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The presence of a dog attenuates cortisol and heart rate in the Trier Social Stress Test compared to human friends

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Abstract Limited research has addressed how social support in the form of a pet can affect both sympathetic and hypothalamic–pituitary–adrenal reactivity in response to a psychological challenge. The present study examined the effects of social support on salivary cortisol and heart rate (HR). Forty-eight participants were randomly assigned to three different conditions (human friend, novel dog, or control). All participants completed the Trier Social Stress Test and provided cortisol, HR, and State-Trait Anxiety Inventory measures. For participants paired with a dog, overall cortisol levels were attenuated throughout the experimental procedure, and HR was attenuated during the Trier Social Stress Test. For all groups, state anxiety increased after the Trier Social Stress Test, and HR during the Trier Social Stress Test was a predictor of cortisol. These results suggest that short-term exposure to a novel dog in an unfamiliar setting can be beneficial. They also suggest a possible mechanism for the beneficial effect associated with affiliation with pets.

Keywords Cortisol · Dogs · Heart rate · Social support · Trier Social Stress Test

Introduction

The leading cause of death in the United States is currently attributed to cardiovascular disease (Hoyert & Xu, 2013), stemming, in part, from sedentary lifestyles and stress. Many studies have found potential links between stress and such health-related illnesses as atherosclerosis and hippocampal degeneration (Nordstrom et al., 2001; Pruessner et al., 2010; Sapolsky et al., 1985). As such, the beneficial effects of social support to protect or buffer one from the negative effects of stress have been extensively investigated. Survey studies find that participants who report many friends or strong social support systems live longer (Rodriguez-Laso et al., 2007), have a greater sense of well-being (Winefield et al., 1992), are more likely to survive a second heart attack (Case et al., 1992) and perhaps delay the progression of cancer (Speigel et al., 1989). In laboratory studies, social support, defined as the presence of a human friend, can reduce cardiovascular reactivity to psychological challenges such as mental arithmetic or concept formation tasks (Kamarck et al., 1990) or speech challenges (Uchino & Garvey, 1997).

The beneficial effects of social support can also be gleaned from non-human companions. Friedmann et al. (1980) and Friedmann and Thomas (1995) found that coronary patients who were pet owners had a higher one-year survival rate compared to non-pet owners after being discharged. Friedmann and colleagues also demonstrated greater HR variability in pet owners (which is associated with reduced cardiac disease and mortality) than non-pet owners in patients recovering from myocardial infarctions (2003). Overall, the literature seems to suggest that pet ownership conveys an array of physiological (e.g., reduced blood pressure: Anderson et al., 1992) and psychological (e.g., diminished sense of loneliness: Zasloff & Kidd, 1994) benefits (see Barker & Wolen, 2008; Jennings, 1997 for a review).

Despite these correlations, exactly how pets improve health is still not clear. A possible mechanism is that pets

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directly affect the stress response. To explore this alternative, experimental studies are required that expose participants to animals and then observe physiological responses. Wilson (1987) examined blood pressure (BP) and HR in college students while reading aloud, while reading quietly, and while petting a dog but not reading. Petting a dog was associated with less physiological responsiveness than reading aloud, but not less than while reading quietly. Somervill et al. (2008) found that diastolic BP was lower in participants when they petted a novel dog (mental stressors were not present in this study). Generally speaking, close affiliation with a pet under baseline conditions tends to decrease autonomic arousal (Jennings, 1997).

