# Acute Psychosocial Stress Modulates the Detection Sensitivity for Facial Emotions

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**Abstract.** Psychosocial stress has been shown to alter social perception and behavior. In the present study, we investigated whether a standardized psychosocial stressor modulates the perceptual sensitivity for positive and negative facial emotions and the tendency to allocate attention to facial expressions. Fifty-four male participants underwent the Trier Social Stress Test for Groups (TSST-G) or a nonstressful control condition before they performed a facial emotions detection task and a facial dot-probe task to assess attention for positive and negative facial expressions. Saliva samples were collected over the course of the experiment to measure free cortisol and alpha amylase. In response to the TSST-G, participants showed marked increases in subjective stress, salivary cortisol, and alpha amylase compared to the control condition. In the control condition, detection performance was higher for angry compared to happy facial expressions, while in the stressful condition this difference was reversed. Here, participants were more sensitive to happy compared to angry facial expressions. Attention was unaffected by psychosocial stress. The results suggest that psychosocial stress shifts social perception in terms of detection sensitivity for facial expressions toward positive social cues, a pattern that is consistent with the tendency to seek social support for coping with stress.

**Keywords:** psychosocial stress, cortisol, Trier Social Stress Test (TSST), TSST-G, emotion recognition, social attention

Acute psychosocial stress has been shown to modulate several aspects of human perception and behavior. One field of studies focuses on the effects of stress on social attention, emotion detection, and emotion recognition, which all represent basic skills for human social interaction. Positive social encounters have been found to downregulate the stress response and buffer for negative effects of acute and chronic stress (e.g., social support, helping; Ditzen & Heinrichs, 2014; Uchino, 2006; Uchino, Cacioppo, & Kiecolt-Glaser, 1996). From this perspective, acute stress leads to psychobiological adaptations of the human organism that influence behavior and thereby promotes acute coping with the situation as well as processing of future stressful situations. Besides subjective effects such as stressful or tense feelings, stress leads to activation of the hypothalamus–pituitary–adrenal (HPA) axis with secretion of the steroid hormone cortisol. The HPA axis responds on a slow time scale (ranging within minutes), showing the maximum increase of cortisol in saliva about 10–20 min after cessation of the stressor. The

sympathetic nervous system (SNS) shows a fast response with increases in heart rate or salivary alpha amylase within seconds (Dickerson & Kemeny, 2004). Although the psychobiological stress response is adaptive for acute stressors, research has already documented for decades that chronic or high intensity stress may have adverse effects on health over the lifespan (Lupien, McEwen, Gunnar, & Heim, 2009; McEwen, 1998). The most prominent behavioral concept of stress, the "'fight-or-flight' response" (Cannon, 1915; Taylor, 2006) introduced by Cannon, implies that stress leads to either aggressive behavior or avoidance. Recently, this concept has been broadened to include behavioral inhibition as a consequence of stress (Roelofs, 2017) and is now often referred to as the "freeze-fight-flight response." A contrary theoretical framework is the "tend-and-befriend" response that describes social approach as a behavioral consequence of stress for men and women, likely involving central opioid and oxytocinergic regulation (Taylor, 2006). Since social cognition (attention to as well as detection and recognition of emotions or mental states of others) is a precursor of social behavior, the modulation of acute stress may already intervene at this level because the neural networks involved in emotion recognition as well as stress processing and regulation are

overlapping (Pessoa & Adolphs, 2010). Surprisingly, studies in this area are scarce, and previous findings have been inconsistent. One recent study using the Trier Social Stress Test (TSST; Kirschbaum, Pirke, & Hellhammer, 1993) to induce stress found an increased threshold for disgust and a decrease for surprise (Daudelin-Peltier, Forget, Blais, Deschênes, & Fiset, 2017), while another study using a virtual variant of the TSST (Zimmer, Buttlar, Halbeisen, Walther, & Domes, 2019) found increased emotion detection of angry and happy faces under stress (Domes & Zimmer, 2019). Using the child version of the TSST, Chen, Schmitz, Domes, Tuschen-Caffier, and Heinrichs (2014) found that boys in the stress condition rated ambiguous fearful-angry faces more often as fearful than angry. One study investigating females with either a diagnosis of borderline-personality disorder (BPD), cluster C personality disorder, or without a diagnosis, reports an increase in emotion recognition performance of basic emotions after stress, but no difference between the three subject groups (Deckers et al., 2015).

