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Hostility Predicts Magnitude and Duration of Blood Pressure Response to Anger

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The hypothesis that hostile and nonhostile individuals would differ in both magnitude and duration of cardiovascular reactivity to relived anger was tested. Participants were 66 older adults (mean age, 62; 38 women and 28 men; 70% Caucasian American, 30% African American). Each took part in a structured interview scored using the Interpersonal Hostility Assessment Technique. Later each relived a self-chosen anger memory while heart rate and systolic and diastolic blood pressures were measured continuously using an Ohmeda Finapres monitor. Hostile participants had larger and longer-lasting blood pressure responses to anger. African Americans also showed longer-lasting blood pressure reactivity to anger. Health and measurement implications are discussed.

KEY WORDS: anger; cardiovascular reactivity; cardiovascular recovery; hostility; Ohmeda Finapres monitor; older adults.

INTRODUCTION

People with a hostile or antagonistic interpersonal style are at increased risk for coronary heart disease (Barefoot *et al.*, 1994; Dembroski *et al.*, 1989; Smith, 1992). This association is supported by both cross-sectional and prospective studies, although the strength and consistency of the data vary

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with method of hostility assessment (Smith, 1992). Two primary strategies for assessing hostility include self-report and behavioral observation, which tend to yield uncorrelated hostility scores (Barefoot, 1992). Measurements based on the observation of behavior during interviews have been particularly fruitful and are the focus of the present study.

One mechanism proposed to account for the link between hostility and coronary heart disease is heightened cardiovascular and neuroendocrine reactivity (Williams *et al.*, 1985). This psychophysiological reactivity model states that, relative to others, hostile people exhibit larger (and potentially more long-lasting) increases in blood pressure, heart rate, and stress-related hormones in response to emotional stressors. In turn, this hyperreactivity is thought to initiate and/or accelerate cardiovascular disease progression. While empirical support for the relationship between hostility and cardiovascular reactivity has been obtained in multiple laboratories, the strength and consistency of the data again vary with the method of hostility assessment and also with the characteristics of laboratory stressors (Smith, 1992; Suls and Wan, 1993). In general, stressors that evoke anger through interpersonal provocation appear most effective in distinguishing the physiological responses of hostile and nonhostile individuals (Suarez and Williams, 1989, 1990; Suls and Wan, 1993).

Although the precise pathways connecting cardiovascular reactivity to disease progression are only beginning to be pinpointed in humans, research with nonhuman primates suggests that the sympathetic hyperreactivity occasioned by recurrent socioemotional stress can injure inner arterial walls, initiate atherosclerosis, and impair vascular responsiveness, each of which can contribute to the development of coronary heart disease (Kaplan *et al.*, 1993; Spence *et al.*, 1996). Cardiovascular reactivity is further implicated in disease progression by the results of animal studies testing the effects of β-blockers: β-blockers reduce both sympathetic reactivity and atherogenesis in stressed animals (Kaplan *et al.*, 1993).

Knowing that exaggerated cardiovascular responses may damage people's health, it becomes critical to learn more about the psychological and physiological characteristics of this hyperreactivity. Our approach has been to examine how hostile and nonhostile individuals differ in their reactions to anger. We chose to study anger because emotion theorists have argued that the affective trait of hostility should predispose some individuals to experience and/or express anger at lower thresholds than other individuals (Ekman, 1984; Lazarus, 1991; Ortony *et al.*, 1988; Rosenberg *et al.*, 1998).

Anger, which typically arises from a perceived demeaning offense or personal injustice (Lazarus, 1991) reliably yields increases in heart rate and both systolic and diastolic blood pressure (Ax, 1953; Schwartz *et al.*, 1981; Siegman, 1993; Sinha *et al.*, 1992). While experiences of anger are certainly not unique to hostile individuals, a transactional model suggests that a hostile person's overt antagonistic style can create more frequent episodes of anger and other negative affects (Smith, 1992). Hostile people, then, may be not only more physiologically reactive to emotional stressors, but also more prone to creating interpersonal conflict and the potential for anger in their daily lives.

