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The temporal dynamics of emotion regulation: An EEG study of distraction and reappraisal

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ABSTRACT

Distraction and reappraisal are two widely used forms of emotion regulation. The process model of emotion regulation (Gross, 1998) holds that they differ (1) in when they act on the emotion-generative process, and (2) in their impact on subsequent responses to regulated stimuli. We tested these two predictions by measuring electrocortical responses to neutral and emotional images during two phases. In the regulation phase, images were watched or regulated using distraction or reappraisal. During the re-exposure phase, the same images were passively watched. As predicted, during regulation, distraction reduced the late positive potential (LPP) earlier than reappraisal. Upon re-exposure, images with a distraction (but not reappraisal) history elicited a larger LPP than images with an attend history. This pattern of results suggests that distraction and reappraisal intervene at separate stages during emotion generation, a feature which may have distinct consequences that extend beyond the regulatory episode.

1. Introduction

The ability to regulate emotions when they are maladaptive is among the most critical of human capacities (Gross, 2007). A growing body of research has begun to examine the cognitive processes which support this vital ability (Ochsner and Gross, 2008), identifying distinct forms of cognitive control which enable us to dynamically alter the type and intensity of our emotional responses. In particular, two widely used strategies – termed distraction and reappraisal – have garnered widespread interest as indispensable tools in the cognitive regulation of emotion.

Distraction – which involves deploying attention away from the emotionally salient aspects of an emotion-eliciting event – has been shown to successfully reduce various indices of emotional responding, including subjective emotional intensity and corrugator muscle activity (Urry, 2010). It has also been shown to decrease the unpleasantness of painful stimulation, and to diminish activation in pain-related brain regions such as the insula (Bantick et al., 2002; Seminowicz and Davis, 2007). Furthermore, in clinically oriented research, a number of studies attest to distraction's efficacy in attenuating dysphoric mood (Lyubomirsky and Nolen-Hoeksema, 1993; Nolen-Hoeksema, 1991; Nolen-Hoeksema and Morrow, 1993). In contrast to distraction, reappraisal involves re-evaluating an emotional event's underlying meaning. It too can successfully attenuate subjective (Gross, 1998), peripheral physiological (Jackson et al., 2000), and neural (Goldin et al., 2008; Ochsner et al., 2002, 2004; Phan et al., 2005) indices of emotional responding such as amygdala and insula activity.

Although outcome-based research suggests that both distraction and reappraisal are capable of diminishing emotional responding across many different affective contexts, it is not yet clear precisely how the mechanisms underlying these two major emotion regulation strategies differ. The goal of the present study was to test theoretically derived predictions regarding the temporal dynamics of these two forms of cognitive emotion regulation. To achieve this goal, we employed a temporally sensitive electroencephalogram (EEG)-derived index of emotional stimulus processing in order to probe the temporal dynamics of these two forms of regulation.

1.1. Temporal dynamics of distraction and reappraisal: theoretical predictions

According to the process model of emotion regulation (Gross, 1998), the key distinction between these two forms of cognitive emotion regulation is that the two strategies engage separable underlying processes: distraction operates primarily through the use of attentional deployment, whereas reappraisal operates primarily through meaning-evaluation mechanisms which serve to compute and alter the affective significance of an emotional stimulus.

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More specifically, the process model holds that the cognitive processes underlying the generation of emotion occur through a temporally extended sequence of stages: upon encountering an emotional stimulus, the deployment of attention towards the stimulus occurs prior to the evaluation of its meaning. Cognitive regulation strategies can be distinguished by which stage in this emotion-generative process they have their primary impact. As distraction operates through the deployment of attention, it should intervene early in the emotion-generative trajectory, before elaborative meaning-processing of the stimulus can occur. By contrast, reappraisal should involve first constructing a default evaluation of the emotional stimulus before a re-construal can be implemented, and should therefore impact the emotion-generative process relatively later (also see Sheppes and Gross, in press, for a new theoretical framework that further elaborates the underlying operations and consequences of attentional distraction and cognitive reappraisal).

This yields the basic prediction that distraction should modulate the unfolding of emotion generation *prior to* the evaluative processing of an emotional stimulus' meaning. By contrast, reappraisal should modulate emotion generation *during* the processing of the stimulus' meaning. While this "timing hypothesis" is central to the process model's conception of distraction and reappraisal, it has not yet been directly tested.

A second prediction regarding the temporal dynamics of distraction and reappraisal is more subtle. In particular, we postulate that the differential impact of distraction and reappraisal on the emotion-generative trajectory during regulation may have consequences that extend to the processing of the stimulus when it is later encountered. This prediction is grounded in a body of research showing that emotional stimuli that have been previously attended to – and whose affective significance has already been evaluated – result in weaker emotional responses than novel emotional stimuli (Wilson and Gilbert, 2008). Insofar as distraction intervenes in the emotion-generative process early – thereby preventing the processing of the stimulus' underlying meaning – it should lead individuals to evaluate the stimulus as more novel upon subsequent re-exposures, compared to a stimulus that was previously attended to and evaluated. This should lead stimuli with a distraction-history (versus a history of simple viewing) to elicit greater emotional responses upon re-exposure. By contrast, to the extent that reappraisal intervenes later in the emotion-generative trajectory – enabling one to construct an evaluation of the stimulus' affective significance – stimuli with a reappraisal-history should not have this detrimental effect.

In fact, insofar as reappraisal involves changing the appraisal of an emotional stimulus, reappraisal could modify the default appraisal for that stimulus. Upon re-exposure, this modified appraisal can become activated. Thus, stimuli with a reappraisal-history might elicit weaker emotional responses upon re-exposure compared to those with a history of simple viewing, a prediction which is supported by recent findings (MacNamara et al., in press).

1.2. Temporal dynamics of distraction and reappraisal: empirical findings

Prior research in which distraction and reappraisal have been directly contrasted has lent support to the idea that there are important differences in their underlying processes. A recent functional magnetic resonance imaging (fMRI) study (McRae et al., 2010) found that although both strategies commonly recruited prefrontal and cingulate neural regions implicated in cognitive control, they differentially activated specific regions as well. Relative to reappraisal, distraction led to greater activation in right prefrontal and parietal regions that have been linked to the control of attention (Mayer et al., 2007). On the other hand, relative to distraction, reappraisal elicited greater activation in specific prefrontal areas (i.e. ventral lateral pFC) involved in tracking a stimulus' current affective value (Van Overwalle, 2008; Teasdale et al., 1999).

