

The Social Dimension of Stress Reactivity: Acute Stress Increases Prosocial Behavior in Humans

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Abstract

Psychosocial stress precipitates a wide spectrum of diseases with major public-health significance. The fight-or-flight response is generally regarded as the prototypic human stress response, both physiologically and behaviorally. Given that having positive social interactions before being exposed to acute stress plays a preeminent role in helping individuals control their stress response, engaging in prosocial behavior in response to stress (tend-and-befriend) might also be a protective pattern. Little is known, however, about the immediate social responses following stress in humans. Here we show that participants who experienced acute social stress, induced by a standardized laboratory stressor, engaged in substantially more prosocial behavior (trust, trustworthiness, and sharing) compared with participants in a control condition, who did not experience socioevaluative threat. These effects were highly specific: Stress did not affect the readiness to exhibit antisocial behavior or to bear nonsocial risks. These results show that stress triggers social approach behavior, which operates as a potent stress-buffering strategy in humans, thereby providing evidence for the tend-and-befriend hypothesis.

Keywords

social stress, psychological stress, social interaction, social decision making, trust, cortisol

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Stress is a ubiquitous challenge that affects mental and physical health across human cultures. The physiological response to both physical and psychological stressors includes increases in cardiovascular and neuroendocrine measures, reflecting autonomic nervous system (ANS) and hypothalamic-pituitary-adrenal (HPA) axis responses (Dickerson & Kemeny, 2004). Alterations in these systems following chronic stress have been linked to the development of several stress-related disorders (Chrousos, 2009; McEwen, 1998). Although it can be maladaptive, stress is an essential psychobiological mechanism that tunes the human organism to react to demanding circumstances. For example, when people are faced with danger, the fight-or-flight response circumscribes the allocation of physiological energy in order to facilitate fighting the imminent danger or escaping from threat.

Positive social interactions have been shown to exert powerful and beneficial effects on health outcomes and longevity. Seeking rewarding social interactions starts in early life and evolves into various forms of social attachment throughout the life cycle (Ainsworth, 1991; Bowlby, 1969). A growing body

of epidemiological research in clinical populations provides support for the hypothesis that social support improves outcomes and recovery following many types of human diseases (House, Landis, & Umberson, 1988; Seeman, 2000; Uchino, Cacioppo, & Kiecolt-Glaser, 1996). Initial experimental investigations regarding the psychobiological mechanisms underlying these effects have been completed. They show that the availability of social support before exposure to acute social stress in the laboratory is associated with attenuated cortisol and cardiovascular responses (Christenfeld et al., 1997; Ditzen et al., 2007; Ditzen et al., 2008; Gerin, Pieper, Levy, & Pickering, 1992; Heinrichs, Baumgartner, Kirschbaum, & Ehlert, 2003; Kirschbaum, Klauer, Filipp, & Hellhammer, 1995; Lepore, Allen, & Evans, 1993; Uchino & Garvey, 1997).

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Given that positive social interaction before acute stress exposure plays a preeminent role in the control of subsequent stress reactivity, prosocial behavior might also be a functional protective response to stress exposure. Humans have a tendency to affiliate, that is, to seek out groups within which they can provide and receive joint protection in threatening times (Baumeister & Leary, 1995). Sensitive to this tendency, Taylor and her colleagues (Taylor, 2006; Taylor et al., 2000) have used the metaphor “tend and befriend” to specifically characterize female stress responses. Whereas tending involves nurturant activities designed to protect oneself and one’s offspring, thereby promoting safety and reducing distress, befriending is the creation and maintenance of social networks that may be beneficial in stress situations (Taylor et al., 2000). The mammalian oxytocin system has recently been postulated as the neuroendocrinological basis of this attachment-caregiving system (Buchheim et al., 2009; Heinrichs, von Dawans, & Domes, 2009; Meyer-Lindenberg, Domes, Kirsch & Heinrichs, 2011), and this idea suggests that the tend-and-befriend pattern applies mainly to women; in contrast, men are expected to show primarily fight-or-flight responses to stress (Taylor, 2006). However, little is known about the immediate prosocial and antisocial responses following stress, particularly among men.

Although researchers have investigated the tend-and-befriend pattern in various ways, we are unaware of any studies that have specifically targeted the immediate prosocial or antisocial responses to exposure to social stress. Therefore, we set out to investigate the effects of a standardized psychosocial laboratory stressor on subsequent prosocial and antisocial interactions. More specifically, we tested whether the pattern of behavior among male participants was more aggressive (fight-or-flight) or more prosocial (tend-and-befriend) following stress.

In our study, participants were assigned to either a stress condition or a control condition. To induce stress among participants in the stress condition, we used the Trier Social Stress Test for Groups (TSST-G; von Dawans, Kirschbaum, & Heinrichs, 2011). The TSST-G provides a naturalistic exposure to a socioevaluative and stressful situation simultaneously involving multiple participants and results in significant increases in cortisol, heart rate, and psychological stress responses. In order to ensure that effects observed in this condition were specific to stress, we had control participants complete the control condition of the TSST-G, which includes all the factors of the stress condition (e.g., orthostasis, speaking aloud, cognitive load, order and timing of tasks) except for the psychosocially stressful components (i.e., socioevaluative threat and uncontrollability; von Dawans et al., 2011).

Following the stress manipulation, participants played interactive games with real monetary stakes. We hypothesized that if social stress really does facilitate prosocial behavior, then inducing social stress should increase trust, trustworthiness, and sharing in these games. In addition, we investigated nonsocial risk taking by including a lottery game. This allowed

us to evaluate whether the effects of acute stress behavior were specific to social contexts. Thus, we tested whether humans behave more aggressively (fight-or-flight) or prosocially (tend-and-befriend) when faced with a social stressor than when faced with a situation without socioevaluative threat.

