



MIT Open Access Articles

The Neural Bases of Distraction and Reappraisal

The MIT Faculty has made this article openly available. **Please share** how this access benefits you. Your story matters.

Citation	McRae, Kateri et al. "The Neural Bases of Distraction and Reappraisal." <i>Journal of Cognitive Neuroscience</i> 22.2 (2010): 248-262. © 2010 Massachusetts Institute of Technology
As Published	http://dx.doi.org/10.1162/jocn.2009.21243
Publisher	MIT Press
Version	Final published version
Citable link	http://hdl.handle.net/1721.1/57447
Terms of Use	Article is made available in accordance with the publisher's policy and may be subject to US copyright law. Please refer to the publisher's site for terms of use.

The Neural Bases of Distraction and Reappraisal

Kateri McRae¹, Brent Hughes², Sita Chopra¹, John D. E. Gabrieli³,
James J. Gross¹, and Kevin N. Ochsner⁴

Abstract

■ Distraction and reappraisal are two commonly used forms of cognitive emotion regulation. Functional neuroimaging studies have shown that each one depends upon interactions between pFC, interpreted as implementing cognitive control, and limbic regions, interpreted as mediating emotional responses. However, no study has directly compared distraction with reappraisal, and it remains unclear whether they draw upon different neural mechanisms and have different emotional consequences. The present fMRI study compared distraction and reappraisal and found both similarities and differences between the two forms of emotion regulation. Both resulted in decreased negative af-

fect, decreased activation in the amygdala, and increased activation in prefrontal and cingulate regions. Relative to distraction, reappraisal led to greater decreases in negative affect and to greater increases in a network of regions associated with processing affective meaning (medial prefrontal and anterior temporal cortices). Relative to reappraisal, distraction led to greater decreases in amygdala activation and to greater increases in activation in prefrontal and parietal regions. Taken together, these data suggest that distraction and reappraisal differentially engage neural systems involved in attentional deployment and cognitive reframing and have different emotional consequences. ■

INTRODUCTION

The ability to influence how we experience and express emotions—known as emotion regulation—is a crucial contributor to mental health (Amstadter, 2008; Gross, 2007; Taylor & Liberzon, 2007). Among the most powerful and flexible forms of emotion regulation are cognitive strategies that alter either the way we attend to a stimulus (distraction) or the way we interpret the meaning of a stimulus (reappraisal). Indeed, distraction and reappraisal are among the best-studied forms of emotion regulation (Ochsner & Gross, 2005, 2008; Li & Lambert, 2007; Sheppes & Meiran, 2007; Totterdell & Parkinson, 1999; Craske, Street, & Barlow, 1989).

Distraction involves the use of selective attention to limit the extent to which the emotionally evocative aspects of an event are attended and appraised. Distraction has been shown to be effective for reducing various kinds of negative affective responses, including dysphoric mood (Rusting, 1998), negative cognitions (Fennell & Teasdale, 1984), anger (Gerin, Davidson, Christenfeld, Goyal, & Schwartz, 2006; Rusting, 1998), and stress (Bennett, Phelps, Brain, Hood, & Gray, 2007). Neuroimaging studies have shown that performing a variety of demanding tasks diminishes the aversiveness of pain, as measured by self-reported experience, as well as activation in pain-related regions such as the insula and the medial pFC (mPFC; Seminowicz & Davis, 2007; Wiech et al., 2005; Bantick et al.,

2002; Frankenstein, Richter, McIntyre, & Remy, 2001). Typically, reductions in indices of pain response are accompanied by greater activation in regions linked to cognitive control, such as lateral pFC (lPFC) and dorsal ACC (dACC; Seminowicz & Davis, 2007; Kalisch, Wiech, Herrmann, & Dolan, 2006; Bantick et al., 2002; Frankenstein et al., 2001).

Reappraisal involves cognitively changing one's appraisal of the affective meaning of a stimulus. Reappraisal is recognized as a key component of one of the most successful interventions for the treatment of mood and anxiety disorders, cognitive behavioral therapy (Beck, Rush, Shaw, & Emery, 1979). In laboratory studies, reappraisal has been shown to be successful in decreasing negative emotional responding, as measured by self-reports of negative affect (Gross, 1998a), peripheral physiological measures of arousal and negative affect (Ohira et al., 2006; Jackson, Malmstadt, Larson, & Davidson, 2000), and activation in brain regions involved in the processing of negative emotion such as the amygdala and the insula (Eippert et al., 2007; Kim & Hamann, 2007; Urry et al., 2006; Phan et al., 2005; Ochsner, Ray, et al., 2004; Ochsner, Bunge, Gross, & Gabrieli, 2002). Neuroimaging studies have shown that successful reappraisal is supported by activation in dorsal and ventral lateral pFC (vlPFC), mPFC, and dACC—all regions associated with various aspects of cognitive control (Miller & Cohen, 2001).

Although growing evidence supports the efficacy of both distraction and reappraisal as emotion regulation strategies, it has been difficult to directly compare distraction and reappraisal for at least three reasons. First,

¹Stanford University, ²University of Texas at Austin, ³Massachusetts Institute of Technology, ⁴Columbia University

distraction manipulations, which include verbal fluency, Stroop, multisource interference, and self-generation tasks, typically involve multiple kinds of processing, at least some of which are controlled and deliberate. It is not clear whether control-related activations reflect processes supporting cognitive task performance, regulation of emotion to reduce interference with the cognitive task, or both. Second, some studies have failed to show reductions in self-reported negativity or stress as a result of distraction (Kalisch et al., 2006; Chua, Krams, Toni, Passingham, & Dolan, 1999), making it difficult to determine whether prefrontal and cingulate activities reflect successful emotion regulation or simply the effort to successfully perform the cognitive task in the face of an affective distracter. The clinical utility of distraction indicates that it can influence self-reported affect, but it is unclear why the experimental designs in these prior studies failed to show that influence. Third, and most importantly, although distraction and reappraisal both have been shown to alter emotional responding, studies have differed in the kinds of stimuli presented and the specificity of the instructions used, and no study has directly compared them. This makes it impossible to determine whether these two emotion regulation strategies engage similar or dissimilar brain mechanisms and whether they have comparable affective consequences.

The goal of this study was to directly compare distraction and reappraisal. On the basis of previous research, we predicted that both distraction and reappraisal would decrease self-reported negative affect and amygdala activation. However, given that distraction has had relatively inconsistent effects on self-reported affect, we expected that reappraisal would lead to greater decreases in this measure of emotional responding. According to our process conception of emotion regulation (Gross, 1998b), our general expectation for regulation-related regions was that both strategies would recruit lateral prefrontal regions (implicated in cognitive control), anterior cingulate regions (implicated in monitoring the success of regulation), and parietal regions (implicated in shifting attention; Ochsner & Gross, 2005, 2008). At the same time, we also expected to see different regions recruited by each of the strategies. Using a cognitive process perspective, we hypothesized that distraction and reappraisal differentially depend upon processes supporting selective attention as opposed to those involved in the generation or manipulation of an emotional narrative, respectively. Therefore, we predicted that reappraisal would recruit additional dorsolateral PFC regions that are known to be involved in generating higher level cognitive strategies, which in this case would involve the specific reinterpretations of images that are part and parcel of reappraisal (Ochsner & Gross, 2005). In addition, we predicted that relative to distraction, reappraisal would differentially recruit dorsomedial pFC (dmPFC) regions that are known to support higher level appraisals of emotional stimuli and monitoring of one's own emotional state (Lane &

McRae, 2004; Ochsner, Knierim, et al., 2004; Teasdale et al., 1999). Finally, we predicted that relative to reappraisal, distraction would differentially recruit areas of prefrontal and parietal cortices that are known to be involved in directing one's attention toward an external stimulus (Wager, Jonides, & Reading, 2004).

METHODS

Participants

Eighteen women (mean age = 24.4 years, $SD = 3.5$ years) participated. Potential participants were recruited via paper and electronic flyers from the campus community in Stanford, California. Interested participants were screened via e-mail and invited to participate provided they met the following criteria: (1) right-hand dominance, (2) English as a native language, (3) fMRI compatibility (no embedded metal in body, not pregnant, not claustrophobic), (4) no current psychiatric diagnosis, and (5) no current use of psychoactive medications.