While McCrae et al.'s (2010) investigation supports the notion that distraction operates through attentional deployment whereas reappraisal acts through evaluative processes that compute the affective significance of the emotional stimulus, the relative temporal insensitivity of fMRI has made it difficult to resolve questions about the time–course of distraction and reappraisal. What is needed is a temporally sensitive measure of the unfolding emotion-generative process, and for this, previous investigations have benefited from the excellent temporal resolution offered by EEG/ERP methods (see Schupp et al., 2006 for a review).

Of particular interest has been a well-known ERP component known as the late positive potential (LPP). The LPP is a positive-going slow-wave that is maximal at central–parietal sites, beginning approximately 300 ms after stimulus onset and often lasting for the entire stimulus duration (up to 6 s). A large number of studies have found the LPP to be robustly enhanced for emotionally arousing compared to neutral stimuli (Cuthbert et al., 2000; Hajcak and Olvet, 2008; Keil et al., 2002; Schupp et al., 2000, 2003, 2004). Importantly, the LPP does not appear to be sensitive to low-level perceptual characteristics of a stimulus, such as image size (De Cesarei and Codispoti, 2006) and figure-ground complexity (Bradley et al., 2007), rendering it a reliable index of the processing of emotionally arousing features of the stimulus (see Hajcak et al., 2010 for a review).

Importantly, several recent studies have shown the LPP to be highly sensitive to appraisal manipulations which alter the meaning attributed to an emotional stimulus. Specifically, the LPP is reliably smaller when an unpleasant stimulus is cognitively evaluated in a neutral compared to a negative manner (Foti and Hajcak, 2008; Hajcak and Nieuwenhuis, 2006). The LPP is also amplified when a neutral stimulus is appraised in aversive terms (MacNamara et al., 2009). Thus, the LPP is sensitive to the evaluative processing of an emotional stimulus' meaning throughout the course of emotion generation. As such, it would seem to be a useful electrocortical index in comparing the hypothesized difference between distraction and reappraisal with respect to when they intervene in the emotion-generative trajectory. More specifically, a reduction of the LPP from its earliest stages (approximately 300 ms) would reflect restricted evaluative processing of the affective significance of the stimulus. By contrast, an attenuation of the LPP beginning at later stages would signify that some elaborative meaning-processing of the stimulus' affective significance has occurred.

Recent studies have shown that directing one's gaze to non-arousing aspects of an emotional stimulus can also modulate the LPP (Dunning and Hajcak, 2009; Hajcak et al., 2009), likely by limiting the processing of affectively significant information. While these studies suggest that distraction may influence the course of the LPP, they do not enable strong inferences about the precise temporal dynamics of attentional deployment as compared to reappraisal since the two strategies were not directly compared within the same paradigm.

1.3. The present study

The goal of this study was to examine two theoretically derived predictions about the temporal dynamics of distraction and reappraisal:

(1) *Distraction should intervene in the emotion-generative trajectory earlier than reappraisal.* Insofar as the LPP tracks the evaluation of a stimulus' affective meaning, we predicted that distraction would reduce the LPP from its very beginning, since attentional redeployment should prevent such meaning-processing. By

contrast, as reappraisal necessitates first constructing a default appraisal of the stimulus before a re-construal can be implemented, we predicted that reappraisal would decrease the LPP later than distraction.

(2) *Upon re-exposure, stimuli with a distraction-history and stimuli with a reappraisal-history should have differential impact on emotional responses*. Since distraction is hypothesized to severely curtail the evaluation of a stimulus' affective meaning, we predicted that upon re-exposure, stimuli with a distraction-history would generate larger LPPs relative to control stimuli with an attend-history. By contrast, to the extent that reappraisal involves assessing the stimulus' meaning, stimuli with a reappraisal-history should not have this effect upon re-exposure. Furthermore, as reappraisal involves changing the appraisal of an emotional stimulus, the modified appraisal may become activated upon re-exposure. Thus, stimuli with a reappraisal-history would be expected to elicit weaker LPPs upon re-exposure compared to those with an attend-history.

2. Methods

2.1. Participants

Nineteen undergraduates (9 women) participated in this experiment. One woman was excluded from analysis due to poor recording quality, leaving 18 for the final sample (mean age = 19.27). Thirteen subjects received $30 pay, and five participated for course credit. All subjects had normal or corrected-to-normal vision, and did not report any psychiatric disorders.

2.2. Materials

One hundred and twelve images (84 negative, 28 neutral) were chosen from the International Affective Picture System (IAPS; Lang et al., 2008). The two categories differed in IAPS-derived ratings of normative valence ($M = 2.37$, $SD = 0.65$ for negative; $M = 5.12$, $SD = 0.53$ for neutral) and arousal ($M = 5.95$, $SD = 0.77$ for negative; $M = 3.17$, $SD = 0.66$ for neutral). These levels of image valence and arousal are similar to previous investigations of the LPP (Cuthbert et al., 2000; Hajcak and Nieuwenhuis, 2006; Schupp et al., 2003). The 84 negative images were divided into three sets of 28 images (Sets A, B, and C), which were equated for both valence and arousal (all p-values > 0.6). These sets were used for the purpose of assigning negative images to conditions (see Section 2.3).[1] Since the presence of human characteristics in images has been shown to affect the strength of the LPP (Schupp et al., 2004), we also matched all of our image sets (A, B, and C, and the neutral image set) on human features, $\chi^2(3, N = 96) = .75$, $p = 0.86$.

The task was presented on a color monitor using E-prime 2 stimulus presentation software (Schneider et al., 2002). Viewing distance was held constant at approximately 20 inches. All testing was conducted in a sound-attenuated EEG chamber.

2.3. Procedure

Upon arrival, subjects first completed informed consent. The experimenter then explained the idea of emotion regulation, followed by a more detailed explanation about the specific cognitive strategies of distraction and reappraisal. Subjects were then guided through several practice trials for each strategy, with feedback and shaping by the experimenter. During these practice trials, we stressed that subjects should only begin implementing each regulation strategy *after* the image appeared on screen. This was followed by several practice trials of both distraction and reappraisal in which the experimenter carefully probed subjects, on each trial, to verbally report the precise manner in which they were implementing each regulation strategy. Among other things, the experimenter ensured during this process that subjects reported applying each strategy only after the image appeared on screen. No subjects reported any difficulty with this requirement. Following training, EEG sensors were attached and subjects were led into the EEG recording chamber.

The experimental session consisted of two stages. In the first stage, subjects were cued to use either distraction or reappraisal to regulate emotional responses elicited by negative images (or in control attend conditions, simply viewed negative and neutral images). Thirty minutes later, in the second stage, these same images were presented again in an unregulated re-exposure task in which subjects simply attended to each image.