Contrary to these findings, Wolf et al. (2015) found no effects of the TSST on cognitive empathy but an increase in emotional empathy in men. Another study including both sexes found an effect of the cortisol increase (high vs. low responders to the TSST) only for more complex stimuli (Movie for the Assessment of Social Cognition, MASC; Dziobek et al., 2006) and not for basic emotion recognition measured with the Reading the Mind in the Eyes Test (RMET; Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001), and this effect differed between men and women (Smeets, Dziobek, & Wolf, 2009).

A different methodological approach to study the role of cortisol and the activation of central mineralocorticoid receptors (MRs) is the application of MR agonists (e.g., fludrocortisone; MR stimulation). Studies using this approach again present ambiguous results. One study did not find an effect of MR stimulation on emotion recognition but a shift in selective attention toward sad faces in a dot-probe paradigm (Schultebraucks et al., 2016). A second study reported complex interactions of sex, task difficulty, and MR stimulation in healthy subjects (Duesenberg et al., 2016), while a study comparing female BPD patients and control subjects found an increase in emotional empathy by MR stimulation in one task (Multifaceted Empathy Test, MET; Dziobek et al., 2008) in both groups (Wingenfeld et al., 2014).

Given this inconclusive state of research, we aimed to investigate the effects of acute psychosocial stress in a group setting (using the TSST for groups, TSST-G) on social attention and emotion detection in healthy young men. The TSST-G has repeatedly led to increases in prosocial behavior in healthy men and women (von Dawans, Ditzen, Trueg, Fischbacher, & Heinrichs, 2019; von Dawans, Fischbacher, Kirschbaum, Fehr, & Heinrichs,

2012; von Dawans, Trueg, Kirschbaum, Fischbacher, & Heinrichs, 2018). Because these previous results are in line with the "tend-and-befriend" hypothesis, we hypothesized that in the present study, (1) stress would lead to increases in social attention (but not to nonsocial stimuli) and that (2) stress would increase the sensitivity to positive social emotions (happiness) while decreasing the sensitivity to negative social emotions (anger).

# Method

## Participants

Male participants were recruited via on-campus advertisement. Only men were allowed to take part in the study to control for the well-known sex differences and variation associated with the menstrual cycle in psychobiological stress reactivity (Kudielka, Hellhammer, & Wüst, 2009). Potential participants were asked to complete a short online screening questionnaire. They were invited to take part in the study if they did not meet any of the following exclusion criteria: BMI <19 or >26 kg/m², age <18 or >50 years, mental illness during the past 12 months, endocrine illness or medication during the past 12 months, regularly smoking >5 cigarettes per day, shift working, or not being fluent in German. In all, 57 healthy men met inclusion criteria and agreed to participate in the study. Due to missing data of the facial dot-probe and emotion recognition task (3 participants), the final sample consisted of 54 participants. Before entering the study, participants gave written informed consent. The study protocol was approved by the ethics committee of the University of Trier.

## Experimental Protocol

Participants were randomly allocated to one of two experimental conditions: the TSST-G ($n = 28$) or a nonstressful control condition ($n = 26$; von Dawans, Kirschbaum, & Heinrichs, 2011). Differences in group sizes are due to no-shows. Participants were tested simultaneously in small groups of 4–6 participants within the same condition. All experimental sessions started at 5 p.m.

After arrival at the lab, participants received detailed information about the experiment and filled out questionnaires to assess demographic and psychopathological variables. Then, participants were brought to the TSST-G room where they received instructions about the following tasks. After a short preparation period, participants performed the TSST-G with two parts (interview and mental arithmetic) in front of the judges as described below. After the TSST-G,
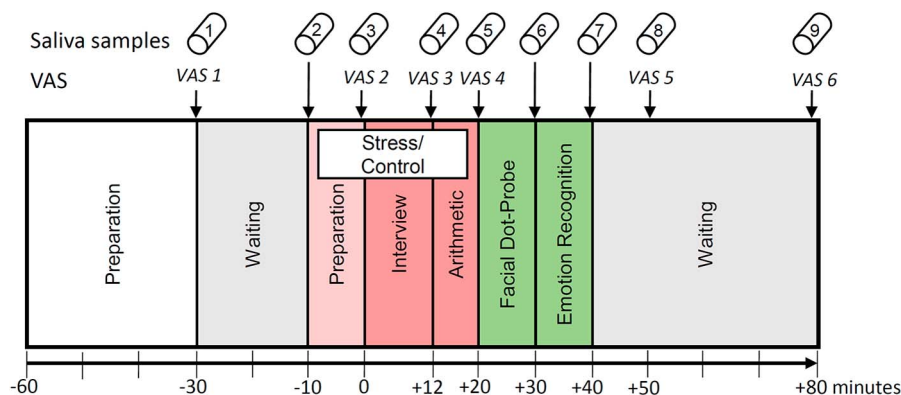
participants were brought to another room where they performed the two facial dot-probe tasks and the emotion detection task (see below). Finally, participants were debriefed after another waiting period and paid for participation. See Figure 1 for an overview of the study procedure.