Task Training

Participants were trained on the experimental procedure in a separate session 3–5 days before scanning in which an experimenter guided the participants through the different instructions presented during the task. When they saw the word “attend,” participants were instructed to pay attention and respond naturally to the subsequent stimulus, allowing themselves to have whatever reaction the picture would normally evoke in them. When they saw the word “decrease,” they were asked to reinterpret the situation depicted in the picture in a way that made them feel less negative about it. When they saw a six-letter string (the distraction instruction), they were instructed to try to keep all six letters in mind during the picture presentation and were told they would be probed for memory directly after the presentation of each picture. Training began with several practice trials of each type (using images not repeated during the experiment). For reappraisal practice images, the experimenter required that all subjects verbalize their reappraisals to ensure (1) that when reappraising, participants used the instructed strategy of reinterpreting the affects/dispositions, outcomes, and contexts depicted in images (this is known as “situation focused” reappraisal; Ochsner, Knierim, et al., 2004; Ochsner, Ray, et al., 2004; or “reinterpretation” more generally; Ochsner & Gross, 2008); and (2) that participants were not actually using distraction (looking away from the picture or only attending to the nonemotional aspects of the picture) or any other regulation strategy (such as expressive suppression). Participants were reminded of the previous task training and reread the description of the different instructions immediately before the scanning session.

To confirm that participants were actually engaging in the desired form of emotion regulation, after scanning, we asked participants to write down the strategies they used to decrease their negative affect during the reappraisal trials and what percentage of the time they used each strategy. Only two participants reported any non-reappraisal strategies on any proportion of the trials, one that used distraction on 10% of the reappraisal trials and one that reported being unable to reappraise on less than 25% of the reappraisal trials. To address the possibility that participants' self-ratings of negative affect might be influenced by demand characteristics, we asked participants to complete the Marlowe–Crown Social Desirability Scale. No significant correlation between the self-reports of negative affect and the Marlowe–Crown Social Desirability Scale scores was obtained ($r = .062, p = .862$). To confirm that participants were actually performing the distraction task, we examined performance accuracy on the forced-choice recognition probe of the six-letter string. Mean accuracy was 94.03% correct ($SEM = 0.081\%$).

Task

Participants viewed pictures drawn from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2001) as well as pictures from an in-house set that were rated in a separate sample for comparable valence and arousal to those from the IAPS. Pictures normatively rated as negative (valence: $M = 2.38, SD = 0.57$; arousal: $M = 6.06, SD = 1.18$) and neutral (valence: $M = 4.97, SD = 0.42$; arousal: $M = 3.40, SD = 1.08$) were selected.

To compare distraction and reappraisal to unregulated responding, negative pictures were seen with three preceding 2-sec displays: the word “decrease” (the reappraisal condition), a six-letter string (the distraction condition), and the word “attend” (the look or the nonregulation condition). To provide a neutral baseline condition, we also presented neutral pictures in the look condition. Three other instruction conditions (the letter string paired with a neutral picture and both the letter string and the look instructions presented before a fixation cross) were interspersed with these conditions. Data from these trials are not of interest to the present report and will be reported elsewhere.

To address the possibility that differences in brain activation or the behavioral consequences of reappraisal and distraction could be attributable to differences in task difficulty, we conducted a separate pilot study designed to equate the distraction and reappraisal trials for effort. For this study, 23 female participants (a separate sample drawn from the same community as the present sample) completed the same regulatory task as did the scanner participants, with the exception that at the end of the study they completed a posttest rating (on a 7-point scale, 1 = *not at all effortful* to 7 = *very effortful*) of how much effort they exerted to hold in mind the letter string or to reappraise on each trial. Average ratings indicated that re-

appraisal ($M = 4.12, SD = 0.68$) and distraction ($M = 3.93, SD = 0.61$) were rated as requiring significantly more effort than the nonregulation negative picture condition ($M = 2.96, SD = 0.21, t(22) = 3.62, p < .002$, for distraction condition, and $t(22) = 4.04, p < .001$, for reappraisal condition). Crucially, the distraction and the reappraisal conditions were not rated as significantly different in effort, $t(22) = 1.18, p = .25$.

Following the 8-sec presentation of each picture,¹ participants were presented with one letter for 4 sec and asked to respond with a keypress to indicate if the letter was part of the six-letter set they saw before the picture (for the distraction trials) or to press any key (for the look and the reappraisal trials; this kept motor responses constant across trial types). Next, participants were asked to indicate how negative they felt. To decrease demand effects, the experimenter emphasized that this rating should correspond to their honest assessment of negative affect and explicitly mentioned the possibility that reappraisals could fail to decrease negative affect. This response was made using a scale that consisted of a horizontal rectangular bar labeled “strength of negative affect” with anchors of 0 = *weak* and 7 = *strong*. At the beginning of the 4-sec rating period, the bar grew from left to right, and participants pressed a key when the bar had grown to a size that corresponded to the strength of their current negative feeling. This bar provided a continuous index of participants' subjective experience of negative affect. Lastly, a screen that read “relax” was presented for 2.5 sec at the end of each trial.

One hundred sixty trials were presented in an event-related fashion in four different stimulus presentation orders, which ensured the counterbalanced pairing of individual negative and neutral stimuli across the different instruction conditions.

Imaging Parameters

Twenty-four axial slices (4.4 mm thick) were collected on a 1.5-T (GE Signa LX Horizon Echospeed, Milwaukee, WI) scanner with a T2*-sensitive gradient-echo spiral-in-out pulse sequence (repetition time = 2.00, echo time = 40 msec, flip angle = 80°, field of view = 24 cm, data acquisition matrix = 64 × 64). Two hundred twenty whole-brain images were taken in each of eight 7-min, 20-sec runs. T2-weighted flow-compensated spin echo scans were acquired for anatomical localization using identical slice prescription as the functional scans. We evaluated signal dropout in the amygdala and, in accordance with previously reported findings, observed 0% dropout in the amygdala (Preston, Thomason, Ochsner, Cooper, & Glover, 2004).

fMRI Preprocessing

For the fMRI data, each of the participant's sequential functional volumes was realigned to the first scan and coregistered to her anatomical MRI using an automated

rigid-body transformation algorithm using statistical parametric mapping software (SPM2; Wellcome Department of Imaging Neuroscience, University College London, UK). Default SPM2 settings were used to warp volumetric MRIs to fit a standardized template (16 nonlinear iterations), and normalization parameters were applied to subjects' coregistered functional images. Normalized images were resampled into $2 \times 2 \times 2$ mm voxels. Finally, images were smoothed with a 6-mm FWHM kernel.

fMRI Analyses

Basic Contrasts

Preprocessed images were entered into a general linear model in SPM that modeled the canonical hemodynamic response function convolved with a 12-sec boxcar representing the instruction and the picture-viewing period. Because encoding-related activity in working memory tasks often extends into the delay period (Postle, Zarahn, & D'Esposito, 2000), it was necessary to model the instruction period and the picture-viewing period together. Consequently, any preparatory activity during the reappraisal instruction that reflects reinterpretations or strategies generated before the onset of the stimulus was included as well. These models were used to create contrasts between conditions of interest (look negative > look neutral, reappraise > look negative, distract > look negative, and reappraise > distract) for each subject. These individual contrasts were then entered into a one-sample *t* test to perform a random-effects group analysis. Because SPM does not correct jointly at the voxel and extent levels, as in prior work (e.g., Ochsner, Knierim, et al., 2004), we used AlphaSim, a Monte Carlo simulation bootstrapping program in the AFNI library, to correct for multiple comparisons. AlphaSim takes into account the voxelwise and the cluster-volume thresholds to establish a clusterwise *p* value that protects against false-positive detection of activation clusters (Forman et al., 1995). For whole-brain analyses, the cluster extent threshold was 42 with a voxel threshold of $p < .001$ to protect against false-positives at a rate of $p < .05$ overall.

To identify regions that were significantly more active during both distraction and reappraisal, we used the Fisher method for combining probabilities as used for conjunction analyses in previous work (Ochsner, Ray, et al., 2004; Kampe, Frith, & Frith, 2003). The voxels identified in the reappraise > look contrast at a threshold of $p < .01$ were used as a mask to display the distraction > look contrast at the same display threshold, for a Fisher combined probability of $p < .001$ that a given region was active in both contrasts. When directly comparing distraction and reappraisal, a different masking approach was used. To identify reappraisal-related regions that were not recruited during distraction, we masked the reappraise > distract contrast by the reappraise > look contrast. This ensured that only regions more active during reappraising than during the

baseline look condition could be identified as reappraisal-specific by the reappraise > distract contrast. Similarly, distraction-related regions were identified by masking the distract > reappraise contrast with the distract > look contrast.

