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Hostility Moderates the Effects of Social Support and Intimacy on Blood Pressure in Daily Social Interactions

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Abstract

Objective—This study sought to determine the role of hostility in moderating the effects of positive social interactions on ambulatory blood pressure (ABP).

Design—Participants (341 adults) completed the Cook-Medley Hostility Scale and underwent ABP monitoring, assessed every 45 min during waking hours across 6 days. An electronic diary measuring mood and social interactions was completed at each ABP assessment.

Main Outcome Measures—The dependent variables from the ABP monitor included systolic blood pressure, diastolic blood pressure, and heart rate.

Results—Different patterns of ambulatory diastolic blood pressure (ADBP) responding to social interactions perceived as intimate or supportive among high- versus low-hostile individuals were observed. Higher intimacy ratings were linked to reductions in ADBP among low-hostile but not high-hostile individuals. Conversely, high-hostile, but not low-hostile, individuals showed increases in ADBP to situations rated high in social support. Although findings for ambulatory systolic blood pressure were nonsignificant, the pattern of results was similar to ADBP.

Conclusion—Hostile individuals may find offers of support stressful and may fail to benefit from intimacy during daily life. The pathogenic effects of hostility may be mediated in part by responses to social interactions, both positive and negative.

Keywords

ambulatory blood pressure; hostility; social support; intimacy; ecological momentary assessment

Trait hostility and social isolation, or lack of social support, have been identified as correlates of coronary heart disease risk (Rozanski, Blumenthal, & Kaplan, 1999). Interpersonal models designed to explain the relationship between hostility and coronary heart disease risk posit that these two characteristics may be interrelated, such that hostile individuals may promote social conflict and may be mistrustful of others' supportive efforts (e.g., Smith, Glazer, Ruiz, & Gallo, 2004). Indeed, evidence has suggested that trait hostility and low social support tend to co-occur and may predict disease outcome synergistically (e.g., Scherwitz, Perkins, Chesney, & Hughes, 1991).

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Some of these data were presented at the 28th annual meeting for the Society of Behavioral Medicine held in March 2007 in Washington, DC.

Saul Shiffman is cofounder and chief science officer of Invivodata, Inc., which provides electronic diary methods like those reported here for use in clinical trials.

Hostile individuals have been found to exhibit exaggerated cardiovascular reactivity to interpersonal provocation relative to their nonhostile counterparts (e.g., Davis, Matthews, & McGrath, 2000). To the extent that these responses are frequent and large in magnitude, they are presumed to contribute to a number of pathogenic processes associated with increased cardiovascular disease risk (e.g., Treiber et al., 2003). Although there is a considerable literature examining the effects of hostility on physiological responses to interpersonal provocation, less is known about the role of hostility in moderating responses to positive social interactions.

Research has suggested that hostile individuals may show more pronounced cardiovascular reactivity than nonhostile individuals under laboratory conditions of social support (e.g., Smith, Ruiz, & Uchino, 2004). In a related finding, Lepore (1995) reported a moderating effect of cynicism, derived from the Cook-Medley Hostility Scale (CMHS; Cook & Medley, 1954), on blood pressure (BP) reactivity to experimentally induced social support during a speech stressor. Results indicated that cynically hostile individuals failed to show the stress-buffering influence of support on BP responses exhibited by those scoring low on cynicism. One study found that hostile individuals showed significant increases in BP relative to low-hostile individuals during self-disclosure of personally troubling events (Christensen & Smith, 1993), suggesting that social interactions characterized by intimacy may promote differential physiological responding among hostile individuals.

Because the prevailing models of hostility and coronary heart disease presume that the pathogenic effects of hostility unfold in the course of daily life events, field assessments may be expected to provide more relevant information with respect to the mechanisms linking hostility and disease. Ecological momentary assessment (EMA) methods, characterized by repeated assessments of individuals' momentary states in their natural environments (Stone & Shiffman, 1994), can be used in conjunction with ambulatory monitoring of BP and heart rate (HR) to ascertain the influence of individual differences in hostility on behavioral and physiological responses to daily life social interactions.

It remains unknown whether the moderating effects of hostility on CV responses to social interactions of self-disclosure and support is apparent in daily living. Previous research using EMA methods among hostile individuals found that CMHS scores predicted more frequent negative and less frequent positive social interactions and that the intensity of negative interactions was linked to elevations in diastolic BP for high-, but not for low-, hostile individuals (Brondolo et al., 2003). In this study, CMHS scores did not moderate the BP responses to positive social interactions assessed as pleasant, friendly, or agreeable. It is possible that these social interactions were too broadly defined to detect BP differences as a function of hostility and that it is necessary to specifically assess social situations characterized by self-disclosure and support (e.g., Christensen & Smith, 1993; Lepore, 1995). Offerings of social support and discussion of personal feelings may serve as an ego threat among hostile individuals, eliciting a sense of vulnerability that may be associated with differential cardiovascular responses relative to those scoring low on hostility.

