RESTING RESPIRATORY SINUS ARRHYTHMIA IS ASSOCIATED WITH AFFECTIVE RESPONSES TO ROMANTIC PARTNER INTERACTIONS IN DAILY LIFE

by

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ABSTRACT

Recent theory and research on psychophysiological aspects of self-regulation emphasizes the central role of resting respiratory sinus arrhythmia (RSA), an index of parasympathetic nervous system functioning. Within the context of close relationships, resting RSA may index an individual's self-regulatory capacity to manage affect associated with interpersonal interactions. In the laboratory, RSA was measured during a 10-minute resting baseline and participants completed measures of relationship quality. Partners were emailed a link to complete an online measure of relationship quality. Following the laboratory sessions, participants were prompted (using experience sampling methodology) to provide ratings of their affect during interactions with a romantic partner throughout a day. Resting RSA was correlated with partner reports of conflict in the relationship but not participant ratings of relationship quality. Multilevel models revealed a positive association between resting RSA and reports of calm and relaxed affect during social interactions with a romantic partner. Resting RSA was negatively associated with upset and angry affect during interactions with a romantic partner. These findings suggest that resting RSA may influence affect regulation during social interactions with a romantic partner and may have implications for understanding processes key to self-regulation and health.

This work is dedicated to my twin brother, Timothy Travis Cribbet.

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CHAPTER I

INTRODUCTION

The presence and quality of social relationships are important for physical health (De Vogli, Chandola, & Marmot, 2007; Holt-Lunstad, Smith, & Layton, 2011). Maintaining relationship quality requires self-regulation through the coordination of emotion and social behavior (Keltner & Kring, 1998). Recent theory and research on psychophysiological aspects of self-regulation (e.g., Porges, 2007; Thayer & Lane, 2009) highlights the role of resting respiratory sinus arrhythmia (RSA), an index of parasympathetic nervous system (PNS) functioning, in the modulation of emotion and social behavior, both of which are key influences on the quality of close relationships (Snyder, Simpson, & Hughes, 2006). Poor self- regulation and difficulty managing interpersonal interactions not only affects relationship functioning, but may also be detrimental to cardiovascular health and overall well-being (DeSteno, Gross, & Kubzansky, 2013; Gross, 2013). Thus, resting RSA may influence affect regulation during social interactions.

Prior studies examining associations between RSA and aspects of relationship quality have been largely limited to the laboratory (e.g., Nealey-Moore, Smith, Uchino, Hawkins, & Olsen-Cerny, 2007; Smith et al., 2009; Smith et al., 2011). In a notable exception, Diamond, Hicks, and Otter-Henderson (2011) demonstrated important modulating effects of resting RSA on associations between participant-rated daily affect and partner ratings of the quality of daily interpersonal interactions. In that study, men with lower resting RSA had more pronounced associations between their own daily negative affect and partner ratings of daily negative interactions than did women. Examining the effects of interpersonal interactions beyond the laboratory is important, not only as a test of ecological validity, but also because exposure to psychological stress and associated physiological responses measured during daily life predict important health outcomes (Zanstra & Johnston, 2010). The present study examined associations among resting RSA as indicator of self-regulatory capacity, perceptions of overall relationship quality, and momentary assessments of affective responses during social interactions with a romantic partner outside of the laboratory.

Romantic Relationships and Self-Regulation

Maintaining relationship quality requires the regulation of critical communication patterns, faulty attributions, and negative emotions that characterize conflict in close relationships (Fincham & Beach, 1999; Weiss & Heyman, 1997). During the course of the day, unpleasant events can build upon each other, resulting in both personal and interpersonal problems (Finkel & Fitzsimons, 2011). For example, effortful self-regulation during nonsocial tasks can impair subsequent social functioning by relaxing restraints on aggressive impulses, disrupting self-presentation, and reducing the tendency to be accommodating to one's partner (DeWall, Baumeister, Stillman, & Gailliot, 2007; Finkel & Campbell, 2001; Vohs, Baumeister, & Ciarocco, 2005).

Even empathizing with another person who is exerting self-control can be sufficient to deplete one's own self-regulatory capacity (Ackerman, Goldstein, Shairo, & Bargh, 2009). For example, while watching a distressing film with another person, attempting to self-regulate through emotional suppression does not effectively decrease negative affect for either individual (Butler, Whilhelm, & Gross, 2006). Moreover, direct efforts to regulate unpleasant affect during social interactions are associated with lower levels of rapport and affiliation for both members of a couple (Butler & Gross, 2009). Thus, effortful self-regulation in close relationships taxes not only the individual, but also impairs relationship quality (Finkel et al., 2006).

Resting RSA as a Marker of Regulatory Capacity: Relevance to Close Relationship Functioning

Tonic parasympathetic inhibition of emotional and expressive responses can be rapidly altered, permitting flexible responding as individuals vary their engagement with the social environment. At rest, the parasympathetic nervous system exerts tonic inhibitory control over heart rate via higher-order brain circuits, reflecting an individual's self-regulatory capacity (Butler et al., 2006; Thayer, Åhs, Fredrikson, Sollars, & Wager, 2012). Variation in this parasympathetic inhibition across the respiratory cycle, labeled respiratory sinus arrhythmia (RSA), can be quantified as the degree of fluctuation in heart rate that corresponds to the frequency of the respiratory cycle (i.e., between 0.12 and 0.40 Hz), commonly referred to as high frequency heart rate variability (HF-HRV).

