



Cortisol modulates men's affiliative responses to acute social stress



Justus Berger^a, Markus Heinrichs^{a,b}, Bernadette von Dawans^a, Baldwin M. Way^c,
Frances S. Chen^{a,d,*}

^a Department of Psychology, Laboratory for Biological and Personality Psychology, Albert-Ludwigs-University of Freiburg, Freiburg i. Br., Germany

^b Freiburg Brain Imaging Center, University Medical Center, Albert-Ludwigs-University of Freiburg, Freiburg i. Br., Germany

^c Department of Psychology and Institute for Behavioral Medicine Research, The Ohio State University, Columbus, OH, USA

^d Department of Psychology, University of British Columbia, Vancouver, BC, Canada

ARTICLE INFO

Article history:

Received 16 June 2015

Received in revised form 1 September 2015

Accepted 2 September 2015

Keywords:

Stress

Cortisol

Tend-and-befriend

Affiliation

Friendship

Relationships

ABSTRACT

The dominant characterization of the physiological and behavioral human stress reaction is the fight-or-flight response. On the other hand, it has been suggested that social affiliation during stressful times (“*tend-and-befriend*”) also represents a common adaptive response to stress, particularly for women. In the current study, we investigate the extent to which *men* may also show affiliative responses following acute stress. In addition, we examine a potential neuroendocrine modulator of the hypothesized affiliative response. Eighty male students (forty dyads) were recruited to undergo either the Trier Social Stress Test for Groups (TSST-G) or a non-stressful control situation. Subsequently, participants completed a dyadic interaction task and were then asked to report their feelings of psychological closeness to their interaction partner. Although participants assigned to the stress condition did not differ overall on psychological closeness from participants assigned to the control condition, participants with high cortisol responses to the stressor showed significantly higher ratings of psychological closeness to their interaction partner than participants with low cortisol responses. Our findings suggest that men may form closer temporary bonds following stressful situations that are accompanied by a significant cortisol response. We suggest that the traditional characterization of the male stress response in terms of “fight-or-flight” may be incomplete, and that social affiliation may in fact represent a common, adaptive response to stress in men.

© 2015 Elsevier Ltd. All rights reserved.

1. Introduction

Typically, the human stress response is portrayed as the “fight-or-flight” response, which describes a physiological mechanism that enables humans to mobilize energy rapidly in order to cope with threats to survival (Cannon, 1932). Expanding on this theory, Taylor et al. (2000) proposed that although both men and women share the physiological aspect of the fight-or-flight response, an alternative behavioral stress response is more characteristic for women—namely, the tendency to “tend-and-befriend”. This theory suggests that when faced with threat, women might be more inclined to tend to offspring, affiliate with others, and seek protection in groups (see Taylor and Master, 2011; for a review of relevant

findings). This pattern of affiliative behavior is assumed to have evolved as a strategy to protect the self and offspring from harm. For example, a meta-analysis of sex differences in coping behavior found that women are overall more likely than men to seek social support in order to cope with stress (Tamres et al., 2002). In a series of classic experimental studies on affiliation and stress, Schachter (1959) reported that female participants expecting painful electric shocks were more inclined to wait with other women than those expecting painless electric shocks. Thus, experimental evidence confirms that the anticipation of threat can increase affiliative tendencies in women.

Geary and Flinn (2002) have suggested that the tend-and-befriend model should be expanded to include men. They argue that parental investment in humans is a reproductive strategy evident in both sexes, and thus male tending during stressful times is similarly adaptive. Also, male befriending in the form of coalition formation in times of threat, as seen in preindustrial human societies and non-human primates, can be seen as a distinct feature of the male fight-or-flight response (Geary and Flinn, 2002). To date, however, there have been very few direct tests of affiliative responses

* Corresponding author: University of British Columbia, Department of Psychology, 2136 West Mall, V6T 1Z4, Vancouver, Canada.

E-mail addresses: justusberger@gmx.de (J. Berger), heinrichs@psychologie.uni-freiburg.de (M. Heinrichs), vondawans@psychologie.uni-freiburg.de (B. von Dawans), way.37@osu.edu (B.M. Way), frances.chen@psych.ubc.ca (F.S. Chen).

following acute stress, in particular addressing the possibility of male affiliative behavior. One recent study showed that male participants who experienced acute social stress were more inclined to exhibit prosocial behavior in the form of trust, trustworthiness and sharing with an anonymous partner in a computer-based interaction task compared to participants that were not stressed (Von Dawans et al., 2012). In another series of studies, physically painful experiences were found to promote the perception of interpersonal bonding and cooperative behavior in an economic game for both men and women (Bastian et al., 2014). Furthermore, both male and female participants who expressed their affection towards a loved one in a letter showed an accelerated endocrine stress recovery compared to control participants (Floyd et al., 2007), and both male and female participants who experienced social exclusion showed increased affiliative motives (Maner et al., 2007). Together, these findings suggest that tend-and-befriend behavior is not exclusive to women, but might also act as an alternative stress response and as an effective stress-coping mechanism in men.

Several studies suggest that cortisol release in response to stress, rather than the mere fact of exposure to a stressor, may be a key factor in the modulation of subsequent social cognition. In a study on moral decision-making following stress, although participants who had undergone stressful and non-stressful control tasks did not differ on moral decisions overall, a larger increase in cortisol levels was associated with more egoistic decision-making (Starcke et al., 2011). In a study on memory following stress, although participants who had undergone stressful and non-stressful situations did not differ on memory performance overall, a larger increase in men's cortisol levels was associated with greater impairments in recall (Wolf et al., 2001). Furthermore, differential effects of cortisol release under acute social stress on a social cognition task have been found in men and women (Smeets et al., 2009). Specifically, whereas high cortisol-responding men showed increased social cognition skills (mind reading abilities) compared to low cortisol-responding men, the opposite effect was observed for female participants. Furthermore, high cortisol-responding men in the Trier Social Stress Test (TSST; Kirschbaum et al., 1993) showed significantly lower performance on a social recognition memory task (face-name associations) compared to low cortisol-responding participants and non-stressed participants (Takahashi et al., 2004). These findings indicate that the magnitude of HPA axis reactivity to acute social stress moderates a range of responses and might therefore also regulate affiliative responses to stress.