Another line of inquiry has examined how the presence of a pet can attenuate autonomic responses in participants while experiencing a psychological challenge. Friedmann et al. (1983) found that the presence of a novel friendly dog in children's homes lowered BP while resting and while reading. Allen et al. (1991) compared autonomic responses in women during a backward subtraction task; three conditions were compared: female friend present, pet dog present, or a no social support control. Participants in the dog condition showed lower HR, skin conductance, and BP than the other two groups. Interestingly, participants in the friend condition displayed the largest increases in autonomic responses. It was suggested that having a friend present can create evaluation apprehension that exacerbates the stress response during a challenging task. In the Kamarck et al. (1990) study, rigorous controls were implemented to reduce reactivity between the participant and friend. Allen and colleagues (2002) later found lower BP and HR during a mental arithmetic and cold pressor task among pet owners with their pets present. In both of these studies by Allen (1991, 2002), participants were paired with their individual pet dogs while at home. In contrast, another study found that a novel but friendly dog in a laboratory setting had no effect on HR and BP during mental stress (Kingwell et al., 2001).

Although there is convincing evidence that psychological stressors can increase hypothalamic–pituitary–adrenal (HPA) responsiveness (Densen et al., 2012; Jönsson et al., 2010; Kirschbaum et al., 1993, 1995; Kudielka et al., 2009), which can negatively affect health (Friedman et al., 2012), fewer studies have investigated the extent to which pets affect the HPA axis in participants. However, Viau et al. (2010) showed that service dogs introduced into the homes of autistic children reduced the cortisol awakening response, but not overall diurnal cortisol. Barker et al. (2010) compared systolic and diastolic BP and salivary cortisol in five therapy dog owners and five dog owners with an unfamiliar dog before and after the Stroop test. Overall, the participants with unfamiliar dogs showed the greatest reduction in these physiological variables.

Aims of the study

In the present study, we sought to determine if the presence of a novel dog in a laboratory setting could attenuate the HR and cortisol response during a social stressor. Several key studies (e.g., Allen et al., 1991, 2002) have found beneficial effects of dogs, but in pet owner's homes with their individual dogs. We wanted to determine if a novel dog in a strange setting would have a similar effect. If so, it would further strengthen the robustness of the health-improving human/pet connection. We compared a dog condition to a supportive friend and no social support control condition. In addition, the current study examined reactivity of the HPA axis via cortisol release in participants. Few pet-related studies have explored HPA activity in participants, which is unfortunate, given the potential beneficial effects of pets on overall health and the relative ease with which salivary cortisol samples can now be taken. Finally, participants were exposed to a well-used and effective psychological challenge for eliciting stress—the Trier Social Stress Test (hereafter: the Trier). We hypothesized that the presence of a novel dog would attenuate cortisol and HR responsiveness to stress, when compared against the control and friend conditions.

Method

Participants

For the initial screening phase, 294 undergraduate students from the authors' university were recruited from several psychology and statistics courses to complete a series of questionnaires (see "Materials" section); they were awarded extra credit for participating. Of the 294 initially screened participants, a total of 85 of those participants met eligibility requirements and expressed their willingness to participate in the experimental study. Forty-eight participants (26 males) were randomly selected (mean age = 18.96 years, $SD = 1.50$). Of these, 31 participants (64 %) were Caucasian; 9 (18 %) were African-American; 5 (10 %) were Hispanic; and 3 (6 %) were Asian, which was consistent with the ethnic composition of the authors' university. The participants in the three conditions were not significantly different in terms of sex, age, and ethnicity.

Materials and procedure

The protocol and procedure employed for the present study was approved in advance by the local Institutional Review Board and has therefore been performed in accordance

with the ethical standards delineated in the 1964 Declaration of Helsinki. The screening survey consisted of the Pet Attitude Scale (PAS: Munsell et al., 2004) that measures attitudes towards companion animals. Participants had to score at least at the 50th percentile on the PAS to participate and also not have a dog phobia or a severe dislike of dogs. Participants were currently not dog owners, but they reported favorable attitudes towards pets in general. Participants were also screened to ensure that they had a close, but non-intimate, same-sex good friend in the event that they were randomly assigned to the friend social support condition. Female participants were screened to ensure that they were not currently taking estrogen-based contraceptives due to these contraceptives reducing HPA/cortisol responsiveness (Kirschbaum et al., 1995).

