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Does stress alter everyday moral decision-making?

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Summary Recent studies in the field of neuropsychological decision-making as well as moral psychology emphasize the role of emotions in decision-making. The current study examines whether stress affects moral decision-making. We induced stress in 20 participants with the Trier Social Stress Test (TSST) and also examined 20 participants in a control condition (Placebo TSST). The level of stress was assessed with questionnaires and endocrine markers (salivary cortisol and alpha-amylase). All participants performed a moral decision-making task in which everyday moral dilemmas were described. Dilemmas varied in emotional intensity and each offered a rather egoistic and a rather altruistic option. Results show that groups did not differ significantly in everyday moral decision-making. However, cortisol responses and egoistic decision-making in emotional dilemmas were positively correlated.

Our results indicate that stress per se does not cause more egoistic decision-making in the current setting but suggest an association between the individual's cortisol stress response and egoistic decision-making in high-emotional situations.

1. Introduction

Recent theories emphasize the role of cognitions as well as emotions for moral decision-making (e.g. Greene and Haidt, 2002; Haidt, 2007). There is also growing evidence that stress affects cognitive and emotional processes such as memory, attention and fear conditioning (review in Wolf, 2009) as well as simple decision-making unrelated to morality (Preston et al., 2007; Starcke et al., 2008; van den Bos et al., 2009). Given that moral dilemmas experienced outside the laboratory elicit stress responses by themselves (for example, moral dilemmas medical staff have to face every day; Kälvemark et al., 2004), it seems plausible to ask how those kinds of decisions are influenced by stress. With a lack of direct empirical evidence in previous research, we study here if and how stress affects moral decision-making.

Moral decision-making in experimental-laboratory studies is frequently assessed by complex moral dilemmas such as the trolley problem (Thomson, 1985) or modified versions (Cushman et al., 2006; Valdesolo and DeSteno, 2006; Greene et al., 2008; Cikara et al., 2010). The trolley problem consists of the switch dilemma and the footbridge dilemma. In the switch dilemma, people typically judge that it is morally acceptable to divert a runaway trolley onto a side track, where it will kill only one person in order to save the lives of five people. In the footbridge dilemma, the only way to save five people from a runaway trolley is to push someone off a

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footbridge onto the railway which will stop the trolley but kill the person being pushed. In this dilemma, people typically judge that it is morally inacceptable to push the person. According to Greene et al. (2001), the footbridge dilemma is perceived as emotionally more aversive (compared to the switch dilemma) and elicits high personal involvement.

The brain regions involved in moral decision-making are areas that are also sensitive to stress (review in Dedovic et al., 2009). Recent neuroimaging studies revealed consistent results indicating that a specific network of brain regions is involved in moral decision-making (Greene et al., 2001, 2004; Moll et al., 2001; Heekeren et al., 2003; Luo et al., 2006; Schaich Borg et al., 2006). The network includes brain areas associated with cognitive processes (i.e., the right dorsolateral prefrontal cortex, and the bilateral inferior parietal lobe), emotional processes (i.e., the medial prefrontal cortex, the posterior cingulate/precuneus, region of the superior temporal sulcus/inferior, the parietal lobe, and the amygdala), and conflict processing such as the anterior cingulate cortex (Greene et al., 2001, 2004). Further evidence for the involvement of brain regions associated with emotion processing for moral decision-making is provided by studies examining patients with lesions or dysfunctions of those brain regions. Patients with lesions of the ventromedial prefrontal cortex show altered moral decision-making. Compared to healthy control participants, these patients judged personal moral violations more often as being acceptable behaviours, and they did so more quickly (Ciaramelli et al., 2007; Koenigs et al., 2007). Patients with fronto-temporal dementia (also affecting ventromedial prefrontal cortex functioning) were also impaired in their ability to make immediate, emotionally based moral judgments (Mendez et al., 2005). Results emphasize the importance of the medial prefrontal cortex and in particular the ventromedial prefrontal cortex for moral decision-making.

Stress — both in real life and experimentally induced by either a social-cognitive stress task or by application of stress hormones — can influence cognitive and emotive functioning. Acute stress leads to an activation of the sympathetic nervous system [SNS] (reviews in Nater and Rohleder, 2009; Rohleder and Nater, 2009) and a release of cortisol through the activation of the hypothalamus pituitary adrenal axis [HPA] (reviews in Kirschbaum and Hellhammer, 1994; Dickerson and Kemeny, 2004). Recent neuroimaging studies have shown that stress can also lead to changes in prefrontal cortex and limbic system functioning (e.g. Pruessner et al., 2004, 2008; Kern et al., 2008; review in Dedovic et al., 2009). These findings are in line with previous studies finding that stress affects cognitive functions associated with prefrontal cortex integrity such as working memory (e.g. Domes et al., 2004; Buchanan et al., 2006; Oei et al., 2006; Schoofs et al., 2008, 2009) and attention (e.g. Bohnen et al., 1990; Vedhara et al., 2000). In addition, emotional reactions linked to limbic system functioning, such as fear conditioning, are also sensitive to stress (e.g. Jackson et al., 2006; Merz et al., 2010). There seems to be an interaction between stress, cognition and emotion; stress effects on memory and attention differ depending on whether emotional or neutral stimuli are processed (review in Wolf, 2009).

In summary, we know that stress can affect cognitive and emotional functioning. Previous findings also emphasize the important role of cognition and emotion in moral decision-making. Moral decisions in everyday life may lead to acute stress responses. The reverse link — effects of acute stress on moral decision-making in everyday life moral dilemmas — has not been studied so far.

