Effects of Social Support on Cardiovascular and Cortisol Reactivity during Passive and Active Behavioral Challenge

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Abstract

The effects of social support on cardiovascular and cortisol reactivity during stressful situations were examined. Sixty healthy male and female participants were randomly allocated to support, no-support, or alone conditions. In the active challenge, participants had higher diastolic blood pressure in the support than the alone condition. In the passive challenge, the support condition reduced systolic and diastolic blood pressure reactivity compared with no-support, and heart rate compared with the alone condition. The active and passive challenges elicited "mixed" and vascular hemodynamic profile, respectively. The results partly support the health benefits of support through reduced reactivity in stressful situations.

Introduction

Evidence shows that social support may be an important determinant of human health, as measured by a wide variety of indices of mortality, morbidity, and psychological well being (Kamarck, 1992; Orth-Gomér & Johnson, 1987; Uchino, Cacioppo, & Kiecolt-Glaser, 1996). Several reviews have reported social support to be inversely related to total mortality (Eriksen, 1994; Schwarzer & Leppin, 1989), total morbidity (Schwarzer & Leppin, 1989; Smith, Fernengel, Holcroft, Gerald, & Marien, 1994), cardiovascular mortality (Krantz & McCeney, 2002), cardiovascular morbidity (Krantz & McCeney, 2002; Orth-Gomér, 1994), changes in cardiovascular reactivity (Thorsteinsson & James, 1999), and health outcome (Hogan, Linden, & Najarian, 2002).

It is important to understand how social support may influence health so that effects can be optimized. Despite the evidence for the health benefits of social support, there is still limited knowledge about underlying physiological mechanisms (Orth-Gomér, 2000). Cardiovascular reactivity has been suggested as a potential mediator of the benefits of social support on health, and experimental studies have been conducted (e.g., Hilmert, Christenfeld, & Kulik, 2002; Kamarck, Manuck, & Jennings, 1990; León, Nouwen, & Sheffield, 2007; Lepore, Allen, & Evans, 1993; Thorsteinsson, James, & Gregg, 1998). Additionally, more recent studies have highlighted the importance of examining cardiac output (CO) and total peripheral resistance (TPR) as part of the hemodynamic profile (Howard, Hughes, & James, 2011; Hughes, Howard, James, & Higgins, 2011). Much of this work derives from the "reactivity" hypothesis which states that excessive cardiovascular response to episodic psychological stress contributes to the development of hypertension and cardiovascular disease (Krantz et al., 1991; Krantz & Manuck, 1984; Lepore, 1998; Manuck, Kasprowicz, & Muldoon, 1990; Obrist, 1981). Participants in experimental studies have generally performed "active" laboratory challenges (e.g., public speaking, mental arithmetic), but rarely "passive" challenges (e.g., viewing an aversive film, cold pressor test), while receiving either supportive verbal or silent supportive gestures as compared with experiencing a neutral (no-support) silent presence of a confederate. Generally, heart rate (HR) and blood pressure (BP) reactivity are monitored (see Lepore, 1998; Thorsteinsson & James, 1999), but findings have been mixed (Thorsteinsson & James, 1999). The trend has been for support to reduce HR and BP, but effect sizes have varied from small to large, and some studies have reported that support increased HR (for a meta-analytic review see Thorsteinsson & James, 1999). These findings suggest that the effects of social support manipulations are dependent on several factors such as type of challenge, type of support, and the relationship between the participant and the support provider.

The lack of consistent findings for the effects of support on cardiovascular reactivity suggests the need for more detailed assessment (e.g., León et al., 2007). In particular, the same change in BP in two individuals may be caused by two very different patterns of increases and decreases in CO and TPR, referred to as "hemodynamic profile" (Gregg, Matyas, & James, 2002; James & Gregg, 2004). Blood pressure increases characterized by increased CO without a compensating decrease in TPR may increase the risk of damage to the heart and blood vessel cell lining due to sheer stress, while change in hemodynamic profile characterized by increased TPR without a compensating decrease in CO may reduce the elasticity of blood vessels (Gregg et al., 2002). Hemodynamic profile (i.e., mixed and vascular) has been linked to ambulatory pulse pressure in young healthy males, a risk factor for cardiovascular disease (Gregg, Matyas, & James, 2005). Hemodynamic profile may also help explain the link between caffeine consumption and cardiovascular disease (James & Gregg, 2004). As such, both types of responses arguably increase the risk of cardiovascular disease.