## Tasks and Measures

### Stress Induction

The TSST-G (von Dawans et al., 2011) was used to induce psychosocial stress. Participants were tested in groups of 4–6 participants and were randomized to either the stress or control condition. Within the first part of the TSST-G stress condition (12 min), participants took part in a public speaking task (mock job interview). The second part (8 min) consisted of a mental arithmetic task (serial subtraction). Participants faced a panel of two neutral evaluators (one male, one female) wearing white lab coats and were videotaped by two cameras. The control condition consisted of simultaneously reading out a text (12 min) followed by counting series of numbers (8 min) in a low voice. This guaranteed a single-blind active control condition that was paralleled for all factors beside the psychosocially stressful components. The procedure was preceded by a 10-min preparation period.

### The Facial Dot-Probe Tasks

Two facial dot-probe tasks were used to assess attentional preferences for angry versus happy faces and for faces in general. The angry/happy facial dot-probe task was a shortened version of the one used in previous studies (Domes et al., 2012; Domes, Normann, & Heinrichs, 2016; Kaiser et al., 2019). Black-and-white facial expressions (angry, happy, and neutral) of six male and six female actors were selected from the Karolinska Directed Emotional Faces Database (Goeleven, De Raedt, Leyman, & Verschuere, 2008). Each trial started with a fixation cross with an average duration of 1,250 ms (varying between 1,000 and 1,500 ms). After the offset, an emotional facial target prime (angry

[A]/happy [H]) each paired with a neutral [N] distractor face of the same person or the control condition (two neutral facial primes [N-N]) appeared on a screen for 500 ms at a horizontal distance of 800 pixels. Then, a dot-probe (10 × 10 pixels gray square) was presented at the location of the previous emotional target (congruent location) or the neutral face (incongruent location). Participants had to indicate the probe's location by pressing one of two buttons as quickly and accurately as possible. Then, a blank screen appeared for 2,000–3,000 ms before the next trial started. The emotional target primes and dot-probes were presented equally often at the left and right position. Trial order was randomized for each participant. The task included five conditions (congruent angry, incongruent angry, congruent happy, incongruent happy, neutral) with 12 trials each, resulting in 60 trials overall. The experiment was presented in a single run which lasted approx. 5 min in total. Median reaction times in congruent trials were subtracted from those in incongruent trials within each facial emotion category. Positive values reflect increased attention ("attentional bias") for the facial target stimulus with a specific emotion.

The second dot-probe task was an adaptation of a previously used task that measures attentional preference for faces compared to nonsocial distractors (Kanat et al., 2017). In this dot-probe task, the 12 neutral facial expressions (see above) served as social target stimuli. Twelve house pictures served as nonsocial distractor stimuli. Each trial started with a fixation cross with an average duration of 1,750 ms (varying between 1,500 and 2,000 ms). Then, two pictures were presented simultaneously in the left and right location at a horizontal distance of 800 pixels lasting for 500 ms. During target trials, a house and a face were simultaneously presented and the probe was presented at the location of the face (congruent) or at the location of the house (incongruent) in half of the trials. During filler trials, either two faces or two houses were presented. Subjects indicated the location of the probe by pressing one of two buttons as quickly as possible. The task comprised a total of 48 trials, half of which

represented target trials or filler trials. Presentation of stimuli and recording of responses were controlled by a PC running Presentation 19.1 (Neurobehavioral Systems, Albany, CA, USA). This task lasted for approx. 5 min. Attentional bias scores were again calculated by subtracting median reaction times in congruent trials from those in incongruent trials. Thus, positive values reflect an attentional preference for faces over houses.

