The relationship between affective flexibility, spontaneous emotion regulation and the response to induced stress

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Abstract

Effective emotion regulation contributes to adapting well to challenging situations. One of the proposed cognitive mechanisms underlying emotion regulation is cognitive flexibility in processing of affective material (i.e. affective flexibility). We investigated (*n* = 118) effects of affective flexibility on the response to a stressor and on spontaneous use of 'adaptive' and 'maladaptive' emotion regulation strategies. Additionally, we examined how emotion regulation influences stress reactivity and recovery. Affective flexibility was measured with a task-switching paradigm in which participants shift attention between affective and non-affective aspects of emotional material. We investigated changes in emotion and heart rate variability to a stress induction. Affective flexibility did not influence the response to stress, but less efficient shifting of attention towards affective aspects of negative information, and more efficient shifting of attention towards non-affective aspects of positive information were related to more use of maladaptive strategies. Emotion regulation strategy use had limited influence on the perceived and actual physiological response to a stress induction, but especially more use of adaptive regulation strategies reduced negative emotional reactivity. Our findings suggest that individual differences in affective flexibility have limited influence on the (acute) response to a stressful event and recovery afterwards, but do influence spontaneous use of emotion regulation strategies.

Keywords: stress response, heart rate variability, affective flexibility, emotion regulation

A crucial component of adequate and adaptive responding to stress is emotion regulation (Gross, 2002). Emotion regulation allows for adaptive coping with stressful situations by up- and down-regulating emotions and physiological responses according to situational demands. One of the proposed cognitive mechanisms underlying effective emotion regulation is cognitive flexibility (Genet & Siemer, 2011; Ochsner & Gross, 2007). Cognitive flexibility is part of a set of executive functions and refers to the ability to shift thoughts and behaviour in line with one's goals and changing situational demands (Meiran, 2010). Cognitive flexibility is typically operationalized as the ability to shift between different task sets according to changing rules (Dajani & Uddin, 2015). Although most research on cognitive flexibility uses tasks with non-affective stimuli, it has been argued that flexibility in processing of affective material—previously termed "affective flexibility"—is especially important in the context of emotion regulation and adapting to stressful events (Genet et al., 2013; Genet & Siemer, 2011; Malooly et al., 2013). Interestingly, research administering both a non-affective cognitive flexibility task and an affective flexibility task, showed that non-affective switch costs and affective switch costs were only weakly related (Genet et al., 2013; Malooly et al., 2013). This may indicate that non-affective and affective flexibility (operationalized in this manner) reflect at least partly distinct processes.

Previous research has shown that affective flexibility, but not non-affective cognitive flexibility, predicts reappraisal efficacy when instructed to down-regulate sad affect during a negative mood induction (Malooly et al., 2013). Specifically, more efficient shifting of attention (i.e. greater flexibility) from processing affective to non-affective aspects of negative material and more efficient shifting of attention from processing non-affective to affective aspects of positive material was associated with greater reappraisal efficacy when instructed to down-regulate sad affect (Malooly et al., 2013). In a recent study (Guassi Moreira et al., 2020) the relationship between cognitive flexibility and reappraisal has also been investigated. Using a probabilistic reversal learning task and a global/local task to measure cognitive flexibility, they found only a weak positive correlation between global/local task performance and reappraisal efficacy, but no further effects on reappraisal efficacy, nor the tendency to use reappraisal (Guassi Moreira et al., 2020). Other work has shown that affective flexibility, but not non-affective cognitive flexibility, is associated with the tendency to use rumination in daily life. Specifically, less efficient shifting of attention from processing affective to non-affective aspects of negative material has been associated with increased rumination use in response to unpleasant events in daily life (Genet et al., 2013). Less efficient shifting from processing affective to non-affective aspects of positive material was associated with less use of rumination, highlighting that inflexibility is not maladaptive per se (Genet et al., 2013).

Although these initial findings provide support for a link between affective flexibility and emotion regulation (i.e., reappraisal, rumination), it remains unclear whether individual differences in affective flexibility directly influence the response to a stressful situation—in the absence of instructions to regulate emotions—or influence the tendency to ‘spontaneously’ use certain emotion regulation strategies when confronted with a stressor. The main questions addressed in this study were therefore: 1) do individual differences in affective flexibility influence the response to a stressful situation and recovery afterwards; 2) does affective flexibility influence spontaneous use of more ‘maladaptive’ or ‘adaptive’ emotion regulation strategies when confronted with a stressful situation. Additionally we investigated 3) if the reported use of certain emotion regulation strategies influences the response to a stressor and recovery afterwards.

Adaptive responding to stressful situations relies on using a diverse repertoire of regulation strategies in different contexts (Bonanno & Burton, 2013) and monitoring if adjustments should be made to the regulation strategy that is used (Sheppes, 2020). Although no one strategy may be universally 'maladaptive' (Bonanno & Burton, 2013), research has shown that frequent use of strategies such as rumination, catastrophizing and self-blame has been reliably and strongly associated with stress-related psychopathology (Aldao & Nolen-Hoeksema, 2010; Aldao et al., 2010; Garnefski & Kraaij, 2006b, 2007; McLaughlin & Nolen-Hoeksema, 2011). On the other hand, for regulation strategies such as reappraisal, problem-solving, or acceptance, the relationship with psychopathology is much more varied (Aldao & Nolen-Hoeksema, 2010; Aldao et al., 2010; Garnefski & Kraaij, 2006b, 2007; McLaughlin & Nolen-Hoeksema, 2011), probably because their efficacy is contextually dependent. Notwithstanding the "fallacy of uniform efficacy", we grouped strategies (e.g. rumination, catastrophizing) for which frequent use has consistently been related to psychopathology under 'maladaptive' emotion regulation strategies. Other regulation strategies were grouped under 'adaptive' strategies.

The experience of emotions in response to a challenging situation is accompanied by varying degrees of physiological arousal (Levenson, 2003), such as changes in heart rate. The influence of the parasympathetic (vagal) branch of the autonomic nervous system on the heart is very fast, allowing for momentary modulation of cardiac activity (Pumprla et al., 2002), for example in response to a stressor. Vagally mediated heart rate variability (HRV) refers to the variation in time intervals between heart beats and reflects this parasympathetic influence on the heart. Recent findings have shown a relationship between individual differences in affective flexibility and HRV during rest (i.e. measured when individuals are doing nothing) (Grol & De Raedt, 2020), and a number of studies have showed a relationship between higher HRV during rest and effective emotion regulation (e.g., Appelhans & Luecken, 2006; Ruiz-Padial et al., 2003; Thayer & Brosschot, 2005). Although these findings support a link between affective flexibility, emotion regulation and HRV during rest, variability in HRV—measured in response to an event—is important as it reflects shifts in the physiological response to meet situational demands. Phasic decreases in HRV have been observed during anticipation and confrontation with challenging or stressful situations (Beauchaine et al., 2007; Filaire et al., 2010; La Marca et al., 2011; Qi & Gao, 2018; Zandara et al., 2018). Whilst individuals with high resting HRV levels tend to show such stress-associated modulation of HRV, individuals with low resting HRV show blunted HRV reactivity (Weber et al., 2010). Importantly, individuals with high resting HRV levels also show increases in phasic HRV during recovery when the stressor is over (Weber et al., 2010). This response of the body to (acute) stress is seen as adaptive as it enables our body to deal effectively with the situation and bring the body back to balance once the stressor is over (Thayer & Lane, 2000).