ROI Analyses

We performed ROI analyses that identified functionally activated voxels falling within an anatomically defined amygdala ROI (defined at the group level, using the AAL atlas; Brett, Anton, Valabregue, & Poline, 2002) as an a priori ROI. This analysis tested for the effects of reactivity (look negative > look neutral contrast) and both types of regulation (look negative > reappraise, look negative > distract). The comparison of each regulation condition with the look negative condition was used to mask direct comparisons between reappraisal and distraction, providing the inverse of the masked contrasts described above. As a region of a priori interest, the threshold for all amygdala ROI analyses was $p < .05$ with an extent threshold of 5. To display the time course of the response in these regions, we used in-house percent signal change code, which extracted and averaged the time series for all voxels that were above threshold in the group-level contrasts. For these voxels, each run's time course was individually filtered and averaged across time and then each time point was divided by the average and multiplied by 100. In addition, the values immediately preceding each event were averaged and subtracted from the event's time course. These values for each subject were fitted with robust regression to compute the mean effect at each time point, and the *SEs* displayed were computed from this robust regression.

Correlation Comparison Analyses

To determine whether activations in different regions of the brain could be predicted by each individual's drop in regulation-related change in self-reported negative affect, we conducted whole-brain robust regression analyses (that are especially resistant to outliers; Wager, Keller, Lacey, & Jonides, 2005). For both reappraisal and distraction, we correlated decreases in negative affect relative to the look negative condition with the whole-brain activity in the reappraise > look negative and distract > look negative contrasts.

RESULTS

Self-reported Negative Affect

Common Effects of Distraction and Reappraisal

Self-reports of negative affect were entered into a repeated measures general linear model in SPSS. Instruction condition was entered as a within-subject factor with four levels

(reappraisal negative, distraction negative, look negative, and look neutral; means in Figure 1). The main effect of condition was significant, $F(3,15) = 60.75, p < .001$, and planned t tests were performed to examine differences across conditions. First, the negative stimuli elicited greater negative affect than the neutral stimuli, $t(17) = 13.32, p < .001$. Second, both forms of emotion regulation were successful in reducing negative affect relative to the look-negative condition: reappraisal, $t(17) = 6.33, p < .001$; distraction, $t(17) = 5.18, p < .001$.

Differential Effects of Distraction and Reappraisal

Because ratings of self-reported negative affect differed by condition, we used planned t tests to investigate the direct comparison of ratings during distraction and reappraisal. This analysis showed that reappraisal led to a greater reduction in negative affect than distraction, $t(17) = 2.19, p < .043$.

Functional Imaging

Common Effects of Distraction and Reappraisal

We had two goals with respect to identifying regions commonly involved in distraction and reappraisal. First, we sought to determine whether activity was decreased in similar regions during the employment of the two strategies. Relative to the look negative condition, we found significant reductions for both strategies in our a priori ROI, the amygdala (right amygdala peak at $[24\ 2\ -24], T = 2.62, p < .005$, uncorrected, left amygdala peak at $[-24\ 0\ -28], T = 2.24, p < .02$, uncorrected), and in whole-brain analyses, we observed common reductions in the left insula, right inferior parietal lobe, and middle temporal gyrus as well (see Table 1A).

Second, we sought to identify regions in which activity increased during both distraction and reappraisal relative to the look negative condition. Regions commonly active for distraction and reappraisal included left-sided middle and inferior LPFC and dmPFC, extending into the dACC. These regions are listed in Table 1B and shown in Figure 3.

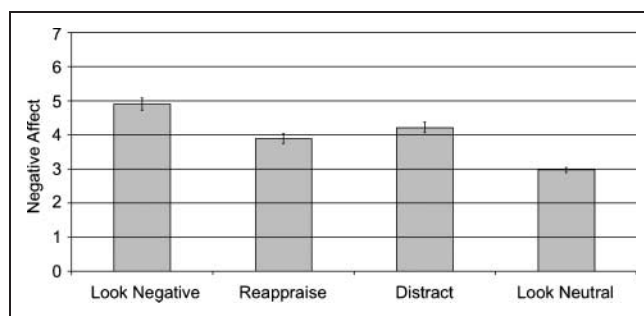


Figure 1. Self-reported negative affect in response to pictures presented in four conditions. Means in all conditions significantly differ from one another ($p < .05$). Error bars represent SEM.

Differential Effects of Distraction and Reappraisal

We also had two goals when directly comparing the neural effects of these two strategies. First, we sought to determine whether they had different modulatory effects on the amygdala using an a priori ROI. As shown in Figure 2, significant clusters were observed in the amygdala that showed greater reduction in activity during distraction than reappraisal (reappraise $>$ distract; right amygdala peak at $[24\ -8\ -12], T = 4.13, p < .001$ uncorrected; left amygdala peak at $[-28\ -6\ -18], T = 3.04, p < .005$, uncorrected). No clusters in the amygdala showed greater activity for distraction than reappraisal.

Second, to identify regions differentially associated with implementing each type of strategy, we directly contrasted whole-brain activation during distraction and reappraisal. Several regions were identified in the reappraise negative $>$ distract negative contrast, including clusters in dmPFC, bilateral dorsal, and vLPFC and several left-sided clusters in temporal cortex. These regions are listed in Table 2A and shown in Figure 3. Only a few regions were identified in the distract $>$ reappraise contrast. These regions included left inferolateral pFC, right LPFC, and bilateral clusters in superior parietal cortex. These regions are listed in Table 2B and shown in Figure 3.

Correlations with Self-reported Negative Affect

Separate regression analyses for each strategy were used to identify the regions that correlated with the difference in negative affect between the nonregulation condition (look negative) and each regulation condition (distraction, reappraisal). Several regions were correlated with decreases in self-report during to reappraisal, including left LPFC, dmPFC, and activation in caudate that extended into the ventral striatum. By contrast, only a few regions, including inferior parietal cortex, were correlated with decreases in self-report during distraction. These results are shown in Figure 4 and Table 3.

DISCUSSION

This study provided the first direct comparison of the behavioral and neural correlates of attentional distraction and cognitive reappraisal. We observed partially overlapping effects of both strategies, along with important distinctions between them. On one hand, both strategies decreased negative affect, decreased activation in the amygdala, and increased activation in prefrontal and cingulate regions that have been implicated in the control of cognition and emotion. On the other hand, there were differential effects of each strategy that provide insight into the processes that define them. Reappraisal resulted in greater decreases in negative affect and increases in activation medial prefrontal and anterior temporal regions associated with processing affective meaning. Distraction

Table 1. Common Effects of Distraction and Reappraisal or Conjunction Analyses

<i>Region</i>	<i>Brodman's area</i>	<i>Extent</i>	<i>T</i>	<i>MNI X</i>	<i>MNI Y</i>	<i>MNI Z</i>	<i>Hemisphere</i>
<i>A. Regions in Which Activity Decreased during Both Reappraisal and Distraction; Look Negative > Reappraise Masked with Look Negative > Distract</i>							
Temporal lobe							
Middle temporal gyrus	21	69	4.1	42	0	-24	Right
Amygdala*		8	4.83	36	2	-24	Right
Amygdala*		17	2.96	28	2	-24	Right
Amygdala*		9	2.29	-26	0	-28	Left
Parietal lobe							
Inferior parietal lobule	40	582	5.44	58	-24	30	Right
Subcortical							
Insula	13	77	3.58	-42	-12	0	Left
<i>B. Regions in Which Activity Increased during Both Reappraisal and Distraction; Reappraise > Look Negative, Masked with Distract > Look Negative</i>							
Frontal lobe							
Superior frontal gyrus	6	701	5.84	-6	10	62	Left
Middle frontal gyrus	10	367	5.06	-36	62	12	Left
Middle frontal gyrus	9	1013	4.51	-42	22	30	Left
Inferior frontal gyrus	47	112	4.36	36	20	-4	Right
Middle frontal gyrus	10	88	3.9	38	64	14	Right
Middle frontal gyrus	9	58	3.59	42	30	34	Right
Parietal lobe							
Inferior parietal lobule	40	100	4.99	-42	-60	46	Left
Subcortical							
Lentiform nucleus		350	4.51	-16	10	8	Left

Voxel threshold was $p < .01$ with an extent threshold of 5 for each contrast, resulting in an overall threshold of $p < .001$.

*The amygdala was explored as an a priori ROI with a voxel threshold of $p < .05$, extent threshold of 5 voxels.

resulted in greater decreases in activation in the amygdala and increases in activation of prefrontal and parietal regions associated with selective attention. As discussed below, these data inform both our specific understanding of distraction and reappraisal and our understanding of the neural architecture supporting emotion regulation more generally.