Previous research has established that women have the tendency to affiliate with others while anticipating stress (Schachter, 1959). Furthermore, a substantial amount of research has demonstrated that social support attenuates physiological and psychological responses to stress (e.g., Kamarck et al., 1998; Kirschbaum et al., 1995; Heinrichs et al., 2003). However, social responses following acute stress have been greatly under-researched, especially in male samples. Unlike the series of studies conducted by Schachter (1959), the present work tested men and examined post-stress social affiliation. One core feature of affiliation is the degree of psychological closeness between individuals (i.e., a feeling of intimacy and connection to the other person; Aron et al., 1997). Thus, subjective feelings of closeness can be seen as both an outcome of tend-and-befriend motivation and behavior, as well as a likely contributor to the stress-buffering properties of social affiliation. To the best of our knowledge, no published studies have examined changes in psychological closeness between strangers following acute stress. We therefore set out to investigate whether stress influences the perception of interpersonal closeness in men. In particular, we tested whether acute stress would increase feelings of interconnectedness and thus lead individuals to form closer temporary relationships to a stranger in a subsequent social interaction.

Male participants were either assigned to the stress or control condition of the Trier Social Stress Test for Groups (TSST-G; Von Dawans et al., 2011). Following the TSST-G, participants underwent the Fast Friends Procedure (Aron et al., 1997). In this procedure, feelings of closeness between strangers are created through reciprocal and personal self-disclosure in a live face-to-face interaction. In line with the tend-and-befriend hypothesis, we expected that stressed participants would report greater feelings of subjective closeness to their conversation partner than control participants. Additionally, given the prior research showing relationships between the magnitude of HPA axis reactivity to an acute stressor and subsequent social cognition, we also specifically examined whether greater cortisol responses in the stress group predicted higher closeness ratings.

2. Material and methods

2.1. Participants

Eighty healthy male students ($M_{age} = 22.49$, $SD = 1.69$) from the University of Freiburg were recruited via flyers and posters and told that they would take part in a study on the effects of hormonal changes on human behavior. Participants were excluded if they indicated that they studied psychology, were familiar with the TSST procedure, had any acute or chronic psychiatric or medical illness, took prescription medicine, abused alcohol or drugs, or smoked more than five cigarettes a day. Participants were instructed to consume standard meals on the day of the study and to abstain from alcohol, exercise, caffeine, and medication 24 h before the study, and from food two hours before the study. All participants received 25€ for participation. The study was approved by the local institutional review board and written consent was obtained from participants prior to testing. We decided a priori to recruit 80 participants, analyze all complete observations, and report all manipulations and measures (Simmons et al., 2011).

2.2. Procedure

Participants were divided into four-person groups¹ and were randomly assigned, as a group, for either the stress or the control condition of the TSST-G. Each group was tested for two and a half hours in the late afternoon, from 16 h 15 to 18 h 45, to control for the daily rhythm of cortisol secretion. Upon arrival at the lab, the group of participants was led to the “waiting room” and completed a first set of online questionnaires for psychometric assessment. Baseline measures for cortisol and subjective stress were obtained. Throughout the experiment, a total of seven samples of saliva for cortisol analysis and five subjective anxiety measures per participant were obtained (see Fig. 1 for timeline). Participants were individually fitted with heart rate monitors (chest straps and watches) in a separate room. After returning to the waiting room, participants were instructed to stand for five minutes for a baseline assessment of heart rate. Heart rate was continuously monitored throughout the primary TSST-G and Fast Friends procedures. Participants were not allowed to talk to each other before and during the stress induction phase, and dividing walls separated the participants before and during stress exposure and prevented visual contact between them.

The instructions for the stress or the control task of the TSST-G were then given to the participants (for a detailed description of the TSST-G, see Von Dawans et al., 2011). Depending on their condition assignment, participants were told to either prepare for a mock

¹ Four individuals were tested in two-person groups due to last-minute participant cancellations.

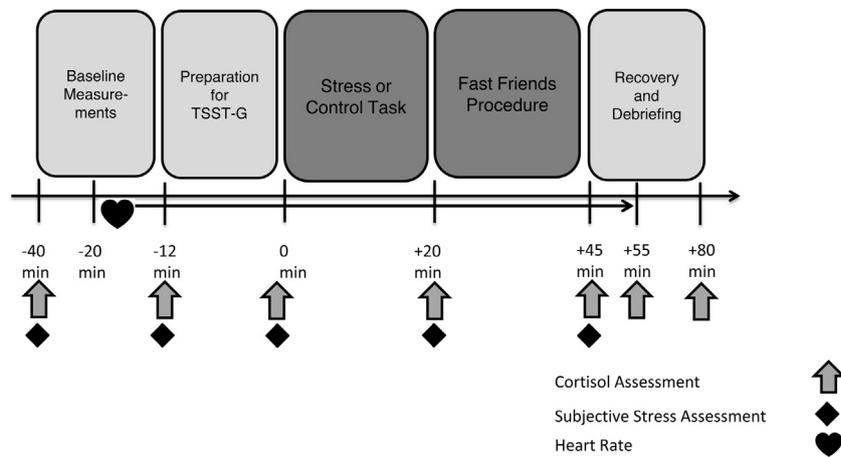


Fig. 1. Sequence of events and timeline.

job interview (stress condition) or to prepare to read a text (control condition). They were also told that an additional task would be explained by a panel of two judges after completion of the first task. Participants had ten minutes to prepare for the interview or text-reading task. Following the preparation phase, participants were led to the “testing room.” There, a panel of two judges, both trained research assistants, led them through the stress or control task. In the stress condition, participants completed a public speaking task followed by a challenging mental arithmetic task. In the control condition the participants followed a similar procedure, but without any of the stressful components. Instead of the simulated job interview and the mental arithmetic task, control participants were asked to read a simple text simultaneously in a low voice followed by an easy counting task. Also, whereas in the stress condition the participants were filmed during the public speaking task and the two judges were dressed in white lab coats, no cameras or lab coats were present in the control condition. After the TSST-G stress or control procedure, participants were divided into groups of two (after the experimenter confirmed that the members of each dyad were strangers to each other) and were led into two different rooms for the Fast Friends Procedure (FFP).