Current Study

In this study we therefore investigated both modulation of HRV and the emotional response to a stress induction based on the Trier Social Stress Test.[1] We measured changes in vagally mediated HRV and emotions across different phases of the stress induction and during a recovery phase afterwards. Based on previous work (e.g. Weber et al., 2010) we operationalized an adaptive HRV response as a phasic decrease in HRV in response to the stressor (relative to baseline), followed by an increase in HRV during the recovery phase when the stressor is over, whereas a blunted HRV response to the stress induction is considered less adaptive (Hamilton & Alloy, 2016; Weber et al., 2010). A greater perceived emotional response to the stress induction was operationalized by greater increases in self-reported negative emotion and physical sensations (i.e. arousal, tension), and a greater decrease in positive emotion. On the other hand,

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[1] In the study we added a negative feedback manipulation after the Trier Social Stress Test procedure to also examine the response to negative feedback (see procedure). However, the feedback manipulation failed, with more than half of the participants reporting not to believe the feedback was real. Therefore, we focused on the part of the procedure consisting of the Trier Social Stress Test.

smaller decreases in negative emotion and physical sensations, and a smaller increase in positive emotion during the recovery period were considered to reflect reduced recovery once the stressor is over.

First, we investigated whether affective flexibility directly influences the response to, and recovery from a stressful situation. We expected less efficient shifting of attention to affective aspects of positive material and more efficient shifting to non-affective aspects of positive material to be associated with blunted HRV reactivity, a greater perceived emotional response, but reduced recovery afterwards. Based on previous findings linking affective flexibility to emotion regulation (Genet et al., 2013; Malooly et al., 2013), we expect less efficient shifting of attention towards non-affective aspects of negative material to be associated with blunted HRV reactivity, a greater perceived emotional response, but reduced recovery. However, recent findings show that more efficient shifting of attention towards non-affective aspects of negative material is associated with lower resting HRV (Grol & De Raedt, 2020) and predicts higher anxiety and worry over time (Twivy et al., 2020). These findings can be understood by considering empirical evidence (for review see, Cisler & Koster, 2010) and theoretical models (e.g. Borkovec et al., 2004; Mogg et al., 2004) associating avoidance of negative information—at longer exposure times—with increased anxiety. Such attentional avoidance is believed to reflect a strategic process underlying emotion regulation goals (Cisler & Koster, 2010) and the use of avoidance as a regulation strategy has been associated with anxiety and depression symptoms (Aldao et al., 2010). Based on this attentional avoidance perspective we would therefore expect more efficient shifting of attention towards non-affective aspects of negative material to be associated with blunted HRV reactivity, a greater emotional response, but reduced recovery after the stressor is over.

Second, we investigated whether affective flexibility influences the reported use of ‘maladaptive’ and ‘adaptive’ emotion regulation strategies when confronted with a stressor. Based on previous findings (Genet et al., 2013) we expected less efficient shifting of attention to affective aspects of positive material and more efficient shifting to non-affective aspects of positive material to be associated with relatively more use of maladaptive regulation strategies and less use of adaptive strategies. Based on recent findings (Twivy et al., 2020), and theoretical models of avoidance in anxiety and worry (Borkovec et al., 2004; Mogg et al., 2004), we expected more efficient shifting of attention towards non-affective aspects of negative material to be associated with relatively more reported use of maladaptive emotion regulation strategies.

Finally, we expected ‘maladaptive’ and ‘adaptive’ emotion regulation strategy use to have different effects on the response to a stressor and recovery afterwards. We expected more reported use of maladaptive regulation strategies to be associated with blunted HRV reactivity, a greater emotional response, but reduced recovery after the stressor is over. We expected opposite effects for reported use of adaptive emotion regulation strategies, but such effects may be weaker given that the efficacy of these ‘adaptive’ strategies may be context dependent.

Method

Participants

Hundred-twenty participants were recruited[2] through online message boards from the

[2] An a-priori power analysis was done for a linear multiple regression model based on R^2 deviation from zero when the four switch costs are in the model. We anticipated to analyse effects of affective flexibility and emotion regulation on stress reactivity during the different stress induction phases (i.e. anticipation, stress, first recovery, feedback, second recovery) separately. Since then we decided a better approach would be to test the effects on the trajectory of HRV and subjective mood across the different phases in one mixed effects analysis. For the original analysis, assuming a medium effect size $f^2 = 0.15$, corrected alpha level of 0.01 and power of 0.80, the necessary sample size is 119 participants. The choice for a medium effect size was based on related work (Malooly et al., 2013) investigating the influence of individual differences in affective flexibility on the effectiveness of using reappraisal to regulate sad affect in response to a negative mood induction. They reported an effect size ($R^2 = .22$) that would be considered a medium effect, when adding specific affective flexibility switch costs to a model to predict differences in sad affect when instructed to use cognitive reappraisal to regulate.

university. Exclusion criteria were seeking help or being treated for psychological/psychiatric complaints in the past six months, current or history of cardiovascular disease, and use of psychoactive medication or medication that influences cardiovascular activity. Two participants were excluded from analysis because the percentage of errors in the switching task was more than 2.5 *SD*s from the sample mean. The final sample therefore consisted of 118 participants (90 females) aged 18-53 years old (M = 23.24, SD = 6.10). An additional nine participants were excluded from statistical analyses on HRV data because beat-to-beat heart rate recordings were very noisy. Participants were paid for their participation. This study was approved by the Medical Ethics Committee at the Ghent University Hospital (reference: EC/2018/1505).

Procedure

Exclusion criteria were first checked at the start of the study, after which the telemetric heartbeat monitor was put on and beat-to-beat heart rate registration continued throughout the rest of the experiment. Participants then completed the self-report questionnaires, followed by the affective flexibility switching task. After the computer task we measured heart rate during a 10-min rest period for which the last 5 mins were used as baseline to have equal duration as the other phases of the stress induction (e.g. anticipation, stress and recovery phase). Participants were asked to sit quietly and to relax. At the end of this baseline period we measured mood state with VAS scales for the first time (T1). Following this, the stress induction procedure started which was based on the Trier Social Stress Test. Participants were instructed to give a 5-min presentation about the following statement: “Why are you suitable for the job that you would like to have or already have, why would you deserve this job?” They were first given a bit of time to imagine which job they would like to have and were then instructed that a 5-min preparation period would follow in which they could prepare the presentation. They would have to argue “why you are suited for the job you would like to have or already have.” They were prompted to think about both their strong and weak points and to give some examples of those. They were not allowed to make any notes. Participants were told that they would give the presentation in front of a webcam as three colleagues of the main researcher with a lot of experience in public speaking would judge the presentation. After this 5-min anticipation phase we measured mood state again (T2). Following the anticipation phase participants were instructed that they would now have to give their presentation and were reminded that they have to argue why they are suited for the job they would like to have or already have and why they would deserve the job. They had to present for the whole 5-min period and were asked to talk clearly into the webcam-camera. The researcher would then start Skype, which would turn on a green light on the webcam, and pretend to check with the colleagues whether they were ready ("Are you ready to start the presentation?" and confirm). Participants could not see the other colleagues—they were not actually there—but the researcher remained present during the presentation. The participant was then told they could start their presentation. If participants fell silent during the five minutes they were prompted with "You still have time left." After this stress phase we measured mood state again (T3) and participants were then instructed that another 5-min rest period would follow in which we asked them to just sit still. This first recovery period was followed by another assessment of mood state (T4). After the recovery phase participants were told that the three colleagues who watched the presentation each recorded some feedback which would be played to them so that they could potentially use this in the future. In between each colleague's feedback (approx. 30-40 secs each), participants were given a minute to process this feedback before the next was played. The feedback period therefore also lasted 5 mins. Pre-recorded, mostly negative, bogus feedback was played. Two recordings were by males and one recording by a female. Participants were told things like "…not all arguments were as convincing and the structure of the presentation could be better…," "The person sounded a bit insecure and therefore seemed unreliable," or "I missed some originality in the arguments, but this is perhaps because the person is inexperienced in presenting." After this feedback period we measured mood state again (T5), which was followed by a second 5-min rest period in which we instructed participants to just sit still. This second recovery period was followed by a final assessment of mood state (T6). Participants then completed the CERQ questionnaire. Upon completion of the experiment we removed the telemetric heartbeat monitor and participants were asked whether they believed the feedback was real (yes/no). At the end participants were debriefed about the nature of the study and the bogus feedback.

