Emotion
2010, Vol. 10, No. 4, 536–543

1528-3542/10/$12.00 DOI: 10.1037/a0018698

Neuroticism's Importance in Understanding the Daily Life Correlates of Heart Rate Variability

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Individual differences in high-frequency heart rate variability (HRV) have been conceptualized in terms of a greater capacity to self-regulate problematic outcomes, but have also been conceptualized in terms of greater moment-to-moment flexibility. From a self-regulation perspective, higher HRV should be inversely correlated with trait neuroticism and problematic daily outcomes. From a flexibility perspective, high HRV should result in more state-like functioning—that is, functioning that is more contextual and less trait-like in nature. In the latter case, HRV and trait neuroticism may interact to predict problematic outcomes such that neuroticism should be a less consequential predictor at higher levels of HRV. The flexibility perspective was systematically supported in a daily experience-sampling protocol. Implications focus on theories of neuroticism and HRV.

Keywords: neuroticism, heart rate variability, stress, negative affect, self-regulation

The distinction between flexible responding and self-regulated responding is a subtle but important one in relation to constructs such as perseveration, inhibition, and switching. A useful way of disentangling flexibility and self-regulation processes involves examining their relation to the broadly dysfunctional trait of neuroticism in combination with problematic daily outcomes known to be correlated with neuroticism. To the extent that self-regulation processes are involved, the measure should be inversely related to neuroticism or the daily outcomes. On the other hand, to the extent that flexibility processes are involved, neuroticism and the measure should interact to predict the outcomes. In particular, flexibility should reduce or eliminate neuroticism–outcome relationships (Robinson & Compton, 2007; Robinson, Goetz, Wilkowski, & Hoffman, 2006; Robinson, Wilkowski, & Meier, 2006). We use this assessment strategy to differentiate two perspectives on heart rate variability (HRV).

HRV: Self-Regulation or Flexibility?

Changes in heart rate have long been viewed as important in understanding reactions to the environment (Obrist, 1981; Selye, 1956; Vila et al., 2007). However, heart rate reflects a heterogeneous mix of sympathetic and parasympathetic nervous system activity, and it is important to disentangle their separate influences (Berntson & Cacioppo, 2007; Berntson, Norman, Hawkley, & Cacioppo, 2008). Whereas activity in the sympathetic branch increases heart rate and does so relatively slowly, activity in the parasympathetic branch decreases heart rate and does so quickly (Shepherd & Vatner, 1996). The latter fast-acting parasympathetic influence can be isolated by assessing individual differences in high frequency (0.15–0.40 Hz) HRV (Friedman, 2007; Porges, 2007).

There is now a reasonably sized literature showing that individual differences in HRV have predictive value in understanding outcomes important to the personality, social, clinical, and emotion literatures (Appelhans & Luecken, 2006). Yet, there appears to be a subtle, often implicit, disagreement as to how best to understand the findings reported to date. On the one hand, higher levels of HRV have been conceptualized in terms of individual differences in *self-regulation* abilities or capacities (e.g., Thayer & Lane, 2000). From this perspective, higher levels of HRV should almost uniformly be beneficial in mitigating problematic processing routines or outcomes. On the other hand, higher levels of HRV have been characterized in terms of individual differences in *flexible responding* (e.g., Beauchaine, Gatzke-Kopp, & Mead, 2007). From this perspective, higher levels of HRV should not be viewed in terms of self-regulation abilities or capacities, but rather in terms of a greater range of responding to situational input. We review the HRV literature according to this distinction among perspectives.

Self-regulation processes are those involved in the controlled override of problematic mental tendencies, broadly conceptualized (Rothbart, Ellis, & Posner, 2004). It is thus informative that Hansen, Johnsen, and Thayer (2003) reported some evidence for the idea that individuals high in HRV perform better in a working memory task, a classic measure of controlled processing abilities (Engle, 2002). This result may be somewhat ambiguous, however, because cognitive flexibility is a major contributor to performance

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Scott Ode acknowledges support from a North Dakota State University Graduate Research Fellowship.