The aim of the present study was to investigate whether moral decision-making is altered by stress. We hypothesised that stress would lead to more egoistic and less altruistic decisions. We make "egoistic" decisions mainly for our own personal benefit, whereas "altruistic" decisions are made for the benefit of other person(s), because we feel their needs (Batson and Shaw, 1991). Emotions are necessary to feel other people's needs. Stress induces emotions itself (especially fear) through a stimulation of the amygdala by stress hormones (review in Rodrigues et al., 2009). Since the acute experience of fear may promote egoistic intentions such as feathering ones own nest and saving ones own bacon, fear may also interfere with empathizing or acting according to other people's needs. Cognitions might provide the best decision strategy to fulfil other people's needs. There is evidence that stress affects simple, non-moral decision-making, based on emotional learning processes as well as strategy application. A negative relationship between life stress, anxiety and decision-making in an analogies-task has been demonstrated (Garvey and Klein, 1993). Students reporting stress due to impending exams showed a bias to short-term thinking in a decision-making task based on emotional feedback processing (Gray, 1999). Recent neuropsychological studies also indicate that stress induced in the laboratory is related to decision-making that leads to disadvantageous results in the long run. In decisions based on emotional feedback processing, stressed participants had a slower learning curve (Preston et al., 2007). In male participants, a relationship between cortisol responses and long-term disadvantageous decisions has been found (van den Bos et al., 2009). We previously observed that stress led to more risky choices in decisions based on strategy application as well as emotional feedback processing. We also observed a correlation between risky decision-making and the cortisol stress response of the participants (Starcke et al., 2008).

In the present study, we used a set of moral dilemmas that could occur in everyday life either high or low in emotionality, each offering a more egoistic and a more altruistic decision alternative (C. Polzer, personal communication; for a detailed description of the task see the methods section). We induced stress with the Trier Social Stress Test (TSST; Kirschbaum et al., 1993) and measured the level of stress with questionnaires and assessed salivary cortisol and alpha-amylase. We hypothesised that stress would lead to more egoistic decisions, because stress affects cognitive and emotional processes that are important for moral decision-making.

2. Participants and methods

2.1. Participants

Forty students, aged 19—33 years (mean = 23.83, S.D. = 3.87; 22 males) were recruited from the University of Duisburg-Essen. Half of the students were randomly assigned to the stress group; the other half was assigned to the control group. Participants with neurological or psychiatric disease, acute or chronic disease, social phobia or extraordinary stressful life circumstances, as determined by a telephone screening, were not included due to ethical reasons. Participants with intake of medication, smoking, body mass index above 26 (kg/m^2), recent immunisation, shift-work, intake of oral contraceptives, or pregnancy were excluded because these factors influence hormonal measures (reviews in Kudielka et al., 2009; Rohleder and Nater, 2009). Participants were asked to be awake at least for 4 h before testing and refrain from eating and drinking anything besides water 1 h before testing because of the saliva measures. All investigations took place between 10 am and 5 pm. The number of participants in the stress group and control group tested am and pm was balanced to ensure that there were no group differences in endocrine measures due to circadian baseline differences (Kudielka et al., 2004). The study was approved by the local ethics committee of the University of Duisburg-Essen. All subjects gave written informed consent prior to the investigation and were paid 15 € for their participation. After participation, participants were fully debriefed about the goal of the study.

2.2. Methods

2.2.1. Stress induction

We used the Trier Social Stress Test (TSST; Kirschbaum et al., 1993) to induce stress in the stress group. Participants had to perform two tasks in front of a selection committee and a video camera. The committee consisted of two experimenters dressed in white coats and introduced as being trained in "behavioural observation". Furthermore, participants were told that their performance would be recorded on video in order to later analyse voice pitch and nonverbal behaviour. Participants had a preparation time of 5 min. After that they had to deliver a speech without using notes for 5 min. During the speech participants had to convince the committee that he or she was the perfect applicant for a vacant position. Then the participant had to serially subtract the number 17 from 2043 as fast and accurately as possible within 5 min. On every failure the committee asked the participant to start again at 2043. The committee did not provide any further feedback but acted in a very cold and reserved manner. The TSST has been shown to lead to a robust release of cortisol through the activation of the hypothalamus pituitary adrenal axis [HPA] (reviews in Kirschbaum and Hellhammer, 1994; Dickerson and Kemeny, 2004) and the sympathetic nervous system [SNS] which can be measured with the enzyme alpha-amylase (reviews in Nater and Rohleder, 2009; Rohleder and Nater, 2009).

2.2.2. Control condition

In the control group, the placebo version of the TSST was used (Het et al., 2009). Participants also had to deliver a speech without using notes and to perform an arithmetic task but without an audience. Thus, the stress-inducing social evaluative components (see Dickerson and Kemeny, 2004) were removed. The participants were led into an empty room and were asked to deliver a speech about a movie, a novel or a recent holiday trip. They were told that no audience would be present and that they would not be recorded in any way. After a preparation time of 5 min the experimenter re-entered the room and asked the participant to talk loudly in a standing position. Then the experimenter left the room. After 5 min the experimenter re-entered the room and asked the participant to start adding the number 15 starting at 0 for 5 min and left the room again. The placebo TSST elicits no cortisol responses and only minor alpha-amylase responses that are significantly smaller than responses elicited by the TSST, most likely reflective of the physical demands of the control condition (standing and talking) (Het et al., 2009).

2.2.3. Measurements of stress response

To measure the change of stress levels in the stress group and the control group, questionnaires and physiological indicators were used. Questionnaires were administered before the TSST/placebo TSST (pre-treatment) and before the debriefing (post-treatment). The German version of the state anxiety subscale of the State Trait Anxiety Inventory (STAI; Spielberger et al., 1977) consists of 20 questions about current anxiety (e.g. "I feel nervous") to be answered on a four-point scale ranging from 1 "not at all" to 4 "extremely". The ratings were summed up to create a score for current anxiety from 20 (minimal anxiety) to 80 (maximal anxiety). The German version of the Positive and Negative Affect Schedule (PANAS; Watson et al., 1988) consists of 10 items for positive affects (e.g. "interested", "enthusiastic") and 10 items for negative affects (e.g. "upset", "ashamed") describing current affect. Answers are given on a five-point scale from 1 "very slightly or not at all" to 5 "extremely". The ratings were summed up to a score for positive affect and a score for negative affect both ranging from 10 (minimum) to 50 (maximum). Both questionnaires have been administered in multiple studies to assess affective changes induced by the TSST. We acquired endocrine indicators of stress by sampling salivary cortisol and salivary alpha-amylase (sAA) concentrations before and during the course of task performance. An increase for both of the latter endocrine indicators has been found during psychosocial stress with cortisol levels rising as a result of HPA axis activity (see Dickerson and Kemeny, 2004), and sAA levels rising as a result of SNS activation (see Nater and Rohleder, 2009; Rohleder and Nater, 2009). Cortisol reactions typically have a latency of 10—15 min after the beginning of the TSST, while the peak typically occurs after 25 min (Kirschbaum and Hellhammer, 1994; Dickerson and Kemeny, 2004). SAA reactions have a rapid increase and a quick normalization. In contrast, in the placebo TSST cortisol reactions decrease rather than increase and sAA reactions are smaller than in the original TSST. Salivary cortisol and sAA levels were assessed out of unstimulated saliva samples obtained using Salivette collection devices (Sarstedt, Nuembrecht, Germany). To determine cortisol and sAA levels, the saliva samples were sent to Dresden (Germany) to Prof. Kirschbaum laboratory. Free cortisol levels were measured using a commercially available immunoassay (IBL, Hamburg, Germany). For sAA analysis, a quantitative enzyme kinetic method was used as described in details elsewhere (van Stegeren et al., 2006). Inter- and intracoefficients of variation were below 10% for both assays.