Common Effects of Distraction and Reappraisal

One of the striking results of this study was that distraction and reappraisal used overlapping prefrontal networks to decrease both amygdala activity and self-reported negative affect. These findings fit with prior work generally implicating prefrontal-amygdala dynamics in the cognitive control of emotion (Ochsner & Gross, 2008; Kim & Hamann, 2007; Lieberman et al., 2007; Stein et al., 2007;

Urry et al., 2006) but go beyond them by implicating specific neural systems as involved in this regulatory process regardless of the strategy used.

The network active during both distraction and reappraisal could reflect their mutual reliance on a set of control operations that play important roles in both strategies. Common activations included a large medial prefrontal region that included the dACC, which has been implicated in signaling the need for cognitive control (Lungu, Binstock, Pline, Yeaton, & Carey, 2007; Milham, Banich, Claus, & Cohen, 2003; Procyk, Tanaka, & Joseph, 2000) and controlling attention to emotional stimuli (McRae, Reiman, Fort, Chen, & Lane, 2008; Hutcherson et al., 2005) as well as left inferior parietal cortex, which may also reflect recruitment of attentional control processes in both strategies (Mayer et al., 2007). Also commonly active were regions of left IPFC associated with verbal or working memory (Wager & Smith,

2003; Paulesu, Frith, & Frackowiak, 1993) and regions of right inferior pFC associated with inhibition of motor responses (Aron, Robbins, & Poldrack, 2004) and other verbal strategies that can be used to down-regulate negative affective responses (Lieberman et al., 2007; Ochsner, Ray, et al., 2004). These prefrontal activations may reflect the need to keep in mind the goals and the contents of each strategy—letters in the case of distraction and an interpretation of the image in the case of reappraisal—as well as the need to withhold prepotent affective appraisals while doing so.

Differential Effects of Distraction and Reappraisal

Perhaps more salient than the common effects of each strategy were their differential effects on emotional responding, which in turn depended on the differential recruitment of specific control systems. These differences provide insight into the distinguishing characteristics of each strategy.

Differential Modulation of Emotional Responses

Distraction and reappraisal led to intriguing differences in self-reported negative affect and amygdala activity. Considering the self-report effects first, prior work is mixed with respect to the question of which strategy more effectively down-regulates negative affect. On one hand, there is some laboratory evidence that both strategies are effective at down-regulating emotions (Sheppes & Meiran, 2007). On the other hand, a study of everyday strategy use found that distraction was rated as less effective than reappraisal (Totterdell & Parkinson, 1999), a finding that fits

with previous behavioral work showing that distraction may be less effective than cognitive reappraisal for down-regulating depressive affect (Kross & Ayduk, 2008) and imaging work showing that distraction may not effectively diminish pain affect (Kalisch et al., 2006; Chua et al., 1999). In part, the inconsistent effects of distraction on self-reports of emotional responding may be due to the variation in the types of distracting tasks used. Overall, our findings dovetail with prior work, suggesting that reappraisal is one of the most effective ways to down-regulate self-reported negative affect.

Distraction, however, down-regulated amygdala activity to a greater extent than reappraisal. Amygdala activity is thought to signal the degree to which a stimulus that is detected in the environment requires some sort of further processing—whether it be to bring the stimulus into focal attention, to prepare motor responses, or to enhance encoding into memory (Phelps, 2006; Whalen et al., 2004; LeDoux, 1996). On this view, distraction should greatly decrease amygdala activity because individuals are not attending to or encoding all the emotional aspects of a stimulus. By contrast, reappraisal involves focusing one’s attention on a stimulus and reinterpreting its meaning. In this case, amygdala activity might decrease to the extent that a cognitive reinterpretation of an aversive stimulus renders it neutral and unarousing (e.g., “That man is tired, not sick”). In other cases, however, reappraising a negative stimulus as positive (e.g., “The crying women are joyful, not sad”) may maintain some level of arousal, albeit with a different valence (Cunningham, Van Bavel, & Johnsen, 2008; McRae, Ochsner, Mauss, Gabrieli, & Gross, 2008;

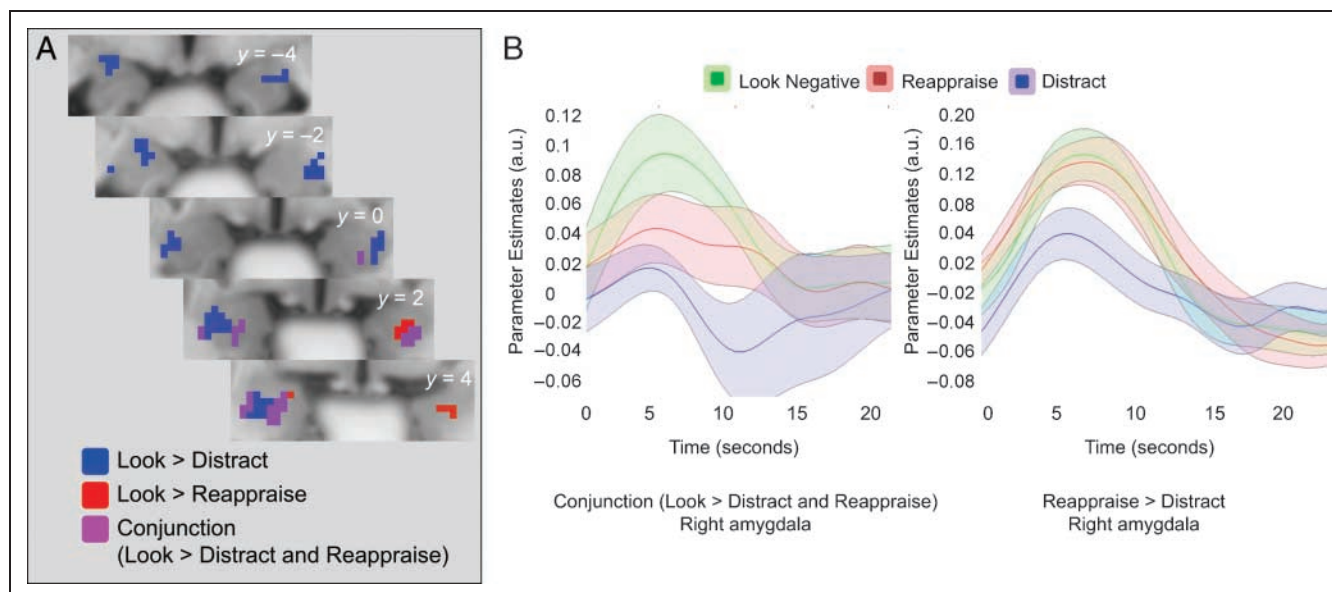


Figure 2. (A) Voxels in the amygdala down-regulated by reappraisal (look negative > reappraise; red), distraction (look negative > distract; blue), and both reappraisal and distraction (conjunction; purple). The display threshold was $p < .05$, with an extent threshold of 5 voxels. (B) Time courses from the right amygdala overlap voxels (top) and the right amygdala voxels from the reappraise > distract contrast (bottom). Means (solid center line) for each time course were estimated robustly, and the SEM (transparent surround) was computed from the standard mean. The time course means and SEs were then smoothed and interpolated using cubic spline to a 0.5-sec resolution.

Table 2. Unique Effects of Distraction and Reappraisal

<i>Region</i>	<i>Brodmann's area</i>	<i>Extent</i>	<i>T</i>	<i>MNI X</i>	<i>MNI Y</i>	<i>MNI Z</i>	<i>Hemisphere</i>
<i>A. Regions in Which Activity Was Greater for Reappraisal Than Distraction; Reappraise Negative > Distract Negative (Masked with Reappraise Negative > Look Negative)</i>							
Frontal lobe							
Middle frontal gyrus	8	6844	8.91	-40	14	46	Left
Middle frontal gyrus	6	70	4.87	48	4	46	Right
Middle frontal gyrus		47	4.65	48	50	-10	Right
Limbic lobe							
Amygdala*		72	3.04	-28	-6	-18	Left
Amygdala*		106	4.13	24	-8	-12	Right
Parahippocampal gyrus	36	399	5.9	-22	-44	-10	Left
Temporal lobe							
Middle temporal gyrus	21	3723	9.16	-54	-12	-18	Left
Middle temporal gyrus	39	2924	8.94	-56	-74	18	Left
Superior temporal gyrus	38	1572	6.83	48	18	-26	Right
Middle temporal gyrus	39	1004	5.76	58	-72	22	Right
Parietal lobe							
Precuneus	7	773	5.75	-6	-60	32	Left
<i>B. Regions in Which Activity Was Greater for Distraction Than Reappraisal; Distract Negative > Reappraise Negative (Masked with Distract Negative > Look Negative)</i>							
Frontal lobe							
Precentral gyrus	6	293	7.76	-56	-4	48	Left
Middle frontal gyrus		64	4.9	48	42	32	Right
Parietal lobe							
Superior parietal lobule	7	324	5.61	-26	-66	42	Left

*The amygdala was explored as an a priori ROI with a voxel threshold of $p < .05$, extent threshold of 5 voxels.