We speculate that in addition to *more frequent* anger episodes that spark *more intense* cardiovascular reactivity, hostile individuals may also experience *longer-lasting* cardiovascular responses to anger. For instance, hostile individuals' antagonistic interpersonal attitudes may predispose them to ruminate on how those with whom they are angry are "untrustworthy, undeserving, and immoral" (Barefoot, 1992, p. 14). Rumination about anger has been shown to prolong its subjective experience (Rusting and Nolen-Hoeksema, 1998) and it seems plausible that rumination might also prolong cardiovascular reactivity. This raises the possibility that the health-damaging effects of cardiovascular reactivity may accumulate in hostile individuals not only from a larger magnitude of reactivity, but also from a longer duration of reactivity (Linden *et al.*, 1997). Protracted episodes of emotion-related cardiovascular reactivity may imply added physical stress on the cardiovascular system, physical stress that may further potentiate atherosclerosis.

Traditionally, cardiovascular hyperreactivity has been indexed by the magnitude of an individual's cardiovascular response to a discrete laboratory event. In more limited instances, cardiovascular recovery, or the degree to which cardiovascular responses return to baseline levels, is also used to index hyperreactivity (Linden *et al.*, 1997; Schuler and O'Brien, 1997). The typical strategy for measuring recovery, however, relies on assessments of the magnitude of an individual's cardiovascular response during a specified postevent recovery phase (Suarez and Williams, 1990; Vitaliano *et al.*, 1995). This empirical strategy captures the duration of the targeted cardiovascular response only indirectly at best. In the present study, we assess the duration of cardiovascular reactivity more *directly* by measuring the time elapsed before cardiovascular responses return to baseline levels. Time-based measures of cardiovascular recovery have been shown to be independent of the magnitude of cardiovascular arousal and to reflect individual and group differences in emotional responding (Fredrickson and Levenson, 1998; Fredrickson *et al.*, 2000; Tugade and Fredrickson, 1997). Our hypothesis was that, relative to their nonhostile counterparts, hostile individuals would exhibit not only greater, but also more long-lasting cardiovascular responses to anger.

METHOD

Participants

Participants were 66 older adults recruited from community organizations. Only those reporting no medication use for high blood pressure were included in this study. Each received $25 for their participation. The sample included 20 African Americans (13 women and 7 men) and 46 Caucasian Americans (25 women and 21 men). The mean age was 62.0, ranging from 41 to 87 (SD = 11.22).

Structured Interview

Participants took part in an abbreviated Western Collaborative Group Study Structured Interview (SI) (Rosenman, 1978) originally designed to measure Type A behavior but subsequently used to measure hostility (Matthews *et al.*, 1977). Questions dealt with issues such as time urgency, competitiveness, and anger. Interviewers were trained to deliver the interview in a businesslike and nonchallenging manner. Previous data (Haney *et al.*, 1996) were used to divide the SI into two versions that elicited comparable numbers of hostile behaviors with adequate reliability. All interviews were conducted individually and were audio- and videotaped for later behavioral analysis.

Assessment of Hostility

Interaction style during the structured interview was rated from audiotapes using the Interpersonal Hostility Assessment Technique (IHAT) (Barefoot, 1992; Haney *et al.*, 1996). The emphasis of this technique is on *how* participants respond rather than on the content of their responses. Within the interview, each occurrence of four types of hostile behavior was coded by a trained assessor: (a) Hostile Withhold/Evade—the participant's response is uncooperative or evasive and is delivered in a hostile fashion; (b) Irritation—the participant's voice stylistics indicate increased arousal due to hostile affect, either directed toward the interviewer or caused by reliving a previous angry episode; (c) Indirect Challenge—the participant answers in a way that deprecates the interview or interviewer by implication (e.g., using a tone of voice suggesting that the answer was obvious and so the question was pointless); and (d) Direct Challenge—the participant openly expresses antagonism toward the interview or interviewer. A Hostile Behavior Index (HBI) is computed by averaging the instances of hostile behavior across major questions and probes. Interrater reliability for this index has been reported at .89 (Haney *et al.*, 1996). Construct validity has been demonstrated with associations between IHAT scores and facial expressions of anger and disgust (Brummett *et al.*, 1998).

In the present sample, HBI scores ranged from 0.04 to 1.77, with a mean of 0.30 (SD = 0.26). The distribution exhibited a positive skew, which was corrected with a logarithmic transformation.[4] In addition, there was an unexpected mean difference in HBI scores between versions of the SI. To compensate for this, the transformed HBI scores were adjusted for version, yielding a mean of 0.21 (median = 0.20, SD = 0.77).

