Cognitive Neurodynamics
https://doi.org/10.1007/s11571-019-09542-z

RESEARCH ARTICLE

Automatic self-focused and situation-focused reappraisal of disgusting emotion by implementation intention: an ERP study

Bin Ma[1] · Xian Xin Meng[2] · Quanshan Long[1] · Zhongming Zhang[1] · Shengdong Chen[1] · Jiemin Yang[1] · Xuan Zhang[1] · Jiajin Yuan[1]

Received: 3 August 2018 / Revised: 14 March 2019 / Accepted: 9 June 2019

Abstract

Detachment (self-focused) and positive reinterpretation (situation-focused) are two important forms of cognitive reappraisal during emotion regulation. Previous research shows situation-focused reappraisal to be more effective than self-focused reappraisal for intentional emotion regulation. How the two differ in emotional consequences as components of automatic emotion regulation is however unclear. In the current study, event-related potentials were recorded to clarify this problem, while participants passively viewed disgusting or neutral scenes or formed implementation intentions based on self-focused or situation-focused reappraisal. Behavioural results showed fewer negative emotions during self-focused reappraisal than during either situation-focused reappraisal or free viewing (which had similar emotion ratings). In addition, self-reported cognitive cost was not enhanced during the two forms of reappraisal compared to passive viewing. Late positive potential (LPP) amplitudes for disgusting stimuli were larger than those elicited for neutral stimuli, at both frontal and posterior-parietal regions. This amplitude enhancement effect, irrespective of whether frontal or parietal LPP were involved, was found to be weaker during self-focused reappraisal than when participants were engaged in situation-focused reappraisal or passive viewing. The latter two conditions showed similar amplitude enhancement. These findings suggest that automatic self-focused reappraisal by implementation intention produces more favourable emotion regulation than situation-focused reappraisal, without enhancing cognitive cost.

Keywords Implementation intention · Self-focused reappraisal · Situation-focused reappraisal · Automatic emotion regulation · Event-related potentials · Late-positive potential

Introduction

The effective regulation of emotions is important for social function as well as for health and well-being in general (Gross 2002; Tamir and Mauss 2011; Mayer and Salovey 1995). Since a model for emotion regulation was proposed by Gross (1998), most studies in the field have focused on what is known as 'intentional' emotion regulation, that is, conscious and voluntary forms of regulation of emotions that require cognitive resources (Buhle et al. 2014; Butler et al. 2003; Dörfel et al. 2014; Goldin et al. 2008; Gross 1998; Ochsner et al. 2004; Richards and Gross 1999; Shiota and Levenson 2012; Van Dillen and Koole 2007; Webb et al. 2012; Xie et al. 2016). Several empirical studies have also shown that intentional emotion regulation strategies can effectively regulate the effects of most negative emotions, such as reducing subjective negative emotional experience and negative emotional expression (Gross 1998; Ochsner et al. 2002; Yuan et al. 2015a).

Cognitive reappraisal is a highly effective strategy of emotion regulation; it is considered to alter emotional responses by encouraging reinterpretation of emotional stimuli (Buhle et al. 2014). A series of experiments showed that reappraisal leads to a reliable reduction in emotion

Bin Ma and Xian Xin Meng are first authors of equal contribution to this work.

✉ Jiajin Yuan
yuanjiajin168@126.com; yuanjiaj@swu.edu.cn

[1] The Affect Cognition and Regulation Laboratory (ACRLab), Key Laboratory of Cognition and Personality of Ministry of Education, Faculty of Psychology, Southwest University, Chongqing 400715, China

[2] School of Psychology, Fujian Normal University, Cangshan Campus, No. 8 Shangsan Road, Cangshan District, Fuzhou 350007, Fujian, China

Published online: 20 June 2019

experience (Gross 2002). Notably, cognitive reappraisal can be divided into situation-focused and self-focused reappraisal. Situation-focused reappraisal, such as positive reappraisal, refers to the reinterpretation of the situational context of a given stimulus, which requires reinterpretation of an emotionally charged situation in a constructive manner (Ochsner et al. 2002, 2004; Urry 2010). Self-focused reappraisal, such as detached reappraisal, describes the reinterpretation of one's subjective relationship to a stimulus, for example by detaching or distancing oneself from the emotional context (Ayduk and Kross 2008; Davis et al. 2011; Liberman et al. 2002), Previous studies have shown differences in the effectiveness of conscious situation-focused and self-focused reappraisal and have indicated that both are processed in different neural networks. Conscious self-focused reappraisal has been found to recruit the medial prefrontal cortical regions, whereas conscious situation-focused reappraisal has been demonstrated to recruit the lateral prefrontal cortical regions (Ochsner et al. 2004); both strategies lead to similar activation in the amygdala (Ochsner et al. 2004). Recently, Willroth and Hilimire (2016) investigated the regulatory effects of conscious reappraisal, situation- as well as self-focused, on electrocortical responses to pictures with negative content. Using an event-related potential (ERP) technique, the authors found an association between conscious situation-focused reappraisal and a reduction of the centroparietal late positive potential (LPP) amplitude; no such association was found for conscious self-focused reappraisal. These results suggest that, for negative pictures, conscious situation-focused reappraisal leads to a stronger attenuation of the LPP than conscious self-focused reappraisal (Willroth and Hilimire 2016).

Notably, several studies demonstrated that when intentional emotion regulation is adopted to reduce negative emotion, subjective efforts or cognitive resources are needed (Gailliot et al. 2007; Muraven et al. 1998). For example, studies have consistently shown that when negative emotions are suppressed intentionally, sympathetic physiological activation is enhanced, which may impair social and cognitive functions (Gross 2002; Butler et al. 2003) and even affect physical health (Gailliot et al. 2007; Muraven et al. 1998; Richards and Gross 2000).

Interestingly, recent behavioural studies have found that as an automatic form of self-regulation, implementation intention is effective in regulating emotions without taxing cognitive resources. Implementation intentions are 'if–then' plans specifying how, when, and where, a pre-determined plan will be carried out (Gollwitzer 1993, 1999): 'If situation X arises, then I will perform behaviour Y.' Implementation intentions differ from goal intentions ('I intend to reach Z'), which only describe one's desired performance or outcome. Rather than a simple goal setup, implementation intentions build up situation-behaviour contingency via the if–then plans, which facilitates goal attainment. Gallo et al. (2009) demonstrated that when emotion regulation instructions are framed as implementation intentions, they are more effective in modifying emotional responses than instructions describing the goal intention. An electroencephalography (EEG) study (Gallo et al. 2006) indicated that implementation intentions affect emotional responses very early on in the perceptual process ($\sim$ 100 ms); this finding is in line with the notion that implementation intentions are a reflection of a relatively automatic process that relies on the associations between specified cues ('If I see blood…') and related goal-directed responses ('I will remain calm and relaxed.'). A number of studies have recently demonstrated how forming implementation intentions affects emotional processing; a meta-analysis has indicated that implementation intentions are effective in modulating emotional consequences (Gollwitzer and Sheeran 2006).