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in working memory tasks (Baddeley, 2003; Unsworth & Engle, 2007). If so, the results may support a flexibility perspective of HRV instead. In any case, it is striking how few investigations have followed the promising work of Hansen et al. From a cognitive control perspective, then, the link of HRV to self-regulation abilities appears preliminary at best on the basis of current results.

Additional evidence regarding relations between HRV and regulatory factors comes from the clinical literature. Clinically significant anxiety symptoms have been viewed in terms of deficient self-regulation or emotion-regulation abilities (D. A. Clark, 2005). It is therefore informative that individuals diagnosed with anxiety disorders exhibit lower levels of resting HRV relative to nonclinical control groups (Friedman, 2007). Such findings have been explained in terms of enhanced cognitive control and self-regulatory capacity among individuals high in HRV. We suggest, however, that such clinical–control group comparisons likely confound two individual difference factors. The first is a temperamental predisposition toward anxiety symptoms, which must somewhat necessarily be higher among clinically anxious groups (L. A. Clark & Watson, 1999). The second is a lack of flexible responding, which should exacerbate anxious symptoms among temperamentally predisposed individuals (Nigg, 2006; Rothbart et al., 2004). To disentangle such factors, we suggest that *both* temperamental predispositions toward anxiety (e.g., trait neuroticism) and individual differences in HRV should be simultaneously assessed. The present investigation sought to do so.

There is also evidence that would seem to contradict the self-regulation view of HRV. Beauchaine (2001) found that higher levels of infant HRV were positively correlated with both emotional and physiological reactivity to adverse events as well as to higher parental reports of such tendencies. Similarly, Butler, Wilhelm, and Gross (2006) found that individual differences in resting HRV predicted greater distress in response to a documentary film clip involving the consequences of the Hiroshima and Nagasaki nuclear bombings. Although not numerous at the present time, such findings suggest that higher levels of HRV, perhaps because of their link to flexible responding, can sometimes be associated with higher rather than lower levels of negative emotional reactivity. Because a self-regulatory perspective would predict that high levels of HRV should dampen rather than heighten negative emotional reactions (Zelazo & Cunningham, 2007), it may be erroneous to view individual differences in HRV in self-regulation terms. The major goal of the present investigation was to contrast self-regulation and flexibility perspectives of HRV in the context of trait neuroticism and daily outcomes.

Neuroticism, HRV, and Daily Outcomes

The Big Five trait of neuroticism is a robust positive predictor of problematic outcomes in cognitive (Flehmig, Steinborn, Langner, & Westhoff, 2007), emotional (Meyer & Shack, 1989), symptom (Watson & Pennebaker, 1989), and behavioral (Widiger, Verheul, & van den Brink, 1999) realms. There are also indications that individuals high in neuroticism are more reactive to and less capable of mitigating problematic events and experiences (Lahey, 2009; Suls & Martin, 2005; Zelenski & Larsen, 1999). As indicated below, potential relations between HRV and neuroticism were of interest, as were a diversity of indices of daily functioning (many of which tend to be correlated with neuroticism). This included measures of daily stress, stress reactivity, negative emotional experiences, somatic symptoms, cognitive failures, and behavioral impulsivity.

No prior study that we know of has examined potential relations between individual differences in HRV and problematic daily outcomes in the comprehensive manner examined here. Therefore, this research offers a unique opportunity to test the differential predictions made by both the self-regulation and flexibility perspectives of HRV. Self-regulation processes are typically viewed as being involved in controlling task-irrelevant thoughts (Miller & Cohen, 2001) and impulsive behaviors (Baumeister, Muraven, & Tice, 2000). In addition, according to the HRV (Friedman, 2007), developmental (Rueda, Posner, & Rothbart, 2005), and emotion regulation literatures (D. A. Clark, 2005; Zelazo & Cunningham, 2007), self-regulation processes also should be inversely related to daily negative emotions and stress reactivity. Particularly damaging to the self-regulation perspective, then, would be results indicating that individual differences in HRV fail to predict predispositions toward negative affect (as measured by neuroticism) and the multiple indices of daily functioning mentioned above (Bolger, Davis, & Rafaeli, 2003; Tennen, Affleck, Armeli, & Carney, 2000).