Recent theoretical perspectives suggest that (PNS) mechanisms might also link close relationships and health (Porges, 2001, 2007; Thayer & Lane, 2009). Specifically, the Polyvagal Theory (Porges, 2001, 2007) and the Neurovisceral Integration Model (Thayer & Lane, 2001, 2009) suggest that a set of neural circuits that regulate emotional expression and social behavior through the coordination of facial gestures, vocalization, eye movement, and respiration, also modulate heart rate. In addition, these brain regions support aspects of shifting attention and response inhibition that are central to effortful control and executive cognitive functions, which are key cognitive underpinnings of emotional and social behavior regulation (Ochsner & Gross, 2007; Posner & Rothbart, 2007). Findings from a recent meta-analysis of neuroimaging studies relating cerebral blood flow to heart rate variability show that the same brain areas (e.g., medial prefrontal cortex) associated with heart rate variability are also involved in affect regulation (Thayer et al., 2012).

Consistent with these models of PNS influences on adaptive emotional and interpersonal functioning, individuals with higher resting levels of RSA experience less negative emotion during interpersonal conflict (Gyurak & Ayduk, 2008), are more likely to enjoy positive social interactions and relationships with others (Kok & Frederickson, 2010; Smith, et al., 2011), and are more likely to experience positive emotions when interacting with romantic partners (Diamond, Hicks, & Henderson, 2011). Conversely, low resting levels of RSA are associated with greater use of maladaptive coping strategies in response to stressors (Fabes & Eisenberg, 1997), negative emotional characteristics such as depression and anxiety (Thayer & Brosschot, 2005), insecurity in romantic relationships (Diamond & Hicks, 2005), hostility (Demaree & Everhart, 2004; Sloan et al., 1994), and greater social isolation (Horsten et al., 1999).

Moreover, resting RSA has been directly associated with self-regulatory processes during social interactions (Butler et al., 2006; Diamond & Hicks, 2005; Kok & Fredrickson; Smith et al., 2011). In one recent marital study, negative interactions with a spouse were associated with a significant decrease in wives' resting RSA, presumably reflecting their efforts to manage their husbands' negative affect during the previous negative interaction; whereas prior positive social interactions were associated with subsequent increases in wives' resting RSA levels (Smith et al., 2011). In addition, higher resting RSA may promote more positive and less negative experiences in personal relationships, and more positive and less negative relationship experiences, in turn, may promote higher resting RSA (Kok & Frederickson, 2010).

In summary, social relationships exert lasting influences on health (Holt-Lunstad, Smith, & Layton, 2011; House, Landis, & Umberson, 1988). Traditionally, proposed mechanisms linking close relationships and health have focused on physiological pathways that include the activation of sympathetic nervous system (SNS) and the hypothalamic-pituitary-adrenocortical (HPA) system in response to negative interpersonal interactions (Kiecolt-Glaser & Newton, 2001). Recent research has highlighted the role of parasympathetic nervous system processes, as indexed by resting RSA, in the regulation of the quality of close relationships (Smith et al., 2011). Maintaining relationship quality involves energy and effort associated with maintaining closeness and providing support (Reblin & Uchino, 2008), but also with regulating negative affect and repairing relationship quality following conflict (Impett & Peplau, 2006). Resting RSA may index a functional neural axis that connects higher-order brain structures and peripheral physiology with aspects of the social world key to managing close relationships.

The Present Study

The present study extended prior laboratory research by examining associations between resting RSA and social interactions with a romantic partner using experience sampling methodology. Participants were asked to rate their affect on electronic diaries during interpersonal interactions with a romantic partner over the course of a day. The present study focused on two key questions: 1) Does participant reported affect during social interactions with a romantic partner vary within a day; and 2) Does affect during social interactions with a romantic partner vary by resting RSA? It was expected that resting RSA would be positively associated with both activated (e.g., alert, excited, happy) and deactivated (e.g., contented, calm, relaxed) positive affective states, during interactions with a romantic partner. It was also hypothesized that resting RSA would be negatively associated with both activated (e.g., upset, angry, tense) and deactivated (e.g., bored, depressed, fatigued) negative affect during social interactions with a romantic partner. In addition, consistent with prior findings, it was predicted that resting RSA would be positively associated with self-reported and partner-reported overall relationship quality.

CHAPTER II

METHOD

Participants

As part of a larger study on individual differences in daily stress, 47 healthy participants (31 female) with romantic partners were examined. Participants were recruited from the University of Utah and Salt Lake City Community. Mean age for participants in the current sample was 27.3 years (*SD*= 6.9 years). The mean age for their partners (*n*=43) was 28.3 years (*SD* = 7.2 years). Mean relationship length was 5.8 years (*SD* = 6.3 years); 47% of the couples were married and the remaining 53% of the couples were in a dating relationship. Participants were generally healthy (M_{BMI} = 26.2, *SD* 5.5) and excluded from participation if they were hypertensive, were currently taking cardiovascular prescription medication use (e.g., beta blockers), had a history of chronic disease with a cardiovascular component (e.g., diabetes), currently using tobacco products, or had a diagnosis of severe psychological disorder (e.g., bipolar disorder). To be included in the current study focused on romantic partner interactions, participants must have been co-sleeping in the same bed with their partner at least 4 nights per week for at least 6 months.

Procedure

Participants were screened for exclusionary criteria, consented, and completed self-report measures of relationship quality. During the same baseline assessment session, resting HF-HRV and respiration were measured while participants were seated quietly for 10 minutes. Baseline assessment sessions were scheduled for a weekend day and were followed by a 3-night/2-day ambulatory protocol that included daily electronic diaries. For the current study, electronic diary measures from the first day were utilized.

Measures

Baseline Physiology

Heart rate and respiration. A MW1000A ambulatory impedance cardiography and heart rate variability monitor (Mindware Technologies, Gahanna, Ohio) was used to obtain both electrocardiogram (ECG) and respiration rate during a resting baseline. ECG data were collected from participants using three spot electrodes placed in the standard lead II configuration. The ECG was measured continuously at a sampling rate of 500Hz. Four spot electrodes were placed according to guidelines for impedance cardiography (Sherwood, Royal, Hutcheson, & Turner, 1992). One spot electrode was placed at the base of the neck, one at the xiphisternal junction, one over the fourth cervical vertebra, and one over the ninth thoracic vertebra. The impedance signal (Zo) and its derivative (dZ/dt) signals were digitized at 500 Hz. Respiration was obtained from the dZ\dt signal (Ernst et al., 1999) and quantified as respiration rate, allowing for removal of the effects of respiratory parameters on HF-HRV.