The primary aim of the current study was to use EMA methods to determine the role of hostility in moderating the effects of positive social interactions, including social support and intimacy, on ambulatory blood pressure (ABP) in a sample of healthy older men and women. Hostility was predicted to correlate negatively with the frequency and strength of social interactions rated as agreeable, intimate, and supportive. Furthermore, hostile individuals were expected to show significant increases in ABP responses to social support and intimacy relative to those scoring low on hostility. To our knowledge, the present study is the first investigation to explore the moderating influence of hostility on ABP in response to self-reported situations of social support and intimacy in daily life. The influence of gender was also considered, as previous

studies have suggested that the relationship between hostility and ABP may be stronger among men (e.g., Linden, Chambers, Maurice, & Lenz, 1993; Raikkonen, Matthews, Flory, & Owens, 1999).

Method

Participants

Three hundred forty-one healthy adults (168 men, 173 women; $M = 60$ years, $SD = 4.71$) were selected from a larger sample involved in the Pittsburgh Healthy Heart Project, an ongoing prospective investigation of biobehavioral predictors for subclinical cardiovascular disease progression. This study received approval from the institutional review board at the University of Pittsburgh. Recruitment involved targeted mailings and media postings in the Pittsburgh metropolitan area. Participants provided written informed consent to all procedures and were paid \$200 for completing the assessments involved in this portion of the study. It should be noted that participants also underwent a number of assessments not described in this report (see Kamarck et al., 2004). Previous articles have reported other findings from this sample (e.g., Kamarck, Janicki, et al., 2002; Kamarck, Polk, Sutton-Tyrell, & Muldoon, 2002; Kamarck, Schwartz, Janicki, Shiffman, & Raynor, 2003; Janicki, Kamarck, Shiffman, Sutton-Tyrell, & Gwaltney, 2005; Stewart, Janicki, & Kamarck, 2006).

Inclusion criteria included age (50–70 years) and peri- or post-menopausal status (absence of menses during past 6 months). Primary exclusion criteria included any history of chronic medical disorders, pharmacologic treatment for hypertension or hypercholesterolemia within the past year, current or regular use of any medication with autonomic effects, or excessive alcohol consumption, defined as 5 or more drinks at least 3 times per week. Persons with diabetes receiving insulin were also excluded, as were those with mean clinic systolic BP greater than 180 mmHg or a diastolic BP greater than 110 mmHg. In addition, individuals whose arm circumference interfered with reliable detection of Korotkoff sounds were not enrolled.

A total of 464 individuals provided written informed consent for participation and were enrolled in the study. From this sample, 13 were found ineligible during the initial data collection period, and an additional 69 individuals dropped out during one of the subsequent visits. For the current study, those with fewer than 30 complete ABP and diary readings for either of the ambulatory assessment periods ($n = 34$) or who began taking antihypertensive medications ($n = 7$) were not included in the analyses. Out of the remaining sample ($n = 341$), 85% were Caucasian and 14% were African American, with 25% of the sample reporting no more than a high school education and 50% reporting a bachelor's degree or higher.

Measures and Procedures

Initial visit—The initial study visit included a medical history interview, BP screening, and a blood draw for risk factor assessment. Participants were instructed to abstain from food or caffeine consumption for 12 hr before this early morning visit, and they were seated for at least 30 min before the BP screening, which was performed by a trained research nurse using a standard mercury sphygmomanometer (Vital Signs Model 63154, Country Technology, Gays Mills, Wisconsin). Following guidelines from the American Heart Association (Perloff et al., 1993), three seated BP readings were taken at 2-min intervals, with the screening value being designated by the average of the last two readings.

A demographics questionnaire was also administered at this visit, which assessed age, gender, race, and education level. Race was coded as a binary (dummy) variable (0 = *Caucasian*, 1 = *minority*). The prevalence of non-African American ethnic minorities in the sample ($n = 5$)

was too small to examine these groups separately. Participants were classified into four categories according to their education level (1 = *high school or less*, 2 = *some college or technical school*, 3 = *bachelor's degree*, and 4 = *graduate degree*).

ABP monitoring—Approximately 1 month following the initial study visits ($Mdn = 31$ days, range = 3–145), participants were trained to use an automated, auscultatory ABP monitor (Accutrack DX, Suntech, Raleigh, North Carolina), in conjunction with an EMA electronic diary (see below). The ABP monitor was programmed to inflate every 45 min during waking hours. Data collection took place across 3 days during two periods separated by approximately 4 months, for a total of 6 days of ABP measurements. Before each 3-day period, participants underwent a 1-day training interval during which they practiced using the equipment and were given feedback on their performance. Invalid ABP readings were deleted using out-of-range and error criteria previously described (Kamarck, Polk, 2002).

Electronic diary—The revised Diary of Ambulatory Behavioral States (DABS) used in the current study is a 45-item self-report diary designed for repeated administration in conjunction with ABP (Kamarck et al., 1998). DABS items were presented on a palmtop computer (Palm Pilot Professional, Palm, Santa Clara, California) programmed specifically for this project (Invivodata, Inc., Pittsburgh, Pennsylvania). The DABS contains ABP-relevant items, such as posture, physical exertion, talking, food consumption, and comfort with ambient temperature. Furthermore, multiitem Likert-type scales from the DABS assess within person-fluctuations in mood and social interaction qualities, with intensity responses ranging from 0 to 10. Responses were recorded using a stylus on an 11-point visual analog scale ranging from *no* to *yes*. An auditory prompt was administered 4 min following the beginning of cuff inflation, if necessary, as a reminder to complete the DABS. As part of the DABS, participants were asked about currently being in a social interaction (*yes* or *no*), which was defined as “a give-and-take exchange with another, which may or may not involve conversation” (Reis & Wheeler, 1991). For this report, observations were not included for analyses unless participants responded in the affirmative to this question.