However, no study has examined the effect and the electrophysiological underpinnings of automatic self-focused and situation-focused reappraisal in regulating emotional responses. In addition, considering how important time courses are in the study of emotion regulation (Gross 2014; Hajcak et al. 2014), ERPs, which provide excellent temporal resolution, seem like the most appropriate measure for comparing the temporal dynamics of self-focused and situation-focused reappraisal. Studies using ERPs to study cognitive reappraisal have identified specific LPP wave profiles. The LPP is widely recognized as a centroparietal ERP whose amplitude increases with the emotional arousal of the stimuli (Cuthbert et al. 2000; Hajcak et al. 2010, 2014). The sensitivity of the centroparietal LPP to cognitive reappraisal has been shown (Hajcak and Nieuwenhuis 2006; Hajcak et al. 2014), and it has successfully been used to track the temporal dynamics of emotion regulation strategies (Paul et al. 2013; Schönfelder et al. 2014; Thiruchselvam et al. 2011). Furthermore, it has been reported that cognitive effort and attentional control during situation-focused reappraisal implementation and the free implementation of self-focused and situation-focused reappraisal are reflected by an enhanced frontal cortical LPP (Moser et al. 2014; Shafir et al. 2015; Bernat et al. 2011).

The present study thus applied an ERP technique to study the role of automatic self-focused and situation-focused reappraisal in the regulation of emotional responses via implementation intentions. Previous studies have shown that automatic emotion regulation (AER) can occur without subjective awareness, and that it requires very little attention or subjective effort (Mauss et al. 2007). Based on this, we hypothesized that the frontal cortical LPP is similar or more pronounced during self-focused reappraisal than during situation-focused reappraisal. In addition, there is evidence suggesting that the intentional application of self-focused reappraisal requires more cognitive resources than situation-focused reappraisal (Shiota and Levenson 2009), and that the automation of emotion regulation benefits a strategy that is hard to perform consciously, rather than one executed skilfully (Williams et al. 2009). We thus hypothesized that automation of self-focused reappraisal, based on implementation intentions (II), would be equally or more useful than automation of situation-focused reappraisal. II-based self-focused regulation should result in a similar or larger reduction of emotional experience than II-based situation-focused reappraisal. Additionally, the effect of emotional regulation on the posterior-parietal LPP amplitude should be similar or more pronounced during self-focused reappraisal than during situation-focused reappraisal.

Materials and methods

Subjects

In total, 23 students (19–23 years; mean age = 20.82 years, 12 male) from Southwest University, Chongqing, China participated in this study. We conducted an a priori statistical power analysis via G*power (Faul et al. 2007), and verified that our sample size was large enough to obtain high statistical power (observed power > 0.8, at an alpha of 0.05). Before the experiment, all subjects were required to complete the Subjective Well-being Scale and callous unemotional trait questionnaires; scores of Subjective Well-being ranged from 15 to 33 (mean = 26.17, SD = 4.86), and callous unemotional trait scores ranged from 40 to 57 (mean = 48.26, SD = 4.57). The Subjective Well-being Scale was conducted as reported in earlier research, by calculating a composite variable that combines standardised scores related to positive affect, negative affect (subtracted) and life satisfaction (Macleod and Conway 2007). The scores in this study (life satisfaction: 12 to 25, mean = 19.65, SD = 3.63; positive affect: 1 to 4, mean = 2.65, SD = 0.77; negative affect: 0 to 4, mean = 2.08, SD = 1.37) were assessed during subject recruitment. The life satisfaction scores were significantly above the mid-point of the rating scale (17.5; t(22) = 2.837, $p = 0.01$). In addition, the subjects showed a predominantly positive affect in general, as the score for positive affect (t(22) = 2.461, $p = 0.036$) was significantly higher than the score for negative affect. These data suggest that our subjects had a comparable range of experience of negative emotions and emotionally healthy.

No participant reported a history of affective disorders or was currently prescribed psychiatric medication. The study design was approved by the local review board for human participant research, and each subject signed an informed consent form prior to the experiment. The experimental procedure was in accordance with the ethical principles of the 1964 Declaration of Helsinki.

Stimuli and procedures

Stimulus materials

The visual material consisted of 93 disgusting and 93 neutral pictures taken from the International Affective Picture System (IAPS; Lang et al. 1999) and the Chinese Affective Picture System (CAPS; Huang and Luo 2004).Thirty independent reviewers assessed the valence and arousal of the pictures (mean age = 21.1; SD = 2.22). The disgusting pictures depicted bloody burn victims and mutilated bodies, that is, contents that the bi-dimensional model of valence/arousal rates as negative and high-arousal. Neutral pictures had low arousal ratings and medium emotional valence. Pictures were displayed in a randomized order, and raters were asked, on scales ranging from 1 (little) to 7 (very), to rate their feeling of sadness, fear, joy, disgust, and anger when seeing the pictures. The results showed a significant main effect for the disgusting pictures (F(4460) = 1153.62, $p < 0.001$, $\eta_p^2 = 0.91$). The most prevalent emotion was disgust (M = 5.75, SD = 0.48), followed by fear (M = 4.22, SD = 0.54), sadness (M = 3.91, SD = 0.48), anger (M = 2.89, SD = 0.47), and joy (M = 1.40, SD = 0.24). These findings suggested that the selected unpleasant pictures can effectively elicit disgust. This was supported statistically by paired-sample t tests: disgust compared with fear: t(92) = 46.90, $p < 0.001$, d = 0.97. Negative pictures (1.62 [standard deviation, SD = 0.31]) had lower valence ratings than neutral pictures (4.81 [SD = 0.32]) (F(1,92) = 4903.06, $p < 0.001$, $\eta_p^2 = 0.982$). Furthermore, negative pictures (7.37 [SD = 0.52]), were rated as more arousing than neutral pictures (2.14 [SD = ± 0.39]) (F(1,92) = 6263.86, $p < 0.001$, $\eta_p^2 = 0.986$). Each of the three task strategies was assigned 62 randomly chosen pictures as stimuli (31 neutral pictures, 31 negative pictures). All pictures were identical in size (15×10 cm^2) and resolution (100 pixels/inch). In addition, luminance levels were tested before the experiment; three conditions of the pictures were thus kept similarly across conditions.

Procedure

The experiment was conducted in a quiet room, and participants were seated at approximately 150 cm from the screen; both horizontal and vertical visual angles were kept below 6°. Participants provided informed consent, completed a brief demographic questionnaire, and were then instructed to perform three tasks: passive viewing, automatic self-focused reappraisal, and automatic situation-focused reappraisal. During passive viewing, no further instructions were given. In the automatic situation-focused condition, the instruction was to form situation-focused reappraisal based on implementation intentions; subjects were first told to form the goal intention 'I will not get disgusted!' and then the if–then plan 'If I see blood, I will think blood represents vitality and health.' In automatic self-focused reappraisal based on implementation intention, subjects were first told to form the same goal intention, and then the if–then plan 'If I see blood, I will take the perspective of a physician.' Subjects had to read the instructions first and then repeat them to themselves for at least 1 min, until they felt ready to start the experiment.

