# Loneliness in Everyday Life: Cardiovascular Activity, Psychosocial Context, and Health Behaviors

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Prior lab research revealed higher basal total peripheral resistance (TPR) and lower cardiac output (CO) in lonely than in nonlonely young adults. In this study, experience sampling was used to obtain ambulatory blood pressure; impedance cardiography; and reports of activities, appraisals, interactions, and health behaviors. Results confirmed that loneliness predicted higher TPR and lower CO during a normal day. Loneliness did not predict differences in time spent alone, daily activities, or health behaviors but did predict higher stress appraisals and poorer social interactions. Independent of loneliness, interaction quality contributed to TPR. Loneliness differences were not mediated by depressed affect or neuroticism. Social support mediated loneliness differences in stress and threat. Concomitants of loneliness were comparable for men and women.

House, Landis, and Umberson (1988) published a classic review of five prospective studies showing that social isolation is a risk factor for broad-based morbidity and mortality. Over the past decade, evidence supporting this association has continued to accrue. Living alone, for example, was found to be an independent risk factor for recurrent myocardial infarctions and cardiac deaths in patients enrolled in the placebo condition of a clinical pharmacological trial (Case, Moss, Case, McDermott, & Eberly, 1992). Similarly, Berkman, Leo-Summers, and Horwitz (1992) controlled for sociodemographic and clinical risk factors and found that the number of sources of social support predicted mortality 6 months after myocardial infarct among 194 participants in the Established Populations for Epidemiologic Studies of the Elderly project. In a recent review, Rozanski, Blumenthal, and Kaplan (1999) reported that among initially healthy populations, those with smaller or less diverse social networks, less frequent social interactions, or fewer people living in the household had significantly increased risk for cardiac and all-cause mortality 2–15 years later.

Loneliness, although associated with objective isolation and dysphoria, has been defined as a perceived discrepancy between desired and actual social relationships (Peplau & Perlman, 1982). Perceived social isolation forms the dominant factor underlying the UCLA Loneliness Scale (Adams, Openshaw, Bennion, Mills, & Noble, 1988; Austin, 1983; McWhirter, 1990; Russell, Peplau, & Cutrona, 1980). The health risk associated with perceived social isolation has been less well studied than that associated with objective social isolation (cf. Seeman, 2000). This is somewhat surprising in light of prior research on social connectedness and physiological functioning. In a meta-analytic review, Uchino, Cacioppo, and Kiecolt-Glaser (1996) found that social connectedness or support was associated with better levels of autonomic activity (e.g., lower resting blood pressure), better immunosurveillance (e.g., greater natural killer cell lysis), and lower basal levels of stress hormones (e.g., urinary catecholamines). If anything, these associations were stronger for perceived than objective social support. Extending this work to health outcomes, perceived social support was found to predict lowered risk for developing atherosclerosis. In a study of 4,643 men and women low to high in familial risk for coronary heart disease, a combination of low

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social support and high hostility significantly increased the odds of carotid artery lesions among high-risk women even after controlling for age, education, body mass index, smoking, drinking, and metabolic rate (Knox et al., 2000). In related work, Herlitz et al. (1998) reported that among 1,290 patients who underwent coronary artery bypass surgery, ratings of the statement "I feel lonely" predicted survival at 30 days and 5 years after surgery, even after controlling statistically for preoperative factors known to increase mortality.

The impact of social isolation and loneliness on health may not become evident until late in life, but the thoughts, feelings, and behaviors associated with these social factors may place individuals at risk early in life. Young adults, for example, are establishing lifestyles and health habits, a process that is influenced, whether for good or ill, by their social partners. In addition, they are making long-term choices ranging from education and occupation to geographic location, adult friendships, and marital partner. Given that these are formative years, young adults may be an important population in which to study mechanisms by which social factors have a long-term impact on health.

Cacioppo, Hawkley, Crawford, et al. (2002) tested a sample of young adults to examine four possible mechanisms by which loneliness may have deleterious effects on health. In Study 1, young adults were selected for testing on the basis of pretests such that they were among the top or bottom quintile in feelings of loneliness as measured using the Revised UCLA (R-UCLA) Loneliness Scale (Russell et al., 1980). Autonomic testing in the laboratory showed that both lonely and nonlonely participants were normotensive but that these blood pressures were achieved differently: Lonely individuals were characterized by relatively high levels of total peripheral resistance (TPR), whereas nonlonely individuals were characterized by relatively high cardiac output (CO). This difference may be significant in that elevated TPR may, over the long term, contribute to the development of hypertension, a condition well known to increase risk for cardiovascular events such as myocardial infarctions and strokes (Brown & Haydock, 2000). Consistent with this possible predisease pathway, (a) loneliness differences in TPR were evident at rest as well as during laboratory tasks, and (b) age-related increases in resting blood pressure were evident in lonely but not in nonlonely older adults (Cacioppo, Hawkley, Crawford, et al., 2002; see also, Uchino, Cacioppo, Malarkey, Glaser, & Kiecolt-Glaser, 1995).[1]

The cardiovascular profiles that Cacioppo, Hawkley, Crawford, et al. (2002) found to differentiate lonely and nonlonely individuals are reminiscent of the cardiovascular profiles seen during the performance of passive versus active coping tasks (e.g., Sherwood, Dolan, & Light, 1990), in studies of "passive-like" versus "active-like" coping in active coping tasks (Kasprowicz, Manuck, Malkoff, & Krantz, 1990), and in studies of threat versus challenge appraisals in active coping tasks (e.g., Blascovich & Tomaka, 1996; Tomaka, Blascovich, Kelsey, & Leitten, 1993). The cardiovascular differences in passive–active coping and in threat–challenge appraisals, however, are observed in response to psychological stressors as differences in the level of cardiovascular activity during a task relative to a resting baseline (i.e., cardiovascular reactivity). In contrast, we found that lonely and nonlonely individuals did not differ in the magnitude of their cardiovascular response but showed chronically altered cardiovascular activity at baseline and during acute psychological and orthostatic stressors.

One explanation for the loneliness difference in cardiovascular profiles is that lonely individuals adopt passive coping strategies chronically in their everyday life (Cacioppo et al., 2000), and these strategies may be associated with altered cardiovascular regulation including higher levels of tonic TPR. The hemodynamic determinants of cardiovascular responses to stress (e.g., CO and vascular resistance) appear to be stable characteristics of individuals regardless of the coping demands of the situation (Sherwood, Dolan, & Light, 1990); thus, the differences in cardiovascular patterns across lonely and nonlonely individuals may be characteristic of their daily functioning.

Alternatively, the laboratory setting in which participants were tested may itself have served as a psychological stressor that, appraised as threatening, could have contributed to the differential cardiovascular patterns observed by Cacioppo, Hawkley, Crawford, et al. (2002). To examine whether cardiovascular differences reflected differential construals of the clinical setting or chronic differences in cardiovascular functioning, the lonely and nonlonely individuals tested in Cacioppo, Hawkley, Crawford, et al. were outfitted with ambulatory blood pressure and impedance cardiography units to assess patterns of cardiovascular activation in everyday life.

Consistent with the hypothesis that the cardiovascular profiles differentiating lonely and nonlonely individuals reflect different construals and coping strategies in their daily life, Cacioppo et al. (2000) found that lonely individuals viewed their world as more threatening and were more likely to cope with stress passively (e.g., lower active coping, higher behavioral withdrawal). These characterizations, however, were obtained using self-report surveys. To evaluate whether or not these retrospective measures accurately reflect actual or remembered differences in the construal of everyday events, we used an experience sampling methodology (ESM) to examine momentary construals of everyday activities in this study.

If there are differences between lonely and nonlonely individuals in their construal or appraisals of daily events, they may be attributable to actual differences in their daily events and activities or they may reflect truly chronic differences in social perception and cognition. We used ESM to address this question. Relatedly, stress and appraisals can differ depending on the social context; we therefore sought also to quantify whether lonely individuals were more likely to spend time alone than nonlonely individuals and whether being alone differentially affected the stress levels of lonely and nonlonely individuals.

When not alone, both men and women appear to be protected against loneliness by spending more time with women but not with men (Wheeler, Reis, & Nezlek, 1983). This may be because interactions with women tend to be rated more positively than interactions with men (Deaux, 1976), and positive qualities of social interactions, such as meaningfulness and closeness, play an

[1] Cacioppo, Hawkley, Berntson, et al. (2002) and Cacioppo, Hawkley, Crawford, et al. (2002) also found that lonely individuals showed poorer sleep than nonlonely individuals but comparable health behaviors and salivary cortisol levels. Health behavior and cortisol regulation may play a role in health, but discerning this role may require more sensitive measures, larger sample sizes, or less resilient populations (e.g., older adults, clinical samples; see, e.g., Kiecolt-Glaser et al., 1984).

important role in staving off loneliness (Vaux, 1988; Wheeler et al., 1983). Lonely individuals, both male and female, tend to report or exhibit more negative interaction qualities, such as distrust (Rotenberg, 1994) and inhibition (Horowitz & French, 1979; Jones, Hobbs, & Hockenbury, 1982), and are unhappy with the degree of intimacy in their social interactions (Segrin, 1998). These loneliness differences in interaction quality could have physiological consequences. For example, hostility during social interactions has been associated with elevated ambulatory blood pressure, at least in men (Guyll & Contrada, 1998; T. W. Smith & Allred, 1989), and with greater vascular resistance during interpersonal stressors (Davis, Matthews, & McGrath, 2000). We examined whether loneliness predicted social interaction quality and differential time with females versus males and whether interaction quality contributed to loneliness differences in cardiovascular activity.

