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Acute stress influences strategy preference when dealing with high intensity emotions in men

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ABSTRACT

Stress has been shown to initiate a shift from flexible to rigid, less demanding cognitive processes. Reappraisal and distraction are two emotion regulation strategies varying in their cognitive demands. Previous studies indicate that stress improves regulatory performances of high arousal stimuli. We thus investigated whether acute stress alters the preference for reappraisal or distraction when downregulating emotions of different intensities and further explored its influence on regulatory outcomes. Eighty males were either socially stressed (n = 40) or exposed to a control condition (n = 40) prior to an emotion regulation choice paradigm. Stress increased the probability to prefer distraction for downregulating high intensity emotions. Stressed (vs. control) participants reported to be generally more successful in regulating high intensity emotions, which was positively associated with cortisol but not alpha-amylase increases. Our findings provide initial evidence that stress fosters a preference for less demanding regulatory options, suggesting favorable strategy choices in response to acute stressors.

1. Introduction

The experience of stress is familiar to everyone but its triggers in daily life are highly diverse, ranging from pressure in social or job-related contexts to mourning or life-threatening incidents. Acute stress initiates an intricate physiological response primarily mediated by the activation of the sympathetic nervous system (SNS), leading to the release of catecholamines (e.g. noradrenaline and adrenaline), and the hypothalamus-pituitary-adrenal (HPA) axis, causing the secretion of glucocorticoids (GCs; cortisol in humans; e.g. Joëls & Baram, 2009). These stress mediators have been shown to critically influence cognitive and affective processes thereby facilitating adaptive coping with challenging events (De Kloet, Joëls, & Holsboer, 2005; Hermans, Henckens, Joëls, & Fernández, 2014; McEwen et al., 2015). Cortisol binds to mineralocorticoid and glucocorticoid receptors (Dedovic, Duchesne, Andrews, Engert, & Pruessner, 2009) numerously located in prefrontal, cingulate and limbic structures of the human brain (McEwen, Nasca, & Gray, 2016). These brain regions are also critically involved in emotion regulation processes (Etkin, Büchel, & Gross, 2015; Wang & Saudino, 2011).

Cognitive emotion regulation denotes all attempts to influence the magnitude, duration, type and expression of an emotional experience (Gross, 2015). Reappraisal and distraction are two effective, frequently studied strategies to downregulate negative emotions, differing in the time point of deployment during the emergence of an emotional experience (Thiruchselvam, Blechert, Sheppes, Rydstrom, & Gross, 2011), their long-term adaptivity (McRae, 2016) and their demands of cognitive resources (Silvers, Weber, Wager, & Ochsner, 2015). Cognitive reappraisal presupposes a reinterpretation of a given situation to change its emotional meaning (Gross, 2015), while distraction aims at redirecting the attention away from a stimulus to limit its emotional impact (McRae *et al.* 2009). Despite individual differences in strategy use, preference for reappraisal or distraction and the regulatory effectiveness have been shown to vary in dependence of emotional intensity (e.g. Shafir, Schwartz, Blechert, & Sheppes, 2015). For instance, available data suggest that people more often choose reappraisal when downregulating low intensity emotions, but prefer to distract when faced with high intensity stimuli (Feldman & Freitas, 2021; Sheppes, Scheibe, Suri, & Gross, 2011). Further research showed that distraction is also more effective to downregulate high intensity negative emotions when compared to reappraisal (Shafir et al., 2015). In line with these findings, enhanced late positive potential amplitudes recorded via EEG (indicator of increases in emotional intensity; Hajcak, Dunning, & Foti, 2009) predicted an increased tendency to choose distraction over reappraisal,

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ultimately leading to a stronger attenuation of emotional arousal (Shafir, Thiruchselvam, Suri, Gross, & Sheppes, 2016). These results point at a switch in strategy preference depending on stimulus intensity that may protect an individual from high arousal negative affective states. Certain strategies cannot be characterized as inherently adaptive or maladaptive. Rather a flexible deployment of various strategies with respect to contextual factors results in regulatory effectiveness (Tull & Aldao, 2015). Thus inter-individual differences in emotion regulation flexibility may account for variance in regulatory performances (Aldao, Sheppes, & Gross, 2015; Goubet & Chrysikou, 2019). Deficits in strategy flexibility and regulatory success have frequently been linked to the onset and maintenance of mental disorders (e.g. Kashdan & Rottenberg, 2010; Aldao & Nolen-Hoeksema, 2012). Given the clinical relevance of emotion regulation deficits, it is of utmost importance to identify factors that influence the flexible use of regulatory strategies.

The acute stress response has been proposed to affect emotion regulatory skills possibly explaining inter-individual differences in recovery from intense emotionally challenging situations. In particular, exposure to acute stress has been demonstrated to alter emotion regulation success when applying a predefined strategy to downregulate negative emotions (Kinner, Het, & Wolf, 2014; Langer et al. 2020; Raio & Phelps, 2015). Some initial studies reported rapid impairing effects of stress on fear regulatory performances (Raio, Orederu, Palazzolo, Shurick, & Phelps, 2013; Raio & Phelps, 2015) that have been linked to alpha-amylase levels as an indirect marker of SNS activity (Nater & Rohleder, 2009). In contrast, there is also work pointing at stress to improve regulatory outcomes of reappraisal to downregulate negative emotions (Kinner et al., 2014), accompanied by increased pupil dilations in men reflecting enhanced regulatory engagement (Langer et al., 2020). Interestingly, these beneficial effects were positively associated with cortisol increases. Consistently, administration of hydrocortisone enhanced regulatory activity in the ventrolateral prefrontal cortex when participants distract the attention away from negative pictures and reduced activation in the amygdala when applying reappraisal (Jentsch, Merz, & Wolf, 2019). These results corroborate with a recent study showing that cortisol exerts beneficial effects on the cognitive downregulation of high intensity negative emotions, resulting in reduced emotional arousal when applying distraction and to a lesser extent when applying reappraisal (Langer, Jentsch, & Wolf, 2021). Interestingly however, cortisol did not modulate regulatory success when dealing with low intensity negative emotions. Stress-induced emotion regulatory improvements might therefore depend on the particular strategy as well as on the intensity of the emotional material used. Taken together, existing evidence suggests that acute stress promotes the cognitive control of particularly high intensity emotions by cortisol actions on core regulatory network functioning.

A flexible choice between different strategies considering context factors rather than a fixed strategy application is crucial for coping with emotional challenges in daily life. Yet, research on the influence of acute stress on emotion regulation strategy choice has received little attention so far. It is known that stress initializes adaptive reallocations of neural resources according to cognitive demands (Hermans et al., 2014). For instance, stress fosters a preference for rigid, undemanding cognitive learning strategies (e.g. procedural strategies) at the cost of flexible, demanding declarative processing (Goldfarb & Phelps, 2017; Schwabe & Wolf, 2012; Wirz, Bogdanov, & Schwabe, 2018), an effect which is primarily driven by cortisol increases (Smeets, van Ruitenbeek, Hartogsveld, & Quaedflieg, 2018). Further research provide evidence for an interaction between stress effects on cognitive learning strategies and genetic MR variants (Langer, Moser, Otto, Wolf, & Kumsta, 2019; Wirz, Reuter, Wacker, Felten, & Schwabe, 2017) indicating inter-individual differences in the cognitive shift under stress. However, it is still unclear whether this stress-induced shift may also be valid for other cognitive functions such as emotion regulation. Reappraising an emotional situation is more effortful than distracting the attention away from the emotional stimulus and thereby requires more cognitive resources, particularly when regulating high intensity emotions (Silvers et al., 2015; Strauss, Ossenfort, & Whearty, 2016). As such, stress might boost the preference for choosing distraction over reappraisal to downregulate negative emotions.