The FFP is a protocol that was designed by Aron et al. to quickly establish closeness between strangers (Aron et al., 1997). Two participants sat next to each other and were provided with an instruction form and a set of 12 cards. Participants were instructed to read aloud the question or task written on the cards in an alternating order. Both participants were required to answer the question or perform the task and then to go on to the next card. An abbreviated version of the original FFP was used in the present study that lasted 15 instead of the original 45 min and involved a slightly modified version of the first out of three sets of cards developed by Aron et al. (1997) (see Appendix). An offline coder confirmed, by watching video recordings of the FFP sessions, that all participants followed task instructions satisfactorily. Following the FFP, the participants were brought back to the “waiting room”, where they filled out the second set of questionnaires, including the interpersonal closeness measures. Participants then removed the heart rate chest straps and watches and the final samples of saliva were obtained. Participants were then debriefed about the purpose of the study and received payment for participation.

2.3. Stress response measures

The endocrine stress response was assessed by measuring salivary levels of cortisol, using Salivettes (Sarstedt, Nümbrecht-Rommelsdorf, Germany). Seven saliva samples were obtained

before and after the stress exposure task (at -40 , -12 , -2 , $+20$, $+45$, $+55$, and $+80$ min relative to TSST-G onset). Samples were stored in a freezer at -20 °C after each experiment. For biochemical analyses, the samples were spun at 3000 revolutions for 10 min to obtain 0.5–1.0 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%.

The autonomic stress response was assessed by measuring heart rate throughout the main tasks of the study using a wireless heart rate chest strap transmitter and a recording wristwatch (Polar RS800TM, Polar Electro, Finland). Continuous beat-to-beat intervals were recorded and subsequently aggregated to mean levels of 60 s intervals for heart rate analyses. For final analyses, heart rate data from five minutes before, to five minutes after, the stress manipulation were used. Due to technical problems, heart rate data was not recorded for three participants (one in the control, two in the stress condition). Heart rate recordings were uploaded and stored on the local hard drive of a computer in a locked room after each session.

Subjective stress was measured with a visual analogue scale (VAS) five times during the study: 40 min and 12 min before the stress manipulation, immediately after the TSST-G and 45 min after TSST-G onset. Participants indicated their level of anxiety, physical discomfort, desire to leave the situation (avoidance), and emotional arousal on a scale ranging from 0 (not strong at all) to 100 (very strong). We dropped from the analyses a fifth item on the VAS (intended to measure control) because of the low and non-significant correlation with the other four items ($r = -.17$). The mean value over the remaining four items was calculated for each participant and each measurement point to obtain an overall value of subjective stress (Cronbach's $\alpha > .77$ between the four scales for all measurement points).

2.4. Interpersonal closeness measures

To assess feelings of interpersonal closeness, participants answered six questions using a 9-point Likert-type scale: “How close do you feel to your conversation partner?”, “How similar are you to your conversation partner?”, “How much do you like your conversation partner?”, “To what degree could you imagine becoming friends with your conversation partner in the future?”, “Compared to all your other relationships, how close would you describe the relationship with your conversation partner to be?”, “Compared to relationships other people have, how close would you describe the relationship with your conversation partner to

be?”. The last two questions are adopted from the Subjective Closeness Index (SCI; Berscheid et al., 1989). Additionally, the Inclusion of Other in the Self (IOS) Scale (Aron et al., 1992) was included as a visual closeness measure. Using the IOS Scale, participants chose one out of seven pairs of increasingly overlapping circles, labeled *Self* and *Other*, that best described the relationship to their conversation partner.

The six interpersonal closeness questions were highly correlated (Cronbach's $\alpha = .85$); thus, we created a composite measure from the mean value (*mean closeness*) of the six items. The visual (IOS) scale showed poor convergent validity with the other closeness measures (whereas Aron et al. (1992) reported that the IOS Scale showed convergent validity with the SCI questions ($r = .34$), no significant correlation was found in our study ($r = .15$), suggesting that it was not a valid measure of closeness for our particular sample). We therefore dropped the IOS and retained the six-item composite *mean closeness* measure for all further analyses of interpersonal closeness.

2.5. Psychometric measures

Several psychometric questionnaires were used to check whether participants in the stress and control condition were comparable on demographic, clinical and personality variables. Specifically, participants' trait anxiety (STAI-T; Laux et al., 1981), social interaction anxiety (SIAS; Stangier et al., 1999), autism spectrum quotient (AQ; Freitag et al., 2007), empathy (IRI; Davis, 1983), extraversion, and openness (NEO-FFI-30; Körner et al., 2008) were assessed.

2.6. Statistics

Cortisol, heart rate and subjective stress were analyzed using two-way analyses of variance (ANOVAs) with repeated measures. The factors were condition (between-subjects factor: stress and control) and time (repeated factor: 30 for heart rate, 7 for cortisol, 5 for subjective stress). We examined the role of condition and cortisol responses on interpersonal relationships using hierarchical linear modeling with robust standard errors to control for non-independence of observations within dyads. We entered both the dependent and the independent variables at the item level and grouped observations by dyad. The area under the curve with respect to increase (AUC) was calculated for the physiological stress measures (cortisol and heart rate), to allow correlational analyses of repeated measures data.² The AUC is a method to aggregate data that assess changes over time, and is frequently used in neuroendocrinological research (Pruessner et al., 2003). To obtain an overall measure of subjective stress for the session, the baseline value on the VAS was subtracted from the maximum value for each participant. Associations between the different stress responses and interpersonal closeness ratings were tested using Spearman's rank correlations (Spearman's ρ), since the aggregated measures of cortisol and heart rate were not normally distributed. The level of significance was set at $p < .05$ and two-tailed tests are reported.

² Specifically, we report AUC-I (area under the curve with respect to the increase), which aggregates changes over time relative to the baseline measurement. Using AUC-G (area under the curve with respect to the ground), which aggregates changes over time relative to zero, does not substantially change any of the main results.

Table 1

Characteristics of Stress and Control Groups. Individual cells depict means \pm standard error of the mean.