Health behaviors are a major determinant of long-term health, and supportive others are known to play a vital role in encouraging and sustaining a healthful lifestyle (Institute of Medicine Committee on Health and Behavior, 2001). To the extent health habits are being established during the college years, poor health behaviors could, over the long term, pose significant health risks. Loneliness has been associated with less frequent health-promoting behaviors (Mahon, Yarcheski, & Yarcheski, 2001; Schwarzer, Jerusalem, & Kleine, 1990) and more frequent high-risk behaviors (Pérodeau & du Fort, 2000; Schwarzer et al., 1990). However, neither epidemiological studies (Seeman, 2000) nor laboratory research (e.g., Cacioppo, Hawkley, Berntson, et al., 2002; Cacioppo, Hawkley, Crawford, et al., 2002) have provided much support for the hypothesis that health behaviors account for poorer health of lonely individuals. These studies have relied on retrospective self-reports of health behaviors, however, which may be biased (Tzetzis, Avgerinos, Vernadakis, & Kioumourtzoglou, 2001). In the present study, we obtained on-line reports of health behaviors to secure a more accurate representation of health-related behaviors.

Although males and females sometimes differ on certain aspects of cardiovascular and psychological functioning, we considered gender differences in the relationship between loneliness and cardiovascular and psychosocial variables. Loneliness tends to be experienced at least as intensely in males as in females (Borys & Perlman, 1985), an effect replicated in an earlier study of the same sample (Cacioppo, Hawkley, Crawford, et al., 2002). In the laboratory study, gender did not moderate the effects of loneliness on cardiovascular activity (Cacioppo, Hawkley, Crawford, et al., 2002) or psychological variables (Ernst et al., 2003). These results have suggested that although males and females may become lonely for different reasons, the cardiovascular accompaniments appear to be similar. Laboratory results notwithstanding, we examined whether gender moderated the effects of loneliness on cardiovascular and psychosocial variables measured in everyday life.

Finally, we examined possible explanations for loneliness effects. Loneliness is correlated with depression (Anderson & Arnoult, 1985) and neuroticism (Stephan, Faeth, & Lamm, 1988) and is inversely correlated with social support (Riggio, Watring, & Throckmorton, 1993). Depressed affect has been linked with poorer personal relationships (Segrin, 1998), greater perceived stress (Zautra & Smith, 2001), poorer health behaviors (Brooks, Harris, Thrall, & Woods, 2002), and altered cardiovascular responses to laboratory stressors (Hughes & Stoney, 2000). Similarly, neuroticism has been associated with reports of greater perceived stress (Penley & Tomaka, 2002), poorer perceived social interactions (Barrett & Pietromonaco, 1997), risky health behaviors (Vollrath & Torgersen, 2002), and the perception of poor health (Goodwin & Engstrom, 2002). Social support, on the other hand, has been associated with lower perceived stress (Cohen & Wills, 1985) and improved cardiovascular functioning (Uchino et al., 1996). We therefore examined whether depressed affect, neuroticism, and social support could account for loneliness differences in stress perceptions, social context, interaction quality, health behaviors, and cardiovascular functioning.

In summary, this study was designed to augment our understanding of the relationships observed among loneliness and cardiovascular functioning in a laboratory setting, using the same sample of undergraduate students. In the current field study, we examined (a) whether loneliness differences in cardiovascular activity were characteristic of daily functioning; (b) whether lonely and nonlonely participants differed in their daily activities, stress appraisals, social context, interaction quality, and health behaviors; (c) whether cardiovascular differences could be attributed to the foregoing behavioral, social, and psychological factors; and (d) whether depressed affect, neuroticism, or social support could account for any loneliness differences.

## Method

### *Participants*

Participants were 135 undergraduate students (83% Caucasian; 7% African American; 7% Asian, Asian American, or Pacific Islander; 3% other or undeclared). Students were screened and recruited to represent the lower (total score $\leq$ 28; 22 men, 22 women), middle (total score $\geq$ 33 and $<$ 39; 23 men, 23 women), and upper quintile (total score $\geq$ 46; 23 men, 22 women) of scores on the R-UCLA Loneliness Scale. Inclusion criteria chosen to enhance the representativeness of our college-age sample were that participants be enrolled in at least 6 credit hours in the quarter during which they were to be tested and not be married or living with a significant other. To minimize effects of geographic transition and the transition into and out of college, additional criteria were that participants be U.S. citizens and not be first-quarter freshmen nor last-quarter seniors during the quarter they were tested. To reduce the possibility of confounding loneliness with depression, participation was restricted to students who scored no higher than 13 on the 13-item version of the Beck Depression Inventory (BDI; Beck & Beck, 1972). Because the laboratory component of the study required participants to give a speech and to have their blood sampled, we also restricted participation to students who were not speech or needle phobic. Concern for good quality cardiovascular signals prompted us to accept only those participants with a body mass index no greater than 27. Finally, to ensure the credibility of participants' responses, participants had to score no more than 8 on a 12-point lie scale (approximately 8% of students were excluded on this basis).

At the time of recruitment, students' mean age was 19.2 years ($SD$ = 1.0) and they had completed at least one and, on average, 3.2 academic quarters ($SD$ = 2.8). Fifty-two percent were freshmen, 32% were sophomores, 8% were juniors, and the remaining 8% were seniors or 5th-year students. Students received $25 for completing this ambulatory component of the study.

### *Procedure*

In the present field study, we used ESM to collect information about psychosocial and behavioral states concurrently with various measures of

cardiovascular activity. Participants completed diaries for a total of 7 days, and cardiovascular data were collected concurrently on the 1st of the 7 days. Henceforth, we refer to the 1st day of the field study as the *ambulatory cardiovascular day*. Of particular relevance for our purposes, concurrent momentary assessments of self-report and ambulatory cardiovascular measures permitted asking questions about the dynamic relationships among cardiovascular measures, events, and cognitions (Shiffman & Stone, 1998).

Ambulatory cardiovascular monitoring was scheduled to occur on a Monday, Tuesday, Wednesday, or Thursday to maintain relatively consistent daily routines across students. Ambulatory cardiovascular day did not differ by loneliness group or gender ($\chi^2 < 4$, $ps > .2$).

On the ambulatory cardiovascular day, participants were awakened at approximately 7 a.m. after having spent the previous afternoon and night in a laboratory in the General Clinical Research Center at the Ohio State University Medical Center (hereafter called the *lab day*). After obtaining a blood sample, participants were served a breakfast of their choice. After breakfast, electrocardiogram (ECG) spot electrodes were applied in a standard Lead II configuration; impedance band electrodes were applied as detailed in Sherwood, Allen, et al. (1990); and a blood pressure cuff was applied to the participant's nondominant arm. Experimenters then confirmed the functionality of each unit.

A programmable watch provided to participants was programmed to beep at nine random times over the course of the ambulatory cardiovascular day, subject to the following constraints: (a) The first beep occurred at 9:30 a.m., (b) the final beep occurred before 9:00 p.m., and (c) the interbeep interval was between 45 min and 120 min. On being signaled, participants were instructed to be seated, take out one of the provided diaries, initiate cardiovascular data collection from each ambulatory instrument, and complete the diary while minimizing body motion. In the event of unusual circumstances, like driving or arguing, participants were instructed to initiate ambulatory data collection and complete a diary as soon as possible after the event. Contact information was provided in the event of equipment problems. Participants returned to the laboratory by 9:00 p.m. to turn in that day's diaries and to have a nurse retrieve ambulatory units and remove all sensors.

On the remaining 6 days of diary data collection, the watch was again programmed to beep at nine random times over the course of the day, but the first beep occurred at or after 10:00 a.m., and the final beep occurred before 12:00 midnight. As was the case on Day 1, the interbeep interval was between 45 min and 120 min.

## Cardiovascular Equipment and Measures

*Ambulatory blood pressure assessment.* The SpaceLabs ambulatory blood pressure monitor (Model 90207, SpaceLabs Medical, Inc., Redmond, WA) was used to track systolic (SBP), diastolic (DBP), and mean ambulatory (MAP) blood pressure via a noninvasive, oscillometric method. Validation of the unit has been provided by Groppelli, Omboni, Parati, and Mancia (1992). To provide a reliable estimate of blood pressure, participants were instructed to obtain two blood pressure readings, one at the onset of each collection epoch, the second on encountering a written instruction midway through the diary booklet. Each blood pressure reading was automatically time stamped for later verification of participant compliance.

*Ambulatory impedance assessment.* The ambulatory impedance unit used in this study (World Wide Medical Instruments, Inc., Dallas, TX) enables the collection and storage of entire ECG and impedance signals for later off-line editing and artifact detection. Validation of the unit has been reported by Nakonezny et al. (2001). On initiation, the device was programmed to collect a 4-min epoch of the ECG signal, the raw impedance ($\Delta Z$) signal, the first derivative of the impedance signal ($dZ/dt$), and basal thoracic impedance ($Z0$) at a sampling frequency of 500 Hz. Each epoch of cardiovascular data was automatically time stamped.