The present study included three blocks, and subjects were instructed to use one of the three strategies in each block. Before the blocks, participants were presented with the task instructions and went through six practice trials. In the passive viewing block, each trial began with a black fixation cross displayed on the white computer screen for 300 ms. Subsequently, a blank screen was presented for 300–500 ms, followed by the onset of the stimulus pictures, which were shown for 2000 ms and followed by another blank screen (6000 ms). Subjects were instructed to simply view and pay close attention to each picture. Subsequently, they were instructed to indicate how the picture made them feel, using a scale from 0 (neutral and non-emotional) to 4 (extremely unpleasant) (Fig. 1).

Subjects first completed the passive viewing block, and then one of the two other blocks (automatic self-focused reappraisal or automatic situation-focused reappraisal). The order of these two blocks was counterbalanced across subjects. Subjects were trained for automatic self-focused reappraisal and automatic situation-focused reappraisal strategies during the practice trials. Upon finishing each block, participants were asked to rate their effort and the difficulty they had experienced while managing their emotional state, on a 5-point scale (0: no effort or difficulty; 4: extreme effort or difficulty; Gallo et al. 2009, 2012). Further, they were required to rate the success of the picture-attending task, at the end of each block, based on a 7-point scale (1: unsuccessful; 7: very successful). Two minutes of rest were provided between blocks.

ERP recordings

EEG signals were recorded from 64 scalp sites, via tin electrodes integrated into an elastic cap (Brain Products, Zeppelinstrasse, Gilching, Germany), with left and right mastoid references (average mastoid reference; Luck 2005), and a ground electrode that was placed on the medial frontal aspect. Vertical electrooculograms (EOGs) were recorded from the left eye, supra- and infra-orbitally. The horizontal EOG was recorded from the left versus the right orbital rim. EEG and EOG were amplified using a DC ($\sim$ 100 Hz) bandpass, and continuously sampled at 1000 Hz/channel. Inter-electrode impedance was maintained below 5 kΩ. Averaging of ERPs was performed offline. Eye-movement artefacts (blinks and random eye-movements) were rejected offline, and a 24-Hz low-pass filter was used. Trials were excluded when they showed EOG artefacts (such as mean EOG voltage exceeding $\pm$ 100 μV) or artefacts caused by amplifier clipping or peak-to-peak deflection exceeding $\pm$ 80 μV.

EEG recordings were averaged separately for each condition. The ERP waveforms were time-locked to the stimulus onset, and the average epoch for ERPs, including a 200-ms pre-stimulus baseline, was 2200 ms. Figure 5 shows that a prominent frontal LPP component was elicited in the 400–1000-ms interval across the frontal-central scalp areas in each block, which is in line with earlier research (Yuan et al. 2012; Kok 2001). The frontal LPP amplitudes were quantified as the average activity across nine electrodes (Fz, F1, F2, FCz, FC1, FC2, C1, Cz, and C2) between 400 and 1000 ms after stimulus onset. Moreover, a prominent posterior-parietal LPP that started at 400 ms and lasted until the stimulus offset (2000 ms) was elicited in each block, at the posterior-parietal scalp region (Fig. 5), consistent with the topographical distributions found earlier (Moser et al. 2014; Paul et al. 2013; Thiruchselvam et al. 2011). The posterior-parietal LPP amplitudes were therefore measured within time windows of 400–1000 ms and 1000–2000 ms at the parietal region (six sites: P1, Pz, P2, CP1, CP2, and CPz).

Statistical analysis

A repeated-measures analysis of variance (ANOVA) was conducted on the frontal and posterior-parietal LPP amplitudes, with strategy (three levels: passive viewing, self-focused, situation-focused), valence (two levels: negative and neutral), and electrode location (nine levels for frontal LPP: Fz, F1, F2,FCz,FC1,FC2, C1, Cz, C2; six levels for posterior-parietal LPP: P1, Pz, P2, CP1, CP2, CPz) as factors. The 400–1000-ms time window was chosen based on previous studies (Moser et al. 2014; Shafir et al. 2015) and on our visual observation. In order to analyse the effect of different instructions on the temporal dynamics of posterior-parietal LPP amplitudes, the amplitude in the posterior-parietal 400–1000-ms range was included in the ANOVA as an independent variable. The degrees of freedom for the F-statistic were corrected using the Greenhouse–Geisser method for violations of