2.3.1. Regulation task

The regulation task consisted of 112 trials, divided into 4 blocks of 28 trials each. Trials were of four types: VIEW (neutral image), WATCH (negative image), DISTRACT (negative image), and REAPPRAISE (negative image). For both the VIEW and WATCH trials, subjects were instructed to simply attend to the presented image, allowing themselves to experience whatever thoughts and feelings happened to arise. VIEW and WATCH trials were functionally identical in that both required subjects to simply attend to the image. However, we chose to use different cues for these two conditions in order to equate the four trial types in the level of anticipatory knowledge subjects had about the upcoming picture. These trials were intended to elicit unregulated forms of emotional responding. For DISTRACT trials, subjects were asked to feel neutral in response to the aversive image by generating thoughts that were unrelated to the image presented on screen, such as by producing mental imagery of complex geometric designs or elaborate scenes around their neighborhood. For REAPPRAISE trials, subjects were asked to feel neutral in response to the aversive image by altering their construal of the image, such as by imagining that the depicted scenario would improve over time or by adopting the perspective of a detached observer (Gross, 1998). In designing these instructions for distraction and reappraisal, our aim was to equate the cognitive demands required to implement each strategy as closely as possible. For all trials, subjects were asked to begin implementing each strategy only after picture onset. Moreover, they were asked to keep their eyes on the screen, and to avoid diverting their gaze away from emotionally salient aspects of aversive images.

The trial structure for the regulation task is illustrated in Fig. 1. Each trial began with a white fixation cross in the center of a black screen for 2 s, followed by an instruction cue (VIEW, WATCH, DISTRACT, or REAPPRAISE) for another 2 s, and then by an image occupying approximately 85% of the entire screen for 5 s. To help subjects toggle effectively between different trial types, the cue screen and the background of the following image's border were color-coded according to the type of instruction. The colors for each trial type were as follows: grey for VIEW, black for WATCH, blue for DISTRACT, and green for REAPPRAISE. After the offset of each image, subjects rated their level of valence, followed by their level of arousal. The ratings for both affective dimensions were obtained on a 1–9 scale using the Self-assessment Manikin (SAM; Lang, 1980). For analyses, arousal ratings were reverse-coded such that higher values represented greater levels of arousal.

Each of the four blocks contained 7 VIEW and 7 WATCH trials. In addition, each contained either 14 DISTRACT or 14 REAPPRAISE trials. This particular blocking structure was used to ensure that no block contained trials from both regulation types, in order to decrease the likelihood that subjects would combine the two strategies. This blocking approach is consistent with other recent ERP studies on emotion regulation, which also segregate instruction type by block (see Moser et al., 2009 for a discussion). The sequence of the 28 trials within each block was separately randomized for each subject, and the order of the blocks was counterbalanced. Moreover, assignment of the three negative image sets (Sets A, B, and C) to each of the WATCH, DISTRACT, and REAPPRAISE conditions was varied across subjects.

2.3.2. Re-exposure task

After approximately a 30-min interval during which they completed individual differences measures,[2] subjects performed a re-exposure task where they were presented with the images from the earlier regulation task. They had not been told that they would be re-exposed to the images. In this re-exposure task, subjects were instructed to simply attend to each image, allowing themselves to respond naturally to it. Each trial began with a white fixation cross in the center of a black screen for 2 s, followed by an image occupying approximately 85% of the entire screen for 5 s. These were then followed by ratings of valence and arousal using the SAM, as in the earlier regulation task. The re-exposure task consisted of a sequence of 112 trials, separately randomized for each subject. It was divided into 4 short blocks of 28 trials, and subjects were given a 1-min resting period between each block.

2.4. EEG recording, data reduction, and analysis

Continuous EEG recordings were made using SynAmps amplifiers, and digitized with Scan 4.3 software (Neuroscan, Inc.). EEG recordings were obtained with standard Ag/AgCl electrodes from 42 sites on the scalp, based on the 10–20 system. During recording, AFz served as the ground and Pz as the online reference. The electro-oculogram (EOG) generated from eye-blinks was recorded from sites 2 cm

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[1] The codes of the IAPS images used in each set are as follows: *SET A* – 1050, 1111, 1300, 1930, 2700, 3030, 3051, 3053, 3060, 3168, 3181, 3220, 3230, 3300, 3301, 3350, 6415, 6830, 8230, 9006, 9040, 9042, 9181, 9433, 9570, 9571, 9800, 9810; *SET B* – 1201, 2095, 2141, 2399,2710, 2750, 2800, 3064, 3100, 3101, 3140, 3550,6211, 6313, 6315, 6350, 6510, 6550, 6555, 9250, 9252,9253, 9300, 9301, 9420, 9421, 9635.1, 9921; *SET C* – 2120, 2130, 2375.1, 2683, 2691, 2810, 2900.1, 2981, 3000, 3010, 3015, 3120, 3130, 3160, 3400, 3530, 6212, 6230, 6243, 6570, 6821, 6831, 7359, 7380, 9050, 9265, 9405, 9410; *NEUTRAL* – 2190, 2221, 2235, 2280, 2320, 2383, 2393, 2394, 2440, 2480, 2495, 2516, 2560, 2579, 2580, 2749, 2840, 2850, 2870, 7025, 7090, 7175, 7211, 7217, 7493, 7496, 7550, 9210.

[2] As data from the individual difference measures are not central to our study's hypotheses, they are not presented here.

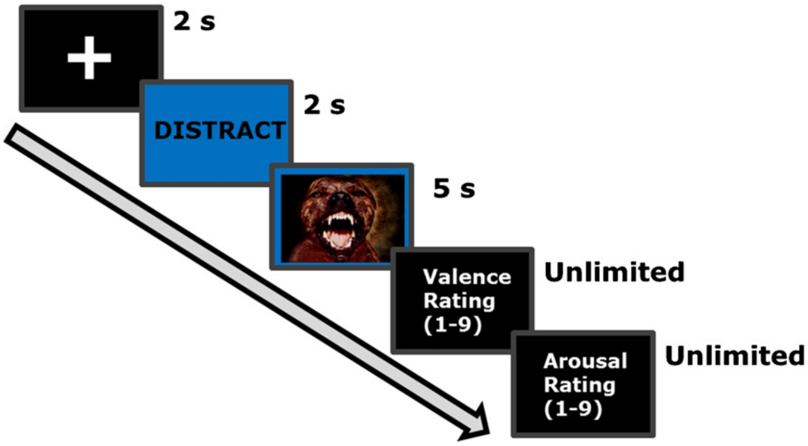

Fig. 1. Trial structure for the regulation task (an example of a DISTRACT trial).

below and above the right eye. During recording, the EEG signal was sampled at a rate of 500 Hz and band-pass filtered from 0.05 Hz to 100 Hz. Impedance levels at all channels were kept below 5 kΩ.