Relived Anger Memory Task

Participants were asked to recall and then later relive a specific past experience of anger (Levenson *et al.*, 1991). To locate a specific anger memory, participants were asked to recall a time when they felt so angry that they wanted to explode. When a participant indicated retrieving a memory, the experimenter then asked, "Tell me what happened and how you felt. Where were you? Who were you with?" After the participant provided details about the selected memory, the experimenter continued:

> Later in this session, instructions on the video monitor will ask you to think about the time when you felt so angry you wanted to explode—the time when . . . [fill in details]. At that point, we want you to relive this time in your mind, and to reexperience the anger that you felt then—just by silently recalling the memories of it in your mind. We want you to concentrate just on the time when you felt your anger strongly. As you are reliving this situation in your mind, we'll ask you to indicate when you begin to feel your anger, and then simply let the feeling grow for a few moments. During the time that you're thinking about this memory, the video monitor will be blank. You may stop reliving your anger as soon as the video presentation begins again.

Emotion Self-Reports

At three points during the study, participants provided ratings of their emotional experience using eight emotion terms (i.e., amusement, anger, contentment, disgust, fear, happiness, sadness, surprise) on 9-point Likert scales (0 = none, 8 = most intense imaginable). This measurement strategy is common in studies that induce specific emotions (Ekman *et al.*, 1980; Fredrickson and Levenson, 1998; Larsen and Fredrickson, 1999).

[4]We also analyzed the raw, untransformed HBI scores and obtained the same basic pattern of results as reported here.

Cardiovascular Measures

An Ohmeda Finapres blood pressure monitor (Model 2300) was used to collect continuous measures of finger arterial pressure[5] and heart rate. The Finapres self-regulating finger cuff was attached to the middle phalange of the middle finger of the participant's nondominant hand. A sling was used to immobilize the participant's arm at heart level. Beat-by-beat measures of heart rate (HR), systolic blood pressure (SBP), and diastolic blood pressure (DBP) were recorded on a microcomputer through a serial interface using custom software. We later converted these beat-by-beat data into a second-by-second metric.

Procedure

All participants were tested individually, either at Duke University or in laboratories set up within community civic centers. Each session lasted about 90 min, with the first half devoted to the structured interview (without cardiovascular assessment) and the second half devoted to the relived anger memory task (with cardiovascular assessment). Informed consent was obtained upon arrival. After completing a brief demographic form, participants took part in the structured interview as described above. The ethnicity and sex of interviewers and participants were counterbalanced. Following the interview, participants were taken to a second room and greeted by a Caucasian American experimenter (counterbalanced across participants by sex). The experimenter attached the blood pressure finger cuff as indicated above. After a 2-min adaptation phase, cardiovascular measures were obtained for a 60-sec initial resting baseline phase. Next, the experimenter introduced the relived anger memory task. Once participants identified a suitable memory, they completed the first emotion report. A number of additional questionnaires were then administered intended to serve as distractions from the anger memory, as well as to give participants a break from the pressurized finger cuff. Next, cardiovascular measurement resumed. At this point, instructions for the relived anger memory task were delivered by a stimulus videotape (without sound), and the experimenter moved out of view. An introductory screen was followed by an abstract visual display (90 sec) which served as the proximal vanilla baseline (Jennings *et al.*, 1992).

[5]Absolute levels of finger arterial pressure as measured by the Ohmeda Finapres device may not be exactly comparable to absolute levels of blood pressure as measured in the upper arm using traditional arm cuff devices. However, validation studies confirm that changes in blood pressure derived from the Finapres device are comparable to those obtained from more traditional devices (Gerin *et al.*, 1993; Godaert, 1995).

After an additional 2-min relaxation phase, instructions to begin recalling the self-chosen anger memory appeared: participants were asked to think about the time they felt so angry they wanted to explode and to raise a finger when they began to feel their anger. The experimenter paused the stimulus tape on this instruction screen, and the participants' finger raise served as the cue to restart it. Twenty seconds after participants indicated feeling anger (with the finger raise), a clip of ocean waves began. This provided the external cue for participants to stop reliving their anger. The ocean waves clip was followed by a blank screen, lasting for 150 sec, which served as the extended recovery period. This ended the stimulus videotape and participants next completed two additional emotion reports to indicate how they felt during the relived anger task and during the presentation of the ocean waves.

RESULTS

Overview of Analytic Strategy

We first tested for group differences in hostility scores and divided the sample at the median into High and Low Hostility groups.[6] We then tested for group differences in levels of cardiovascular activity during the two baseline phases. Next, we confirmed that the relived anger task successfully induced anger by examining data from the emotion self-reports. We then tested for group differences in the magnitude of cardiovascular responses during the relived anger task and in the duration of these responses following the anger task. Due to the sample size (especially the low number of African American males), we limited all tests of interaction effects to two-way interactions.