Social support has been reported to not only affect cardiovascular indices but also *total* mortality and morbidity, suggesting underlying variables additional to cardiovascular ones. One such variable might be the hypothalamus-pituitary-adrenal (HPA) axis stress-response (Kirschbaum, Klauer, Filipp, & Hellhammer, 1995; Krantz & Manuck, 1984; Thorsteinsson et al., 1998). Cortisol levels may play a significant role in this support-health relationship by regulating a host of stress-related processes, including cardiovascular function (Krantz & Manuck, 1984; Kuhn, 1989), immune function, inflammation, and metabolic homeostasis (Munck, Guyre, & Holbrook, 1984; Parker, 1991). To date, only three studies have examined the effects of social support on cortisol reactivity. Kirschbaum et al. (1995) reported attenuating effects for support for male but not for female participants; Heinrichs, Baumgartner, Kirschbaum, and Ehlert (2003) found attenuating effects for male participants (female participants not employed); while Thorsteinsson et al. (1998) reported attenuating effects for both male and female participants.

The present study aimed to improve understanding of the support-health relationship by extending the examination of potential underlying factors of this relationship to include hemodynamic profile and cortisol for active and passive challenges and BP during passive challenges. The present study made several predictions. First, the support condition would reduce HR, systolic (SBP) and diastolic (DBP) blood pressure reactivity compared with an alone and a no-support condition for both active and passive challenges. Second, BP reactivity would have different characteristics (as indicated by hemodynamic profile) in the support condition compared to the no-support and alone conditions. Third, the support condition would reduce cortisol reactivity compared with an alone and a no-support condition for both active and passive challenges.

Method

Participants

Participants were 60 healthy volunteers, comprising 28 males and 32 females, ranging in age from 18 to 31 years ($M = 20$), and body mass index (BMI) from 18 to 28 kg/m² ($M = 22$). All participants were normotensive during screening (BP less than 140/90 mmHg), and all were screened for general health, some pregnancy-related symptoms, and health-behavior status using a modified version of the Symptom Substance Questionnaire (James, Bruce, Lader, & Scott, 1989). Cigarette smokers and users of oral contraceptive steroids were excluded as these factors may, alone and in combination, affect BP (Emmons & Weidner, 1988) and cortisol level (Kirschbaum, Wust, & Strasburger, 1992; Vining & McGinley, 1986). Participants were instructed not to consume alcohol for at least 12 hours before the laboratory session. A randomized control trial was implemented, thus participants were randomly assigned to one of the three conditions. On completion of the laboratory session, participants were paid AU\$10 for their participation. The top 10% of performers on the active challenge received a bonus of AU\$10 each. One participant was dropped from hemodynamic analysis for the active challenge and two for the passive challenge due to incomplete data. One participant was dropped from cortisol analysis due to incomplete information and two were dropped due to an apparent technical error.

Hemodynamic Recoding

Hemodynamic measures were obtained using a *Finapres Continuous Blood Pressure NIBP Monitor; model 2300E* (Ohmeda, Ohmeda House, Hertfordshire, England) in combination with dedicated data-processing software ('Modelflo', *FAST -mf system*, TNO Biomedical Instrumentation Research Unit, Amsterdam, The Netherlands). The Finapres cuff was placed on the third digit of the non-dominant hand. Validation of Finapres measures and Modelflo has been detailed (Jensen et al., 2001; Wesseling, Jansen, Settels, & Schreuder, 1993). Measures obtained included HR, SBP, DBP, CO, and TPR. CO is derived from HR and stroke volume (SV); $CO = HR * SV$. SV is based on the flow waveform (shape and form of a signal) between the current upstroke and the dicrotic notch and captures the difference between left ventricular end-diastolic volume (LVEDV; amount of blood present in the left ventricle after the mitral valve closes and before ejection occurs) and left ventricular end-systolic volume (LVESV; amount of blood remaining in the left ventricle following ejection after the aortic valve closes and before reopening of the mitral valve initiates a new diastolic filling period); $SV = LVEDV - LVESV$. TPR is based on mean arterial pressure (MAP) and CO; $TPR = MAP / CO$. Hemodynamic profile was also assessed. It takes into account the reciprocal relationship between CO and TPR, is independent of BP level and indicates, on a continuous scale, a myocardial, vascular or mixed response (Gregg et al., 2002). The lower a group mean for hemodynamic profile (negative), the greater the myocardial reactivity (CO) and the higher (positive) the mean, the greater the vascular reactivity (TPR). Groups with means that are not significantly different from zero are classified as having a mixed hemodynamic profile.

Cortisol Recording

Salivary cortisol was measured using a standardized protocol where unstimulated (i.e., no chewing) saliva samples of about 2.5 ml were collected in a tube. These were stored at -20°C until assayed using a commercial radioimmunoassay kit (*Coat-a-Count Cortisol*, Bio-Mediq, Melbourne, Australia). Saliva offers advantages over plasma and urine for assessing cortisol, including less obtrusive sampling. In addition, because salivary cortisol is

proportional to the fraction of cortisol in blood that is not bound to plasma protein, it reflects the concentration of the "biologically active" fraction of circulating cortisol (e.g., Kirschbaum & Hellhammer, 1989). Variations in cortisol diurnal variation were addressed by starting experimental procedure at the same time in both the morning and afternoon sessions (for a comparison of the morning and afternoon sessions see the Results section) and by employing the area under the curve increase (AUC_I) for the active and passive tasks as described by Pruessner, Kirschbaum, Meinlschmid, and Hellhammer (2003). This involved entering exact individual time points for pre-task baseline, task, and post-task baseline with both challenges sharing the pre-task and post-task baseline time points.