The flexibility perspective, we suggest, should result in a different pattern of findings. Specifically, we have shown that personality traits are less predictive of outcomes among individuals exhibiting more flexible processing in implicit tasks (Robinson & Cervone, 2006; Robinson & Clore, 2007; Robinson, Goetz, et al., 2006; Robinson & Oishi, 2006). From a flexibility perspective of HRV, then, one would predict a potential interaction between neuroticism and HRV in predicting the daily dysfunctional outcomes. Furthermore, the interactive pattern should be one in which neuroticism is a stronger predictor of such outcomes at low levels of HRV relative to high levels of HRV (for analogous results, see Robinson, Goetz, et al., 2006).

Finally, we have also shown that flexible processing is a double-edged sword, depending on trait and temperamental factors (e.g., Robinson, Solberg, Vargas, & Tamir, 2003). Among individuals who have a somewhat automatic tendency to experience problematic outcomes (e.g., individuals high in neuroticism), enhanced cognitive, emotional, and behavioral flexibility should be beneficial—that is, predictive of lower levels of daily dysfunction (Robinson, Goetz, et al., 2006). By contrast, in the absence of tendencies toward problematic outcomes (e.g., when neuroticism is low), such flexibility should be somewhat costly—that is, predictive of higher levels of daily dysfunction (Robinson & Clore, 2007). Therefore, flexible processing can be viewed in terms of mitigating trait-related influences on daily functioning: When flexibility is high, individuals should exhibit less *trait-like* and more *state-like* tendencies. This perspective on flexible processing is revisited in the Discussion.

Method

Recruitment Efforts and the Final Participant Sample

Participants initially completed a cardiovascular reactivity study conducted by the second and third authors in exchange for course credit (n = 81). Following completion of this cardiovascular reactivity study, the first and fourth authors invited the same

participants to return to their lab a short time later, at which time the trait of neuroticism was assessed. Only a subset of the initial sample chose to participate in this follow-up assessment ($n = 42$). Following the second lab assessment session, participants completed a 15-day Internet-based diary study in exchange for course credit or monetary compensation ($30). Thirty-eight of the 42 individuals provided usable daily outcome data, defined in terms of completion of over 60% of the daily reports. Thus, the present results are based on 38 (21 men, 17 women) North Dakota State University students who successfully completed all phases of the investigation.

Procedure and Measures

Individual differences in HRV. Individual differences in HRV were assessed in an initial laboratory session, which involved a single participant and experimenter. Participants were informed that the study consisted of a "challenging task" to be completed later in the session. After obtaining informed consent, electrodes for electrocardiogram (EKG) recordings were attached by trained laboratory assistants at standard chest placements. After electrode attachment, participants were seated and a 10-min resting baseline measurement period began. Participants were encouraged to relax and the experimenter left the room during this time. The EKG was recorded using BioPac System (Goleta, CA) hardware. Mindware Technologies software (Gahanna, OH) was then used to derive accurate heartbeat-to-beat intervals from the EKG signal and to calculate HRV.

An a priori decision was made to quantify resting HRV using the last 4 min of the 10-min baseline. This 4-min period should be relatively free of laboratory orienting processes, yet sufficiently long in duration to quantify HRV in a reliable manner (Berntson et al., 1997). Mindware Technologies software was used to identify potential artifacts (Berntson, Quigley, Jang, & Boysen, 1990) and data were also checked manually. The Mindware Technologies software then used a fast Fourier transformation algorithm to derive assessments of high-frequency (0.15–0.40 Hz) HRV, which were then natural log-transformed to reduce positive skew. All such procedures have been recommended in this literature (Task Force, 1996).