In addition, participants completed the State-Trait Anxiety Inventory (STAI), Form Y, (Spielberger et al., 1970, 1983) in order to measure *state* anxiety (i.e., anxiety about an event or situation) and *trait* anxiety (i.e., anxiety more related to an individual's personality characteristics). The STAI includes statements such as "I am tense," and participants respond using a 4-point Likert scale. Finally, demographic information was also collected such as age, ethnicity, and sex. All participants were in good self-reported physical and mental health with no chronic medical conditions, and all reported having normal or corrected-to-normal vision.

All eligible participants were randomly assigned to participate in one of the three conditions, dog ($n = 16$, 8 males), friend ($n = 16$, 9 males), or control ($n = 18$, 9 males). The participants were asked to refrain from engaging in heavy exercise the day prior to their visit. They were also asked to avoid eating a heavy meal or consuming any caffeinated beverages at least two hours prior to their appointment. All experiments began at 1500 or 1600 h to control for circadian changes in the cortisol rhythm.

Upon arriving at the lab, participants were questioned to verify adherence to the study requirements and were provided informed consent. The participants were fitted with a Garmin wireless heart rate transmitter and their HR was recorded on a dedicated Garmin 305 Forerunner receiver (Garmin Ltd., Olathe, KS, USA). Previous literature has shown that the Garmin can be used to obtain a valid measure of HR (e.g., Collins et al., 2012). All participants were asked to relax in the lab for 40 min. Those in the control condition were asked to sit quietly while those in the friend condition sat and spoke with their good friend who was enlisted (by the participant) to accompany them for the experiment. Those assigned to the dog condition were introduced to *Jazz*, a 7 year old therapy-trained, female golden retriever. The dog was provided by Fogle's Dog Training and Service and was bathed and groomed before each experimental session. The dog condition participants were allowed to acquaint themselves and interact with the dog inside the lab. The interaction was limited to providing treats, talking to and petting the dog. After 40 min, the first free-salivary cortisol sample was obtained from the participant. Participants expectorated at least 1.0 mL of saliva into a Wheaton plastic vial. Two participants could not provide the first saliva sample and were removed before actually beginning the experiment (one female and one male participant, each from the control group) due to insufficient expectoration of saliva and bleeding gums, respectively. The heart-rate monitor recorded the participants' average HR during this 40 min period.

After obtaining the saliva sample, the participants were escorted into an adjacent room (dimensions approximately 3 meters long × 3.5 meters wide × 2.75 meters high) where the Trier was conducted (Kudielka et al., 2007). Three mix-gendered research assistant teams wearing white lab coats were seated behind a long table. The participants were asked to imagine being interviewed for a long, sought-after work position for which they had 5 min to convince the panel they were the best candidate. Participants had 3 min to prepare for this interview, during which time they could write down notes. Participants were informed that the interview would be audio and visually recorded for future behavioral analysis (although recordings were not actually taken). During the briefing, the participants were informed that the panel members were trained in non-verbal behavior. Previous research has shown that talking aloud can increase cardiac responsiveness (Friedmann et al., 1982), especially to "high status" individuals (Long et al., 1982). Once the participants were briefed by the experimenter, they were invited to sit in a chair for three minutes and take notes to help prepare for their presentation. The chair was deliberately positioned in full view of the seemingly apathetic and non-responsive panel.

After the three-minute preparation opportunity, participants were instructed to place their notes face-down and stand before an upright microphone, which was positioned 2 m in front of the middle, and lead, panel member. While the participant was directed to turn the microphone on, the panel member closest to the tripod-equipped video camera turned the camera on and focused it on the participant. The lead panel member then instructed the participants to begin their talk. During the entire Trier interview, panel members took notes of the participants' responses. If the participants stopped speaking, the Trier panel remained passive for 20 s, at which time the lead member would remind the participants they had more time. If the participants stopped talking again, the members had a series of pre-determined Trier-protocol questions to ask, pausing roughly 10 s after each answer before introducing a new question to the

participants. An audible alarm indicated the end of the 5 min interview and a transition into the mental math task.