Hamann, Ely, Hoffman, & Kilts, 2002). Thus, because reappraisal involves attending to the emotional stimulus and possibly reframing its meaning as positive but still arousing, we might not expect amygdala activity to be entirely diminished during reappraisal.

The possibility that reappraisal results in relatively sustained amygdala activation compared with distraction was supported by two additional results reported here. The first is that reappraisal and distraction appear to down-regulate amygdala voxels that are not entirely overlapping (Figure 2). This raises the possibility that these two strategies could have their maximal effects in different parts of the amygdala. However, our imaging parameters do not permit precise localization of activations within amygdala subnuclei, and so it is impossible for the present data to strongly address this. The second result is the relationship between self-reported decreases in negative affect due to reappraisal and reappraisal-related activation.

The ventral striatum, which has a strong role in processing reward and positive affect, was more active in those that had greater reappraisal-related decreases in negative affect (McRae et al., 2008; Wager, Davidson, Hughes, Lindquist, & Ochsner, 2008). This was not true of the decreases in negative affect due to distraction. Future work should investigate the difference of reappraising to a positive versus a neutral target.

Differential Reliance on Control Systems

As outlined above, a network of regions generally implicated in cognitive control was recruited by both distraction and reappraisal. The regions that distinguish between the two strategies, however, provide important clues as to the key processes that uniquely define them. Whereas distraction depended more on right prefrontal and parietal regions implicated in the control of attention

(Mayer et al., 2007), reappraisal depended more on regions implicated in appraising an affective stimulus in the context of one's current individual goals and context (Van Overwalle, 2008; Teasdale et al., 1999). This network included mPFC, which has been associated with emotional awareness and mental state attribution (Olsson & Ochsner, 2008; Gilbert et al., 2006; Teasdale et al., 1999), vLPFC regions that may reflect a stimulus's current affective value (Bender, Hellwig, Resch, & Weisbrod, 2007; Boettiger & D'Esposito, 2005; Hornak et al., 2004), and inferior temporal regions important for recognizing social cues (Britton et al., 2006; Tsukiura et al., 2002; Fletcher et al., 1995).

Here it is noteworthy that a subset of the regions that positively covaried with decreases in self-reported negative affect during reappraisal negatively covaried with decreases in self-reported negative affect during distraction (see Figure 3B). These findings are consistent with the argument advanced earlier that to reappraise an emotional stimulus, the initial appraisal (or affective meaning) of the stimulus must be attended and then altered so that the emotional meaning is changed (Scherer, Schorr, & Johnstone, 2001). By contrast, when effective, distraction can prevent the affective meaning of a stimulus from being processed. Thus, one of the primary differences between distraction and reappraisal is the degree to which the affective meaning of the stimulus is attended and appraised.

It also is worth noting that, as can be seen in Figure 4, clusters showing greater activation for reappraisal, for distraction, or that were activated by them both are in some cases spatially close to one another. This raises the question

as to whether such spatially similar, but statistically distinct, activation peaks reflect differential dependence on distinct cognitive processes or quantitative differences in the recruitment of similar processes. This question is, of course, not unique to this study, and within cognitive neuroscience there currently are no clear criteria for determining the answer. That being said, we favor the idea that in regions showing distinct but spatially similar peaks for reappraisal and distraction, the two strategies recruit similar processes but to different degrees. Future replication and extension of the present study may serve to better address this issue, including determining whether small differences in the specific foci of activation may be affected by the constellation of other regions that are simultaneously engaged during performance of each strategy.

Implications for the Use of Distraction and Reappraisal

Our interpretation of the behavioral and imaging results has several implications for understanding the consequences of using distraction and reappraisal both in everyday life and in the course of clinical interventions. Some of these implications follow from the finding that a set of prefrontal and cingulate regions associated with cognitive control supported the performance of both strategies. This suggests that success in implementing distraction or reappraisal depends in part on the integrity of domain-general control processes. This could have im-

Figure 3. Whole-brain results from three contrasts. Orange: Reappraise > Distract masked with Reappraise > Look negative; blue: Distract > Reappraise masked with Distract > Look negative; Purple: Reappraise > Look negative masked by Distract > Look negative).

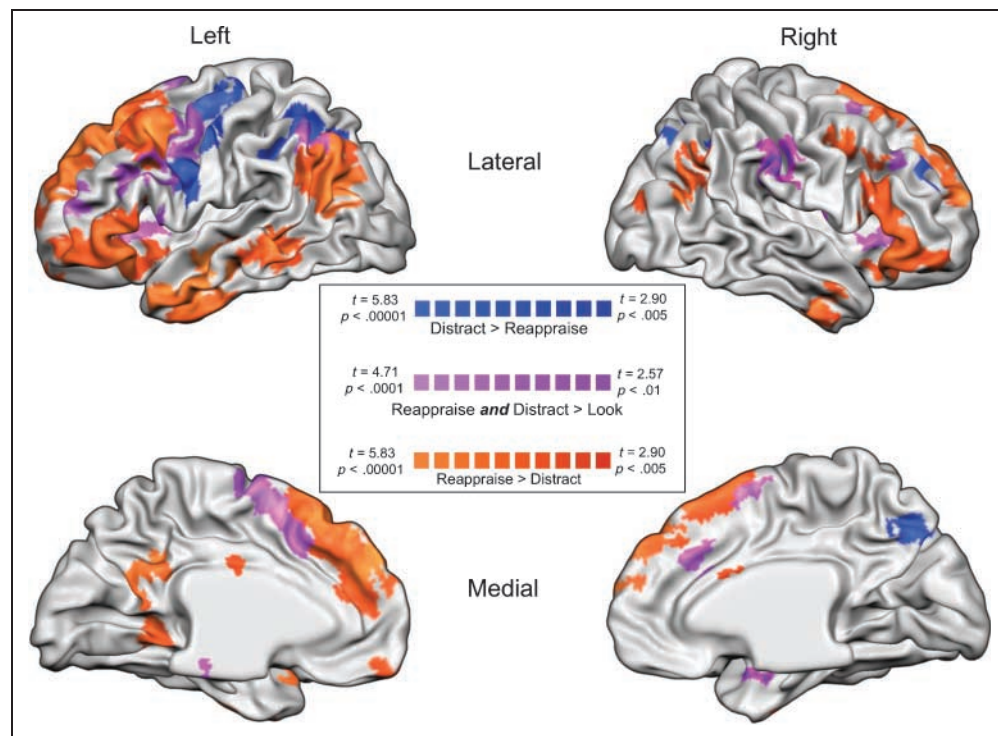


Table 3. Regions Correlated with Decreases in Self-reported Negative Affect during Reappraisal or Distraction

<i>Region</i>	<i>Brodman's area</i>	<i>Extent</i>	<i>Pearson r</i> <i>Reappraise</i>	<i>p</i>	<i>Pearson r</i> <i>Distract</i>	<i>p</i>	<i>x</i>	<i>y</i>	<i>z</i>	<i>Hemisphere</i>
<i>Reappraise > Look</i>										
Frontal lobe										
Inferior frontal gyrus	47	35	.74	<.001	-.07	.400	-45	29	-11	Left
Superior frontal gyrus	6	54	.68	.002	.01	.487	-17	19	67	Left
Superior frontal gyrus	10	55	.75	<.001	-.25	.178	-27	57	29	Left
Inferior frontal gyrus	47	77	.65	.003	-.19	.241	-57	25	-9	Left
Middle frontal gyrus	8	192	.72	.001	-.05	.429	-37	21	47	Left
Middle frontal gyrus	6	37	.61	.005	-.12	.323	59	3	49	Right
Middle frontal gyrus	46	51	.65	.003	-.24	.183	55	27	29	Right
Medial frontal gyrus	8	61	.59	.007	-.32	.111	3	33	45	Right
Middle frontal gyrus	10	66	.68	.002	.22	.206	33	61	9	Right
Middle frontal gyrus	11	78	.77	<.001	-.12	.325	45	51	-13	Right
Parietal lobe										
Superior parietal lobule	7	244	.63	.004	.29	.138	-31	-71	51	Left
Occipital lobe										
Superior occipital gyrus	19	37	.64	.003	.13	.311	35	-95	19	Right
Temporal lobe										
Superior temporal gyrus	22	51	.6	.006	-.11	.337	-61	-55	19	Left
Subcortical										
Lentiform nucleus	Putamen	91	.64	.004	.36	.081	21	17	3	Right
<i>Distract > Look</i>										
Frontal lobe										
Superior frontal gyrus	6	51	.33	.107	.72	.001	-7	-1	71	Left
Parietal lobe										
Angular gyrus	39	121	.05	.425	.77	<.001	-27	-63	37	Left
Superior parietal lobule	7	98	.25	.174	.68	.002	31	-71	49	Right
Occipital lobe										
Cuneus	30	34	.39	.065	.66	.002	-21	-75	7	Left
Subcortical										
Lentiform nucleus	Putamen	63	-.22	.202	.71	.001	-21	11	15	Left