Method

Participants

Male students were recruited at the University of Zurich to be target participants in a study on the effects of different kinds of stress on social interaction. Telephone interviews were used to screen out potential participants who had acute or chronic psychiatric or medical illness, were taking prescription medication, abused drugs or alcohol, or smoked more than five cigarettes per day. Moreover, participants needed to be naive to the TSST procedure and similar stress paradigms and could not be students of psychology or economics. These exclusion criteria resulted in a sample of 72 healthy male students, who were divided into 6-person groups that were randomly assigned to the stress condition or the control condition. Of these 72 students, 5 were excluded from analyses because they had clinically high levels of anxiety symptoms (3 participants) or baseline cortisol above 30 nmol/L (2 participants: 36.40 nmol/L and 36.04 nmol/L). The final sample (mean age = 21.31 years, $SD = 1.99$) included 34 participants in the stress condition and 33 participants in the control condition. The groups did not differ in age, body mass index, competitiveness, psychiatric symptoms, or social anxiety (all $ps > .15$; see Psychological Stress Responses and Psychometric Measures). Because of technical problems, heart rate data were obtained for only 64 participants. The study was approved by the institutional review board of the University of Zurich. Participants received a flat fee of 80 Swiss francs, or CHF 80 (CHF 1 = \$1.15) and could earn additional money in the social-interaction paradigm ($M = CHF 16.63$, $SD = CHF 2.20$).

A second group of 72 participants (mean age = 23.78 years, $SD = 4.65$) was recruited as interaction partners for the target participants. This second group did not complete the stress or control condition of the TSST-G or other measures and was involved only in the interaction games. Members of the second group received a flat fee of CHF 10 and could earn additional money in the social-interaction paradigms ($M = CHF 16.85$, $SD = CHF 2.75$).

Social and nonsocial decision paradigms

We used decision paradigms to measure participants’ trust, trustworthiness, sharing, punishment, and nonsocial risk behavior. Target participants in the stress condition and in the control condition completed the same paradigms. To avoid a “misery loves company” effect, we had target participants interact anonymously with interaction partners who did not complete the stress or control condition of the TSST-G. In all

games, players had binary choices (e.g., trust or no trust, trustworthiness or no trustworthiness). Figure 1 shows the payoff structure of each type of game. All variants of the games (i.e., the structures and possible outcomes) are provided in the Supplemental Material available online.

The *trust game* and *trustworthiness game* were sequential two-player games. The player with the first move could choose to trust or not trust. If he did not trust, both players received 14 monetary units (MU). If he trusted, a higher total amount

could be gained, but the resulting payoffs depended on whether the second player was trustworthy or not. If he was not trustworthy, he received a payoff of 60 MU, and the player with the first move received nothing. If the player with the second move was trustworthy, the two players received the same payoff; in Figure 1, we show an example in which the payoff equals 30 MU. (The other variants are provided in the Supplemental Material.) All subjects played four variants of this game as the player with the first move (trust game) and four

