Journal of Personality and Social Psychology
1992, Vol. 63, No. 5, 839–846

0022-3514/92/$3.00

Age-Related Changes in Cardiovascular Response as a Function of a Chronic Stressor and Social Support

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The effects of aging, chronic stress, and social support on cardiovascular functioning were examined using a cross-sectional design. Thirty-six family caregivers of Alzheimer's disease victims and 34 control Ss performed 2 active coping tasks while continuous noninvasive measures of cardiovascular activity were monitored. Results revealed that caregivers high in social support displayed typical age-related decreases in heart-rate reactivity, whereas caregivers low in social support displayed age-related increases in heart-rate reactivity. Analyses further indicated that only Ss with low social support were characterized by age-related increases in systolic blood pressure. These results suggest that social support can moderate age-related changes in cardiovascular functioning, particularly in Ss exposed to a chronic stressor.

Age-related changes in cardiovascular functioning are well documented, but the potential impact of social factors on these changes has not received much attention. Studies of age and its relation to cardiovascular functioning suggest that (a) physiological and chronological age are not isomorphic (Smith, 1984) and (b) social factors may play a role in the aging process (Editorial, 1981; Szklo, 1979). Our aim was to examine the potential contribution of social factors on age-related changes in cardiovascular functioning. We pursued this aim along two fronts. First, we sought to examine the moderating effects of a chronic stressor (i.e., caregiving responsibilities for a family member with Alzheimer's disease) on the relationship between chronological age and cardiovascular functioning. Second, because of a substantial social component in caregiving stress (e.g., Biegel, Sales, & Schulz, 1991) and the putative stress-buffering effects of social support, we examined the potential moderating effect of perceived social support on cardiovascular functioning in young and elderly caregivers.

We thank Robert Kelsey and William Guethlein for providing us with copies of their data-acquisition and reduction software for the Cortronics 7000 and for their helpful advice. We would also like to thank Thomas W. Kamarck for his comments on a draft of this article. This research and preparation of this article were supported by National Institute of Mental Health Grant MH42096 to Janice K. Kiecolt-Glaser and National Science Foundation Grant BNS-8940915 to John T. Cacioppo.

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Age-Related Changes in Cardiovascular Activity and Reactivity

Between the ages of 30 and 70, decreases in the muscle mass of the heart and the contractility of the myocardium produce declines in stroke volume. Additionally, maximal heart rate declines by about 24 beats per minute, contributing to a 30% reduction in cardiac output and a 25% to 30% reduction in maximal work capacity in elderly individuals (see review by Smith, 1984). There is also an apparent down regulation of beta-adrenergic receptors as a function of age (Schocken & Roth, 1977). Although cardiac performance tends to decrease with age, resistance to blood flow tends to increase (Palmer, Ziegler, & Lake, 1978). Not surprisingly in light of these facts, aging has been associated with an increase in systolic blood pressure both at rest and in response to psychological and physical stressors (Faucheux, Bourliere, Baulon, & Dupuis, 1981; Garwood, Engel, & Capriotti, 1982; Fleg, Tzankoff, & Lakatta, 1985; Johansson & Hjalmarson, 1988; Harrison & Kelly, 1989; Steptoe, Moses, & Edwards, 1990; but see Ginter, Hollandsworth, & Intrieri, 1986). In an illustrative study of men 30–70 years of age, Garwood, Engel, and Capriotti (1982) found that age predicted resting systolic blood pressure (prestimulus $r = .47$, poststimulus $r = .49$) and pressor reactivity to mental arithmetic ($\Delta r = .25$). The evidence for age-related changes in diastolic blood pressure activity and reactivity appears more equivocal (Faucheux et al., 1981; Garwood et al., 1982; Ginter et al., 1986; but see Steptoe et al., 1990).

Although many studies have found no age-related changes in resting heart rate (e.g., Garwood et al., 1982; Ginter et al., 1986; Fleg et al., 1985), age-related decreases in heart-rate reactivity are well documented. Decreases in heart-rate reactivity with age have been demonstrated with psychological stressors

(Furchtgott & Busemeyer, 1979; Garwood et al., 1982; Faucheux, Dupuis, Baulon, Lille, & Bourliere, 1983; Barnes, Raskind, Gumbrecht, & Halter, 1982; Ginter et al., 1986; but see Steptoe et al., 1990), physical challenges (Palmer et al., 1978; Bertel, Buhler, Kiowski, & Lutold, 1980; Hossack & Bruce, 1982; Fleg et al., 1985; Johansson & Hjalmarson, 1988), and postural changes (Palmer et al., 1978; Simpson & Wicks, 1988). For example, Ginter et al. (1986) examined age-related changes in heart-rate reactivity to an active coping task. Male subjects, 15–55 years of age, were instructed to press a telegraph key as quickly as possible whenever a red light appeared. Monetary incentives for success or mild electric shocks for failure were given for performance during successive trials. When Ginter et al. (1986) statistically controlled for the effects of parental history of hypertension, weight, and exercise, they found that relatively old subjects exhibited significantly lower heart-rate reactivity to the active coping task than did relatively young subjects. It is important that these results were not attributable to age differences in reaction time or self-reported effort.