Respiratory sinus arrythmia (RSA). The raw ECG data were inspected using automated software and then visually inspected according to the guidelines for detecting artifacts and abnormal beats (Berntson, Quigley, Jang, & Boysen, 1990). For the purpose of the current study, HRV Analysis Software 3.0.12 (Mindware Cardiography system, Gahanna, Oh) was used to verify, edit, and summarize cardiovascular data. For each participant, ECG data were ensemble averaged for each minute. The same HRV analysis software was used to derive heart rate variability (ms^2/Hz) by applying spectral analysis to the interbeat interval series (IBI series – the time between successive R-peaks) from the ECG. The IBI series was time sampled at 4Hz to produce an equal time series. Time series analysis of IBI series using spectral approaches assumes that data points are equally spaced. Successive IBI series are spaced unevenly in time, and thus must be subjected to methods to derive an equal time series. A sampling rate of 4 Hz was used to sufficiently capture HF rhythms even at the high respiratory rates.

The equal time series was detrended, end tapered, and submitted to a fast Fourier Transformation according to procedures outlined by Bernston et al. (1997). The detrending process involves the application of a second-order polynomial to the heart rate time series. Spectral analysis was used to decompose heart rate variability at specific frequency components. The frequency component of RSA is the parasympathetically-driven oscillations that corresponded to the High Frequency (HF) portion of the interbeat interval power spectrum corresponding to the respiration cycle (0.12-0.40 Hz). Baseline RSA was calculated by averaging the last 5 minutes of the 10-minute resting baseline period.

Baseline Assessment Questionnaires

Relationship quality. Participants completed the Quality of Relationship Inventory (QRI; Pearce, Sarason, & Sarason, 1991). The QRI has subscales assessing perceived support from the partner, conflict within the relationship, and relationship depth, each of which has been found to have adequate internal consistency, temporal stability and convergent validity (Pearce et al., 1991). Cronbach's alpha in the current sample was .54, substantially lower than that reported in the validation study (Pearce et al., 1991).

Partner assessment of relationship quality. Following the baseline assessment, partners were emailed a link to an on-line survey site to complete a set of self-report measures, including demographics and measures of relationship quality (QRI; Pearce, Sarason, & Sarason, 1991) to complete using a secure online data collection software program (Cronbach's alpha in the current study was .80).

Experience Sampling Assessment

Participants completed a series of programmed questions on a personal digital assistant (PDA) (Palm V PDA handheld organizer) installed with Experience Sampling Program (ESP, version 4.0). Participants were asked to respond to questions about their affect and to indicate whether they were interacting with their romantic partner from 8:00 AM to 9:00 PM based on a random interval-contingent monitoring procedure once per hour (total 13 prompts per day). This procedure minimized participants' anticipation of an assessment that might lead them to alter their activities.

Each assessment took approximately 2-3 minutes to complete. The ambulatory diary included an item determining whether an interaction with romantic partner had recently occurred and the nature of the interaction: “If you were interacting with your romantic partner, what was the nature of the interaction (phone call, direct conversation, email, text message)?” In the current sample, 84% of social interactions with a romantic partner were in-person conversations, 10% were phone calls, 3% were text messages, and 3% were rated “not applicable.”

The ambulatory diary also included affect items designed to capture both affective valence and arousal rated on a 5-point likert-type scale from 1 (*not at all*) to 5 (*very much*). For the current study, four subscales from items assessing affective valence (e.g., Positive vs. Negative) and arousal (e.g., Activated vs. Deactivated), were created from the 16 items in a circumplex-based measure of affect (Feldman-Barrett & Russell, 1998), plus an additional item asking about angry affect: 1) Activated Positive Affect: *Alert, Excited, Elated, Happy* (α= .39); 2) Deactivated Positive Affect: *Contented, Serene, Relaxed, Calm* (α = .77); 3) Activated Negative Affect: *Upset, Stressed, Nervous, Tense, Angry* (α = .90); and 4) Deactivated Negative Affect: *Fatigued, Bored, Depressed, Sad* (α = .85).

Overview of Analyses

Correlations were used to test the hypothesis that resting RSA will be associated with perceptions of overall relationship quality. To test study hypotheses focused on associations between resting RSA and affect during daily social interactions with a romantic partner, multilevel models were used. Multilevel models account for sources of statistical dependence and allow for the partitioning of variance and covariance across levels of nesting (e.g., occasions within participants). Full information maximum likelihood estimation was utilized because it is robust to departures from normality assumptions and performs well with low sample sizes (Graham, 2009). All analyses were run in HLM version 7 (Raudenbush, Bryk, & Condgdeon, 2011). Standardized coefficients for all models were calculated by multiplying each unstandardized coefficient by the standard deviation of the predictor divided by the total standard deviation of affect during a social interaction with a romantic partner (Raudenbush, Rowan, & Kang, 1991). Effect sizes were calculated by squaring (r^2) standardized beta values for each predictor.