This task was initiated by the lead member instructing the participants to continually subtract a prime number from a preselected number. Serial subtraction tasks have previously been found to induce stress (Nater et al., 2005). In our case, and consistent with the Trier protocol, participants were asked to continuously subtract 17 from 2023 (Kirschbaum et al., 1993). The goal was to reach zero without error. If a participant provided an incorrect answer, the lead panel member immediately interrupted the participant and instructed him or her to start again from the beginning number. None of the participants were able to accurately complete the task during the 5-min duration.

Although the control condition did not have any social support, those in the friend condition had their chosen friend present in the room during the Trier. Similar to another study (e.g., Allen et al., 1991), the friend was instructed to provide support in any way they viewed appropriate. We requested, however, that the friend not coach the participant during the Trier. During the interview, the friend was within one meter of the participant, standing either to the left or right of the participant. The participants assigned to the dog condition performed the Trier while the dog sat on a pedestal approximately 38 cm off the floor and to the participant's left. The pedestal allowed participants to keep the dog within their peripheral vision, yet sufficiently out of reach. Average HR was recorded during the 10-min Trier task.

Upon completing the Trier, all participants were invited into a third room to relax. Those assigned to the friend or dog condition were separated from their social support and asked to sit quietly, again absent of cell phone or computer use. All participants completed the STAI state-anxiety inventory, form Y-1(Spielberger et al., 1970), a self-reporting measure to evaluate their present post-Trier state of anxiety. At the 20-min mark from the start of the Trier, the experimenter asked the participants to provide a second saliva specimen. Finally, a third and final recovery saliva specimen was provided 23 min after the second sample. The three cortisol samples were taken (1) before the Trier, (2) 7 min post-Trier, and (3) 30 min post-Trier. Mean HR was calculated for the pre-Trier period, during the Trier, and after the Trier. Upon completing the study, participants were paid $15.00 for participating, debriefed, and thanked for participating.

The saliva samples were stored at −80 °C prior to lab analysis. All HR recordings were uploaded and stored in a secured, password protected file. All samples were assayed for salivary cortisol in duplicate using a highly sensitive enzyme immunoassay (Salimetrics, PA). The test uses 25 µl of saliva per determination, has a lower limit of sensitivity of 0.003 µg/dl, standard curve range from 0.012 to 3.0 µg/dl, and average intra-and inter-assay coefficients of variation 3.3 and 5.1 %, respectively. Method accuracy, determined by spike and recovery, and linearity, determined by serial dilution are 100.8 and 91.7 %. The intra- and inter-assay coefficient of variation for the actual sample was 5.2 and 4.8 %, respectively. All cortisol data and scores were recorded and analyzed on IBM® SPSS® v.21.

Results

A Kolmogorov–Smirnov test indicated that cortisol measures were not normally distributed (positive skew), and, as such, a logarithmic transformation was performed on the data, making the data set normally distributed. Statistical calculations were performed with the transformed data; results presented in figures include the raw data.

Participants from the control ($M = 36.94$), pet ($M = 41.25$), and friend ($M = 35.38$) conditions did not differ in their initial STAI State anxiety scores, $F(2, 47) = 1.56$, $p = .22$, $\eta_p^2 = .065$ nor did they differ for the STAI Trait anxiety scores ($M = 40.19$, 40.18, and 38.56, respectively), $F(2, 45) = .228$, $p = .80$, $\eta_p^2 = .010$. STAI State anxiety scores did not differ between male ($M = 37.62$) and female ($M = 38.14$) participants, $t(46) = .181$, $p = .86$, or between male ($M = 39.08$) and female ($M = 40.32$) participants for STAI Trait anxiety scores, $t(46) = .540$, $p = .59$. STAI State or Trait anxiety did not significantly correlate with any measures of cortisol or HR (all $p > .05$).