Laboratory Setup

Participants were seated in front of three adjacent monitors. From left to right, the first monitor was used to present a time-pressured cognitive computer challenge (active challenge). The second presented the confederate in respective experimental manipulations (support or no-support, described below). The third presented questionnaires for participants to answer. The cold pressor bath (passive challenge) was located behind the participant. To perform the cold pressor task, the participant's chair was moved into an appropriate position. It was important that both challenges (described below) had the appearance of being closely and continuously visually monitored by an independent observer stationed at a remote location.

Experimental Manipulation

Participants were randomly assigned to three conditions: support, no-support, or alone. The manipulation of the support and no-support conditions was based on a previous study (Thorsteinsson et al., 1998) with the alone condition added to aid in the interpretation of the results. Prior to performing the computer and cold pressor challenges (described below), participants in the *support and no-support conditions* were told that a confederate (same sex) who had considerable experience in dealing with the relevant challenge would appear on the monitor. The monitor was blank for participants in the alone condition. For the computer challenge, the confederate was shown sitting in front of a computer screen on which the participant's responses appeared to be displayed, ostensibly allowing the confederate to monitor the participant's performance. For the cold pressor challenge, the confederate was shown sitting in front of a TV monitor, ostensibly observing the participant via one of two cameras located in the experimental room. Participants were led to believe that the confederate was in another room when in reality the monitor showed a videotape prepared prior to the study (see Thorsteinsson et al., 1998 for discussion on video-relayed support). A pre-recording was employed to maintain consistency in the support manipulation across participants.

In the *support condition*, the confederate adopted a friendly posture and expression, introducing him- or herself with, "Hi! Don't mind me. I'm just here to help if I can." This was followed by a commentary designed to enhance the participant's perceived level of social support without influencing performance on the challenges. The commentary continued intermittently throughout the computer challenge and the cold pressor challenge (e.g., "OK this is going well ... You're still doing well ... OK no problems ..."). An illusion was created that the confederate was monitoring the participant's performance closely and that the supportive commentary was actually in response to the participant's performance on the respective challenge. In reality, because the videotape was pre-recorded, the comments were generic and non-contingent on performance in either challenge. In the *no-support condition*, the same confederates were shown in the same manner as in the support condition, with the exception that the confederate adopted a "neutral" posture and "monitored" the participant's performance in silence.

Challenges

The Fire Chief *computer challenge* (a 5-minute active challenge) is a computerized micro-world generator used to create an interactive fire-fighting simulation (Omodei & Wearing, 1995). This challenge was used in place of other active laboratory stressors (e.g., mental arithmetic) commonly used in reactivity research because of the high level of congruence between the challenge features and the social support manipulation to be employed in the study, and to enable comparison with a previous study using the same challenge (Thorsteinsson et al., 1998). This challenge is also intended to capture a different type of real life stress, namely, complex decision making, not captured by tasks such as mental arithmetic or public speaking that are commonly used as stressors in this area. In this challenge, participants used a computer mouse to manipulate computer icons representing a fire truck and a fire-fighting helicopter to extinguish fires that ignited spontaneously and spread inexorably throughout a large, sparsely populated forest.

The *cold pressor test* was chosen as the passive challenge for several reasons. First, BP reactivity in response to the cold pressor challenge has been reported to predict future incidence of hypertension (Manuck et al., 1990) and coronary heart disease-related mortality or infarction (Keys et al., 1971). Secondly, the cold pressor test has been widely used as a laboratory stressor making comparisons possible (Gregg et al., 2002; Krantz & Manuck, 1984; Manuck et al., 1990). Thirdly, it was preferred to previously reported passive challenges employed in conjunction

with experimental manipulations of social support such as electric shock (Amoroso & Walthers, 1969), aversive film (Glass, Gordon, & Henchy, 1970), and anticipation of electric shock (Buck & Parke, 1972; Friedman, 1981). For the cold pressor challenge, participants were asked to immerse their dominant hand up to the wrist into cold water ($4^{\circ}\text{C} \pm 1$) and to keep the hand in the water for up to 3 minutes. The challenges were not counterbalanced due to the strong cardiovascular reactions to the cold pressor test. There was a 30-minute interval from the time the computer task ended until the cold pressor task began.