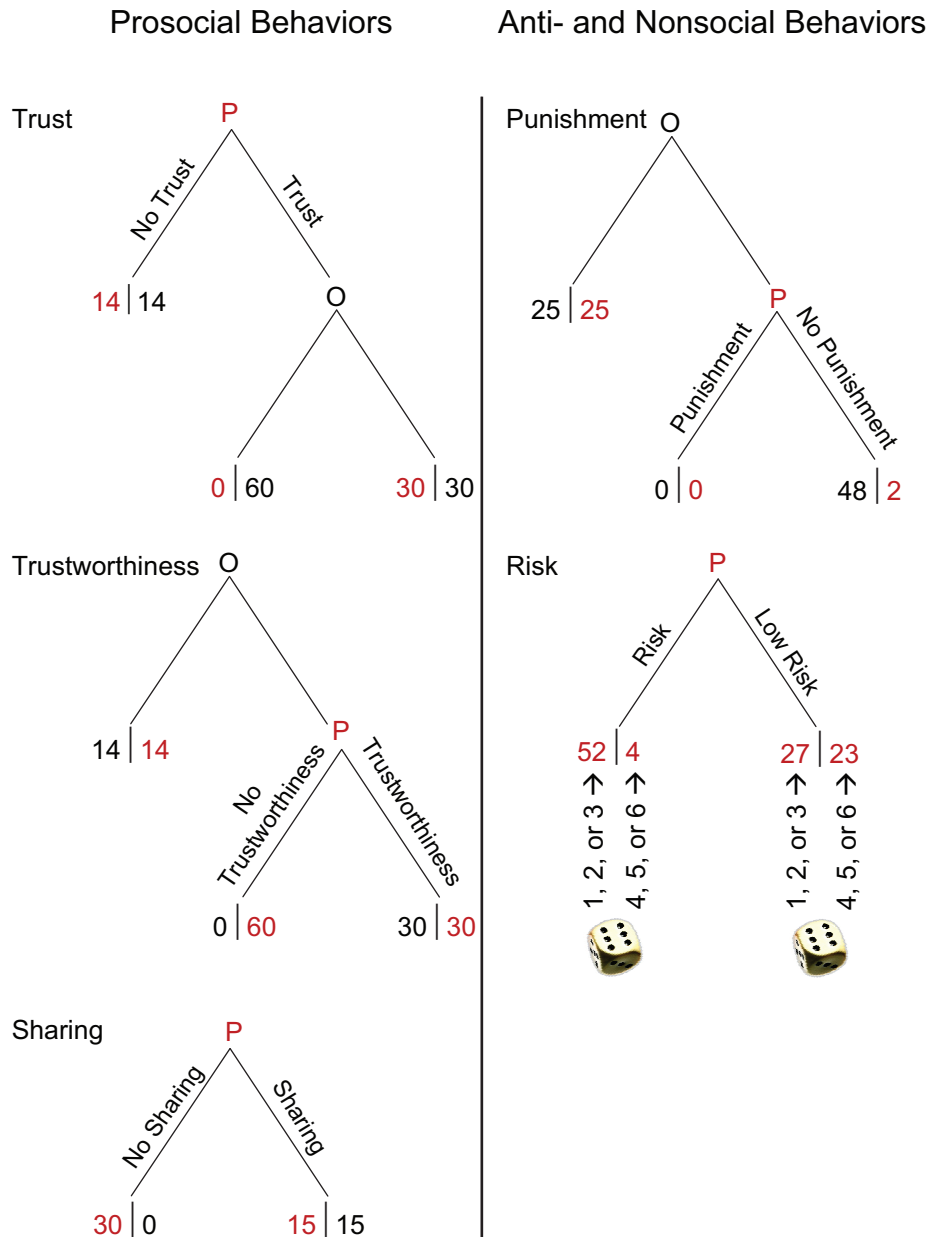


Fig. 1. Examples of payoff structures for the games assessing prosocial behaviors (left column) and antisocial and nonsocial behaviors (right column). The target participant and that participant's interaction partner are represented by a red P and black O, respectively (interaction partners were not in either the stress or the control condition). The pairs of numeric values are examples of the outcomes (in monetary units) received by the target participant (red values) and interaction partner (black values). In the risk game, target participants rolled a die, and its value determined which outcome resulted.

variants of this game as the player with the second move (trustworthiness game). For the decision of the second player, we applied the strategy method; in other words, the second player decided whether to be trustworthy or not before knowing whether the first mover trusted or not. His decision then applied if the first mover trusted.

The *punishment game* was also a sequential two-player game. In this case, the interaction partner always had the first move, and he could decide how to distribute 50 MU. He could either make a fair split (25 MU and 25 MU) or choose a given unfair distribution. If he chose the fair offer, there was no further choice. But if he chose the unfair offer, the target participant could either accept the offer (Fig. 1 displays the variant in which he received 48 MU for himself and the target participant received 2 MU) or punish the interaction partner by refusing the offer. In this latter case, both players received 0 MU. We applied the strategy method in this game as well, which meant that the target participants decided whether to reject the unfair offer before knowing if that was the offer the first player chose. There were four variants of this game, which are all listed in the Supplemental Material.

In the *sharing game*, the target participant could either receive 30 MU for himself (leaving 0 MU for the interaction partner) or share the reward (e.g., 15 MU for himself and 15 MU for the interaction partner, as illustrated in Fig. 1). There was no opportunity for the interaction partner to influence the outcome.

In the *nonsocial risk game*, the target participant played alone. In each of eight rounds, he could choose between a low-risk gamble (e.g., having a 50% chance of receiving 27 MU and a 50% chance of receiving 23 MU) or a risky gamble (e.g., having a 50% chance of receiving 52 MU and a 50% chance of receiving 4 MU). Next, the participant rolled a die to determine the outcome of the chosen gamble: Rolling a 1, 2, or 3 resulted in the higher outcome, whereas rolling a 4, 5, or 6 resulted in the lower outcome. Each participant played each variant once. (These variants are provided in the Supplemental Material.)

Each game was played several times in each of two sets. Each set involved a total of 12 decision rounds—6 were prosocial (2 rounds of the trust game, 2 of the trustworthiness game, and 2 of the sharing game), 2 were antisocial (punishment game), and 4 were nonsocial (nonsocial risk game)—and each round had a different payoff. In order to ensure that all decisions were made under acute psychosocial stress or under the effects of a control condition, we had target participants complete the first set of decisions immediately after the speaking task and the second set of decisions immediately after a stressful mental-arithmetic task or an easy counting task that followed the first set of decisions (see Procedure). The set order was randomized.

For each of the prosocial and antisocial games, the number of decisions reflecting trust, trustworthiness, sharing, or punishment was tallied. Thus, for these measures, the maximum score was 4, and the minimum score was 0. For the nonsocial

risk game, 1 point was given for each decision in favor of the risky gamble; the maximum score was 8, and the minimum was 0. Monetary units earned from all decisions were disbursed after the experiment according to the following exchange ratio: 100 MU = CHF 2.50. The experiment was programmed and conducted with z-Tree software (Fischbacher, 2007).

Procedure

One week before the experiment, participants filled out an online questionnaire assessing trait competitiveness, social anxiety, and psychiatric symptoms. Participants were told not to take any medication and to abstain from alcohol, caffeine, and smoking for 24 hr prior to the experiment. They were also instructed to have a standard breakfast and lunch on the day of the experiment and to stop food consumption by 4:00 p.m. Participants were reminded of these criteria via e-mail the day before the experiment. They were randomly assigned to the stress or control condition and were invited to the lab in groups of 6 for the TSST-G (von Dawans et al., 2011). The 2.5-hr sessions took place between 5:15 p.m. and 7:45 p.m. in order to control for diurnal variations in cortisol secretion.

On arrival at the laboratory, target participants were seated individually in the waiting room and were not allowed to communicate with each other. After reading and signing informed-consent forms, participants were introduced to the saliva-sampling method and were each provided with a heart rate device (Polar RS800TM, Polar Electro, Oy, Kempele, Finland). Baseline measures of saliva cortisol and of psychometric variables were then taken. (Additional measurements of saliva cortisol, heart rate, and subjective stress were taken throughout the experiment, as described in the Endocrine and Autonomic Stress Responses section and the Psychological Stress Responses and Psychometric Measures section). Written instructions for the decision paradigms were handed out, and participants were instructed to read them carefully and to complete control tasks (examples of each type of game). The results were checked immediately by the experimenters; all participants responded to the control tasks correctly, indicating full understanding of the interaction procedure.

Participants were then provided with the instructions for the TSST-G stress or control task. After 5 min, they were guided to the test room, where they received a summary of the procedure. The sequence of activities in the test room was as follows: 12 min of either the public-speaking task (stress) or simultaneous group reading in a low voice (control), first set of 12 decisions (5 min), 8 min of a mental-arithmetic task (stress condition) or easy counting task (control condition), the second set of 12 decisions (5 min), and finally an attention test (d2; Brickenkamp & Zillmer, 1998). The games were pencil-and-paper tasks. We included the attention test so that we could check for cognitive load.