2.2.4. Moral decision-making task

The Everyday Moral Decision-Making Task (EMDM; C. Polzer, personal communication; see appendix for the dilemmas, development of the dilemmas and psychometric properties) was used. In this task, 20 everyday dilemmas were presented in written format on a computer screen in a randomized order via the program "Presentation" (Neurobehavioral Systems) in the participant's native language (i.e., German). Half of

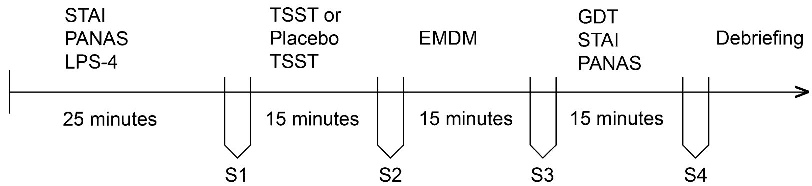

Figure 1 Design and procedure of the experiment.

the 20 dilemmas were highly emotional, the other half were low-emotional in nature. Each of the 20 dilemmas offered a more egoistic and a more altruistic decision alternative. Each dilemma had to be answered with "yes" or "no" within a time limit of 30 s. An example of a low-emotional dilemma is: "You have slightly scratched another car while parking. It is dark and nobody has seen you. Would you leave a message for the owner of the car?" The answer "yes" is the altruistic alternative, while the answer "no" is the egoistic alternative. An example of a high-emotional dilemma is: "Your partner is suicidal and you feel uncomfortable in this relationship. Would you leave your partner?" The answer "no" is the altruistic alternative, while the answer "yes" is the egoistic alternative. For the purpose of analysis, the percentage of altruistic decisions is calculated.

2.2.5. Intelligence test

We assessed intelligence with the subtest "Logical Reasoning" of a German intelligence test (subtest 4 of the *Leistungsprüfsystem*, LPS-4; Horn, 1983) in order to demonstrate that experimental groups did not differ in global intellectual functioning. The test consists of 40 rows of sequences of letters and numbers that follow a logical rule. Each row contains one element that does not logically fit into the order of the row. Subjects are given a time limit of 8 min to discover and cross out the illogical element in as many rows as possible. Results are transformed into IQ values.

2.2.6. Design and procedure

First, participants gave written informed consent. Then the procedure — as shown in Fig. 1 — started. Saliva measures were taken immediately before (S1), 15 min (S2), 33 min (S3) and 51 min (S4) after the beginning of the treatment (TSST vs. Placebo TSST). Each saliva measure was conducted with one salivette for 3 min. After the third point of measurement another decision-making task, the Game of Dice Task (GDT; Brand et al., 2005) (not a topic of this paper) was performed. Finally, participants were debriefed, paid and thanked for participation.

2.2.7. Statistical analysis

All analyses have been carried out with SPSS 17.0. *T*-tests for independent samples were used to analyse between-group differences in age, intelligence, peak cortisol response (S3), psychological indicators of stress and everyday moral decision-making. Cohens *d* was used as a measure of effect sizes when appropriate. Analysis of variance with repeated measurements (ANOVA) was used to compare endocrine measures between groups with "group" as the between subject factor and "points in time" as the within subject factor. Greenhouse—Geisser corrected *p*-values were used when appropriate. Partial eta squared ($\eta_p{}^2$) was used as a measure of effect size. The relationship between cortisol responses (delta increase), affect and everyday moral decision-making was calculated with Pearson's correlation. The interaction of cortisol response and affect on decision-making was analysed with a moderated hierarchical regression analysis. Two-tailed tests were performed for all analyses and *p* was set to .05.

3. Results

3.1. Demographic variables

The experimental groups did not differ in age (mean stress group = 23.15, S.D. = 3.98; mean control group = 24.50, S.D. = 3.74; $t(38) = -1.11$, $p > .05$), gender (in both groups there were nine female and 11 male subjects), and IQ (mean stress group = 118.0, S.D. = 10.57; mean control group = 115.0, S.D. = 13.75; $t(38) = .62$, $p > .05$) thereby demonstrating successful randomization.

3.2. Level of stress

3.2.1. Psychological indicators of stress

Comparisons between groups showed that anxiety, positive and negative affect did not differ between groups before stress was induced in the stress group. After the stress induction, the stress group had higher anxiety scores and

Table 1 Results of the questionnaires assessing psychological indicators of stress before (pre) and after (post) the treatment.

Questionnaire	Stress group mean (S.D.)	Control group mean (S.D.)	*T*	*df*	*p*	*d*
STAI-State-pre	38.15 (7.39)	35.75 (6.30)	1.11	38	.28	.35
STAI-State-post	40.95 (9.05)	36.20 (5.42)	2.02	31.07	≤.05	.64
PANAS-PA-pre	28.85 (5.29)	31.75 (5.00)	−1.78	38	.08	.56
PANAS-PA-post	27.70 (7.18)	32.95 (5.94)	−2.52	38	<.05	.80
PANAS-NA-pre	12.45 (2.63)	12.15 (2.39)	.38	38	.71	.11
PANAS-NA-post	14.10 (4.17)	12.85 (3.00)	1.09	38	.28	.35

STAI = State Trait Anxiety Inventory; PANAS = Positive and Negative Affect Schedule; PA = Positive Affect; NA = Negative Affect.