To the best of our knowledge, there is no study to date exploring whether and how stress may alter emotion regulation strategy preference. To address this question, we sought to investigate acute stress effects on the preference for reappraisal and distraction as a function of stimulus intensity and additionally examined its influence on cognitive regulatory outcomes. To this end, eighty participants were either exposed to the Trier Social Stress Test (TSST; $n = 40$) or a placebo version ($n = 40$) prior to an emotion regulation choice paradigm. In this task, participants were either asked to view low or high arousal negative pictures or to choose between reappraisal and distraction. Beyond HPA axis related salivary cortisol concentrations and subjective affect ratings, salivary alpha-amylase levels were additionally assessed as a marker of noradrenergic activity (Nater & Rohleder, 2009) to verify successful stress induction. Arousal, valence and regulatory success ratings served as subjective emotion regulation outcome measures. Additionally, pupil dilations were recorded as an objective physiological proxy of regulatory performances. Pupil sizes are usually thought to mirror emotional arousal (Bradley, Miccoli, Escrig, & Lang, 2008). However, a growing body of work suggests that the pupil also dilates as a function of prefrontal activation (Urry, 2006) and emotion regulatory effort (Kinner *et al.* 2017; Langer et al., 2020). Collectively, pupil dilations may reflect both, emotional arousal as well as the cognitive effort required for regulation purposes.

We expected stress to improve regulatory outcomes primarily of high intensity emotions, evidenced by reduced subjective arousal, enhanced valence and regulatory success ratings. Based on our previous research indicating that stress increases the cognitive regulatory engagement (Langer et al., 2020), we hypothesized enlarged pupil sizes during regulation trials in stressed participants compared to controls. Given that cortisol has frequently been linked to increases in effectiveness of emotion regulation attempts, we expected stress-induced cortisol increases to be associated with reduced negative emotional experiences in response to cognitive emotion regulation. In view of evidence showing that stress promotes less cognitively demanding processing (e.g. Schwabe & Wolf, 2013; Wirz et al., 2018), we further hypothesized that stress favors the preference for distraction, particularly when downregulating high intensity emotions. Moreover, we assumed cortisol increases to predict higher rates of distraction preference.

2. Materials and methods

2.1. Participants and experimental design

A priori calculations of the required sample size were conducted with G*Power 3.1 (Faul, Erdfelder, Buchner, & Lang, 2009). According to previous findings (Langer et al., 2020), we assumed a small-to-medium sized effect ($d = 0.3$) of stress on cognitive emotion regulation in men. With respect to the given mixed study design, power analysis was conducted with two groups (stress vs. control) and six repeated measures (view low intensity pictures, view high intensity pictures, reappraise low intensity pictures, reappraise high intensity pictures, distract from low intensity pictures, distract from high intensity pictures). In order to detect an interaction between stress, emotion regulation condition and stimulus intensity with a power of $1\text{-}\beta \geq 0.95$, an alpha error probability of 0.05 and an assumed correlation of $r = 0.4$ for repeated measurements, 78 participants were required. Effects of acute stress on cognitive emotion regulation have been shown to be larger in men than in women (Langer et al., 2020), a finding that might result from sex differences in physiological stress reactivity (Kirschbaum, Kudielka, Gaab, Schommer, & Hellhammer, 1999). For this reason, we restricted study participation to males only. Due to well-established effects of smoking, overweight and chronic diseases on stress hormone release (Narvaez Linares, Charron, Ouimet, Labelle, & Plamondon, 2020), eighty healthy, non-smoking males, aged between 18 and 33 (M = 24.14, SD = 3.83) with a Body Mass Index (BMI) ranging from 19.5 to 29.3 (M = 24.02, SD = 2.22 kg/m^2) participated in this study. Volunteers were recruited via online advertisements in social media networks and notice boards throughout the Ruhr University Bochum and surroundings. All participants reported normal or corrected-to-normal vision of ± 1.5 diopters at most, no chronic or acute illnesses, history or current medical or psychological treatment, drug use or experiences with the current stress protocol. Participants refrained from alcohol consumption and physical activity 24 h prior to the start of testing. Furthermore, they reported to refrain from caffeinated drinks on the testing day as well as from eating and drinking anything except for water 2 h before. The testing procedure was conducted in accordance with the Declaration of Helsinki and approved by the local ethics committee of the Faculty of Psychology at the Ruhr University Bochum (n. 523).

A mixed 2 × 3 × 2 design with the between-subjects factor *stress* (stress vs. control) and the within-subject factors emotion regulation *condition* (view vs. reappraisal vs. distraction) and stimulus *intensity* (low vs. high) served to examine the effects of acute stress on emotion regulation strategy preference and performance as a function of emotional intensity. Participants were randomly assigned to the stress (n = 40) and the control group (n = 40), which did not differ in age (p = .931), BMI (p = .563), habitual use of reappraisal (emotion regulation inventory [ERI], König, 2011; p = .861), distraction (ERI; p = .654) or flexibility in the use of different emotion regulation strategies in daily life (flexible emotion regulation scale [FlexER-12-Scale], Dörfel, Gärtner, & Strobel, 2019; p = .823).

2.2. Procedure

Prior to study participation, exclusion criteria were checked in a standardized telephone interview. To control for diurnal changes in cortisol secretion (Guilliams & Edwards, 2010) all testing took place between 12.30 p.m. and 6.30 p.m.. The testing procedure (Fig. 1) started with a 28 min resting period during which participants answered questionnaires (demographic data, ERI, FlexER-12-Scale) and gave written informed consent. All participants provided four saliva samples concurrent to affective ratings at different time points across the experiment (baseline, +2 min, +15 min, +55 min relative to stress offset). Subsequent to the baseline sample, participants underwent the Trier Social Stress Test (TSST; stress group) or a placebo version (P-TSST; control group) before being instructed and familiarized with the emotion regulation choice paradigm and prepared for pupillary recordings. The emotion regulation choice paradigm started 15 min after TSST/P-TSST offset, when cortisol was expected to reach its peak. Finally, participants were debriefed and reimbursed with 20 €.

2.3. Stress and control manipulation

In order to meet a 25 min time window between stress onset and start of the emotion regulation choice paradigm, a short version of the Trier Social Stress Test (TSST; Kirschbaum, Pirke, & Hellhammer, 1993), as implemented in Langer et al. (2020) was used to induce psychosocial stress. The TSST reliably activates the SNS and HPA axis (Dickerson & Kemeny, 2004). After a 2 min preparation period, participants underwent a 5 min free speech talking about personal characteristics that qualifies them for a desired job and a 3 min mental arithmetic task (counting backwards from 2043 in steps of 17). At the same time, participants were evaluated by a reserved panel (1 male / 1 female) and videotaped. The placebo version of the TSST (P-TSST; Het, Rohleder, Schoofs, Kirschbaum, & Wolf, 2009) also consisted of an oral presentation (about the last holiday, a book or a movie) and an easy arithmetic task (counting forwards in steps of 15), but without any stress-eliciting factors (no audience, no videotaping), serving as a control condition.

2.4. Physiological and subjective stress measures

Saliva samples using Salivette sampling devices (Sarstedt, Nümbrecht, Germany) and affective state ratings were taken at four different time points (see Fig. 1) across the experiment to validate the effectiveness of the TSST on a physiological and subjective level. Saliva samples were stored at −20 °C. Salivary cortisol was analyzed on a Synergy2 plate reader (Biotek, Winooski, USA) using commercial enzyme-linked immunosorbent assays (ELISAs; free cortisol in saliva; Demeditec, Kiel, Germany). In addition, a colorimetric test using 2-chloro-4-nitrophenyl-α-maltro-triosoide (CNP-G3) as a substrate reagent was applied to assess salivary alpha-amylase concentrations (sAA; Lorentz et al., 1999). Inter- and intracoefficients of variations of both analyses were less than 8%. The emotional response to stress was evaluated using the Differential Emotions Scale (DES; Izard, Dougherty, Bloxom, & Kotsch, 1974; negative affect factors: *sadness, anger, disgust, contempt, anxiety, shame, guilt*; positive affect factors: *joy, surprise, interest*) on a 5-point likert scale (ranging from 1 (not at all) to 5 (very strong)). Mean summary scores of negative and positive affect factor values were calculated for each time point. In addition, participants rated how stressful they experienced the situation on a visual analogue scale (VAS; ranging from 0 = not stressful at all to 100 = extremely stressful) directly after stress/control offset.