Offline, pre-processing was conducted using Avg_Q software (Feige, 1999). EEG data were first corrected for eye-blink artefacts using the procedure developed by Gratton et al. (1983). Single-trial EEG epochs were then extracted for a period beginning 200 ms prior to image onset and continuing for the entire duration of the image presentation (5000 ms). Next, all activity was re-referenced to the average of the left and right mastoids, and low-pass filtered at 20 Hz. Trials which contained excessive physiological artifact (i.e. voltages exceeding 150 μV) were discarded from further processing. The number of discarded trials did not vary by condition either for the regulation task, $F(3,51) = 1.84$, $p = .15$, or for the re-exposure task, $F(3,51) = .82$, $p = .49$. The resulting ERPs were baseline-corrected using the average activity in the 200 ms window immediately preceding image onset. Based on a large body of prior research indicating that the LPP is typically maximal at central-parietal sites (Cuthbert et al., 2000; Hajcak and Nieuwenhuis, 2006; Keil et al., 2002; Schupp et al., 2000, 2003), we quantified the LPP as the average signal amplitude collapsed across three sensors within the central–parietal region (CPz, CP1, and CP2).

3. Results

In presenting our results, we first describe a manipulation check, followed by an examination of our two central predictions regarding the temporal dynamics of distraction and reappraisal. Then, we proceed to describe additional analyses of self-reported valence and arousal for both the regulation and re-exposure tasks. Greenhouse–Geisser correction was applied to *p*-values associated with multiple-degrees of freedom, repeated-measures comparisons.

3.1. Manipulation check

We first sought to ensure that our manipulations modulated the overall LPP in the expected directions. Based on a growing body of research, we expected the LPP to be enhanced in the negative-watch compared to the neutral-view condition, thereby signifying the basic emotional modulation of the LPP. Furthermore, we expected that both distraction and reappraisal would attenuate the LPP relative to negative-watch (Foti and Hajcak, 2008; Hajcak and Nieuwenhuis, 2006; Dunning and Hajcak, 2009). To test these expectations, mean LPP amplitudes for the entire image duration (300–5000 ms) were submitted to a repeated-measures ANOVA, with Instruction Type as a within-subjects factor consisting of four levels (neutral-view, negative-watch, negative-distract, negative-reappraise). This revealed a main effect of Instruction Type, [$F(3,51) = 7.26$, $p < .003$, $\eta_p{}^2 = .29$].

Planned *t*-tests showed that, as predicted, negative-watch ($M = 5.86$, $SD = 4.28$) elicited a larger LPP than neutral-view ($M = 2.21$, $SD = 4.36$), $t(17) = 6.07$, $p < .001$. Importantly, relative to negative-watch, both distraction ($M = 3.36$, $SD = 5.54$) and reappraisal ($M = 4.13$, $SD = 5.46$) reduced the LPP: distraction, $t(17) = 2.68$, $p < .02$; reappraisal, $t(17) = 3.04$, $p < .01$. The LPP by Instruction Type for the entire stimulus duration during the regulation task is presented in panel A of Fig. 2.

3.2. During regulation, does distraction modulate the LPP earlier than reappraisal?

To test the points at which each regulation strategy modulated the LPP, we divided the first 1400 ms of the early stages of the LPP (300–1700 ms) into seven equal 200 ms time segments (300–500, 500–700, 700–900, 900–1100, 1100–1300, 1300–1500, and 1500–1700 ms). We chose to analyze the LPP up to the 1700 ms time point due to recent findings by MacNamara et al. (2009) suggesting that the effect of an appraisal manipulation on electrocortical positivities reached a maximum at 1688 ms post stimulus onset. Furthermore, a segmentation period of 200 ms was used in order to be consistent with prior studies which have attempted time-course analyses on the LPP (Foti and Hajcak, 2008). We performed a 4 (Instruction Type) X 7 (Time Segment) repeated-measures ANOVA. This revealed a main effect of Instruction Type, [$F(3,51) = 18.34$, $p < .001$, $\eta_p{}^2 = .52$] a main effect of Time Segment, [$F(6,102) = 20.17$, $p < .001$, $\eta_p{}^2 = .54$] and importantly, an interaction between Instruction Type and Time Segment, [$F(18,306) = 2.35$, $p < .04$, $\eta_p{}^2 = .12$]. In order to then delineate when the LPP for each regulation strategy began differentiating from negative-watch, we performed planned *t*-tests comparing each strategy to negative-watch across the seven time segments. To minimize Type I error, we applied a modified Bonferroni correction (Holm's test).[3] The planned comparisons between negative-watch and each regulation strategy across the seven time segments are presented in Tables 1 and 2. Supporting our main hypothesis, this revealed that distraction reduced the LPP relative to negative-watch from its very beginning at 300 ms, and consistently remained lower for the remainder of the time segments examined. Reappraisal, however, began attenuating the LPP comparatively later, at the 1500 ms time point.[4] The LPP by Instruction

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[3] The modified Bonferroni correction for multiple comparisons (Holm's test; Holm, 1979) was performed as follows. The 7 *p*-values in each time-course analysis (time-course of distraction, time-course of reappraisal) were ordered from smallest to largest. Then, a unique alpha level for each *p*-value was calculated by the formula: .05/(7-position in sequence +1). Each *p*-value was then compared against its corresponding alpha.

[4] Without the Holm's correction, reappraisal began modulating the LPP earlier (at 1100 ms). But the *p*-values for the 1100–1300 ms and 1300–1500 ms time ranges did not survive the Holm's correction.