The following four scales were designed to assess positive qualities of social interactions: Agreeableness (three items), Intimacy (three items), Instrumental Support (three items), and Emotional Support (three items). Sample items include “Pleasant Interaction?” (Agreeableness), “Did you discuss personal feelings?” (Intimacy), “Someone helped you with an errand/task?” (Instrumental Support), and “Someone expressed care/concern for you?” (Emotional Support). Social interactions rated as high in agreeableness were assessed on average to involve content that was less personal in nature than those rated high on social support or intimacy. Because there were a number of within-subject observations for each scale, the observations were averaged within person. When averaged for each 3-day period, the test–retest reliabilities for these scales across the 4-month interval ranged from .69 to .83, with internal consistencies ranging from .82 to .90, suggesting that these measures may reflect individual differences in social interaction quality that are relatively stable over time.

Use of the electronic diary facilitates data entry and feedback, permitting rapid data downloads and display. The diary precluded missing or out-of-range entries, and the time stamp associated with each entry provided a check on timely compliance and facilitated merging of data from the electronic diary with that from the ABP monitor. “Delay” and “suspend” software features enable participants to postpone or forgo interviews when necessary (e.g., during church or while driving). Participants are discouraged from overusing these features, however, and their use is recorded, as with other responses (Shiffman, 1999). Compliance data for use of the DABS in this sample has been documented in a recent report (Kamarck et al., 2007).

Hostility assessment—The CMHS consists of 50 true–false items from the Minnesota Multiphasic Personality Inventory (Hathaway & McKinley, 1943). Participants completed the CMHS on a computer during a laboratory visit that took place in between the two ABP monitoring periods. The CMHS scale is characterized by both high internal consistency (Cronbach's $\alpha = .80$ – $.82$; Smith & Frohm, 1985), and high test–retest reliability ($r > .8$ over periods of 1–4 years; Barefoot, Dahlstrom, & Williams, 1983; Schekelle, Gale, Ostfeld, & Paul, 1983). Sample items include “It is safer to trust nobody” and “Most people inwardly dislike putting themselves out to help others.”

Analytic Strategy

Because the primary aim of this study was to determine the relationship between hostility and positive social interactions in predicting ABP, analyses were restricted to ABP recordings taking place during social interactions. Multilevel modeling (PROC MIXED; SAS Institute, 2001) was used for most of the analyses in this report. The advantages to this approach over conventional regression analyses include the ability to handle repeated within-subjects measurements of both predictors (e.g., DABS social interaction quality subscales) and dependent (e.g., ABP) variables in conjunction with between-subjects predictors (i.e., demographic variables and CMHS), to model autocorrelation effects, and to handle missing data (Schwartz & Stone, 1998). Maximum likelihood methods were used to obtain solutions for the models. A spatial power function was used to model autocorrelated errors (Polk, Kamarck, & Shiffman, 2002).

Pearson correlation was used (two tailed) to determine the strength and direction of the relationship between hostility and social interaction frequency, indexed by the proportion of times participants indicated they were in a social interaction during cuff inflation. Additional correlations were tested to examine the relationship between hostility and the frequency of social interactions characterized by the DABS positive social interaction subscales, with separate correlations for agreeableness, intimacy, and the social support variables. Frequencies of “highly” agreeable, intimate, and supportive social interactions were indexed by proportion of encounters rated above the grand median (sample median of participant means) for agreeableness, intimacy, and the social support variables, respectively.

To test the effect of hostility on the mean scores for each of these social interaction scales, multilevel models were conducted treating repeated DABS scales as dependent variables with agreeableness, intimacy, and the social support variables analyzed in separate models. Main effects were estimated for gender and hostility, in addition to the interaction term of Gender $\times$ Hostility, to determine whether the relationship between hostility and social interaction quality varies as a function of gender.

A second set of multilevel models were conducted to determine the main effects of hostility and statistical interactions among gender and the DABS positive social interaction scale scores (e.g., agreeableness, intimacy, and social support) in predicting ABP and ambulatory heart rate (AHR). Main effects for hostility are reported, followed by any significant two-way or three-way interaction effects. Separate tests were conducted for systolic BP, diastolic BP, and HR. Positive social interaction scale scores from the DABS were included as random coefficients so that individual differences in the magnitude of these effects could be taken into consideration with these models. In accordance with recommendations by Aiken and West (1991), significant interactions were followed up by simple slopes analyses. For visual display purposes and analysis of simple slopes, ABP responding associated with “high” and “low” hostility was plotted at 1 and 2 standard deviations above and below the mean, and “high” and “low” DABS were represented at the mean maximum (i.e., the sample average of the maximum score for each person) and mean minimum scores for the sample.

To calculate the effect sizes associated with significant interaction effects between hostility and DABS variables on ABP, we estimated the between-person variance associated with the main effects predictor model (e.g., individual differences in the effects of intimacy as a predictor of ADBP), and we compared this with the between-person variance associated with the same model that also included the interaction with hostility (e.g., Intimacy $\times$ Hostility added as an additional predictor of ADBP). The percentage reduction in this variance after adding the interaction term (r^2) is a measure of the extent to which hostility accounts for individual differences in ABP changes during these daily social interactions, the square root of which is expressed as r .