While participants completed the test of attention, the experimenters entered the participants' decisions in computers

in another laboratory. The interaction partners were then brought into this laboratory and seated at computers in individual cubicles. They were introduced to the paradigms and made their decisions. After the target participants finished the attention test, they entered the same laboratory and were also seated at computers in individual cubicles. Their previously made decisions were matched to the interaction partners' decisions by computer to determine everyone's outcomes.

The instructions for the decision paradigms guaranteed that all interactions would involve real human partners who would enter the laboratory after the TSST-G procedure. All target participants and interaction partners were familiar with the laboratory and did not doubt the credibility of the social interactions, as indicated by a manipulation check during the debriefing ("Did you have any doubt about the existence of real social interaction partners throughout the experiment?"). Target participants and interaction partners were shown the results of each of their 24 decisions, including the sum of their profits, on their computer screen. The interaction partners then received the money they had earned (the converted sum of the outcomes for all 24 decisions plus the flat fee), which was paid out anonymously, and left the laboratory. Target participants had to stay in the lab until the last saliva sample was taken (85 min after the start of TSST-G procedure) and were then debriefed. Finally, they were paid the converted sum of the outcomes for all 24 decisions plus the flat fee.

Endocrine and autonomic stress responses

Recent studies have found that cortisol levels are highly predictive of psychosocial stress (Foley & Kirschbaum, 2010). Saliva samples, for assaying cortisol levels, were collected using a commercially available sampling device (Salivette, Sarstedt, Nümbrecht, Germany). Saliva collection took place at nine time points: baseline (−40 min), immediately before the onset of the speaking task (−1 min), after the speaking task (+12 min), after the mental-arithmetic task or the easy counting task (+25 min), and repeatedly after the second stress or control task to span the recovery period of cortisol responses (+35, +45, +55, +70, and +85 min). After each experimental session, samples were stored at −20 °C. For biochemical analyses of free cortisol concentration, saliva samples were thawed and spun at 3,000 revolutions per minute for 10 min to obtain 0.5 to 1.0 ml of clear saliva with low viscosity. Salivary cortisol concentrations were determined by a commercially available chemiluminescence immunoassay (CLIA; IBL, Hamburg, Germany). Interassay and intra-assay coefficients of variation were below 8%.

Heart rate was assessed by continuous recording of beat-to-beat intervals (aggregated to mean levels per minute) using a wireless chest transmitter and a wrist monitor recorder. Data from thirty-five 1-min intervals (5 min of anticipation, 12 min of speaking, 5 min of decision making for Set 1, 8 min of arithmetic, 5 min of decision making for Set 2) were entered into heart rate analyses.

Psychological stress responses and psychometric measures

To measure subjectively perceived levels of stress, we gave participants a visual analogue scale at baseline (−40 min), after introduction to the game paradigms (−20 min), before the TSST-G (0 min), in between the TSST-G and the first set of decisions (+12 min), after the mental-arithmetic or counting task (+25 min), and at the end of the experiment (+70 min). Measures of trait social anxiety (Liebowitz, 1987), trait general competitiveness (Competitiveness Index, CI; Houston, Farese, & La Du, 1992), and psychiatric symptoms (Brief Symptom Inventory, BSI; Derogatis & Melisaratos, 1983) were obtained 1 week before the experiment via an online questionnaire.

Statistical analyses

Cortisol, heart rate, and psychological data were analyzed using two-way analyses of variance (ANOVAs) with repeated measures. The factors in these analyses were condition (stress, control) and time (repeated factor; 9 for cortisol, 35 for heart rate, 6 for the visual analogue scale of subjective stress). In cases of heterogeneity of covariance (Mauchly test of sphericity), we determined the significance of the results of the repeated measures ANOVAs by using Greenhouse-Geisser corrections. Independent-samples *t* tests were used for comparing the two conditions at single time points. Behavioral data in the interaction paradigms were analyzed using Mann-Whitney *U* tests. In order to test for associations between psychological and physiological responses to stress, and between these stress responses and the decisions in the five games, we calculated Spearman's rank correlations (Spearman's ρ). For cortisol levels and heart rate, the areas under the individual response curves with respect to ground (AUC_G) were calculated with the trapezoid formula, which allows an aggregated sensitive measure of physiological changes over time (Pruessner, Kirschbaum, Meinlschmidt, & Hellhammer, 2003). For the psychological stress response, the increase from baseline to the maximum stress level was used as an aggregated measure (each participant's baseline value on the visual analogue scale subtracted from his maximum value). Effect sizes are reported as η_p^2 for ANOVAs and as Cohen's *d* for *t* tests and *U* tests. Data were analyzed using SPSS Version 19. All tests were two-sided, with the level of significance set at $p < .05$.

Results

To test the effects of the stress manipulation, we conducted two-way ANOVAs with repeated measures, separately for cortisol, heart rate, and subjective ratings of stress. The analysis of cortisol levels revealed significant effects of time, $F(2.85, 185.10) = 38.44, p < .001, \eta_p^2 = .37$, and condition, $F(1, 65) = 41.53, p < .001, \eta_p^2 = .39$, as well as a significant Condition \times

Time interaction, $F(2.85, 185.10) = 37.99, p < .001, \eta_p^2 = .37$. The stress manipulation was successful: Cortisol showed a significant increase over time in the stress condition, but a decrease over time in the control condition. Significant results were also found for heart rate—time: $F(10.46, 648.37) = 58.19, p < .001, \eta_p^2 = .48$; condition: $F(1, 62) = 6.94, p < .05, \eta_p^2 = .10$; Condition \times Time: $F(10.46, 648.37) = 2.46, p < .010, \eta_p^2 = .04$ —and for psychological responses—time: $F(3.44, 223.87) = 10.05, p < .001, \eta_p^2 = .13$; condition: $F(1, 65) = 2.95, p < .10, \eta_p^2 = .04$; Condition \times Time: $F(3.44, 223.87) = 4.13, p < .010, \eta_p^2 = .06$ (Fig. 2).

