation involves an exchange between intrapersonal and interpersonal processes (Zaki & Craig Williams, 2013). Maladaptive and adaptive intrapersonal emotion regulation strategies tend to have opposing effects on interpersonal outcomes (Butler et al., 2003; Richards et al., 2003). Brooding rumination is theorized to increase risk of exhibiting negative interpersonal behaviors, and to reduce social support availability (Nolen-Hoeksema et al., 2008). Brooding has been associated with the generation of interpersonal stress, both cross-sectionally (Lam et al., 2003), and longitudinally (McLaughlin & Nolen-Hoeksema, 2012; Stroud et al., 2015, 2018). While much of the work that links rumination and interpersonal stress has been conducted with adolescent populations

(McLaughlin & Nolen-Hoeksema, 2012; Stroud et al., 2015, 2018), the findings from manuscript 1 replicates that rumination also associated with greater interpersonal stress across adult relationships in two independent samples. Further, by grouping negative interpersonal behaviors into a single scale, the findings from manuscript 1 both confirm the variety of negative interpersonal behaviors that have been independently associated with brooding rumination (Carr et al., 2012; Collins & Bell, 1997; Lyubomirsky & Nolen-Hoeksema, 1995; Potthoff et al., 1995; Stroud et al., 2018; Watkins et al., 2015; Weinstock & Whisman, 2007) and adds that they can be conceptualized as a more general deficit in interpersonal functioning that is associated with rumination. This latter point expands on previous work that shows excessive reassurance seeking mediates the association between brooding and interpersonal stress (Stroud et al., 2018). Further, within the context of romantic couples, findings from manuscript 2 showing that both couple members' rumination independently contributes to marital conflict over a 1-year period extends previous associations between daily rumination and partner-rated marital tension (King & DeLongis, 2014). Results from the present dissertation thus extends the empirical literature on the associations of rumination with increased negative interpersonal behaviors.

Regarding social support, previous work has established that ruminators perceive less global emotional support (Nolen-Hoeksema & Davis, 1999), and elicit more withdrawal behaviors from intimate partners when they ruminate (King & DeLongis, 2014). Findings from manuscript 1 suggests that daily emotional support may not be affected when considering daily support across adult relationships, but that rumination interferes with the receipt of daily instrumental support. One possible mechanism that may interfere with instrumental support may be the promotion of excessive emotional support mobilization by eliciting help using a self-focused and abstract style (Watkins & Roberts, 2020). In turn, others may perceive and respond

to the negative emotion, but neglect providing concrete help because problems are not framed and communicated in a way where another person can provide instrumental support. The habitual and uncontrollable nature of rumination may also exhaust close partners – causing withdrawal, tension, and conflict (King & DeLongis, 2014; Manuscript 2); while also leading to a more general lack of instrumental support across all supportive relationships (Manuscript 1). These findings converge with other work showing that brooding rumination likely exacerbates negative mood by reducing support and increasing interpersonal stress (Lam et al., 2003; McLaughlin & Nolen-Hoeksema, 2012; Stroud et al., 2015, 2018).

Current research also suggests that the link between rumination and interpersonal stress generation is inconsistent across studies (Hamilton et al., 2017, 2013; Shapero et al., 2013), which may be partially explained by the self-regulatory capacity of their social support networks. The findings from both manuscripts 1 and 2 support the conceptualization of RSA as an index of self-regulatory capacity within interpersonal relationships (Porges, 2003; Thayer & Lane, 2009). Moreover, the present findings indicate that RSA moderates both intrapersonal and interpersonal emotion regulation. Intrapersonally, greater RSA assists individuals resist urges to perform negative interpersonal behaviors that are associated with negative affect and depressed mood (Connell et al., 2011, 2015; Diamond et al., 2011; Switzer et al., 2018). The findings from manuscript 1 are consistent with this, showing that individuals that engage in high levels of rumination but also had greater RSA report performing fewer negative interpersonal behaviors, and generate less interpersonal stress than those with lower RSA. Recent models of the maintenance of rumination predict that reduced executive control and difficulty over-riding habitual responses (Watkins & Roberts, 2020), which is supported by greater RSA (Williams et al., 2019), works synergistically with other factors to maintain rumination and may decrease