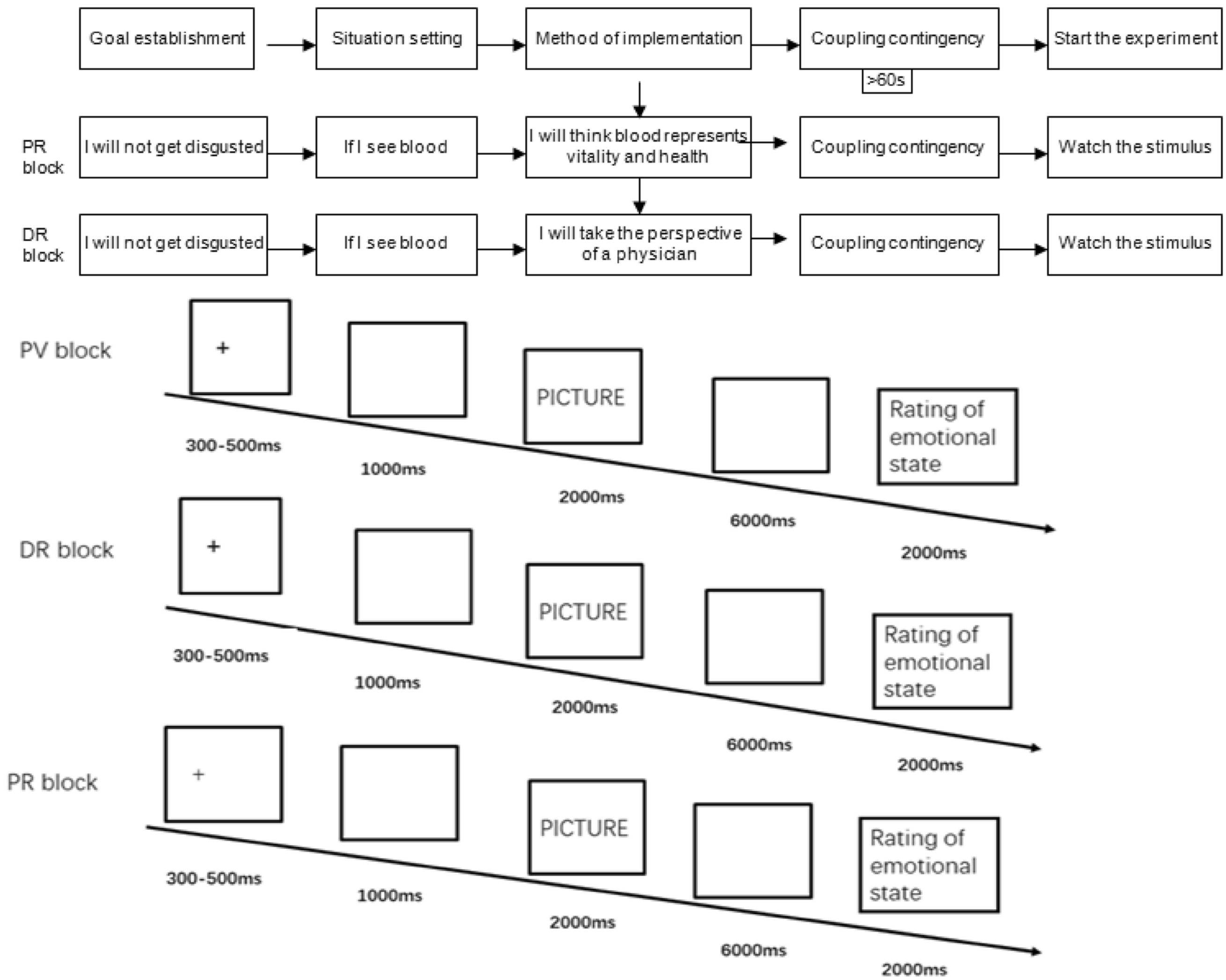

Fig. 1 Schematic illustration of the experimental procedure. In the automatic self-focused reappraisal and automatic situation-focused reappraisal blocks, the stimulus display was the same as in the passive viewing block, while the instruction changed to either 'automatic self-focused reappraisal' or 'automatic situation-focused reappraisal,' prompting participants to switch to the corresponding strategy in order to regulate unpleasant emotions. PV: passive viewing, DR: detached reappraisal, PR: positive reappraisal

sphericity, and, when significant main or interaction effects were detected, the Bonferroni-Holm method was applied to adjust the *p* value during post hoc pairwise comparisons (Paul et al. 2013). Effect sizes are presented as partial eta-square (η_p^2) for F tests and as Cohen's d for t tests.

Results

Manipulation check

An analysis of the instruction confirmation data, on a 7-point scale (answers to the question 'How did you attend to the picture in the task?'; 1: unsuccessful; 7: very successful) showed similar rating scores during the passive viewing, self-focused reappraisal, and situation-focused reappraisal conditions (6.47, 6.23, and 6.31, respectively; $F(2, 66) = 0.695$, $p = 0.503$). The scores were significantly above the mid-point of the rating scale (4) during passive viewing ($t(22) = 20.03$, $p < 0.001$, $d = 0.96$), self-focused reappraisal ($t(22) = 14.45$, $p < 0.001$, $d = 0.95$), and situation-focused reappraisal ($t(22) = 11.85$, $p < 0.001$, $d = 0.93$) blocks (Fig. 2). These data suggest that subjects attended to the pictures in a similar way across the three blocks.

Emotional assessment

The analysis of the emotional state rating data (on a 5-point Likert scale) revealed a significant main effect of block ($F(2, 44) = 12.31$, $p < 0.001$; $\eta_p^2 = 0.359$). The unpleasant rating score was significantly higher during passive

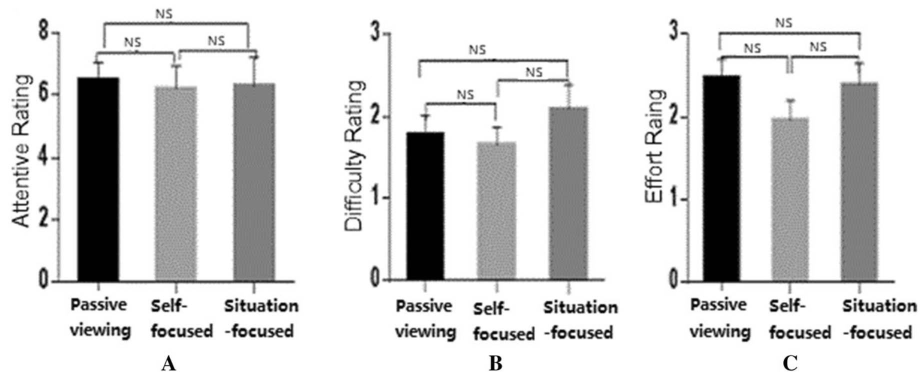

Fig. 2 The three experimental conditions. Manipulation check for each block (**a**). Ratings of subjective effort (**b**) and difficulty (**c**) in negative emotion regulation during the control, self-focused reappraisal, and situation-focused reappraisal conditions. Data are represented as mean ± standard deviation

viewing (2.62) than during the self-focused block (1.70). In addition, the unpleasant rating score for the self-focused block was lower than the scores for the passive viewing and situation-focused blocks (both $p < 0.001$), while the emotion rating score during passive viewing (2.62) did not significantly differ from that for the situation-focused block (2.41; $p = 0.348$; Fig. 3). These data suggest that automatic self-focused reappraisal reduces the intensity of unpleasant emotional reactions more effectively than automatic situation-focused reappraisal.

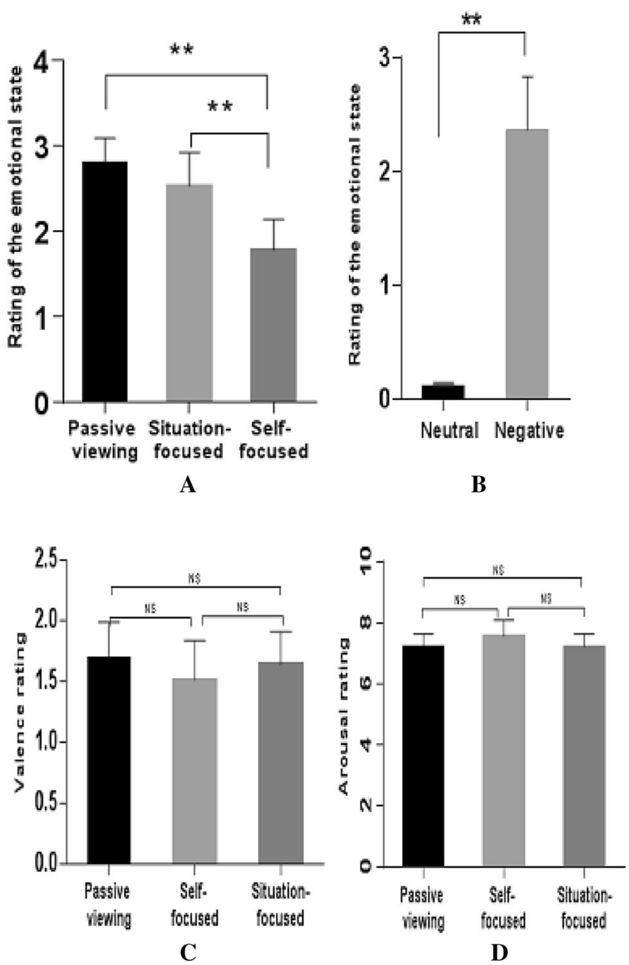

Fig. 3 Participant rating scores across blocks. Results of the ratings of the participant's emotional state for each block (**a**). Results of the ratings for neutral and negative pictures (**b**), and results of valence (**c**) and arousal (**d**) assessments for the pictures in each block. Data are represented as mean ± standard deviation. **Indicates $p \leq 0.01$

Assessment of cognitive demand

The analysis of the rating data for the required effort (on a 5-point Likert scale) did not reveal a significant main effect of block ($F(2, 44) = 2.386$, $p = 0.105$; $\eta_p^2 = 0.098$), and neither did the analysis of difficulty level rating data (on a 5-point Likert scale) ($F(2, 44) = 1.807$, $p = 0.185$; $\eta_p^2 = 0.076$; Fig. 2). These data suggest similar ratings of cognitive demand, indexed by both difficulty scores and perceived effort scores, across passive viewing, automatic self-focused, and situation-focused reappraisal conditions. This suggests that the two automatic forms of reappraisal, self-focused and situation-focused, do not involve additional cognitive costs compared to the passive viewing condition.