2.5. Emotion regulation choice paradigm

A slightly modified version of the emotion regulation choice task developed by Shafir et al. (2015, 2016) was applied. In this task, participants were either asked to view low and high intensity negative pictures or to freely choose between reappraisal and distraction, based on which strategy would help them most to downregulate upcoming emotional responses to the respective picture. Instructions of both available strategies were similar to those used in previous research on deliberate attempts to downregulate negative emotions (Kanske, Heissler, Schönfelder, Bongers, & Wessa, 2011; Shafir et al., 2016; Langer et al., 2020). If participants chose *reappraisal*, they were requested to change the emotional impact of the picture by reinterpreting the presented situation in a more positive context or with a positive ending. If participants chose *distraction*, they were instructed to shift the attention away from the presented picture disengaging from the emotional content by thinking about a neutral situation (such as walking

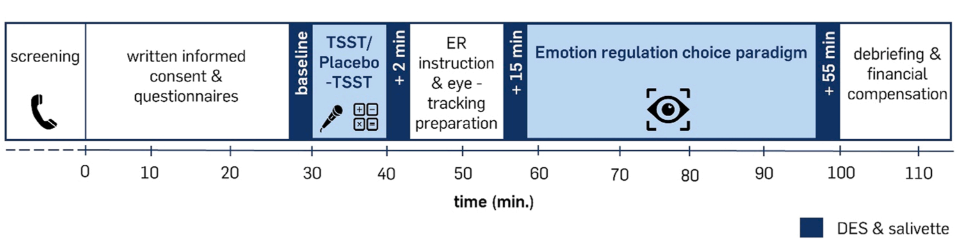

Fig. 1. Schematic procedure of the experimental testing. Participants provided four saliva samples concurrent to affective state ratings (Differential Emotions Scale; DES) at different time points across the experiment (highlighted by dark blue boxes: baseline, +2 min, +15 min, +55 min after TSST/P-TSST offset). 15 min after the offset of the Trier Social Stress Test (TSST) or a placebo version, participants underwent an emotion regulation (ER) choice paradigm during which pupil diameter was continuously recorded.

through a supermarket). In the *view* condition, participants were asked to just watch and respond naturally to the presented picture without regulatory attempts serving as a control condition. After having received the instructions for the emotion regulation conditions, the experimenter practiced both strategies together with the participant with sample pictures in order to ensure task comprehension, giving corrective feedback if necessary. Introducing the procedure of the paradigm, the experimenter provided a schematic trial structure of both conditions (see Fig. 2) to the participants. Prior to the start of the paradigm, six computer-based practice trials (one trial of each emotion regulation condition for low and high intensity negative pictures, respectively) were completed to further familiarize participants with the structure and timing. Stimulus presentation and behavioral recordings were controlled by MATLAB R2018a (MathWorks Inc. Natick, MA).

Each trial (see Fig. 2) started with a 750 ms instructional cue (view or regulate) followed by a 1500 ms fixation cross. After a brief picture preview (1000 ms), participants were asked to choose between reappraisal and distraction via mouse click (regulate condition) or were presented to a black screen (view condition) for 1000 ms. Participants were then instructed to prepare for the respective condition (view, reappraise, distract). Subsequent to a fixation cross (1500 ms), participants implemented the chosen strategy (regulation phase) or just viewed the low or high intensity picture for 5000 ms before they rated their emotional experience on a 9-point visual analog scale with respect to arousal (ranging between 1 = emotionally quiet to 9 = emotionally active) and valence (ranging between 1 = unpleasant to 9 = pleasant). In addition, they were asked to rate how successful they were in applying the respective strategy ranging from 1 = not successful at all to 5 = very good. Each rating scale was displayed for 5000 ms, followed by a black screen (1000 ms, inter-trial interval). For each trial, participants strategy choice was logged.

The emotion regulation choice paradigm consisted of 80 trials with 40 low intensity (valence: $M = 3.68$, $SD = 0.28$; arousal: $M = 5.18$, $SD = 0.25$) and 40 high intensity negative pictures (valence: $M = 2.34$, $SD = 0.55$; arousal: $M = 7.26$, $SD = 0.31$) selected from the Nencki Affective Picture System (NAPS; Marchewka, Zurawski, Jednoróg, & Grabowska, 2014). According to normative ratings, high intensity negative pictures were rated as significantly more arousing ($t(78) = 32.70$, $p < .001$) and less pleasant ($t(56.28) = -13.79$, $p < .001$) than low intensity negative pictures. All pictures were presented in greyscale and matched for content and complexity. Additionally, all pictures and the fixation cross (on a gray background) were matched for luminosity using the MATLAB R2016a SHINE toolbox (MathWorks Inc.). Low and high intensity negative pictures were randomly assigned to the *view* and *regulation* condition resulting in four different categories, each comprising an equal number of trials (view low, view high, regulate low, regulate high). In order to check whether the random assignment of pictures has been successful, we conducted repeated measure ANOVAs analyzing differences in normative arousal and valence ratings (Marchewka et al., 2014) between the *view* and the *regulation* condition in dependence of stimulus intensity. Analyses revealed that pictures shown in the *view* and the *regulation* condition did not differ in normative affective ratings (no main effect of Condition: both $ps \geq 0.100$; no Condition x Intensity interaction: both $ps \geq 0.415$) verifying successful randomization. Trial order was arranged in blocks of five trials per category randomly presented in each quarter of the paradigm.

2.5.1. *Assessment of strategy preference*

In line with Scheibe, Sheppes, & Staudinger (2015), we calculated the proportion of distraction relative to reappraisal choices for each participant with respect to low and high intensity pictures. If the proportion was > 1, a distraction-over-reappraisal preference was coded. In turn, a reappraisal-over-distraction preference was coded if the proportion was < 1. If the number of distraction choices was identical to reappraisal (proportion = 1), no strategy preference could be determined. Although dichotomization may cause a loss of information, the categorical classification allows examination of stress effects on the predominant cognitive system (Wirz, Wacker, Felten, Reuter, & Schwabe, 2017). Additional analyses with continuous data (distraction relative to reappraisal choice ratio) are provided in the Supplementary Information D.

2.6. *Pupillometry*

Recordings of changes in pupil diameter were conducted with iView eye-tracking glasses (iViewETG 2.0, SensoMotoric Instruments, Germany) connected to an SMI-ETG recording device (Lenovo X230-Notebook). Prior to experimental recordings, a one-point calibration procedure ensured correct tracking of the pupil. Participant́s head was stabilized in a chin rest with a distance of 60 cm to the screen. The