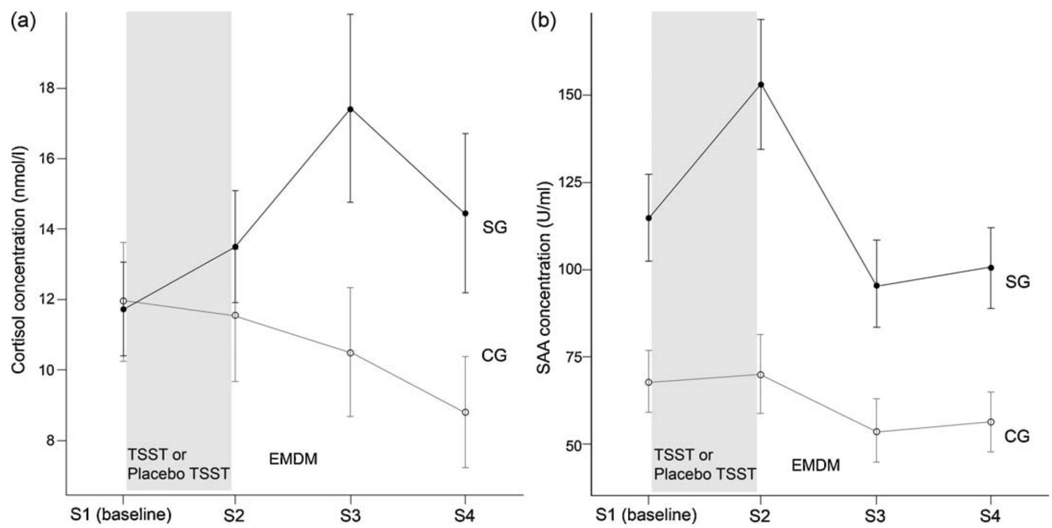

Figure 2 (a) Results of the cortisol measures in the stress group (SG) and the control group (CG) at the four points of measurement. Error bars represent standard errors of the mean. S = salivary sample; nmol = nanomole; l = liter. (b) Results of the alpha-amylase measures (sAA) in the stress group (SG) and the control group (CG) at the four points of measurement. Error bars represent standard errors of the mean. S = salivary sample; U = units; ml = milliliter.

lower positive affect scores than the control group, whereas negative affect did not differ between groups. Results are shown in Table 1.

3.2.2. Physiological indicators of stress

For cortisol measures there was no significant main effect for "group", $F(1, 35) = 2.93$, $p > .05$, $\eta_p^2 = .08$, but a significant main effect for "point in time", $F(1.42, 49.56) = 3.99$, $p < .05$, $\eta_p^2 = .10$, and a significant interaction of "group" × "point in time", $F(1.42, 49.56) = 8.86$, $p < .005$, $\eta_p^2 = .20$. Significant differences between groups at the third point of measurement (S3) were observed, indicating higher values in the stress group than in the control group, $t(37) = 2.36$, $p < .05$, $d = .76$. Results are shown in Fig. 2a. SAA measures revealed significant main effects for "group", $F(1, 32) = 10.34$, $p < .005$, $\eta_p^2 = .24$, "point in time", $F(2.26, 72.44) = 23.57$, $p < .001$, $\eta_p^2 = .42$, and also a significant interaction of "group" × "point in time", $F(2.26, 72.44) = 3.87$, $p < .05$, $\eta_p^2 = .11$. Results are shown in Fig. 2b.

3.3. Everyday moral decision-making

To compare groups on EMDM, the percentage of altruistic decision-making was calculated. Groups did not differ in the percentage of altruistic decisions, neither across all dilemmas nor within high-emotional or low-emotional dilemmas. Results are shown in Table 2.

3.4. Relationships between decision-making and physiological indicators of stress

We performed correlations between decision-making and cortisol-delta increases for all participants. Cortisol-delta increases were used in previous studies (e.g. Wolf et al., 2001): the baseline value was subtracted from the value at the third point of measurement (S3 [peak value] − S1). A significant negative correlation between the cortisol-delta (cortisol increase) and decision-making in high-emotional dilemmas was observed ($r = -.37$, $p < .05$) indicating that a stronger cortisol response co-varies with a tendency towards egoistic decisions in the high-emotional moral dilemmas. However, there was no correlation between cortisol-delta and decisions in low-emotional dilemmas ($r = -.01$, $p = .96$). Within the high-emotional dilemmas only, correlations between cortisol-delta and decision-making were then analysed for the two groups separately. The negative correlation remained significant in the stress group ($r = -.56$, $p < .05$), but not the control group ($r = -.13$, $p = .59$). Results are shown in Fig. 3a and b. For sAA measures (S2 [peak value] − S1 [baseline value]) no such correlations were observed.

Positive affect after the experimental manipulation correlated with decision-making in high-emotional dilemmas ($r = .34$, $p < .05$) indicating positive affect co-varies with altruistic decision-making. This pattern was not observed for low-emotional dilemmas ($r = .21$, $p = .18$). In addition,

Table 2 Percentage of altruistic answers in the everyday moral decision-making task.

Decision-making	Stress group mean (S.D.)	Control group mean (S.D.)	*T*	*df*	*p*	*d*
Over all dilemmas	49.50 (17.16)	47.50 (11.41)	.43	33.06	.67	.14
High-emotional dilemmas	49.00 (16.00)	50.50 (15.04)	−.31	38	.76	.10
Low-emotional dilemmas	50.00 (25.34)	44.50 (15.38)	.83	31.33	.41	.26

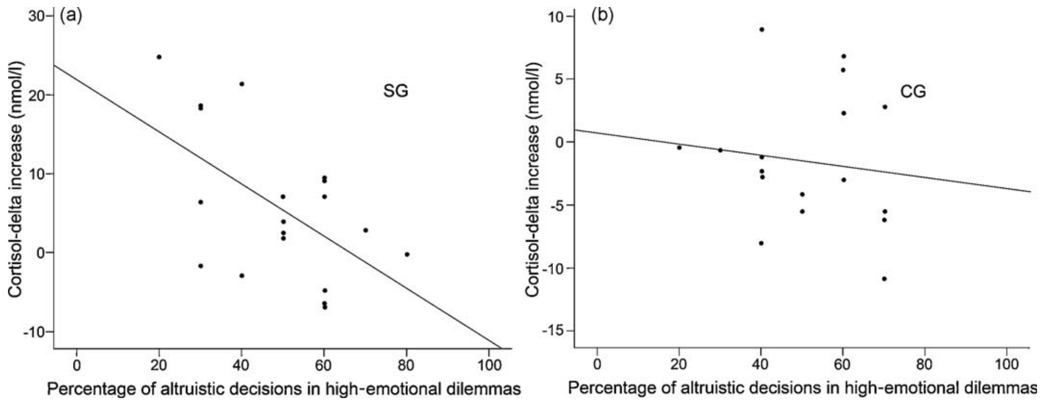

Figure 3 (a) Correlation between the cortisol-delta increase and the number of altruistic decisions in high-emotional dilemmas ($r = -.56$) in the stress group (SG). (b) Correlation between the cortisol-delta increase and the number of altruistic decisions in high-emotional dilemmas ($r = -.13$) in the control group (CG).