ERP results

Frontal LPP (400–1000 ms)

There were statistically significant main effects of valence ($F(1, 66) = 98.361$, $p < 0.001$, $\eta_p^2 = 0.598$) and electrode location ($F(8, 528) = 87.681$, $p < 0.001$, $\eta_p^2 = 0.571$). Amplitudes for negative pictures were larger than those elicited by neutral pictures. In addition, there was a significant interaction between valence and strategy ($F(2, 66) = 4.160$, $p = 0.020$, $\eta_p^2 = 0.112$). The breakdown of this interaction revealed a significant main effect of valence for passive viewing ($F(1, 22) = 30.423$, $p < 0.001$, $\eta_p^2 = 0.580$), self-focused ($F(1, 22) = 14.684$, $p < 0.001$, $\eta_p^2 = 0.400$), and situation-focused ($F(1, 22) = 83.109$, $p < 0.001$, $\eta_p^2 = 0.791$) reappraisal. More importantly, there was a larger difference in LPP amplitude between the viewing of negative and neutral pictures during passive viewing ($F(1, 44) = 7.928$, $p = 0.007$, $\eta_p^2 = 0.153$) and during the situation-focused condition ($F(1, 44) = 5.766$, $p = 0.021$, $\eta_p^2 = 0.116$) than during the self-focused condition. However, the amplitude difference between the viewing of negative and neutral stimuli was similar during passive viewing and the situation-focused condition ($F(1, 44) = 0.138$, $p = 0.712$, $\eta_p^2 = 0.003$; Fig. 4). The analysis of the frontal LPP amplitudes, which reflect cognitive resource consumption, shows that self-focused reappraisal produced smaller amplitude enhancement for disgusting pictures in comparison with situation-focused reappraisal and passive-viewing.

Posterior-parietal LPP (400–1000 ms)

There were statistically significant main effects of valence ($F(1, 66) = 172.258$, $p < 0.001$, $\eta_p^2 = 0.723$) and electrode location ($F(5330) = 10.812$, $p < 0.001$, $\eta_p^2 = 0.141$). Negative stimuli elicited larger amplitudes than neutral stimuli. Moreover, the interaction between valence and strategy was significant ($F(2, 66) = 3.989$, $p = 0.023$, $\eta_p^2 = 0.108$). The breakdown of this interaction revealed significant main effects of valence for passive viewing ($F(1, 22) = 40.571$, $p < 0.001$, $\eta_p^2 = 0.648$) and for self-focused ($F(1, 22) = 37.172$, $p < 0.001$, $\eta_p^2 = 0.628$) and situation-focused ($F(1, 22) = 193.827$, $p < 0.001$, $\eta_p^2 = 0.898$) reappraisal. More importantly, the amplitude difference between the viewing of negative and neutral pictures was larger during passive viewing ($F(1, 44) = 10.783$, $p = 0.002$, $\eta_p^2 = 0.197$) and situation-focused reappraisal ($F(1, 44) = 4.444$, $p = 0.041$, $\eta_p^2 = 0.092$) than during self-focused reappraisal. By contrast, the amplitude difference between the viewing of negative and neutral pictures was similar during passive viewing and situation-focused reappraisal ($F(1, 44) = 0.002$, $p = 0.939$, $\eta_p^2 = 0.001$; Fig. 5). The analysis of the posterior-parietal LPP amplitudes, which reflect individual's experiencing emotions, shows that self-focused reappraisal

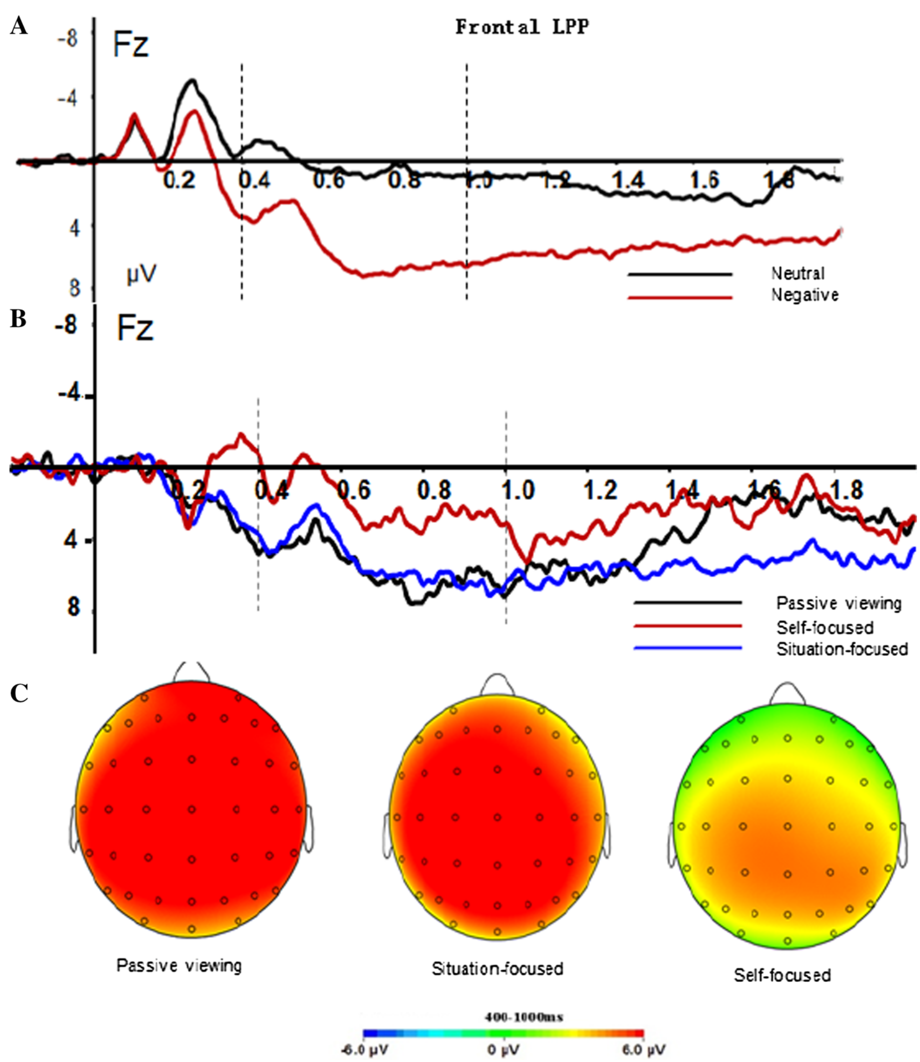

Fig. 4 Event-related potential amplitudes induced at Fz for neutral and negative images across the three emotion regulation strategies (**a**). Emotional effects on event-related potential amplitudes at Fz for the different emotion regulation strategies (negative-neutral) (**b**). Brain topography of emotional effects for the different emotion regulation strategies (**c**)