The following time-varying covariates were included as fixed effects in each model: posture, physical activity, temperature, recent meal, snack, caffeine or alcohol consumption within the past 45 min, antihistamine or decongestant use within the past 4 hr, talking during cuff inflation, cigarette smoking within the past 5 min, and number of cigarettes smoked within the past 45 min. Age, race, body mass index, education, and gender were also included as fixed effects covariates in all the multilevel models included in this report. As significant Gender $\times$ Race Effects on ABP and AHR were observed, this interaction term was included in all models (race effects on ABP and AHR were generally present only for women).

Results

Descriptive Statistics

Average CMHS scores were in the low to moderate range, with a mean of 13.27 ($SD = 6.47$, range = 2–35). Men scored higher on the CMHS than women, $t(338) = 3.088$, $p < .005$. Average ABP and AHR for all participants (averaged by individual) was 128.48 mmHg ($SD = 12.01$) for systolic BP, 78.50 mmHg ($SD = 7.04$) for diastolic BP, and 80.31 ($SD = 9.23$) beats per minute for HR. Table 1 displays the mean values for ABP, AHR, CMHS, and DABS positive social interaction scale scores by gender. Preliminary analyses revealed men to exhibit significantly greater ambulatory systolic BP (ASBP; $B = -3.66$, $SE = 1.30$), $t(36000) = -2.81$, $p < .01$, and ADBP ($B = -2.71$, $SE = 0.75$), $t(36000) = -3.62$, $p < .001$, and women to exhibit significantly greater AHR ($B = 4.08$, $SE = 0.94$), $t(36000) = 4.33$, $p < .001$.

Frequency of social interactions—Out of an average 113.26 ($SD = 11.98$, range = 76–165) total electronic diary entries completed by each participant, 43.55 ($SD = 19.22$, range = 1–104; 38.45%) entries took place during social interactions. Table 2 displays means and standard deviations of DABS positive social interaction variables for participants scoring in the low and high CMHS quartiles. A marginal negative relationship was observed between CMHS scores and proportion of overall social interactions by participant ($r = -.103$, $p < .06$). Moreover, individuals with higher CMHS scores reported a lower frequency of agreeable interactions ($r = -.164$, $p < .005$) and intimate social interactions ($r = -.109$, $p < .05$). The frequency of social interactions characterized by instrumental or emotional support was not correlated with CMHS scores ($ps > .20$).

Influence of Hostility on Mean DABS Positive Social Interaction Scale Scores

Multilevel models were conducted to observe the influence of CMHS on the mean of positive social interaction scale scores, restricting analyses to social interactions during cuff inflation. Age, race, education, body mass index, and gender were included as fixed effects covariates in each model. Analyses revealed a marginal positive association between CMHS and magnitude of daily instrumental support ratings ($B = 0.024$, $SE = 0.013$), $t(14000) = 1.87$, $p = .062$, as well as a significant negative association between CMHS and magnitude of agreeable interactions ($B = -0.03$, $SE = 0.008$), $t(14000) = -4.07$, $p < .0001$ (see Table 2). These findings suggest that in addition to reporting fewer social interactions characterized as being high in

agreeableness and intimacy, hostile individuals tend to report their social interactions as being higher in instrumental support and as less pleasant. There were no significant Gender $\times$ Hostility interactions for any of the positive social interaction variables.

Influence of Hostility on ABP and AHR

Multilevel models were conducted to determine the association between CMHS and ABP/AHR, with demographic between-subjects variables and within-subjects time-varying factors being used as covariates. There was no relationship between CMHS and ABP ($ps > .15$), although a marginal positive association was observed between CMHS and AHR ($B = 0.15$, $SE = 0.08$), $t(13000) = 1.81$, $p = .07$. CMHS did not interact with gender to predict ABP or AHR.

To determine whether hostility is associated with the magnitude of cardiovascular response to social support, intimacy, or agreeable social interactions, the statistical interactions between hostility and these DABS variables were tested. Social interaction variables served as within-subjects random effects predictor variables. Results revealed an interaction between CMHS and instrumental support in predicting ADBP ($B = 0.017$, $SE = 0.007$), $t(13000) = 2.35$, $p < .05$. Simple slopes analyses revealed that participants scoring high on hostility exhibited significant increases in ADBP during social interactions rated high in instrumental support (1 SD above mean: $B = 0.27$, $p < .001$; 2 SD above mean: $B = 0.38$, $p < .001$), whereas low-hostile participants displayed nonsignificant changes in ADBP as a function of increases in instrumental support (1 SD below mean: $B = 0.05$, ns ; 2 SD below mean: $B = -0.06$, ns ; see Figure 1). Hostility did not interact with emotional support or agreeableness in predicting ABP or AHR ($ps > .2$).