	Stress	Control	Group comparison
N	42	38	
Age (years)	22.6 (± 3)	22.4 (± 3)	$t(76) = -.3$, ns
Trait Anxiety (STAI-T)	38.6 (± 1.6)	38.0 (± 1.2)	$t(76) = -.3$, ns
Social Interaction Anxiety (SIAS)	18.4 (± 1.5)	21.1 (± 1.6)	$t(76) = 1.2$, ns
Autism (AQ)	17.6 ($\pm .9$)	19.3 (± 1.1)	$t(76) = 1.2$, ns
Empathy (IRI)	58.6 (± 1.4)	58.0 (± 1.3)	$t(76) = -.5$, ns
Extraversion (NEO-FFI-30)	15.3 ($\pm .6$)	14.7 ($\pm .6$)	$t(74) = -.8$, ns
Openness (NEO-FFI-30)	16.2 ($\pm .7$)	16.5 ($\pm .7$)	$t(73) = .2$, ns

3. Results

3.1. Participant characteristics

Participants in the stress and control condition did not differ significantly in age, trait anxiety, social interaction anxiety,³ autism,³ empathy, extraversion or openness (See Table 1).

3.2. Stress responses

The effect of the stress manipulation was tested using two-way ANOVAs with repeated measures, with time of sampling as the within-subject factor and condition as the between-subjects factor. Cortisol increased significantly more over time in the stress condition than in the control condition (main effect of time, $F(2.54, 197.73) = 12.02$, $p < .001$, $\eta_p^2 = .13$; main effect of condition, $F(1, 78) = 13.02$, $p < .001$, $\eta_p^2 = .14$; time by condition interaction, $F(2.54, 197.73) = 25.48$, $p < .001$, $\eta_p^2 = .25$). The stress group also showed a significantly greater increase in heart rate over time (main effect of time, $F(8.88, 666.23) = 35.37$, $p < .001$, $\eta_p^2 = .32$; main effect of condition, $F(1, 75) = 1.75$, $p = .19$, $\eta_p^2 = .02$; time by condition interaction, $F(8.88, 666.23) = 2.82$, $p < .05$, $\eta_p^2 = .04$) as well as subjective stress (main effect of time, $F(2.44, 187.7) = 23.32$, $p < .001$, $\eta_p^2 = .23$; main effect of condition, $F(1, 75) = 2.56$, $p = .114$, $\eta_p^2 = .03$; time by condition interaction, $F(2.44, 187.7) = 10.79$, $p < .001$, $\eta_p^2 = .12$). These results indicate that the stress manipulation was successful in eliciting the endocrine, autonomic and subjective stress response. Mean levels of cortisol, heart rate and subjective stress for control and stress participants are shown in Fig. 2.

3.3. Interpersonal closeness

We examined the role of condition and cortisol responses on interpersonal relationships using hierarchical linear modeling with robust standard errors to control for non-independence of observations within dyads. Salivary cortisol is considered one of the most reliable stress measures and as the main biomarker in stress research (Kirschbaum and Hellhammer, 1994) and we assumed that HPA axis reactivity could influence social responses to stress, in accordance with previous findings (e.g., Smeets et al., 2009; Starcke et al., 2011). Although no differences in relevant personality traits were found between the stress and control groups in our study, preliminary analyses showed that ratings of interpersonal closeness were significantly correlated to self-reported empathy and extraversion ($r = .35$, $p = .001$, and $r = .31$, $p = .005$, respectively), and also that extraversion was significantly correlated to cortisol

³ Eight participants scored above the suggested clinical cutoff score of 36 on the SIAS (Peters, 2000). Two participants scored equal to or above the suggested clinical cutoff score of 32 on the AQ (Baron-Cohen et al., 2006). Excluding these participants does not change results of any of the main tests; thus, they are included in the reported results.