Material

Questionnaires[3]

The exclusion criteria were assessed with three yes/no questions. Participants were asked if they ever received a diagnosis for a cardiovascular disease (and if yes, what type of condition), whether they sought help or were treated for psychological/psychiatric complaints in the past six months, and whether they were currently using psychoactive medication or medication that influences cardiovascular activity.

Trait anxiety was measured with the trait component of the State-Trait Anxiety Inventory (STAI-T; Spielberger et al., 1983; Van der Ploeg et al., 2000) in which participants were asked to rate how they generally feel on a 4-point scale from 1 (almost never) to 4 (almost always). The total score can range between 20 and 80. In the current sample, the STAI-T had high internal consistency ($\alpha = 0.91$).

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[3] We also administered the Connor-Davidson Resilience Scale (CD-RISC; Connor & Davidson, 2003) to measure self-reported resilience and the Perceived Criticism Measure (Hooley & Teasdale, 1989) to measure perceived criticism. However, these measures will not be used to test the hypotheses of the current study.

The presence and severity of depressive symptoms in the past two weeks was measured with the Beck Depression Inventory (BDI; Beck et al., 1996; Van der Does, 2002). Participants are asked to rate 21 items on a 0-3 scale. The total score can range between 0 and 63. In the current sample, the BDI had high internal consistency (α = 0.91).

Perceived emotions were measured with visual analogue scales (0 to 10 cm, resulting in a 0-100 scale). We measured how happy, sad, aroused, angry, and tense participants were feeling "at this moment" across different time points. We measured how happy and sad participants were feeling on a scale from "neutral" to "as happy/sad as I can imagine." We measured arousal on a scale from "calm" to "aroused." Anger and tenseness were measured on a scale from "not at all" to "as angry/tense as I can imagine." The happy scale was used as a positive mood scale. We averaged the sad and anger scales into a negative mood scale, and the arousal and tense scales into a physical sensations scale.

The use of emotion regulation strategies was measured with the Cognitive Emotion Regulation Questionnaire short version that consists of 18 items (CERQ; Garnefski & Kraaij, 2006a). We adjusted the instructions such that participants were asked to indicate what they thought about the previous event (stress induction procedure). The original instructions are about what people generally think when they have experienced something bad. Participants rate each item on a 5-point scale from 1 (almost never) to 5 (almost always). The CERQ short version has 9 subscales, each consisting of two items: self-blame, rumination, catastrophizing, other-blame, acceptance, positive refocusing, refocus on planning, positive reappraisal, putting into perspective. For the purpose of this study we made a distinction between use of generally more 'maladaptive' and 'adaptive' emotion regulation strategies. We calculated a maladaptive emotion regulation score, summing item scores of the first four subscales, and an adaptive emotion regulation score, consisting of the latter five subscales. In the current sample, both the maladaptive emotion regulation score (α = 0.76) and the adaptive emotion regulation score (α = 0.71) had acceptable internal consistency.

Affective Flexibility

Affective flexibility was measured using a task switching paradigm previously developed by Malooly et al. (2013). Participants have to sort emotional images according to either an affective rule (positive or negative) or a non-affective rule (≤ 1 or ≥ 2 people depicted). Forty images were selected from the International Affective Picture System (IAPS; Lang et al., 2008) for each of the following categories: positive with one or fewer people, positive with two or more people, negative with one or fewer people and negative with two or more people (i.e. 160 images in total). Positive and negative images were different based on valence, but were balanced in terms of arousal ratings. Twenty additional images were used for practice.

Each trial started with a black screen (250ms), followed by the presentation of a central fixation cross (250ms). Next an emotional image was presented in the centre with cues indicating the relevant task rule on either side of the image: "+" and "-" for the affective task rule and "≤ 1" or "≥ 2" for the non-affective task rule. The image and cues were presented until the participant responded or for maximum 5000ms (response limit). The background screen colour (white or grey) during presentation of the emotional image also indicated the task rule. Participants had to respond by pressing one of two adjacent keys on the keyboard (labelled as "L" and "R"). Instructions told participants to work quickly but try to be as accurate as possible.

Participants first practiced the task running through two blocks, each consisting of 10 trials, in which participants had to apply the affective rule only, followed by the second block using the non-affective rule only. Participants then completed two 160-trial test blocks with a break in between. Trials were presented in a pseudorandom order (Malooly et al., 2013). There were eight versions of the task, counterbalancing different combinations of cue to key mappings and rule (affective/non-affective) to background colour (grey/white) mappings. The task cue to response key mapping and task rule to background colour mapping remained the same throughout the task.

Calculation of Switch Costs. The difference between mean RT on repetition trials and switch trials is termed the switch cost. Four different types of RT-based switch costs were calculated following Malooly et al. (2013): non-affective negative switch costs, affective negative switch costs, non-affective positive switch costs, and affective positive switch costs. For example, affective positive switch costs were calculated by subtracting the mean RT on trials in which the affective task rule was repeated in the presence of positive images, from the mean RT on trials in which the task rule switched from non-affective to affective in the presence of positive images. Negative non-affective switch costs were calculated by subtracting the mean RT on trials in which the non-affective rule was repeated in the context of negative images, from the mean RT on trials in which the task rule switched from affective to non-affective in the presence of negative images. Larger switch costs reflect poorer flexibility.

Heart Rate Variability

Beat-to-beat heart rate was recorded continuously throughout the experiment using a telemetric heartbeat monitor (Polar V800; Polar Electro Oy, Kempele, Finland), which wirelessly received data from a chest strap worn by participants. Heart rate and inter-beat interval sequences (RR intervals) for each of the different phases during the stress induction procedure were extracted and further analyzed with Kubios HRV Standard software 3.1.0 (Biosignal Analysis and Medical Imaging Group, n.d.; Tarvainen, Niskanen, Lipponen, Ranta-aho, & Karjalainen, 2014). RR interval series were visually inspected for artifacts and corrected using Kubios artefact correction, which replaces detected artefact beats using cubic spline interpolation. We used time-domain based root mean square successive difference in beat-to-beat intervals (RMSSD) as an index of HRV.

Frequency-domain based HF-HRV was highly correlated with RMSSD throughout the baseline phase (Spearman $r = 0.95$, $p < .001$), anticipation phase (Spearman $r = 0.94$, $p < .001$), stress phase (Spearman $r = 0.91$, $p < .001$), first recovery phase (Spearman $r = 0.93$, $p < .001$), feedback phase (Spearman $r = 0.94$, $p < .001$), and second recovery phase (Spearman $r = 0.93$, $p < .001$). Therefore, we only used RMSSD to examine effects on stress reactivity. The RMSSD reflects vagally mediated HRV and is relatively free of respiratory influences as compared to high frequency parameters (Laborde et al., 2017).

Data Analysis

We used R (R Core Team, 2019) for statistical analyses. Specifically we used the R packages tidyverse (Wickham, 2017), pastecs (Grosjean & Ibanez, 2018), Hmisc (Harrell Jr, 2019) and cowplot (Wilke, 2019) for data exploration, descriptive statistics and calculating correlations. The package rmcorr was used to compute the repeated measures correlation (Bakdash & Marusich, 2020). For linear regression analysis we used the packages stats (R Core Team, 2019), car (Fox & Weisberg, 2019) and QuantPsyc (Fletcher, 2012). We used nlme for mixed effects modelling (Pinheiro et al., 2018).