we calculated interactions between cortisol-delta and positive affect using moderated regression analysis with decision-making in high-emotional dilemmas as dependent variable. In the first step (hierarchical regression analysis), both variables explained 21.6% of variance in decision-making, F (2, 35) = 4.81, $p < .05$. In a second step, we calculated the interaction effect of cortisol-delta increase and positive affect (all variables centralized, see Cohen et al., 2003). The inclusion of cortisol-delta contributed 12.2% of variance explanation (change in $R^2 = .12$, $F(1, 38) = 5.30$, $p < .05$) and positive affect 8.3% (change in $R^2 = .08$, $F(1, 37) = 3.89$, $p = .05$). The interaction of both variables did not significantly increase the explanation of variance in the moral decisions (0.5%, change in $R^2 = .01$, $F(1, 36)$, $p = .62$).

4. Discussion

In contrast to our hypothesis, we did not find a main effect of acute experimentally induced stress on decision-making in everyday moral dilemmas. However, we observed a positive relationship between the individuals' cortisol response and egoistic decision-making in high-emotional dilemmas. A larger increase was associated with more egoistic decisions.

As expected, a necessary precondition for interpreting results of the moral decision-making performance, the TSST was effective as a stressor: Participants of the stress group showed subjective and physiological stress responses. This result has been shown in numerous studies using the TSST. Cortisol reactions, under control of the HPA axis, are established endocrine markers of psychosocial stressors (review in Dickerson and Kemeny, 2004). Recent studies have shown that sAA secretion, which is under adrenergic control and therefore an indirect marker of SNS activity, also increases during psychosocial stress tasks (reviews in Nater and Rohleder, 2009; Rohleder and Nater, 2009). However, endocrine stress reactions show large inter-individual differences (Kudielka et al., 2009) which might explain why no group differences but a correlation between cortisol increase and decision-making was found.

As previously stated, participants in the stress condition did not overall decide more egoistically than participants in the control condition, no matter whether dilemmas were high-emotional or low-emotional. To our best knowledge, this is the first study investigating the effect of stress on everyday moral decision-making. Results do not support our hypothesis that stress leads to more egoistical decision-making. This prediction was drawn from studies indicating that moral decision-making relies on brain regions associated with cognition and emotion such as the prefrontal cortex and the limbic system (Greene et al., 2001, 2004; Moll et al., 2001; Heekeren et al., 2003; Mendez et al., 2005; Luo et al., 2006; Schaich Borg et al., 2006; Ciaramelli et al., 2007; Koenigs et al., 2007). These regions are affected by stress (review in Dedovic et al., 2009). In addition, decision-making in neuropsychological tasks (fictitious monetary tasks) also relies on these brain regions (reviews in Brand et al., 2006; Dunn et al., 2006) and stress affects performance in these tasks (Preston et al., 2007; Starcke et al., 2008; van den Bos et al., 2009).

Although we found no group differences between stressed and unstressed participants in decision-making, an interesting correlation was detected: The increase of cortisol was negatively correlated with altruistic decision-making in emotional dilemmas. This might indicate that the HPA axis stress response is related to egoistic decision-making. This correlation is in line with the neuropsychological studies that found correlations between physiological stress responses and decision-making (Starcke et al., 2008; van den Bos et al., 2009) and subjective stress and decision-making (Garvey and Klein, 1993). Correlations between endocrine stress responses and neuropsychological functions such as memory have also been found in several studies (e.g. Wolf et al., 2001; Schoofs et al., 2008). The differential relationship between cortisol increase and decision-making in high-emotional, but not in low-emotional dilemmas found in the current study is of special interest. It is generally in line with neuropsychological studies demonstrating that stress has more pronounced effects on the processing of emotional compared to neutral material (reviews in Roozendaal et al., 2009; Wolf, 2009). Brain regions associated with emotional processing, such as the amygdala, have numerous cortisol receptors and are very sensitive to stress (review in Rodrigues et al., 2009). A stimulation of the amygdala by stress responses might lead to more fearful and egoistic decisions. The effect of the stress hormone cortisol on moral decision-making could be specified pharmacologically through the exogenous application of cortisol in future studies. A more psychological explanation for the putative relationship between stress responses and egoistic decisions in emotional situations is that stress induces emotions itself (especially fear) and that those emotions might interfere with the situation-specific emotions that are necessary for making a morally good decision. In such situations, the intention to save one's own bacon and to feather one's own nest might be more pronounced than feeling other people's needs.

In the current study, positive affect was correlated with altruistic decision-making. This seems to be consistent with the relationship of cortisol responses and egoistic decision-making. However, we observed no interaction between physiological stress response, positive affect and decision-making was observed. Recent studies investigating the effects of manipulated affect and self-worth on moral decision-making have shown different results. Valdesolo and DeSteno (2006) found that positive mood leads to more utilitarian judgments, Sachdeva et al. (2009) found that reduced self-worth leads to more altruistic decision-making (a phenomenon the authors call ''moral cleansing''). Thus, the exact mechanisms that connect stress responses and affect moral decision-making remain to be investigated in future studies.