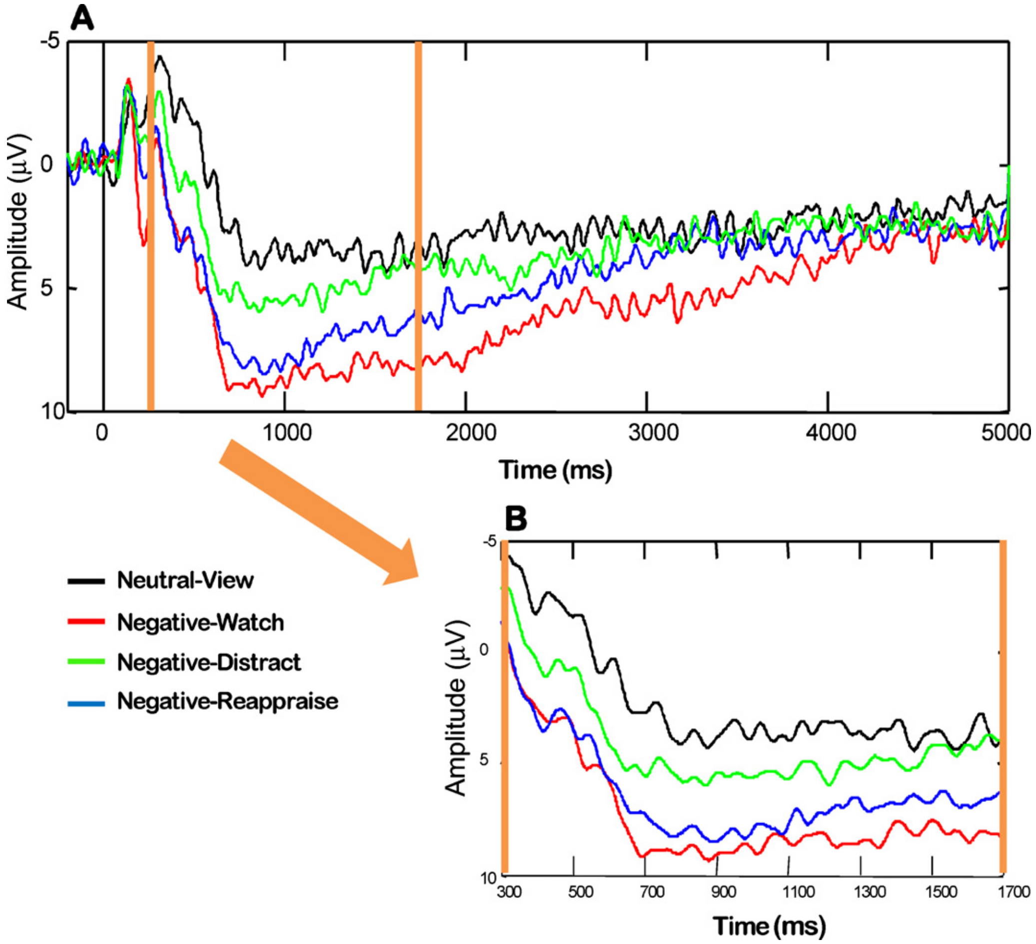

Fig. 2. ERPs by Instruction Type during picture presentation of the regulation task. The LPP by Instruction Type during the 300–1700 ms time window (the range between the two orange lines) is shown as a separate panel for clarity. Note that the *y*-axis is reversed (positive voltage is plotted downwards) as per convention. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article.)

Type during the 300–1700 ms time range is presented in panel B of Fig. 2.

One potential explanation for this timing difference in LPP modulation between distraction and reappraisal is that it could be an artifact of our experimental task rather than a result of the sequential nature of attentional redeployment vs. meaning evaluation, as we have hypothesized. More specifically, the concern is that subjects might have begun implementing distraction as soon as the cue to distract was presented, whereas they had to wait to implement reappraisal until after the image appeared on screen. Even though we carefully instructed subjects to only begin implementing each regulation strategy after picture onset, we also sought to ensure that there were no observable differences between the distraction and reappraisal conditions prior to picture onset by analyzing ERPs during the presentation of the instruction cue. In particular, we examined the frontally maximal stimulus-preceding negativity (SPN) ERP component during the cueing window (the 2000 ms window in which subjects saw a cue to either VIEW, WATCH, DISTRACT, or REAPPRAISE). The SPN is believed to reflect attentional orienting towards and anticipation of impending stimuli (van Boxtel and

Table 1
Means (standard deviations) for pair-wise comparisons between negative-watch and negative-distract at each 200 ms time increment within the first 1400 ms (300–1700 ms) of the LPP.

Time (ms)	Negative-watch	Negative-distract	*t*-value	*p*-value	Holm's alpha
300–500	2.37 (5.28)	0.17 (4.70)	2.97	.009*	.025
500–700	6.60 (6.09)	4.17 (5.00)	2.63	.017*	.050
700–900	8.93 (5.58)	5.82 (4.82)	3.37	.004*	.008
900–1100	8.66 (4.70)	5.74 (5.26)	2.98	.008*	.016
1100–1300	8.48 (4.84)	5.45 (5.55)	3.09	.007*	.010
1300–1500	8.17 (4. 60)	5.12 (4.96)	3.07	.007*	.012
1500–1700	8.15 (4.31)	4.32 (5.37)	3.69	.002*	.007

* Significance after Holm's correction. The Holm's alpha for each *p*-value was calculated by ordering the 7 *p*-values from smallest to largest, and then applying the formula: .05/(7 − position in sequence + 1).

Table 2
Means (standard deviations) for pair-wise comparisons between negative-watch and negative-reappraise at each 200 ms time increment within the first 1400 ms (300–1700 ms) of the LPP.

Time (ms)	Negative-watch	Negative-reappraise	*t*-value	*p*-value	Holm's alpha
300–500	2.37 (5.28)	2.35 (5.49)	0.02	.982	.050
500–700	6.60 (6.09)	5.79 (6.15)	1.15	.264	.025
700–900	8.93 (5.58)	7.83 (5.59)	1.42	.171	.012
900–1100	8.66 (4.70)	7.68 (5.02)	1.37	.186	.016
1100–1300	8.48 (4.84)	6.76 (5.11)	2.34	.031	.010
1300–1500	8.17 (4. 60)	6.28 (5.14)	2.78	.013	.008
1500–1700	8.15 (4.31)	6.08 (5.28)	3.90	.001*	.007

* Significance after Holm's correction. The Holm's alpha for each *p*-value was calculated by ordering the 7 *p*-values from smallest to largest, and then applying the formula: .05/(7 − position in sequence + 1).