Feedback Manipulation

Based on the manipulation check whether participants thought the feedback was real, 75 participants reported “no,” 24 participants reported “in doubt,” and only 19 participants reported “yes.” This was supported by paired t-tests showing that receiving the feedback did not result in significant changes in heart rate or HRV (HRV data was log-transformed because of non-normality). There was no significant difference between the first recovery phase and the feedback phase in HR, $t(104) = 1.17$, $p = .243$, nor in HRV, $t(104) = -1.09$, $p = .280$. Similarly, there was no significant difference between the first recovery phase and the second recovery phase in HR, $t(103) = 1.07$, $p = .288$, nor in HRV, $t(103) = -0.96$, $p = .340$. Given that more than half of the participants reported not to believe the feedback was real (e.g., "the feedback was too general"), we focused our analyses on data from the first phases of the stress induction: anticipation period, stress period (giving the presentation) and the first recovery period afterwards.

Affective Flexibility, Induced Stress and Recovery

To investigate whether affective flexibility predicted changes in HRV and perceived emotion across the anticipation period, stress period, and recovery period afterwards (research question 1), we tested mixed effects models using maximum log-likelihood method. We tested separate models for our four outcome measures: HRV, positive emotion, negative emotion, and physical sensations. We first tested a baseline model including the linear effect of time. We added random intercepts and to account for the correlation between time points within each participant we added an unstructured covariance structure (model 1). Building on this model, we then included the quadratic effect of time (model 2), because we expected HRV and perceived emotions to first increase/decrease (depending on the outcome measure) during the anticipation and stress phase, but then decrease/increase again during recovery once the stressor is over, following a quadratic pattern. Finally, we added the four types of affective flexibility switch costs to the model, to test their interaction with both linear and quadratic effects of time (model 3). The (relatively) best fitting model was determined based on a combination of comparing the log-likelihoods of the fitted models, AIC and BIC.

Affective Flexibility and Reported Emotion Regulation Strategy Use

To investigate whether affective flexibility influenced reported use of 'maladaptive' and 'adaptive' emotion regulation (ER) strategies when confronted with the stressful situation (research question 2), we tested two multiple regression models, separately for reported use of maladaptive and adaptive ER strategies. For each model, we added the four affective flexibility switch costs as predictors. We first examined if the multiple regression models were significant and then examined the effects of the individual switch costs.

Emotion Regulation Strategy Use, Induced Stress and Recovery

To investigate whether reported ER strategy use predicted changes in HRV and perceived emotion across the anticipation period, stress period, and recovery period afterwards (research question 3), we also tested mixed effects models using maximum log-likelihood method. We first tested the same model 1 and model 2 as for research question 1, but in model 3 we instead added reported use of 'maladaptive' ER strategies and 'adaptive' ER strategies, to test their interaction with both linear and quadratic effects of time.

To control for multiple comparisons when testing the effects of affective flexibility on changes in both HRV and perceived emotion across time (research question 1), we applied the Benjamini-Hochberg false discovery rate-controlling procedure to calculate adjusted p-values. The false discovery rate was set at 0.05. The number of tests was based on doing two tests to compare models (model 1 vs. 2, model 2 vs. 3) when testing the effect on changes in HRV and perceived emotion (positive emotion, negative emotion, physical sensations) across the anticipation period, stress period and recovery afterwards. This results in a total number of 8 tests, to investigate whether affective flexibility influences the changes in both HRV and perceived emotion across time. The same correction procedure was applied to control for multiple comparisons when testing the effects of emotion regulation strategy use on changes in HRV and emotions over time (research question 3). We report both the original *p*-values and the FDR-controlled *q*-values as calculated with the R Stats package. Where applicable, results are reported after log-transforming data and/or removing cases with outlying standardized residuals (> 2.58) to improve the model in terms of normality of the residuals.

Results

Preliminary Analysis

The first trial of each test block in the affective flexibility task was excluded from analysis. Additionally, we only included trials that were preceded by a correct trial (Demanet et al., 2011; Mocan et al., 2014), because of post-error slowing and if the preceding trial was incorrect it is ambiguous whether the current trial is a repetition or switch from the participant's perspective. Accuracy was thus calculated by dividing the number of correct trials preceded by a correct response, by the total number of trials (correct and incorrect) that were preceded by a correct response. Only correct trials preceded by a correct response were included in the calculation of mean RT, which resulted in deleting an average of 11.35% of trials for each participant. To be consistent with previous studies (Genet et al., 2013; Greenwald et al., 2003; Malooly et al., 2013), we replaced RT values 2.5*SD* above and below the mean RT for each participant and specific trial type by these upper and lower cut-off values, to reduce the influence of outlying RTs.

Nonparametric Wilcoxon signed-rank tests (because data was not normally distributed) on all repetition and switch trials confirmed that accuracy on repetition trials ($M = 0.95$, $SD = 0.03$) was significantly higher than accuracy on switch trials ($M = 0.93$, $SD = 0.03$), $V = 5569$, $p = < .001$. RTs on repetition trials ($M = 1250$, $SD = 245.24$) were significantly lower than RTs on switch trials ($M = 1381$, $SD = 274.04$), $V = 7$, $p = < .001$. This confirms overall switch costs for both RT and accuracy and rules out the possibility of a speed-accuracy trade-off. We then calculated the four different types of switch costs.

We combined the sad and anger scales into a negative mood scale, and the arousal and tense scales into a physical sensations scale. Visual inspection (see Supplemental Figure 1) showed that the sad and angry, and arousal and tense scales follow a similar pattern over time.

Moreover, we computed the repeated measures correlations to determine the overall within-individual relationship among the paired measures, assessed across the anticipation period, stress period, and recovery period. The repeated measures correlation for the sad and anger scales was medium to large, $r = 0.41$, $p = 0$, 95% CI [0.32, 0.49], and for the arousal and tense scales the correlation was large, $r = 0.74$, $p = 0$, 95% CI [0.69, 0.79], supporting the decision to pair these scales.

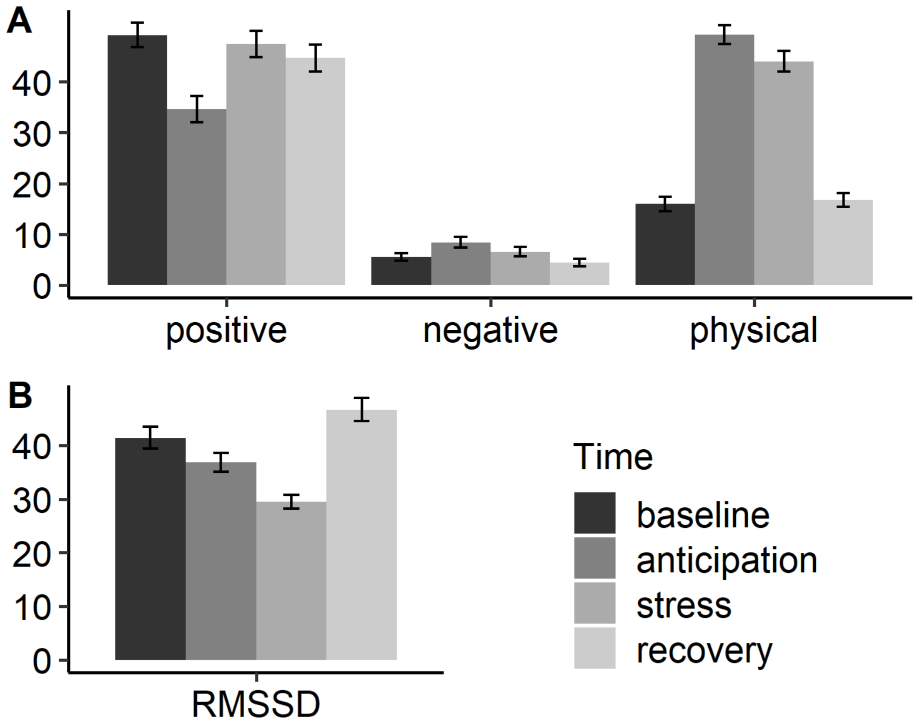

Figure 1. Stress reactivity across the different stress induction phases. A) subjectively perceived stress; B) heart rate variability. Error bars represent standard errors of the mean.