Potential Factors Impacting on Age-Related Changes in Cardiovascular Activity and Reactivity

Despite the apparent replicability of age-related changes in cardiovascular function, these changes are not biologically invariant with aging. Blood pressure, for instance, remains unchanged over relatively long periods in a large proportion of adults in industrialized (Jenkins, Somervell, & Hames, 1983) and unindustrialized societies (Fries, 1976; Mugambi, 1983; Pobee, 1983). Smith (1984) acknowledged that "categorization of the older adult population by chronological age is convenient, but physiological age [i.e., physiological or functional capacity] is more expressive of a specific individual's capability" (p. 525). Whereas Smith (1984) emphasized the important contributions to aging of a sedentary lifestyle, aging is also associated with a variety of social (e.g., sociodemographic factors and social support), psychological (e.g., stress and hostility), and behavioral (e.g., diet and exercise) changes, each of which may have powerful instigatory or moderating effects on cardiovascular function.

Prior researchers have examined the effects of aging on cardiovascular functioning, but much less is known about such changes in individuals who are undergoing a chronic stressor. Previous research by Kiecolt-Glaser, Dura, Speicher, Trask, & Glaser (1991) has demonstrated that caregiving for an individual with Alzheimer's disease is associated with negative changes in psychological and immune function. One aim of this study, therefore, was to provide data on cardiovascular functioning as a function of age in a group of individuals who live with a chronic social stressor, that is, caregivers for relatives (e.g., spouse or parent) with Alzheimer's disease.

The second aim of this study was to investigate the possible additive or interactive effects of social support on cardiovascular functioning in young and elderly caregivers. Social support is a potentially important moderator of pathophysiological processes because of its putative stress-buffering effects (e.g., S. Cohen & Wills, 1985; Kennedy, Kiecolt-Glaser, & Glaser, 1990). For example, Kiecolt-Glaser et al. (1991) examined the longitudinal effects on immune function of spousal caregiving for an Alzheimer's disease victim. Caregivers with low levels of perceived social support at intake experienced greater negative changes in immune function compared with control subjects. It is important that this effect remained unchanged when statistically controlling for group differences in depression.

Recent evidence that perceived social support may also moderate cardiovascular functioning was obtained by Unden, Orth-Gomer, and Elofsson (1991). Unden et al. (1991) examined the effects of social support at work on 24-hr ambulatory electrocardiogram (ECG) recordings. Social support was negatively related to heart rate during work, leisure time, and sleep. In addition, subjects with relatively low levels of social support had higher systolic blood pressure than subjects with relatively high levels of social support. Unfortunately, no information was provided regarding the possible additive or interactive effects of age and social support.

In the present study, cardiovascular functioning was assessed in subjects from Ohio State University's (OSU's) Alzheimer's Caregiver Research Project. Repeated measures of cardiovascular activity were obtained during pretask baselines and task periods for each of two psychological stressors (i.e., active coping tasks of mental arithmetic and structured interview). Prior research using cardiovascular measures has occasionally been plagued by relatively poor psychometrics (see Kamarck et al., 1992). Kamarck et al. demonstrated that the psychometric properties of cardiovascular measures were enhanced considerably by aggregation over repeated measures within measurement periods (e.g., pretask baseline and task) and across psychological stressors. Therefore, this approach was adopted in the present research. Beat-by-beat measures of cardiovascular activity were aggregated within pretask baseline periods and within task periods to enhance measurement reliability. In addition, two psychological stressors that had comparably activating cardiovascular effects (i.e., mental arithmetic and structured interview) were developed in pilot testing. Although the purpose in using multiple stressors was to allow further aggregation and to enhance generalizability, psychological stressor was treated as a within-subject variable to ensure the comparability of these tasks in the present study. Finally, heart-rate reactivity to active coping tasks (e.g., mental arithmetic) has been found to be a particularly sensitive discriminator of populations at risk for cardiovascular problems (e.g., Krantz & Manuck, 1984; Light, 1981). Therefore, we included period (baseline vs. task) as a repeated measures variable.[1]

Method

Subjects and Design

Thirty-six family caregivers of Alzheimer's disease victims (13 men and 23 women) and 34 control subjects (6 men and 28 women) from the

[1] A common procedure in studies of physiological reactivity is to analyze change scores (i.e., task minus pretask baselines). However, the use of change scores can mask group differences in the pretask baseline. By treating period (pretask baseline, task) as a within-subject factor, one is better able to identify the contribution of pretask baselines on the treatment means (see Cacioppo, Berntson, & Andersen, 1991). Thus, the Psychological Stressor × Period interaction test of the means is equivalent to a psychological stressor main effect test on change scores, but only in the former can one also assess differences in baseline means and differences in task-period means.