Hostility Scores

We tested for group differences in (transformed and adjusted) hostility scores using a 2×2 (Sex $\times$ Ethnicity) ANOVA. This test yielded a main effect for Ethnicity [$F(1,62) = 5.80$, $p < .05$], with Caucasian Americans (M = 0.37, SD = 0.72) outscoring African Americans (M = −0.14, SD = 0.78). Previous work using self-report measures (not behavioral observations), found African Americans to score higher on hostility, but lower on trait anger, and concluded that the constructs of hostility and anger may function somewhat differently across ethnicities (Durel *et al.*, 1989). The absence of a sex

[6]We also analyzed the data with regression using continuous hostility scores and obtained an identical pattern of results as that reported here. We chose to report the data based on the median split for ease of presentation.

difference is consistent with previous work using the IHAT with similar age groups (Barefoot *et al.*, 1996). When the sample was divided at the median into Low and High Hostile groups, the Low Hostile group ($n = 33$) included 13 African Americans (8 women and 5 men) and 20 Caucasian Americans (14 women and 6 men). The High Hostile group ($n = 33$) included 7 African Americans (5 women and 2 men) and 26 Caucasian Americans (11 women and 15 men).

Baseline Cardiovascular Activity

Mean levels of HR, SBP, and DBP were calculated for both the initial resting baseline phase (pre-memory retrieval) and the proximal vanilla baseline phase (post-memory retrieval). Table I presents these means separately for Low and High Hostile participants. Within-subject *t* tests (conducted separately for Low and High Hostile groups) revealed that the two baselines were not comparable, particularly for the High Hostile participants (see Table I). This suggests that participants did not reliably return to their initial resting baseline levels following the anger retrieval and raises the possibility that the distraction tasks following memory retrieval were not equally effective across Hostility groups.

We tested for group differences *within* each baseline phase using $2 \times 2 \times 2$ ANOVAs (Sex × Ethnicity × Hostility). Only one group difference reached significance: During the initial resting baseline, DBP levels differed

Table I. Mean Cardiovascular Activity During Baseline Phases and Relived Anger

	Experimental phase		
Variable	Initial baseline	Proximal baseline	Relived anger
Low hostile			
HR	74.01_a	73.15_a	74.55_b
	(10.12)	(10.13)	(9.78)
SBP	131.71_a	141.63_b	148.71_c
	(26.51)	(25.02)	(26.44)
DBP	70.06_a	72.71_a	76.33_b
	(15.15)	(13.92)	(14.54)
High hostile			
HR	72.36_a	71.58_b	74.38_c
	(13.02)	(13.74)	(14.31)
SBP	131.81_a	139.57_b	151.50_c
	(22.31)	(25.48)	(28.92)
DBP	68.57_a	72.22_b	78.15_c
	(13.78)	(14.19)	(15.24)

Note. HR, heart rate (bpm); SBP, systolic blood pressure (mm Hg); DBP, diastolic blood pressure (mm Hg). Standard deviations are presented in parentheses. Means in the same row that do not share subscripts differ at $p < .05$ by within-subject *t* tests.

Table II. Mean Emotion Self-Reports for Original Anger Experience, Relived Anger Memory, and Ocean Waves Videoclip

	Emotion episode		
Emotion	Original anger	Relived anger	Ocean waves
Amusement	1.38	1.72	3.05
Anger	7.21	4.23	1.48
Contentment	1.58	2.79	4.63
Disgust	6.02	3.61	1.31
Fear	2.44	1.14	0.80
Happiness	0.41	1.62	3.92
Sadness	4.75	3.26	1.62
Surprise	5.05	2.58	1.82

by sex [$F(1,57) = 7.50$, $p < .01$]. Follow-up tests showed that women had a lower DBP during the initial resting baseline (women, M = 65.57, SD = 13.80; men, M = 74.45, SD = 13.79), a difference consistent with prior findings with this age group (Vitaliano *et al.*, 1995).