Descriptive Statistics

Table 1 shows the mean and standard deviations for measures of trait anxiety, depressive symptoms, use of adaptive and maladaptive emotion regulation strategies, and switch costs from the affective flexibility task. We also calculated Spearman correlations (some variables were not normally distributed) between these variables. The scores on the STAI-T and BDI showed that our sample reported average levels of trait anxiety (Spielberger et al., 1983) and depressive symptoms for a healthy, highly educated sample (Roelofs et al., 2013). Figure 1 shows both HRV and subjectively experienced emotions across the different phases of the stress induction.

Table 1. *Descriptive statistics and Spearman correlations*

	M (*SD*)	1	2	3	4	5	6	7
Trait anxiety	38.05 (8.57)							
Depressive symptoms	7.26 (7.48)	.78***						
Adaptive ER	34.20 (5.52)	-.21*	-.13					
Maladaptive ER	18.75 (4.37)	.55***	.45***	.24**				
NA negative switch costs (ms)	78.62 (204.84)	-.08	-.17	-.09	.02			
A negative switch costs (ms)	182.80 (207.88)	.15	.05	-.06	.12	.32***		
NA positive switch costs (ms)	184.87 (161.36)	-.05	.06	<.01	-.14	.11	.16	
A positive switch costs (ms)	119.20 (165.66)	-.07	.04	.03	.04	.05	.05	-.05

* $p < .05$; ** $p < .01$; *** $p < .001$; NA = non-affective; A = affective

Affective Flexibility, Induced Stress and Recovery

Heart Rate Variability

Model comparison for effects of affective flexibility on log-transformed HRV across time showed that the model with both linear and quadratic effects of time was the best fitting model, $\chi^2(1) = 23.18$, $p = < .001$, $q = < .001$ (see Supplemental Table 1 for model comparison). Adding the switch costs did not further improve model fit and none of the switch costs (nor in interaction with time) had a significant effect on HRV. The best fitting model showed a linear effect of time, $b = -0.42$, $t(316) = -5.32$, $p = < .001$, 95% CI [-0.57, -0.27], and a quadratic effect of time, $b = 0.09$, $t(316) = 5.89$, $p = < .001$, 95% CI [0.06, 0.12], reflecting that HRV decreased during the anticipation and stress period and then increased again during the recovery period afterwards (see Figure 1).

Positive Emotion

Model comparison for effects of affective flexibility on positive emotion across time showed that the model with both linear and quadratic effects of time was the best fitting model, $\chi^2(1) = 8.48$, $p = .004$, $q = .007$ (see Supplemental Table 2 for model comparison). Adding switch costs did not further improve model fit and none of the switch costs (nor in interaction with time) had a significant effect on changes in positive emotion. The best fitting model showed a linear effect of time, $b = -14.46$, $t(346) = -3.67$, $p = < .001$, 95% CI [-22.17, -6.74], and a quadratic effect of time, $b = 2.84$, $t(346) = 3.63$, $p = < .001$, 95% CI [1.31, 4.37], reflecting that perceived positive emotion first decreased during the anticipation period and then increased again across the stress period and recovery period afterwards (see Figure 1).

Negative Emotion

Model comparison for effects of affective flexibility on log-transformed negative emotion across time showed that the model with both linear and quadratic effects of time was the best fitting model, $\chi^2(1) = 19.11$, $p = < .001$, $q = < .001$ (see Supplemental Table 3 for model comparison). Adding the switch costs did not improve model fit and none of the switch costs (nor in interaction with time) had a significant effect on changes in negative emotion. The best fitting model showed a linear effect of time, $b = 0.39$, $t(339) = 3.41$, $p = .001$, 95% CI [0.17, 0.62], and a quadratic effect of time, $b = -0.10$, $t(339) = -4.59$, $p = < .001$, 95% CI [-0.14, -0.06], reflecting that perceived negative emotion first increased during anticipation of the stressor and stress period, and then decreased during recovery afterwards (see Figure 1).

Physical Sensations

Model comparison for effects of affective flexibility on self-reported physical sensations across time showed that the model with both linear and quadratic effects of time was the best fitting model, $\chi^2(1) = 151.17$, $p = < .001$, $q = < .001$ (see Supplemental Table 4 for model comparison). Adding the switch costs did not improve model fit and none of the switch costs (nor in interaction with time) had a significant effect on self-reported physical sensations. The best fitting model showed a linear effect of time, $b = 75.73$, $t(351) = 18.12$, $p = < .001$, 95% CI [67.54, 83.93], and a quadratic effect of time, $b = -15.13$, $t(351) = -18.63$, $p = < .001$, 95% CI [-16.72, -13.53], reflecting that self-reported physical sensations increased during the anticipation and stress period and then decreased during the recovery period afterwards (see Figure 1).

Affective Flexibility and Reported Emotion Regulation Strategy Use

Maladaptive Emotion Regulation Strategies

The multiple regression model with affective flexibility on the self-reported use of maladaptive ER strategies was significant, $F(4, 113) = 2.98$, $p = .022$, adj. $R^2 = 0.06$. There was an effect of affective negative switch costs, $b = 0.01$, $t = 2.75$, $p = .007$, 95% CI [0.00, 0.01], reflecting that less efficient shifting of attention towards affective aspects of negative information (i.e. higher switch costs) was associated with more reported use of maladaptive ER strategies. Additionally, there was an effect of non-affective positive switch costs, $b = -0.01$, $t = -2.24$, $p = .027$, 95% CI [-0.01, 0.00], reflecting that more efficient shifting of attention towards non-affective aspects of positive information (i.e. lower switch costs) was associated with more reported use of maladaptive ER strategies.

Adaptive Emotion Regulation Strategies

The model with affective flexibility on the self-reported use of adaptive ER strategies was not significant, $F(4, 113) = 0.14$, $p = .966$, adj. $R^2 = -0.03$.

Emotion Regulation Strategy Use, Induced Stress and Recovery

Heart Rate Variability

Model comparison for effects of ER strategy use on log-transformed HRV across time showed that the model with both linear and quadratic effects of time was the best fitting model, $\chi^2(1) = 23.18$, $p = < .001$, $q = < .001$ (see Supplemental Table 5 for model comparison). Adding emotion regulation strategy scores did not further improve model fit and neither adaptive nor maladaptive emotion regulation strategy use (nor in interaction with time) had a significant effect on HRV. The best fitting model showed a linear effect of time, $b = -0.42$, $t(316) = -5.32$, $p = <$ .001, 95% CI [-0.57, -0.27], and a quadratic effect of time, $b = 0.09$, $t(316) = 5.89$, $p = < .001$, 95% CI [0.06, 0.12], reflecting that HRV decreased during the anticipation and stress period and then increased during the recovery period afterwards (see Figure 1).

Positive Emotion

Model comparison for effects of ER strategy use on positive emotion across time did not result in one clear best fitting model. AIC and comparing log-likelihood indicated the final model including ER strategy use as the best fitting model, $\chi^2(6) = 16.48$, $p = .011$, $q = .013$ (see Supplemental Table 6 for model comparison). However, the BIC–which penalizes model complexity more heavily–indicated the model with just linear and quadratic effects of time as the best fitting model. In the model including ER strategy use, there was a marginally significant interaction between the linear effect of time and reported maladaptive ER strategy use, $b = -1.98$, $t(345) = -1.95$, $p = .052$, 95% CI [-3.96, 0]. Additionally, there was a marginally significant interaction between the quadratic effect of time and reported maladaptive ER strategy use, $b = 0.37$, $t(345) = 1.87$, $p = .062$, 95% CI [-0.01, 0.76]. This effect reflected that more reported use of maladaptive ER strategies tended to be associated with a relatively stronger decrease in perceived positive emotion across the anticipation period and stress period, but also increase again in positive emotion during recovery, whereas less reported use of maladaptive ER strategies was associated with a more stable level of perceived positive emotion across the stress induction and recovery period (see Figure 2).