Procedure

The experiment was conducted with the participant seated alone in a sound-attenuated room observed via camera by an experimenter in the adjoining room. A 5-minute period from the relaxation phase was used for the hemodynamic and cortisol baseline period. Cardiovascular activity was then measured during the 5-minute challenge period for the active challenge and the 3-minute period for the passive challenge. On completion of a challenge, participants were instructed to relax.

Saliva samples. Four saliva samples were obtained from each participant, taking into account the time lag between HPA response and change in salivary cortisol levels reflecting this response (Kirschbaum & Hellhammer, 1994). Thus, the first sample was taken 45 minutes after the participant arrived, reflecting the participant's cortisol levels for the first baseline period. During these 45 minutes, participants (a) signed the consent form, (b) relaxed during the baseline period, and (c) answered questionnaires. The second and third samples were taken 25 minutes after each challenge, reflecting cortisol levels for the active and passive challenge, respectively. The fourth sample was taken 50 minutes after completion of the second challenge (the cold pressor test), reflecting a return to baseline.

Measures

Perceived support. The confederate's *perceived support* was rated by the participants in the support and no-support conditions during each challenge on a six-item bipolar adjective scale (Evans & Lepore, 1993; Lepore et al., 1993) (*supportive-non-supportive; close-distant; rejecting-accepting; friendly-unfriendly; warm-cold; helpful-unhelpful*). The Cronbach's alpha for support was .93 and .91 for the active and passive challenges, respectively. Participants in the support and no-support conditions used a visual analogue bipolar adjective scale (*harder-easier*) to rate the effect of the confederate on their performance during the respective challenges.

Stress and arousal. A modified version of a self-report stress and arousal inventory (Mackay, Cox, Burrows, & Lazzerini, 1978) was employed during periods of relaxation (baseline) and challenge. Stress was measured employing ratings of five variables (*peaceful, uptight, tense, calm, pleasant, and uneasy*) with Cronbach's alphas of .81, .90, and .89 for the baseline, and active and passive challenges, respectively. Arousal was measured employing six variables (*alert, energetic, lively, sleepy, sluggish, and tired*) with Cronbach's alphas of .75, .78, and .91 for the baseline, and active and passive periods, respectively.

Challenge ratings. On completion of both challenges, participants used visual analogue scales to indicate how they found the respective challenges (*easy-hard, unpleasant-pleasant, and unenjoyable-enjoyable*). Participants also indicated the extent to which they were trying to *succeed*, how *mentally engaged* they had been while performing the challenges (*not at all-very much*), and how *painful* the challenges had been (*not at all-extremely*).

Statistical Analyses and Interpretation

Power was estimated to be up to .85 for comparing support with no-support and up to .73 for comparing support with alone, based on results from previous studies (for effect size estimates see Thorsteinsson & James, 1999). Factorial ANOVA with support by gender was employed for HR SBP, and DBP using change scores (baseline to task), except where noted (i.e., raw score repeated measures ANOVAs employed to test the change from baseline to task rather than comparing change scores to test values of zero), cortisol using AUC_i, and hemodynamic profile. Interpretation of the results emphasizes effect sizes (for an in-depth discussion see Harlow, Mulaik, & Steiger, 1997), but *p* values are also reported. A rule of thumb for effect sizes (Cohen, 1988; Lipsey & Wilson, 2001) suggests that r^2 and partial η^2 less than .01 are small, between .01 and .16 are medium, and greater than .16 are large. For effect sizes in standard deviation units (e.g., Cohen's *d*, Hedges' *g*), small is 0.20 or less, medium 0.50, and large 0.80 and above, with a 95% confidence interval reported in square parentheses. The present paper focuses not on "statistical significance" (Schmidt & Hunter, 1997) but on effect sizes (partial η^2) greater than or equal to .04 or *d* (unbiased Hedges' *g*) greater than or equal to 0.40 in relation to the effects for the experimental manipulation and gender on hemodynamic and cortisol measures.

Results

Cardiovascular Reactivity

Repeated measures ANOVAs showed that there was a large increase from baseline to task for HR, SBP, and DBP in the active challenge, $F(1, 58) = 9.92, p = .003$, partial $\eta^2 = .15$, $F(1, 58) = 183.02, p = .001$, partial $\eta^2 = .76$, and $F(1, 58) = 165.47, p = .001$, partial $\eta^2 = .74$, respectively, and in the passive challenge, $F(1, 57) = 6.53, p = .013$, partial $\eta^2 = .10$, $F(1, 57) = 378.76, p < .001$, partial $\eta^2 = .87$, and $F(1, 57) = 362.61, p < .001$, partial $\eta^2 = .86$. The inclusion of participants who did not fully complete the passive challenge did not bias the pattern of findings in the passive challenge.