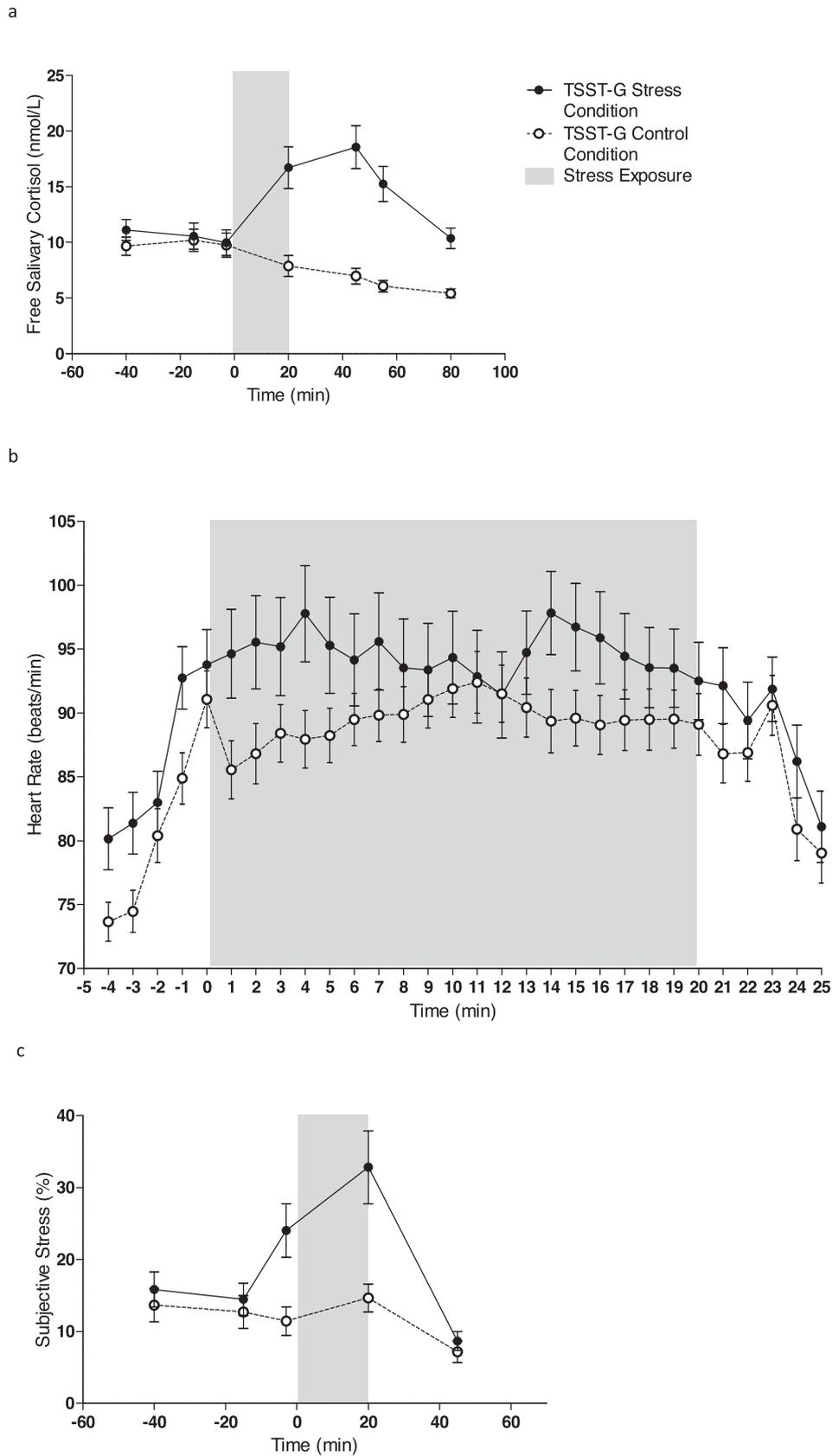


Fig. 2. Mean levels of salivary cortisol (a), heart rate (b), and subjective stress (c) for the stress and control group. Errors bars indicate standard errors of the mean.

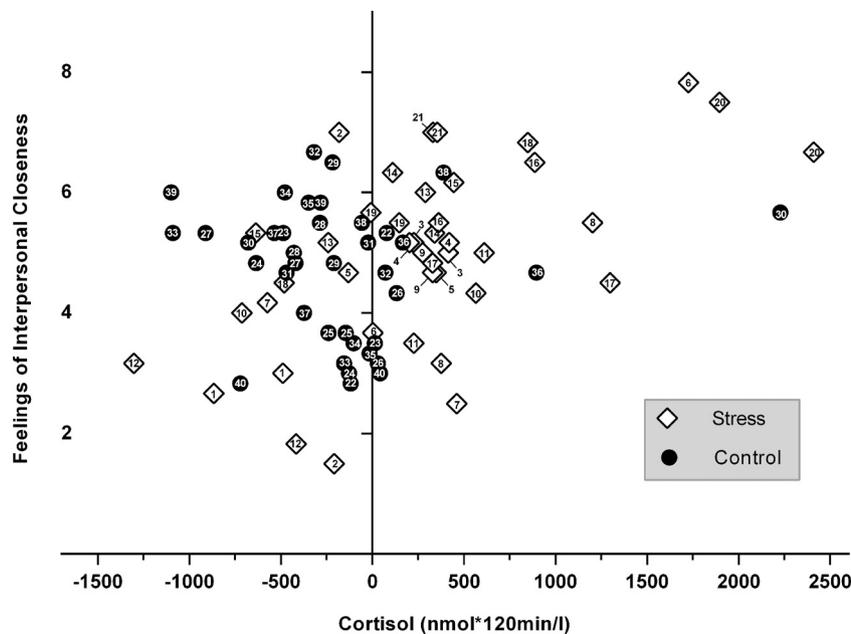


Fig. 3. Relationship between cortisol reactions (AUC-I, area under the curve with respect to the increase) and feelings of psychological closeness. Negative values for the cortisol measure indicate that cortisol levels decreased through the session. Label inside each data point indicates the dyad (Stress condition = dyads 1–21; Control condition = dyads 22–40).

responses ($r_s = .28, p = .01$). Thus, empathy and extraversion scores were also entered into the regression as covariates.⁴

We entered the dependent variable (*mean closeness*), two independent variables (*condition*, dummy coded with 0 = control and 1 = stress, and *cortisol*), and two covariates (*empathy* and *extraversion*) at the item level. We grouped observations by dyad and z-scored all continuous variables.

Undergoing the stress (versus control) condition did not, on its own, predict significantly different ratings of interpersonal closeness, ($b = -.14, z = -.69, p = .49$). Cortisol increase, however, was a significant predictor of ratings of interpersonal closeness ($b = .32, z = 3.39, p = .001$). Specifically, participants who showed greater increases in cortisol reported more interpersonal closeness with their conversational partner (see Fig. 3). This relationship held regardless of whether empathy and extraversion were included in the regression model. When the interaction between condition and cortisol was included in the model, the main effect of cortisol dropped to non-significance ($b = .06, z = 0.39, p = .70$) because of the presence of a significant interaction ($b = .42, z = 2.12, p = .03$). The positive relationship between cortisol increase and ratings of interpersonal closeness was driven by participants in the stress condition ($b = .49, z = 4.07, p < .001$) and was not significant for participants in the control condition ($b = .05, z = .30, p = .76$).

3.4. Correlations between stress responses and interpersonal closeness

Correlational analyses were used to test for associations between aggregated values (see “Stress Response Measures”) of the endocrine, autonomic and subjective stress measures, and between these measures and interpersonal closeness ratings. Cortisol and heart rate responses were not significantly correlated in the stress group ($r_s = .17, p = .29$), or in the control group ($r_s = .11, p = .53$). Subjective stress ratings were also not significantly correlated with cortisol responses in either the stress ($r_s = -.06, p = .69$) or control

condition ($r_s = .16, p = .34$). There was also no significant correlation between subjective stress ratings and heart rate responses for stress ($r_s = -.08, p = .64$) and control participants ($r_s = -.29, p = .08$). In the control condition, all three stress response measures showed no significant association with mean closeness (all p s > .19). In the stress group, mean closeness was found to be highly positively correlated to cortisol levels ($r_s = .47, p < .001$), but not to subjective stress or heart rate measures (all p s > .54).

4. Discussion

The current study investigated the effects of acute social stress on men’s subjective feelings of post-interaction closeness. Overall, participants in the stress group did not show higher ratings on the psychological closeness measures than those in the control group. However, larger cortisol responses predicted significantly higher feelings of interpersonal closeness to conversation partners on the closeness questions. These findings suggest that the combination of stress and cortisol secretion can lead individuals to experience closer bonds when interacting socially.