We then tested the effects of the stress manipulation on cognitive variables measured using the d2 attention test in order to rule out unspecific effects of cognitive load as explanations for the differences in participants' decision behavior. Independent-samples t tests on results from the d2 revealed that participants in the stress and control conditions did not differ in speed, $t(65) = -0.31, p = .76, d = 0.07$; number of mistakes, $t(65) = 0.636, p = .53, d = -0.16$; percentage of errors, $t(65) = 0.71, p = .48, d = -0.17$; error-corrected performance, $t(65) = -0.59, p = .56, d = 0.14$; or ability to concentrate, $t(65) = -0.67, p = .51, d = 0.16$.

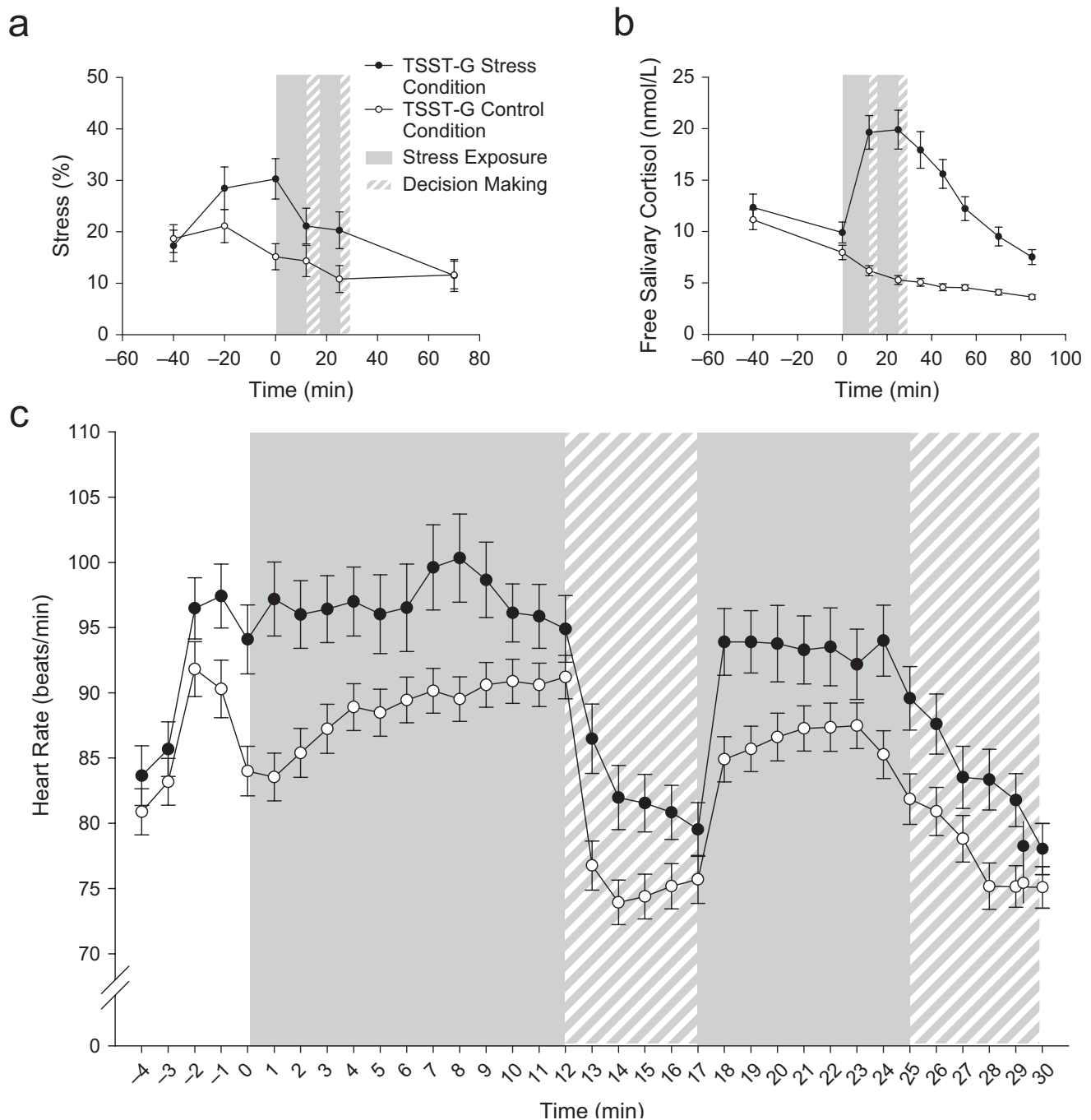


Fig. 2. Participants' (a) mean level of subjective stress, (b) mean level of free salivary cortisol, and (c) heart rate during the experimental session. Results are shown separately for the stress and control conditions. Time 0 was the start of the Trier Social Stress Test for Groups (TSST-G; von Dawans, Kirschbaum, & Heinrichs, 2011). Error bars indicate standard errors of the mean.

To test our main hypothesis, we entered the scores for trust, trustworthiness, sharing, punishment, and nonsocial risk taking in separate Mann-Whitney U tests. Stress led to substantial increases in the three prosocial behaviors: trust ($z = 2.298, p < .05, d = 0.62$), trustworthiness ($z = 2.335, p < .05, d = 0.60$), and sharing ($z = 2.270, p < .05, d = 0.57$; Fig. 3). There was no difference in the levels of antisocial behavior (punishment; $z = -0.704, p = .482, d = -0.10$) or nonsocial risk-taking behavior ($z = -0.253, p = .800, d = -0.07$) between participants in the stress and control conditions (Fig. 3). These findings indicate that the effects of stress were specific to prosocial behavior.