Next, a two-way mixed ANOVA was performed on mean cortisol levels with time of sampling as the within-subject factor and condition as the between-subject factor. Time of sampling was significant, $F(2, 90) = 3.91$, $p = .024$, $\eta_p^2 = .080$. The nature of this relationship was such that cortisol at sample 1 ($M = .214$) was significantly lower than at sample 2 ($M = .286$, $p = .020$), but not sample 3 ($M = .226$, $p = .58$). Cortisol at sample 2 was also different from sample 3 ($p = .006$). There was also a main effect for Condition, $F(2, 45) = 3.27$, $p = .047$, $\eta_p^2 = .127$. The nature of this relationship was such that participants in the Dog condition ($M = .180$) had significantly lower cortisol than participants in both the control condition ($M = .296$, $p = .024$) and the friend condition ($M = .251$, $p = .045$). The friend and control conditions did not significantly differ. The interaction of time and condition was not significant (Fig. 1).

Finally, a two-way mixed ANOVA was also performed on mean HR with Time of Sampling as the within-subject factor and Condition as the between-subject factor. The main effect of Condition was not significant ($p > .05$), but the main effect of Time was significant, $F(2, 88) = 64{,}74$, $p < .001$, $\eta_p^2 = .595$. HR was significantly higher during the Trier ($M = 95.39$) than before ($M = 79.49$, $p < .001$) and after ($M = 78.56$, $p < .001$) the Trier. Importantly, the interaction between condition and time was significant, $F(4, 88) = 2.74$, $p = .033$, $\eta_p^2 = .111$. As can be observed

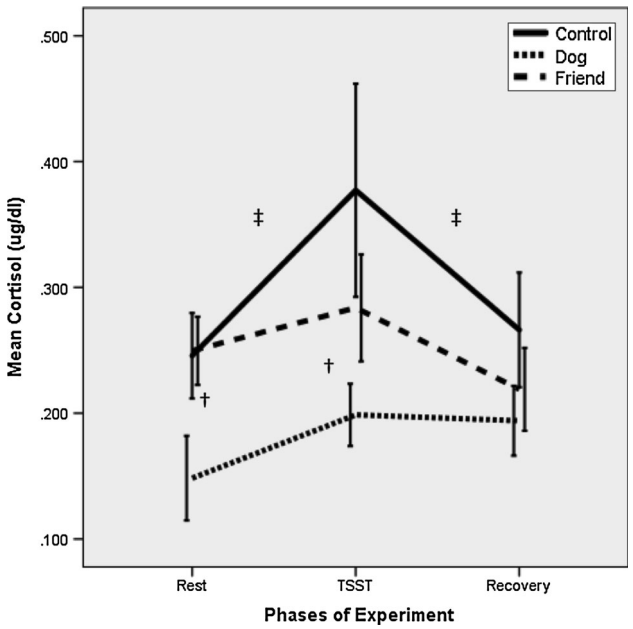

Fig. 1 Mean cortisol levels for the three experimental groups, control, dog, and friend, during the three phases of the experiment. Participants in the dog group had significantly lower cortisol than participants in the control and friend groups (main effect: $p < .05$). *Error bars* represent standard error of the mean. †significant between-group difference (dog vs. control and friend), ‡significant within-group differences (TSST vs. rest and recovery). *TSST* Trier Social Stress Test

in Fig. 2, the nature of this interaction was such that mean HR *during* the Trier was significantly attenuated in the dog group compared to the friend and control groups.

Mean Trier HR was associated with cortisol at sample 1 (before the Trier), $r = .399$, $p = .006$; sample 2 (7 min post-Trier), $r = .443$, $p = .002$; sample 3 (30 min post-Trier), $r = .385$, $p = .007$; as well as total cortisol calculated as area under the curve with respect to ground, AUC_G (see Pruessner et al., 2003), $r = .487$, $p = .001$. Post-Trier HR only predicted AUC_G cortisol, $r = .340$, $p = .017$ and sample 2 cortisol, $r = .300$, $p = .038$. Pre-Trier HR did not predict cortisol measures.