Our results are in line with theorizing that humans tend to affiliate with others in times of distress (Taylor et al., 2000). Although the tend-and-befriend response was originally hypothesized to be specifically relevant to women, our study suggests that men also use affiliation as a stress coping mechanism, in the case that a pronounced endocrine stress response also occurs. This strategy might have been useful for our evolutionary ancestors in times of threat, when immediate aggressive behavior or escape from danger were not appropriate options. Feelings of closeness may have promoted the formation or maintenance of alliances or coalitions. This understanding of the tend-and-befriend hypothesis corresponds to the considerations made by Geary and Flinn (2002), who have advocated male tending and befriending from an evolutionary standpoint. Although the evolutionary function of the affiliative stress response remains speculative, different behavioral consequences for men and women could be hypothesized. Whereas women could be more inclined to establish and maintain protective relationships when stressed (Taylor, 2006), affiliation under

⁴ Removing either or both of these covariates does not significantly change the reported findings.

stress in men could also have evolved in order to form coalitions for the purpose of attacking or defending against enemies (Geary and Flinn, 2002). In addition to behavioral benefits, the affiliative stress response could also have evolved as an efficient biological coping mechanism to accelerate recovery from physiological stress symptoms, as indicated by Floyd et al. (2007).

We found that higher ratings of post-interaction closeness were specifically predicted by higher cortisol levels, rather than exposure to an acute laboratory-based stressor *per se*. The fact that 13 out of 42 participants in our stress group showed a low, or no, salivary cortisol stress response (less than 2.5-nmol/l salivary cortisol increase, in accordance to findings by Wüst et al., 2000) may explain the lack of overall condition differences in mean closeness ratings. It should be noted, however, that using a median peak-baseline split of the stress group, we found that “low cortisol responders” did not differ from “high cortisol responders” in subjective levels of stress directly following stress exposure, or heart rate (AUC₁'s), suggesting that they were indeed affected by the stressor despite their lack of a cortisol response. This discrepancy among subjective, endocrine and physiological responses to stress has been previously reported in other studies using the TSST-G (e.g., Von Dawans et al., 2011) and the original TSST (e.g., Kirschbaum et al., 1995; Nicolson, 2007). In additional analyses, mean closeness was found to be positively correlated to cortisol responses, but not to subjective stress and heart rate in the stress group. Our current finding therefore suggests that affiliation in response to stress may be particularly modulated by the magnitude of the cortisol response.

Individual differences in cortisol responses to stress could indicate for whom, and under which circumstances, social affiliation under stress occurs. Gaab et al. (2005) demonstrated that anticipatory cognitive appraisal is an important psychological determinant of the cortisol stress response and can explain up to 35% of the variance of cortisol secretion in response to acute stress. It has been found that participant's perception of psychological stressors as uncontrollable and as posing a threat of negative evaluation is associated with the largest cortisol changes (Dickerson and Kemeny, 2004). Correspondingly, Epel et al. (1998) showed that individuals who feel challenged instead of threatened by a stressor display a more resilient endocrine profile, including quicker cortisol recovery. Individuals with a high stress-induced cortisol response may perceive the TSST-G as more of a threat, whereas those with less pronounced HPA axis activation might feel more positive affect in form of being challenged by the stress task (Buchanan and Preston, 2014). It could therefore be speculated that the affiliation stress response only emerges as a coping strategy in situations that are perceived as threatening and that consequently induce endocrine stress responses. This interpretation would correspond to previous considerations about the evolutionary function of the affiliative stress response discussed above.

Although it is uncertain how HPA axis activity regulates affiliation under stress, recent research indicates that the neuropeptide oxytocin is involved in mediating social stress buffering. Taylor et al. (2000) have suggested that the oxytocin system is also a possible neuroendocrinological basis for tend-and-befriend responses to stress. The link between social affiliation and oxytocin has been documented in a number of mammalian species (e.g., Carter, 1998; Insel and Young, 2001; Meyer-Lindenberg et al., 2011). Of specific relevance to the current findings, it has been shown that oxytocin released in response to stress regulates HPA axis activity (Neumann et al., 2000). An elevated release of oxytocin, as found in breastfeeding women, has been shown to attenuate the endocrine stress response (Heinrichs et al., 2002). In addition, male participants who received exogenous (intranasal) oxytocin showed lower cortisol responses to acute social stress and the effect was strongest

when oxytocin was combined with prior social support (Heinrichs et al., 2003). Chen et al. (2011) demonstrated that a genetic variation of the oxytocin system mediates the stress-buffering effects of social support in men. Direct experimental support for the involvement of oxytocin in affiliative stress responses comes from Cardoso et al. (2013), who demonstrated that oxytocin administered via nasal spray promotes social approach behavior in times of distress by increasing self-perceived trust in both male and female participants. Thus, the oxytocin system appears to function within affiliative neurocircuitry that could also be responsible for the evocation of social approach behavior in response to acute stress in men. Increased availability of brain oxytocin after stress is assumed to attenuate physiological stress reactions and to stimulate social bonding. Additional research will be necessary to examine the specific relationships among HPA axis activity, oxytocin and affiliative stress responses. In particular, future research should address the possibility that heightened levels of oxytocin following stress can play a causal role in the relationship between stress and subsequent social cognition and behavior.

Since we examined participants' perception of interpersonal closeness after a structured social task and not naturalistic social approach behavior, future research will be necessary to confirm whether stress-induced HPA axis activity would also prompt individuals to choose or actively seek out social contact. By using a diary method (Bolger et al., 2003), for example, the influence of daily stressors experienced in a more naturalistic setting on affiliation behavior could be assessed. Also, although none of the personality trait measures included in our study explained the relationship between cortisol and affiliation responses, further research should be conducted in which cortisol levels are experimentally manipulated to confirm the existence of a causal relationship between cortisol and affiliation responses. This design would also clarify whether exogenous administration of cortisol (independent of stress induction) yields a comparable effect on feelings of closeness as the one demonstrated in our study. Future studies designed to quantify specific actions by participants during the stress procedure as well as during the Fast Friends Procedure may provide insight into whether particular behaviors mediate the link between cortisol and closeness ratings. In our study, conversational partners underwent the stressor together, which may have influenced their subsequent impressions of their conversational partner; future studies should also investigate affiliative responses after individual stress exposure. Finally, as the current study and previous research (Von Dawans et al., 2012) focused on examining the affiliative stress response in men, future research will be necessary to confirm whether women would show similar, or even increased, feelings of closeness using comparable study designs. Future studies incorporating participants of both sexes within the same study design could more directly compare affiliative stress responses of men and women, as well as affiliation towards same- and opposite-sex strangers.