Alzheimer's Caregiver Research Project at OSU, aged 30–84 (*Mdn* = 63.5), participated in the study. Family caregivers were recruited through local dementia-evaluation centers, neurologists' referrals, Alzheimer's Disease and Related Disorders Association support groups and its monthly newsletter, respite care programs, and governmental caregiver support groups. To be admitted to the study, caregivers had to be providing at least 5 hr of care per week. On average, subjects had been caregiving for more than 8 years (M = 101.97 months) before their participation in this study and had previously shown evidence of immunosuppression and psychological distress as a result of the chronic demands of caregiving (Kiecolt-Glaser et al., 1987; Kiecolt-Glaser et al., 1991). Control subjects were recruited through newspaper advertisements, church groups, posted notices in senior citizen centers, and referrals from other participants. Control subjects that reported any caregiving activities were excluded from the sample. Caregivers and control subjects were matched in terms of gender, age, and education (see Kiecolt-Glaser et al., 1991).

Participants in the OSU Alzheimer's Caregiver Research Project undergo an annual 3-hr psychological and immunological assessment. The cardiovascular component reported in this article was introduced to the project in its fourth year and required approximately 20 min to complete. Participants were screened such that no subject was taking cardiovascular-altering medication (e.g., beta blockers or diuretics). In addition, subjects refrained from smoking, eating, or drinking caffeinated liquids (coffee, tea, and colas) at least 2 hr before their participation in the study.

Median splits were performed on the blocking variables of age and social support. Age was determined from demographic data provided by subjects at intake each year and verified by consistency with reports from the previous 3 years. Social support was quantified using the Social Support Interview (Fiore, Becker, & Coppel, 1983; Kiecolt-Glaser et al., 1991), in which subjects listed up to 10 important people in their lives with whom they have contact. Subjects then rated how helpful each relationship was in terms of (a) emotional support (0 = *not at all*, 6 = *extremely*) and (b) tangible support (0 = *not at all*, 6 = *extremely*). These ratings have been found to load on a single factor (Kiecolt-Glaser et al., 1991), so an index of Total Social Support was calculated by summing these ratings for all members of the support network. The correlation between ratings of emotional and tangible support was .85 ($p < .001$). Preliminary analyses indicated that the test–retest reliability of the Total Social Support index over the preceding 12 months was satisfactory for conceptualizing social support as a stable individual-difference variable (rs = .61 for caregivers and .62 for control subjects, ps < .001).

Apparatus

A Cortronics Model 7000 blood pressure monitor was used to measure heart rate and blood pressure. Once calibrated, the Cortronics deflates the occluding cuff over the brachial artery to 20 mmHg and provides continuous beat-by-beat information on heart rate, systolic blood pressure, diastolic blood pressure, and mean arterial pressure.[2] These data were transmitted on-line to a microcomputer and stored for subsequent analysis using software developed by Guethlein (1990). To increase measurement reliability, the beat-by-beat measures were averaged within each of the two baselines and within each of the two task periods.

Procedure

The cardiovascular reactivity test was typically the last of the laboratory tests (i.e., psychological and immunological assessments) and consisted of a mental arithmetic and a structured interview task. The order of the tasks was counterbalanced across subjects. Following placement of an occluding cuff of appropriate size over the brachial artery of the left arm, the tasks were described in detail, and subjects' questions about the tasks were answered.

Mental arithmetic. Subjects were informed that the mental arithmetic task, which involved serial subtraction, was difficult even for individuals who had experience with numbers and that their goal was simply to work as quickly and accurately as possible. Subjects performed a brief practice task (i.e., count backward by 2s beginning at 200), after which a 4-min baseline was obtained. The mental arithmetic task consisted of three 1-min serial subtraction problems, which subjects performed without stopping. During the 1st min, subjects counted backward by 7s beginning with 956. After 1 min had elapsed, the experimenter interrupted to announce that the subject should now count backward by 7s from 572, and after the 2nd min had elapsed, the experimenter announced that the subject should count backward by 7s from 739.