The regions listed for each contrast were identified in the regression with that contrast, but *r* and *p* values for the other contrast are listed for comparison purposes. Extent threshold is listed in voxels.

portant implications for understanding how individual differences in general control abilities may influence the efficacy of emotion regulation. For example, developing adolescents who show impairments in “cold” cognitive control abilities such as working memory and inhibition of prepotent responses might be expected to be less effective emotion regulators. In like fashion, struc-

tural or functional deficits in the commonly recruited prefrontal and cingulate regions might also be expected to impact both distraction and reappraisal. For instance, older adults or individuals with schizophrenia show deficits in structure and function in cingulate and pFC and might be expected to show relatively diminished capacities to regulate using either strategy, just as they would show

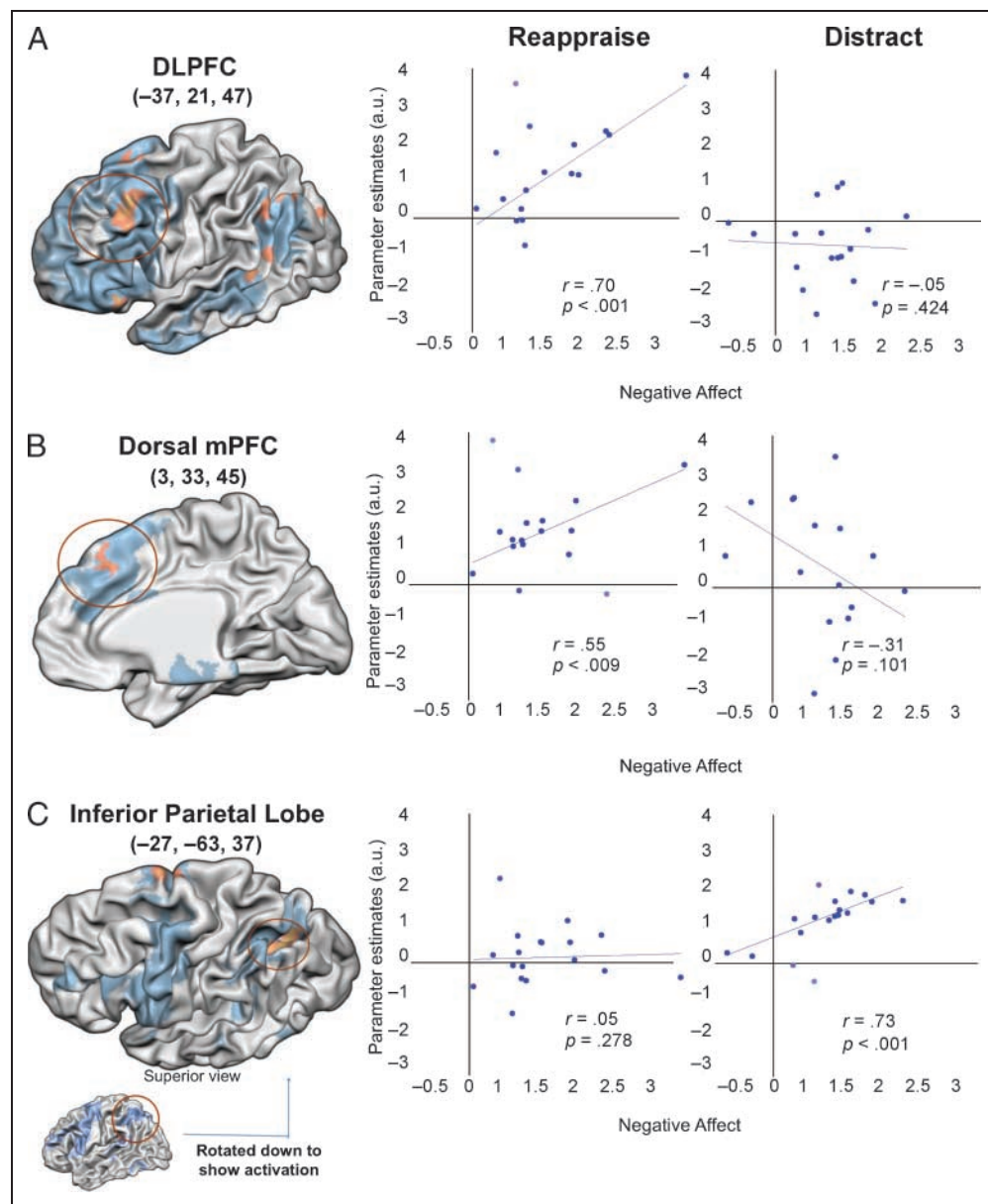
impaired abilities to perform other types of higher level cognitive control (Carter & Barch, 2007; Grieve, Williams, Paul, Clark, & Gordon, 2007; Bell-McGinty et al., 2005; Davidson & Heinrichs, 2003; Andreasen et al., 1994).

Many other implications of our data and interpretations follow from the finding that reappraisal involves greater processing of the affective meaning of the stimulus, whereas distraction involves lesser attention to and poorer encoding of affective meaning than unregulated responding. This suggests superior memory for items viewed while reappraising, which has been demonstrated in several studies (Dillon, Ritchey, Johnson, & LaBar, 2007; Sheppes & Meiran, 2007; Richards & Gross, 2000) and impaired memory for items viewed during distraction, which also has been observed (Sheppes & Meiran, 2007).

These findings further suggest divergent effects of reappraisal and distraction upon unregulated reexposure to

emotional stimuli. In particular, one might predict that when reexposed to stimuli initially viewed under instructions to reappraise, to the extent that prior reappraisal altered the meaning of the stimulus and that this new meaning is reaccessed, then several aspects of the emotional response would be diminished. However, if one is reexposed to stimuli previously viewed during distraction, the stimulus may be processed as if it was being seen for the first time. This idea has been borne out by laboratory studies showing that cognitive reinterpretation has long-lasting effects, whereas distraction only has immediate effects (Kross & Ayduk, 2008). This suggests that distraction may be best used in situations when ignoring the affective meaning of the eliciting stimulus is permissible—such as situations that do not require memory for the stimulus or when reexposure is unlikely. Reappraisal, while requiring more extensive processing of

Figure 4. Whole-brain correlations with decreases due to negative affect during reappraisal (A and B) and distraction (C). Regions in blue represent the main effect (regulation > attend). Regions in orange show a significant correlation with decreases in self-reported negative affect during reappraisal (A and B) and during distraction (C).



affective meaning, might be more appropriate when this meaning must be addressed, manipulated, and remembered and when reexposure is likely. These predictions are consistent with the intuition that it is often permissible to use distraction when watching a gruesome movie or listening to a sad story about a stranger because there are very few consequences of poor encoding of the affective meaning of the story. However, when one is faced with a more personally relevant situation, such as handling the sickness or death of a loved one, oftentimes it is important to be aware and reappraise the meaning of the emotionally charged aspects of the situation so that future reminders of the event do not retain the power to continually reevoke the sadness or the trauma of the past event.

Limitations and Future Directions

One important direction for future research concerns stimulus generalizability. One strength of the present study is that our use of picture stimuli permits contact with a large number of previous studies using an emotional picture paradigm to study cognitive reappraisal (e.g., Urry et al., 2006; Ochsner et al., 2002). In this context, the present results replicate and extend prior work. By contrast, much of the work in distraction has used painful stimulation rather than image-based paradigms (e.g., Kalisch et al., 2006; Bantick et al., 2002). Therefore, a direct comparison of distraction and reappraisal in the context of pain anticipation or delivery—or in the context of other types of emotionally charged stimuli—might further illuminate the similarities and differences between the two strategies.