### Emotion Detection Task

The facial emotion detection task (Domes & Zimmer, 2019) comprised facial stimuli from the NIMStim face database (Tottenham et al., 2009) with two different emotional expressions (angry and happy) displayed at three different intensities (low, medium, high). Every block started with the written instruction indicating which emotional expression (angry or happy) had to be detected in the following trials. Twelve stimuli of a specific condition were shown in each block in a random order (six faces with the specific emotion and six neutral faces). Participants had to decide spontaneously whether the emotion was present or absent in the specific face shown by pressing one of two buttons. Stimuli were presented until the button press. Each condition was repeated three times and presented in a random order, resulting in 216 trials with a total duration of approx. 10 min. Presentation of stimuli and recording of responses were controlled by a PC running Presentation 19.1 (Neurobehavioral Systems, Albany, CA, USA). After the initial inspection, the high intensity category was omitted from further analyses because more than 60% of participants showed ceiling effects in terms of 100% correct answers.

The analysis of response data followed signal detection theory (SDT) to reveal both a robust measure of emotion recognition and an independent measure of response bias (Stanislaw & Todorov, 1999). Average hit rate and average false alarms rate of every stimulus category were $z$-transformed and subtracted yielding the sensitivity index $d'$ as a measure of signal detection performance ($d' = z$[hit rate] $- z$[false alarms rate]). In addition, bias scores $c$ were calculated ($c = -0.5 \times (z$[hit rate] $+ z$[false alarms rate]).

### Questionnaires

To assess the subjective psychological response to the TSST-G and the control condition, visual analog scales (VAS) were given to participants at six time points ($-30$, 0, +12, +20, +50, +80; see Figure 1). Participants were asked to rate their momentary level of anxiety and stress. We replaced single missing values by the mean of the preceding and following values of the respective missing data point (14 out of 648 values were missing = 2.2%).

To control for group differences that might interfere with social attention and/or facial emotion recognition, a

number of psychopathological variables were assessed with self-report questionnaires: depressive symptoms with the Beck Depression Inventory (BDI II; Hautzinger, Keller, & Kühner, 2009), chronic stress with the Perceived Stress Scale (PSS; Klein et al., 2016), alexithymia with the Toronto Alexithymia Scale (TAS-20; Bagby, Parker, & Taylor, 1994), social anxiety with the Social Interaction Anxiety Scale (SIAS; Mattick & Clarke, 1998), and gaze anxiety and avoidance with the Gaze Anxiety Rating Scale (GARS; Domes, Marx, Spenthof, & Heinrichs, 2016).

### Saliva Sampling and Analyses

At nine time points ($-30$, $-10$, 0, +12, +20, +30, +40, +50, and +80 min; see Figure 1), saliva samples were collected using Salivettes (Sarstedt, Nümbrecht, Germany). Samples were stored at $-20$ °C until biochemical analysis that measured concentrations of free salivary cortisol and alpha amylase.

For cortisol analysis, a time-resolved fluorescence immunoassay (Dressendörfer, Kirschbaum, Rohde, Stahl, & Strasburger, 1992) was used. Hundred microliter of saliva was used for duplicate analysis (50 µl per well). Salivary alpha amylase was analyzed using the chromogenic molecule 2-chloro-4-nitrophenyl-α-D-maltotrioside (Lorentz, Gütschow, & Renner, 1999). Saliva was diluted 1:200 with assay diluent. Sixteen microliter of the diluted saliva was used for duplicate analysis (8 µl per well). The intra-assay coefficients of variation as well as the corresponding inter-assay coefficients of variation were all below 10%.

## Statistical Analyses

Group differences regarding demographic and psychometric variables were tested with $t$-tests for independent samples.

VAS scores were tested with separate two-way ANOVAs comprising group (stress vs. control) as the between-subject factor and time (six time points) as the repeated measures factor. Effects of stress on the physiological stress response (free salivary cortisol and salivary alpha amylase) were tested with two separate two-way ANOVAs comprising group (stress vs. control) as the between-subject factor and time (nine time points) as the repeated measures factor. In cases where the Mauchly's test for sphericity was significant, Greenhouse–Geisser's ε was used to correct degrees of freedom.

Effects of stress on emotion detection (sensitivity index $d'$) and response tendency ($c$) were tested with two separate three-way ANOVAs comprising group (stress vs. control) as the between-subject factor and valence (angry vs. happy) and intensity (low vs. high) as the repeated measures factors.