The myocardial measures of interest were heart rate (HR), preejection period (PEP), respiratory sinus arrhythmia (RSA), and stroke volume (SV). HR is a measure of heart beats per minute and was quantified as the number of R-spikes in the ECG waveform in each minute. PEP is a time interval used to measure myocardial contractility and decreases in duration with increased sympathetic activation of the heart (Cacioppo et al., 1994). PEP was quantified as the time interval in milliseconds from the onset of the ECG Q-wave to the B-point of the $dZ/dt$ wave (Sherwood, Allen, et al., 1990). RSA is a measure of changes in heart period associated with respiration, which increases in magnitude with increased parasympathetic activation of the heart (Berntson, Cacioppo, & Quigley, 1993; Cacioppo et al., 1994). RSA was derived by spectral analysis (fast-Fourier transform) of an interbeat interval time series calculated from ECG following procedures specified by Berntson et al. (1997). SV is a measure of blood volume ejected from the left ventricle with each beat of the heart and was derived using the Kubicek equation (Kubicek, Karnegis, Patterson, Witsoe, & Mattson, 1966). These measures were scored using software developed in our laboratory (ANS Suite, Version 5.2.1). CO (liters per minute) was defined as HR $\times$ SV. TPR (dyne-sec $\times$ $cm^{-5}$) was derived using the formula MAP/CO $\times$ 80. All myocardial measures were ensemble averaged into 1-min periods (Kelsey & Guethlein, 1990) and were verified or edited prior to analyses.

## Diary Measures

Teleform software (Cardiff Software, Inc., San Marcos, CA) was used to design a detailed paper-and-pencil diary to capture participants' psychosocial and behavioral state at the time of each beep of the watch. Diary format consisted primarily of closed-ended questions (multiple options) requiring participants to check the appropriate response. Participants were also asked to provide the time they started and finished filling out the diary to enable time matching of diary and cardiovascular data and to evaluate the extent of discrepancies between diary and cardiovascular data collection.

## Individual Difference Measures

*Loneliness.* Loneliness was assessed during recruitment and again on the lab day immediately preceding the ambulatory cardiovascular day, using the R-UCLA Loneliness Scale (Russell et al., 1980). Although loneliness assessed with this instrument has been shown to be made up of several factors (Austin, 1983; Hays & DiMatteo, 1987; McWhirter, 1990), when the instrument is used as a unidimensional measure of loneliness, it captures a common core of the multifaceted nature of the loneliness experience (Cramer & Barry, 1999). Loneliness decreased slightly from recruitment ($M = 37.0$, $SD = 11.0$) to laboratory testing ($M = 35.4$, $SD = 10.1$; $M_{diff} = -1.6$, $SD = 7.7$), but the rank ordering of loneliness scores was temporally reliable, $r_s(135) = .77$, $p < .01$.

Loneliness scores at the time of recruitment were the basis for choosing participants as low, middle, and high in loneliness, so this raw score was used as a predictor variable in all analyses. However, because these young adults were in developmentally formative years, we also expected meaningful changes in loneliness. We chose to model loneliness change effects by using the difference in the raw loneliness score between recruitment and testing as an additional predictor in all analyses in which loneliness was a predictor variable.

*Depressed affect.* On the lab day, participants completed the BDI (Beck & Beck, 1972) to assess level of dysphoria.

*Neuroticism.* On the lab day, participants completed the Big Five personality inventory (Goldberg, 1992), which includes a 20-item subscale that assesses neuroticism.

*Social support.* On the lab day, participants also completed the 12-item Appraisal Support subscale of the Interpersonal Support Evaluation List (Cohen & Hoberman, 1983) to assess level of social support.

*Health history.* Also on the lab day, nurses obtained participants' parental history of hypertension and each participant's height and weight, from which body mass index was calculated: weight in kilograms/(height in meters)$^2$.

## Cardiovascular Data Preparation

Usable ambulatory blood pressure data were obtained from 124 (93%) of the 134 participants outfitted with a blood pressure unit ($M = 7.8$ assessments, $SD = 1.6$, range = 1–9, with 95% of the 124 participants providing at least five observations). The amount of usable data did not differ by loneliness group, $F(2, 118) = 1.15$, $p = .32$, or gender, $F(1, 118) = 2.06$, $p = .15$.

Because of equipment problems, only 113 (84%) of the participants were outfitted with an ambulatory impedance cardiograph unit, and 103 (91%) of these provided ambulatory ECG and impedance data. However, technical difficulties, excessively noisy signals, and 1 participant with a marked cardiac arrhythmia resulted in usable impedance data from only 81 participants ($M = 6.9$ assessments, $SD = 2.2$, range = 1–9, with 78% of the 81 participants providing at least five observations). The amount of usable impedance data did not differ by loneliness group, $F(2, 75) = 2.40$, $p = .10$, or gender, $F(1, 75) = 1.22$, $p = .27$.

Of the 124 participants who provided blood pressure or impedance data, 77 (62%) provided 512 observations that included blood pressure, ECG (HR, RSA), and at least partial impedance data (PEP, SV, CO).

## Outlier and Error Detection

The SpaceLabs monitor records zeros for unsuccessful blood pressure readings due to technical difficulties (inadequate cuff pressure, movement during reading) and automatically makes another attempt at a blood pressure reading. All successful blood pressure readings, therefore, were accepted unless the values were deemed artifactual according to criteria outlined by Marler, Jacob, Lehoczky, and Shapiro (1988). No artifacts were identified, so the data were averaged across the two readings taken at each time point to increase reliability.

The impedance data were analyzed in 1-min epochs and then averaged to produce mean values of each cardiovascular measure at each recording occasion. The mean MAP and CO values were used to calculate one TPR value for each recording occasion. Artifactual HR and CO values were defined as those exceeding maximal exercise values in college students (HR $>$ 192 and CO $>$ 20; Blomqvist & Saltin, 1983). Neither HR nor CO values exceeded these maximums.

## Diary Data Preparation

The 134 participants who completed diaries during the cardiovascular ambulatory day provided 1,081 of a possible 1,206 diary entries (90%) for that day. Invalid diary entries (e.g., those missing start or end times) accounted for 15% of total entries (30 entries), leaving a final sample of 1,051 valid entries from 134 participants. Hereafter, these 1,051 diary entries are called the *ambulatory diary data set*. On average, participants provided 7.8 valid diaries ($SD = 1.4$; 87% return rate). Valid diary return rate did not differ by loneliness group, $F(2, 128) = 2.58$, $p = .08$, or by gender, $F(1, 128) = 1.77$, $p = .19$.

Diary data were also analyzed using entries collapsed across all 7 days of experience-sampling questionnaires. The return rate over the course of the week was 80% (6,771 returned diaries of a possible 8,442). The lonely group returned significantly fewer diaries than the nonlonely group, $F(2, 128) = 4.03$, $p = .02$ ($M_{\text{nonlonely}} = 53.1$, $SD = 6.9$; $M_{\text{control}} = 51.9$, $SD = 11.3$; $M_{\text{lonely}} = 46.6$, $SD = 14.7$). Men and women did not differ in their return rate, nor was there a significant Gender $\times$ Loneliness interaction in return rate.

*Activities.* Activities were determined by participants' responses to an open-ended question asking, "What was the main thing you were doing?" (Csikszentmihalyi & Larson, 1984). Two independent raters agreed on a set of 23 subcategories within three main activity categories (i.e., productive, maintenance, and leisure activities) previously used by Csikszentmihalyi and Larson (1984). Using these subcategories, inter-rater agreement was 94%. Consensus was achieved with a final discussion of categorization discrepancies. Because some of the 23 original activity subcategories were infrequently endorsed (i.e., $<$ 10% of occasions), the original 23 were grouped to form a final set of seven activity types for further analysis. These were (a) school work; (b) other productive activities (job, meetings, writing or typing not related to class work or socializing); (c) transportation, chores, and errands; (d) other maintenance activities (eating, personal care, waiting, rest and napping); (e) socializing, real or virtual; (f) watching television; and (g) other leisure activities (listening to music, art and hobbies, reading, thinking, computer activities, other). The number of endorsements of each activity category was summed across the day within participant, and endorsement rate was calculated as a percent of the total observations available for each participant. To assure unbiased data, only those participants who provided at least four diary observations during the ambulatory cardiovascular day were included in analyses ($n = 132$).

*Stress ratings and cognitive appraisals.* Participants rated how stressful and threatening they found the main thing they were doing on a scale of 1 (*not at all*) to 5 (*very*). The same scale was used to ask participants to rate how demanding they found the main activity and the degree to which they felt capable of meeting the demands of the activity. Cognitive appraisals were calculated as the ratio of demand to ability to meet demand.

*Social context and interaction quality.* The number of times participants reported being alone was summed across the day within participant, and proportion of time alone was calculated as a percent of the total observations available for each participant. Similarly, proportions of time with males or females were calculated as a percent of total observations for each participant.

Participants' responses to 16 adjectives, 8 positive and 8 negative (scaled from 1 = *not at all* to 5 = *very*) were used to assess ratings of social interactions. Responses to adjectives related to positive aspects of interactions (i.e., *comfortable*, *intimate*, *involved*, *sharing*, *uninhibited*, *supported*, *affectionate*, *understood*) were averaged to create an interaction positivity score, and responses to adjectives related to negative aspects of interactions (i.e., *cautious*, *disconnected*, *conflicted*, *closed off*, *distant*, *phony*, *dishonest*, *distrustful*) were averaged to create an interaction negativity score.

*Health behaviors.* Health behaviors were quantified by summing the number of endorsements of questions about exercise, sleep, and tobacco use at the time of being beeped, as well as by summing endorsements of food intake (currently and since last diary entry), alcohol intake (how recent and how much), and caffeine intake (how recent and how much).

*Physical state.* Participants' physical states were determined by responses to questions about their posture and activity level (choice of sitting, upright, lying down, walking, running) and whether they had been talking.

## Preparation of the Final Data Sets

Although the ambulatory diary data set contained 1,051 observations, only 483 observations also provided blood pressure and at least partial impedance data. The distribution of time intervals between diary and cardiovascular measures revealed that 90% of these data were provided within 10 min of each other, and only 1% of time intervals exceeded 25 min. Cardiovascular data collection preceded diary entries in 86% of cases, reflecting our instructions to fill out a diary as soon as possible after the event if it was impossible to fill it out at the time of cardiovascular data collection. To maximize temporal coherence between diary and cardiovascular measures, data were considered invalid when diary completion time was unknown or exceeded 25 min or when the time interval between diary entry and impedance data collection was unknown or exceeded 25 min.