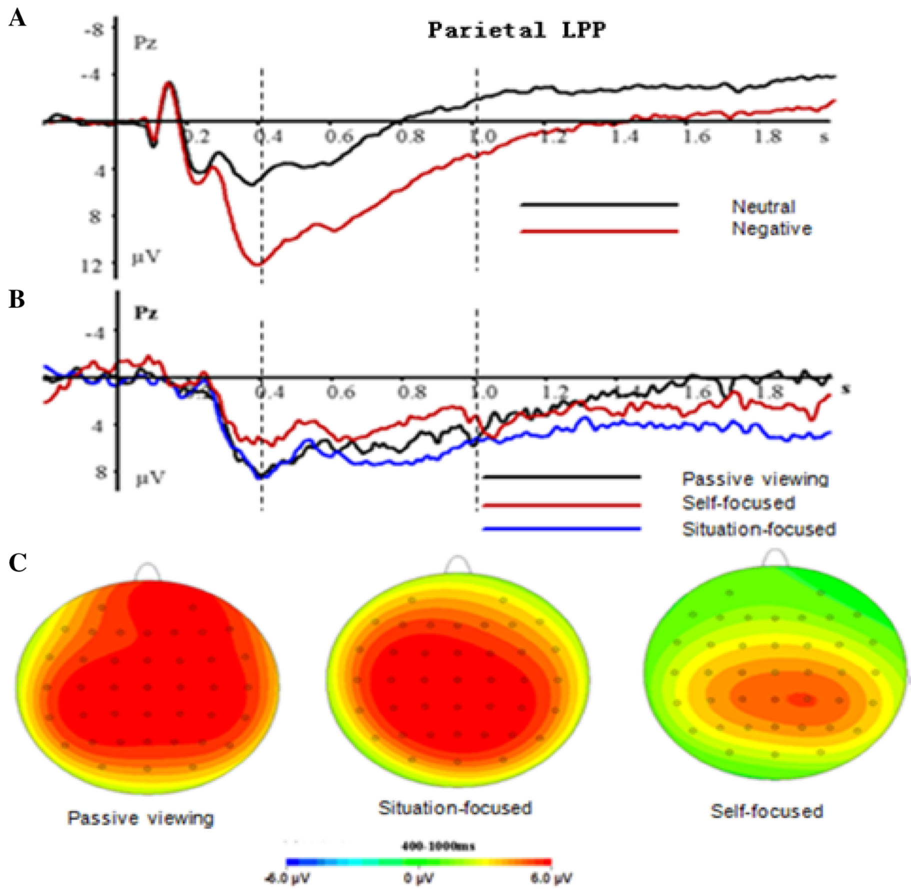

Fig. 5 Event-related potential amplitudes induced at Pz for neutral and negative pictures across the three emotion regulation strategies (**a**). Emotional effects on event-related potential amplitudes at Pz for the different emotion regulation strategies (negative-neutral) (**b**). Brain topography of emotional effects for the different emotion regulation strategies (**c**)

implementation is linked to lower emotional intensity for disgust pictures, compared to situation-focused reappraisal and passive viewing.

Posterior-parietal LPP (1000–2000 ms)

The analysis revealed significant main effects of valence (F(1, 66) = 32.109, $p < 0.001$, $\eta_p^2 = 0.327$) and electrode location (F(5, 330) = 50.874, $p < 0.001$, $\eta_p^2 = 0.435$). Centroparietal sites (5.295 μV) exhibited larger amplitudes than parietal sites (− 2.834 μV). The posterior-parietal LPP (1000–2000 ms) amplitudes were smaller for neutral pictures (− 1.62 μV) than for negative pictures (1.94 μV). However, no significant interaction was observed between valence and strategy (F(2, 66) = 2.735, $p = 0.061$; η_p^{2} = 0.154), suggesting that the differences in amplitudes between disgusting and neutral stimuli were not modulated by the two forms of reappraisal during this time window.

Discussion

The present study used ERP to explore the differential effects of automatic self-focused and situation-focused reappraisal using implementation intentions. Behavioural data showed similar ratings of cognitive demand, indexed by both difficulty scores and perceived effort scores, across passive viewing, automatic self-focused, and situation-focused reappraisal conditions. This suggests that the two automatic forms of reappraisal, self-focused and situation-focused, do not involve additional cognitive costs compared to the passive viewing condition. We observed prominent frontal LPP activity starting at 400 ms post-stimulus, and that frontal LPP amplitudes were smaller for neutral than for negative pictures. It has been reported that the increase of the frontal LPP amplitudes occurs with greater mobilization of resources for cognitive processing (Saito and Ishida 2002). The current results thus suggest that greater cognitive resources are needed for the processing of negative pictures than for neutral pictures. So the increased frontal LPP amplitudes indicate that more cognitive resources would be consumed during emotional processing. Moreover, previous research has suggested that an enhanced frontal LPP is an index of cognitive effort or attentional control during situation-focused reappraisal implementation (Moser et al. 2014; Shafir et al. 2015). More interestingly, in the present study, we observed a significant interaction effect of valence and strategy on frontal LPP amplitudes. The frontal LPP amplitudes difference between negative and neutral pictures was smaller during self-focused than during situation-focused and passive viewing conditions. However, the magnitude of this difference was similar during passive viewing and situation-focused reappraisal. These results suggest that less cognitive effort is needed during automatic self-focused than during automatic situation-focused reappraisal.

This study demonstrates prominent posterior-parietal LPP activity from 400 ms until 2000 ms post-stimulus. Posterior-parietal LPP amplitudes, elicited by emotional stimuli, have been found to be a valid indicator of subjective emotional arousal (Schönfelder et al. 2014; Yuan et al. 2015a, b); they are also positively associated with the participant's subjective experience of negative emotions (Schönfelder et al. 2014). Consistent with previous reports (Moser et al. 2014; Paul et al. 2013; Thiruchselvam et al. 2011), we found posterior-parietal LPP amplitudes to be larger for unpleasant than for neutral pictures during the 400–2000-ms time window in the passive viewing block. This is consistent with previous research that observed enhanced LPP during viewing emotional stimuli (Hajcak et al. 2010). More importantly, we observed a significant interaction between valence and strategy. The difference in posterior-parietal LPP amplitudes between the conditions involving negative and neutral pictures was larger during passive viewing and the situation-focused condition than during the self-focused condition. However, the difference in posterior-parietal LPP amplitudes between the conditions involving negative and neutral pictures was similar during passive viewing and the situation-focused condition. This suggests that automatic self-focused reappraisal reduces the intensity of unpleasant emotional reactions more effectively than automatic situation-focused reappraisal. Consistent with this, the analysis of mood rating scores demonstrated a significant main effect of condition: unpleasant ratings during the self-focused condition were lower than those during passive viewing and situation-focused reappraisal, while mood rating scores during passive viewing did not significantly differ from those during the situation-focused condition.