sensitivity to context. Therefore, these findings support the hypothesis that greater RSA may be supporting ruminators' ability to shift attention, identify social cues, and over-ride their habitual ruminative responses in favor of more responsive and less negative social behaviors. Future research should examine the specific mechanisms through which high RSA attenuates the negative interpersonal consequences of rumination.

Interpersonally, greater self-regulatory capacity of social network members, may also moderates the negative interpersonal consequences of rumination. Here, greater RSA is associated with a set of characteristics that promotes positive interpersonal functioning such as emotion recognition (Quintana et al., 2012), self-reported empathy (Lischke et al., 2018), and the maintenance of self-reported affiliative social behaviors when experiencing negative affect (Gyurak & Ayduk, 2008), that may improve interpersonal emotion regulation (Smith et al., 2020). Supportive social contexts are associated with more adaptive intrapersonal emotion regulation (DeLongis & Holtzman, 2005; Holtzman et al., 2004) while unsupportive social contexts have the opposite effect (Cacioppo & Hawkley, 2009; DeLongis & Holtzman, 2005; Holtzman et al., 2004). The finding in manuscript 2 that the contribution of a partners' rumination to couples' conflict is mitigated by actors' RSA suggests that the negative interpersonal impact of rumination can also be buffered by the self-regulatory capacity of others in the social environment, in this case a romantic partner. Together, this supports the broad hypothesis that rumination negatively impacts interpersonal functioning, and that RSA acts as a moderator of the negative impact of rumination through its effects on both intrapersonal and interpersonal mechanisms.

A comparison between the findings from manuscripts 1 and 2 suggests that greater RSA in ruminating individuals should have predicted an actor-effect in manuscript 2. Instead, greater

actor RSA moderated the impact of their partners' brooding on conflict within the relationship. One explanation for this discrepancy could be the difference in interpersonal context (single intimate partner vs. across adult relationships). Speculatively, the discrepancy could be caused by multiple factors, including: not meeting the ruminators' relatively greater expectations for support within an intimate relationship (versus across adult relationships) more consistently leading to conflict, less self-regulatory effort of ruminating individuals within the context of an intimate relationship, or that the conflict associated with ruminating is not related to the ruminators' negative internal state as much as their partners' reaction to the ruminator's negative change in behavior (i.e. the ruminators' unmet need for support versus the partners' reaction to a more general negative change in their behavior). In this last interpretation of the findings, actors with greater RSA may be better able to prevent conflict by inhibiting negative interpersonal responses that would otherwise be elicited by ruminating partners' behaviors. Nolen-Hoeksema (2008) reported anecdotal findings that ruminators are sometimes criticized by their support networks for not "getting over" stressors quickly enough, which could be evident to romantic partners by their observation of the ruminators' persistent negative interpersonal behaviors, and may lead to greater couples' conflict. This latter interpretation of the findings suggests that within intimate relationships, failures at interpersonal emotion regulation are a more important predictor of couples' conflict than intrapersonal emotion regulation; and that actors with greater RSA may respond to the needs of their ruminating partners more effectively, because they demonstrate better emotion recognition (Quintana et al., 2012), empathic accuracy (Côte et al., 2011), greater control over emotive facial expressions (Tuck et al., 2016), and maintain more affiliative social behaviors when experiencing negative affect (Gyurak & Ayduk, 2008). Thus, the discrepancy between the findings from manuscript 1 and 2 suggests that the intrapersonal

regulatory role of RSA may dominate when all interpersonal relationships are considered, but that the interpersonal regulatory role of RSA likely take special priority in determining interpersonal outcomes within intimate relationships.