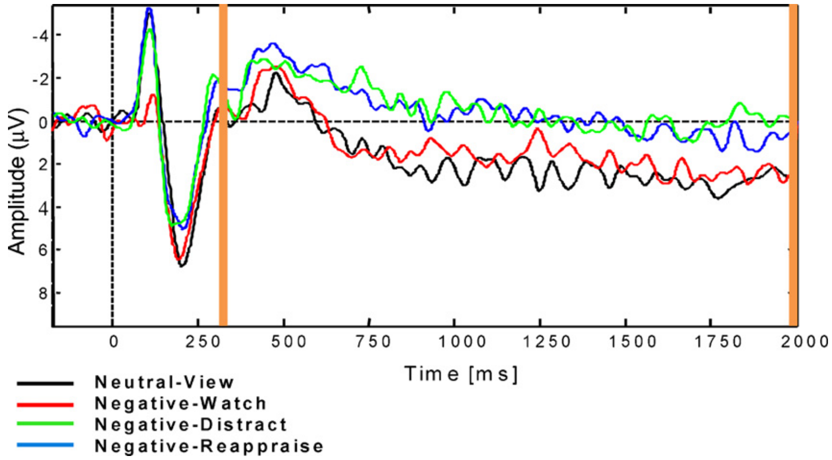

Fig. 3. ERPs by Instruction Type during the cueing window of the regulation task. The stimulus-preceding negativity (SPN) was coded at site Fz (Moser et al., 2009), in the 300–2000 ms time window (the range between the two orange lines) following cue onset. Note that the *y*-axis is reversed (positive voltage is plotted downwards) as per convention. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article.)

Bocker, 2004; Moser et al., 2009), and recent studies have found that it is enhanced when subjects anticipate to regulate emotions to upcoming unpleasant stimuli (Moser et al., 2009). The key question here is whether DISTRACT and REAPPRAISE trials are associated with divergent SPNs during the cueing window.

The ERPs from our regulation task displaying the SPN by Instruction Type during the 2000 ms cueing window are presented in Fig. 3. Following visual inspection, the SPN was quantified as the average signal amplitude in the 300–2000 ms period during the cueing window at frontal site Fz. Consistent with Moser et al. (2009), analysis of SPN amplitudes during the cueing window revealed an effect of Instruction Type, [$F(3,51) = 4.99$, $p < .01$, $\eta_p{}^2 = .23$]. Follow-up pairwise comparisons showed that SPNs during the distraction and reappraisal cueing windows were both greater than that during the negative-watch cueing window: distraction, $t(17) = 2.10$, $p = .05$; reappraisal, $t(17) = 2.61$, $p = .02$. Crucially, however, SPN amplitudes did not differ during the distraction and reappraisal cueing windows, $t(17) = .15$, $p = .88$. If subjects were employing distraction during this window, one would predict SPN amplitudes to be reduced (relative to the reappraisal cuing window), since distraction would interfere with anticipation of the upcoming stimulus. This therefore supports the notion that, upon a cue to distract, subjects oriented their attention towards anticipation of the upcoming picture in a way that is similar to what they did upon a cue to reappraise. We do not believe that the lack of an SPN difference between distraction and reappraisal is due to a lack of statistical power, since we found the expected SPN difference between both regulatory types and the negative-watch condition.

3.3. Upon re-exposure, do stimuli with a distraction-history and stimuli with a reappraisal-history differentially modulate the LPP?

To examine this, we submitted the mean LPP amplitudes (300–5000 ms) at re-exposure to a repeated-measures ANOVA, with Instruction History as a within-subjects factor. As expected, a main effect of Instruction History was found, [$F(3,51) = 5.79$, $p < .005$, $\eta_p{}^2 = .25$]. Planned *t*-tests showed that, consistent with our predictions, images with a distraction-history ($M = 5.70$, $SD = 3.81$) generated a larger LPP than those with a negative-watch history ($M = 3.70$, $SD = 4.88$), $t(17) = 2.27$, $p < .04$. However, contrary to prediction, the LPP generated by images with a reappraisal-history ($M = 2.92$, $SD = 3.99$) was indistinguishable from negative-watch history, $t(17) = .60$, $p = .55$.[5] It is interesting to note nevertheless that images with a distraction-history elicited a larger LPP than those with a reappraisal-history, $t(17) = 3.17$, $p < .01$. The LPP by Instruction History for the entire stimulus duration upon re-exposure is presented in Fig. 4.

Although the overall magnitude of the LPP under reappraisal-history and negative-watch history were indistinguishable, visual inspection of the ERP waveform signaled an interesting difference between the two conditions: reappraisal-history appeared to elicit a smaller LPP than negative-watch history during the 800–1400 ms time window. Given its potential theoretical import, we sought to formally examine this difference. To this end, mean LPP amplitudes in the 800–1400 ms time range at re-exposure were submitted to a repeated-measures ANOVA, with Instruction History as a within-subjects factor. This revealed a main effect of Instruction History, [$F(3,51) = 18.14$, $p < .001$, $\eta_p{}^2 = .52$]. A follow-up pairwise comparison confirmed that the LPP under reappraisal history ($M = 6.84$, $SD = 3.66$) was in fact smaller than the LPP under negative-watch history ($M = 8.76$, $SD = 3.85$), $t(17) = 2.21$, $p < .05$. The implications of this finding are explored in Section 4.

3.4. Secondary analyses

3.4.1. Regulation task

Self-reported ratings of valence and arousal during the regulation task were each separately submitted to a repeated-measures ANOVA, with Instruction Type as a within-subjects factor. For self-reported valence, a main effect of Instruction Type was found, [$F(3,51) = 58.82$, $p < .001$, $\eta_p{}^2 = .78$]. Planned *t*-tests demonstrated that, as expected, negative-watch ($M = 6.65$, $SD = 1.15$) elicited greater unpleasantness ratings than neutral-view ($M = 3.40$, $SD = 1.12$), $t(17) = 11.21$, $p < .001$. Relative to negative-watch, both distraction ($M = 5.33$, $SD = 1.09$) and reappraisal ($M = 4.88$, $SD = 1.27$) reduced unpleasantness: distraction, $t(17) = 5.77$, $p < .001$; reappraisal, $t(17) = 6.25$, $p < .001$. Furthermore, reappraisal led to a

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[5] In fact, the overall LPPs under reappraisal history and negative-watch history were both statistically indistinguishable from neutral: reappraisal history, $t(17) = 1.43$, $p = 0.17$; negative-watch history, $t(17) = 1.94$, $p = 0.06$. Follow-up analyses revealed that although both conditions elicited a substantially stronger LPP relative to neutral within the early stages of stimulus processing (approximately within the 300–1500 ms time range), they both spontaneously returned to a neutral level soon thereafter. These analyses are not presented here as they are not central to our hypotheses.