CMHS interacted with intimacy ratings to predict ADBP levels ($B = 0.017$, $SE = 0.008$), $t(13000) = 2.08$, $p < .05$. Simple slopes analyses revealed low-hostile individuals to show significant reductions in ADBP as intimacy ratings increased (1 SD below mean: $B = -0.14$, $p < .05$; 2 SD below mean: $B = -0.26$, $p < .05$), whereas high-hostile individuals showed nonsignificant elevations in ADBP as intimacy increased (1 SD above mean: $B = 0.07$, ns ; 2 SD above mean: $B = 0.19$, ns ; see Figure 2). To calculate the effect sizes associated with these significant interaction effects, we examined the reduction in the (total) variance of the person-specific effects of these psychosocial variables accounted for by the addition of the interaction term. Resulting correlation values were .286, $p < .001$, for the Instrumental Support $\times$ Hostility interaction, and $-.211$, $p < .001$, for the Intimacy $\times$ Hostility interaction effect. These coefficients reflect the magnitude of the relationship between hostility and ADBP during these social interactions. The statistical interactions with CMHS and instrumental support or intimacy were nonsignificant in predicting ASBP and AHR ($ps > .13$). Moreover, gender was not found to moderate the relationship between hostility and any of the DABS positive social interaction variables, as evidenced by nonsignificant three-way interactions in predicting ABP and AHR ($ps > .13$).

Discussion

The purpose of this study was to ascertain the relationships among trait hostility and social interaction qualities in predicting daily BP and HR in an older healthy sample. Hostility was expected to be negatively associated with daily reports of agreeableness, intimacy, and social support. Moreover, hostile individuals were expected to show significant increases in daily cardiovascular responses as social support and intimacy increased. Finally, gender differences were examined as potential moderators of these effects.

The findings regarding the first hypothesis of hostility as a predictor of daily social interaction qualities were mixed. Hostile individuals were found to have fewer agreeable and intimate

social interactions and tended to have fewer social interactions overall. However, hostility was not associated with the frequency of encounters characterized by instrumental or emotional support and was marginally associated with more pronounced ratings of instrumental support. Nonetheless, hostility was negatively associated with agreeableness ratings during social interactions. The inverse relationship between hostility and frequency of social interactions, as well as between hostility and frequency and intensity of agreeable interactions, has been reported elsewhere (e.g., Brondolo et al., 2003) and may reflect behavioral and perceptual influences of a cynical mistrust.

Hostility was only marginally associated with AHR in this study ($p = .064$) and was not associated with average ABP during social interactions. The lack of main effects for the CMHS has been reported in other research (e.g., Brondolo et al., 2003; Enkelmann et al., 2005) and corroborates interpersonal models of hostility that take into account type and intensity of social interaction in predicting cardiovascular responses to stress.

In accordance with the second hypothesis of the current study regarding the moderating influence of hostility on ABP responses to the strength of social interactions, hostile individuals were found to show significant increases in ADBP during situations rated high in instrumental support, whereas low-hostile individuals showed nonsignificant decreases in ADBP (see Figure 1). Therefore, although hostility was marginally associated with ratings of higher instrumental support, these instances were characterized by increases in ABP for hostile individuals. Moreover, type of social support seemed to make a difference, as hostility interacted with instrumental support, but not emotional support, in predicting ADBP. These findings suggest that hostile individuals may fail to benefit from situations of instrumental support and may find offers of assistance stressful, as if suggestive of an inability for the hostile person to complete a task alone.

In partial support of the second hypothesis for the current study, a statistical interaction was observed between hostility and intimacy ratings on ADBP, indicating that low-hostile participants display significant reductions in ADBP along with increases in intimacy ratings, whereas hostile participants showed nonsignificant elevations in ADBP in intimate social interactions (see Figure 2). Previous findings in the laboratory have revealed hostile individuals to show significant increases in BP responses to a speech stressor involving self-disclosure of a personally troubling event compared with low-hostile individuals, suggesting that hostile individuals may find discussing personal feelings with others stressful (Christensen & Smith, 1993).

Unlike this laboratory study, we did not find significant elevations in BP among hostile individuals during intimate interactions. Although hostile participants showed an increase in ADBP with increases in intimacy ratings, the effect was nonsignificant ($B = 0.07$, *ns*, at 1 *SD* above mean; $B = 0.19$, *ns*, at 2 *SD* above mean). One explanation for this effect in comparison to Christensen and Smith (1993) concerns the topic of discussion. In their laboratory self-disclosure study, participants were instructed to specifically discuss a topic of personal distress, whereas in the current study participants merely reported having discussed personal feelings. It is possible that discussing personally distressing matters is requisite to observe significant elevations in BP responses among hostile individuals. Nonetheless, the current findings are broadly consistent with the laboratory evidence insofar as they suggest that hostile individuals fail to benefit from the presence of intimacy in their social interactions.

It should be noted that hostility interacted with instrumental support and intimacy to predict ADBP, whereas these statistical interactions for ASBP were nonsignificant. However, the general pattern of results for ASBP was similar to that observed with ADBP, whereby hostility was positively associated with ASBP to instrumental support and intimacy. The notion that

vascular (i.e., diastolic BP) responses may be differentially sensitive to anger or hostility effects is not unprecedented. For example, meta-analyses have revealed average effect sizes associated with BP reactivity to provocative laboratory stressors among individuals rating high on the CMHS to be stronger for diastolic BP than systolic BP (Suls & Wan, 1993). Moreover, similar findings have been reported in previous ambulatory research, whereby CMHS interacted with daily experiences of social conflict to predict ADBP, but not ASBP (Brondolo et al., 2003).