In conclusion, the findings of the present study support the existence of stress-induced affiliation responses in healthy young men. We found that the magnitude of the cortisol response predicted participants' subjective ratings of interpersonal closeness to their conversation partners in a post-stress communication task. These findings suggest that men may form closer temporary bonds following stressful situations that are accompanied by a significant cortisol response. As such, the present study contributes to the understanding of social stress regulation and challenges commonly-held views on the behavioral fight-or-flight response in men. Although acute stress has traditionally been associated with negative outcomes, it may actually serve an important role in social affiliation and bonding processes in humans.

Conflict of interest

None.

Role of the funding source

This study was supported by a postdoctoral research fellowship from the AXA Research Fund to F.S.C. The sponsor had no involvement in the study design; in the collection, analysis and interpretation of data; in the writing of the report; nor in the decision to submit the article for publication.

Contributors

All authors contributed substantially to the conception and design of the study. J.B., F.S.C., and B.v.D. oversaw data acquisition. J.B. and F.S.C. analyzed and interpreted the data. J.B. wrote the first draft of the manuscript. All authors contributed to its critical revision. All authors have approved the final version of the article.

Acknowledgements

We thank Dr. Susan C. Johnson for helpful feedback and assistance during study design, Dr. Valentina Colonnello for assistance during study preparation, Robin Bührle, Corinna Schreiber, Charlotte Fürstenberger, Yannis Krüger, and Leonie Bauer for assistance during data collection and data coding, and Hanne Collins for editorial assistance.

Appendix A.

Fast Friends questions (adapted from Aron et al., 1997).

1. Given the choice of anyone in the world, whom would you want as a dinner guest?
- 5 Would you like to be famous? In what way?
3. Before making a telephone call, do you ever rehearse what you are going to say? Why?
- 6 What would constitute the “perfect” day for you?
- 7 When did you last sing to yourself? To someone else?
6. If you were able to live to the age of 90 and retain either the mind or body of a 30-year-old for the last 60 years of your life, which would you want?
- 8 Name three things that you and your conversation partner seem to have in common.
8. If you could wake up tomorrow having gained any one quality or ability, what would it be?
- 9 For what in your life do you feel most grateful?
10. If you could change anything about the way you grew up, what would it be?
11. Take three minutes and tell your partner your life story in as much detail as possible.
12. If a crystal ball could tell you the truth about yourself, your life, the future, or anything else, what would you want to know?