Affect during an interaction with a romantic partner was the primary criterion variable to be predicted in the analyses. There were two types of prediction equations in the multilevel analyses: a Level 1 equation that examined the influence of within-person variations on affect during social interaction with a romantic partner and a Level 2 equation that tested the effects of between-person variations on criterion variables. Level 1 questions address questions about *when* and for the current study, took the following form: *Do participants differ in their average rating of affect during a social interaction with a romantic partner?* In contrast, Level 2 variables are between-participants variables. Level 2 variables address questions about *who* and in the current study, took the following form: *Is resting RSA negatively associated with negative affect (or decreased positive affect), or positively associated with positive affect during social interactions with a romantic partner?*

To answer these questions about associations between affect during interactions with a romantic partner and resting RSA, a model building approach was utilized. To examine the extent to which participants varied in their mean ratings of affect during romantic partner interactions, a model was constructed from two equations with no predictors specified at either Level 1 or Level 2. This model predicts the outcome within each Level 1 unit with just one Level 2 parameter, the intercept. Depicted below is an example of an expanded model where each participant outcome was modeled as a function of resting RSA and resting respiration rate.

Level 1: Deactivated Positive Affect $_{\text{social interaction i, participant j}} = \beta_{0j} + r_{ij}$

Level 2: $\beta_{0j} = \gamma_{00} + \gamma_{01}$(Resting RSA) + γ_{02} (Respiration Rate) + u_{0j}

The Level 1 equation predicts an outcome variable (in this example Deactivated Positive Affect) from an intercept β_{0j} that represents the mean deactivated positive affect for participant *j* at occasion *i* and an error term r_{ij}. At Level 2, differences in Level 1 intercepts represent mean differences in the dependent variable (Deactivated Positive Affect) that can be predicted from the independent variables, resting RSA, γ_{01} and respiration rate, $\gamma_{02,}$ and an error term, u_{0j}. These Level 2 predictors were centered around a grand mean by subtracting each participant's value on the independent variable from the mean of that variable across the mean of all other participants in the study.

CHAPTER III

RESULTS

Descriptive and Correlational Statistics

Means, standard deviations, and correlations among the study variables are presented in Table 1. Associations between resting RSA and other physiological parameters (e.g., respiration rate and heart rate) are consistent with expected associations between these variables (Butler et al., 2006; Cribbet et al., 2011). As shown in Table 1, participants' resting RSA was not significantly associated with their own reports of conflict within relationship, but were significantly negatively correlated with their partners' perception of conflict within the relationship.

Associations Between Resting RSA and Affect During Social Interactions with a Romantic Partner

Multilevel Modeling (MLM) was used to test associations between resting RSA and ratings of affect during romantic partner interactions. For these analyses, 24 participants reported interactions with a romantic partner around at least one prompt during day 1 ESM assessments. First, an unconditional model addressed the question: *Do participants differ in their average rating of affect during a social interaction with a romantic partner?* By examining intraclass correlations depicted in Table 2, average ratings of Activated Positive Affect during interactions with a romantic partner did not vary considerably across participants, but average ratings of Deactivated Positive Affect, Activated Negative Affect, and Deactivated Negative Affect during romantic partner interactions did vary across participants.

A second series of models examined the unique effect of two predictors simultaneously by expanding the unconditional model to include resting RSA (and resting respiration rate as a covariate; Grossman & Taylor, 2007). In all expanded models, the within-participant affect variable (e.g., Deactivated Positive and Negative Affect and Activated Positive and Negative Affect) during romantic partner interactions was regressed onto the between-participant (Level-2) variables of resting RSA while controlling for resting respiration rate. As shown in Table 3, there were two significant between-participants effects on ratings of affect during romantic partner interactions and resting RSA at Level-2. Resting RSA was negatively associated with participants' Activated Negative Affect, during romantic partner interactions. Conversely, resting RSA was positively associated with participants' Deactivated Positive Affect, while interacting with a romantic partner.

Item Level Analyses

In order to understand which aspects of Deactivated Positive Affect and Activated Negative Affect were associated with resting RSA, individual items comprising these subscales were examined using MLM. In all expanded models, the within-participant item-level affect variable during interactions with a romantic partner was regressed onto the between-participant (Level-2) variables of resting RSA while controlling for resting respiration rate. As shown in Table 4, several significant between-participants effects on the association between ratings of affect during romantic partner interactions and resting

RSA emerged at Level-2. Specifically, resting RSA was negatively associated with ratings of *upset*, and *angry*, during romantic partner interactions. Resting RSA was positively associated with ratings of *calm*, and *relaxed*, while interacting with a romantic partner.

Table 1. Zero-order correlations among study variables.

Variable	1	2	3	4	5	6	7	8	9
1. Resting RSA	_	-0.27	-0.52***	0.08	-0.13	-0.06	-0.07	-0.23	-0.44**
2. Resting Respiration Rate		_	0.009	-0.04	-0.08	0.14	-0.07	0.02	0.19
3. Resting Heart Rate			_	-0.03	0.17	0.04	0.07	0.21	0.04
4. Participant Rated QRI Support				_	0.62***	-0.52**	0.14	0.09	-0.30*
5. Participant Rated QRI Depth					_	-0.48***	0.17	0.27	-0.19
6. Participant Rated QRI Conflict						_	-0.009	0.12	0.15
7. Partner Rated QRI Support							_	0.76***	-0.32*
8. Partner Rated QRI Depth								_	-0.27
9. Partner Rated QRI Conflict									_
Mean	6.29	16.16	72.69	25.59	21.89	22.65	24.34	21.63	22.83
Standard Deviation	.96	7.14	14.08	2.89	1.99	5.24	3.47	2.71	6.62

Note: HF-HRV= High Frequency Heart Rate Variability. QRI =Quality of Relationships Inventory. * p<.05. **p<.01 *** p<.001

Table 2.
Means, Standard Errors, and Intraclass Correlations for Affective Ratings During Social Interactions with a Romantic Partner.

Variable	Mean	SE	95% CI	ICC
Activated PA	2.71	0.13	(1.81, 3.61)	.46
Deactivated PA	3.13	0.19	(1.52, 4.74)	.78
Activated NA	1.97	0.21	(0.01, 3.93)	.93
Deactivated NA	2.06	0.21	(0.32, 3.80)	.79

Note: PA= Positive Affect; NA = Negative Affect; SE= Robust Standard Error; CI = Confidence Interval;ICC = Intraclass Correlation Coefficient.