On the whole, the current findings provide support for interpersonal models of hostility by suggesting that hostile individuals exhibit significant BP responses to situations of social support and may not appear to be soothed by intimate social interactions, and they corroborate results reported from laboratory studies on social support (e.g., Chen, Gilligan, Coups, & Contrada, 2005; Lepore, 1995) and self-disclosure (Christensen & Smith, 1993). Furthermore, hostility was not found to interact with the agreeableness scale of social interactions characterized as pleasant and friendly in predicting ABP, a null finding that has been reported previously (Brondolo et al., 2003). Perhaps it is only those positive interactions potentially threatening in nature to hostile individuals (e.g., those involving disclosure of personal feelings or receiving offers of help on a task, which could be perceived as intrusive or condescending) that evoke differential physiological responses. Thus, encounters simply characterized as pleasant or agreeable may be too superficial to tap into these effects among hostile individuals, and it may be necessary to inquire about qualities of social interactions that may pose an ego threat or influence a sense of vulnerability.

Although this study makes important contributions to the extant literature, a couple of key limitations need to be noted. First, although hostility was characterized by a single score in the current study, hostility is a multifaceted construct, including affective, behavioral, and cognitive components (e.g., Smith, Glazer et al., 2004), each of which may be differentially associated with physiological responses to social situations. For example, the cognitive component of hostility (e.g., cynical mistrust) may be especially important for the phenomena observed in this study, insofar as it may relate to an inability to use positive social experiences (e.g., social support and intimacy) as a buffer from daily stressors. To the extent that more sensitive measures of hostility may inform a stronger understanding of psychophysiological contributions to disease processes, future studies may consider pitting different hostility scales against one another to observe which components of this construct better predict physiological responses to social interactions. A second limitation to the current study concerns the use of only healthy older adults. For example, insofar as normotensive individuals may show smaller BP responses to psychological challenge relative to hypertensive individuals (Georgiades, Lemne, de Faire, Lindvall, & Fredrikson, 1996), this could potentially result in a restriction in range with respect to the observed effects, thereby underestimating the strength of association between hostility and ABP. The generalizability of these results to younger samples cannot be determined from these data, although it should be noted that previous laboratory studies showing similar patterns of results (Christensen & Smith, 1993; Lepore, 1995) have involved younger samples than that represented here.

To our knowledge, the current study represents the first investigation to use EMA methods to assess the moderating influence of hostility on ABP responses to daily situations of social support and intimacy. The findings suggest that social context matters when predicting the influence of hostility on ABP responses in healthy older adults and may have implications for conceptualizations of the social psychophysiology of hostility. Other studies have indicated hostile individuals to show significant ABP responses to interpersonal stressors (e.g., Brondolo et al., 2003). Our findings reveal hostile individuals may also fail to benefit from social situations of a more positive valence, such as social support and intimacy. Use of EMA methods permits a noninvasive assessment of physiological responses to a variety of social situations

in real time, which may have important ramifications for understanding individual differences in psychophysiological processes related to hostility.

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References

- Aiken, LS.; West, SG. Interactions between categorical and continuous variables. In: Aiken, LS.; West, SG., editors. *Multiple regression: Testing and interpreting interactions*. Thousand Oaks, CA: Sage; 1991. p. 116-138.
- Barefoot JC, Dahlstrom G, Williams RB. Coronary heart disease incidence and total mortality: A 25-year follow-up study of 255 physicians. *Psychosomatic Medicine* 1983;45:59-63. [PubMed: 6844529]
- Brondolo E, Rieppi R, Erickson SA, Bagiella E, Shapiro PA, McKinley P, Sloan RP. Hostility, interpersonal interactions, and ambulatory blood pressure. *Psychosomatic Medicine* 2003;65:1003-1011. [PubMed: 14645779]
- Chen YY, Gilligan S, Coups EJ, Contrada RJ. Hostility and perceived social support: Interactive effects on cardiovascular reactivity to laboratory stressors. *Annals of Behavioral Medicine* 2005;29:37-43. [PubMed: 15677299]
- Christensen AJ, Smith TW. Cynical hostility and cardiovascular reactivity during self-disclosure. *Psychosomatic Medicine* 1993;55:193-202. [PubMed: 8475234]
- Cook WW, Medley DM. Proposed hostility and pharisaic-virtue scales for the MMPI. *Journal of Applied Psychology* 1954;238:414-418.
- Davis MC, Matthews KA, McGrath CE. Hostile attitudes predict elevated vascular resistance during interpersonal stress in men and women. *Psychosomatic Medicine* 2000;62:17-25. [PubMed: 10705907]
- Enkelmann HC, Bishop GD, Tong EMW, Diong SW, Why YP, Khader M, Ang J. The relationship of hostility, negative affect and ethnicity to cardiovascular responses: An ambulatory study in Singapore. *International Journal of Psychophysiology* 2005;56:185-197. [PubMed: 15804452]
- Georgiades A, Lemne C, de Faire U, Lindvall K, Fredrickson M. Stress-induced laboratory blood pressure in relation to ambulatory blood pressure and left ventricular mass among borderline hypertensive and normotensive individuals. *Hypertension* 1996;28:641-646. [PubMed: 8843891]
- Hathaway, SR.; McKinley, JC. *Booklet for the Minnesota Multiphasic Personality Inventory*. New York: Psychological Corporation; 1943.
- Janicki DL, Kamarck TW, Shiffman S, Sutton-Tyrrell K, Gwaltney CJ. Frequency of spousal interaction and 3-year progression of carotid artery intima medial thickness: The Pittsburgh healthy heart project. *Psychosomatic Medicine* 2005;67:889-896. [PubMed: 16314593]
- Kamarck TW, Janicki DL, Shiffman S, Polk DE, Muldoon MF, Liebenauer LL, Schwartz JE. Psychological demands and ambulatory blood pressure: A field assessment approach. *Physiology & Behavior* 2002;77:699-704. [PubMed: 12527022]
- Kamarck TW, Muldoon MF, Shiffman S, Sutton-Tyrrell K, Gwaltney C, Janicki DL. Experiences of demand and control in daily life as correlates of subclinical carotid atherosclerosis in a healthy older sample. *Health Psychology* 2004;23:24-32. [PubMed: 14756600]
- Kamarck TW, Polk DE, Sutton-Tyrrell K, Muldoon MF. The incremental value of ambulatory blood pressure persists after controlling for methodological confounds: Associations with carotid atherosclerosis in a healthy sample. *Journal of Hypertension* 2002;20:1535-1541. [PubMed: 12172315]
- Kamarck TW, Schwartz JE, Janicki DL, Shiffman S, Raynor DA. Correspondence between laboratory and ambulatory measures of cardiovascular reactivity: A multilevel modeling approach. *Psychophysiology* 2003;40:675-683. [PubMed: 14696722]