The distribution of time intervals between blood pressure and impedance measures revealed that 82% of data were provided within 2 min of each other, and only 2% of time intervals exceeded 10 min. To maximize validity of TPR values derived from ostensibly concurrent blood pressure and CO values, data were considered invalid if there was a greater than 10-min interval between blood pressure and impedance data collection. This left a final data set of 441 observations from 70 participants, hereafter called the *ambulatory cardiovascular data set.* Number of observations ranged from one to nine, with 70% of participants providing at least five observations. The mean number of observations per participant was 6.3 ($SD = 2.4$), and this did not differ by loneliness group, $F(2, 64) = 1.45$, $p = .24$, or gender, $F(1, 64) = 0.86$, $p = .36$.

## Data Analytic Strategy

*Multilevel regression analyses.* The ambulatory cardiovascular data set ($n = 70$; 441 observations) was used to evaluate the relationships among loneliness and loneliness changes, momentary states, and cardiovascular activity. In this study, repeated assessments of diary measures and cardiovascular variables (Level 1) are nested within participants (Level 2). In consideration of the hierarchically nested data structure, momentary data were examined using a multilevel linear regression technique (see Kreft & de Leeuw, 1998; Schwartz & Stone, 1998). A major advantage of a multilevel regression approach is that it does not require participants to have data at each measurement occasion, a concern in our study because participants varied in the number of observations they provided. Unlike repeated-measures analyses of variance that exclude participants from the analysis if they are missing data on any occasion, a multilevel approach takes advantage of all available data to generate parameter estimates.

Another advantage of a multilevel model is that it unconfounds within- and between-subjects variance in data of the form obtained in ESM studies. Moreover, this approach enables treating lower order (i.e., Level 1; within-subject, in our case) regression parameters as random coefficients. In a random-coefficients model, regression coefficients are considered to originate from a population distribution of possible coefficients, and the mean and variance of these coefficients can then be modeled as a function of higher order (i.e., Level 2; between-subjects, in our case) predictors. For example, a random-intercept regression model with a Level 2 predictor (e.g., loneliness), addresses the question, "Is TPR higher among lonelier participants?" A regression model with a Level 1 predictor (e.g., stress rating), addresses the question, "Is TPR higher when participants report greater stress?" If the Level 1 intercept is allowed to vary between subjects (i.e., a random-slope model), the addition of a Level 2 predictor (e.g., loneliness) addresses the question, "Are differences in the relationship between stress and TPR predicted by differences in loneliness?" In addition, the assumption of correlated residuals between repeated assessments of the dependent variables (i.e., first-order autoregressive correlations) can be tested so that models can incorporate the appropriate error structure.

*Simple linear regression analyses.* The ambulatory diary data set ($n = 134$; 1,051 observations) was used to examine the relationship between loneliness and participants' activities and social states during the ambulatory cardiovascular day. Diary variables involving event frequencies (e.g., activities, occasions alone) were aggregated within subject and then submitted to linear regression analyses, with the raw loneliness score at the time of recruitment as the predictor variable and changes in loneliness scores between recruitment and testing as a covariate. Analyses were repeated using data aggregated within subject across all 7 days of the diary component of the study ($n = 134$; 6,771 observations) to test the reliability of the data from the single ambulatory diary day.

*Covariates.* In field studies, statistical control of various physical states is recommended when assessing the effects of psychological factors on cardiovascular activity (Carels, Sherwood, & Blumenthal, 1998). Postural changes and physical activity, for example, have known cardiovascular consequences that need to be considered (Berne & Levy, 1997; Levick, 1995). Among other behaviors that have cardiovascular consequences, the more prevalent in everyday life are talking (Liehr, 1992; Tardy, Thompson, & Allen, 1989), eating (A. P. Smith, Clark, & Gallagher, 1999), drinking alcohol (Sheffield et al., 1997), smoking (Green, Kirby, & Suls, 1996; Sheffield et al., 1997), and caffeine ingestion (Pincomb, Sung, Lovallo, & Wilson, 1993). In the current study, to permit statistical control of the cardiovascular effects of physical states, participants were asked at each time point to indicate their posture; physical activity; whether they were talking; and whether they were ingesting food, alcohol, caffeine, or nicotine.

In addition to physical activity and consummatory behaviors that could obscure the relationship between cardiovascular activity and psychosocial states, body mass index and parental history of hypertension were also included as covariates in analyses involving cardiovascular activity. Body mass index has strong associations with elevated blood pressure and with lipid abnormalities that may contribute to cardiovascular health risk (Rabkin, Chen, Leiter, Liu, & Reeder, 1997). Parental history of hypertension has been associated with elevated blood pressure and, among males, with higher vascular resistance at rest and in response to psychological stress (Marrero, al'Absi, Pincomb, & Lovallo, 1997; Sherman, McCubbin, & Matenga, 1998).

Finally, we examined the unique contribution of loneliness in predicting psychosocial and cardiovascular measures. Specifically, we repeated all analyses to see whether loneliness effects were independent of or mediated by (a) depressed affect, (b) neuroticism, and (c) social support.

All analyses were performed using SPSS (Version 11.0). Statistical significance was set at $p < .05$, two-tailed, unless otherwise stated. Degrees of freedom were adjusted for incomplete data. In random-intercept multilevel regression analyses, effect sizes were calculated as the proportion of between-subjects variance explained by the addition of predictor variables to base models described below.

# Results

## Covariates: Preliminary Analyses

The impact of posture, exercise, nicotine (smoking), caffeine, eating, and talking on cardiovascular activity was assessed by performing a series of multilevel regression analyses. The prevalence and frequency of these behaviors are listed in Table 1. In this study, participants were specifically asked to be seated prior to cardiovascular data collection, so we did not expect pronounced residual postural effects. In fact, analyses of variance revealed that mean levels of cardiovascular activity did not differ between prone, sitting, and upright postures when beeped. Walking, relative to these stationary postures, when beeped, however, was associated with elevated cardiovascular responses during the recording period and was therefore dummy coded to contrast cardiovascular levels with those in stationary postures. Specifically, walking immediately prior to data collection and exercise or caffeine consumption in the previous 2 hr showed a significant relationship to all cardiovascular variables except TPR; each of these behaviors was associated with elevated HR, diminished PEP (enhanced sympathetic activity), diminished RSA (diminished vagal activity), increased CO, and elevated SBP, DBP, and MAP. Elevated HR was also predicted by smoking and talking behaviors. Alcohol and drug use were rarely reported and were not correlated with any of the cardiovascular variables.

Separate multilevel analyses for each between-subjects covariate indicated that parental history of hypertension predicted increased TPR, explaining 8% of the between-subjects variance in TPR. Parental history of hypertension also predicted a longer PEP, explaining 15% of the between-subjects variance in PEP. BMI

Table 1
*Prevalence and Frequency of Behavioral Variables (N = 124; 1,051 Observations)*

| Variable | Occasions per participant (%) | Participants (%) with frequency ≥ 3 | Participants (%) with frequency ≥ 1 |
|---|---|---|---|
| Posture | | | |
| Lying down | 11.7 | 13.4 | 53.7 |
| Sitting | 60.3 | 88.8 | 100.0 |
| Standing | 17.3 | 16.4 | 69.4 |
| Physical activity | | | |
| Walking | 9.7 | 4.5 | 50.0 |
| Exercising | 3.0 | 1.5 | 17.8 |
| Talking | 30.5 | 38.6 | 81.4 |
| Ingestion | | | |
| Nicotine | 1.5 | 1.5 | 7.4 |
| Caffeine | 4.1 | 2.2 | 22.2 |
| Food | 9.9 | 4.4 | 54.8 |
| Alcohol | 0.2 | 0 | 1.5 |
| Recreational drugs | 0.2 | 0 | 1.5 |
| Behavior | | | |
| School work | 20.9 | 22.2 | 77.8 |
| Other productive work | 7.9 | 2.2 | 43.0 |
| Errands, chores, transportation (etc.) | 16.8 | 15.6 | 74.8 |
| Other maintenance activity | 13.0 | 8.1 | 66.7 |
| Socializing, real or virtual | 14.6 | 11.9 | 65.9 |
| Watching TV | 11.2 | 8.1 | 56.3 |
| Other leisure activity | 14.0 | 11.1 | 60.7 |
| Social setting | | | |
| Alone | 44.5 | 67.9 | 95.5 |
| Roommate | 15.4 | 15.7 | 57.5 |
| Male friend | 13.4 | 13.4 | 50.0 |
| Female friend | 13.3 | 14.9 | 57.5 |
| Friend (male and/or female) | 23.0 | 27.6 | 75.4 |
| Coworkers and/or neighbors | 4.0 | 3.0 | 20.1 |
| Classmates and/or teachers | 12.4 | 9.7 | 57.5 |
| Acquaintances and/or strangers | 9.6 | 9.0 | 47.0 |
| Other | 6.5 | 5.2 | 29.9 |

predicted higher SBP, explaining 8% of the between-subjects variance in SBP. Gender did not exert a main effect on any of the covariates nor did it interact with loneliness to predict any of the covariate measures.

In combination, the within- and between-subjects covariate predictors with significant main effects constituted base models for all analyses in which cardiovascular variables served as criteria. The null model for each cardiovascular criterion indicated a statistically significant autoregression coefficient (all $p$s $< .05$); therefore, a first-order autoregressive covariance structure was incorporated in each multilevel analysis. Table 2 lists the unstandardized coefficients for predictors in each of the base models. The between-subjects variance to be accounted for ranged from .38 (HR) to .69 (SV), as indicated by the intraclass coefficient (ICC) in Table 2; the balance of the variance in each criterion variable is attributable to within-subject variations.