Notably, a recent study reported that when subjects were required to consciously reduce negative emotions, positive reinterpretation was more effective than detached reinterpretation (Willroth and Hilimire 2016). However, the present study demonstrates that automatic self-focused reappraisal reduces the intensity of emotional reactions to unpleasant stimuli more effectively than automatic situation-focused reappraisal. This is consistent with previous findings of that AER refers to the process of unconsciously adjusting emotional responses in the absence of cognitive control, which is driven by automated goals (Mauss et al. 2007), and AER goals may be particularly useful when the implementation of conscious emotion regulation strategies is less efficient (Dijksterhuis et al. 2006; Posner and Snyder 1975; Shiffrin and Schneider 1977).

Taking together the results for the frontal and posterior-parietal LPP, the present study demonstrates that automatic self-focused reappraisal reduces the intensity of emotional reactions to unpleasant stimuli more effectively than automatic situation-focused reappraisal, without enhancing cognitive cost. The analysis of the frontal LPP amplitudes, which reflect cognitive resource consumption, shows that self-focused reappraisal produced smaller amplitude enhancement for disgusting relative to neutral pictures in comparison with situation-focused reappraisal and passive-viewing. This suggests that self-focused reappraisal implementation may occur automatically, and that it requires only few attentional resources or subjective efforts. On the other hand, the analyses of posterior-parietal LPP amplitudes, regarding their implications for experiencing emotions, indicate that self-focused reappraisal implementation is linked to lower emotional intensity for disgust pictures, compared to situation-focused reappraisal and passive viewing.

This study has several limitations. First, we only explored automated reappraisal strategies, without comparing them to conscious reappraisal strategies. This made it impossible to determine the extent to which implementation intention saves cognitive resource consumption. Second, we focused on the reappraisal of negative stimuli, because of its adaptive applications and potential implications for well-being and cognitive therapy. However, reappraisal can also be employed to up- or down-regulate positive emotions, and future research should thus further investigate the effectiveness of this approach. Third, only disgusting pictures were used as experimental stimuli for inducing emotions. Future studies are required to determine how other basic emotions are modulated by AER via implementation across different types of reappraisal. fMRI (**f**unctional **m**agnetic **r**esonance **i**maging) would be used to discriminate ERP generators to varying emotionally tinged stimuli. And also fMRI will be used to investigate automatic self-focusing and situational focusing to find neural structures related to these two emotional regulation modes.

Funding This work was supported by the National Natural Science Foundation of China (Grant Nos. 31671164, 31871103, 31600886).

Complaince with ethical standards

Conflict of interest All authors report no biomedical financial interests or potential conflicts of interest.

References

Ayduk O, Kross E (2008) Enhancing the pace of recovery: self distanced analysis of negative experiences reduces blood pressure reactivity. Psychol Sci 19:229–231. https://doi.org/10.1111/j.1467-9280.2008.02073.x

Bernat EM, Cadwallader M, Seo D, Vizueta N, Patrick CJ (2011) Effects of instructed emotion regulation on valence, arousal, and attentional measures of affective processing. Dev Neuropsychol 36(4):493–518

Buhle JT, Silvers JA, Wager TD, Lopez R, Onyemekwu C, Kober H et al (2014) Cognitive reappraisal of emotion: a meta-analysis of human neuroimaging studies. Cereb Cortex 24(11):2981

Butler EA, Egloff B, Wilhelm FH, Smith NC, Erickson EA, Gross JJ (2003) The social consequences of expressive suppression. Emotion 3(1):48–67

Cuthbert BN, Schupp HT, Bradley MM, Birbaumer N, Lang PJ (2000) Brain potentials in affective picture processing: covariation with autonomic arousal and affective report. Biol Psychol 52:95–111

Davis JI, Gross JJ, Ochsner KN (2011) Psychological distance and emotional experience: what you see is what you get. Emotion 11:438–444. https://doi.org/10.1037/a0021783

Dijksterhuis A, Bos MW, Nordgren LF, Van Baaren RB (2006) On making the right choice: the deliberation without-attention effect. Science 311:1005–1007

Dörfel D, Lamke JP, Hummel F, Wagner U, Erk S, Walter H (2014) Common and differential neural networks of emotion regulation by detachment, reinterpretation, distraction, and expressive suppression: a comparative fMRI investigation. NeuroImage 101:298–309

Faul F, Erdfelder E, Lang AG, Buchner A (2007) G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behav Res Meth 39(2):175–191

Gailliot MT, Baumeister RF, DeWall CN, Maner JK, Plant EA, Tice DM, Schmeichel BJ (2007) Self-control relies on glucose as a limited energy source: willpower is more than a metaphor. J Pers Soc Psychol 92(2):325

Gallo IS, Keil A, Mc Culloch KC, Rockstroh B, Gollwitzer PM (2006) Strategic automation of emotion control. J Person Soc Psychol 96:11

Gallo IS, Keil A, McCulloch KC, Rockstroh B, Gollwitzer PM (2009) Strategic automation of emotion regulation. J Pers Soc Psychol 96(1):11–31. https://doi.org/10.1037/a0013460

Gallo IS, McCulloch KC, Gollwitzer PM (2012) Differential effects of various types of implementation intentions on the regulation of disgust. Soc Cogn 30(1):1

Goldin PR, McRae K, Ramel W, Gross JJ (2008) The neural bases of emotion regulation: reappraisal and suppression of negative emotion. Biol Psychiat 63(6):577–586. https://doi.org/10.1016/j.biopsych.2007.05.031

Gollwitzer PM (1993) Goal achievement: the role of intentions. Eur Rev Soc Psychol 4(1):141–185

Gollwitzer PM (1999) Implementation intentions: strong effects of simple plans. Am Psychol 54(7):493

Gollwitzer PM, Sheeran P (2006) Implementation intentions and goal achievement: a meta-analysis of effects and processes. Adv Exp Soc Psychol 38:69–119

Gross JJ (1998) Antecedent-and response-focused emotion regulation: divergent consequences for experience, expression, and physiology. J Pers Soc Psychol 74(1):224

Gross JJ (2002) Emotion regulation: affective, cognitive, and social consequences. Psychophysiology 39:281–291. https://doi.org/10.1017/S0048577201393198

Gross JJ (2014) Emotion regulation: conceptual and empirical foundation. In: Gross JJ (ed) Handbook of emotion regulation, 2nd edn, Guilford Press: New York, pp 3–20