After performing the mental arithmetic task, subjects rated how mentally effortful the task was (1 = *mentally easy*, 9 = *mentally effortful*) and how unpleasant (1 = *extremely pleasant*, 9 = *extremely unpleasant*) and aroused (1 = *completely aroused*, 9 = *completely relaxed*) he or she felt during the serial subtraction task. Two task performance measures were also calculated: the number of subtractions performed and the percentage that was correct.

Structured interview. The structured interview lasted 2 min and was also preceded by a 4-min baseline. Caregivers were instructed to talk about an event or events that had been especially frustrating or difficult for them while caregiving. Control subjects were instructed to talk about an event or events that had been especially frustrating or difficult for them. A standardized set of questions was used to prompt subjects to talk freely about their frustrations and difficulties until the 2 min elapsed. Pilot testing indicated that the structured interview task was equally stressful for caregivers and control subjects.

After the structured interview, subjects rated how mentally effortful the task was (1 = *mentally easy*, 9 = *mentally effortful*) and how unpleasant (1 = *extremely pleasant*, 9 = *extremely unpleasant*) and aroused (1 = *completely aroused*, 9 = *completely relaxed*) he or she felt during the interview.

Results

Preliminary Analyses

We performed a set of preliminary analyses before we examined the experimental hypotheses to ensure that appropriate conditions were established. First, a 2 (age: low vs. high) × 2 (group: caregivers vs. controls) analysis of variance (ANOVA) was performed on the measure of perceived social support to determine the independence of these blocking variables. Analyses revealed no significant main effects or interaction. Second, a 2 (age: low vs. high) × 2 (social support: low vs. high) ANOVA was performed within the caregiver group on the number of months subjects had previously served as caregivers to examine the possibility that older individuals or individuals with low

[2] Mean arterial pressure is a simple function of systolic and diastolic blood pressure. To reduce the redundancy in our dependent variables (and to minimize the possibility of Type I errors), we treated the data for mean arterial pressure as ancillary. No new information was found in these exploratory analyses, so mean arterial pressure is not discussed further. However, interested readers can obtain a copy of these analyses by contacting Bert N. Uchino.

social support had been caregiving longer. The analyses revealed no significant main effects or interactions.[3]

Next, we performed analyses that bore specifically on the two aims of the study: (a) to investigate the effects of long-term exposure to a chronic social stressor (i.e., experienced caregivers for relatives with Alzheimer's disease) on age-related changes in cardiovascular functioning, and (b) to determine the additive or interactive effects of social support on cardiovascular functioning in young and elderly caregivers. To examine these issues, we conducted 2 (age: low vs. high) × 2 (social support: low vs. high) × 2 (group: caregivers vs. controls) × 2 (psychological stressor: mental arithmetic vs. structured interview) × 2 (period: baseline vs. task) mixed-model ANOVAs on the measures of heart rate, systolic blood pressure, and diastolic blood pressure. Age, social support, and group were between-subjects variables, whereas psychological stressor and period were within-subject variables.

Age-Related Changes in Cardiovascular Functioning in Caregivers and Control Subjects

The ANOVAs revealed the acute psychological stressors were effective and generally comparable in elevating cardiovascular activity. Significant period effects were found for the measures of heart rate, $F(1, 62) = 187.63$, $p < .001$, systolic blood pressure, $F(1, 62) = 21.84$, $p < .001$, and diastolic blood pressure, $F(1, 62) = 49.81$, $p < .001$. A significant psychological stressor main effect was found for diastolic blood pressure, $F(1, 62) = 4.53$, $p < .04$, indicating higher levels of diastolic blood pressure during the mental arithmetic compared with the interview (mental arithmetic $M = 84.12$, structured interview $M = 82.92$). No other statistical test involving psychological stressor was significant. Cell means are summarized in Table 1.

Analyses of both blood pressure and heart rate revealed that the presence of a chronic social stressor did not impact on cardiovascular functioning in a simple fashion. Prior research in general populations has demonstrated age-related increases in systolic blood pressure activity. We observed a similar pattern for systolic blood pressure (young $M = 126.06$, elderly $M = 135.12$), $F(1, 62) = 3.26$, $p < .04$, one-tailed. The Age × Period interaction was not significant, indicating no age-related differences in systolic blood pressure reactivity. Furthermore, the Age × Group interaction was not significant, suggesting that both caregivers and control subjects evidenced comparable age-related increases in systolic blood pressure. Finally, neither the age effect nor the Age × Period effect was significant for diastolic blood pressure.

Analyses of heart rate revealed that the age main effect was not significant, $F < 1$. The Age × Period interaction was consistent with past research in general populations indicating decreased heart-rate reactivity in the elderly (young $M = 7.22$, elderly $M = 6.22$), $F(1, 62) = 2.98$, $p < .05$, one-tailed.[4] The Age × Group and the Age × Group × Period interactions for heart rate were not significant, $Fs < 1$.