### *Does Loneliness Predict Elevated Ambulatory Vascular Resistance?*

Table 3 displays mean overall levels of cardiovascular activity. As hypothesized, and consistent with laboratory findings, a random-intercept regression analysis revealed that loneliness predicted higher TPR ($b = 5.49$, $SE = 2.79$, $p = .05$) in the field, explaining 10% of the between-subjects variance in TPR. Diminished sympathetic activation of the myocardium can elicit compensatory vascular resistance, so a supplementary analysis was performed to test the relationship between PEP and TPR. This analysis revealed that PEP levels predicted TPR ($b = 7.96$, $SE = 0.64$, $p < .05$). However, holding PEP constant, loneliness continued to predict TPR ($b = 7.41$, $SE = 2.77$, $p < .05$).

The effect of loneliness on CO, although only approaching statistical significance, was in the predicted direction ($b = -0.04$, $SE = 0.02$, $p = .11$). Loneliness explained 11% of the between-subjects variance in CO. Given that CO was calculated as the product of HR and SV, we examined whether either or both of these variables contributed to the loneliness effect on CO. Although loneliness showed no relationship to HR ($p > .1$), loneliness was a significant predictor of SV ($b = -0.68$, $SE = 0.30$, $p < .05$), explaining 14% of the between-subjects variance in SV.

Loneliness tended to predict lower PEP ($b = -0.27$, $SE = 0.14$, $p = .06$). In addition, loneliness changes between recruitment and testing predicted lower PEP ($b = -0.50$, $SE = 0.24$, $p < .05$). In combination, loneliness and loneliness changes explained 9% of the between-subjects variance in PEP. Loneliness also showed a modest inverse relationship with RSA ($b = -0.02$, $SE = 0.01$, $p < .07$), explaining 8% of the between-subjects variance in RSA.

Table 2
*Nonstandardized Partial Regression Coefficients for Covariates in Base Models With Cardiovascular Criteria*

| Criterion | Intercept (*SE*) | Walking | Exercise | Smoking | Caffeine | Talking | Hypertensive parents | BMI | ICC |
|---|---|---|---|---|---|---|---|---|---|
| SBP | 101.35 (10.51) | | | | | | | | .57 |
| *β* | | 2.98* | 6.64* | — | 3.80** | — | — | 1.05* | |
| *SE* | | 1.25 | 2.69 | — | 1.05 | — | — | 0.46 | |
| DBP | 74.78 (0.79) | | | | | | | | .47 |
| *β* | | 2.14 | 4.84 | — | 1.71 | — | — | — | |
| *SE* | | 1.11 | 2.28 | — | 0.93 | — | — | — | |
| MAP | 91.03 (0.79) | | | | | | | | .47 |
| *β* | | 3.43** | 4.81* | — | 2.61 | — | — | — | |
| *SE* | | 1.09 | 2.23 | — | 0.92 | — | — | — | |
| TPR | 994.41 (33.02) | | | | | | | | .62 |
| *β* | | — | — | — | — | — | 152.10* | — | |
| *SE* | | — | — | — | — | — | 67.42 | — | |
| CO | 7.61 (0.24) | | | | | | | | .62 |
| *β* | | 0.45 | 0.82 | — | 0.43* | — | — | — | |
| *SE* | | 0.24 | 0.49 | — | 0.23 | — | — | — | |
| SV | 93.73 (3.15) | | | | | | | | .69 |
| *β* | | — | — | — | — | — | — | — | |
| *SE* | | — | — | — | — | — | — | — | |
| HR | 80.95 (1.03) | | | | | | | | .38 |
| *β* | | 5.35** | 8.78** | 9.35* | 3.75** | 2.00* | — | — | |
| *SE* | | 1.44 | 2.93 | 3.98 | 1.23 | 0.84 | — | — | |
| PEP | 113.8 (1.70) | | | | | | | | .50 |
| *β* | | −2.97 | −10.72** | — | −6.02** | — | 9.49** | — | |
| *SE* | | 2.04 | 4.10 | — | 1.69 | — | 3.45 | — | |
| RSA | 5.93 (0.11) | | | | | | | | .42 |
| *β* | | −0.42** | −1.06** | — | −0.35** | — | — | — | |
| *SE* | | 0.14 | 0.29 | — | 0.12 | — | — | — | |

*Note.* Dashes in cells indicate nonsignificant main effects. BMI = body mass index; ICC = intraclass coefficient; SBP = systolic blood pressure (mm Hg); DBP = diastolic blood pressure (mm Hg); MAP = mean arterial pressure (mm Hg); TPR = total peripheral resistance (dyne-sec × $cm^{-5}$); CO = cardiac output (liters per minute); SV = stroke volume (milliliters); HR = heart rate (beats per minute); PEP = preejection period (milliseconds); RSA = respiratory sinus arrhythmia (natural log transform).
* $p < .05$, one-tailed. ** $p < .01$, one-tailed.

SBP, DBP, and MAP did not show a statistically significant relationship with loneliness or loneliness changes.

Holding loneliness and loneliness changes constant, gender predicted HR, RSA, and SBP, indicating that women had higher HR ($b = 5.93$, $SE = 1.82$, $p < .05$), lower RSA ($b = -0.42$, $SE = 0.20$, $p < .05$), and lower SBP ($b = -6.96$, $SE = 1.91$, $p < .05$) than did men. Gender had no other main effects on cardiovascular variables and did not confound or interact with loneliness to predict any of the cardiovascular variables.[2]

Table 3
*Means and Standard Deviations of Cardiovascular Variables (N = 70)*

| Variable | *M* | *SD* |
|---|---|---|
| SBP | 125.90 | 8.96 |
| DBP | 75.43 | 6.34 |
| MAP | 91.82 | 6.41 |
| TPR | 1035.86 | 259.16 |
| CO | 7.65 | 1.96 |
| SV | 93.00 | 25.98 |
| HR | 83.00 | 8.40 |
| PEP | 114.86 | 12.84 |
| RSA | 5.79 | 0.89 |

*Note.* SBP = systolic blood pressure (mm Hg); DBP = diastolic blood pressure (mm Hg); MAP = mean arterial pressure (mm Hg); TPR = total peripheral resistance (dyne-second × $cm^{-5}$); CO = cardiac output (liters per minute); SV = stroke volume (milliliters); HR = heart rate (beats per minute); PEP = preejection period (milliseconds); RSA = respiratory sinus arrhythmia (natural log transform).

### *Are There Differences in Actual Daily Demands and Activities as a Function of Loneliness?*

The prevalence and frequency of each category of activity on the ambulatory study day are presented in Table 1. Simple linear regression analyses revealed that none of the activity categories differed in endorsement rate as a function of loneliness scores (all *p*s > .05). However, an increase in loneliness between recruitment and testing predicted a smaller proportion of time spent socializing ($b = -0.55$, $SE = 0.19$, $p < .05$). Loneliness change scores did not predict any other activity endorsement rate. Furthermore, analyses of all 7 days of diaries replicated the absence of loneliness differences in activity endorsement rate, with the exception of

[2] The pattern of results reported in this section did not differ when analyses were repeated using all available cardiovascular data (512 observations).

"other leisure activities," which had higher endorsement rates as a function of loneliness ($b = 0.16$, $SE = 0.07$, $p < .05$).[3] The absence of statistically significant differences in the activities performed by lonely and nonlonely participants on the ambulatory study day therefore does not seem attributable to a lack of statistical power or to participants altering their normal daily activities on the day ambulatory measurements were taken.

During the ambulatory study day, women spent more time socializing than did men ($b = 4.89$, $SE = 2.45$, $p < .05$). This result was replicated across the 7 diary days ($b = 4.91$, $SE = 1.22$, $p < .01$). Gender did not predict any other differences in activity endorsement rate on the ambulatory study day. However, the larger number of observations across the 7 experience-sampling days revealed that women spent less time watching TV ($b = -2.88$, $SE = 1.24$, $p < .05$) and engaging in other leisure activities ($b = -3.63$, $SE = 1.44$, $p < .05$) than did men. None of the Gender × Loneliness interactions was statistically significant.

### *Do the Lonely Appraise Everyday Circumstances Differently?*

Null multilevel linear regression models of ratings of stress, threat, demand, ability to meet demands, and cognitive appraisal ratios in the ambulatory diary data set revealed significant or near significant first-order autoregression coefficients (all $p$s $< .07$). In addition, autoregressive residual covariance models provided superior fit to models with a diagonal identity residual covariance matrix ($p$s $< .05$), so an autoregressive covariance structure was incorporated in multilevel analyses for these criterion variables. Mean levels of stress and threat ratings are displayed in Table 4. As hypothesized, loneliness predicted higher stress ratings ($b = 0.02$, $SE = 0.01$, $p < .05$), explaining, in combination with loneliness changes, 20% of the between-subjects variance in stress ratings. In addition, loneliness predicted higher threat ratings ($b = 0.010$, $SE = 0.003$, $p < .01$), explaining, in combination with loneliness changes, 15% of the between-subjects variance in threat ratings.