Another important direction for future research concerns subtypes of distraction and reappraisal. On the basis of previous comparisons of different types of reappraisal strategies (Ochsner, Ray, et al., 2004), we might expect different types of reappraisal to compare with distraction in different ways. Similarly, the specific way in which one is distracted may also be important. We selected a well-characterized verbal working memory task that was intended to depend on verbal rehearsal processes like those thought to be involved in reappraisal and that was matched to reappraisal in terms of subjective effort. Previous studies of distraction have used other types of demanding cognitive tasks that involve various kinds and combinations of control processes whose relative level of effort is not clear. Therefore, comparisons of several methods of distraction and several types of reappraisals may be important in future research.

The distraction and the reappraisal conditions also differed in an important psychological respect. The reappraisal instruction necessarily called the participant's attention to the fact that successful reduction of negative affect could be taking place. This might have created a situation of greater experimental demand during the reappraisal condition compared with distraction. Although we took several precautions against these demand effects, we can-

not rule out the possibility that experimenter demand may be reflected in some of the results reported here.

A final direction for future research concerns the role that individual and group differences play in determining whether reappraisal or distraction is more effective. In the present study, we chose to include only women so as to avoid gender-related factors that might influence emotional responding (Wrase et al., 2003; Bradley, Codispoti, Sabatinelli, & Lang, 2001) or emotion regulation (McRae et al., 2008; Rusting, 1998). It is possible that the relationship between distraction and reappraisal is different in men, and these gender differences should be investigated in the future. The presence and nature of a clinical disorder may be another important factor determining whether distraction or reappraisal is more effective. For instance, distraction has been shown to be a successful emotion regulation strategy for those who suffer from past or current major depression (Joorman, Siemer, & Gotlib, 2007; Fennell & Teasdale, 1984). However, paradoxical effects of distraction have been reported when it is used during exposure therapy for specific phobias (Telch et al., 2004; Craske, Street, Jayaraman, & Barlow, 1991; Foa & Kozak, 1986). Future work could examine whether and how clinical contexts dictate when distraction can facilitate the down-regulation of negative emotion.

Conclusion

The present study compared the emotional effects and the neural bases of two commonly used emotion regulation strategies: attentional distraction and cognitive reappraisal. We found that both strategies successfully reduced emotional experience and amygdala activity while engaging prefrontal regions important for working memory, selective attention, and cognitive control more generally. In addition, reappraisal preferentially activated a network associated with processing affective meaning and resulted in more successful down-regulation of emotional experience than distraction. Distraction, by contrast, preferentially activated regions associated with the allocation of attention and resulted in down-regulation of amygdala activity to a greater extent than reappraisal. We interpret these results as indicating that reappraisal requires attending to and processing affective meaning of the stimulus to be regulated whereas distraction results in decreased processing of affective meaning. Future work should identify the situational and clinical contexts in which enhancing or ignoring affective meaning results in maximally effective emotion regulation.

Acknowledgments

The authors would like to thank Jeffrey Cooper, Rebecca D. Ray, PhD, Matthew Davidson, Jochen Weber, Elaine Robertson, and Sean Pereira for their assistance with data analysis and display. Completion of this research was supported by NIH grants MH076137 (K. N. O.) and MH58147 and MH66957 (J. J. G.).

Reprint requests should be sent to Kevin Ochsner, Department of Psychology, Columbia University, 1190 Amsterdam Avenue, New York City, NY 10027, or via e-mail: kochsner@paradox.psych.columbia.edu.

Note

1. Ten women between the ages of 18 and 22 years were asked to view negative IAPS pictures under the instructions to re-appraise. They were asked to indicate when they were finished with a keypress. The average time to finish was 6.93 sec ($SD = 3.52$ sec). The time in seconds it took people to indicate they were finished was moderately related to their degree of down-regulation of negative affect ($r = 0.60, p < .07$).

REFERENCES

- Amstadter, A. (2008). Emotion regulation and anxiety disorders. *Journal of Anxiety Disorders, 22*, 211–221.
- Andreasen, N. C., Flashman, L., Flaum, M., Arndt, S., Swayze, V., O'Leary, D. S., et al. (1994). Regional brain abnormalities in schizophrenia measured with magnetic resonance imaging. *Journal of the American Medical Association, 272*, 1763–1769.
- Aron, A. R., Robbins, T. W., & Poldrack, R. A. (2004). Inhibition and the right inferior frontal cortex. *Trends in Cognitive Sciences, 8*, 170–177.
- Bantick, S. J., Wise, R. G., Ploghaus, A., Clare, S., Smith, S. M., & Tracey, I. (2002). Imaging how attention modulates pain in humans using functional MRI. *Brain, 125*, 310–319.
- Beck, A. T., Rush, S., Shaw, P., & Emery, N. (1979). *Cognitive therapy of depression*. New York: Guilford Press.
- Bell-McGinty, S., Lopez, O. L., Meltzer, C. C., Scanlon, J. M., Whyte, E. M., DeKosky, S. T., et al. (2005). Differential cortical atrophy in subgroups of mild cognitive impairment. *Archives of Neurology, 62*, 1393–1397.
- Bender, S., Hellwig, S., Resch, F., & Weisbrod, M. (2007). Am I safe? The ventrolateral prefrontal cortex “detects” when an unpleasant event does not occur. *Neuroimage, 38*, 367–385.
- Bennett, P., Phelps, C., Brain, K., Hood, K., & Gray, J. (2007). A randomized controlled trial of a brief self-help coping intervention designed to reduce distress when awaiting genetic risk information. *Journal of Psychosomatic Research, 63*, 59–64.
- Boettiger, C. A., & D'Esposito, M. (2005). Frontal networks for learning and executing arbitrary stimulus-response associations. *Journal of Neuroscience, 25*, 2723–2732.
- Bradley, M. M., Codispoti, M., Sabatinelli, D., & Lang, P. J. (2001). Emotion and motivation: II. Sex differences in picture processing. *Emotion, 1*, 300–319.
- Brett, M., Anton, J. L., Valabregue, R., & Poline, J.-B. (2002). Region of interest analysis using an SPM toolbox. *Neuroimage, 16*, Abstract No. 497.
- Britton, J. C., Phan, K. L., Taylor, S. F., Welsh, R. C., Berridge, K. C., & Liberzon, I. (2006). Neural correlates of social and nonsocial emotions: An fMRI study. *Neuroimage, 31*, 397–409.
- Carter, C. S., & Barch, D. M. (2007). Cognitive neuroscience-based approaches to measuring and improving treatment effects on cognition in schizophrenia: The CNTRICS initiative. *Schizophrenia Bulletin, 33*, 1131–1137.
- Chua, P., Krams, M., Toni, I., Passingham, R., & Dolan, R. (1999). A functional anatomy of anticipatory anxiety. *Neuroimage, 9*, 563–571.
- Craske, M. G., Street, L., & Barlow, D. H. (1989). Instructions to focus upon or distract from internal cues during exposure treatment of agoraphobic avoidance. *Behaviour Research and Therapy, 27*, 663–672.
- Craske, M. G., Street, L. L., Jayaraman, J., & Barlow, D. H. (1991). Attention versus distraction during in vivo exposure: Snake and spider phobias. *Journal of Anxiety Disorders, 5*, 199–211.
- Cunningham, W. A., Van Bavel, J. J., & Johnsen, I. R. (2008). Affective flexibility: Evaluative processing goals shape amygdala activity. *Psychological Science, 19*, 152–160.
- Davidson, L. L., & Heinrichs, R. W. (2003). Quantification of frontal and temporal lobe brain-imaging findings in schizophrenia: A meta-analysis. *Psychiatry Research: Neuroimaging, 122*, 69–87.
- Dillon, D. G., Ritchev, M., Johnson, B. D., & LaBar, K. S. (2007). Dissociable effects of conscious emotion regulation strategies on explicit and implicit memory. *Emotion, 7*, 354–365.
- Eippert, F., Veit, R., Weiskopf, N., Erb, M., Birbaumer, N., & Anders, S. (2007). Regulation of emotional responses elicited by threat-related stimuli. *Human Brain Mapping, 28*, 409–423.
- Fennell, M. J., & Teasdale, J. D. (1984). Effects of distraction on thinking and affect in depressed patients. *British Journal of Clinical Psychology, 23*, 65–66.
- Fletcher, P. C., Happe, F., Frith, U., Baker, S. C., Dolan, R. J., Frackowiak, R. S. J., et al. (1995). Other minds in the brain: A functional imaging study of “theory of mind” in story comprehension. *Cognition, 57*, 109–128.
- Foa, E. B., & Kozak, M. J. (1986). Emotional processing of fear: Exposure to corrective information. *Psychological Bulletin, 99*, 20–35.
- Forman, S. D., Cohen, J. D., Fitzgerald, M., Eddy, W., Mintun, M., & Noll, D. (1995). Improved assessment of significant activation in functional magnetic resonance imaging (fMRI): Use of a cluster-size threshold. *Magnetic Resonance in Medicine, 33*, 636–647.
- Frankenstein, U. N., Richter, W., McIntyre, M. C., & Remy, F. (2001). Distraction modulates anterior cingulate gyrus activations during the cold pressor test. *Neuroimage, 14*, 827–836.
- Gerin, W., Davidson, K. W., Christenfeld, N. J. S., Goyal, T., & Schwartz, J. E. (2006). The role of angry rumination and distraction in blood pressure recovery from emotional arousal. *Psychosomatic Medicine, 68*, 64–72.
- Gilbert, S. J., Spengler, S., Simons, J. S., Steele, J. D., Lawrie, S. M., Frith, C. D., et al. (2006). Functional specialization within rostral prefrontal cortex (area 10): A meta-analysis. *Journal of Cognitive Neuroscience, 18*, 932–948.
- Grieve, S. M., Williams, L. M., Paul, R. H., Clark, C. R., & Gordon, E. (2007). Cognitive aging, executive function, and fractional anisotropy: A diffusion tensor MR imaging study. *American Journal of Neuroradiology, 28*, 226–235.
- Gross, J. J. (1998a). Antecedent- and response-focused emotion regulation: Divergent consequences for experience, expression, and physiology. *Journal of Personality and Social Psychology, 74*, 224–237.
- Gross, J. J. (1998b). The emerging field of emotion regulation: An integrative review. *Review of General Psychology, 2*, 271–299.
- Gross, J. J. (Ed.). (2007). *Handbook of emotion regulation*. New York: Guilford Press.
- Hamann, S., Ely, T. D., Hoffman, J. M., & Kilts, C. D. (2002). Ecstasy and agony: Activation of the human amygdala in positive and negative emotion. *Psychological Science, 13*, 135–141.
- Hornak, J., O'Doherty, J., Bramham, J., Rolls, E. T., Morris, R. G., Bullock, P. R., et al. (2004). Reward-related reversal learning after surgical excisions in orbito-frontal or dorsolateral