- Kamarck, TW.; Shiffman, S.; Muldoon, F.; Sutton-Tyrrell, K.; Gwaltney, CJ.; Janicki, DL.; Schwartz, J. Ecological momentary assessment as a resource for social epidemiology. In: Stone, A.; Shiffman, S.; Atienza, A.; Nebeling, D., editors. *The science of real-time data capture: Self report in health research*. New York: Oxford University Press; 2007. p. 268-285.
- Kamarck, TW.; Shiffman, S.; Smithline, L.; Goodie, J.; Thompson, H.; Ituarte, PH., et al. The diary of ambulatory behavioral states: A new approach to assessment of ambulatory cardiovascular activity. In: Krantz, DS.; Baum, A., editors. *Technology and methods in behavioral medicine*. Hillsdale, NJ: Erlbaum; 1998. p. 163-193.
- Lepore SJ. Cynicism, social support, and cardiovascular reactivity. *Health Psychology* 1995;14:210–216. [PubMed: 7641661]
- Linden W, Chambers L, Maurice J, Lenz JW. Sex differences in social support, self deception, hostility, and ambulatory cardiovascular activity. *Health Psychology* 1993;12:376–380. [PubMed: 8223361]
- Perloff D, Grim C, Flack J, Frohlich ED, Hill M, McDonald M, Morgenstern BZ. Human blood pressure determination by sphygmomanometry. *Circulation* 1993;88:2460–2467. [PubMed: 8222141]
- Polk DE, Kamarck TW, Shiffman S. Hostility explains some of the discrepancy between daytime ambulatory and clinic blood pressures. *Health Psychology* 2002;21:202–206. [PubMed: 11950111]
- Raikkonen K, Matthews KA, Flory JD, Owens JF. Effects of hostility on ambulatory blood pressure and mood during daily living in healthy adults. *Health Psychology* 1999;18:44–53. [PubMed: 9925045]
- Reis HT, Wheeler L. Studying social interaction with the Rochester Interaction Record. *Advances in Experimental Social Psychology* 1991;24:269–317.
- Rozanski A, Blumenthal JA, Kaplan J. Impact of psychological factors on the pathogenesis of cardiovascular disease and implications for therapy. *Circulation* 1999;99:2192–2217. [PubMed: 10217662]
- SAS Institute. SAS/STAT software: Changes and enhancements through release 8.2. Cary (NC): SAS Institute; 2001.
- Schekelle RB, Gale M, Ostfeld AA, Paul O. Hostility, risk of coronary heart disease, and mortality. *Psychosomatic Medicine* 1983;45:109–114. [PubMed: 6867229]
- Scherwitz L, Perkins L, Chesney M, Hughes G. Cook-Medley Hostility scale and subsets: Relationship to demographic and psychosocial characteristics in young adults in the CARDIA study. *Psychosomatic Medicine* 1991;53:36–49. [PubMed: 2011649]
- Schwartz J, Stone A. Strategies for analyzing ecological momentary assessment data. *Health Psychology* 1998;17:6–16. [PubMed: 9459065]
- Shiffman, S. Real-time self-report of momentary states in the natural environment: Computerized ecological momentary assessment. In: Stone, AA.; Turkkan, JS.; Jobe, J.; Bachrach, C.; Kurtzman, H.; Cain, V., editors. *Science of self-report: Implications for research and practice*. Mahwah, NJ: Erlbaum; 1999. p. 277-296.
- Smith TW, Frohm K. What's so unhealthy about hostility? Construct validity and psychosocial correlates to the Cook & Medley hostility scale. *Health Psychology* 1985;4:503–520. [PubMed: 3830702]
- Smith TW, Glazer K, Ruiz JM, Gallo LC. Hostility, anger, aggressiveness, and coronary heart disease: An interpersonal perspective on personality, emotion, and health. *Journal of Personality* 2004;72:1217–1270. [PubMed: 15509282]
- Smith TW, Ruiz JM, Uchino BN. Mental activation of supportive ties, hostility, and cardiovascular reactivity to laboratory stress in young men and women. *Health Psychology* 2004;23:476–485. [PubMed: 15367067]
- Stewart JC, Janicki DL, Kamarck TW. Cardiovascular reactivity to and recovery from psychological challenge as predictors of 3-year change in blood pressure. *Health Psychology* 2006;25:111–118. [PubMed: 16448304]
- Stone AA, Shiffman S. Ecological momentary assessment in behavioral medicine. *Annals of Behavioral Medicine* 1994;16:199–202.
- Suls J, Wan CK. The relationship between trait hostility and cardiovascular reactivity: A quantitative review. *Psychophysiology* 1993;30:615–626. [PubMed: 8248453]
- Treiber FA, Kamarck T, Schneiderman N, Sheffield D, Kapuku G, Taylor T. Cardiovascular reactivity and development of preclinical and clinical disease states. *Psychosomatic Medicine* 2003;65:46–62. [PubMed: 12554815]