Effects of stress on the attentional preference for angry versus happy faces (attention bias in the angry/happy faces

dot-probe task) were tested with a two-way ANOVA comprising group (stress vs. control) as the between-subject factor and valence (angry vs. happy) as the repeated measures factor. The general attention preference for faces (attentional in the face/house dot-probe task) was tested with a $t$-test for independent samples.

Statistical analyses were conducted with SPSS for Windows (Version 25). Significance threshold was set at $p < .05$.

# Results

## Descriptives

The stress and the control group did not differ in age, chronic stress (PSS sum), depressive symptoms (BDI), alexithymia (TAS-20), social anxiety (SIAS), and gaze anxiety and avoidance (GARS). None of the comparisons were significant (see Table 1).

## Manipulation Check: Psychobiological Stress Responses

Separate ANOVAs were calculated on VAS scores over the course of the experiment. For subjective stress, the main effect of time, $F(3.5, 180.9) = 19.7$, $\varepsilon = .696$, $p < .001$, $\eta_p^2 = .275$, the main effect of group, $F(1, 52) = 8.4$, $p = .005$, $\eta_p^2 = .140$, and the time-by-group interaction were significant, $F(3.5, 180.9) = 5.20$, $\varepsilon = .696$, $p = .001$, $\eta_p^2 = .09$ (Figure 2a). The same was true for the VAS on anxiety: The main effect of time, $F(3.2, 168.3) = 17.7$, $\varepsilon = .647$, $p < .001$, $\eta_p^2 = .254$, the main effect of group, $F(1, 52) = 6.64$, $p = .013$, $\eta_p^2 = .113$, and the time-by-group interaction were significant, $F(3.2, 168.3) = 7.59$, $\varepsilon = .647$, $p < .001$, $\eta_p^2 = .127$ (Figure 2b).

The ANOVA on free salivary cortisol levels as a function of time and group revealed a significant main effect of time, $F(2.25, 117.1) = 16.1$, $\varepsilon = .283$, $p < .001$, $\eta_p^2 = .236$, a

significant effect of group, $F(1, 52) = 17.7$, $p < .001$, $\eta_p^2 = .254$, and a significant time-by-group interaction, $F(2.25, 117.1) = 24.4$, $\varepsilon = .283$, $p < .001$, $\eta_p^2 = .319$ (Figure 2c).

The ANOVA on salivary alpha amylase levels as a function of time and group revealed a significant main effect of time, $F(2.21, 115.0) = 12.5$, $\varepsilon = .277$, $p < .001$, $\eta_p^2 = .194$, a nonsignificant effect of group, $F(1, 52) = 0.09$, $p = .770$, $\eta_p^2 = .002$, and a nonsignificant time-by-group interaction, $F(2.21, 115.0) = 2.01$, $\varepsilon = .277$, $p = .134$, $\eta_p^2 = .037$ (Figure 2d).

## Emotion Detection

The ANOVA on detection performance (sensitivity index $d'$) revealed a significant main effect of emotion intensity, $F(1, 52) = 170.9$, $p < .001$, $\eta_p^2 = .767$, and a significant emotion-by-group interaction, $F(1, 52) = 5.34$, $p < .025$, $\eta_p^2 = .093$. No other effects were significant (all $p > .05$). Explorative analyses revealed that the group-by-emotion interaction was mainly driven by increased sensitivity to happy faces with low intensity in the stressed group ($M = 1.16$, $SD = 0.62$) compared to controls ($M = 0.81$, $SD = 0.50$), $t(52) = 2.28$, $p < .027$, $d = 0.62$, and a marginally reduced sensitivity to angry faces with high intensity in the stressed group ($M = 2.06$, $SD = 0.87$) compared to controls ($M = 2.49$, $SD = 0.90$), $t(52) = -1.80$, $p < .077$, $d = -0.49$ (see Figure 3a).

For the confirmatory response tendency ($c$), the ANOVA revealed significant main effects of emotion, $F(1, 52) = 36.9$, $p < .001$, $\eta_p^2 = .415$, and intensity, $F(1, 52) = 168.9$, $p < .001$, $\eta_p^2 = 0.765$. No other effects were significant (all $p < .05$; Figure 3b).