Assessments of trait neuroticism. Several weeks after the HRV assessment, participants were contacted by e-mail to return to a different lab (i.e., that of the first and fourth authors) in which no physiological data would be collected. In addition to assessments not relevant to the present report, trait neuroticism levels were assessed in terms of Goldberg's (1999) reliable and valid 10-item neuroticism scale (e.g., "worry about things": 1 = *very inaccurate*; 5 = *very accurate*). Neuroticism as assessed by this scale correlates highly with other measures of neuroticism (Goldberg, 1999; John & Srivastava, 1999), including the NEO-Personality Inventory (Costa & McCrae, 1992). Alpha was .86 in the present study.

Daily life outcomes. Shortly after participants completed the second lab session, they began a daily diary protocol. Participants were to log onto a Web site for 15 consecutive days and report on their experiences, cognitions, and behaviors for that day. Surveys were not posted until late afternoon and were removed early the following morning, thus ensuring that the report was made during the relevant time window. To facilitate maximum compliance, we also sent reminder e-mails each morning. Among the 38 participants retained for the following analyses, the average participant compliance rate was 88% ($M = 13.2/15$, $SD = 1.5$). The survey included assessments of stress appraisals, stress reactivity, negative emotions, somatic symptoms, cognitive failures, and impulsive behaviors, as these outcomes allowed us to understand how HRV functions in the context of neuroticism.

Stress is a subjective state theoretically linked to perceptions that life demands exceed one's capabilities to cope with them (Monat & Lazarus, 1991). We assessed stress in terms of four items from the International College Student Inventory of Recent Life Experiences (Kohn, Lafreniere, & Gurevich, 1990). The particular items selected were those that appeared most likely to vary on a day-to-day basis. Participants were asked to indicate whether (1 = *not at all true today*; 5 = *very much true today*) they "had a deadline to worry about," "had a lot of responsibilities," "had too many things to do at once," and "did not have enough time to meet obligations." An alpha of .97 was obtained across days.

Stress reactivity can be defined in terms of what may be viewed as ruminative activity in response to stressors (Kuhl, 2000). Theories of neuroticism (Watson & Clark, 1984) and HRV (Brosschot, Van Dijk, & Thayer, 2007) emphasize such stress reactivity processes, and we therefore sought to assess them in the daily diary protocol. We did so by asking individuals to indicate how frequently (0 = *not a single time*; 3 = *more than two times*) they "felt overwhelmed," "worried about something," and "criticized myself" on the day in question. Alpha for this stress reactivity scale was .80 across days.

Negative emotional experiences have been implicated in theories of both neuroticism (McCrae & Costa, 1999) and HRV (Appelhans & Luecken, 2006). Accordingly, participants were asked to rate the extent (1 = *not at all*; 5 = *extremely*) to which they felt four markers of negative affect (*annoyed*, *irritated*, *dejected*, and *sad*) on the day in question. Markers were taken from the Positive and Negative Affect Schedule—Expanded Form (Watson & Clark, 1994), and we sought to include a balance of high- and low-arousal items. Alpha for the negative emotion scale was .89 across days.

Neuroticism is a medium to strong predictor of somatic symptoms (Watson & Pennebaker, 1989), yet this relationship is moderated by other factors related to interpersonal or cognitive flexibility (e.g., Ode & Robinson, 2007). In experience-sampling protocols, somatic symptom reports are more likely to reflect actual physical conditions than belief-driven retrospective reporting biases (Brown & Moskowitz, 1997). We asked individuals to indicate the extent (1 = *not at all*; 5 = *extremely*) to which they experienced four common somatic symptoms (headache, faintness, muscle aches, and nausea) on each of the 15 days. Alpha for this scale was .91 across days.