Age-Related Changes in Cardiovascular Activity as a Function of Social Support and a Chronic Social Stressor

Analyses revealed several significant tests involving social support.[5] Contrary to the notion that social support acts in a simple or additive fashion (e.g., as a uniform stress buffer), no main effect for social support approached significance. Instead, significant interactions involving social support were found.[6]

First, analyses of heart rate revealed a significant four-way interaction among age, social support, group, and period, $F(1, 62) = 13.07$, $p < .001$ (see Table 1).[7] Subsequent analyses revealed that the simple three-way interaction among age, social support, and period was highly significant for caregivers, $F(1, 32) = 19.57$, $p < .001$, but not for control subjects, $F < 1.20$. As a result, we conducted further analyses of the caregiver group, blocking on social support while examining the simple two-way interactions between age and period. These analyses revealed that low levels of social support were associated with age-related increases in heart-rate reactivity, $F(1, 19) = 5.82$, $p < .03$, whereas high levels of social support were associated with age-related decreases in heart-rate reactivity, $F(1, 13) = 11.68$, $p < .005$.[8] Thus, caregivers high in social support were character-

[3] The preliminary analyses were also conducted using moderated regression procedures that treat the blocking variables of age and social support as continuous variables. Results of these analyses also revealed no significant main effects or interactions.

[4] Preliminary analyses revealed that the Age × Period interaction for heart rate was subsumed by a significant Order × Age × Period effect, $F(1, 54) = 7.22$, $p < .01$. In this interaction, significant age-related decreases in heart-rate reactivity were only observed when the structured interview task was presented first.

[5] To ensure the generality of the results, we conducted a parallel set of analyses using moderated regression procedures. In moderated regression, both age and social support are treated as continuous rather than as discrete independent variables. These analyses revealed the same pattern of data reported in the text. We focused in the text on the ANOVA using median splits for two reasons: (a) Moderated regression procedures are more sensitive to outliers than are ANOVAs based on median splits and (b) the ANOVAs are performed on mean scores, which yield a simple and familiar graphical representation. The similarity in the results, however, attests to the generality of our results across the age range spanning middle age and late life.

[6] Past research on social support has drawn a distinction between structural (e.g., number of social contacts) and functional (e.g., perceptions of support) measures of social support (S. Cohen & Wills, 1985). In our measure of perceived social support, subjects listed up to 10 important people in their lives and rated how helpful each of these individuals was in terms of emotional and tangible support. The correlation between the number of people listed in the social support interview and the measure of total perceived social support was .81 ($p < .001$). Nevertheless, we repeated our analyses, blocking on the number of important people listed in the social support interview as the measure of social support ($Mdn = 5.5$). Results revealed the same significant effects (and pattern of means) as reported in the text.

[7] Analyses indicated that these groups did not differ significantly in baseline heart rate, $F < 1$. Thus, the significant four-way interaction is not attributable to differences in pretask baselines.

[8] It should be noted that most of the young caregivers were offspring of the Alzheimer's patient, whereas most of the elderly caregivers were spouses of the Alzheimer's patient. We therefore examined the data for the spousal and offspring caregivers separately in each of the Age × Social Support cells. The pattern of means was the same for both samples. Thus, the form of the simple three-way interaction for caregivers does not appear to be skewed by the lesser number of spouses in the young caregiver group or the greater number of spouses in the elderly caregiver group.

Table 1
Mean Heart Rate and Blood Pressure as a Function of Age, Social Support, and Period

Group	N	Baseline	Task
Heart rate (beats per minute)			
Caregivers			
Young–low social support	11	71.06	75.02
Young–high social support	7	67.89	79.52
Elderly–low social support	10	67.27	74.61
Elderly–high social support	8	76.68	80.32
Control subjects			
Young–low social support	6	71.18	80.93
Young–high social support	12	67.27	73.63
Elderly–low social support	9	71.01	77.77
Elderly–high social support	7	71.97	78.84
Systolic blood pressure (mmHg)			
Caregivers			
Young–low social support	11	118.50	123.45
Young–high social support	7	135.03	135.98
Elderly–low social support	10	142.40	148.25
Elderly–high social support	8	127.34	132.36
Control subjects			
Young–low social support	6	124.18	125.83
Young–high social support	12	122.83	128.63
Elderly–low social support	9	133.74	135.28
Elderly–high social support	7	124.53	130.18
Diastolic blood pressure (mmHg)			
Caregivers			
Young–low social support	11	79.65	81.53
Young–high social support	7	84.23	86.54
Elderly–low social support	10	90.01	92.51
Elderly–high social support	8	80.23	82.59
Control subjects			
Young–low social support	6	74.43	77.14
Young–high social support	12	82.86	84.91
Elderly–low social support	9	82.51	84.97
Elderly–high social support	7	81.59	85.00

ized by typical age-related decreases in heart-rate reactivity, whereas caregivers low in social support were characterized by atypical age-related increases in heart-rate reactivity.