References

- Aron, A., Aron, E.N., Smollan, D., 1992. Inclusion of other in the self scale and the structure of interpersonal closeness. *J. Pers. Soc. Psychol.* 63, 596–612.
- Aron, A., Melinat, E., Aron, E.N., Vallone, R.D., Bator, R.J., 1997. The experimental generation of interpersonal closeness: a procedure and some preliminary findings. *Pers. Soc. Psychol. B* 23, 363–377.
- Baron-Cohen, S., Hoekstra, R.A., Knickmeyer, R., Wheelwright, S., 2006. The autism-spectrum quotient (AQ)—adolescent version. *J. Autism Dev. Disord.* 36, 343–350.
- Bastian, B., Jetten, J., Ferris, L.J., 2014. Pain as social glue: shared pain increases cooperation. *Psychol. Sci.* 25, 2079–2085.
- Berscheid, E., Snyder, M., Omoto, A.M., 1989. The relationship closeness inventory: assessing the closeness of interpersonal relationships. *J. Pers. Soc. Psychol.* 57, 792–807.
- Buchanan, T.W., Preston, S.D., 2014. Stress leads to prosocial action in immediate need situations. *Front. Behav. Neurosci.* 8, 1–6.
- Bolger, N., Davis, A., Rafaeli, E., 2003. Diary methods: capturing life as it is lived. *Annu. Rev. Psychol.* 54, 579–616.
- Cannon, W.B., 1932. *The wisdom of the body*. W.W. Norton & Co., New York, NY, US.
- Cardoso, C., Ellenbogen, M.A., Serravalle, L., Linnen, A.-M., 2013. Stress-induced negative mood moderates the relation between oxytocin administration and trust: evidence for the tend-and-befriend response to stress? *Psychoneuroendocrinology* 38, 2800–2804.
- Carter, C.S., 1998. Neuroendocrine perspectives on social attachment and love. *Psychoneuroendocrinology* 23, 779–818.
- Chen, F.S., Kumsta, R., von Dawans, B., Monakhov, M., Ebstein, R.P., Heinrichs, M., 2011. Common oxytocin receptor gene (OXTR) polymorphism and social support interact to reduce stress in humans. *Proc. Natl. Acad. Sci. U. S. A.* 108, 19937–19942.
- Davis, M.H., 1983. Measuring individual differences in empathy: evidence for a multidimensional approach. *J. Pers. Soc. Psychol.* 44, 113–126.
- Dickerson, S.S., Kemeny, M.E., 2004. Acute stressors and cortisol responses: a theoretical integration and synthesis of laboratory research. *Psychol. Bull.* 130, 355–391.
- Epel, E.S., McEwen, B.S., Ickovics, J.R., 1998. Embodying psychological thriving: physical thriving in response to threat. *J. Soc. Issues* 54, 301–322.
- Floyd, K., Mikkelsen, A.C., Tafoya, M.A., Farinelli, L., La Valley, A.G., Judd, J., Haynes, M.T., Davis, K.L., Wilson, J., 2007. Human affection exchange: XIII. Affectionate communication accelerates neuroendocrine stress recovery. *Health Commun.* 22, 123–132.
- Freitag, C.M., Retz-Junginger, P., Retz, W., Seitz, C., Palmason, H., Meyer, J., Rösler, M., von Gontard, A., 2007. Evaluation der deutschen Version des Autismus-Spektrum-Quotienten (AQ)—die Kurzversion AQ-k. *Z. Klin. Psychol. Psychother.* 36, 280–289.
- Gaab, J., Rohleder, N., Nater, U.M., Ehlert, U., 2005. Psychological determinants of the cortisol stress response: the role of anticipatory cognitive appraisal. *Psychoneuroendocrinology* 30, 599–610.
- Geary, D.C., Flinn, M.V., 2002. Sex differences in behavioral and hormonal response to social threat: commentary on Taylor et al., 2000. *Psychol. Rev.* 109, 745–750.
- Heinrichs, M., Baumgartner, T., Kirschbaum, C., Ehlert, U., 2003. Social support and oxytocin interact to suppress cortisol and subjective responses to psychosocial stress. *Biol. Psychiatry* 54, 1389–1398.
- Heinrichs, M., Neumann, I., Ehlert, U., 2002. Lactation and stress: protective effects of breast-feeding in humans. *Stress* 5, 195–203.
- Insel, T.R., Young, L.J., 2001. The neurobiology of attachment. *Nat. Rev. Neurosci.* 2, 129–136.
- Kamarck, T.W., Peterman, A.H., Raynor, D.A., 1998. The effects of the social environment on stress-related cardiovascular activation: current findings, prospects, and implications. *Ann. Behav. Med.* 20, 247–256.
- Kirschbaum, C., Hellhammer, D.H., 1994. Salivary cortisol in psychoneuroendocrine research: recent developments and applications. *Psychoneuroendocrinology* 19, 313–333.
- 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. *Psychosom. Med.* 57, 23–31.
- Kirschbaum, C., Pirke, K.M., Hellhammer, D.H., 1993. The Trier Social Stress Test—a tool for investigating psychobiological stress responses in a laboratory setting. *Neuropsychobiology* 28, 76–81.
- Körner, A., Geyer, M., Roth, M., Drapeau, M., Schmutz, G., Albani, C., Schumann, S., Brähler, E., 2008. *Persönlichkeitsdiagnostik mit dem NEO-Fünf-Faktoren-Inventar: die 30-Item-Kurzversion (NEO-FFI-30)*. *Psychother. Psych. Med.* 58, 238–245.
- Laux, L., Glanzmann, P., Schaffner, P., Spielberger, C.D., 1981. *State-Trait-Angstinventar*. Beltz, Weinheim, Germany.
- Maner, J.K., DeWall, C.N., Baumeister, R.F., Schaller, M., 2007. Does social exclusion motivate interpersonal reconnection? Resolving the porcupine problem. *J. Pers. Soc. Psychol.* 92, 42–55.
- Meyer-Lindenberg, A., Domes, G., Kirsch, P., Heinrichs, M., 2011. Oxytocin and vasopressin in the human brain: social neuropeptides for translational medicine. *Nat. Rev. Neurosci.* 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. *Regul. Peptides* 96, 31–38.
- Nicolson, N.A., 2007. Measurement of cortisol. In: Luecken, L.J., Gallo, L.C. (Eds.) *Handbook of Physiological Research Methods in Health Psychology*. Sage Publications Inc., pp. 37–74.
- Peters, L., 2000. Discriminant validity of the Social Phobia and Anxiety Inventory (SPAI), the Social Phobia Scale (SPS) and the Social Interaction Anxiety Scale (SIAS). *Behav. Res. Ther.* 38, 943–950.
- Pruessner, J.C., Kirschbaum, C., Meinschmid, 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.
- Schachter, S., 1959. *The Psychology of Affiliation: Experimental Studies of the Sources of Gregariousness*. Stanford University Press.

- Simmons, J.P., Nelson, L.D., Simonsohn, U., 2011. False-positive psychology: undisclosed flexibility in data collection and analysis allows presenting anything as significant. *Psychol. Sci.* 22, 1359–1366.
- 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. *Horm. Behav.* 55, 507–513.
- Stangier, U., Heidenreich, T., Berardi, A., Golbs, U., Hoyer, J., 1999. Die Erfassung sozialer Phobie durch die Social Interaction Anxiety Scale (SIAS) und die Social Phobia Scale (SPS). *Z. Klin. Psychol. Psychother.* 28, 28–36.
- Starcke, K., Polzer, C., Wolf, O.T., Brand, M., 2011. Does stress alter everyday moral decision-making? *Psychoneuroendocrinology* 36, 210–219.
- Takahashi, T., Ikeda, K., Ishikawa, M., Tsukasaki, T., Nakama, D., Tanida, S., Kameda, T., 2004. Social stress-induced cortisol elevation acutely impairs social memory in humans. *Neurosci. Lett.* 363, 125–130.
- Tamres, L.K., Janicki, D., Helgeson, V.S., 2002. Sex differences in coping behavior: a meta-analytic review and an examination of relative coping. *Pers. Soc. Psych. Rev.* 6, 2–30.
- Taylor, S.E., 2006. Tend and befriend: biobehavioral bases of affiliation under stress. *Curr. Dir. in Psychol. Sci.* 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. *Psychol. Rev.* 107, 411–429.
- Taylor, S.E., Master, S.L., 2011. Social responses to stress: the tend-and-befriend model. In: Contrada, R.J., Baum, A. (Eds.), *The handbook of stress science: Biology, Psychology, and Health*. Springer Publishing Co., New York, pp. 101–109.
- Von Dawans, B., Fischbacher, U., Kirschbaum, C., Fehr, E., Heinrichs, M., 2012. The social dimension of stress reactivity: acute stress increases prosocial behavior in humans. *Psychol. Sci.* 23, 651–660.
- 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.
- Wolf, O.T., Schommer, N.C., Hellhammer, D.H., McEwen, B.S., Kirschbaum, K., 2001. The relationship between stress induced cortisol levels and memory differs between men and women. *Psychoneuroendocrinology* 26, 711–720.
- Wüst, S., Wolf, J., Hellhammer, D.H., Federenko, I., Schommer, N., Kirschbaum, C., 2000. The cortisol awakening response—normal values and confounds. *Noise Health* 2, 79–88.