Self-Reported Emotion

Table II provides mean self-reports of eight emotions for the original anger experience, the relived anger memory, and the clip of ocean waves. These data suggest that participants recalled relatively intense anger experiences that were blended with high levels of disgust and moderate levels of sadness and surprise (see Table II, column 2) and that participants reported reexperiencing moderate levels of anger in the lab testing situation (see Table II, column 3). Nonetheless, participants' emotional responses to the subsequent videoclip of ocean waves were generally positive, with reports of moderate levels of contentment and happiness (see Table II, column 4). We analyzed the emotion reports for the relived anger memory and the ocean waves clip with 2 × 2 × 2 MANOVAs (Sex × Ethnicity × Hostility). No significant group differences in self-reported emotion emerged.

Magnitude of Cardiovascular Responses to Anger

We calculated the magnitude of cardiovascular reactivity by subtracting initial resting baseline levels from mean levels during the relived anger task. Given the differences across the two baseline means (see Table I), using proximal baseline levels here would underestimate the full magnitude of reactivity for the High Hostile group. Across all participants, the mean magnitude of response during relived anger was 1.18 bpm for HR (SD = 4.21 bpm),

Table III. Mean Magnitude of Blood Pressure Response (mm Hg) to Anger by Hostility Group

	Hostility group	
Variable	Low	High
SBP	12.55	20.04
	(21.24)	(20.59)
DBP	4.53	9.60
	(9.80)	(10.88)

Note. Standard deviations are presented in parentheses.

16.29 mm Hg for SBP (SD = 21.10 mm Hg), and 7.06 mm Hg for DBP (SD = 10.59 mm Hg). We tested for group differences in these change scores using 2 × 2 × 2 ANCOVAs (Sex × Ethnicity × Hostility). Given the sex difference in cardiovascular activity evident at rest, we used initial resting baseline means as covariates. Analysis of HR change yielded no significant effects. In contrast, analysis of SBP change produced main effects for Hostility Group [$F(1,56) = 4.53$, $p < .05$] and Sex [$F(1,56) = 5.61$, $p < .05$; male M = 10.14, SD = 11.78; female M = 20.78, SD = 25.09], with no interaction effects, and analysis of DBP change produced a sole main effect for Hostility Group [$F(1,56) = 7.38$, $p < .01$], with no interaction effects. Table III presents the magnitude of SBP and DBP responses by Hostility Group. Note that High Hostile participants showed greater blood pressure responses to anger. Evidence for greater cardiovascular reactivity to anger among High Hostile participants is consistent with past empirical work (Suarez and Williams, 1989, 1990; Suls and Wan, 1993). Past work is less consistent regarding sex differences in cardiovascular responses to anger (Lawler *et al.*, 1993; Levenson *et al.*, 1991).

Duration of Cardiovascular Responses to Anger

To quantify the duration of participants' cardiovascular responses, we measured the time that it took for cardiovascular responses to return to proximal baseline levels. We calculated duration variables with respect to proximal baseline levels and not initial baseline levels because preliminary analyses indicated that a large subset of participants failed to exhibit recovery to within *initial* baseline levels during the extended recovery phase. Most did, however, exhibit recovery to within *proximal* baseline levels. These time-based measures of recovery were computed separately for each participant on each cardiovascular measure (i.e., HR, SBP, and DBP). These duration measures reflected the time elapsed until each participant's response on a

Table IV. Mean Duration of DBP Response (sec) Following Relived Anger by Hostility Group and Ethnicity

	Hostility group		Ethnicity	
Variable	Low	High	Caucasian-American	African-American
DBP	42.31 (83.60)	80.18 (87.50)	43.16 (69.20)	102.90 (108.78)

Note. Standard deviations are presented in parentheses.

given cardiovascular measure returned to within the interval defined by his or her own proximal baseline mean for that measure ± 1 SD of that mean (Fredrickson and Levenson, 1998). Specifically, durations of HR, SBP, and DBP reactivity, respectively, were defined as the time elapsed (seconds) after the onset of the ocean waves clip until levels of each index returned to within each participant's own proximal baseline range and remained within this range for 5 or 6 consecutive sec.[7] As in previous studies, duration of cardiovascular reactivity was uncorrelated with magnitude of reactivity (r's = .10, .17, and .14 for HR, SBP, and DBP, respectively; all ns).

Across all participants, the mean times to recover were 27.17 sec for HR (SD = 57.65 sec), 37.31 sec for SBP (SD = 63.24 sec), and 61.54 sec for DBP (SD = 87.05 sec). We tested for group differences in recovery times using 2 × 2 × 2 ANCOVAs (Sex × Ethnicity × Hostility). Given the group differences evident at rest and in response magnitude, we used as covariates each individual's initial resting baseline mean and mean magnitude of response during relived anger.