Neuroticism not only predicts the experiences above, but also predicts cognitive failures, another outcome reflective of dysregulation (Flehmig et al., 2007). We thus asked participants the extent (1 = *strongly disagree*; 5 = *strongly agree*) to which they exhibited two common cognitive failures ("I forgot appointments today" and "I had conflicting thoughts today"), both taken from Broadbent's Cognitive Failures Questionnaire (Broadbent, Cooper, FitzGerald, & Parkes, 1982). Although the scale was short, it was internally reliable ($\alpha = .73$ across days) and it assessed both lapses of attention and cognitive conflict, two markers of cognitive con-

trol failure (Robertson, Manly, Andrade, Baddeley, & Yiend, 1997; van Veen & Carter, 2006).

Finally, a behavioral correlate of neuroticism was examined. In factor analytic studies, impulsive behavior emerges as one of the facets of neuroticism (McCrae & Costa, 1999). Neuroticism is a robust, although moderate, correlate of behavioral impulsivity as well (Fetterman, Robinson, Ode, & Gordon, in press). To assess daily impulsive behavior, we asked individuals to indicate the frequency (0 = *not a single time*; 3 = *more than two times*) with which they engaged in three characteristic behaviors ("ate more than I intended to," "bought something on impulse," and "gave in to an urge"), closely modeled after Tangney, Baumeister, and Boone's (2004) dispositional measure of self-control. Alpha was .70 for our three-item scale.

The daily protocol first assessed negative emotional experiences and somatic symptoms. Stress and stress reactivity were measured next, followed by the most behaviorally anchored scales pertaining to cognitive failures and impulsive behaviors. Such an order of measures was deemed appropriate as it would preclude the likelihood that completing more behaviorally anchored scales would influence responses to scales of a more subjective type.

Hypotheses

In total, the daily protocol assessed a wide set of outcomes previously linked to the trait of neuroticism—that is, stress appraisals, stress reactivity, negative emotion, somatic symptoms, cognitive failures, and impulsive behaviors. Our primary hypothesis was that relations between neuroticism and all of these daily outcomes would be reduced or eliminated in the context of high levels of HRV. Zero-order correlations among the measures and patterns involving potential neuroticism by HRV interactions were further examined to provide potential insight into whether relations between HRV and daily outcomes could be better viewed in terms of self-regulation or flexible responding perspectives.

Results

Correlations Between Neuroticism, HRV, and Daily Outcomes

Means and standard deviations for all of the variables are reported in Table 1. For this set of analyses, daily outcome measures were averaged, for each participant separately, across the daily reports provided by the individual. Thus, standard deviation statistics for the daily outcome measures in this table reflect differences between individuals in terms of their average daily tendencies rather than differences across days within an individual.

Table 1 also reports correlations among the individual difference measures. Neuroticism was a positive predictor of all daily outcome variables and a significant predictor in relation to the majority of these outcomes. On the other hand, neuroticism did not significantly predict resting HRV levels in our study and, in fact, the direction of the correlation indicated that higher levels of neuroticism were associated with higher (not lower) levels of HRV. Furthermore, HRV did not predict any of the daily outcome variables and, again, the direction of the relationships was often positive in nature.

Potential Interactions Between Neuroticism and HRV

The correlations reported above are problematic for the idea that higher levels of HRV are generally beneficial, which would argue against the self-regulation perspective of HRV. To test predictions drawn from the flexibility perspective of HRV, we examined potential interactions between the trait of neuroticism and HRV in predicting the daily outcome variables. Because daily reports were nested within individuals, we used multilevel modeling (MLM) procedures to test the significance of each interaction (Tabachnick & Fidell, 2007). Six such analyses were conducted, one for each of the daily outcome measures. Level 2 (between-subjects) variables were z scored prior to such analyses (Tabachnick & Fidel, 2007).

Results from these analyses are reported in Table 2. Neuroticism was a significant predictor of five of the six daily outcome measures and a positive predictor of the sixth outcome measure (somatic symptoms) as well. On the other hand, individual difference in HRV again failed to predict any of these outcomes in main effect terms. Thus, the daily correlates of HRV appear more complex than captured by "main effect" models that have sometimes been proposed.