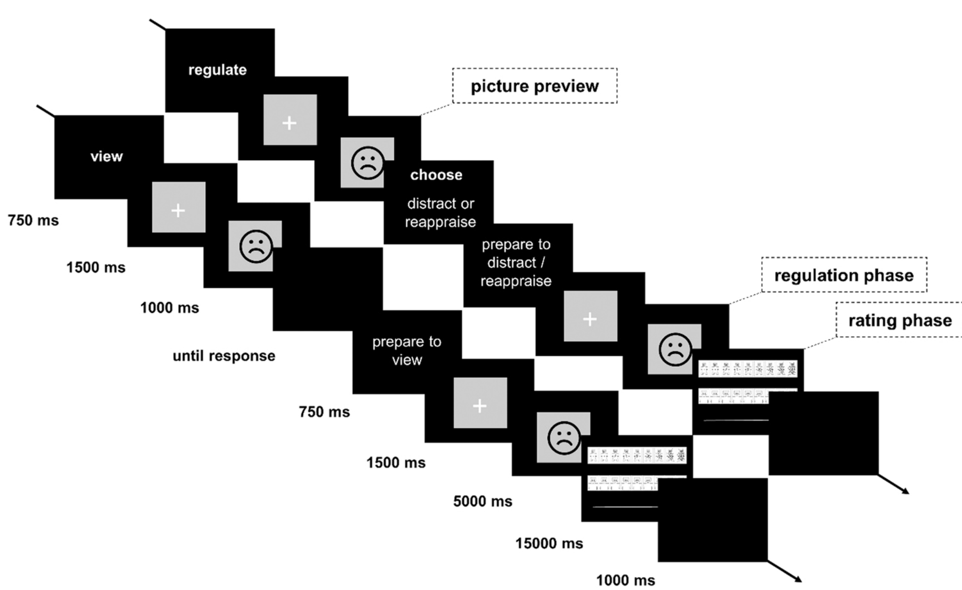

Fig. 2. Trial structure of the emotion regulation choice paradigm. Participants were either asked to simply view low and high arousal negative pictures or to choose between reappraisal and distraction subsequent to a brief picture preview in order to apply the chosen strategy during the second picture presentation (regulation phase). Finally, participants rated their emotional experience and regulatory success (rating phase).

testing room was permanently illuminated at a moderate level without daylight luminance and pupil data were recorded at a binocular sampling rate of 30 Hz. Due to failures to save some triggers appropriately, pupillary data of four participants could not be analyzed.

2.6.1. Analysis of pupillary data

Preprocessing of pupillary data was conducted according to routines reported in previous studies of our lab (Kinner et al., 2017; Langer et al., 2020). Pupil diameter was averaged across both eyes and subsequently smoothed with a finite impulse response filter at 6 Hz. For each trial, onsets of event-locked segments (instructional cue, fixation cross, first and second picture presentation) were marked. We discarded trials with pupil sizes outside a range between 1.5 mm and 9 mm (Kret, Tomonaga, & Matsuzawa, 2014) and removed outliers in dilation speed with a maximum cutoff threshold of 6 median absolute deviations (MAD; Kret and Sjak-Shie, 2019). We used a MATLAB-based algorithm to discard trials with major eye blinks (>100 ms). Consequently, across all participants a median of 11.8% of all trials were excluded from further analyses. Trials with smaller gaps due to eyelid occlusions were corrected with linear interpolation. For each participant and each trial, baseline pupil size was defined as the mean pupil diameter recorded during the 300 ms prior to first picture presentation. Baseline pupil size was then subtracted from the mean pupil diameter during both picture presentation time points for each trial to correct for individual differences in pupil sizes. As a measure of total pupillary increase in response to the second presentation of the emotional stimulus, we calculated the area under the curve with respect to ground (AUCg) from 2 s to 5 s after picture onset (Langer et al., 2020; Langer, Wolf, & Jentsch, 2021). Pupil dilations were averaged across each emotion regulation condition (view, reappraisal, distraction) for low and high intensity negative pictures, respectively.

2.7. Statistical analysis

Statistical analyses were conducted using IBM SPSS Statistics 20 (Armonk, USA) for Windows with a significance level set to $\alpha = 0.05$. All data were checked for normality (Kolmogorov-Smirnov tests) and homogeneity of variance (Levene-tests). If normality was not given, data were log-transformed or non-parametric tests were applied (Chi-square tests). In case of violation of the sphericity assumption, *p*-values and degrees of freedom underwent a Greenhouse-Geisser correction (epsilon (ε) and uncorrected degrees of freedom are reported; Picton et al., 2000). Partial eta square (η_p^2) values and the odds ratio (OR) served as estimations of effect sizes.

All analyses of variance (ANOVAs) included the between-subjects factor *stress* (stress vs. control). For the analyses of cortisol, alpha-amylase concentrations and negative affect ratings, ANOVAs with the repeated measures factor *time* (baseline, +2 min, +15 min, +55 min) were conducted. A t-test was used to analyze differences in the subjective stress experience (VAS) between stressed and control participants. The McNemar test using binomial distribution for dependent values served to examine the relationship between strategy preference and stimulus intensity on the level of trials. Binary logistic regression models were used to explore whether stress predicts strategy preference with respect to low and high intensity negative pictures. To verify emotional differences between low and high intensity negative pictures, successful emotion regulation as well as to test whether stress had an influence on emotion regulatory outcomes, mixed-design ANOVAs with the repeated measures factors *condition* (view vs. reappraisal vs. distraction) and stimulus *intensity* (low vs. high) for subjective ratings (arousal, valence, success) and pupil dilations were applied. (Trend-) significant interactions were solved using appropriate (Bonferroni-corrected) *post-hoc* tests. Furthermore, we examined the link between stress-induced increases in cortisol as well as alpha-amylase and strategy preference. Therefore, we calculated delta cortisol and alpha-amylase by subtracting the baseline sample from the expected peak sample (Δ cortisol = t_{+15} – baseline; Δ amylase = t_{+2} – baseline) and conducted binary logistic regression analyses with Δ cortisol, Δ amylase and its interaction with stress as predictors and type of strategy preference for low and high intensity pictures as outcome variables. In order to examine the relationship between increases in physiological stress mediators and emotion regulation outcome measures in stressed participants (n = 40), we conducted linear regression analyses with Δ cortisol, Δ amylase and its interaction with stimulus intensity as predictors and mean subjective ratings as well as pupil dilation per emotion regulation condition as outcome variables.

3. Results

3.1. Physiological and subjective response to stress

3.1.1. Physiological stress response

Significant increases in salivary cortisol (main effect of Time: $F(3,228) = 39.11$, $p < .001$; $\varepsilon = .671$, $\eta_p^2 = .340$, main effect of Stress: $F(1,76) = 5.87$, $p = .018$; $\eta^2 = .072$, Stress x Time interaction: $F(3,228) = 14.46$, $p < .001$; $\varepsilon = .671$, $\eta_p^2 = .160$) and alpha-amylase concentrations (main effect of Time: $F(3,234) = 22.75$, $p < .001$; $\varepsilon = .538$, $\eta^2 = .226$, Stress x Time interaction: $F(3,234) = 4.29$, $p = .023$; $\varepsilon = .538$, $\eta_p^2 = .052$) in response to stress compared to the control manipulation indicated successful stress induction by the TSST (Fig. 3a–b). Follow-up pairwise comparisons revealed significant higher alpha-amylase concentrations immediately after the TSST compared to the placebo condition ($t(78) = -2.00$, $p = .049$). Relative to controls, stressed participants also exhibited significantly elevated cortisol levels 15 min ($t(78) = -5.08$, $p < .001$) and 55 min ($t(78) = -2.83$, $p = .006$) after stress offset. Critically, in this time period (from t_{+15} until t_{+55}), participants underwent the emotion regulation choice paradigm. However, baseline levels of cortisol and alpha-amylase did not significantly differ between the stress and the control group (both $ps \geq .575$). For descriptive statistics and details about log-transformation, see Supplementary Information A.

3.1.2. Subjective stress response

Stressed participants rated their affective state as significantly more negative than controls (main effect Time: $F(3,234) = 13.96$, $p < .001$; $\varepsilon = .759$, $\eta_p^2 = .152$, main effect of Stress: $F(1,78) = 4.01$, $p = .049$; $\eta_p^2 = .049$, Stress x Time interaction: $F(3,234) = 6.69$, $p = .001$; $\varepsilon = .759$, $\eta_p^2 = .079$), both 2 min ($t(69.49) = -4.54$, $p < .001$) as well as 15 min ($t(65.00) = -2.25$, $p = .028$) after TSST offset (Fig. 3c). Neither were there significant differences in negative affect scores at baseline ($p = .224$) nor directly after the emotion regulation choice paradigm (t_{+55}, $p = .460$). T-tests analyzing group differences in the subjective stress experience additionally confirmed that the TSST was experienced as significantly more stressful than the placebo version ($t(68.51) = -10.40$, $p < .001$).