The current findings must be interpreted in light of several important methodological limitations. First, each of the present analyses is cross-sectional, and while reverse causality models were examined and were not supported, longitudinal models are needed to confirm the directionality of the effects. While the study design in manuscript 2 was longitudinal (over 1-year), no change over time, and no variance in the change over time, was detected and a longer follow-up was probably needed in this case to facilitate a longitudinal analysis. Further, several of the findings are derived from samples of parents in both manuscripts 1 and 2, limiting generalizability. This is particularly important, as the dyadic environment was selected to expound the significance of emotion regulation, but is likely to be different in couples without children and other dyadic relationships. Similarly, the findings were derived from convenience samples, and as such, two of the studies were exclusively female, also limiting generalizability. The current findings also did not control for respiration when estimating RSA, which is a point of ongoing debate (Grossman & Taylor, 2007), however the strength of the association between vagal control and social functioning is not moderated by adjustments for respiratory influences when this was evaluated in meta-analysis (Graziano & Derefinko, 2013). Finally, as will be discussed further below, all studies relied on trait-like variables representing rumination and self-regulatory capacity and cannot describe the timing, fluctuation, or duration of the associations within their real-life context.

The current dissertation suggests several possible future research directions. Both manuscripts focused on trait measures of rumination, RSA, and negative interpersonal outcomes.

Both polyvagal theory and the neurovisceral integration model suggest mechanisms by which RSA is hypothesized to buffer negative interpersonal outcomes, including improved executive functioning, empathic accuracy, communicative behaviors, coping strategies, or better intrapersonal emotion regulation broadly defined. In addition, the interpersonal emotion regulation theory outlined in Zaki & Williams (2013) provides a useful framework to tease apart the intrapersonal mechanisms by which RSA reduces the association between rumination and poor interpersonal functioning; and the interpersonal mechanisms by which greater RSA in supportive partners mitigates the negative interpersonal consequences of another ruminating individual. Replication studies that use longitudinal designs would add support for the proposed direction of causality, from rumination to poor interpersonal functioning, and would dovetail with the mechanism studies proposed. Further, state levels of rumination and RSA are more strongly associated than trait measure (Ottaviani et al., 2015), yet the social consequences of moment-to-moment associations of RSA with situation-specific rumination have not yet been described. Longitudinal and dyadic daily diary data could be used to delineate the specific behaviors that underlie the associations observed in the current studies across different social contexts. Concomitant physiological recordings could also clarify the significance and timing of state-measurements of rumination and RSA to interpersonal functioning.

Clinically, the findings are consistent with previous recommendations that interventions targeting social skills, social and instrumental problem-solving, and repairing damaged social relationships would be particularly beneficial for individuals that ruminate, especially among those with lower self-regulatory capacities (Nolen-Hoeksema et al., 2008). Additionally, the current analysis considers RSA as a trait-like individual difference variable, but changes in RSA are possible with lifestyle interventions that are common targets in the treatment of anxiety and

depression, like increasing cardiovascular exercise (Routledge, Campbell, McFetridge-Durdle, & Bacon, 2010) and reducing substance use (reviewed in Leyro, Buckman, & Bates, 2019). Delineating the functional improvements in behaviour, self-regulatory capacity, and interpersonal functioning associated with intervention-related changes in RSA may provide insights into the mechanisms of these treatment interventions.

Conclusion

This dissertation examined the moderating role of self-regulatory capacity, as indexed by RSA, on the negative interpersonal consequences of rumination within an interpersonal emotional regulation framework. RSA was examined as both an intrapersonal and interpersonal moderator of the negative interpersonal consequences of rumination. It was found that higher rumination and lower RSA were associated with worse interpersonal outcomes, including more negative interpersonal behaviors, impaired support mobilization, and interpersonal stress. Reciprocally, lower RSA and higher rumination in romantic partners strengthened the association between the partners' rumination and conflict within romantic relationships. Together, the findings suggest that RSA moderates interpersonal emotion regulation processes.

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