Mean cognitive appraisal ratings are displayed in Table 4. Loneliness predicted higher demand ratings ($b = 0.05$, $SE = 0.01$, $p < .01$) and lower ratings of ability to meet demands ($b = -0.02$, $SE = 0.01$, $p < .01$). Loneliness changes also predicted ratings of ability to meet demands ($b = -0.02$, $SE = 0.01$, $p < .05$). Together, loneliness and loneliness changes explained 17% of the variance in ratings of demand and 13% of the variance in ability to meet the demands of everyday situations. Not surprisingly, cognitive appraisal ratios, defined as ratios of demand to ability to meet demand, were predicted by loneliness ($b = 0.008$, $SE = 0.002$, $p < .01$) and loneliness changes ($b = 0.007$, $SE = 0.003$, $p = .01$). Together, loneliness and loneliness changes explained 27% of the variance in cognitive appraisals. This pattern of results was replicated when analyses of all 7 days of diaries were performed.

Holding loneliness and loneliness changes constant, gender did not predict stress, threat, or cognitive appraisal-related ratings (all $p$s $> .40$). Furthermore, gender neither confounded nor moderated the effects of loneliness on any of these variables.

*Cardiovascular effects.* The ambulatory cardiovascular data set was used to perform a series of multilevel analyses assessing the relationship between each of the stress and appraisal variables and cardiovascular activity. The analyses indicated that the stress, threat, and appraisal ratings were unrelated to any of the cardiovascular variables.

Table 4
*Means and Standard Deviations of Psychological Variables (N = 134)*

| Variable | *M* | *SD* |
|---|---|---|
| Stress | 1.75 | 0.59 |
| Threat | 1.23 | 0.33 |
| Cognitive appraisal ratio | 0.55 | 0.23 |
| Demand | 2.12 | 0.60 |
| Ability to meet demand | 4.32 | 0.61 |
| Interaction positivity ($n = 133$) | 2.85 | 0.63 |
| Interaction negativity ($n = 132$) | 1.45 | 0.44 |

*Note.* With the exception of cognitive appraisal ratios, all measures have scale ranges of 1–5. Cognitive appraisal ratio represents the ratio between demand and ability to meet demand, hence ranges from 2.0 to 5.0.

### *Do the Lonely Spend More Time Alone?*

Overall, participants reported being alone on 44.5% of all occasions on the ambulatory study day, with more than 95% of participants reporting being alone at least once over the course of this day. A simple linear regression analysis indicated that loneliness was not a significant predictor of time spent alone on the ambulatory study day ($p > .4$). A focus on the two most frequently endorsed activities, schoolwork and errands, confirmed the absence of loneliness differences in time spent alone while performing these activities ($p$s $> .6$).

For undergraduate students, weekends typically permit more freedom of choice of social context than do weekdays. A repeated-measures analysis of variance revealed that students were less frequently alone on weekends than on weekdays, $F(1, 127) = 11.85$, $p < .05$ ($M_{\text{weekends}} = 46.0\%$, $SD = 18.7$; $M_{\text{weekdays}} = 51.5\%$, $SD = 15.7$). A regression analysis did not detect a linear relationship between loneliness and time spent alone during weekdays ($p > .40$). Loneliness changes, however, did predict time spent alone on weekdays ($b = 0.43$, $SE = 0.20$, $p < .05$), such that an increase in loneliness from recruitment to testing was associated with more time spent alone. Neither gender, nor its interaction with loneliness, predicted time spent alone on weekdays.

During weekends, loneliness showed a tendency to predict time alone ($b = 0.29$, $SE = 0.17$, $p = .089$). This effect achieved statistical significance ($b = 0.60$, $SE = 0.23$, $p = .01$) when a Gender × Loneliness interaction term was added to the model. Although gender did not predict differential time alone on weekends, a significant Gender × Loneliness interaction indicated that lonely women spent less time alone on weekends than did lonely men ($b = -0.57$, $SE = 0.29$, $p = .05$).

Additional simple regression analyses were performed to see whether, when interacting with others, loneliness predicted the proportion of time spent interacting with men versus women. Overall, male and female participants spent significantly more

[3] The more sensitive nonparametric Kruskal–Wallis test confirmed the absence of loneliness group differences in activity endorsement rate.

time with same-gender than with opposite-gender interaction partners ($ps < .01$). Loneliness did not predict time spent with women, $p > .90$, but a Loneliness × Gender interaction approached significance ($b = -0.80$, $SE = 0.45$, $p < .08$). An examination of loneliness group means illuminated the nature of this interaction: Lonely and nonlonely men did not differ in time spent with women, but lonely women spent less time interacting with other women than did nonlonely women. On the other hand, loneliness predicted more time with men ($b = 0.60$, $SE = 0.28$, $p < .05$), but a significant Loneliness × Gender interaction ($b = -0.94$, $SE = 0.35$, $p < .01$), followed up by a comparison of loneliness group means, revealed that whereas lonely men spent more time interacting with other men than did nonlonely men, lonely women spent less time doing so than did nonlonely women. This pattern of results was replicated using data from all 7 days of diaries.

Cardiovascular activity did not differ as a function of social context (i.e., being alone vs. with others), nor did loneliness interact with social context to predict cardiovascular activity.

### *Do the Lonely Have Poorer Interaction Quality?*

Null multilevel linear regression models of interaction positivity and negativity on the ambulatory study day revealed first-order autoregression coefficients that approached significance ($ps < .09$). In addition, autoregressive residual covariance models provided superior fit to models with a diagonal identity residual covariance matrix ($ps < .05$), so an autoregressive covariance structure was incorporated in multilevel analyses for these criterion variables. Table 4 includes mean overall levels of interaction positivity and negativity. A multilevel random-intercept regression analysis with raw loneliness score and loneliness change score as predictors revealed that loneliness predicted significantly lower interaction positivity ($b = -0.01$, $SE = 0.01$, $p < .05$) and significantly higher interaction negativity ($b = 0.016$, $SE = 0.004$, $p < .01$). In addition, increases in loneliness between recruitment and testing predicted higher interaction negativity scores ($b = 0.02$, $SE = 0.01$, $p < .01$). Gender did not predict interaction negativity, but women showed a tendency toward higher interaction positivity ratings than men ($b = 0.18$, $SE = 0.10$, $p = .09$). Gender and loneliness did not interact to predict positivity or negativity ratings. The pattern of results observed here did not differ when analyses of all 7 days of diaries were performed.

As noted above, lonely men spent more time with male interaction partners than did nonlonely men, and lonely women spent less time with female interaction partners than did nonlonely women. Exploratory analyses of interaction quality revealed no interactions between loneliness and partner's gender in predicting interaction positivity or negativity. However, a Participant Gender × Partner Gender interaction indicated that interactions with male partners were rated less positively by male than by female participants ($b = -0.55$, $SE = 0.22$, $p = .01$). In addition, interactions with female partners were rated more negatively by male than by female participants ($b = 0.38$, $SE = 0.11$, $p < .01$). Neither negativity of interactions with males nor positivity of interactions with females differed as a function of participant's sex.

Mean interaction negativity on the day of cardiovascular assessments was not significantly related to TPR. Mean interaction positivity predicted lower TPR ($b = -39.85$, $SE = 16.80$, $p < .05$) and only slightly decreased the loneliness effect on TPR ($b = 5.19$, $SE = 3.03$, $p < .05$, one-tailed). Neither interaction positivity nor interaction negativity interacted with loneliness to predict TPR.

### *Do the Lonely Engage in More Health-Compromising Behaviors?*

Although health-compromising and -promoting behaviors were infrequently endorsed during the ambulatory study day (see Table 1), simple linear regressions indicated that loneliness did not predict differences in the frequency of sleeping, eating, or consuming caffeine.[4] Drug and alcohol use and exercising were endorsed too infrequently for analysis. The only gender difference was that women spent more time eating than men ($b = 4.05$, $SE = 1.89$, $p < .05$). Loneliness did not interact with gender to predict any of the health behaviors.

Averaging across all 7 days of diaries, loneliness predicted lower levels of alcohol use ($b = -0.05$, $SE = 0.02$, $p < .05$). However, this effect was moderated by gender. The significant interaction indicated that men, but not women, exhibited an inverse relationship between alcohol use and loneliness ($b = 0.07$, $SE = 0.04$, $p < .05$). This interaction may have been attributable, at least in part, to significantly lower levels of alcohol consumption among women compared with men ($b = -0.80$, $SE = 0.41$, $p = .05$). Mirroring results of the ambulatory study day, women tended to report eating more frequently than did men over the course of the week ($b = 1.99$, $SE = 0.08$, $p = .05$). Neither loneliness nor its interaction with gender predicted any other health-related behaviors across the week.

### *Do Depressed Affect, Neuroticism, or Social Support Account for Loneliness Differences?*

*Cardiovascular activity.* The relationship between loneliness and cardiovascular functions underlying blood pressure regulation (i.e., CO, TPR) proved robust even when we controlled for depression, neuroticism, and social support. Consistent with prior research, lonely individuals tended to be more dysphoric ($r_{\text{loneliness, BDI}} = .46$, $p < .01$), more negative by disposition (i.e., neurotic; $r = .28$, $p < .01$), and lower in appraisal support ($r = -.62$, $p < .01$). However, in random-intercept multilevel regression models, none of these variables accounted for loneliness differences in TPR and CO. In fact, with depression scores statistically controlled, loneliness had a larger net effect on TPR ($b = 8.50$, $SE = 3.46$), CO ($b = -0.06$, $SE = 0.03$), and SV ($b = -0.91$, $SE = 0.37$) than was evident when depression scores were not included in the models.

Expansion of the analyses to include measures of cardiac activity revealed only one significant association: Appraisal support predicted increased RSA ($b = 0.05$, $SE = 0.02$, $p < .05$). Neither appraisal support nor loneliness predicted RSA net of each other's effects on RSA ($ps > .10$), but the association between appraisal support and RSA should be considered tentative in light of the number of such tests. No other association between these socio-

[4] A Kruskal–Wallis nonparametric test confirmed the absence of loneliness group differences in the frequency of engaging in any of the health behaviors.

emotional assessments and cardiovascular measures reached statistical significance.