Analyses of systolic blood pressure further revealed a significant Age × Social Support interaction, $F(1, 62) = 5.26$, $p < .03$ (see Table 1). Simple main effect tests for age revealed that systolic blood pressure did not vary as a function of age in subjects with relatively high levels of social support, $F < 1$. In contrast, systolic blood pressure was significantly elevated in elderly subjects with relatively low levels of social support compared with their younger counterparts, $F(1, 34) = 12.79$, $p < .002$. This result was significant even when analyses were conducted using only the systolic blood pressure measured at baselines, $F(1, 62) = 6.34$, $p < .02$. The three-way interaction among age, social support, and group did not approach significance, suggesting that these effects were characteristic of both caregivers and control subjects.[9] No test involving social support was significant in the analyses of diastolic blood pressure.

The preliminary analyses indicated that the length of time subjects had spent caregiving and overall levels of social support were comparable for the young and elderly groups. It is possible, however, that the cardiovascular responses reflected differences in psychological reactions to the stressors. For instance, young subjects with high levels of social support may have been especially motivated to perform well on the tasks and, therefore, exhibited elevated cardiovascular responses. To examine such possibilities, we performed 2 (group) × 2 (age) × 2 (social support) ANOVAs on (a) the measures of task performance during the serial subtraction task and (b) subjects' ratings of mental effort, unpleasantness, and arousal experienced during the mental arithmetic and structured interview tasks. These analyses revealed a significant social support main effect for the percentage correct during the mental arithmetic task, $F(1, 60) = 6.67$, $p < .02$. The significant social support main effect revealed that subjects with low levels of social support performed better (low $M = 90\%$, high $M = 80\%$) than subjects with high levels of social support. It is important that no interactions were significant. Thus, the moderating effects of social support and group on age-related changes in cardiovascular functioning do not appear to be attributable to differences in task performance, effort, or affect.

It is also possible that group differences in lifestyle variables (e.g., exercise) impacted on cardiovascular functioning. An intake interview provided information about each subject's weight, caffeine consumption over the prior 48 hr, alcohol consumption, smoking habits, and hours of vigorous physical activity during the previous week. Each of these measures was subjected to a 2 (group) × 2 (age) × 2 (social support) ANOVA to determine possible associations with the blocking variables in this study. The analyses indicated that the group of young subjects reported consuming more caffeinated beverages during the past 48 hr than the group of elderly subjects (young $M = 4.46$, elderly $M = 2.39$), $F(1, 60) = 6.92$, $p < .02$. It is important that no interaction was statistically significant. Thus, these lifestyle differences do not provide an alternative account for the results reported in Table 1.[10]

[9] The small number of men who participated in the study precluded analyses with gender serving as a fourth between-subjects variable. A chi-square analysis, however, indicated that the number of men in the caregiver versus the control group did not differ, $\chi^2(1, N = 19) = 2.58$, *ns*, nor did the number of men in each Age × Social Support group, $\chi^2(3, N = 19) = 5.63$, *ns*. Nonetheless, to ensure that our significant results were not skewed by the male subjects, we repeated our analyses using only female subjects. Results revealed that the deletion of the male subjects did not alter the pattern of findings reported above.

[10] We also performed a series of hierarchical regressions and separately statistically controlled for each measure of task affect, task performance, and the life-style variables. As suggested by J. Cohen and Cohen (1983), we also tested the product set consisting of the covariate and the highest order interaction of interest in the final step of the regression analysis. The presence of a nontrivial interaction between the covariate and group membership renders the analysis invalid because of violation of the assumption of homogeneity of regression slopes. In all but two cases in which the assumption of homogeneity of regression slopes was met, the hierarchical regressions yielded the same decision about statistical significance as did the ANOVAs. The two exceptions were the Age × Social Support interaction on systolic blood pressure using (a) weight and (b) smoking habits. Although the F ratio was not changed much in either test, it was sufficient to move the p level from <.03 to .10 and from <.03 to <.08, respectively. These results raise questions about the generalizability of the stress-buffering