It should be noted here that the large individual variance in the actual stress response (see above) may have precluded any group differences. Another limitation of the current study — also related to individual variance and the small sample size — is that we assessed stress responses before and after the treatment, but performance in the moral decision-making task was only assessed once, after the treatment. In future studies, a within-subjects design might be useful to detect a global effect of the stressor on moral decision-making. Furthermore, the lack of group differences might due to the fact that the current study differs from other decision-making studies in several ways. First, a homogeneous sample of healthy and highly educated university students was tested. The stress induction might have had less influence on functional brain activity than would a dysfunction due to a neurological or psychiatric disease. Students might respond to moral dilemmas in a more sophisticated way than other populations. Secondly, the everyday moral decision-making task differs from the moral dilemmas used in previous studies as well as from neuropsychological decision-making tasks. The dilemmas were intended to mimic situations in everyday life. As a consequence, it might be that these dilemmas elicit weaker emotional responses than the dilemmas developed by Greene et al. (2001) involving more extreme life-and-death decisions. Emotional and non-emotional dilemmas elicit different activation patterns in the brain (Greene et al., 2004) and might therefore be differentially affected by stress. Emotional dilemmas that do not elicit such strong emotions might be less susceptible for stress-induced changes. An important difference between the current task and neuropsychological decision-making tasks is that the everyday dilemmas do not offer feedback whether the decision was good or bad. In previous neuropsychological studies, stress was suggested to affect decision-making by deteriorating the feedback processing abilities (Preston et al., 2007; Starcke et al., 2008; van den Bos et al., 2009). In the study by Starcke et al. (2008), differences in decision-making between stressed and unstressed participants only occurred when feedback was provided, otherwise group differences vanish. Thus, feedback processing is an important component of decision-making that has been provided neither in the current study nor in previous studies using complex moral dilemmas. It might be worth investigating in future studies how feedback may influence moral decisions. Providing feedback after a moral decision may be helpful for detecting changes of moral decision-making due to stress-related changes of feedback processing. When no feedback is provided, previous experiences with a certain decision-situation might be a moderating variable. We asked for this type of information in the current study, but only broadly, i.e., no details about the decision and the consequences were collected. Furthermore, one has to keep in mind that we used a laboratory stressor and a laboratory decision-making task that differ from both, real life stressors and real life moral dilemmas. There are many types of stressors outside the laboratory that would probably elicit stronger stress reactions than the TSST (e.g. mobbing, death of a relative). The moral dilemmas were not created on the basis of philosophical considerations, but based on their plausibility and likelihood for occurring in everyday life. Nonetheless, there are many factors that might influence moral decision-making in real life. Personal relevance of decisions' outcomes and attitudes towards certain themes might determine the stress reactions as well as the decisions themselves. The actual stress reaction that is elicited when a person is confronted with a moral dilemma and the stress reaction's influence on subsequent decision-making behaviour should be addressed in future studies.

In summary, our results indicate that stress overall does not impair everyday moral decision-making in the current setting, but endocrine stress responses might be related to egoistic decision-making. This relationship was only found in high-emotional situations suggesting that emotional and cognitive processes involved in moral decision-making are differentially affected by stress reactions. Moral decision-making outside the laboratory has been shown to elicit stress responses by itself (e.g. Kälvemark et al., 2004). Thus, not only external stressors but also situation-specific stressors might elicit stress reactions that could be a risk factor for making an egoistic decision. Possibly, such dilemmas elicit stronger stress reactions and emotions than those created in the laboratory. If even moderate laboratory stress and decision-making are related, the implications of our results for the risk of making an egoistic decision when confronted with a real high-emotional moral dilemma become evident.

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The funding source (University of Duisburg-Essen) had no further role in the design of the study, and in the collection, analysis and interpretation of the data. It had no role in the decision to submit the paper for publication either.

Conflict of interest

The authors declare that they have no conflict of interest.

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Appendix A. Everyday moral dilemmas

For the current study 40 dilemmas were created on the basis of consideration (modified after Stock, 1987) and 20 of them were selected on the basis of empirical testing for the final test. Low-emotional dilemmas contain at most two emotional words, high-emotional dilemmas at least four emotional words. The 40 dilemmas were performed by 106 participants. Dilemmas with high, middle and low item difficulties (index of altruistic decisions) in each category (high- and low-emotional) were selected. Dilemmas were also rated on a four-point Likert scale if the situation has elicited an emotion from 1 ("not at all") to 4 ("extremely"). Only dilemmas that were rated on average as either high-emotional or low-emotional (cut off at 2) were selected. It was also asked whether a similar situation has ever occurred to the participant in everyday life with the options 0 ("no") or 1 ("yes"). Only dilemmas that have occurred in everyday life at least to some participants were selected. Students and non-students including participants of middle age did not differ concerning the rating if similar situations have ever occurred to them in everyday life. Differences were significant neither for all dilemmas, $t(103.08) = .56$, $p = .58$, $d = .11$, nor in one of the single dilemmas. In each category (high- and low-emotional) half of the answers "yes" represent the altruistic decision, whereas the answers "no" represent the egoistic decision and vice versa. Following the selection process, another sample of 130 participants performed the selected dilemmas and rated their emotionality, thus the complete sample consists of 236 participants. A retest reliability of .89 concerning the altruistic vs. egoistic decisions in all dilemmas has been observed in a sample of 19 participants. The single dilemmas, item difficulty and ratings of emotionality and percentage of occurrence in everyday life are presented below.

Low-emotional dilemmas

Item difficulty: mean = .48, S.D. = .18.
Emotionality ratings: mean = 1.81, S.D. = .44.
Rating of occurrence in everyday life: mean = 46.32%, S.D. = 21.62%.

Altruistic answer = no; egoistic answer = yes

1. You have purchased concert tickets for you and a friend. The tickets differed in price. Would you pay for the cheaper ticket?
2. After an accident your insurance provides you with a home help, but you have already recovered. Would you still use the home help?
3. You watch a boring theatre play which has few visitors. Would you leave the play early?
4. A friend always tells you incredible stories and you suspect that they are made up. Would you confront your friend?
5. In the supermarket you wait at the meat counter and an elderly man pushes to the front. Would you complain?

Altruistic answer = yes; egoistic answer = no

6. You find a 20 € note on the pavement. Then you see a homeless man looking for food in the dustbin. Would you give him the money?
7. When you move out your landlord gives you a drawing that he does not like. You know that this drawing is quite valuable. Would you tell him?
8. A well-dressed passerby asks you for money to buy a bus ticket because he lost his wallet. Would you give him the money?
9. Another air passenger asks you to bring cigarettes through customs because she has already the maximum amount of cigarettes. Would you do this?
10. You have slightly scratched another car while parking. It is dark and nobody has seen you. Would you leave a message for the owner of the car?