3.2. Emotion regulation and stimulus intensity

3.2.1. Strategy preference

Due to an equal number of reappraisal and distraction choices (proportion = 1), strategy preference of 9 participants for low intensity negative pictures (11.25%) could not be determined (control: n = 6, stress: n = 3). Participants generally preferred reappraisal relative to distraction for low (reappraisal: 66.25%, distraction: 22.5%) and high intensity pictures (reappraisal: 58.8%, distraction: 41.2%). The McNemar test, however, revealed a significant association between stimulus intensity and strategy preference (n = 71; exact $p = .035$) indicating that participants more often preferred to choose distraction after presentation of high (41.2%) compared to low (22.5%) intensity pictures (Fig. 4a).

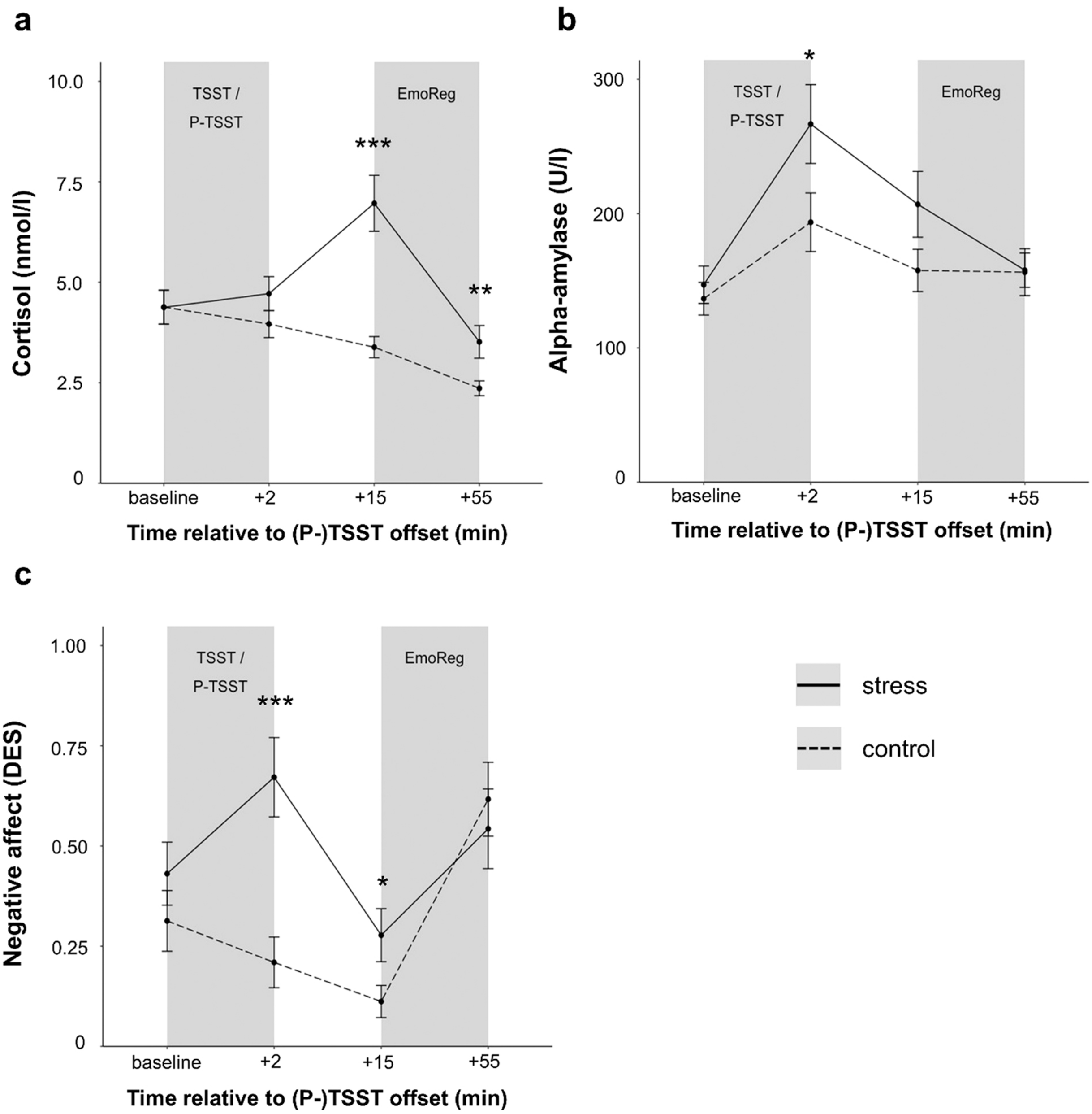

Fig. 3. Physiological and subjective stress response. Mean (±SEM) salivary cortisol (a), alpha-amylase concentrations (b) and negative affect ratings (c) at baseline, 2 min, 15 min and 55 min after stress/control offset. Exposure to stress (Trier Social Stress Test, TSST) led to significant increases in cortisol, alpha-amylase concentrations and subjective negative affect compared to the control group (placebo version of the TSST, P-TSST). When the emotion regulation choice paradigm started, stressed participants showed significantly higher levels of cortisol than controls. There were no differences in alpha-amylase levels anymore. The time windows of the TSST/P-TSST and the emotion regulation choice paradigm (EmoReg) are displayed by shaded areas. Significant effects after Bonferroni-corrected *post-hoc* t-tests are marked by asterisks: *** $p < .001$; ** $p < .01$; * $p < .05$.

3.2.2. Emotion regulation outcome

3.2.2.1. Subjective ratings. In order to check whether the induction of different emotional intensities as well as emotion regulation has been successful, we analyzed whether subjective ratings differed between *view, reappraisal* and *distraction* trials as a function of stimulus *intensity*. Of note, since participants could freely choose between reappraisal and distraction, the emotion regulation conditions could differ in the number of trials. As expected, participants rated high intensity pictures as significantly more arousing and less pleasant than low intensity pictures (main effects of Intensity: arousal: $F(1,78) = 242.17$, $p < .001$; $\eta_p^2 = .756$, valence: $F(1,78) = 349.01$, $p < .001$; $\eta_p^2 = .817$) verifying successful induction of different emotional intensities. Further, analyses also revealed significant differences in valence and regulatory success ratings between the emotion regulation conditions independent of stimulus intensity (main effects of Condition, valence: $F(2,140) = 76.36$, $p < .001$; $\varepsilon = .850$, $\eta_p^2 = .528$; success: $F(2,140) = 24.65$, $p < .001$; $\varepsilon = .799$, $\eta_p^2 = .260$). *Post-hoc* comparisons showed that participants rated negative pictures as more pleasant and reported to be more successful when reappraising the presented situation relative to distracting from or just viewing the picture (both $ps < .001$). In addition, participants rated negative pictures as less pleasant and reported to be less successful when distracting from the pictures compared to viewing them (both $ps \leq .003$). Analyses of arousal ratings revealed a Condition x Intensity interaction ($F(2,140) = 5.37$, $p = .006$; $\eta_p^2 = .071$) pointing at significant differences between the emotion regulation conditions after presentation of high intensity pictures (main effect of Condition: $F(2,154) = 14.63$, $p < .001$; $\varepsilon = .987$, $\eta_p^2 = .160$). *Post-hoc* pairwise