Table 3.
Multilevel Models of Self-Rated Affect During Social Interactions with a Romantic Partner.

	Parameter	β	SE	*t*	*p*	r^2
DV: Activated PA (*df* =21)	Parameter	β	SE	*t*	*p*	r^2
	RSA	0.29	0.11	1.823	*ns*	.08
	Respiration	0.10	0.005	1.662	*ns*	.01
	τ^2	.188				
	σ^2	.234				
DV: Deactivatd PA (*df* =21)	Parameter	β	SE	*t*	*p*	r^2
	RSA	0.44	0.16	2.51	.05	.19
	Respiration	0.08	0.005	2.17	< .05	.006
	τ^2	.560				
	σ^2	.180				
DV: Activated NA(*df* =21)	Parameter	β	SE	*t*	*p*	r^2
	RSA	-0.34	0.20	-2.01	< .05	.12
	Respiration	-0.26	0.009	-3.02	< .01	.07
	τ^2	.804				
	σ^2	.078				
DV: Deactivated NA(*df* =21)	Parameter	β	SE	*t*	*p*	r^2
	RSA	-0.15	0.19	-0.888	*ns*	.22
	Respiration	-0.26	0.01	-2.629	< .01	.07
	τ^2	.770				
	σ^2	.230				

Note: RSA= Respiratory Sinus Arrhythmia. Respiration = Respiration Rate. Robust standard errors are listed. A homogenous error structure was used to model the error variance on the dependent variable. τ^2 = Between-person variance in participant ratings of average affect accounted for by respiratory sinus arrhythmia and respiration rate.σ^2 = Within-person variance in participant ratings of average affect while interacting with a romantic partner accounted for by respiratory sinus arrhythmia and respiration rate

Table 4.
Multilevel Models of Self-Rated Affect During Social Interactions with a Romantic Partner.

	Parameter	β	SE	*t*	*p*	r^2
DV: Upset (*df* =21)	Parameter	β	SE	*t*	*p*	r^2
	RSA	-0.34	0.23	-2.139	< .05	.12
	Respiration	-0.29	0.02	-2.353	< .05	.08
	τ^2	1.134				
	σ^2	.650				
DV: Angry (*df* =21)	Parameter	β	SE	*t*	*p*	r^2
	RSA	-0.41	0.23	-2.14	<.05	.17
	Respiration	0.28	0.02	-2.00	*ns*	.07
	τ^2	.793				
	σ^2	.334				
DV: Relaxed (*df* =21)	Parameter	β	SE	*t*	*p*	r^2
	RSA	0.37	0.19	2.32	< .05	.14
	Respiration	0.13	0.009	1.90	*ns*	.02
	τ^2	.549				
	σ^2	.641				
DV: Calm (*df* =21)	Parameter	β	SE	*t*	*p*	r^2
	RSA	0.47	0.20	2.57	< .01	.22
	Respiration	-0.26	0.01	-2.629	*ns*	.07
	τ^2	.569				
	σ^2	.350				

Note: RSA= Respiratory Sinus Arrhythmia. Respiration = Respiration Rate. Robust standard errors are listed. A homogenous error structure was used to model the error variance on the dependent variable. τ^2 = Between-person variance in participant ratings of average affect accounted for by respiratory sinus arrhythmia and respiration rate.σ^2 = Within-person variance in participant ratings of average affect while interacting with a romantic partner accounted for by respiratory sinus arrhythmia and respiration rate.

CHAPTER IV

DISCUSSION

Recent theoretical models of self-regulation of emotion and social behavior (Porges, 2001; Thayer & Lane, 2000, 2009) suggest that resting RSA provides an index of self-regulatory capacity. In the present study, associations between resting RSA, perceptions of overall relationship quality, and affect during interactions with a romantic partner in daily life were examined. Consistent with prior research, partners' perceptions of relationship quality were associated with participants' resting RSA. Specifically, resting RSA was negatively associated with perceptions of conflict within the relationship as rated by a romantic partner. Partners' perceptions of support and depth within the relationship were unrelated to the participant's resting RSA. Participants' perceptions of support, conflict, and depth within the relationship were not related to their own resting RSA.

The current findings support prior research on the predictive strength of partner ratings of relationship quality (Smith et al., 2008). Perhaps the stronger effects for associations between participant resting RSA and partner ratings of relationship conflict indicate that the participants were less willing to report undesirable aspects of their romantic relationship. Self-reports of relationship quality are more likely to index socio-emotional functioning, but only if affect and behavior are effectively regulated (Smith, et al., 2011). Thus, the greater predictive utility of partner reports could be capturing the extent to which participants are able to regulate their affect and associated behavior patterns that underlie relationship quality. If partner reports are indeed a better indicator of the regulation of emotion and social behavior patterns key to relationship quality, then those ratings should be more strongly associated with resting RSA, an index of self-regulatory capacity (Butler, 2006; Smith et al., 2011). It is likely that the discrepancies between partner and participant reports of relationship quality reflect a distinction between social and emotional behavioral patterns that reflect poor self-regulation within romantic relationships and subjective perceptions that may not be evident in behavior among well-regulated individuals.

In the present study, resting RSA was associated with participant-rated affect during romantic partner interactions. A strength of the current study was that resting RSA was measured *prior to* obtaining ratings of social interaction-related affect using experience sampling methodology. In the current study, resting RSA was negatively associated with ratings of Activated Negative Affect, particularly ratings of *upset* and *angry* while interacting with a romantic partner. These results are consistent with prior laboratory-based studies showing that lower resting RSA is associated with maladaptive coping strategies (Gyurak & Ayduk, 2008), negative affective states (Thayer & Brosschot, 2005), insecurity in romantic relationships (Diamond & Hicks, 2005), poor stress regulation (Weber et al., 2010), and a reduced regulation of negative affect (Pu, Schmeichel, & Demaree, 2010). In the current study, the finding that resting RSA was negatively associated with *upset* and *angry* affect likely reflects participants' inability to regulate their affect during social interactions. When faced with relationship problems, negative emotions and problematic behavior patterns tend to be reciprocated over time, perhaps reflecting diminished self-regulatory capacity (Smith et al., 2011), and potentially setting in motion a transactional cycle that could have implications for poor health.