To examine changes in state anxiety, STAI State anxiety scores were subjected to a 2 (Time: pre- vs. post-Trier) x 3 (Group) mixed ANOVA. The effect of Time was significant, $F(1, 45) = 25.52$, $p < .001$, $\eta_p^2 = .362$, such that pre-Trier anxiety ($M = 37.85$) was lower than post-Trier scores ($M = 45.73$). The main effect of Group and the interaction between Group and Time was not significant.

Discussion

Consistent with our experimental prediction, non-human social support in the form of a dog served to attenuate salivary cortisol levels when compared to the friend (human social support) and control (no social support) conditions. This potentially beneficial effect of a dog is also consistent with Allen (1991, 2002) and, in addition, augments her findings given that participants were not previously familiar with the dog and the social support occurred in a novel laboratory setting (but not consistent with Kingwell et al., 2001). Vormbrock and Grossberg (1988) tested different hypotheses concerning why pets are beneficial, and found support for the *touch* (contact comfort) and *cognitive* hypotheses (dogs are non-evaluative), but not classical conditioning. Although our data cannot distinguish between the above two hypotheses since touching of the dog was permitted prior to the Trier and the dog (Jazz) was non-judgmental, the finding of reduced cortisol in the dog group provides a putative mechanism for why pet owners enjoy many health benefits (see Levine et al., 2013). That is, in addition to reduced cardiac output (HR and BP), pets may affect the other component of the stress response, the HPA-axis. The current study adds to this nascent body of literature related to pets and cortisol (e.g., Barker et al., 2010; Viau et al., 2010). Our dog may have acted as a pleasant arousal-reducing stimulus, as viewing appetitive rewarding pictures before participating in the Trier can also reduce cortisol (Creswell et al., 2013), as well as engaging in gardening (Van Den Berg & Custers, 2011).

Although speculative because the present study did not measure this hormone, reductions in cortisol may be mediated by the polypeptide hormone, oxytocin, which has been known to increase when pet dogs gaze at their respective participant owners (Nagasawa et al., 2009). Additionally, our study allowed participants in the dog condition to give the dog treats during the first phase. The dog's responsiveness to the nurturing act of hand-feeding may have caused a rise in oxytocin levels. It is possible that oxytocin served to buffer robust HR and HPA responsiveness in these participants (Heinrichs et al., 2003), but further research is needed on the relation between oxytocin and the stress response.

Since this reduction in the stress response was observed for the participants paired with the dog and not those paired with a human friend, it may be that social support gleaned from a human friend can be counterproductive because of evaluation apprehension, as has been suggested previously (Allen, 1991; 2002). Unlike the Kamarck et al. (1990) study that effectively minimized contact between participants and friends so as to reduce this reactivity (and found beneficial effects associated with a human friend), the current study allowed the participants and friend to interact. This reactivity may have exacerbated the deleterious effects of evaluation apprehension. Indeed, one "friend" said to a participant after struggling with the backward