## Attention to Faces

For the dot-probe task testing the potential effects of stress on the attentional preference for angry versus happy faces,

**Table 1.** Group differences in age and psychopathologic variables.

| | Control | | | Stress | | | t-Test | |
|---|---|---|---|---|---|---|---|---|
| | M | SD | Range | M | SD | Range | t | p |
| Age | 25.3 | 4.7 | 19–31 | 24.7 | 3.4 | 20–45 | 0.37 | .710 |
| Chronic stress (PSS; 0–40) | 13.9 | 6.5 | 4–32 | 15.6 | 6.0 | 7–30 | −1.01 | .317 |
| Depressive symptoms (BDI; 0–63) | 7.0 | 7.6 | 0–24 | 7.3 | 6.9 | 0–29 | −0.15 | .885 |
| Alexithymia (TAS; 20–100) | 45.0 | 10.8 | 24–66 | 48.9 | 12.6 | 22–79 | −1.23 | .226 |
| Social anxiety (SIAS; 0–80) | 23.0 | 15.0 | 2–59 | 23.8 | 13.1 | 4–54 | −0.22 | .830 |
| Gaze anxiety (GARS; 0–102) | 13.7 | 17.3 | 0–79 | 18.6 | 19.3 | 0–68 | −1.00 | .321 |

*Note.* BDI = Beck Depression Inventory; GARS = Gaze Anxiety Rating Scale; PSS = Perceived Stress Scale; SIAS = Social Interaction Anxiety Scale; TAS = Toronto Alexithymia Scale; possible ranges are depicted in brackets.
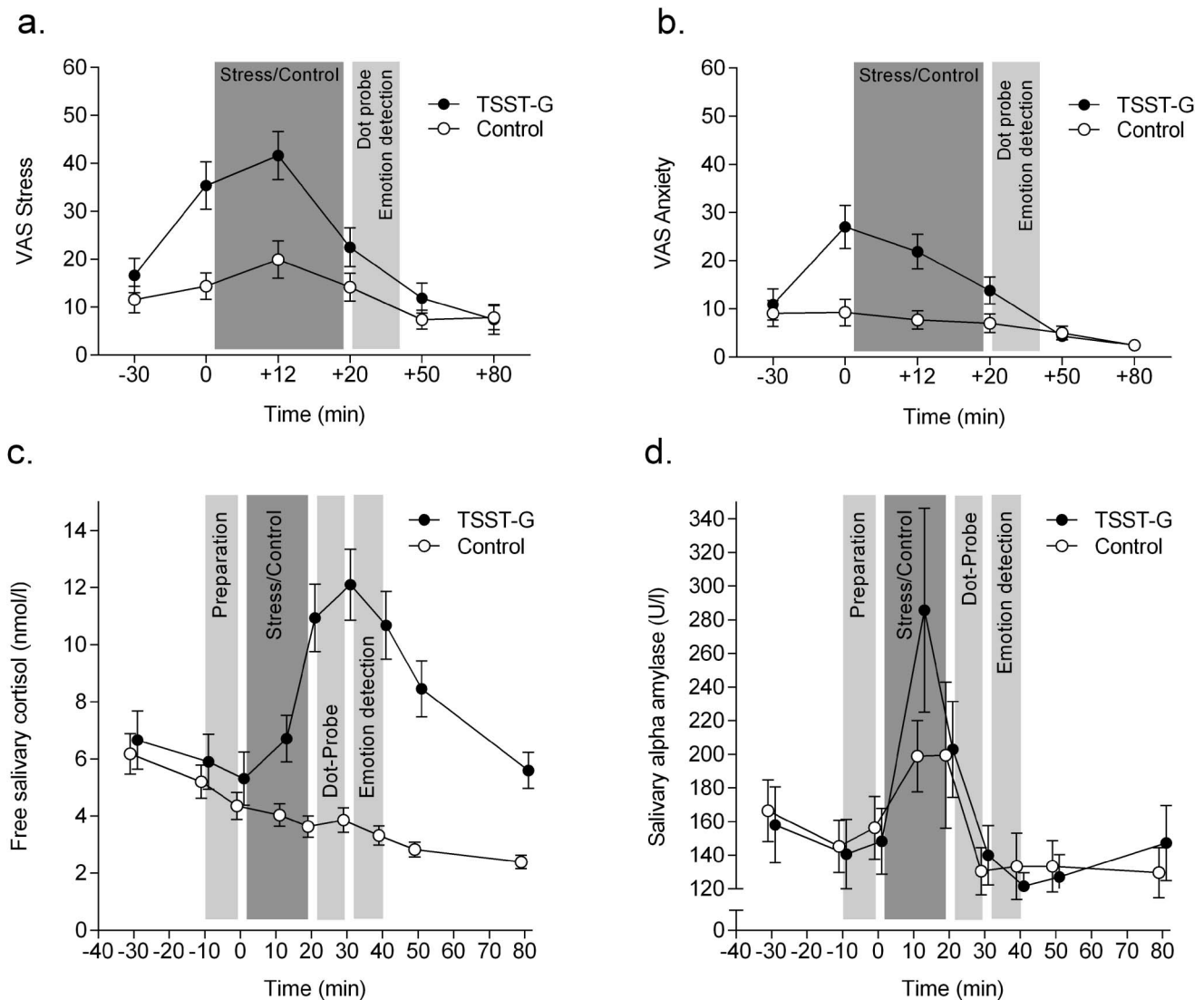
**Figure 2.** (a) Stress, (b) anxiety, (c) free salivary cortisol, and (d) salivary alpha amylase over the course of the experiment. TSST-G = Trier Social Stress Test for Groups; VAS = visual analog scales.