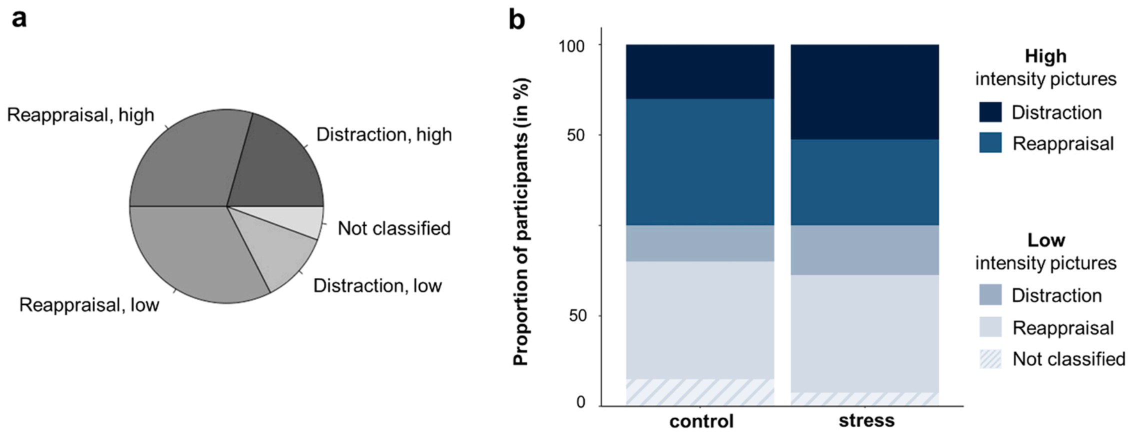

Fig. 4. Strategy preference as a function of stimulus intensity (a) and stress (b). Proportion of participants preferring distraction or reappraisal for low and high intensity negative pictures for the whole sample (a) and separately for stressed and control participants (b). Overall, participants more frequently preferred reappraisal relative to distraction for low and high intensity negative pictures. Compared to controls, stressed participants more often preferred distraction over reappraisal to downregulate high intensity emotions.

comparisons showed that participants rated high intensity pictures as less arousing when applying reappraisal compared to distraction ($p < .001$) and simply viewing the picture ($p = .001$). However, participants did not significantly differ in arousal ratings after distraction relative to viewing the pictures ($p = .330$). Thus, on a subjective level and with respect to the given regulatory instructions, participants successfully downregulated negative emotions via reappraisal but not via distraction. For a graphical illustration of the results, see Supplementary Information B. To further examine whether variance in picture intensity may account for differences in regulatory outcomes between reappraisal and distraction, we conducted exploratory ANOVAs with the repeated measures factors *strategy* (reappraisal vs. distraction) and stimulus *intensity* (low vs. high) for normative ratings of the respective pictures in each regulation condition (arousal, valence; Marchewka et al., 2014). Analyses revealed that pictures which were followed by distraction choices were normatively rated as significantly more arousing and unpleasant than pictures which were chosen to reappraise (main effects of Strategy, arousal: $F(1,72) = 17.07$, $p < .001$; $\eta_p^2 = .192$; valence: $F(1, 72) = 35.87$, $p < .001$; $\eta_p^2 = .332$). Strategy x Intensity interactions (arousal: $F(1,72) = 3.40$, $p = .069$; $\eta_p^2 = .045$; valence: $F(1,72) = 16.27$, $p < .001$; $\eta_p^2 = .184$) revealed that this effect was even stronger in the high (arousal: $F(1,77) = 14.01$, $p < .001$; $\eta_p^2 = .154$; valence: $F(1,77) = 52.66$, $p < .001$; $\eta_p^2 = .406$) compared to low intensity picture category (arousal: $F(1,72) = 4.04$, $p = .048$; $\eta_p^2 = .053$; valence: $F(1,72) = 5.35$, $p = .024$; $\eta_p^2 = .069$) suggesting that distraction was particularly chosen for the most intense negative emotional material.

3.2.2.2. Pupil diameter. Repeated measures ANOVA of pupillary data (AUCg) revealed significant larger pupil size increases in response to high intensity compared to low intensity pictures (main effect of Intensity: $F(1,74) = 15.47$, $p < .001$; $\eta_p^2 = .173$) indicating pupil size enlargements with increasing emotional arousal. In addition, a main effect of Condition ($F(1,148) = 6.99$, $p = .001$; $\eta_p^2 = .086$) showed that the pupil was significantly enlarged during distraction compared to reappraisal or the simple view condition (both $ps \leq .011$). For a figure showing pupil data with respect to each emotion regulation condition and stimulus intensity, see Supplementary Information B. We additionally compared mean changes in pupil diameter during the first and second picture presentation to analyze pupillary differences between picture preview and the actual regulation phase. Results revealed significant larger pupil size increases in response to regulatory compared to view trials during second picture presentation only, indicating that the pupil has been sensitive to the cognitive effort during deliberate attempts to downregulate negative emotions (for statistical details and a graphical illustration showing the trajectory of the pupil over time, see Supplementary Information C).

3.3. Stress effects on emotion regulation in dependence of stimulus intensity

3.3.1. Strategy preference

Binary logistic regressions revealed that stress significantly predicted strategy preference to downregulate high intensity negative emotions ($B(1) = -0.947$, $p = .043$, OR= 2.58; Fig. 4b). In particular, stress was associated with an increased probability to prefer distraction over reappraisal for downregulating high intensity negative pictures relative to the control manipulation ($p = .043$). By contrast, there was no significant prediction of strategy preference to downregulate low intensity emotions by stress ($p = .556$). Consistently, additional linear regression analyses predicting strategy choice frequency by Stress x Intensity interaction showed that stress was related to more frequent distraction choices when faced with high in contrast to low intensity stimuli (for details, see Supplementary Information D).

3.3.2. Emotion regulation outcome

3.3.2.1. Subjective ratings. Analyses of regulatory success ratings resulted in a significant three-way interaction between stress, emotion regulation condition and stimulus intensity ($F(2,140) = 3.82$, $p = .024$; $\eta_p^2 = .052$). *Post-hoc* repeated measures ANOVAs separately for each emotion regulation condition revealed significant Stress x Intensity interactions for reappraisal ($F(1,77) = 6.01$, $p = .017$; $\eta_p^2 = .072$) and distraction ($F(1,71) = 5.23$, $p = .025$; $\eta_p^2 = .069$) but not for view trials ($p = .594$). Subsequent t-tests indicated that stressed participants reported to be more successful applying reappraisal ($t(78) = -2.30$, $p = .024$) and distraction ($t(76) = -2.63$, $p = .010$) after high intensity pictures when compared to controls (Fig. 5c). No such stress effect was found for low intensity pictures (both $ps \geq .422$). With respect to arousal and valence ratings, no significant main or interaction effects of stress were found (all $ps \geq .237$).

3.3.2.2. Pupil diameter. Analysis of pupillary responses showed no significant differences in pupil dilations between stressed and control participants (no main effect of Stress: $p = .991$, no Stress x Condition interaction: $p = .127$). In addition, no significant interactions between stress and stimulus intensity occurred (no Stress x Intensity interaction: $p = .271$; no Stress x Condition x Intensity interaction $p = .358$).