Table 1 reports active and passive baseline and challenge means (*SD*) for HR, SBP, and DBP by support condition. Two-way ANOVAs, support by gender, for HR, SBP, and DBP in the *active challenge* found a main effect for support on DBP, $F(2, 53) = 1.38, p = .259$, partial $\eta^2 = .05$, see Figure 1. This was followed up with a pairwise comparison (Sidak adjustment for *p*) using *d* adjusted for baseline to task correlation, $r = .72$ (Lipsey & Wilson, 2001). The support condition was more reactive than the alone condition, $d = 0.73$ [0.08, 1.38], $p = .308$. Female participants were more reactive than males for HR ($M = 5.09, SD = 8.18$ vs. $M = 0.94, SD = 6.35$), $F(1, 53) = 4.85, p = .032$, partial $\eta^2 = .08$, and DBP ($M = 16.19, SD = 8.02$ vs. $M = 11.95, SD = 8.52$), $F(1, 53) = 4.16, p = .046$, partial $\eta^2 = .07$. There was a support by gender interaction for HR, $F(2, 53) = 2.36, p = .104$, partial $\eta^2 = .08$. Pairwise comparison (Sidak adjustment for *p*; baseline to task, $r = .82$) showed that males had lower HR reactivity than females in the support condition, $d = 1.31$ [0.32, 2.32], $p = .074$, ($M = 0.53, SD = 4.84$ vs. $M = 6.66, SD = 9.11$) and the alone condition, $d = 2.11$ [1.01, 3.21], $p = .018$, ($M = -1.59, SD = 3.10$ vs. $M = 6.41, SD = 7.60$), while reactivity was similar for males and females in the no-support condition, $d = 0.29$ [-0.62, 1.19], $p = .645$, ($M = 3.58, SD = 8.78$ vs. $M = 2.06, SD = 7.82$).

Table 1

Active and Passive Challenge Baseline, and Challenge Means ($\pm$ *SD*) Raw Scores for Heart Rate (HR), Systolic (SBP), and Diastolic (DBP) Blood Pressure

Measure	Social support		No-support		Alone	
	Baseline	Challenge	Baseline	Challenge	Baseline	Challenge
<i>Active (N = 59)</i>						
HR (bpm)	81.36 (8.67)	85.11 (13.16)	76.45 (9.41)	79.27 (10.58)	76.81 (11.18)	79.62 (15.18)
SBP (mmHg)	120.90 (11.77)	147.44 (13.28)	117.99 (16.22)	142.23 (19.90)	117.39 (9.14)	141.08 (14.41)
DBP (mmHg)	72.32 (10.13)	88.42 (11.30)	67.79 (13.16)	82.56 (13.45)	69.21 (9.20)	80.96 (9.36)
<i>Passive (N = 58)</i>						
HR (bpm)	81.36 (8.67)	81.61 (9.19)	76.60 (9.65)	78.74 (8.37)	76.81 (11.18)	83.17 (15.93)
SBP (mmHg)	120.90 (11.77)	156.90 (17.34)	118.28 (16.22)	166.08 (17.60)	117.39 (9.14)	158.07 (16.07)
DBP (mmHg)	72.32 (10.13)	97.51 (11.52)	68.30 (13.32)	101.24 (12.91)	69.21 (9.20)	96.33 (10.56)

Note. The baseline for the no-support condition in the passive challenge will vary from the baseline in the active challenge as there is one less participant in the passive no-support condition.

Two-way ANOVAs, support by gender, for HR, SBP, and DBP in the *passive challenge* found a main effect for support on HR, SBP, and DBP, $F(2, 52) = 2.29, p = .112$, partial $\eta^2 = .08$, $F(2, 52) = 2.53, p = .089$, partial $\eta^2 = .09$, and $F(2, 52) = 2.49, p = .093$, partial $\eta^2 = .09$, respectively, see Figure 2. Pairwise comparison found that participants in the support condition had lower reactivity than participants in the no-support condition for SBP, $d = 0.70$ [0.05, 1.36], $p = .085$, ($M = 36.00, SD = 18.48$ vs. $M = 47.80, SD = 11.87$), baseline to task $r = .44$, and DBP, $d = 0.71$ [0.06, 1.37], $p = .103$, ($M = 25.19, SD = 10.96$ vs. $M = 32.93, SD = 10.21$), baseline to task $r = .50$, and lower HR than alone, $d = 0.81$ [0.16, 1.47], $p = .117$, ($M = 0.26, SD = 7.68$ vs. $M = 6.36, SD = 10.31$), baseline to task $r = .68$. Participants in the no-support condition had higher reactivity than participants in the alone condition for SBP, $d = 0.51$ [-0.13, 1.15], $p = .490$, ($M = 47.80, SD = 11.87$ vs. $M = 40.68, SD = 16.21$), baseline to task $r = .54$, and DBP, $d = 0.51$ [-0.13, 1.15], $p = .319$, ($M = 32.93, SD = 10.21$ vs. $M = 27.12, SD = 11.90$), baseline to task $r = .50$. There was also a gender main effect on SBP, $F(1, 52) = 3.29, p = .076$, partial $\eta^2 = .06$. Males had higher reactivity than females, $d = 0.52$ [-0.01, 1.04] ($M = 45.59, SD = 17.14$ vs. $M = 37.64, SD = 14.59$), baseline to task $r = .54$.