neither the main effects nor the interaction was significant in the two-way ANOVA (all $p > .05$; Figure 4a).

In addition, there was no significant effect of stress on the general preference for faces in the dot-probe task comparing the attentional preference for faces compared to houses ($p > .05$; Figure 4b).

## Discussion

The results show successful stress induction in the stress compared to the control group using the TSST-G procedure with regard to subjective increases as well as activation of the HPA axis and the SNS. There was no effect of stress induction on social attention, neither with

angry versus happy facial stimuli nor with social (faces) versus nonsocial (houses) stimuli. With respect to emotion detection, we found the expected higher response tendency for emotion (happy compared to angry) and intensity (higher compared to lower intensity) for the response bias $c$. For the detection index $d'$, we found the expected improvement in detection of emotions with increasing intensity. Moreover, a significant emotion by group interaction revealed the following pattern: While in the control condition the detection rate for angry faces was higher than the detection rate for happy faces, stress inversed this ratio with a higher detection rate of happy faces compared to angry faces. In order to further examine this pattern, we conducted post hoc analyses that revealed a significantly higher recognition rate ($d'$) of low intensity happy faces in the stress group compared to the control
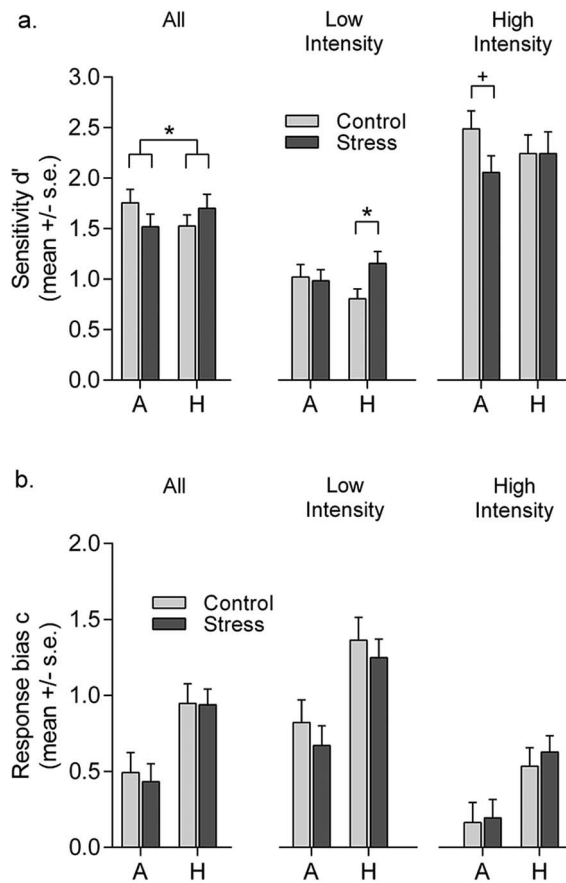
**Figure 3.** Emotion detection performance for angry (A) and happy (H) facial expressions of low and high intensity. (a) Sensitivity index $d'$ and (b) response bias $c$ (positive values represent confirmatory tendency). *$p < .05$; +$p < .10$.
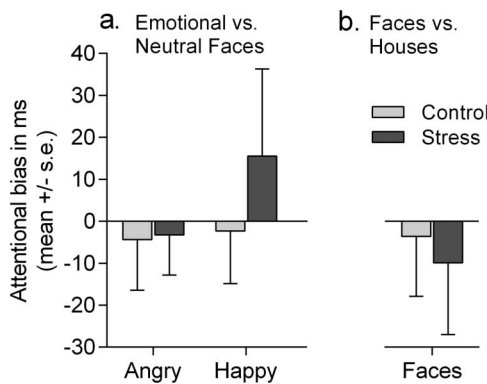