Analyses of the duration of HR and SBP responses yielded no significant main effects or interactions. In contrast, analyses of the duration of DBP responses yielded a main effect for Hostility group [$F(1,54) = 7.60$, $p < .01$], as well as a main effect for Ethnicity [$F(1,54) = 6.28$, $p < .05$], with no interaction effects. Table IV displays the mean durations of cardiovascular reactivity broken down by Hostility group and Ethnicity.[8] Note that High Hostile participants and African Americans showed more protracted DBP responses to anger (see Table IV). The observation of an ethnicity difference solely for DBP is consistent with a recent meta-analysis (Schuler and O'Brien, 1997) reporting that African Americans reliably show delayed DBP

[7]For those few who still did not exhibit recovery by the latter criterion, duration values were conservatively estimated at 250 sec, which was the remaining duration of cardiovascular assessment. For HR, 3 of 60 participants (4.5%) had not achieved recovery and were therefore estimated. For SBP, 3 of 66 (4.5%) were estimated. For DBP, 8 of 66 (12.1%) were estimated. Those with estimated duration values were equally represented across Hostility groups.

[8]As is typical of time-based data, the duration scores exhibited a positive skew, with standard deviations increasing with increasing means. To explore whether outliers accounted for the observed patterns of results, analyses of duration scores were repeated using nonparametric tests on ranked data. All effects remained significant.

recovery relative to Caucasian Americans. To our knowledge, our hypothesized finding that High Hostiles show longer-lasting DBP responses to anger is unprecedented in the empirical literature.

DISCUSSION

We hypothesized that individuals identified as hostile using the IHAT behavioral assessment would show not only greater, but also more long-lasting cardiovascular responses when reliving a self-chosen anger memory. The data support this hypothesis: hostile individuals exhibited greater SBP and DBP reactivity during relived anger and longer-lasting DBP reactivity following relived anger.

Although this study has some limitations (e.g., sample diversity, short baseline assessments), its findings cast new light on the purported link between hostility and coronary heart disease as well as possible health-promotion strategies. Prior studies have documented positive associations between behavioral hostility (measured with IHAT scores) and the presence and severity of coronary heart disease (Barefoot *et al.*, 1994; Haney *et al.*, 1996). The present study suggests that the duration of cardiovascular reactivity may be a fruitful parameter to explain this positive association. Duration measures may be more reflective of relatively sustained and/or chronic arousal, which might be especially pathogenic for disease processes such as atherosclerosis that develop over extended time periods (Linden *et al.*, 1997). The relative importance of duration versus magnitude of cardiovascular reactivity in predicting actual health outcomes has not yet been addressed. Future studies that decompose cardiovascular reactivity into magnitude and duration measures and link these to the incidence and severity of coronary heart disease are needed. At the very least, our data add to the evidence that the magnitude and duration of cardiovascular reactivity may reflect and/or be influenced by different underlying factors and merit study (Linden *et al.*, 1997).

Psychological interventions aimed at health promotion through emotion regulation may in fact modify the duration of emotion-related reactivity more effectively than they modify the magnitude of reactivity. Rumination, for instance, has been proposed to prolong negative emotional arousal (Linden *et al.*, 1997) and is known to prolong subjective experiences of anger (Rusting and Nolen-Hoeksema, 1998). In contrast, distracting activities are known to speed recovery from subjective experiences of anger (Rusting and Nolen-Hoeksema, 1998), and distractions that evoke positive emotions are known to speed recovery from negative emotional arousal (Fredrickson and Levenson, 1998; Fredrickson *et al.*, 2000). Cutting short the duration of emotion-related cardiovascular reactivity may in turn serve to lessen the exposure of the cardiovascular system to the health-damaging effects of excessive sympathetic activity, thereby slowing the purported incremental progression toward disease.

The present findings also illustrate the promise of measures that index the duration of cardiovascular recovery directly in units of time. Calculating time-based measures like these, however, requires continuous or beat-by-beat assessment, a temporal resolution only recently available in noninvasive measures of blood pressure. Previous work with similar time-based measures of cardiovascular recovery has shown that such measures are sensitive to individual differences in the propensity to smile and in parasympathetic cardiac control (Fredrickson and Levenson, 1998; Tugade and Fredrickson, 1997). The data reported here add to the evidence that emotion-related individual differences can translate into differences in the longevity of cardiovascular reactivity, which, in turn, can be captured by time-based measures of cardiovascular recovery.

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