We conducted correlation analyses in order to test for associations between aggregated measures of psychological and

physiological responses, and between these stress responses and social decisions. Whereas physiological responses to stress (cortisol and heart rate) were not correlated with psychological responses to stress (subjective ratings) (all $ps > .4$), and neither cortisol nor subjective responses were correlated with social decisions (all $ps > .25$), there were significant correlations between cortisol and heart rate responses in both conditions (all $ps < .04$) and between mean heart rate and prosocial behaviors (trust, trustworthiness, and sharing) in the stress condition only. Specifically, there were positive correlations between mean heart rate and trust ($r = .363, p < .04$), trustworthiness ($r = .411, p < .02$), and sharing ($r = .326, p = .07$) during the public-speaking task and positive correlations between

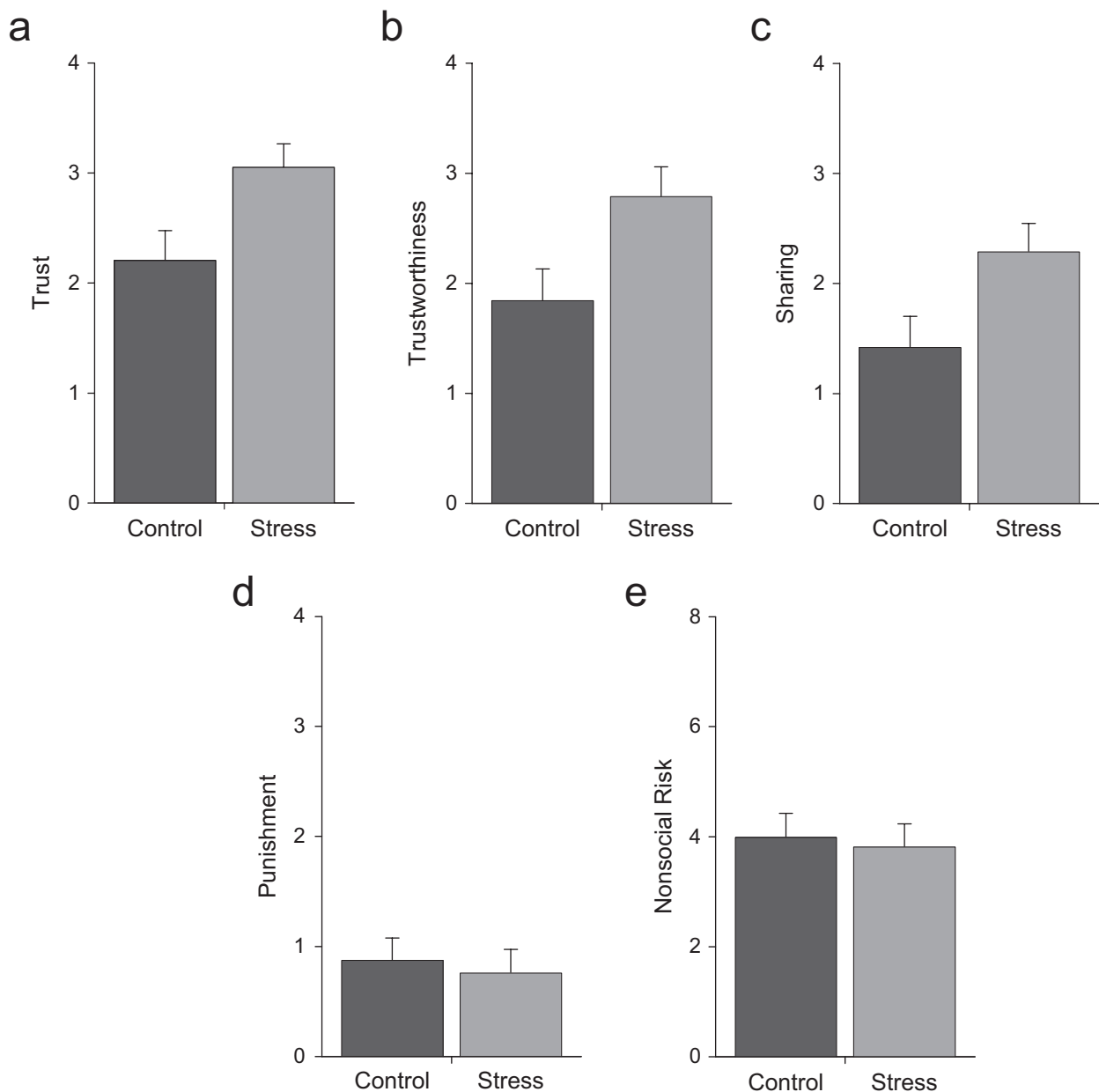


Fig. 3. Mean score in each game as a function of condition. Error bars indicate standard errors of the mean. TSST-G = Trier Social Stress Test for Groups (von Dawans, Kirschbaum, & Heinrichs, 2011).

mean heart rate and trust ($r = .453, p < .01$), trustworthiness ($r = .499, p < .01$), and sharing ($r = .463, p < .01$) during the mental-arithmic task.

Discussion

In this study, acute psychosocial stress increased prosocial behavior in men. More specifically, stress exposure increased trust, trustworthiness, and sharing behavior in social interactions. We also showed that prosocial behavior following stress is not due to a general increase in the readiness to bear risks. On the contrary, stress specifically affected willingness to accept risks arising through social interactions, but nonsocial risk taking was not influenced. Moreover, stress induction did not affect negative social interactions (i.e., punishment behavior).

These findings support the idea that humans have a tendency to provide and receive joint protection within groups during threatening times (Baumeister & Leary, 1995). Although previous studies have implicated tend-and-befriend behavior as a sex-specific stress response in women (Taylor, 2006), this is the first study to demonstrate this coping behavior in men. As one of the strongest positive reinforcers, social contact could foster further prosocial behavior. This interpretation is consistent with the results of a recent study showing an improvement in social cognition after stress among individuals who responded to acute psychosocial stress with high cortisol levels (Smeets, Dziobek, & Wolf, 2009).