Figure 1.

Interaction between daily reports of instrumental support and Cook-Medley Hostility Scale (CMHS) scores in predicting ambulatory diastolic blood pressure (ADBP). Simple slopes reflect predicted values at 1 and 2 standard deviations above and below the centered mean for hostility and the sample average minimum and maximum values of instrumental support for each person. $**p < .001$.

Figure 2.

Interaction between daily reports of intimacy and Cook-Medley Hostility Scale (CMHS) scores in predicting ambulatory diastolic blood pressure (ADBP). Simple slopes reflect predicted values at 1 and 2 standard deviations above and below the centered mean for hostility, and the sample average minimum and maximum values of intimacy for each person. $*p < .05$.

Table 1
Ambulatory Blood Pressure, Heart Rate, Social Interaction Subscales, and Hostility $\times$ Gender

Variable	Women (<i>n</i> = 173)		Men (<i>n</i> = 168)		<i>t</i>	<i>p</i>	<i>df</i>
	<i>M</i>	(<i>SD</i>)	<i>M</i>	(<i>SD</i>)			
ABP							
Systolic (mmHg)	126.74	(12.00)	130.33	(11.77)	-2.81	.01	36000
Diastolic (mmHg)	77.34	(7.35)	79.74	(6.46)	-3.62	.001	36000
Heart rate (bpm)	82.74	(8.41)	77.84	(9.36)	4.33	.001	36000
Instrumental support	3.76	(1.39)	4.24	(1.45)	-1.94	.053	14000 ^a
Emotional support	3.97	(1.56)	4.65	(1.69)	-2.36	.05	14000 ^a
Intimacy	4.57	(1.25)	4.94	(1.36)	-1.24	.22	14000 ^a
Agreeableness	7.31	(0.91)	7.44	(0.98)	-0.85	.40	14000 ^a
Cook-Medley Hostility Scale	12.22	(6.07)	14.36	(6.69)	-3.88	.005	388

Note. *N* = 341. ABP = ambulatory blood pressure; bpm = beats per minute.

^aAnalyses restricted to social interactions.

Table 2

Ambulatory Blood Pressure, Heart Rate, and Social Interaction Subscales by Low and High Hostility Quartile

Variable	Cook-Medley Hostility Quartile	
	<26% (<i>M</i> [<i>SD</i>])	<75% (<i>M</i> [<i>SD</i>])
ABP		
Systolic (mmHg)	127.01 (11.1)	131.10 (13.0)
Diastolic (mmHg)	78.10 (6.5)	79.49 (7.9)
Heart rate (bpm)	80.61 (7.9)	80.68 (8.9)
Frequency		
Total observations	113.45 (11.7)	111.30 (10.9)
Social interactions	43.95 (18.5)	38.59 (21.6)
Instrumental support	23.72 (16.5)	22.66 (18.4)
Emotional support	25.45 (18.9)	22.31 (19.9)
Intimacy ^a	25.25 (17.5)	19.74 (18.2)
Agreeableness ^b	24.78 (17.5)	17.30 (17.4)
Social interaction intensity		
Instrumental support	4.01 (1.39)	4.17 (1.48)
Emotional support	4.32 (1.61)	4.48 (1.72)
Intimacy	4.83 (1.23)	4.57 (1.33)
Agreeableness ^c	7.53 (0.87)	7.17 (1.02)

Note. ABP = ambulatory blood pressure; bpm = beats per minute.

^a Hostility inversely associated with proportion of observations rated above the sample median of subject means for intimacy ($r = -.109, p < .05$).

^b Hostility inversely associated with proportion of observations rated above the sample median of subject means for agreeableness ($r = -.164, p < .005$).

^c In mixed-models, regression hostility predicted lower agreeableness ratings during social interactions ($B = -0.03, SE = .008, t(14000) = -4.07, p < .0001$).