High-emotional dilemmas

Item difficulty: mean = .45, S.D. = .15.
Emotionality ratings: mean = 2.77, S.D. = .50.
Rating of occurrence in everyday life: mean = 28.58%, S.D. = 17.37%.

Altruistic answer = no; egoistic answer = yes

11. You have a wife and kids and your employer offers you to work for unspecified time in Japan. Would you accept this offer?
12. When your grandparents move, you find the diary of your grandmother and you are curious. Would you read it?
13. You meet the love of your life, but you are married and have children. Would you leave your family?
14. Your partner is suicidal and you feel uncomfortable in this relationship. Would you leave your partner?
15. You play cards for money and you can catch a glance of the cards of your opponent. Would you use this knowledge?

Altruistic answer = yes; egoistic answer = no

16. Your mother gives you pictures she has painted herself—but you don't like them. Would you hang them up?
17. A person you really like but is fatally ill tells you that he is in love with you. Would you build up a relationship?
18. Your department talks about a colleague saying that he is lazy and just talks about himself. Would you tell him?
19. You are married and had a one-night stand during a business trip. Would you tell your partner?
20. A close friend is dying. In his fever he asks you to go and get a favourite book, but he could die while you are going. Would you do it?

References

Batson, C.D., Shaw, L.L., 1991. Evidence for altruism: toward a pluralism of prosocial motives. Psychol. Inquiry 2, 107—122.

Bohnen, N., Houx, P., Nicolson, N., Jolles, J., 1990. Cortisol reactivity and cognitive performance in a continuous mental task paradigm. Biol. Psychol. 31, 107—116.

Brand, M., Fujiwara, E., Borsutzky, S., Kalbe, E., Kessler, J., Markowitsch, H.J., 2005. Decision-making deficits of Korsakoff patients in a new gambling task with explicit rules- associations with executive functions. Neuropsychology 19, 267—277.

Brand, M., Labudda, K., Markowitsch, H.J., 2006. Neuropsychological correlates of decision-making in ambiguous and risky situations. Neural Netw. 19, 1266—1276.

Buchanan, T.W., Tranel, D., Adolphs, R., 2006. Impaired memory retrieval correlates with individual differences in cortisol response but not autonomic response. Learn. Membr. 13, 382—387.

Ciaramelli, E., Muccioli, M., Ladavas, E., di Pellegrino, G., 2007. Selective deficit in personal moral judgment following damage to ventromedial prefrontal cortex. Soc. Cogn. Affective Neurosci. 2, 84—92.

Cikara, M., Farnsworth, R.A., Harris, L.T., Fiske, S.T., 2010. On the wrong side of the trolley track: neural correlates of relative social valuation. Soc. Cogn. Affective Neurosci. doi: 10.1093/scan/nsq011.

Cohen, J., Cohen, P., West, S.G., Aikan, L.S., 2003. Applied Multiple Regression/Correlation Analysis for Behavioral Science, 3rd ed. Mahwah, Lawrence Erlbaum, New Jersey.

Cushman, F., Young, L., Hauser, M., 2006. The role of conscious reasoning and intuition in moral judgment: Testing three principles of harm. Psychol. Sci. 17, 1082—1089.

Dedovic, K., D'Aguiar, C., Pruessner, J.C., 2009. What stress does to your brain: a review of neuroimaging studies. Can. J. Psychiatry 54, 6—15.

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.

Domes, G., Heinrichs, M., Rimmele, U., Reichwald, U., Hautzinger, M., 2004. Acute stress impairs recognition for positive words-association with stress-induced cortisol secretion. Stress 7, 173—181.

Dunn, B.D., Dalgleish, T., Lawrence, A.D., 2006. The somatic marker hypothesis: A critical evaluation. Neurosci. Biobehav. Rev. 30, 239—271.

Garvey, B.J., Klein, K., 1993. Relationship of life stress and body consciousness to hypervigilant decision-making. J. Pers. Soc. Psychol. 64, 267—273.

Gray, J.R., 1999. A bias towards short term thinking in threat-related negative emotional states. Pers. Soc. Psychol. Bull. 25, 65—75.

Greene, J.D., Haidt, J., 2002. How (and where) does moral judgment work? Trends Cogn. Sci. 6, 517—523.

Greene, J.D., Morelli, S.A., Lowenberg, K., Nystrom, L.E., Cohen, J.D., 2008. Cognitive load selectively interferes with utilitarian moral judgment. Cognition 107, 1144—1154.

Greene, J.D., Nystrom, L.E., Engell, A.D., Darley, J.M., Cohen, J.D., 2004. The neural bases of cognitive conflict and control in moral judgment. Neuron 44, 389—400.

Greene, J.D., Sommerville, R.B., Nystrom, L.E., Darley, J.M., Cohen, J.D., 2001. An fMRI investigation of emotional engagement in moral Judgment. Science 293, 2105—2108.

Haidt, J., 2007. The new synthesis in moral psychology. Science 316, 998—1002.

Heekeren, H.R., Wartenburger, I., Schmidt, H., Schwintowski, H.P., Villringer, A., 2003. An fMRI study of simple ethical decision-making. Neuroreport 14, 1215—1219.

Het, S., Rohleder, N., Schoofs, D., Kirschbaum, C., Wolf, O.T., 2009. Neuroendocrine and psychometric evaluation of a placebo version of the "Trier Social Stress Test". Psychoneuroendocrinology 34, 1075—1086.

Horn, W., 1983. Leistungsprüfsystem L-P-S [abilities testing system]. Hogrefe, Göttingen.

Jackson, E.D., Payne, J.D., Nadel, L., Jacobs, W.J., 2006. Stress differentially modulates fear conditioning in healthy men and women. Biol. Psychiatry 59, 516—522.

Kälvemark, S., Höglund, A.T., Hansson, M.G., Westerholm, P., Arnetz, B., 2004. Living with conflicts-ethical dilemmas and moral distress in the health care system. Soc. Sci. Med. 58, 1075—1084.

Kern, S., Oakes, T.R., Stone, C.K., McAuliff, E.M., Kirschbaum, C., Davidson, R.J., 2008. Glucose metabolic changes in the prefrontal cortex are associated with HPA axis response to a psychosocial stressor. Psychoneuroendocrinology 33, 517—529.

Kirschbaum, C., Hellhammer, D.H., 1994. Salivary cortisol in psychoneuroendocrine research: recent developments and applications. Psychoneuroendocrinology 19, 313—333.