Figure 1. Experimental condition by cardiovascular measure in the active challenge (fire chief task).

Figure 2. Experimental condition by cardiovascular measure in the passive challenge (cold pressor task).

Hemodynamic Profile

Hemodynamic profile classification into vascular, mixed, and myocardial was examined using a one-sample t test, with values less than zero being myocardial, values higher than zero vascular, and values equal to zero being mixed (Gregg et al., 2002; James & Gregg, 2004), based on statistical significance ($\alpha = .05$). The active challenge produced a mixed hemodynamic profile, $M = 0.01$, $SD = 0.12$, $t(58) = 0.39$, $p = .70$ (two-tailed), $d = 0.10$ [-0.41, 0.61]. Participants in the passive challenge had a vascular hemodynamic profile, $M = 0.09$, $SD = 0.14$, $t(57) = 5.05$, $p < .001$ (two-tailed), $d = 1.31$ [0.75, 1.88]. This pattern of small effect sizes for the active challenge and large for the passive was the same for the three support conditions and both genders.

Cortisol Reactivity

There was a statistically significant *decrease* in cortisol levels ($\mu\text{g/dl}$) according to AUC_i in the active challenge, $t(56) = -2.06$, $p = .044$, $M = -6.03$, $SD = 22.13$, and a statistically significant *increase* in the passive challenge, $t(56)$

= 2.26, $p = .028$, $M = 6.72$, $SD = 22.50$. Further examination of the effects of gender, time of day, and support manipulation showed that there was a main effect for time of day in the active challenge where participants in the morning had lower AUC_i ($M = -11.44$, $SD = 24.32$) than participants in the afternoon ($M = -1.16$, $SD = 19.08$), $t(55) = -1.79$, $p = .080$, $d = 0.47$ [-0.06, 0.99], suggesting that time of day should be entered as a factor when analyzing cortisol data for the active challenge.

Following up on the prediction of a main effect for support on cortisol, a one-way ANOVA found a main effect for support in the passive challenge, $F(1, 54) = 1.72$, $p = .188$, partial $\eta^2 = .06$. Pairwise comparison, Sidak, showed that there was a higher increase in the support condition ($M = 7.18$, $SD = 14.52$) than the no-support condition ($M = 0.08$, $SD = 12.40$), $d = 0.52$ [-0.13, 1.16], $p = .699$, and that the no-support condition had a moderately lower increase than the alone condition, $d = 0.52$ [-0.12, 1.16], $p = .194$.

Subjective measures

The effects of support condition and gender on perceived support were examined, as was the effect of support provider in making the task easier. Each challenge was assessed for difficulty, pleasantness, painfulness, enjoyment, trying to succeed, mental engagement, and objective performance. Table 2 shows that in the *active challenge*, participants in the support condition reported higher levels of support than participants in the no-support condition. *Performance* scores revealed little difference between conditions. Participants in the support condition found the confederate made the challenge *easier* ("helpfulness") compared with participants in the no-support condition. In the *passive challenge*, participants in the support condition reported higher levels of support than participants in the no-support condition, see Table 2.

Table 2
Mean Values (SD) for Subjective and Objective Challenge-Related Measures for Each Experimental Support Condition