Finally, to examine the possible contributions of depression to the effects reported in Table 1, we subjected heart rate and systolic blood pressure to hierarchical regression procedures, partialing out depression. We used the Hamilton Depression Rating Scale (Hamilton, 1967), administered as part of the program project, as the measure of depression. If depression were underlying the significant effects reported in Table 1, then the hierarchical regressions should render these effects nonsignificant. Results of the analyses, however, indicated depression was not underlying these cardiovascular responses. The interaction of Age × Social Support × Group × Period was highly significant for heart rate, $F(1, 61) = 12.69$, $p < .001$. In addition, the interaction of Age × Social Support was significant for systolic blood pressure, $F(1, 65) = 5.94$, $p < .02$.[11]

Discussion

Prior research on age and cardiovascular function has reliably documented age-related increases in systolic blood pressure (e.g., Faucheux, Bourliere, Baulon, & Dupuis, 1981; Garwood et al., 1982) and age-related decreases in heart-rate reactivity (e.g., Faucheux et al., 1981; Ginter et al., 1986; Lakatta, 1985). We provided partial replications of these results, although the present study differed from previous research in several important respects. Most studies examining age-related changes in cardiovascular functioning have not used aggregation over beat-by-beat heart-rate and blood pressure measures and over multiple stressors. These procedures are preferred, however, because they provide superior measurement reliability (Kamarck et al., 1992). In addition, we studied subjects who had been caregiving for a relative with Alzheimer's disease, on average, for more than 8 years before their participation in this study. Age-related changes in cardiovascular functioning had not been studied previously in a population as chronically stressed. Despite the duration of caregiving, we found complex rather than simple relationships between the chronic stressor, social support, and age-related changes in cardiovascular functioning.

This was also the first study to our knowledge to investigate the interactive effects of naturalistic social support on cardiovascular functioning in young and elderly individuals exposed to a chronic stressor. Caregivers of relatives with Alzheimer's disease live a more isolated existence than their age peers (Kiecolt-Glaser et al., 1991). Therefore, we anticipated social support would help buffer caregivers from the effects of the chronic social stressor with which they lived. Analyses of heart-rate reactivity in caregivers provided support for this hypothesis.

Analyses of systolic blood pressure activity suggested that the beneficial effects of social support in moderating age-related changes in blood pressure produced comparable effects for both caregivers and control subjects. One question that arises is why did the chronic stress of caregiving not interact with age and social support for systolic blood pressure? Although the information provided by heart rate and blood pressure may be related (e.g., baroreceptor reflex), the physiological regulation of heart rate and blood pressure are complex and distinct (Papillo & Shapiro, 1990).[12] Thus, it becomes important to examine the pattern of cardiovascular functioning represented by our data. Our pattern of results suggests that caregivers with low levels of social support may evidence greater age-related increases in cardiovascular sympathetic control. For instance, age-related increases in heart-rate reactivity for caregivers with low social support were mirrored by age-related increases in systolic blood pressure, as might occur if cardiovascular activity were under significant sympathetic control. Age-related differences in systolic blood pressure for subjects with low social support in all other groups, on the other hand, were not mirrored in heart-rate reactivity. Research is now underway to determine whether high levels of perceived social support do indeed slow the shift toward age-related sympathetic control of the heart.

An important question is how might social support moderate age-related changes in cardiovascular functioning for caregivers and control subjects? According to Kenney (1989), "Aging may be defined as the sum of all the changes that occur in man with the passage of time and lead to functional impairment and death." (p. 15). Recent research by Lepore, Evans, and Schneider (1991) suggests that a chronic social stressor (i.e., crowding) may impact on psychological functioning by diminishing perceptions of social support. Our preliminary analyses suggest that both aging and the chronic stress of caregiving were not significantly related to our measure of social support. Hence, one model of our results might suggest that life events (e.g., stressors) that accumulate with age lead to subsequent changes in cardiovascular functioning. Social support, however, may diminish the impact or actual number of stressful events, perhaps through direct emotional and tangible support. For example, Russell and Cutrona (1991) found that elderly subjects who reported high levels of perceived social support experienced fewer daily hassles over a subsequent 11-month period compared with subjects with lower levels of perceived social support. Importantly, the incidence of daily hassles exerted a direct positive effect on levels of depression. Clearly, future research should examine specific process models of social support (e.g., Russell & Cutrona, 1991) and their potential impact on physiological functioning.

Analyses of cardiovascular reactivity to the acute psychological challenges confronted by caregivers during this study, however, suggested that having others available with whom to talk and compare may not be uniformly beneficial. Although perceived social support tended to limit the heart-rate responses to the tasks shown by elderly subjects, perceived social support

effects of social support on systolic blood pressure. To further investigate this effect, we performed the hierarchical regressions on the significant interactions obtained when blocking on the number of people listed in the social support interview (see footnote 6). None of the hierarchical regressions altered the significance of these results. For instance, the significant Age × Social Support interaction on systolic blood pressure remained significant when weight and smoking behavior each served as the covariate. Thus, group differences on task affect, task performance, or the various lifestyle variables do not appear to generally alter the stress-buffering effects of social support reported in this study.