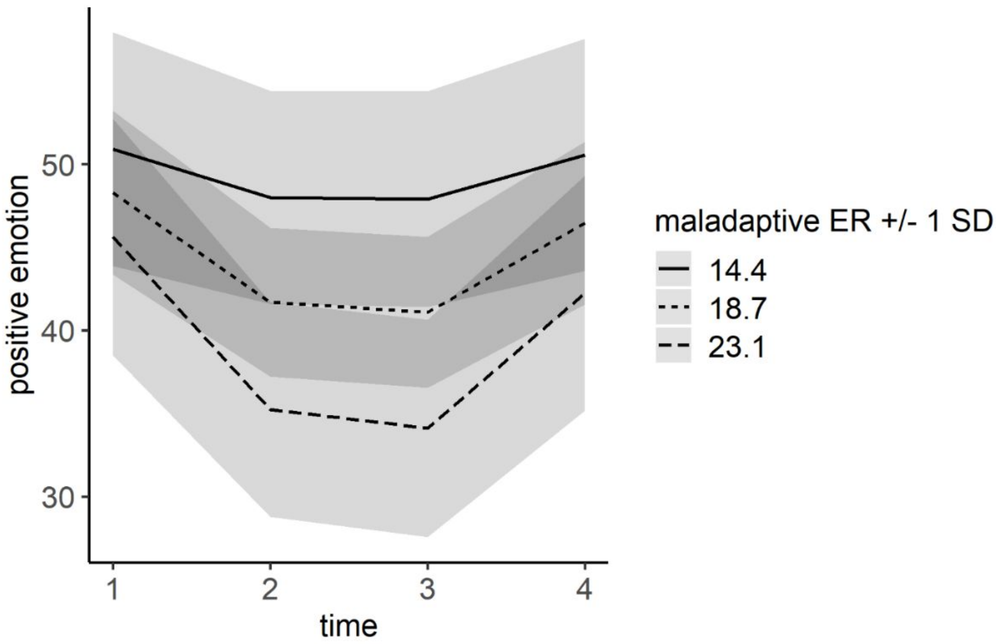

Figure 2. Predicted positive emotional reactivity across stress induction and recovery, depending on level of reported maladaptive emotion regulation strategy use. 95% CI are plotted.

Negative Emotion

Model comparison for effects of ER strategy use on log-transformed negative emotion across time did not result in one clear best fitting model. AIC and comparing log-likelihood indicated the final model including ER strategy use as the best fitting model, $\chi^2(6) = 34.16$, $p = < .001$, $q = < .001$ (see Supplemental Table 7 for model comparison). However, the BIC indicated the model with just linear and quadratic effects of time as the best fitting model. In the model including ER strategy use, there was a linear effect of time, $b = 2.03$, $t(342) = 2.25$, $p = .025$, 95% CI [0.27, 3.78], and a quadratic effect of time, $b = -0.40$, $t(342) = -2.34$, $p = .020$, 95% CI [-0.73,

-0.07]. Reported use of adaptive ER strategies further qualified the linear effect of time, *b* = -0.07, *t*(342) = -2.71, *p* = .007, 95% CI [-0.11, -0.02], and the quadratic effect of time, *b* = 0.01, *t*(342) = 2.74, *p* = .006, 95% CI [0, 0.02]. This effect reflected that less reported use of adaptive ER strategies was associated with a relatively stronger increase in perceived negative emotion across the anticipation period and stress period, but also decrease again in negative emotion during recovery once the stressor was over, whereas more reported use of adaptive ER strategies was associated with a more stable level (or slightly decreasing) of perceived negative emotion across the stress induction and recovery period (see Figure 3).

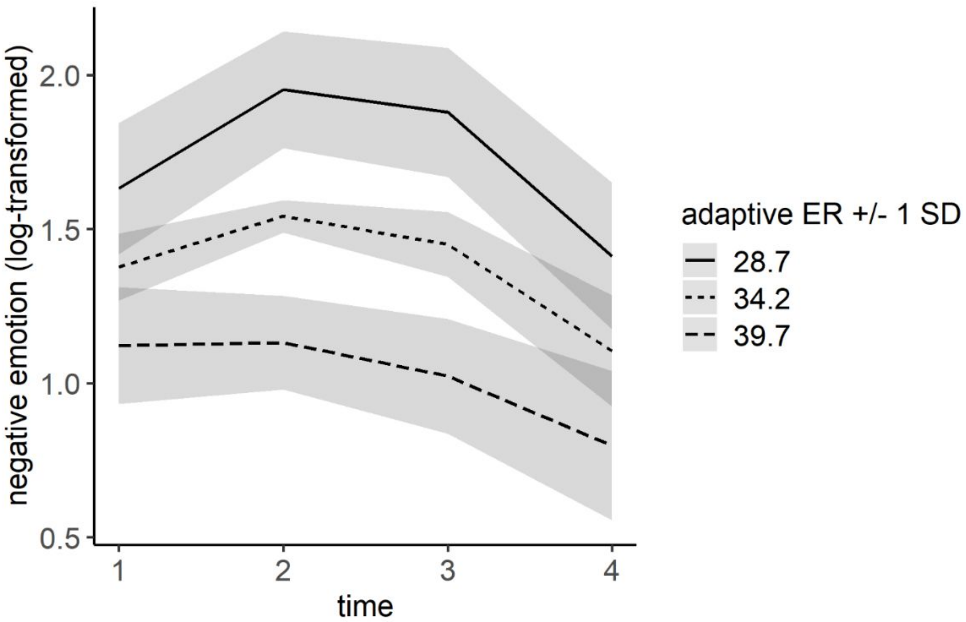

Figure 3. Predicted negative emotional reactivity across stress induction and recovery, depending on level of reported adaptive emotion regulation strategy use. 95% CI are plotted.

Physical Sensations

Model comparison for effects of ER strategy use on self-reported physical sensations across time did not result in one clear best fitting model. AIC and comparing log-likelihood indicated the final model including ER strategies as the best fitting model, $\chi^2(6) = 20.04$, *p* = .003, *q* = .004 (see Supplemental Table 8 for model comparison). However, the BIC indicated the model with just linear and quadratic effects of time as the best fitting model. Yet, in the model including ER strategy use, there was only a marginally significant linear effect of time, $b = 54.85$, $t(347) = 1.89$, $p = .059$, 95% CI [-1.63, 111.33], and a quadratic effect of time, $b = -11.36$, $t(347) = -2.02$, $p = .045$, 95% CI [-22.34, -0.38], but neither adaptive nor maladaptive ER strategy use modulated changes in self-reported physical sensations over time.

Discussion

The ability to regulate emotional and physiological responses contributes to adapting well to challenging and stressful situations. Several mental disorders are characterized by a dysfunctional response to stress, so understanding which cognitive mechanisms underlie adequate and adaptive responding to stress plays a critical role in understanding mental health and resilience. The aim of this study was therefore to investigate whether affective flexibility directly influences the response to a stressor and recovery afterwards, and/or influences the spontaneous use of emotion regulation strategies when confronted with a stressful situation, which in turn can influence the response to the stressor.

Although it is widely agreed upon that flexibility in shifting mindset and behaviour according to situational demands is a fundamental aspect of (mental) health and resilience (Kashdan & Rottenberg, 2010), surprisingly little is known about whether individual differences in affective flexibility directly influence one's response to, and recovery from stress. In the current study we did not find evidence for a direct effect of individual differences in the flexible processing of affective material on the response to a stressful situation and recovery once the stressor is over. Rather than directly influencing the response to adverse events, cognitive processes that allow flexible attending to and disengaging from affective material may be linked to emotion regulation processes.