Measure	Condition			$F(df_{error})$	Partial η^2
	Social support	No-support	Alone		
<i>Active (N = 59)</i>					
Support provider					
Perceived support	79.54 (15.09)	39.18 (14.61)	na	72.01 (37)	.66***
Made things easier	66.42 (18.70)	39.95 (13.64)	na	25.70 (37)	.41***
Challenge					
Difficulty	56.68 (16.99)	60.90 (19.25)	65.70 (15.08)	1.34 (56)	.05
Pleasantness	54.05 (17.72)	51.45 (23.09)	50.20 (19.44)	0.18 (56)	.01
Painful	21.42 (18.51)	23.30 (25.52)	20.65 (22.45)	0.07 (56)	< .01
Enjoyment	63.00 (19.61)	54.35 (23.61)	55.40 (20.71)	0.94 (56)	.03
Trying to succeed	80.37 (15.05)	72.85 (17.66)	78.25 (16.34)	1.10 (56)	.04
Mentally engaged	76.00 (17.55)	70.45 (17.22)	72.30 (20.64)	0.45 (56)	.02
Change in stress	17.64 (28.10)	23.76 (21.65)	24.33 (19.52)	0.49 (56)	.02
Change in arousal	16.91 (18.38)	13.46 (19.85)	15.93 (21.88)	0.15 (56)	.01
Performance (%)	47.32 (18.23)	45.41 (18.58)	55.85 (21.48)	1.62 (56)	.06
<i>Passive (N = 58)</i>					
Support provider					
Perceived support	75.36 (13.35)	42.28 (16.38)	na	44.10 (34)	.57***
Made things easier	65.50 (21.45)	55.83 (13.73)	na	2.60 (34)	.07
Challenge					
Difficulty	75.11 (24.13)	71.16 (31.34)	71.15 (26.53)	0.13 (55)	.01
Pleasantness	13.42 (13.97)	15.00 (17.57)	11.30 (12.50)	0.31 (55)	.01
Painful	76.79 (22.37)	83.16 (17.76)	82.15 (14.55)	0.66 (55)	.02
Enjoyment	17.42 (21.53)	13.89 (19.80)	19.20 (19.76)	0.34 (55)	.01
Trying to succeed	84.84 (16.66)	85.00 (17.33)	84.75 (19.08)	0.00 (55)	< .01
Mentally engaged	79.79 (24.64)	78.47 (20.84)	75.55 (30.24)	0.14 (55)	.01
Change in stress	26.72 (29.14)	37.55 (25.74)	37.12 (23.80)	1.04 (55)	.04
Change in arousal	15.97 (24.25)	13.40 (14.54)	15.91 (19.26)	0.11 (55)	< .01
Performance (seconds)	173.68 (27.53)	174.05 (25.92)	155.65 (50.45)	1.62 (55)	.06

Note. Scales are in the high score direction allowing for a range from a minimum of 0 to a maximum of 100 except for performance which allowed for a range from high 60% to low 90%. na = not applicable.

*** $p < .001$.

Three-way repeated measures ANOVAs of challenge (baseline to challenge), support, and gender showed significant increases for stress and arousal in the active challenge, $F(1, 53) = 59.66$, $p < .005$, partial $\eta^2 = .53$ and

$F(1, 53) = 36.32, p < .005$, partial $\eta^2 = .41$, respectively; and in the passive challenge for stress and arousal, $F(1, 52) = 102.69, p < .005$, partial $\eta^2 = .66$ and $F(1, 52) = 32.45, p < .005$, partial $\eta^2 = .38$, respectively. Table 2 reports the mean change for stress and arousal. There was a challenge by support by gender interaction for stress in the active challenge, $F(2, 53) = 4.61, p < .05$, partial $\eta^2 = .15$. This was due to lower perceived stress for females than males in the support condition, with the reverse pattern in the no-support and alone conditions. In the passive challenge, there was also a challenge by support by gender interaction for stress $F(2, 52) = 3.20, p < .05$, partial $\eta^2 = .11$. Females had lower perceived stress than males in the support condition, similar in the no-support condition, and higher in the alone condition. There was an association between reactivity and arousal for the active challenge for HR, SBP, and DBP ($r_s = .23$ to $.38$), while in the passive challenge, perceived stress was related to increased HR, SBP, and CO reactivity ($r_s = .23$ to $.44$) and decreased TPR reactivity ($r = -.28$).

Discussion

The results showed that in the active challenge, support increased DBP compared with alone, but in the passive challenge, support reduced SBP and DBP compared with no-support and reduced HR and cortisol compared with alone. Hemodynamic profile was mixed for the active challenge when a myocardial profile had been expected, and vascular for the passive challenge as expected. The pattern of hemodynamic profile was the same for support conditions and gender within each challenge. Support did not reduce cortisol reactivity in comparison with the no-support or alone conditions in either challenge.

This study did not replicate the results of a previous study by Thorsteinsson et al. (1998), with the previous study reporting attenuating effects of social support on cortisol and HR reactivity during an active challenge. This difference in findings may have been due to a difference in support manipulation between the two studies. The social support statements in the present study were changed to minimize differences between the support and no-support conditions for difficulty associated with the active challenge. Potentially "informative" comments (e.g., "Remember to scan the whole screen once in a while") were replaced with "neutral" comments (e.g., "Good, fine").

In the present study, the passive challenge showed that support was effective in reducing stress-induced increases in SBP and DBP compared with the no-support condition and in reducing HR reactivity compared with the alone condition. Furthermore, support also marginally reduced cortisol reactivity compared with the alone condition.