What are the putative mediators between stress exposure, prosocial behavior, and coping? In nonhuman mammals, the stress-buffering effect of proximity and affiliation has been shown to be primarily mediated by the activation of specific endocrine systems within the central nervous system (Insel & Young, 2001). In particular, the oxytocin system is postulated as the biological basis of both social approach behavior and social buffering of stress reactivity (Heinrichs & Domes, 2008). Because animal research shows that oxytocin is secreted during stressful situations (Neumann, Krömer, Toschi, & Ebner, 2000) and that oxytocin increases social approach behavior (Donaldson & Young, 2008), acute stress might also lead to higher availability of brain oxytocin, thereby increasing the willingness to respond with social approach behavior. We previously showed that social support and intranasal oxytocin administration interact to reduce cortisol levels and subjective responses to psychosocial stress in men (Heinrichs et al., 2003). In addition, we found that intranasally administered oxytocin increases trusting behavior (Kosfeld, Heinrichs, Zak, Fischbacher, & Fehr, 2005), thereby attenuating the activity in brain areas mediating emotional processing (amygdala, midbrain regions) and the behavioral adaptation to feedback (dorsal striatum; Baumgartner, Heinrichs, Vonlanthen, Fischbacher, & Fehr, 2008).

Also, recent evidence from a genetic study indicates that a common single-nucleotide polymorphism (rs53576) in the oxytocin receptor gene interacts with stress-protective effects of social support, such that only carriers of the G allele show

reduced cortisol responses to stress following social support (Chen et al., 2011). These results suggest that genetic variation in the oxytocin system modulates the effectiveness of positive social interaction as a protective buffer against a stressful experience. Further studies using a combination of pharmacological approaches and genotyping for oxytocin receptor polymorphisms are needed to clarify the role of the oxytocin system in influencing prosocial behavior following stress exposure (Meyer-Lindenberg, Domes, Kirsch, & Heinrichs, 2011).

Similar to what has been shown previously in women, our findings show that healthy men seem to exhibit social approach behavior under stress. However, as this study included only men, it should be noted that the data do not allow comparisons between males' and females' tend-and-befriend behavior; a direct comparison including men and women in one study design is needed in future research to examine potential sex-specific differences in tend-and-befriend behavior under social stress. Regardless of possible sex differences, a first step toward a positive social encounter can generally establish social networks that result in more positive social interactions, which in turn may lead to stress reduction. As the fundamental ability to form attachment is essential for human social relationships (Beckes, Simpson, & Erickson, 2010; Dykas & Cassidy, 2011), and attachment theory shows that repeated interactions with a supportive and sensitive caregiver early in life result in development of a stable cognitive-emotional schema of the caregiver's availability to reduce stress and provide comfort and protection (Bowlby, 1969), future studies should explicitly dissect the tend-and-befriend concept in the context of attachment theory and its biological basis, the brain oxytocin system.

A better understanding of potential dysfunctions in the interaction between stress and behavior might help researchers and clinicians tailor new diagnostic and treatment strategies for stress-related disorders and mental disorders involving social deficits (e.g., social anxiety disorder, borderline personality disorder). Stress does not necessarily lead to negative feelings, social conflicts, and aggressive behavior; acute psychosocial stress can instead increase prosocial behavior. Tend-and-befriend behavior appears to be a potentially inherent and effective coping mechanism in healthy humans during stress.

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Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

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Supplemental Material

Additional supporting information may be found at <http://pss.sagepub.com/content/by/supplemental-data>