We instead hypothesized that neuroticism and HRV would interact to predict the affective, cognitive, and behavioral daily outcomes assessed. This hypothesis was systematically supported for all six daily outcome measures, as reported in Table 2. To better understand the nature of these interactive results, we estimated means for each outcome measure as a function of low (−1 *SD*) versus high (+1 *SD*) levels of neuroticism at low (−1 *SD*) versus high (+1 *SD*) levels of HRV (Aiken & West, 1991). Results are dis-

Table 1
Descriptive Statistics and Correlations Among Measures

Variable	*M*	*SD*	1	2	3	4	5	6	7
1. Neuroticism	2.6	0.72	—						
2. HRV (log)	6.3	1.20	.11	—					
3. Daily stressful events	2.4	0.63	.49*	.13	—				
4. Daily stress reactivity	1.4	0.58	.38*	−.05	.73*	—			
5. Daily negative affect	1.9	0.43	.29	.23	.50*	.47*	—		
6. Daily somatic symptoms	1.7	0.54	.14	.18	.16	.26	.65*	—	
7. Daily cognitive failures	2.2	0.57	.51*	.18	.50*	.43*	.66*	.49*	—
8. Daily impulsivity	0.7	0.67	.44*	.11	.44*	.53*	.70*	.60*	.70*

Note. HRV = heart rate variability. Daily outcomes were averaged across daily reports for purposes of these analyses.
* $p < .05$.

Table 2
Multilevel Results

Variable	Neuroticism		HRV		Neuroticism × HRV	
	$t(34)$	β	$t(34)$	β	$t(34)$	β
Daily stressful events	4.05*	.35	1.35	.12	−2.74*	−.30
Daily stress reactivity	3.06*	.27	0.05	.00	−2.26*	−.25
Daily negative affect	2.23*	.15	1.95	.13	−2.35*	−.20
Daily somatic symptoms	1.36	.12	1.76	.15	−2.50*	−.27
Daily cognitive failures	3.95*	.32	1.41	.12	−2.02†	−.21
Daily impulsivity	3.32*	.19	1.02	.06	−2.04*	−.15

Note. HRV = heart rate variability.
† $p = .05$. * $p < .05$.

played in Figure 1, all of which suggest that neuroticism predicted such outcomes only at low levels of HRV.

Follow-up MLM analyses (Tabachnick & Fidell, 2007) tested simple slopes to confirm the apparent trends depicted in Figure 1. Among individuals 1 *SD* below the mean in HRV, neuroticism was a robust predictor of all six daily outcomes (ps $< .05$). However, neuroticism did not significantly predict any of the daily outcomes among individuals 1 *SD* above the mean in HRV (ps $> .20$). These results, then, confirm the hypothesis that neuroticism should be a more consequential predictor of daily dysfunction at lower levels of HRV, which is consistent with the flexibility perspective of HRV presented in the introduction.

Simple Slopes Involving Individual Differences in HRV

We hypothesized that neuroticism would be a consequential predictor of daily outcomes at low, but not high, levels of HRV. Such hypotheses were systematically verified. We had sufficient power to assess such simple slopes because of the dramatic crossover patterns hypothesized. On the other hand, we did not have sufficient power for assessing HRV simple slopes at low versus high levels of neuroticism, which would not equally benefit from the crossover nature of our interactive hypotheses.

Regardless, we viewed it as potentially important to better clarify HRV effects at low versus high levels of neuroticism. To afford more sufficient power for such analyses, we standardized and then averaged all of the daily outcome measures (which tended to be positively correlated with each other; see Table 1). With reference to this composite daily outcome variable, we then performed MLM simple slope analyses. Higher levels of HRV were associated with problematic daily outcomes at low (−1 *SD*) levels of neuroticism ($p < .05$), but were marginally associated with less problematic outcomes at high (+1 *SD*) levels of neuroticism ($p < .08$). Such results further reinforce the idea that trait levels of neuroticism appear crucial in understanding the daily correlates of individual differences in HRV.