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.

Koenigs, M., Young, L., Adolphs, R., Tranel, D., Cushman, F., Hauser, M., Damasio, A., 2007. Damage to prefrontal cortex increases utilitarian moral judgements. Nature 446, 908—911.

Kudielka, B.M., Hellhammer, D.H., Wüst, S., 2009. Why do we respond so differentially? Reviewing determinants of human salivary cortisol responses to challenge. Psychoneuroendocrinology 34, 2—18.

Kudielka, B.M., Schommer, N.C., Hellhammer, D.H., Kirschbaum, C., 2004. Acute HPA axis responses, heart rate, and mood changes to psychosocial stress (TSST) in humans at different times of day. Psychoneuroendocrinology 29, 983—992.

Luo, Q., Nakic, M., Wheatley, T., Richell, R., Martin, A., Blair, R.J., 2006. The neural basis of implicit moral attitude- an IAT study using event-related fMRI. Neuroimage 30, 1449—1457.

Mendez, M.F., Anderson, E., Shapira, J.S., 2005. An investigation of moral judgement in frontotemporal dementia. Cogn. Behav. Neurol. 18, 193—197.

Merz, C.J., Tabbert, K., Schweckendiek, J., Klucken, T., Vaitl, D., Stark, R., Wolf, O.T., 2010. Investigating the impact of sex and cortisol on implicit fear conditioning with fMRI. Psychoneuroendocrinology 35, 33—46.

Moll, J., Eslinger, P.J., Oliveira-Souza, R., 2001. Frontopolar and anterior temporal cortex activation in a moral judgment task: preliminary functional MRI results in normal subjects. Arq. Neuropsiquiatr. 59, 657—664.

Nater, U.M., Rohleder, N., 2009. Salivary alpha-amylase as a non-invasive biomarker for the sympathetic nervous system: Current state of research. Psychoneuroendocrinology 34, 486—496.

Oei, N.Y., Everaerd, W.T., Elzinga, B.M., van Well, S., Bermond, B., 2006. Psychosocial stress impairs working memory at high loads: an association with cortisol levels and memory retrieval. Stress 9, 133—141.

Preston, S.D., Buchanan, T.W., Stansfield, R.B., Bechara, A., 2007. Effects of anticipatory stress on decision-making in a gambling task. Behav. Neurosci. 121, 257—263.

Pruessner, J., Champagne, F., Meanes, M.J., Dagher, A., 2004. Dopamine release in response to a psychological stress in humans and its relationship to early life maternal care: a positron emission tomography study using [11C] raclopride. J. Neurosci. 24, 2825—2831.

Pruessner, J.C., Dedovic, K., Khalili-Mahani, N., Engert, V., Pruessner, M., Buss, C., Renwick, R., Dagher, A., Meaney, M.J., Lupien, S., 2008. Deactivation of the limbic system during acute psychosocial stress: evidence from positron emission tomography and functional magnetic resonance imaging studies. Biol. Psychiatry 63, 234—240.

Rodrigues, S.M., LeDoux, J.E., Sapolsky, R.M., 2009. The influence of stress hormones on fear circuitry. Annu. Rev. Neurosci. 32, 289—313.

Rohleder, N., Nater, U., 2009. Determinants of salivary α-amylase in humans and methodological considerations. Psychoneuroendocrinology 34, 485—496.

Roozendaal, B., McEwen, B.S., Chattarji, S., 2009. Stress, memory and the amygdale. Nat. Rev. Neurosci. 10, 423—433.

Sachdeva, S., Iliev, S., Medin, D.L., 2009. Sinning saints and saintly sinners. The paradox of moral self-regulation. Psychol. Sci. 20, 523—528.

Schaich Borg, J., Hynes, C., Van Horn, J., Grafton, S., Sinnott-Armstrong, W., 2006. Consequences, action, and intention as factors in moral judgments: An fMRI investigation. J. Cogn. Neurosci. 18, 803—817.

Schoofs, D., Preuss, D., Wolf, O.T., 2008. Psychosocial stress induces working memory impairments in an n-back paradigm. Psychoneuroendocrinology 33, 643—653.

Schoofs, D., Wolf, O.T., Smeets, T., 2009. Cold pressor stress impairs performance on working memory tasks requiring executive functions in healthy young men. Behav. Neurosci. 123, 1066—1075.

Spielberger, C.D., Gorsuch, R.L., Lushene, R.E., Vagg, P.R., Jacobs, G.A., 1977. Stait-Trait Anxiety Inventory for Adults. Mind Garden, Redwood City.

Starcke, K., Wolf, O.T., Markowitsch, H.J., Brand, M., 2008. Anticipatory stress influences decision-making under explicit risk conditions. Behav. Neurosci. 122, 1352—1360.

Stock, G., 1987. The Book of Questions. Workman Publishing, New York.

Thomson, J., 1985. The trolley problem. Yale Law J. 94, 1395—1415.

Valdesolo, P., DeSteno, D., 2006. Manipulations of emotional context shape moral judgment. Psychol. Sci. 17, 476—477.

van den Bos, R., Harteveld, M., Stoop, H., 2009. Stress and decision-making in humans: performance is related to cortisol reactivity, albeit differentially in men and women. Psychoneuroendocrinology 34, 1449—1458.

van Stegeren, A., Rohleder, N., Everaerd, W., Wolf, O.T., 2006. Salivary alpha amylase as marker for adrenergic activity during stress: Effect of betablockade. Psychoneuroendocrinology 31, 137—141.

Vedhara, K., Hyde, J., Gilchrist, I.D., Tytherleigh, M., Plummer, S., 2000. Acute stress, memory, attention and cortisol. Psychoneuroendocrinology 25, 535—549.

Watson, D., Clark, L., Tellegen, A., 1988. Development and validation of brief measures of positive and negative affect: The PANAS scales. J. Pers. Soc. Psychol. 54, 1063—1070.

Wolf, O.T., 2009. Stress and memory in humans: twelve years of progress? Brain Res. 1293, 142—154.

Wolf, O.T., Schommer, N.C., Hellhammer, D.H., McEwen, B.S., Kirschbaum, C., 2001. The relationship between stress induced cortisol levels and memory differs between men and women. Psychoneuroendocrinology 26, 711—720.