The use and effectiveness of emotion regulation strategies may depend on individual differences in cognitive processes such as affective flexibility. We found a small effect of individual differences in affective flexibility on reported (spontaneous) use of maladaptive strategies, but not on use of adaptive strategies. As expected, we found that greater flexibility in shifting attention towards non-affective aspects of positive material was associated with greater reported use of maladaptive emotion regulation strategies, in line with previous findings associating this to greater use of rumination in daily life (Genet et al., 2013). We did not find that less flexibility in shifting attention towards affective aspects of positive material is related to maladaptive emotion regulation use. Although this has previously been associated with less reappraisal efficacy (Malooly et al., 2013), it neither predicted use of rumination in daily life (Genet et al., 2013). Our finding suggests that cognitive processes that could facilitate attentional avoidance of positive information are associated with more use of maladaptive emotion regulation strategies. That is, cognitive processes that promote attentional avoidance of positive information link to strategies such as rumination where one repetitively focusses attention on possible causes and consequences of one’s distress, which may increase self-focus and self-blame, or viewing a situation considerably worse than it actually is (catastrophizing).

In terms of processing negative material, we did not find support for our hypothesis that differences in flexibility when shifting attention towards non-affective aspects of negative material relate to use of maladaptive regulation strategies. Instead, we found that less efficient shifting of attention from non-affective towards affective aspects of negative information was associated with more reported use of maladaptive emotion regulation strategies. As with positive information, cognitive processes that facilitate attentional avoidance of negative affective information or impede engagement with negative affective information thus seem to relate to greater use of maladaptive strategies. This finding may be best explained in the context of theoretical models linking attentional avoidance of negative emotional information to worry (Borkovec et al., 2004). Rumination (like worry) is also proposed to function as an avoidance strategy that prevents active engagement with—and thus change of—events that may be responsible for the experience of distress (Stroebe et al., 2007). Similarly, it has been suggested that rumination, via behavioural or cognitive avoidance and reduced concreteness, functions to avoid feelings and physical sensations (Cribb et al., 2006). Ironically, although experiential avoidance has been associated with similar or blunted reactivity of physiological arousal (heart rate) to a stressor or emotion induction, it has been associated with heightened subjective emotional reactivity (Feldner et al., 2003; Sloan, 2004).

Our findings concerning the influence of emotion regulation strategy use on the response to the stress induction and recovery afterwards, follow a comparable pattern. Reported use of adaptive and maladaptive emotion regulation strategies did not influence modulation of HRV across the anticipation and stress phase, nor during recovery, with our (healthy) sample showing the expected decrease of HRV when confronted with a stressor and increase again during recovery. Similarly, we found no significant effects of emotion regulation strategy use on self-reported physical sensations. Emotion regulation strategy use thus appeared to have no (or limited) influence on the actual and perceived physiological (bodily) response to a stressful situation and recovery, but it was rather related to *how* this was emotionally experienced. We found that relatively more reported use of adaptive emotion regulation strategies was associated with a relatively more stable level (even slight decrease) of experienced negative emotion across the stress induction and recovery period. For the positive emotional response we found that more reported use of maladaptive emotion regulation strategies only tended to be associated with a relatively stronger decrease in reported positive emotion across the anticipation period and stress period, but also increase again in positive emotion during recovery.

Taken together, we find that affective flexibility did not directly influence the response to a stressful event, nor recovery once the stressor was over, and only explained a small amount of variability in the reported use of maladaptive emotion regulation strategies during the stressful situation. Although cognitive flexibility, or specifically affective flexibility, has been proposed to play a role in emotion regulation success (e.g., Malooly et al., 2013; Ochsner & Gross, 2007), our results suggest that the impact of individual differences in affective flexibility on stress regulation and emotion regulation strategy use is limited. It is likely that a combination of different cognitive (and other) factors influence our response to stressful situations and recovery afterwards, or influence emotion regulation processes. Affective and non-affective cognitive flexibility are also part of a set of executive functions, so the impact of a cognitive process in isolation may only be small and emotion regulation processes are likely supported by several executive functions. Consequently, this highlights the need for nuance in thinking that cognitive training, or specifically affective flexibility training, can improve emotion regulation success. Instead, a combination of different types of interventions or targeting multiple cognitive processes may prove to be more successful. Future research could further investigate whether it is a limited set of executive functions that have a more pronounced influence on the response to stressful situations, or whether executive function processes each have limited influence on their own but exert a combined influence. Additionally, future research should aim to replicate our findings that individual differences in affective flexibility influence the reported use of maladaptive emotion regulation strategies when confronted with a stressful situation. Such research could also systematically investigate whether affective flexibility, or executive functions more generally, influences people’s tendency to use certain emotion regulation strategies and/or how effectively they use these strategies, i.e., regulation efficacy.

In this study we focused on measuring the spontaneous use of different emotion regulation strategies during the stress induction. It is likely though that the strategies reportedly used during the stressful situation are related to 'trait' emotion regulation usage. Adaptive responding to stressful situations is believed to rely on using a diverse repertoire of regulation strategies (Bonanno & Burton, 2013) and most (healthy) individuals probably use a variety of regulation strategies across different contexts and time ('emotion regulation flexibility'), with potential preferences to using certain strategies more often. It is thus possible that the specific stress induction we used evoked the selection of one or a subset of emotion regulation strategies from people's repertoire, but for another type of stressful situation a different subset would be selected. Nevertheless, the regulation strategies individuals use when confronted with this specific stressful situation are part of their repertoire, and are thus a reflection of those strategies that people tend to spontaneously apply when confronted with challenges in life. It would be interesting for future research to further study the relationship between affective flexibility, or executive functions generally, reported use of emotion regulation strategies when confronted with stress and how that links to the full repertoire of regulation strategies that people report to generally use in life. One could manipulate certain characteristics of the challenging situation, e.g., social vs. non-social or controllable vs. uncontrollable, to examine how that influences the selection of emotion regulation strategies–and variation across situations–and if that is in any way related to individual differences in executive function processes.

A few limitations to the study should be discussed. First, our sample consisted mostly of young, healthy adults with average levels of depressive and anxiety symptoms. Our results therefore likely pertain to factors influencing normal variation in use of emotion regulation strategies and the response to a stressful situation. It remains unclear to what extent our findings generalize to other populations. Second, based on our feedback manipulation check and results showing that receiving the feedback was not associated with significant changes in heart rate or HRV, we decided to focus our analyses on the first phases of the stress induction and recovery. However, we did not include a similar manipulation check on whether participants believed they were watched by colleagues of the experimenter during their speech. It is possible that this adaptation to the Trier Social Stress Test resulted in a weaker stressor as compared to the original procedure. Nevertheless, previous studies using a similar adaptation of the Trier Social Stress Test (Pulopulos et al., 2020; Wandel et al., 2020) have shown a robust stress response, and current results also show a significant decrease in HRV from baseline to speech task, and a significant increase in subjectively experienced negative emotion and physical sensations. Third, there is continued debate around respiratory influences on HRV and controlling for this (Laborde et al., 2017). We did not measure respiratory rate and let participants breathe spontaneously. However, we used RMSSD as index of HRV which is less affected by breathing than HF-HRV and the effects of respiration on parasympathetic indices of resting HRV have shown to be minimal (Laborde et al., 2017). Additionally, there are several variables that can influence HRV such as age, gender, smoking, weight, cardioactive medication, oral contraceptive intake for female participants, and habitual levels of alcohol consumption (for an overview see Laborde et al., 2017). Although we excluded individuals using psychoactive or cardioactive medication, restricted the age range (18-55 years) and RMSSD has shown to decline more gradually with age (Umetani et al., 1998), we cannot rule out that unmeasured factors have influenced our results. Given that we examined intra-individual phasic changes in HRV, the influence of these confounding variables may be limited. Finally, it is important to note that we cannot draw any conclusions about the direction of the relationship between individual differences in affective flexibility and the reported use of maladaptive emotion regulation strategies. Although it is possible that individual differences in cognitive processes that facilitate avoidance of processing affective aspects of (positive and negative) emotional information lead to the use of more maladaptive regulation strategies, the opposite may be true as well. That is, a tendency to use maladaptive emotion regulation strategies (e.g. strategies that serve experiential or behavioural avoidance) when confronted with stress may lead to increased efficiency in shifting attention towards non-affective aspects of emotional material and decreased efficiency in shifting attention towards affective aspects of emotional material.