Stress-induced increases in HR and BP were not affected by the social support manipulation in the present study for the active challenge. Previous studies comparing confederate support with no confederate support, for example, have generally found a large or moderately attenuating effect of support on HR and BP, as detailed by Thorsteinsson and James (1999). This discrepancy could be indicative of a real difference attributable to (a) the moderate increase in HR limiting any attenuating effects of support (see Table 1), (b) the difference in active challenge employed in the present study compared with previous studies which tended to employ speech delivery as the active challenge, and (c) the difference in verbal support provided in the present study from previous studies that often used speech delivery as the active challenge, thus employing mainly silent support (e.g., eye contact, nodding in agreement, smiling) but sometimes short verbal support (e.g., Gerin, Pieper, Levy, & Pickering, 1992; Lepore et al., 1993). A complex decision-making task, as employed in the present study, may have characteristics that limit the potential for support to decrease cardiovascular reactivity. Conversely, verbal support may have added to the participants' cognitive processing load, which may, in turn, have increased their BP. This is partly supported by the results showing that the support condition had higher DBP than the alone condition. Gender differences may also play a role, with males generally having lower reactivity in this task than females (HR and DBP). This may have been caused by the greater pleasantness and enjoyment reported by males compared with females for this challenge. Further studies are needed to elicit what role gender plays exactly in moderating the effects of support on reactivity in this and similar tasks.

The attenuating effect of support on BP (compared with no-support) and HR (compared with alone) in the passive challenge, provides support for the findings of previous studies using *active* challenges (e.g., Christenfeld et al., 1997; Gerin et al., 1992; Uchino & Garvey, 1997). Comparison of the present BP findings with findings from other *passive* challenges was not possible because the other studies in question did not measure BP (i.e., Amoroso & Walthers, 1969; Buck & Parke, 1972; Friedman, 1981; Glass et al., 1970). However, lower HR reactivity in the support condition compared with the alone condition corroborates the findings of previous studies. The findings for BP show that it is important for future studies to employ passive challenges and to measure a more "complete" set of cardiovascular indicators such as hemodynamic profile. As expected, hemodynamic profile for the passive challenge was vascular. However, for the active challenge, the profile was mixed, not myocardial as expected, suggesting there may be a component of the present active task that differentiates it from more commonly used tasks. Further studies may elucidate components of stressful situations that might contribute to hemodynamic responses that differ from the currently reported ones. Future studies should also consider using a more complex statistical analysis such as structural equation modeling to incorporate different factors (e.g., D personality, neuroticism) that are emerging as potential risk and protective factors affecting cardiovascular reactivity and hemodynamic profile (Howard et al., 2011; Hughes et al., 2011).

The general lack of attenuating effects for the social support compared with the alone condition, and the attenuating effects of the support compared with the no-support condition (such as for Lepore et al., 1993), could indicate that the absence of support in a situation where the confederate "chooses" not to provide support (the no-support condition) may be seen by participants as an act of "hostility". This may especially apply in a painful challenge such as the cold pressor test, where the confederate showed no reaction to the participant's "suffering". Hostile conditions are reported to increase cardiovascular reactivity (Sheffield & Carroll, 1996).

Participants across all three conditions showed a reduction in cortisol levels in response to the active challenge, as did participants in the support condition in a previous study (Thorsteinsson et al., 1998). The only other study to examine the effects of a support manipulation on cortisol levels was a study by Kirschbaum et al. (1995) that employed a public speaking (mock job interview) challenge immediately followed by a mental arithmetic challenge, with participants receiving support from a stranger, their partner, or not at all. The challenges induced increases in cortisol levels across all conditions, with females showing lower levels than males in the no-support and stranger support conditions but increased cortisol in the partner condition. Together, these three studies suggest that evaluation potential during active challenges may contribute to increased cortisol levels at least for partner support, where participants were performing in front of a person who was significant to them.

In the present study, cortisol levels increased in response to the passive challenge, with participants in the support condition exhibiting a smaller reactivity than in the alone condition, but a larger reactivity than in the no-support condition thus showing a similar pattern for HR and cortisol reactivity. Cardiovascular and cortisol reactivity were not associated in either challenge except for HR and cortisol in the passive challenge ($r = .43$) suggesting independent underlying mechanisms for cardiovascular and cortisol reactivity.

The present study has its limitations such as limited power to examine small effects or gender by support interactions. The cortisol findings are unclear and do not fit easily within previous findings. However, there are very few studies that have examined cortisol and manipulated social support suggesting that more research is needed that gives careful consideration to factors such as time of day, drug use, age, and gender.

The present findings, in combination with previous findings, suggest a complex relationship between social support and physiological reactivity. The suggestion is that studies examining the relationship between social support and physiological reactivity should try to control for a diverse range of potentially influential variables, including evaluation potential (friends, strangers, or confederates), types of stressors (e.g., active and passive) and expression of support (e.g., verbal or silent gestures). Larger attenuating effects of social support in the laboratory seem to be associated with stressors that have a higher emotional content such as verbal attack during a discussion (Gerin et al., 1992) and anticipated electric shock (Friedman, 1981). The interaction between the emotional "properties" of stressors and the type of support provided should be explored further in future studies. The findings of the present study support the theory that cardiovascular and cortisol reactivity may be two underlying factors in the relationship between social support and health.

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