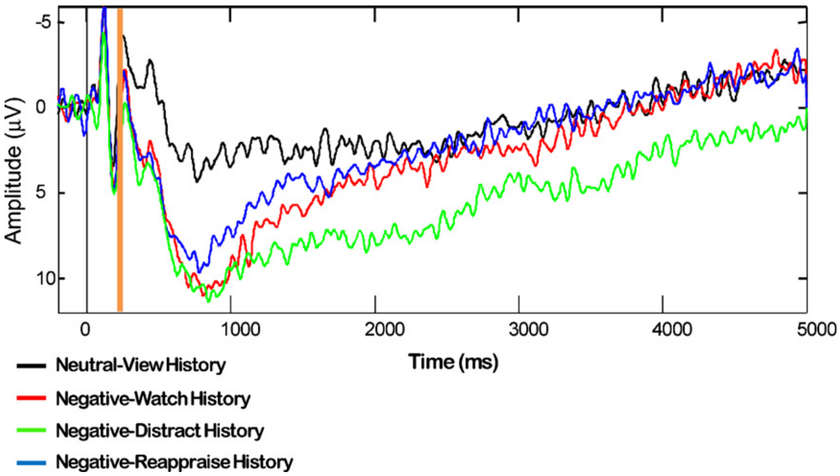

Fig. 4. ERPs by Instruction History during picture presentation of the re-exposure task. The LPPs are the waveforms to the right of the orange line (marking the 300 ms time point after stimulus onset). Note that the *y*-axis is reversed (positive voltage is plotted downwards) as per convention. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article.)

greater reduction in unpleasantness than distraction, $t(17) = 2.37$, $p < .04$. Ratings of self-reported arousal – for which a main effect of Instruction Type was evident as well, [$F(3,51) = 66.04$, $p < .001$, $\eta_p^2 = .79$] – exhibited a similar pattern as that of valence. That is, negative-watch ($M = 5.67$, $SD = 1.19$) elicited greater arousal than neutral-view ($M = 2.49$, $SD = .86$), $t(17) = 12.94$, $p < .001$, but both distraction ($M = 4.42$, $SD = 1.14$) and reappraisal ($M = 4.25$, $SD = 1.30$) reduced arousal relative to negative-watch: distraction, $t(17) = 4.63$, $p < .001$; reappraisal, $t(17) = 6.36$, $p < .001$. However, self-reported arousal did not differ between distraction and reappraisal, $t(17) = 1.09$, $p = .29$.

3.4.2. Re-exposure task

We examined whether self-reported ratings of valence and arousal varied as a function of Instruction History upon re-exposure. For valence ratings, a main effect of Instruction History was found, [$F(3,51) = 78.63$, $p < .001$, $\eta_p^2 = .82$]. Planned *t*-tests showed that images with a negative-watch history ($M = 6.53$, $SD = 1.43$) elicited greater unpleasantness relative to those from neutral-view ($M = 3.47$, $SD = 1.38$), $t(17) = 8.87$, $p < .001$. Furthermore, images with a distraction-history ($M = 6.55$, $SD = 1.31$) as well as reappraisal-history ($M = 6.42$, $SD = 1.38$) led to greater unpleasantness ratings relative to those from neutral-view: distraction-history, $t(17) = 9.80$, $p < .001$; reappraisal-history, $t(17) = 8.91$, $p < .001$. However, images associated with a distraction or reappraisal history did not differ from negative-watch history, or from each other (all *p*s > .09). Similarly, self-reported arousal differed by Instruction History at re-exposure as well, [$F(3,51) = 79.96$, $p < .001$, $\eta_p^2 = .82$]. Planned *t*-tests showed that images with a negative-watch history ($M = 5.49$, $SD = 1.29$) elicited greater arousal than those from neutral-view ($M = 2.41$, $SD = 1.05$), $t(17) = 8.72$, $p < .001$. Moreover, images with a distraction-history ($M = 5.51$, $SD = 1.13$) and reappraisal-history ($M = 5.37$, $SD = 1.27$) elicited greater arousal ratings than those with a neutral-view history: distraction-history, $t(17) = 10.16$, $p < .001$; reappraisal-history, $t(17) = 9.05$, $p < .001$. Mirroring the pattern obtained for valence, arousal ratings for images with a distraction-history or reappraisal-history did not differ from negative-watch history, or from each other (all *p*s > .11).

4. Discussion

Distraction and reappraisal are two powerful forms of cognitive emotion regulation that are thought to differ in *when* they intervene in the emotion-generative process. More specifically, according to the process model of emotion regulation (Gross, 1998), distraction is thought to influence the emotion-generative trajectory at the early attentional deployment stage, prior to the evaluative processing of an emotional stimulus' meaning. By contrast, reappraisal is thought to influence the emotion-generative trajectory later on, during evaluative processing. In the first direct test of this hypothesis, the present study used EEG/ERP methods to assess the temporal dynamics of distraction and reappraisal, comparing the two strategies in order to track when each modulated an electrocortical index that is sensitive to the sustained meaning-evaluation of an emotional stimulus, the late positive potential (LPP).

As predicted, we found that although both strategies robustly attenuated the LPP during regulation, they did so at different stages: distraction began modulating the LPP from its very beginning (at 300 ms), whereas reappraisal began modulating the LPP later on (at 1500 ms). This pattern of results suggests that distraction is implemented prior to the sustained evaluative-processing of an emotional stimulus, thereby restricting the extent to which its affective significance is appraised. Reappraisal, however, involves first attending to and constructing a default evaluation of the emotional stimulus before a re-construal can be implemented.

Also as predicted, we found that upon unregulated re-exposure, images with a distraction-history – but not those with a reappraisal-history – elicited a larger LPP compared to control images that were simply attended to during the regulation task. We argue that this pattern of findings at re-exposure stems from those we obtained during regulation: that is, the greater LPP elicited by images with a distraction-history upon re-exposure could be attributed to distraction's early locus of impact during regulation, which would have prevented evaluative processing of the stimulus' affective significance and thereby rendered it more novel and arousing upon re-exposure (Wilson and Gilbert, 2008). Since reappraisal intervenes relatively later in the emotion-generative trajectory, as it involves first appraising the affective significance of the stimulus, images with a reappraisal history did not elicit a greater LPP compared to those from the control attend condition. However, our prediction that images with a reappraisal-history will elicit a smaller LPP than those with an attend-history was only partially supported, since we found this modulation only for a specific temporal window (800–1400 ms) of the LPP.

4.1. Implications for the separability of distraction and reappraisal

In addition to providing a test of the process model (Gross, 1998), the findings obtained in the present study have broader implications for our understanding of the separability of distraction and reappraisal. These findings are important because the distinction between distraction and reappraisal may be questioned on both theoretical and empirical grounds.