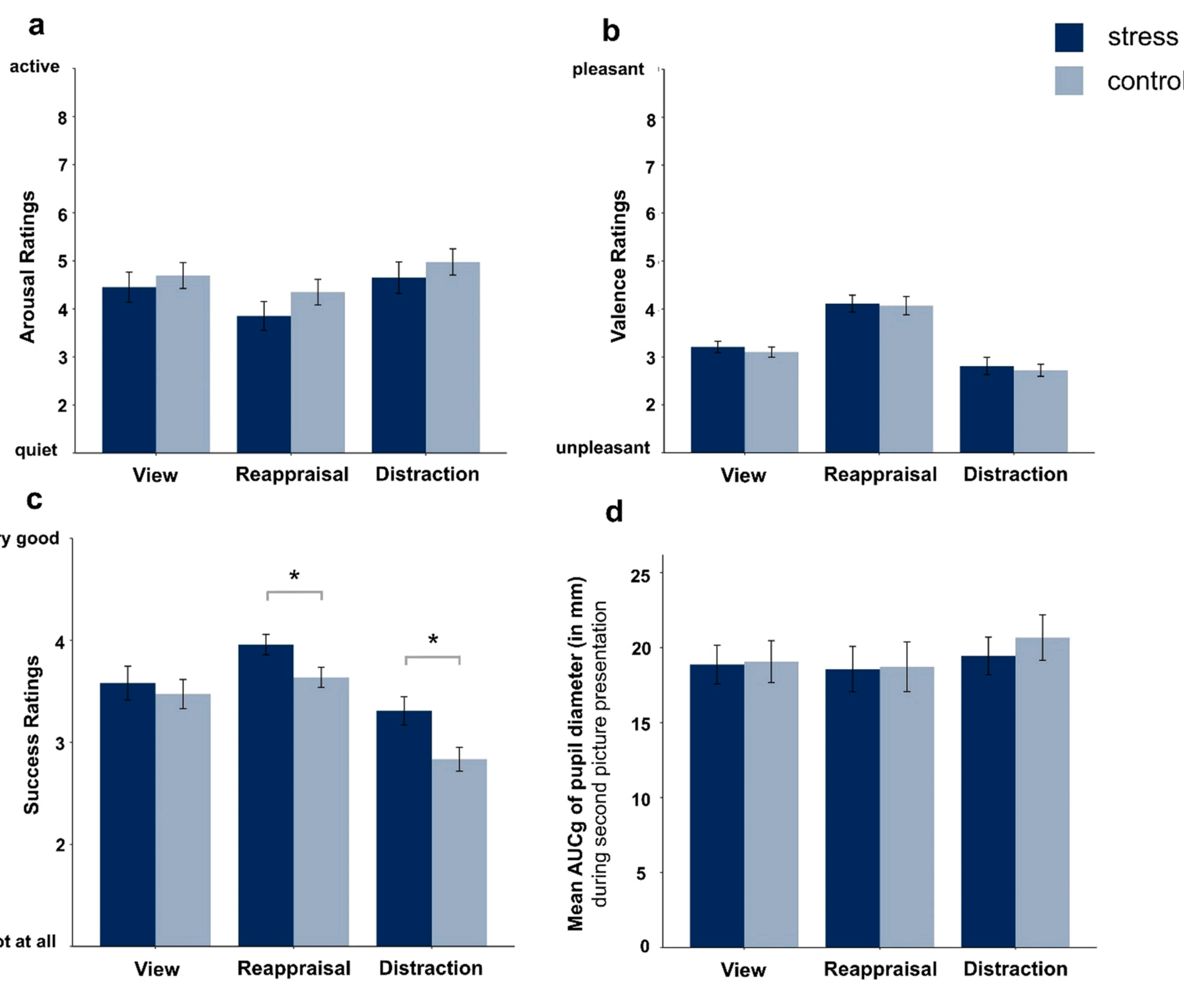

Fig. 5. Emotion regulation outcomes for high intensity negative pictures in the stress and control group. Mean (±SEM) subjective arousal (a), valence (b) and success ratings (c) as well as mean (±SEM) changes in pupil diameter (d) indexed by the area under the curve with respect to ground (AUCg). Data display regulatory outcome measures after the second presentation of high intensity negative pictures in the emotion regulation choice paradigm comparing stressed (TSST) and control (P-TSST) participants. The stress group reported to be more successful in downregulating high intensity emotions via reappraisal and distraction than the control group. However, no significant stress-induced changes in arousal and valence ratings or pupil diameter occurred. Significant effects after Bonferroni-corrected pairwise comparisons are marked as follows: * $p < .05$.

3.4. The relationship between physiological stress mediators and emotion regulation

3.4.1. Strategy preference

Binary logistic regressions served to examine the relationship between increases in salivary cortisol, alpha-amylase levels and strategy preference. Analyses indicated that neither cortisol (Δ cortisol), alpha-amylase increases (Δ amylase) nor their interaction with stress significantly predicted strategy preference (high: both $ps \geq .181$, low: both $ps \geq .726$).

3.4.2. Emotion regulation outcome

Linear regression models predicting emotion regulation outcomes of stressed participants per condition (view, reappraisal, distraction) revealed a positive association between cortisol increases and valence ratings applying reappraisal (b=0.58, SE=0.19, $\beta = 0.33$, $t = 3.09$, $p = .003$) and distraction (b=1.00, SE=0.28, $\beta = 0.52$, $t = 3.54$, $p = .001$). No such association was found for Δ alpha-amylase (all $ps \geq .106$). Consistently, cortisol increases significantly predicted subjective regulatory success of reappraisal (b=0.33, SE=0.14, $\beta = 0.34$, $t = 2.39$, $p = .019$) and distraction (b=0.50, SE=0.21, $\beta = 0.37$, $t = 2.37$, $p = .021$) showing that stronger stress-induced cortisol increases were associated with higher subjective regulatory success for both strategies. Moreover, cortisol increases were significantly related to valence ratings after distraction from particularly high intensity pictures (Δ Cortisol x Intensity interaction: b=−1.01, SE=0.34, $\beta = -0.43$, $t = -2.92$, $p = .005$). However, success ratings of reappraisal and distraction were not significantly predicted by the Δ Cortisol x Intensity interaction (both $ps \geq .135$). No association between cortisol increases and subjective ratings in the view condition occurred (all $ps \geq .121$). Likewise, cortisol increases did not serve as a significant predictor of other regulatory outcome measures (arousal ratings, pupil dilations; all $ps \geq .158$).

4. Discussion

In this study, we investigated the effects of acute stress on the preference for choosing reappraisal or distraction to downregulate negative emotions of varying intensity in men and further explored its influence on regulatory outcomes. Stress increased the probability of preferring distraction over reappraisal to downregulate high intensity negative emotions. Moreover, stressed male participants reported to be more successful in downregulating high intensity emotions via reappraisal and distraction than controls. Cortisol increases were positively related to subjective reappraisal and distraction success. In contrast, stress neither influenced strategy preference nor regulatory outcomes for low intensity emotions.

As hypothesized, stress favored the preference for distraction especially when dealing with high intensity negative emotions, accompanied by increases in subjective emotion regulation success of both strategies. In contrast to reappraisal, distraction is thought to be less cognitively demanding and almost immediately effective (Sheppes & Meiran, 2007; Strauss et al., 2016). Hence, our findings are in accordance with a large set of studies showing that stress fosters a shift towards rigid, less demanding cognitive strategies (Schwabe & Wolf, 2012; Wirz et al., 2018) that may aid successful coping (Vogel, Fernández, Joëls, & Schwabe, 2016). Notably, in case of emotion regulation, certain strategies and regulatory outcomes cannot be determined by their adaptiveness without taking environmental factors into account. Especially in the context of acute stress, distraction might be favorable for downregulating high intensity negative emotions for several reasons. Firstly, low effort strategies such as distraction save cognitive resources, which is particularly relevant under high stress states in order to provide sufficient resources to cope with the stressor. Secondly, distraction intervenes earlier in the generation process of the emotional response compared to reappraisal (Thiruchselvam et al., 2011). Therefore, distraction quickly interrupts the emergence of the full-blown emotion being especially helpful in the context of stress to impede hyperexcitation. Thirdly, distraction has been shown to be superior relative to reappraisal when regulating high intensity negative emotions (Shafir et al., 2015; Sheppes et al., 2011) thereby contributing to emotional recovery. Consequently, our results further support the idea that acute stress effects are typically adaptive (De Kloet et al., 2005), in case of emotion regulation by promoting the switch in strategy preference towards distraction when dealing with high intensity negative emotions.