References

- Ainsworth, M. D. S. (1991). Attachments and other affectional bonds across the life cycle. In C. M. Parkes, J. Stevenson-Hinde, & P. Marris (Eds.), *Attachment across the life cycle* (pp. 33–51). London, England: Routledge.
- Baumeister, R. F., & Leary, M. R. (1995). The need to belong: Desire for interpersonal attachments as a fundamental human motivation. *Psychological Bulletin*, *117*, 497–529.
- Baumgartner, T., Heinrichs, M., Vonlanthen, A., Fischbacher, U., & Fehr, E. (2008). Oxytocin shapes the neural circuitry of trust and trust adaptation in humans. *Neuron*, *58*, 639–650.
- Beckes, L., Simpson, J. A., & Erickson, A. (2010). Of snakes and sugar: Learning secure attachment associations with novel faces via negative stimulus pairings. *Psychological Science*, *21*, 721–728.
- Bowlby, J. (1969). *Attachment and loss: Vol. 1. Attachment*. New York, NY: Basic Books.
- Brickenkamp, R., & Zillmer, E. (1998). *The d2 test of attention*. Seattle, WA: Hogrefe & Huber.
- Buchheim, A., Heinrichs, M., George, C., Pokorny, D., Koops, E., Henningsen, P., . . . Gündel, H. (2009). Oxytocin enhances the experience of attachment security. *Psychoneuroendocrinology*, *34*, 1417–1422.
- Chen, F. S., Kumsta, R., von Dawans, B., Monakhov, M., Ebstein, R. P., & Heinrichs, M. (2011). A common oxytocin receptor gene (OXTR) polymorphism and social support interact to reduce stress in humans. *Proceedings of the National Academy of Sciences, USA*, *108*, 19937–19942.
- Christenfeld, N., Gerin, W., Linden, W., Sanders, M., Mathur, J., Deich, J. D., & Pickering, T. G. (1997). Social support effects on cardiovascular reactivity: Is a stranger as effective as a friend? *Psychosomatic Medicine*, *59*, 388–398.
- Chrousos, G. P. (2009). Stress and disorders of the stress system. *Nature Reviews Endocrinology*, *5*, 374–381.
- Derogatis, L. R., & Melisaratos, N. (1983). The Brief Symptom Inventory: An introductory report. *Psychological Medicine*, *13*, 595–605.
- Dickerson, S. S., & Kemeny, M. E. (2004). Acute stressors and cortisol responses: A theoretical integration and synthesis of laboratory research. *Psychological Bulletin*, *130*, 355–391.
- Ditzen, B., Neumann, I. D., Bodenmann, G., von Dawans, B., Turner, R. A., Ehlert, U., & Heinrichs, M. (2007). Effects of different kinds of couple interaction on cortisol and heart rate responses to stress in women. *Psychoneuroendocrinology*, *32*, 565–574.
- Ditzen, B., Schmidt, S., Strauss, B., Nater, U. M., Ehlert, U., & Heinrichs, M. (2008). Adult attachment and social support interact to reduce psychological but not cortisol responses to stress. *Journal of Psychosomatic Research*, *64*, 479–486.
- Donaldson, Z. R., & Young, L. J. (2008). Oxytocin, vasopressin, and the neurogenetics of sociality. *Science*, *322*, 900–904.
- Dykas, M. J., & Cassidy, J. (2011). Attachment and the processing of social information across the life span: Theory and evidence. *Psychological Bulletin*, *137*, 19–46.
- Fischbacher, U. (2007). z-Tree: Zurich toolbox for ready-made economic experiments. *Experimental Economics*, *10*, 171–178.
- Foley, P., & Kirschbaum, C. (2010). Human hypothalamus-pituitary-adrenal axis responses to acute psychosocial stress in laboratory settings. *Neuroscience & Biobehavioral Reviews*, *35*, 91–96.
- Gerin, W., Pieper, C., Levy, R., & Pickering, T. G. (1992). Social support in social interaction: A moderator of cardiovascular reactivity. *Psychosomatic Medicine*, *54*, 324–336.
- Heinrichs, M., Baumgartner, T., Kirschbaum, C., & Ehlert, U. (2003). Social support and oxytocin interact to suppress cortisol and subjective responses to psychosocial stress. *Biological Psychiatry*, *54*, 1389–1398.
- Heinrichs, M., & Domes, G. (2008). Neuropeptides and social behaviour: Effects of oxytocin and vasopressin in humans. *Progress in Brain Research*, *170*, 337–350.
- Heinrichs, M., von Dawans, B., & Domes, G. (2009). Oxytocin, vasopressin, and human social behavior. *Frontiers in Neuroendocrinology*, *30*, 548–557.
- House, J. S., Landis, K. R., & Umberson, D. (1988). Social relationships and health. *Science*, *241*, 540–545.
- Houston, J. M., Farese, D. M., & La Du, T. J. (1992). Assessing competitiveness: A validation study of the competitiveness index. *Personality and Individual Differences*, *13*, 1153–1156.
- Insel, T. R., & Young, L. J. (2001). The neurobiology of attachment. *Nature Reviews Neuroscience*, *2*, 129–136.
- Kirschbaum, C., Klauer, T., Filipp, S. H., & Hellhammer, D. H. (1995). Sex-specific effects of social support on cortisol and subjective responses to acute psychological stress. *Psychosomatic Medicine*, *57*, 23–31.
- Kosfeld, M., Heinrichs, M., Zak, P. J., Fischbacher, U., & Fehr, E. (2005). Oxytocin increases trust in humans. *Nature*, *435*, 673–676.
- Lepore, S. J., Allen, K. A., & Evans, G. W. (1993). Social support lowers cardiovascular reactivity to an acute stressor. *Psychosomatic Medicine*, *55*, 518–524.
- Liebowitz, M. R. (1987). Social phobia. *Modern Problems of Pharmacopsychiatry*, *22*, 141–173.
- McEwen, B. S. (1998). Stress, adaptation, and disease: Allostasis and allostatic load. *Annals of the New York Academy of Sciences*, *840*, 33–44.
- Meyer-Lindenberg, A., Domes, G., Kirsch, P., & Heinrichs, M. (2011). Oxytocin and vasopressin in the human brain: Social neuropeptides for translational medicine. *Nature Reviews Neuroscience*, *12*, 524–538.
- Neumann, I. D., Krömer, S. A., Toschi, N., & Ebner, K. (2000). Brain oxytocin inhibits the (re)activity of the hypothalamo-pituitary-adrenal axis in male rats: Involvement of hypothalamic and limbic brain regions. *Regulatory Peptides*, *96*, 31–38.
- Pruessner, J. C., Kirschbaum, C., Meinlschmidt, G., & Hellhammer, D. H. (2003). Two formulas for computation of the area under the

- curve represent measures of total hormone concentration versus time-dependent change. *Psychoneuroendocrinology*, *28*, 916–931.
- Seeman, T. E. (2000). Health promoting effects of friends and family on health outcomes in older adults. *American Journal of Health Promotion*, *14*, 362–370.
- Smeets, T., Dziobek, I., & Wolf, O. T. (2009). Social cognition under stress: Differential effects of stress-induced cortisol elevations in healthy young men and women. *Hormones and Behavior*, *55*, 507–513.
- Taylor, S. E. (2006). Tend and befriend: Biobehavioral bases of affiliation under stress. *Current Directions in Psychological Science*, *15*, 273–277.
- Taylor, S. E., Klein, L. C., Lewis, B. P., Gruenewald, T. L., Gurung, R. A., & Updegraff, J. A. (2000). Biobehavioral responses to stress in females: Tend-and-befriend, not fight-or-flight. *Psychological Review*, *107*, 411–429.
- Uchino, B. N., Cacioppo, J. T., & Kiecolt-Glaser, J. K. (1996). The relationship between social support and physiological processes: A review with emphasis on underlying mechanisms and implications for health. *Psychological Bulletin*, *119*, 488–531.
- Uchino, B. N., & Garvey, T. S. (1997). The availability of social support reduces cardiovascular reactivity to acute psychological stress. *Journal of Behavioral Medicine*, *20*, 15–27.
- von Dawans, B., Kirschbaum, C., & Heinrichs, M. (2011). The Trier Social Stress Test for Groups (TSST-G): A new research tool for controlled simultaneous social stress exposure in a group format. *Psychoneuroendocrinology*, *36*, 514–522.