Theoretically, it might be argued that reappraisal is really a form of attentional deployment – like distraction – in that reappraisal involves accessing one of the many competing representations possible for an emotional stimulus by selectively attending to one representation to the exclusion of the others. Empirically, a recent study (van Reekum et al., 2007) found that when implementing reappraisal, individuals altered their patterns of gaze fixation relative to a control attend condition. Moreover, these changes in gaze fixation accounted for a sizeable portion of the variance in reappraisal-induced neural activation across several brain regions. This finding led to questions over whether the effects that have been frequently observed for reappraisal in prior research (Goldin et al., 2008; Gross, 1998; Jackson et al., 2000; Ochsner et al., 2002, 2004) may largely be mediated through attentional redeployment rather than through meaning-change as had been presumed.

The present study lends support to the idea that distraction and reappraisal engage separable processes both by showing differential effects during the regulatory episode, and by showing differential effects on the subsequent processing of the emotional stimulus upon unregulated re-exposure. Based on its temporal patterning, we argue that reappraisal is more than a form of attentional redeployment in that, unlike distraction, it involves first actively constructing a representation of the emotional stimulus by evaluating its affective significance. Our findings on the separability of the two strategies also corroborate a recent study by Urry (2010) which directly addressed this issue by demonstrating that reappraisal modulated self-reported and EMG (e.g. corrugator muscle activity) indices of emotional responding even when attentional deployment was fixed towards a circumscribed part of the stimulus.

4.2. *Implications for the utility of distraction and reappraisal*

Our findings also have implications for the relative utility of distraction and reappraisal. Both forms of emotion regulation led to clear reductions in behavioral and neural indicators of negative emotional responding. There were, however, differences between the two strategies that may have implications for their relative utility over the longer term.

Our results showed that, during regulation, distraction is able to alter the emotion generative trajectory very early. Distraction's comparative efficacy in rapidly attenuating the processing of the emotional stimulus may make it particularly rewarding to use, leading individuals to rely on it frequently. However, the present study shows that this reinforcing property of distraction may come at a cost over the long-term by eliciting greater emotional responses upon re-exposure to the stimulus, compared to simply attending to it. Such a cost would naturally be most pronounced when distraction is consistently employed towards aversive events that can be expected to recur with much frequency.

Our reappraisal findings suggest a contrasting view of reappraisal. As noted, upon re-exposure, we found that images with a reappraisal-history generated a smaller LPP than those with a negative-watch history during the 800–1400 ms time window. We believe this reflects the fact that, compared to the negative-watch condition in which subjects simply attended to the aversive stimulus, reappraisal partially altered the default appraisal for that stimulus. Upon re-exposure, this more neutral appraisal of the stimulus may have been activated, attenuating the LPP for a period of time. This beneficial effect of reappraisal upon unregulated re-exposure is consistent with recent research showing that reappraisal is capable of exerting enduring effects on emotional responding. For instance, Walter et al. (2009) demonstrated that arousing images with a reappraisal-history elicited less amygdala activation upon re-exposure relative to those that were not previously reappraised. Similar findings have also been reported by MacNamara et al. (in press), who showed that images previously appraised in a neutral manner elicited a smaller ERP positivity peaking at approximately 1100 ms relative to those appraised in a negative manner.

4.3. *Limitations and future directions*

It is important to note some key limitations of the present study. First, we used a fairly small sample of healthy subjects. In addition to studying a larger sample, future studies should examine whether the temporal dynamics of distraction and reappraisal differ between healthy individuals and those with psychopathology. Emerging empirical findings highlight the possibility that regulatory processes in certain affective disorders may be characterized by distinct temporal dynamics. For instance, relative to low anxious individuals, those high in anxiety show a slowed disengagement of attention from threatening stimuli (Fox et al., 2001; Yiend and Mathews, 2001). Delineating how the temporal features of specific regulation strategies such as distraction and reappraisal compare between healthy and psychopathological samples may serve to illuminate the mechanisms behind the regulatory impairments that underlie specific psychiatric disorders.

A second limitation concerns the fact that, contrary to predictions, a difference between reappraisal-history and attend-history was only found during a specific temporal window (800–1400 ms) of the LPP during re-exposure. However, it is noteworthy that the single ERP study which has examined the effect of reappraisal on re-exposure (MacNamara et al., in press) found a similar pattern: in that study, an earlier positivity (peaking at 359 ms) and a later positivity (peaking at 2436 ms) were both insensitive to reappraisal-history. It is unclear why only specific temporal windows were modulated by reappraisal-history in both studies. One possibility is that a single "dose" of reappraisal, as was used in both studies, is not sufficient to enduringly modify the default, dominant appraisal for a given emotional stimulus. Thus, reappraisal might have weakly biased the appraisal of the stimulus towards a neutral direction upon re-exposure, but did not serve to fully override the original, dominant appraisal. Future studies can examine whether administering a greater number of "doses" of reappraisal can lead to a more sustained effect upon re-exposure.

A third limitation concerns the fact that, upon re-exposure, the effects of distraction-history and reappraisal-history on the LPP were not accompanied by a similar effect on self-reported valence or arousal. Although MacNamara et al. (in press) found an effect of their appraisal manipulation on self-reported valence and arousal upon delayed re-exposure to the stimuli, they used a different paradigm (description-based reappraisal) from the one used in the current study. A description-based approach in which pre-made neutral descriptions are provided for each emotional stimulus might have allowed individuals to more easily encode the appraisals into explicit memory, which could have then been recalled when making self-report ratings during re-exposure. It is important to note that while some studies find an association between the LPP and self-reported emotional intensity (Cuthbert et al., 2000; Hajcak and Nieuwenhuis, 2006), other studies fail to find such a link (Foti and Hajcak, 2008; MacNamara et al., 2009). It is plausible that self-report measures of emotion are simply more "noisy" in that they can be more easily contaminated by influences not directly related to one's veridical emotional state, such as one's expectation of task demands and one's willingness and ability to introspect about his or her valence/arousal levels (see Nielsen and Kaszniak, 2007, for a review). Such influences may have rendered these self-report measures less sensitive than neural measures to detect differences in one's emotional state.

Finally, although distraction is a fairly heterogeneous category which comprises visually directed forms of selective attention (i.e. simply looking away) as well as conceptually driven forms of selective attention (i.e. generating unrelated neutral thoughts), we restricted our focus to the latter in the present study. Similarly, reappraisal is also a heterogeneous category, and can be broadly divided into situation-focused reappraisal (which serves to alter the meaning of the emotional situation directly) versus self-focused reappraisal (which alters one's relationship with the situation, such as by becoming a detached observer; Ochsner et al., 2004). In the present study, we did not constrain the type of reappraisal, giving subjects the option to use one from each of the two broad categories. One important direction for future research is to systematically compare strategies both within and between different emotion regulation families.

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