*Stress ratings.* Psychological stress as measured using an experience-sampling method in this study was predicted by depression scores ($b = 0.04$, $SE = 0.01$, $p < .01$). Interestingly, in the random-intercept multilevel regression model in which the effects of loneliness and depression were assessed net of each other's effects, depressed affect no longer predicted stress ratings, and the impact of loneliness on stress ratings was attenuated ($p = .08$). This functional differentiation of the putative effects of depression and loneliness took a similar form when the component processes underlying psychological stress were analyzed. As was the case for loneliness, depression scores predicted ambulatory study day ratings of threat ($b = 0.02$, $SE = 0.01$, $p < .01$), demand ($b = 0.03$, $SE = 0.01$, $p < .05$), ability to meet the demands of everyday activities ($b = -0.04$, $SE = 0.01$, $p < .01$), and cognitive appraisal ratios ($b = 0.015$, $SE = 0.004$, $p < .01$). The additional variance explained by loneliness beyond that predicted by depression scores was 6% for threat ratings, 5% for demand ratings, 6% for ratings of ability to meet demands, and 12% for cognitive appraisals ($ps < .05$). As was the case for stress ratings, loneliness appeared to mediate the effect of depressed mood on cognitive appraisals: Net of the effects of loneliness, depression scores no longer predicted cognitive appraisals ($p > .20$). Finally, men and women did not differ on any of the stress or appraisal ratings, nor did gender moderate the loneliness effects.

Neuroticism predicted higher threat ratings ($b = 0.08$, $SE = 0.03$, $p < .05$), higher cognitive appraisal ratios ($b = 0.07$, $SE = 0.02$, $p < .01$), and higher demand ($b = 0.12$, $SE = 0.05$, $p < .05$), but again, loneliness appeared to mediate these effects. In a random-intercept regression model that evaluated the unique effects of loneliness and neuroticism net of each other's effects, loneliness retained significance as a predictor of these variables ($ps < .05$) whereas the effects of neuroticism were reduced to nonsignificance. Net of each other, loneliness and neuroticism had independent effects on ratings of ability to meet demands; in a random-intercept regression model, both loneliness and neuroticism retained significance as predictors of ability to meet demands. Neuroticism did not predict stress ratings, nor did it alter the influence of loneliness on stress ratings.

Appraisal support predicted reduced stress ($b = -0.04$, $SE = 0.01$, $p < .01$) and threat ratings ($b = -0.03$, $SE = 0.01$, $p < .01$), and, in contrast to depression and neuroticism, appraisal support appeared to mediate the effect of loneliness on stress and threat ratings. In a random-intercept regression model that evaluated the unique effects of loneliness and appraisal support net of each other's effects, the loneliness effect on stress was reduced to nonsignificance ($b = 0.01$, $SE = 0.01$, $p < .17$), and appraisal support retained a tendency toward significance ($b = -0.03$, $SE = 0.01$, $p < .08$). In an equivalent analysis, net of each other's effects, loneliness no longer predicted threat ($b = 0.002$, $SE = 0.004$, $p > .50$), whereas the effects of appraisal support retained significance ($b = -0.02$, $SE = 0.01$, $p < .01$).

Appraisal support also predicted lower cognitive appraisal ratios ($b = -0.014$, $SE = 0.004$, $p < .01$), lower demand ratings ($b = -0.03$, $SE = 0.01$, $p < .05$), and higher ratings of ability to meet demands ($b = 0.04$, $SE = 0.01$, $p < .01$). Contrary to the preceding analyses, loneliness appeared to mediate the effects of appraisal support on each of these variables. Loneliness retained significance as a predictor of each variable, net of the effects of appraisal support, whereas the predictive capacity of appraisal support, net of loneliness effects, was reduced to nonsignificance.

In sum, the results were consistent with the hypothesis that differences in feelings of stress and threat during the course of the day between lonely and nonlonely individuals are explained in part by differences in the availability or use of appraisal support. Differences in the perceptions of demands, however, were not mediated by appraisal support.

*Interaction quality.* Depression scores predicted interaction negativity ($b = 0.03$, $SE = 0.01$, $p < .01$), but loneliness appeared to mediate this effect. When both loneliness and depression scores were entered into a random-intercept regression model, loneliness, net of the effects of depression, continued to predict interaction negativity ($b = 0.01$, $SE = 0.01$, $p < .01$), whereas depression scores, net of loneliness, no longer predicted interaction negativity ($p > .4$). Interaction positivity was not predicted by depression scores, and when entered into a regression model with loneliness, depressed mood attenuated the loneliness effect only slightly ($b = -0.01$, $SE = 0.01$, $p = .07$).

Like depression scores, neuroticism predicted interaction negativity ($b = 0.15$, $SE = 0.04$, $p < .01$) but not interaction positivity ($p > .2$). The effects of loneliness and neuroticism on interaction negativity were independent and summative in effect. Controlled for each other, both loneliness ($b = 0.01$, $SE = 0.04$, $p < .01$) and neuroticism ($b = 0.09$, $SE = 0.04$, $p < .05$) predicted interaction negativity in a random-intercept regression model.

Similarly, appraisal support predicted interaction negativity ($b = -0.04$, $SE = 0.01$, $p < .01$) and failed to predict interaction positivity ($b = 0.02$, $SE = 0.01$, $p = .09$). Neither appraisal support nor loneliness predicted interaction positivity when effects were controlled for each other in a random-intercept regression model. On the other hand, appraisal support retained significance as a predictor of interaction negativity ($b = -0.003$, $SE = 0.010$, $p < .01$) and only slightly attenuated the effect of loneliness ($b = 0.01$, $SE = 0.01$, $p = .09$) in a regression model that included both predictors.

## Discussion

One mechanism by which loneliness might affect health is through differential activation of the cardiovascular system. In the laboratory, Cacioppo, Hawkley, Crawford, et al. (2002) observed higher TPR and lower CO in lonely young adults at baseline, across posture, and during active coping stressors. Although the young adults in this study were normotensive, Cacioppo, Hawkley, Crawford, et al. (2002) observed significantly greater age-related increases in blood pressure in a sample of lonely than nonlonely older adults. Together, these data led to the hypothesis that lonely individuals would be characterized by chronically higher TPR and lower CO and that over years, this would contribute to diminished cardiovascular health in lonely individuals. The present research confirmed that the differences in TPR and CO observed in the laboratory generalized to everyday life: Lonely participants exhibited higher TPR and tended to exhibit lower CO than the nonlonely across the various situations and social contexts in which they were measured during a normal day. Furthermore, and as found in the laboratory setting, lonely and nonlonely participants exhibited comparable blood pressure (even when gender, BMI, and parental

history of hypertension were held constant). Longitudinal research is underway in our laboratory to examine whether loneliness predicts higher levels of TPR across the lifespan and whether TPR predicts subsequent elevations in blood pressure.

The function of the cardiovascular system is to provide optimum perfusion of tissues, with the blood passing through multiple vascular beds (e.g., cerebral, cutaneous, renal, coronary, hepatic, muscular) before returning to the heart (Johnson & Anderson, 1990). TPR refers to the level of resistance to blood flow caused by the relative constriction of all the blood vessels in the circulatory system. The sympathetic branch of the autonomic nervous system, via alpha-adrenergic receptors on blood vessel walls, plays a major role in regulating the caliber of blood vessels throughout the circulatory system and thus is a primary regulator of TPR.

Contrary to the view of sympathetic activation as a homogeneous arousal mechanism across the periphery, blood flow in each vascular bed can be individually adjusted in large part through the localized adjustment of sympathetic tone via alpha-adrenergic receptors to increase or decrease vessel diameter. Various hormones (e.g., antidiuretic hormone, angiotensin II, histamine) mimic the effects of sympathetic activation and, therefore, also play a minor role in determining TPR (Papillo & Shapiro, 1990). Even differences in parasympathetic activation of the vasculature may play a role, because vascular endothelial cells respond to acetylcholine with the release of nitric oxide, a potent vasodilator (Furchgott, 1993).

The autonomic nervous system's influences on the heart (and cardiodynamics generally) are now well known and are distinct from its influences on the vasculature (and hemodynamics generally) noted above. Vagal activation of the heart is the primary determinant of HR during resting states, and the primary influence of vagal activation on CO is via HR. Sympathetic activation of the heart operates through beta-adrenergic rather than alpha-adrenergic receptors, with some influence on HR and a major influence on myocardial contractility. CO is the product of HR and SV. Both cardiac vagal and sympathetic activation (measured by vagal tone and PEP, respectively) contribute to HR and SV and hence to CO. However, nonneural factors also have potentially powerful effects on SV and hence CO (Cacioppo et al., 1994). For instance, increased preload, which originates from venous return mechanisms, increases SV and CO independently of cardiac sympathetic and vagal activation, and increased afterload, which originates from increased arterial resistance, decreases SV and CO independently of cardiac sympathetic and vagal activation. Consequently, there is neither a necessary relationship between beta-adrenergic and alpha-adrenergic activation nor between beta-adrenergic activation and the sympathetic activation of specific vascular beds or the vasculature as a whole. This was the case in the current study, because differences in TPR between lonely and nonlonely participants remained even after we controlled statistically for differences in beta-adrenergic activation as measured by PEP (Berntson et al., 1994; Cacioppo et al., 1994). These factors point to possible differences in local norepinephrine release, alpha-adrenergic receptors, circulating vasopressin and angiotensin, vagal influences on the vasculature, and patterns of perfusion as foci of future research.