The results of this study are consistent with findings from the only other known study to examine associations between resting RSA and the quality of interpersonal interactions with a romantic partner outside the laboratory (Diamond, Hicks, & Otter-Henderson, 2011). In contrast to the study by Diamond et al., (2011) where participants and their partners provided paper and pencil ratings of affect and the quality of interpersonal interactions at bedtime for 3 weeks, in the current study, participants were prompted to rate their momentary affect during (or immediately after) an interaction with a romantic partner. Thus, in the current study, ratings of affect were directly linked to interactions with a romantic partner in real time.

The results of the current study also demonstrated that resting RSA is positively associated with Deactivated Positive Affect, particularly ratings of *calm* and *relaxed*. These findings are consistent with the notion that individuals with higher resting RSA appear more able to produce context appropriate responses such as experiencing less negative emotion during interpersonal conflict (Gyurak & Ayduk, 2008), and are more likely to enjoy positive social interactions and relationships with others (Kok & Frederickson, 2010; Smith, et al., 2011). The finding between resting RSA and ratings of *relaxed* and *calm affect* in present study may suggest that one of the benefits of being in a close relationship includes a “broadening and building” of interpersonal resources and associated positive affect (Fredrickson, 2001).

The results of the current study are similar to findings by Lane and colleagues (2011), which found that among participants with long QT syndrome (i.e., a condition characterized by alterations in the QT interval, which may be associated with increased risk for sudden cardiac death), individuals with higher resting RSA were more likely to endorse low-arousal positive affective states such as feeling calm and relaxed outside of the laboratory. However, the current study extends those findings by demonstrating associations between resting RSA and Deactivated Positive Affect during social interaction in healthy individuals. In summary, the results of the current study support the supposition that resting RSA is an index of self-regulatory capacity, including affect regulation during social interactions (Thayer et al., 2012).

Limitations and Future Directions

There are some limitations to the current study. This was a relatively small sample of young, healthy adults, so generalizations to chronically ill populations, individuals with mood disorders, and other age groups should be made cautiously. Moreover, these data are cross-sectional in nature, limiting the ability to draw causal inference. Daily affect and the quality of daily interpersonal interactions are related to one another in a bidirectional fashion (Reis Sheldon, Gable, Roscoe, & Ryan, 2000). The current study did not test whether resting RSA modulates bidirectional associations between affect and interpersonal interactions (i.e., lagged effects over the course of a day or across several days). In general, longitudinal investigations conducted outside of the laboratory may increase our understanding of associations between resting RSA and affect during social interactions.

Despite these limitations, the current study provides evidence for associations between resting RSA and specific affective responses during interactions with a romantic partner that likely reflect a broader ability (or inability) to self-regulate during social interactions. In general, the findings of the current study provide ecologically valid support for theoretical models linking RSA to the social world (Porges 2001, 2007; Thayer & Lane, 2000, 2009). The results of the current study also support recent meta-analytic findings that heart rate variability may index the degree to which lower order-brain structures, higher-order brain structures, and peripheral physiology are functionally integrated to permit flexible affective responses during social interactions (Thayer et al., 2012). Given associations between low resting RSA and depression (Rottenberg, 2007; Yaroslavsky, Rottenber, & Kovacs, 2013), future research should examine associations between resting RSA and affect during social interactions among couples where one member of the dyad is depressed.

The findings of the current study can be viewed within a broader theoretical framework of close relationships and health (Kiecolt-Glaser & Newton, 2001). Specifically, individual differences in negative affect such as depression, anxiety, and anger that are associated with conflict and strain in close relationships (Beach, 2001) are also associated with resting RSA (Thayer & Brosschot, 2005). Thus, associations between relationship quality and health may reflect a common third variable, resting RSA, as an indicator of self-regulatory capacity. Diminished self-regulatory capacity may contribute to conflict and negative affective states. Over time, reciprocal patterns of conflict and associated emotional difficulties may in turn lead to further decrements in resting RSA. The degree to which parasympathetic physiology consistently permits flexible and adaptive emotional responses that may have particular implications for associations between close relationships and health.

REFERENCES

Ackerman, J. M., Goldstein, N. J., Shapiro, J. R., & Bargh, J. A. (2009). You wear me out: The vicarious depletion of self-control. *Psychological Science, 20*(3), 326-332.

Berntson, G. G., Bigger, J. T., Jr., Eckberg, D. L., Grossman, P., Kaufmann, P. G., Malik, M., et al. (1997). Heart rate variability: Origins, methods, and interpretive caveats. *Psychophysiology, 34*(6), 623-648.

Berntson, G. G., Quigley, K. S., Jang, J. F., & Boysen, S. T. (1990). An approach to artifact identification: Application to heart period data. *Psychophysiology, 27*(5), 586-598.

Butler, E. A., & Gross, J. J. (2009). Emotion and emotion regulation: Integrating individual and social levels of analysis. *Emotion Review, 1*(1), 86-87.

Butler, E. A., Wilhelm, F. H., & Gross, J. J. (2006). Respiratory sinus arrhythmia, emotion, and emotion regulation during social interaction. *Psychophysiology, 43*(6), 612-622.

Cribbet, M.R., Williams, P.G., Gunn, H.E. & Rau, H.K., (2011). Effects of tonic and phasic respiratory sinus arrhythmia on affective stress responses. *Emotion, 11*(1), 188-193.