Previous research indicated that the shift towards less demanding strategies under stress is predominantly driven by glucocorticoids (Schwabe et al., 2013; Smeets et al., 2018) that act on core structures of the emotion regulation network (Etkin et al., 2015; Wang & Saudino, 2011). However, contrary to our hypothesis, we did not find a significant prediction of strategy preference by cortisol increases. One critical moderating factor might be the individual genetic code. Several studies reported that the stress-induced shift towards less demanding cognitive processes is mediated by polymorphisms of the MR gene (Langer et al., 2019; Vogel et al., 2016; Wirz, Reuter, et al., 2017). These studies argue for genotype dependent cortisol actions on strategy choice in the aftermath of stress. It has to be noted though that stress does not only trigger the secretion of cortisol but also other steroids, neuropeptides (e.g. vasopressin) and catecholamines, which act in concert to influence cognitive and affective processes (De Kloet et al., 2005). Stress effects on strategy preference might therefore be also driven by other physiological stress mediators. Interestingly, existing literature debates potentially opposing time-dependent effects of catecholaminergic and glucocorticoid-driven actions on cognitive emotion regulation processes (Hermans et al., 2014; Langer et al., 2020; Langer, Wolf, et al., 2021; Sandner, Zeier, Lois, & Wessa, 2021). Future work administering pharmacological agents to block or activate glucocorticoid and noradrenergic receptors may help to explore the specific contribution of each system to induce stress effects on emotion regulation strategy use.

Flexible emotion regulation choice is a special case for decision-making (Suri *et al.* 2018). Previous studies demonstrated that participants more often decide to use distraction relative to reappraisal when aspiring short-term goals leading to better regulatory performances (Hermann, Kress, & Stark, 2017; Sheppes *et al.* 2012). Therefore, our data tentatively indicate that stress strengthens the focus on the expected short-term regulatory success mediated by altered decision-making processes. In favor of this idea, Shields, Lam, Trainor and Yonelinas (2016) postulated that stress improves real-world decision-making competences probably mediated by increases in dopaminergic activity within the prefrontal cortex (Butts, Weinberg, Young, & Phillips, 2011). Consistently, dopaminergic actions have been shown to decrease preference for a high effort option in an effort-discounting task (Floresco, Tse, & Ghods-Sharifi, 2008). Together with these findings, our data imply that stress influences decision-making processes in favor of less cognitively demanding options and short-term goal orientation, such as the preference for distraction when regulating high intensity negative emotions. Future studies increasing the number of strategy options with varying cognitive demand might be promising to test for a potential general favor of less effortful regulatory strategies in the aftermath of stress.

In view of previous evidence showing that distraction over reappraisal choices account for more effective regulation of high intensity emotions (Shafir et al., 2015, 2016), acute stress might ultimately contribute to better emotion regulation outcomes. Consistent with this idea, stressed participants reported to be more successful when downregulating high intensity emotions than controls, which was positively associated with cortisol increases. These effects occurred for both strategies, which appears somewhat counterintuitive. However, previous studies of our lab revealed beneficial effects of stress on reappraisal success (Kinner et al., 2014), which additionally have been shown to be positively associated with cortisol increases in men (Langer et al., 2020). In these studies, participants were asked to implement a predefined emotion regulation strategy. The present findings might thus result from a stress-induced improvement of reappraisal added by a preference-driven favor of the low effort strategy distraction under stress. Together, these effects could lead to a general regulatory improvement for high intensity emotions. Along this line, administration of hydrocortisone resulted in improved regulatory success for reappraisal and distraction downregulating high intensity emotions (Langer, Jentsch, et al., 2021). Our results may thus provide further evidence for stress-induced beneficial effects on the cognitive regulation of high intensity emotions adding strategy choice as a potential moderating factor.

Even though we found stress to alter emotion regulation strategy preference and the subsequent experience of regulatory success, no significant stress effects occurred for any of the other regulatory outcome measures, such as arousal and valence ratings or pupil dilation. Based on these results one could assume that stressed participants only thought to regulate more successfully than controls but in fact did not manage to reduce their emotional experience. In contrast to this assumption, increases of the stress hormone cortisol were positively associated with both, valence and regulatory success ratings of reappraisal and distraction. Importantly, stressed participants more often preferred to choose distraction than controls, an outcome that might have reduced effect sizes of stress. Of note, distraction overall neither significantly reduced arousal nor increased valence ratings, indicating that participants were not successful in downregulating negative emotions via this strategy. At the same time, significantly enlarged pupil sizes during distraction point to an increase in cognitive regulatory effort. These findings are in contrast to some previous studies suggesting more effective regulation and less cognitive effort for distraction compared to reappraisal when dealing with high intensity emotions (Shafir et al., 2015, 2016). Exploratory analyses of normative NAPS ratings revealed that the emotional material of distraction choice trials was more intense than for reappraisal choice trials, in particular within the high intensity picture category. Pictures which were chosen for distraction might thus have been too deterrent to enable successful cognitive downregulation. This in turn might explain why participants fail to distract despite expending increased cognitive effort to do so. Alternatively, characteristics of the current paradigm may account for discrepancies in regulatory outcomes to previous studies using the same strategy instructions and stimuli (Langer et al., 2020; Langer, Jentsch, et al., 2021). In these studies, stimuli were presented only once, whereas participants, here, previewed the pictures prior to the regulation phase. Since distraction occurs early in the generation process of the emotional response (Gross, 1998), it might be more demanding to distract at a later stage of this process when the emotional response has already been evolved, especially for stimuli with extreme high negative intensity.

Notably, whereas distraction tends to create a neutral emotional experience, reappraisal aims at changing the valence of the presented stimulus. Given data may therefore reflect that distraction has less potential to cause significant changes in the emotional experience when compared to reappraisal. In addition, a lack of statistical power may have contributed to reduced effect sizes. Counter to findings of previous studies (Shafir et al., 2015, 2016; Sheppes et al., 2011), participants generally preferred reappraisal more often than distraction irrespective of emotional intensity. As a consequence, the number of trials in which participants chose distraction were proportionally lower than the number of reappraisal trials. As opposed to previous studies (e.g. Shafir et al., 2015; Sheppes et al., 2011), we restricted study participation to young male students. In light of evidence suggesting an influence of sex (Goubet & Chrysikou, 2019), age and cognitive resources (Scheibe et al., 2015) on context-sensitive strategy choices, the present sample characteristics may account for the general reappraisal dominance.

Some limitations are important to note. First, our sample consisted of males only. Given a large amount of evidence showing that stress reactivity and its impact on cognitive functioning (Merz & Wolf, 2017; Shields, 2020), emotion regulation (Kinner et al., 2014; Langer et al., 2020) and emotional reactivity (Bradley, Codispoti, Sabatinelli, & Lang, 2001) is influenced by sex hormones, our findings cannot be generalized to women. Future work on stress effects on emotion regulation preference may for example benefit from comparing men and women varying in their hormonal status. Second, given high heterogeneity in methodological approaches in this research field, our findings cannot be generalized to other forms of stress (i.e. chronic stress), other stress induction methods (i.e. other psychological or physical stressors such as SECPT or physical exercise), other emotional stimuli (e.g. videos) or older age groups. Third, pupil dilation is thought to reflect both, emotional arousal and the cognitive regulatory effort (e.g. Kinner et al., 2017) but is less sensitive to the valence of the emotional experience (Zaehringer, Jennen-Steinmetz, Schmahl, Ende, & Paret, 2020). In future studies, it will be of utmost importance to include additional physiological measures such as the startle reflex (Zaehringer et al., 2020), skin conductance response, changes in heart rate variability (Appelhans & Luecken, 2006; Matejka et al., 2013) or corrugator electromyography (Heller, Lapate, Mayer, & Davidson, 2014; Tan et al., 2016) in order to provide more information about objective emotion regulation outcomes.

5. Conclusion

In conclusion, our findings demonstrate that acute stress prompts a preference for choosing distraction over reappraisal to downregulate high intensity negative emotions and enhanced subjective emotion regulation success in men. We thereby provide first evidence for an influence of stress on emotion regulation strategic decisions, fostering less cognitively demanding and short-term goal-oriented options that might aid quick and adequate coping with challenging emotions in daily life.

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Author contributions

KL designed the work, acquired, analyzed and interpreted data, drafted the manuscript, prepared figures and edited the manuscript. **OTW** and **VLJ** designed the work, interpreted data, edited and revised the manuscript.

Data availability

The data that support the findings of this study are available at the Open Science Framework (OSF) under https://osf.io/b9ae3/.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.biopsycho.2022.108264.

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