This is also the first study to examine the momentary everyday experiences of lonely and nonlonely individuals. Prior laboratory studies have suggested that lonely individuals rate their lives as more stressful than do nonlonely individuals (e.g., see review by Ernst & Cacioppo, 1999). These studies, however, were based on retrospective reports, which may reflect differences in memory rather than differences in daily stress per se. Nevertheless, examination of momentary stress reports in the current study were consistent with prior studies: In contrast to nonlonely individuals, lonely individuals reported higher overall stress and threat in response to the circumstances of daily life. Relatedly, lonely individuals were more likely to evince threat appraisals of everyday events than nonlonely individuals, and they tended to appraise everyday events as more demanding and themselves as less able to meet these demands than did nonlonely individuals. Furthermore, increases in loneliness between recruitment and testing predicted an even greater tendency toward threat appraisals, suggesting a causal role for loneliness in cognitive appraisals of everyday events. Importantly, all these differences were observed even though the actual activities and behaviors (e.g., amount of school work or outside employment, leisure activities) performed by the participants did not differ as a function of loneliness.

What are the psychological differences between lonely and nonlonely participants that may contribute to the differences in cardiovascular patterning? The threat–challenge appraisal distinction made by Blascovich and colleagues has what might seem to be similar autonomic effects, but their formulation applies to a very different circumstance: the change in cardiovascular activity from baseline during an active coping task–stressor (e.g., Blascovich & Tomaka, 1996; Tomaka et al., 1993; see also Wright & Kirby, in press). We instead measured basal autonomic activity (the subject's only task was to sit and complete a survey when beeped) at random moments during the day. Although subjects may have engaged in active coping tasks since the last beep, at the moment autonomic activity was recorded these individuals were engaged only in completing a brief experience-sampling survey. It is conceivable that, relative to nonlonely individuals, lonely individuals have, as a default, a threat appraisal regarding not active coping stressors but the very contexts of their lives. Alternatively, the same autonomic pattern has also been associated with active and passive coping differences, coping differences that are consistent with those previously found to differentiate lonely and nonlonely individuals (Cacioppo, Hawkley, Crawford, et al., 2002). For instance, passive coping tasks have been found to produce higher levels of TPR and lower levels of CO than active coping tasks (e.g., Sherwood, Dolan, & Light, 1990), and passive-like coping on active coping tasks produces higher levels of TPR and lower levels of CO than active-like coping in active coping tasks (Kasprowicz et al., 1990). It is therefore equally if not more likely that lonely, compared with nonlonely, individuals are more likely to adopt a passive coping perspective on their world (Cacioppo et al., 2000), which would explain the differences we found in cardiovascular activity during the course of a normal day in the life of lonely and nonlonely individuals.

Foregoing evidence suggests that psychological construal is more important than objective life circumstances in characterizing loneliness. First, our covariates did not eliminate loneliness differences in cardiovascular patterning. Second, lonely and nonlonely undergraduate participants in this study not only engaged in similar activities but spent equivalent time alone during the day. Indeed, an examination of the two most frequently endorsed activities indicated no difference in social context: Lonely and non-

lonely participants were equally likely to be doing schoolwork and errands alone as with others. Furthermore, loneliness had a unique effect on both psychological construal and cardiovascular patterning: Depressed affect, neuroticism, and appraisal support failed to account for differences in cognitive appraisals, TPR, or CO. In fact, the loneliness effects on TPR and CO were more pronounced when depressed mood was held constant. Only stress and threat ratings showed a mediational role for appraisal support in explaining loneliness differences. This latter finding is perhaps not surprising, given that the purported and documented advantage of social support is a reduction in the perception and experience of stress (Cohen & Wills, 1985). However, appraisal support did not account for loneliness differences in perceptions of demand and ability to meet demands. In fact, the converse was true: Loneliness explained support-related differences in demand and ability to meet demands. Similarly, the effects of dysphoria on cognitive appraisals appeared mediated by loneliness.

The separability of the effects of loneliness and dysphoria serves to emphasize that these two states, although related, are not synonymous. Furthermore, depression scores had a suppressive effect on loneliness differences in vascular resistance, CO, SV, and cognitive appraisals. Given that we restricted participation to those who were not severely depressed, this finding suggests that loneliness effects may be underestimated when depressed mood is not taken into consideration.

The unique effect of loneliness on psychological construal was also evident in ratings of social interactions. Appraisal support appeared synonymous with loneliness in predicting social interaction quality, but loneliness exerted a unique effect on social interaction quality independent of the effects of depressed affect and neuroticism. Replicating prior research (Wheeler et al., 1983), loneliness was associated with less comfort, intimacy, understanding, and other positive feelings during social interactions. Conversely, and consistent with previous reports (Jones et al., 1982; Rotenberg, 1994; Segrin, 1998), loneliness was associated with a greater degree of caution, conflict, distrust, and other negative feelings during social interactions. In fact, interaction negativity was associated with an increase in loneliness between recruitment and testing. Although causal direction cannot be ascertained, this finding appears consistent with Rook (2001), who found that negative social interactions (those involving arguments, hurt feelings, unwanted time with someone whom one does not enjoy, etc.) predicted increases in loneliness over the course of a year, whereas positive interactions did not possess this predictive ability. Whether the cumulative effect of frequent disturbances in social interaction quality is similar to that of more frequent negative social interactions remains to be tested.

Importantly, interaction positivity was related to TPR: The more positive the interaction, the lower the TPR. Interaction positivity did not mediate loneliness differences in TPR but added to the impact of loneliness on TPR. Thus, the social world can affect TPR in at least two ways—via loneliness and via interaction quality. Whether an overarching third factor exists that can explain both effects remains to be seen. Interestingly, because nonlonely participants experienced more positivity in their interactions, they derived a greater TPR-lowering effect of interaction positivity than did lonely participants. These results emphasize the importance of considering not only the costs of loneliness but also the unique psychological and physiological health benefits afforded by social embeddedness.

Prior research has suggested that women may be particularly effective at diminishing a sense of isolation in their social partners. Consistent with Wheeler et al. (1983), loneliness predicted less time with women, although this was true only for female participants in our sample. In contrast with Wheeler et al., for men, loneliness was related to more time spent with men. This difference between our results and Wheeler et al.'s could be partially attributable to the fact that Wheeler et al. evaluated only those interactions that lasted at least 10 min, whereas we considered interactions of any duration, however brief. In addition, whereas Wheeler et al. tested only college seniors, our sample consisted primarily of freshmen and sophomores. During students' 1st year in college, the importance of friendships increases, whereas the importance of romantic relationships actually declines (Shaver, Furman, & Buhrmester, 1985). Thus, the younger students in our study may have been fostering good same-sex friendships to a greater extent than was evident among the senior students in the study by Wheeler et al.

Interestingly, Wheeler et al. (1983) noted that a majority of nonlonely women and a distinct group of nonlonely men merely reported meaningful relationships with men (i.e., high scores on positive dimensions of interactions) and did not report more time with females. In our sample, regardless of loneliness levels, men, compared with women, gave lower positive ratings to their interactions with other men. In addition, men, compared with women, gave higher negative ratings to their interactions with women. Coupled with the fact that lonely men, compared with nonlonely men, spent more time with male interaction partners and equivalent time with female interaction partners, it is possible that loneliness in men was attributable more to the relative lack of positivity in their interactions with men than to greater negativity in their interactions with women. In addition, the fact that interaction negativity and positivity had unique patterns of relationship with the gender of participant and partner and with cardiovascular activity (as described above) reinforces the importance of distinguishing between these two qualitative dimensions of interactions and examining their unique effects on psychological and physiological outcomes in lonely and nonlonely individuals.

Loneliness has been linked with a smaller likelihood of engaging in high-risk health behaviors, such as smoking and drinking, and a smaller likelihood of engaging in health-promoting behaviors, such as exercise and good nutrition (Schwarzer et al., 1990). In the current study, we replicated the lack of loneliness differences noted in these participants' retrospective self-reports of health-promoting and compromising behaviors (Cacioppo, Hawkley, Crawford, et al., 2002). Loneliness did not predict frequency of exercising, smoking, or drinking in everyday life. The absence of loneliness differences in our study is perhaps not surprising given epidemiological evidence indicating that social ties (i.e., social pressures) have the potential to both encourage and discourage health-promoting behaviors (Seeman, 2000). Moreover, health behaviors did not contribute to loneliness differences in cardiovascular activity. This is not to suggest that health behaviors are unimportant in understanding health outcomes, but rather that health behaviors per se appear to be an unlikely cause of the differences in health outcomes between lonely and nonlonely individuals.

In review, the present study showed that loneliness in young adults was associated with higher TPR and lower CO during a normal day and that these cardiovascular differences were not attributable to objective differences in daily activities, time spent alone, exposure to everyday events, or health behaviors. Despite these similarities, lonely individuals reported greater levels of stress, greater interaction negativity, and less interaction positivity during the day than did nonlonely individuals. Interaction positivity contributed to TPR levels but did not moderate or mediate loneliness differences in TPR. Appraisal support appeared to mediate loneliness differences in stress and threat ratings. However, loneliness differences in cardiovascular activity, cognitive appraisals, and interaction quality were not explained by differences in depressed affect, neuroticism, or appraisal support.

Whether these findings will generalize to an older sample remains to be seen. The young adult college students we tested live in a constrained university environment; older adults presumably have more choice in how and where they spend their time. Data we are collecting in a mid-aged sample of men and women will enable us to assess whether loneliness predicts differences in the behaviors, activities, and social interactions of older adults and to what degree behavioral choices and level of loneliness contribute to psychological construal and physiological functioning.

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