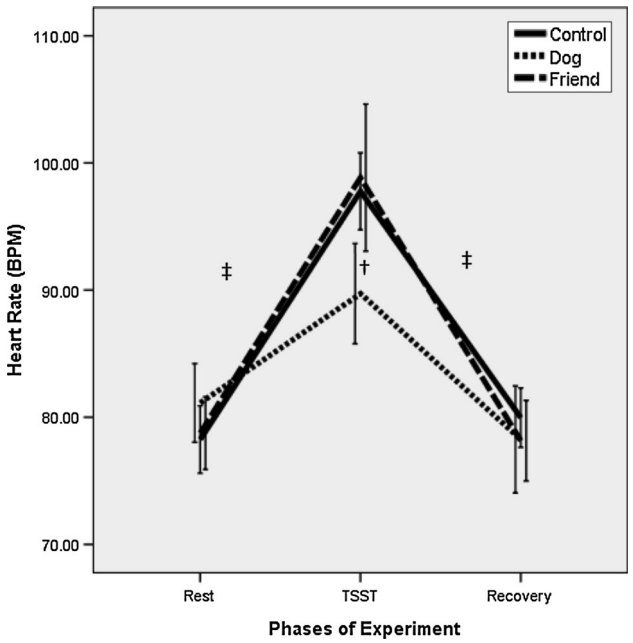

Fig. 2 Mean HR for the three experimental groups, control, dog, and friend, during the three phases of the experiment. The observed interaction between group and phase was significant ($p = .033$). *Error bars* represent standard error of the mean. †significant between-group difference (dog vs. control and friend), ‡significant within-group differences (TSST vs rest and recovery). *TSST* Trier Social Stress Test

counting task, "way to go, dumbass." Clearly, such negative evaluations were not present in the dog condition, and, more broadly, when humans interact with their pets.

A limitation of our study is that we only measured HR and not BP, which is more commonly measured. However, concerning HR, all participants experienced an increase in HR during the Trier, but HR was significantly attenuated in the dog group, relative to the friend and control groups. Although HR was lower before and after the Trier, there were no group differences. The relationship between HR and BP is complex, but increases in HR during the Trier do indicate increases in cardiovascular reactivity, making these results consistent with other studies finding that the Trier increases cardiovascular reactivity (e.g., Jönsson et al., 2010) and pet studies finding that exposure to dogs can help decrease BP and HR (e.g., Allen et al., 1991, 2002).

The present study also employed a standard friendly dog but not a standard friendly human. Since our participants were college students who did not currently have pets in their dormitories, the dog condition, out of necessity, had to consist of a friendly, but unfamiliar, dog. We feel that this manipulation is a valuable addition to the literature, as many studies (e.g., Allen et al., 1991) have researchers go into participants' homes, examining the effects of a friendly, but familiar, dog. The fact that we obtained the current results with an unfamiliar dog in an unfamiliar setting would appear to validate the effectiveness and importance of pets in therapy. However, the present study did not employ an unfamiliar human friend because of concerns that the unfamiliar friend would be too similar to the experimenter or the assistants on the Trier panel, making the "friend" not a friend at all and just another confederate in the experiment. Future extensions of this work could benefit, though, by having an extra condition so as to permit comparisons of these two forms of social support.

STAI state and trait anxiety scores did not differ for the participant groups prior to the Trier, but mean state anxiety scores were elevated after the Trier, suggesting that the Trier was stressful for the participants and produced an increase in anxiety. STAI measures were not associated with any measure of cortisol production, which is consistent with other research that also employed the Trier (Lam et al., 2009). However, HR (especially during the Trier) was significantly associated with cortisol levels; higher HRs correlated with higher concentrations of cortisol. This is interesting since during period of high stress, critical care personnel's HR can also predicted salivary cortisol, but not during times of low stress (Looser et al., 2010). The nature of the relationship between cortisol and HR warrants further investigation.

Improved health could stem from pet (especially dog) owners walking their pet, or it could be that already healthy people are more likely to obtain pets. Additionally, having a pet may more directly attenuate the stress response. Undoubtedly, exercise has been shown to lower BP (Lesniak & Dubbert, 2001), and dog owners compared to non-dog owners are more likely to obtain exercise (Oka & Shibata, 2009), qualifying exercise as one mechanism that could mediate this health-improving effect (Arhandt-Sudhir et al., 2011). However, not all dog owners walk their dogs (Oka & Shibata, 2009), and some studies have found that having a caged bird (Mugford & M'Comisky, 1975) or pet cat (Qureshi et al., 2009, but see Friedmann & Thomas, 1995) can improve health and well-being. Another possible mechanism is that pets directly affect the stress response, a mechanism that our study supports. Collectively, our data suggest that dogs are beneficial because close affiliation with them attenuates two aspects of the stress response, the HPA-axis and HR-reactivity, qualifying this form of social support as a viable means of reducing the risk for stress-related illnesses.

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Conflict of interest The authors declare no conflict of interest.

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