**Figure 4.** Results of the two dot-probe tasks. Attentional bias to angry and happy facial expressions and to neutral faces compared to houses. Positive values represent attentional preference.

condition, while there was a trend toward a lower recognition rate ($d'$) for high intensity angry faces in the stress condition compared to the control condition. This effect of stress on emotion detection is in line with behavioral results, showing increases in prosocial behavior such as trust,

trustworthiness, or sharing during acute stress (von Dawans et al., 2012). With a shift toward higher recognition rates of positive facial stimuli (happy) and lower recognition rates for negative social stimuli (anger), stress may prepare for prosocial behavioral responses in healthy adults. Participants in the stress condition were better in detecting positive (happy) faces of low intensity, which means that acute stress facilitates the perception of happy faces. Taken together, the effects of acute social stress on early emotion recognition processes may resemble a key prerequisite for the initiation of prosocial behavior and represent one mechanism of action of stress on social behavior. On the other hand, the lower detection rate of high intensity negative (angry) faces may reflect a buffering of high threat cues. This is in accordance with data from Jiang et al. (2017) who documented a reduction in attentional bias to threat after stress in an EEG study. This further elucidates a stress-related preparation of approach behavior that may lead to regulatory stress behavior in healthy adults. Taken together, these results strengthen the theory purporting activation of a "tend-and-befriend" stress response pattern in healthy adults, as has already been shown with respect to empathy or emotion recognition (Smeets et al., 2009; Wolf et al., 2015). Domes and Zimmer (2019) found an increase in recognition rate for both emotional categories in the stress group. This, however, may be due to methodological differences in the stress induction method. In their study, they used a virtual reality variant of the TSST (Zimmer et al., 2019) compared to a real-life group stress procedure in our study. As we have already shown that behavioral effects of acute stress are prone to characteristics of the stress situation (e.g., social vs. physical stress; von Dawans et al., 2018), it may be possible that the group versus single setting or real-life versus virtual reality method may exert different effects on behavior.

Our results did not corroborate our second hypothesis. There was no effect of acute stress on social attention. Although measured in another task, one may conclude that the effects of acute stress on emotion recognition were not driven by overall attentional shifts after stress but may rather reflect differences in processing of emotional stimuli with respect to their emotional valence.

The present study also bears general limitations. First, we only included healthy young male participants due to influences of the menstrual cycle, age, or several diseases on the stress response (Kudielka et al., 2009). This limits the generalizability of our results to other groups. Although the "tend-and-befriend" stress response was originally introduced for women (Taylor et al., 2000), it later was extended to be one possible reaction pattern for men, too (Taylor, 2006). There is already behavioral evidence for the "tend-and-befriend" response in women (von Dawans et al., 2019; Youssef, Bachew, Bissessar, Crockett, &

Faber, 2018) but for social cognition, for example, the evidence is less clear (e.g., Smeets et al., 2009). Future studies should try to compare women and men in one study to further clarify gender-specific effects of stress response patterns on social cognitive variables.

In addition, our design did not allow us to test for several interindividual differences that may have modulated the effects of stress on our dependent variables. As Dandeneau et al. (2007) have shown, it may be of interest to include self-esteem in future experiments.

Moreover, our study puts emphasis on emotion attention and detection and lacks a behavioral component. It would be interesting to include social interaction in future designs in order to test the hypothesis of behavioral consequences of the stress effects on the detection rates of different emotions. In order to reveal the underlying psychobiological mechanisms of our effects, either pharmacological approaches or neuroimaging or stimulating techniques would be of interest to further understand the effects of stress and the psychobiological stress response on emotion recognition and behavior in humans.

Taken together, our study adds important evidence to the existing behavioral results on the effects of acute psychosocial stress. With a shift toward higher detection rates of positive versus negative emotions, stress may prepare humans for approach behavior and positive social encounters in order to accomplish protective stress regulating behavior.

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