Hajcak G, Nieuwenhuis S (2006) Reappraisal modulates the electrocortical response to unpleasant pictures. Cogn Affect Behav Neurosci 6:291–297

Hajcak G, Macnamara A, Olvet DM (2010) Event-related potentials, emotion, and emotion regulation: an integrative review. Dev Neuropsychol 35(2):129

Hajcak G, Dunning JP, Foti D, Weinberg A (2014) Temporal dynamics of emotion regulation. In: Gross JJ (ed) Handbook of emotion regulation, 2nd edn. Guilford Press, New York, pp 441–474

Huang YX, Luo YJ (2004) Native assessment of international affective picture system. Chin Mental Health J 9:631–634

Kok A (2001) On the utility of p3 amplitude as a measure of processing capacity. Psychophysiology 38(3):557

Lang PJ, Bradley MM, Cuthbert BN (1999) International affective picture system (IAPS): technical manual and affective ratings. Gainesville, FL: The Center for Research in Psychophysiology, University of Florida

Liberman N, Sagristano MD, Trope Y (2002) The effect of temporal distance on level of mental construal. J Exp Soc Psychol 38:523–534. https://doi.org/10.1016/S0022-1031(02)00535-8

Luck SJ (2005) An introduction to the event-related potential technique. MIT press, Cambridge

Macleod AK, Conway C (2007) Well-being and positive future thinking for the self versus others. Cogn Emot 21(5):1114–1124

Mauss IB, Bunge SA, Gross JJ (2007) Automatic emotion regulation. Soc Pers Psychol Compass 1(1):146–167. https://doi.org/10.1111/j.1751-9004.2007.00005.x

Mayer JD, Salovey P (1995) Emotional intelligence and the construction and regulation of feelings. Appl Prev Psychol 4(3):197–208

Moser JS, Hartwig R, Moran TP, Jendrusina AA, Kross E (2014) Neural markers of positive reappraisal and their associations with trait reappraisal and worry. J Abnorm Psychol 123:91–105

Muraven M, Tice DM, Baumeister RF (1998) Self-control as a limited resource: regulatory depletion patterns. J Personal Soc Psychol 74(3):774. https://doi.org/10.1111/j.1467-6494.2004.00298.x

Ochsner KN, Bunge SA, Gross JJ, Gabrieli JD (2002) Rethinking feelings: an FMRI study of the cognitive regulation of emotion. J Cogn Neurosci 14(8):1215–1229

Ochsner KN, Ray RD, Cooper JC, Robertson ER, Chopra S, Gabrieli JD, Gross JJ (2004) For better or for worse: neural systems supporting the cognitive down- and up-regulation of negative emotion. NeuroImage 23:483–499. https://doi.org/10.1016/j.neuroimage.2004.06.030

Paul S, Simon D, Kniesche R, Kathmann N, Endrass T (2013) Timing effects of antecedent- and response-focused emotion regulation strategies. Biol Psychol 94:136–142

Posner MI, Snyder CRR (1975) Attention and cognitive control. In: Solso RL (ed) Information processing and cognition. Erlbaum, Hillsdale

Richards JM, Gross JJ (1999) Composure at any cost? The cognitive consequences of emotion suppression. Pers Soc Psychol Bull 25(8):1033–1044

Richards JM, Gross JJ (2000) Emotion regulation and memory: the cognitive costs of keeping one's cool. J Pers Soc Psychol 79(3):410

Saito M, Ishida T (2002) Cognitive resource model for the information-processing of task-irrelevant visual stimuli. Psychiatry Clin Neurosci 56(2):145–151

Schönfelder S, Kanske P, Heissler J, Wessa M (2014) Time course of emotion-related responding during distraction and reappraisal. Soc Cogn Affect Neurosci 9:1310–1319

Shafir R, Schwartz N, Blechert J, Sheppes G (2015) Emotional intensity influences pre-implementation and implementation of distraction and reappraisal. Soc Cogn Affect Neurosci 10:1329–1337

Shiffrin RM, Schneider W (1977) Controlled and automatic human information processing: II. Perceptual learning, automatic attending and a general theory. Psychol Rev 84(2):127–190

Shiota MN, Levenson RW (2009) Effects of aging on experimentally instructed detached reappraisal, positive reappraisal, and emotional behavior suppression. Psychol Aging 24(4):890–900

Shiota MN, Levenson RW (2012) Turn down the volume or change the channel? Emotional effects of detached versus positive reappraisal. J Pers Soc Psychol 103(3):416–429. https://doi.org/10.1037/a0029208

Tamir M, Mauss I (2011) Social cognitive factors in emotion regulation: implications for well-being. In: Nyklíček I, Vingerhoets A, Zeelenberg M (eds) Emotion regulation and well-being. Springer, New York, pp 31–47

Thiruchselvam R, Blechert J, Sheppes G, Rydstrom A, Gross JJ (2011) The temporal dynamics of emotion regulation: an EEG study of distraction and reappraisal. Biol Psychol 87:84–92

Urry HL (2010) Seeing, thinking, and feeling: emotion-regulating effects of gaze-directed cognitive reappraisal. Emotion 1:125–135. https://doi.org/10.1037/a0017434

Van Dillen LF, Koole SL (2007) Clearing the mind: a working memory model of distraction from negative mood. Emotion 7(4):715–723

Webb TL, Miles E, Sheeran P (2012) Dealing with feeling: a meta-analysis of the effectiveness of strategies derived from the process model of emotion regulation. Psychol Bull 138(4):775–808. https://doi.org/10.1037/a0027600

Williams LE, Bargh JA, Nocera CC, Gray JR (2009) The unconscious regulation of emotion: nonconscious reappraisal goals modulate emotional reactivity. Emotion 9(6):847–854. https://doi.org/10.1037/a0017745

Willroth EC, Hilimire MR (2016) Differential effects of self- and situation-focused reappraisal. Emotion 16:468–474

Xie X, Mulej Bratec S, Schmid G, Meng C, Doll A, Wohlschläger A, Finke K, Förstl H, Zimmer C, Pekrun R, Sorg C (2016) How do you make me feel better? Social cognitive emotion regulation and the default mode network. NeuroImage 134:270–280. https://doi.org/10.1016/j.neuroimage.2016.04.015

Yuan J, Meng X, Yang J, Yao G, Hu L, Yuan H (2012) The valence strength of unpleasant emotion modulates brain processing of behavioral inhibitory control: neural correlates. Biol Psychol 89(1):240–251

Yuan J, Long Q, Ding N, Lou Y, Liu Y, Yang J (2015a) Suppression dampens unpleasant emotion faster than reappraisal: neural dynamics in a Chinese sample. Sci China Life Sci 58:1–12

Yuan J, Ding N, Liu Y, Yang J (2015b) Unconscious emotion regulation: nonconscious reappraisal decreases emotion-related physiological reactivity during frustration. Cognit Emot 29(6):1042–1053. https://doi.org/10.1080/02699931.2014.965663