[11] In none of our analyses did the interaction between the covariate and group membership approach statistical significance, $Fs < 1$. Thus, the assumption of homogeneity of regression slopes was not violated.

[12] In our study, heart-rate reactivity was not significantly correlated with systolic blood pressure ($r = .21$, *ns*).

was associated with larger increases in heart rate in the younger group of caregivers. These results were not attributable to differences in affect, mental effort, task performance, or any lifestyle variable measured in this study. Although we can only speculate at this point, social comparisons that highlight the constraints on one's own opportunities, activities, and achievements may occur more frequently when young than when elderly caregivers interact with others in their social network. For instance, young caregivers of relatives with Alzheimer's disease may feel more victimized by the limiting circumstances in which they find themselves and, accordingly, they may feel more stigmatized by or hostile about these circumstances than elderly caregivers. Dynamic social processes such as social comparisons, therefore, may hold a key to identifying the conditions under which social support is stress buffering or stress enhancing.

There has been evidence suggesting perceptions of social support may be confounded with prior mental health and personality variables such as neuroticism (Bolger & Eckenrode, 1991). Bolger and Eckenrode suggested that prior mental health and neuroticism may lead to lower perceptions of social support through mood-induced biases (e.g., negativity bias). Consistent with their mood-bias explanation, Bolger and Eckenrode reported that the beneficial effects of perceived social support on examination anxiety were nonsignificant when statistically controlling for personality variables such as neuroticism. A mood bias should also be related to depression levels (see Bolger & Eckenrode, 1991, p. 441). Our results involving perceived social support were unchanged, however, when we statistically controlled for group differences in depression. Thus, although we cannot entirely rule out the influence of personality variables such as neuroticism, our results do not appear to be due to the confounding mechanism suggested by Bolger and Eckenrode.

The pattern of results reported in this study is of particular interest in light of the hypothesized relationship between cardiovascular activity and cardiovascular heart disease (see review by Krantz & Manuck, 1984). For instance, heart-rate reactivity (e.g., Manuck, Kaplan, & Clarkson, 1983; Manuck, Kaplan, & Matthews, 1986) has been implicated as a possible factor influencing the development of coronary artery atherosclerosis. Of course, the use of age alone to predict cardiovascular disorders usually results in a high rate of false positives. Leon (1987), therefore, has emphasized the importance of examining age in conjunction with other potentially modifiable risk factors (e.g., elevated blood pressure) to improve early prevention, detection, and treatment of cardiovascular disease.

Our data suggest that social factors may help to predict, and may affect, these physiological developments. We suggested earlier that high levels of social support may slow the shift toward age-related sympathetic control of the heart. If this is the case, low social support might be associated with an increased risk for coronary heart disease in the elderly. Several large-scale studies support this notion (Haynes & Feinleib, 1980; Reed, McGee, Yano, & Feinleib, 1983; Ruberman, Weinblatt, Goldberg, & Chaudhary, 1984). Ruberman et al. (1984), for instance, found evidence that social isolation was associated with an independent, increased risk for death after myocardial infarctions in the Beta-Blocker Heart Attack Trial. Especially relevant for our study, the combined effects of social isolation and high levels of life stress were associated with an even higher risk. Thus, individuals such as elderly caregivers who have little social support may be especially at risk for mortality from cardiovascular heart disease.

There are several limitations and issues pertaining to the current study that should be noted. First, the study is cross-sectional; therefore, we do not have direct longitudinal evidence for the pattern of results reported in this article. Second, replication and related research are especially important. In addition, differential social roles within the young and elderly caregivers may be important to consider in future research. Young caregivers tended to be offspring of the Alzheimer's patient, whereas elderly caregivers tended to be spouses of the Alzheimer's patient (see footnote 8). Elderly spousal caregivers may be especially vulnerable to the stress of caregiving because they both lose a longtime friend and spouse and are shackled with caregiving responsibilities at a time when their energies and coping responses are limited (Biegel et al., 1991). Therefore, the effects of social support may have been particularly beneficial for these elderly caregivers.

In conclusion, there appears to be evidence that social support may impact on physical health and mortality (e.g., Blazer, 1982; C. Cohen, Teresi, & Holmes, 1985). More research is now needed on the physiological mechanisms by which social support may exert such influences. Our research is an attempt at such investigations. If social support can indeed be shown to moderate the complex physiological mechanisms associated with an increased risk for cardiovascular heart disease, then interventions aimed specifically at increasing social support in such groups become worthwhile.

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Received January 17, 1992
Revision received May 26, 1992
Accepted June 6, 1992 ■