Discussion

The investigation was novel as it sought to understand potential relations between trait and biological measures of personality and between a biological measure (HRV) and everyday outcomes. The trait of neuroticism did not predict individual differences in HRV. Furthermore, individual differences in HRV did not predict problematic daily outcomes in zero-order terms. Instead, neuroticism interacted with HRV and did so in a highly informative manner. The discussion elaborates on these points, which have significant implications for multiple individual difference literatures.

Two Perspectives on HRV

Our reading of the HRV literature led us to contrast two perspectives on HRV. Because there is central nervous system control over parasympathetic influences on heart rate, some have suggested that HRV may be a marker, if not an indicator, of higher levels of *self-regulation* abilities or capacities (Thayer & Lane, 2000). On the other hand, the HRV measurement procedures most directly implicate individual differences in cardiovascular flexibility, which in turn may support higher levels of *flexible responding* to the environment more generally considered (Appelhans & Luecken, 2006). Flexible responding could support adaptive self-regulation, but need not do so. Our results speak to such overlapping, but in other ways divergent, perspectives of HRV.

The correlates of the trait of neuroticism almost uniformly suggest a dysregulated personality system (Suls & Martin, 2005; Widiger et al., 1999). From a self-regulation perspective, then, it would seem intuitive to hypothesize an inverse relation between neuroticism and HRV levels. This result was not found. On the other hand, trait- and process-based assessments of personality

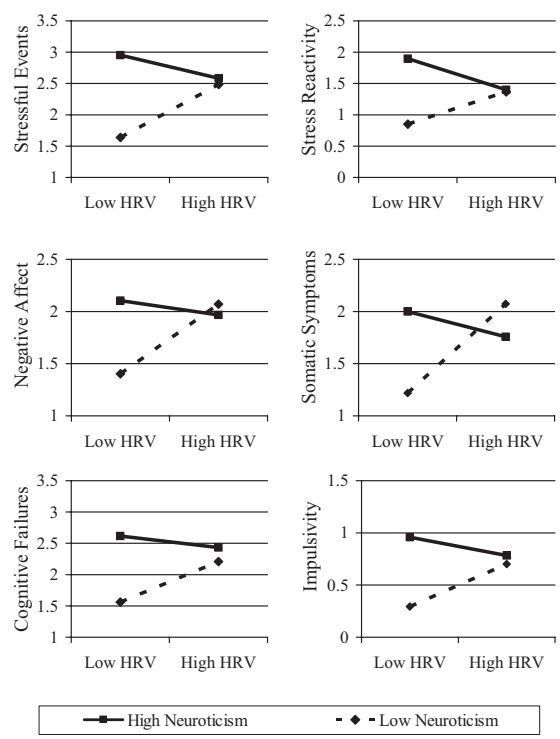

Figure 1. Neuroticism by heart rate variability (HRV) interactions in the prediction of daily stress (top panel, left), stress reactivity (top panel, right), negative affect (middle panel, left), somatic symptoms (middle panel, right), cognitive failures (bottom panel, left), and impulsive behaviors (bottom panel, right).

rarely correlate with each other (Robinson, 2007; Robinson & Compton, 2007). Thus, in retrospect, we do not view it particularly problematic to the self-regulation perspective of HRV that no correlation with the trait of neuroticism was observed.

On the other hand, we regard it more damaging to the self-regulation perspective of HRV that there were no correlations between HRV and problematic daily outcomes of multiple types. Individuals higher in HRV were not protected from daily stress, stress reactivity, negative emotions, somatic symptoms, cognitive failures, or impulsive behaviors. Furthermore, interactions involving the trait of neuroticism indicated that high levels of HRV were problematic to the extent that the individual was low in trait neuroticism. Self-regulation processes should not operate in this manner (Muraven & Baumeister, 2000; Zelazo & Cunningham, 2007).