Demaree, H. A., & Everhart, D.E. (2005) Healthy high-hostiles: Reduced parasympathetic activity and decreased sympathovagal flexibility during emotional processing. *Personality and Individual Differences, 36*(2), 457-469.

DeSteno, D., Gross, J.J., & Kubzansky, L. (2013). Affective science and health: The importance of emotion and emotion regulation. *Health Psychology, 32*(5), 474-486.

De Vogli, R., Chandola, T., & Marmot, M. G. (2007). Negative aspects of close relationships and heart disease. *Archives of Internal Medicine,167*(18), 1951-1957.

DeWall, C. N., Baumeister, R. F., Stillman, T. F., & Gailliot, M. T. (2007). Violence restrained: Effects of self-regulation and its depletion on aggression. *Journal of Experimental Social Psychology, 43*(1), 62-76.

Diamond, L. M., & Hicks, A. M. (2005). Attachment style, current relationship security, and negative emotions: The mediating role of physiological regulation. *Journal of Social and Personal Relationships*, *22*, 499-518.

Diamond, L. M., Hicks, A. M., & Otter-Henderson, K. D. (2011). Individual differences in vagal regulation moderate associations between daily affect and daily couple interactions. *Personality and Social Psychology Bulletin, 37,* 731-744.

Ernst, J. M., Litvack, D. A., Lozano, D. L., Cacioppo, J. T., & Berntson, G. G. (1999). Impedance pneumography: Noise as signal in impedance cardiography. *Psychophysiology*, *36*(3), 333-338.

Fabes, R. A., & Eisenberg, N. (1997). Regulatory control and adults' stress-related responses to daily life events. *Journal of Personality and Social Psychology*, *73*(5), 1107-1117.

Feldman Barrett, L. & Russell, J.A. (1999). The structure of current affect: Controversies and emerging consensus. *Psychological Science, 8,* 10-14.

Feldman-Barrett, L. & Russell, J.A. (1998). Independence and bipolarity in the structure of current affect. *Journal of Personality and Social Psychology, 74,* 967-984.

Fincham, F. D., & Beach, S. R. H. (1999). Conflict in marriage: Implications for working with couples. *Annual Review of Psychology, 50,* 47-77.

Finkel, E. J., & Campbell, W. K. (2001). Self-control and accommodation in close relationships: An interdependence analysis. *Journal of Personality and Social Psychology*, *81*(2), 263-277.

Finkel, E. J., Campbell, W. K., Brunell, A. B., Dalton, A. N., Scarbeck, S. J., & Chartrand, T. L. (2006). High-maintenance interaction: Inefficient social coordination impairs self-regulation. *Journal of Personality and Social Psychology*, *91*(3), 456-475.

Fitzsimons, G. M., & Finkel, E. J. (2010). Interpersonal influences on self-regulation. *Current Directions in Psychological Science,19,*101-105.

Fredrickson, B.L. (2001). The role of positive emotions in positive psychology: The broaden-and-build theory of positive emotions. *American Psychologist, 56,* 218-226.

Graham, J. (2009). Missing data analysis: Making it work in the real world. *Annual Review of Psychology*, *60*(1), 549-576.

Gross, J. J. (2013). Emotion regulation: Taking stock and moving forward. *Emotion*, *13*(3), 359-365.

Grossman, P., & Taylor, E.W. (2007). Toward understanding respiratory sinus arrhythmia: Relations to cardiac vagal tone, evolution, and biobehavioral functions, *Biological Psychology,74*, 263-285.

Gyurak, A., & Ayduk, Ã. z. (2008). Resting respiratory sinus arrhythmia buffers against rejection sensitivity via emotion control. *Emotion, 8*(4), 458-467.

Holt-Lunstad, J., Smith, T. B., & Layton, J. B. Social relationships and mortality risk: A meta-analytic review. *PLoS Med, 7*(7), e1000316.

Horsten, M., Ericson, M., Perski, A., Wamala, S. P., Schenck-Gustafsson, K., & Orth-Gomer, K. (1999). Psychosocial factors and heart rate variability in healthy women. *Psychosomatic Medicine, 61*(1),49-57.

House, J. S., Landis, K. R., & Umberson, D. (1988). Social relationships and health. *Science 241*(4865), 540-545.

Impett, E. A., & Peplau, L. A. (2006). "His" and "her" relationships? A review of the empirical literature. In A. L. Vangelisti & D. Perlman (Eds.), *The Cambridge handbook of personal relationships* (pp. 273–291). New York, NY: Cambridge University Press.

Keltner, D., & Kring, A. M. (1998). Emotion, social function, and psychopathology. *Review of General Psychology, 2*, 320-342.

Kiecolt-Glaser, J. K., & Newton, T. L. (2001). Marriage and health: His and hers. *Psychological Bulletin, 127*(4), 472-503.

Kok, B. E., & Fredrickson, B. L. (2010). Upward spirals of the heart: Autonomic flexibility, as indexed by vagal tone, reciprocally and prospectively predicts positive emotions and social connectedness. *Biological Psychology, 85*(3), 432-436.

Lane, R.D., Zareba, W., Reis, H.T., Peterson, D.R., & Moss, A.J. (2011). Changes in ventricular repolarization duration during typical daily emotion in patients with long QT syndrome. *Psychosomatic Medicine,73,*98-105.

Nealey-Moore, J., Smith, T., Uchino, B., Hawkins, M., & Olson-Cerny, C. (2007). Cardiovascular reactivity during positive and negative marital interactions. *Journal of Behavioral Medicine, 30*(6), 505-519.

Ochsner, K. N., & Gross, J. J. The neural architecture of emotion regulation. In J.J. Gross (Ed.), *Handbook of emotion regulation* (pp. 87-109). New York, NY, US: Guilford Press.