In summary, our findings suggest that individual differences in the flexible processing of affective material do not directly influence the response to stressful events. Affective flexibility was associated with the self-reported use of maladaptive emotion regulation strategies, but this effect is small. Specifically, flexibility in shifting of attention that could facilitate avoidance or impedes processing of affective aspects of (positive and negative) emotional information was related to greater reported use of maladaptive regulation strategies. Emotion regulation strategy use did not seem to influence the perceived and actual physiological (bodily) response to a stressful situation nor recovery afterwards, but it rather influenced *how* this was experienced emotionally. Whereas greater use of maladaptive strategies when confronted with a stressful situation tended to be associated with a bigger impact on positive emotion, especially the use of adaptive emotion regulation strategies seemed to be associated with reduced negative emotional reactivity to the stress induction. Our findings indicate that individual differences in affective flexibility have limited influence on the (acute) response to a stressful event and recovery afterwards, but do have some influence on spontaneous use of maladaptive emotion regulation strategies.

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Authorship

Both authors contributed to the study concept and design. Data collection, analysis and interpretation was performed by M. Grol, with the supervision of R. De Raedt. M. Grol drafted the paper, and R. De Raedt provided critical reviews. Both authors approved the final version of the paper for submission.

Open Practices Statement

The data and analysis scripts for this study are available on the Open Science Framework: [doi to be added].

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Supplemental Material

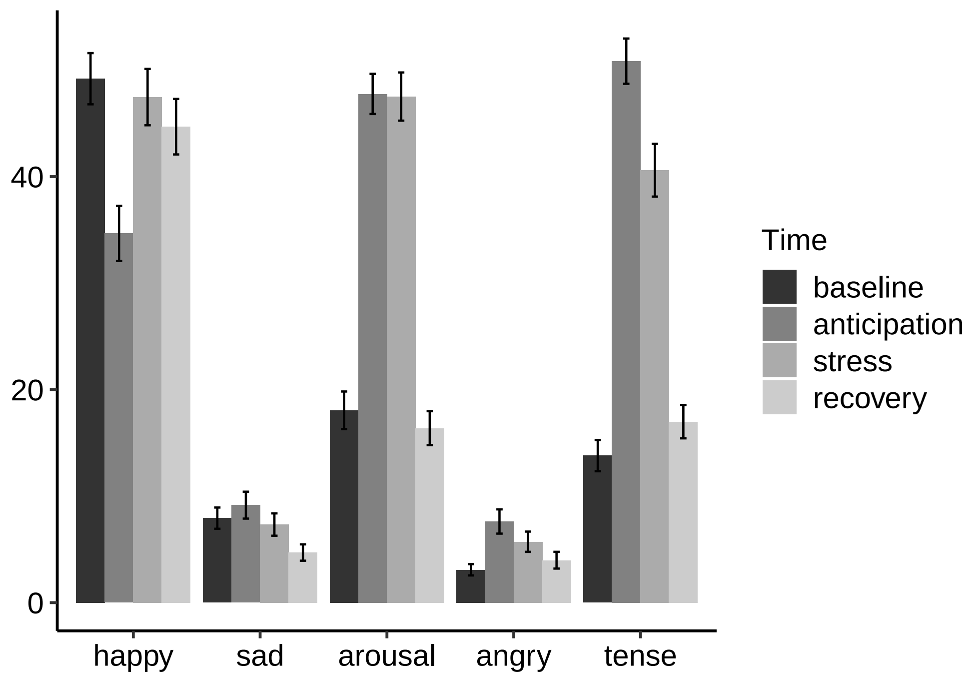

Figure 1: Self-reported mood state across the different stress induction phases. Error bars represent standard errors of the mean

Table 1: Model comparison effects of affective flexiblity on HRV

	df	AIC	BIC	logLik	L.Ratio	p-value
model1	10	327.93	368.49	-153.96	NA	NA
model2	11	306.74	351.37	-142.37	23.18	0.000
model3	23	320.87	414.17	-137.43	9.87	0.627

df = degrees of freedom; AIC = Akaike Information Criterion; BIC = Bayesian Information Criterion

Table 2: Model comparison effects of affective flexiblity on positive mood

	df	AIC	BIC	logLik	L.Ratio	p-value
model1	10	4135.08	4176.52	-2057.54	NA	NA
model2	11	4128.60	4174.18	-2053.30	8.48	0.004
model3	23	4141.24	4236.56	-2047.62	11.35	0.499

df = degrees of freedom; AIC = Akaike Information Criterion; BIC = Bayesian Information Criterion

Table 3: Model comparison effects of affective flexiblity on negative mood

	df	AIC	BIC	logLik	L.Ratio	p-value
model1	10	907.22	948.51	-443.61	NA	NA
model2	11	890.11	935.53	-434.06	19.11	0.000
model3	23	908.81	1003.77	-431.40	5.31	0.947

df = degrees of freedom; AIC = Akaike Information Criterion; BIC = Bayesian Information Criterion

Table 4: Model comparison effects of affective flexiblity on physical sensations

	df	AIC	BIC	logLik	L.Ratio	p-value
model1	10	4089.42	4130.97	-2034.71	NA	NA
model2	11	3940.25	3985.96	-1959.13	151.17	0.000
model3	23	3957.67	4053.23	-1955.83	6.59	0.884

df = degrees of freedom; AIC = Akaike Information Criterion; BIC = Bayesian Information Criterion

Table 5: Comparison of the different models for effects of emotion regulation on HRV

	df	AIC	BIC	logLik	L.Ratio	p-value
model1	10	327.93	368.49	-153.96	NA	NA
model2	11	306.74	351.37	-142.37	23.18	0.000
model3	17	308.50	377.46	-137.25	10.25	0.115

df = degrees of freedom; AIC = Akaike Information Criterion; BIC = Bayesian Information Criterion

Table 6: Model comparison effects of emotion regulation on positive mood

	df	AIC	BIC	logLik	L.Ratio	p-value
model1	10	4180.84	4222.34	-2080.42	NA	NA
model2	11	4175.77	4221.42	-2076.88	7.07	0.008
model3	17	4171.28	4241.84	-2068.64	16.48	0.011

df = degrees of freedom; AIC = Akaike Information Criterion; BIC = Bayesian Information Criterion

Table 7: Model comparison effects of emotion regulation on negative mood

	df	AIC	BIC	logLik	L.Ratio	p-value
model1	10	974.55	1015.99	-477.27	NA	NA
model2	11	954.22	999.81	-466.11	22.33	0
model3	17	932.06	1002.51	-449.03	34.16	0

df = degrees of freedom; AIC = Akaike Information Criterion; BIC = Bayesian Information Criterion

Table 8: Model comparison effects of emotion regulation on physical sensations

	df	AIC	BIC	logLik	L.Ratio	p-value
model1	10	4089.42	4130.97	-2034.71	NA	NA
model2	11	3940.25	3985.96	-1959.13	151.17	0.000
model3	17	3932.22	4002.85	-1949.11	20.04	0.003

df = degrees of freedom; AIC = Akaike Information Criterion; BIC = Bayesian Information Criterion