Instead, our results support a flexible responding perspective on HRV. Given the variability of life's situational stressors (Zika & Chamberlain, 1992), one would expect flexible individuals to display moderate average levels of the daily outcomes that we assessed rather than very low or high levels of these outcomes. As Figure 1 shows, this was precisely the case: Regardless of whether individuals were low or high in neuroticism, the daily experiences, reactions, emotions, cognitions, and behaviors of individuals high in HRV were at a moderate level relative to those low in HRV.

More compelling to the flexibility perspective were results involving interactions with neuroticism. Neuroticism, as a trait, predisposes one to problematic outcomes of multiple types (L. A. Clark & Watson, 1999). Our findings show that this dispositional tendency appears inert in accounting for the daily life outcomes of individuals high in HRV. This pattern is precisely what one would expect from a flexibility perspective (Robinson, Goetz, et al., 2006). In particular, it appears that the daily lives of those low in HRV are "traited"—that is, governed by dispositional habits and tendencies. On the other had, this was not at all true among those with high levels of HRV, whose daily tendencies might be better characterized as "stated." Such ideas appear to be consistent with the results of Butler et al. (2006) and Gyurak and Ayduk (2008).

In further support of this flexibility perspective of HRV, we found that higher levels of HRV had somewhat opposite predictive value at low versus high levels of neuroticism, although we do mention that power was low for such simple slope comparisons. Among individuals high in neuroticism, higher levels of HRV appeared somewhat beneficial. However, among individuals low in neuroticism, higher levels of HRV appeared problematic. Such results, we suggest, can only be understood in terms of the benefits of flexibility at high levels of neuroticism and the costs of the very same tendencies at low levels of neuroticism.

Caveats and Future Directions

Individual differences in HRV may reflect peripheral physiological processes and mechanisms rather than those directly linked to cortical functioning (Berntson, Cacioppo, & Grossman, 2007; Grossman & Taylor, 2007). However, other perspectives on this measure have been proposed (Thayer & Lane, 2000). Further research on the biological basis of HRV is thus necessary and warranted. Even so, HRV appears to an important *indicator* of flexible responding (e.g., Appelhans & Luecken, 2006; Beauchaine, 2001; Porges, 2007). From the standpoint of predictive validity, then, the present work extends the idea that this biological model, perhaps in contrast to some others (Matthews & Gilliland, 1999), has a wide potential scope in understanding individual differences in social and emotional functioning.

Although the use of a daily diary protocol guards retrospective biases (Bolger et al., 2003; Robinson & Clore, 2002; Tennen et al., 2000), it was nonetheless true that all daily outcomes were self-reported in nature. Physiological measures, informant reports, and experimental paradigms would seem useful in extending the evidentiary basis of the present results. For example, experimental paradigms have been developed to capture individual differences in cognitive failures (Robertson et al., 1997). The same is true in relation to behavioral impulsivity (Dougherty, Mathias, Marsh, & Jagar, 2005). In short, several of the outcomes examined in our study could be profitably assessed in other ways as well.

We focused on potential relations between neuroticism, HRV, and problematic daily outcomes because there were several theoretical reasons for doing so. However, the consistent pattern of results obtained suggests that a wider consideration of HRV as a moderator of trait-related tendencies is warranted. Robinson, Goetz, et al. (2006) found that cognitive flexibility moderated extraversion–positive affect relations, which were less pronounced among flexible individuals. Wilkowski and Robinson (2008) suggest that cognitive flexibility appears to attenuate relations between trait–state anger and aggression. Thus, high levels of HRV may similarly moderate other trait–outcome relations aside from those examined here. Patterns of this type would further support the traited–stated distinction that emerged from our investigation.

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Received April 2, 2009
Revision received December 21, 2009
Accepted December 21, 2009 ■