Pierce, G. R., Sarason, I. G., & Sarason, B. R. (1991). General and relationship-based perceptions of social support: Are two constructs better than one? *Journal of Personality and Social Psychology*, *61*(4), 1028-1039.

Porges, S. W. (2001). The polyvagal theory: Phylogenetic substrates of a social nervous system. *International Journal of Psychophysiology, 42*(2), 123-146.

Porges, S. W. (2007). The polyvagal perspective. *Biological Psychology, 74*(2), 116-143.

Posner, M. I., & Rothbart, M. K. (2007). Research on attention networks as a model for the integration of psychological science. *Annual Review of Psychology, 58*, 1-23.

Pu, J., Schmeichel, B.J., & Demaree, H.A. (2010). Cardiac vagal control predicts spontaneous regulation of negative emotional expression and subsequent cognitive performance. *Biological Psychology, 84(3),* 531-540.

Raudenbush, S., Bryk, A., & Congdon, R. (2011). *HLM 7:Hierarchical linear and nonlinear modeling.* Chicago, IL: Scientific Software International.

Raudenbush, S., Rowan, B., & Kan, S.J. (1991). A multilevel, multivariate model for studying school climate with estimation via the EM algorithm and application to U.S. high school data. *Journal of Educational Statistics,16*(4), 295-330.

Reblin, M. & Uchino, B.N. (2008). Social and emotional support and its implication for health. *Current Opinions in Psychiatry, 21*, 201-205.

Reis, H.T., Sheldon, K.M., Gable, S.L., Roscoe, J., & Ryan, R.M. (2000). Daily well-being: The role of autonomy, competence, and relatedness. *Personality and Social Psychology Bulletin, 26,* 419-435.

Rottenberg, J. (2007). Cardiac vagal control in depression: A critical analysis. *Biological Psychology, 74*, 200-211.

Sherwood, A., Royal, S. A., Hutcheson, J. S., & Turner, J. R. (1992). Comparison of impedance cardiographic measurements using band and spot electrodes. *Psychophysiology*, *29*(6), 734-741.

Sloan, R. P., Shapiro, P. A., Bigger Jr, J. T., Bagiella, E., Steinman, R. C., & Gorman, J. M. (1994). Cardiac autonomic control and hostility in healthy subjects. *The American Journal of Cardiology, 74*(3), 298-300.

Smith, T. W., Cribbet, M. R., Nealey-Moore, J. B., Uchino, B. N., Williams, P. G., MacKenzie, J., et al. (2011). Matters of the variable heart: Respiratory sinus arrhythmia response to marital interaction and associations with marital quality. *Journal of Personality and Social Psychology, 100*(1), 103-119.

Smith, T. W., Uchino, B. N., Berg, C. A., Florsheim, P., Pearce, G., Hawkins, M., et al. (2009). Conflict and collaboration in middle-aged and older couples: II. Cardiovascular reactivity during marital interaction. *Psychology and Aging, 24*(2), 274-286.

Smith, T.W., Uchino, B.N., Berg, C.A., Florsheim, P., Pearce, G., Hawkins, M., et al. (2008). Associations of self-reports versus spouse ratings negative affectivity, dominance, and affiliation with coronary artery disease: Where should we look and who should we ask when studying personality and health? *Health Psychology, 71*(27), 676-684.

Snyder, D. K., Simpson, J., & Hughes, J. N. (2006). *Emotion regulation in couples and families: Pathways to dysfunction and health*: Washington, DC, US: American Psychological Association.

Thayer, J. F., & Brosschot, J. F. (2005). Psychosomatics and psychopathology: Looking up and down from the brain. *Psychoneuroendocrinology, 30*(10), 1050-1058.

Thayer, J. F., & Lane, R. D. (2000). A model of neurovisceral integration in emotion regulation and dysregulation. *Journal of Affective Disorders, 61*(3), 201-216.

Thayer, J. F., & Lane, R. D. (2007). The role of vagal function in the risk for cardiovascular disease and mortality. *Biological Psychology, 74*(2), 224-242.

Thayer, J. F., & Lane, R. D. (2009). Claude Bernard and the heart-brain connection: Further elaboration of a model of neurovisceral integration. *Neuroscience & Biobehavioral Reviews, 33*(2), 81-88.

Thayer, J.F., Åhs, F., Fredrikson, M., Sollers III, J.J., & Wager, T. (2012). A meta-analyssi of heart rate variability and neuroimaging studies: Implications for heart rate variability as a marker of stress and health. *Neuroscience and Biobehavioral Reviews, 36*, 747-756.

Vohs, K. D., Baumeister, R. F., & Ciarocco, N. J. (2005). Self-regulation and self-presentation: regulatory resource depletion impairs impression management and effortful self-presentation depletes regulatory resources. *Journal of Personality and Social Psychology, 88*(4), 632-657.

Yaroslavsky, I., Rottenberg, J., & Kovacs, M. (2013). The utility of combining RSA indices in depression prediction. *Journal of Abnormal Psychology, 122*, 314-321.

Weber, C.S., Thayer, J.F., Rudat, M., Wirtz, P.H., Zimmerman-Viehoff, F., Thomas, A., Perschel, F.H., et al., (2010). Low vagal tone is associated with impaired post stress recovery of cardiovascular, endocrine, and immune makers. *European Journal of Applied Physiology*, *109*,201-211.

Weiss, R. L., & Heyman, R. E. A clinical-research overview of couples interactions. In W.K. Halford & H.J. Markman (Eds.), *Clinical handbook of marriage and couples interventions* (pp. 13-41). Hoboken, NJ, US: John Wiley & Sons Inc.

Zanstra, Y. J., & Johnston, D. W. (2009). Cardiovascular reactivity in real life settings: Measurement, mechanisms and meaning. *Biological Psychology*, *86*(2), 98-105.