- prefrontal cortex in humans. *Journal of Cognitive Neuroscience*, *16*, 463–478.
- Hutcherson, C. A., Goldin, P. R., Ochsner, K. N., Gabrieli, J. D. E., Feldman Barrett, L., & Gross, J. J. (2005). Attention and emotion: Does rating emotion alter neural responses to amusing and sad films? *Neuroimage*, *27*, 656–668.
- Jackson, D. C., Malmstadt, J. R., Larson, C. L., & Davidson, R. J. (2000). Suppression and enhancement of emotional responses to unpleasant pictures. *Psychophysiology*, *37*, 515–522.
- Joorman, J., Siemer, M., & Gotlib, I. H. (2007). Mood regulation in depression: Differential effects of distraction and recall of happy memories on sad mood. *Journal of Abnormal Psychology*, *116*, 484–490.
- Kalisch, R., Wiech, K., Herrmann, K., & Dolan, R. J. (2006). Neural correlates of self-distraction from anxiety and a process model of cognitive emotion regulation. *Journal of Cognitive Neuroscience*, *18*, 1266–1276.
- Kampe, K. K. W., Frith, C. D., & Frith, U. (2003). “Hey John”: Signals conveying communicative intention toward the self activate brain regions associated with “mentalizing,” regardless of modality. *Journal of Neuroscience*, *23*, 5258–5263.
- Kim, S. H., & Hamann, S. (2007). Neural correlates of positive and negative emotion regulation. *Journal of Cognitive Neuroscience*, *19*, 776–798.
- Kross, E., & Ayduk, O. (2008). Facilitating adaptive emotional analysis: Distinguishing distanced-analysis of depressive experiences from immersed-analysis and distraction. *Personality and Social Psychology Bulletin*, *34*, 924–938.
- Lane, R. D., & McRae, K. (2004). Neural substrates of conscious emotional experience: A cognitive-neuroscientific perspective. In M. Beauregard (Ed.), *Consciousness, emotional self-regulation and the brain*. Amsterdam: John Benjamins.
- Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (2001). *International Affective Picture System (IAPS). Instruction manual and affective ratings* (Tech. Rep.). Gainesville, FL: The University of Florida, The Center for Research in Psychophysiology.
- LeDoux, J. E. (1996). *The emotional brain: The mysterious underpinnings of emotional life*. New York: Simon & Schuster.
- Li, J., & Lambert, V. A. (2007). Coping strategies and predictors of general well-being in women with breast cancer in the People’s Republic of China. *Nursing & Health Sciences*, *9*, 199–204.
- Lieberman, M. D., Eisenberger, N. I., Crockett, M. J., Tom, S. M., Pfeifer, J. H., & Way, B. M. (2007). Putting feelings into words: Affect labeling disrupts amygdala activity in response to affective stimuli. *Psychological Science*, *18*, 421–428.
- Lungu, O. V., Binstock, M. M., Plone, M. A., Yeaton, J. R., & Carey, J. R. (2007). Neural changes in control implementation of a continuous task. *Journal of Neuroscience*, *27*, 3010–3016.
- Mayer, J. S., Bittner, R. A., Nikolic, D., Bledowski, C., Goebel, R., & Linden, D. E. J. (2007). Common neural substrates for visual working memory and attention. *Neuroimage*, *36*, 441–453.
- McRae, K., Ochsner, K. N., Mauss, I. B., Gabrieli, J. D., & Gross, J. J. (2008). Gender differences in emotion regulation: An fMRI study of cognitive reappraisal. *Group Processes and Intergroup Relations*, *11*, 143–162.
- McRae, K., Reiman, E. M., Fort, C. L., Chen, K., & Lane, R. D. (2008). Association between trait emotional awareness and dorsal anterior cingulate activity during emotion is arousal-dependent. *Neuroimage*, *41*, 648–655.
- Milham, M. P., Banich, M. T., Claus, E. D., & Cohen, N. J. (2003). Practice-related effects demonstrate complementary roles of anterior cingulate and prefrontal cortices in attentional control. *Neuroimage*, *18*, 483–493.
- Miller, E. K., & Cohen, J. D. (2001). An integrative theory of prefrontal cortex function. *Annual Review of Neuroscience*, *24*, 167–202.
- Ochsner, K. N., Bunge, S. A., Gross, J. J., & Gabrieli, J. D. (2002). Rethinking feelings: An fMRI study of the cognitive regulation of emotion. *Journal of Cognitive Neuroscience*, *14*, 1215–1229.
- Ochsner, K. N., & Gross, J. J. (2005). The cognitive control of emotion. *Trends in Cognitive Sciences*, *9*, 242.
- Ochsner, K. N., & Gross, J. J. (2008). Cognitive emotion regulation: Insights from social cognitive and affective neuroscience. *Current Directions in Psychological Science*, *17*, 153–158.
- Ochsner, K. N., Knierim, K., Ludlow, D., Hanelin, J., Ramachandran, T., & Mackey, S. (2004). Reflecting upon feelings: An fMRI study of neural systems supporting the attribution of emotion to self and other. *Journal of Cognitive Neuroscience*, *16*, 1746–1772.
- Ochsner, K. N., Ray, R. D., Cooper, J. C., Robertson, E. R., Chopra, S., Gabrieli, J. D., et al. (2004). For better or for worse: Neural systems supporting the cognitive down- and up-regulation of negative emotion. *Neuroimage*, *23*, 483–499.
- Ohira, H., Nomura, M., Ichikawa, N., Isowa, T., Iidaka, T., Sato, A., et al. (2006). Association of neural and physiological responses during voluntary emotion suppression. *Neuroimage*, *29*, 721–733.
- Olsson, A., & Ochsner, K. N. (2008). The role of social cognition in emotion. *Trends in Cognitive Sciences*, *12*, 65–71.
- Paulesu, E., Frith, C. D., & Frackowiak, R. S. J. (1993). The neural correlates of the verbal component of working memory. *Nature*, *362*, 342–345.
- Phan, K. L., Fitzgerald, D. A., Nathan, P. J., Moore, G. J., Uhde, T. W., & Tancer, M. E. (2005). Neural substrates for voluntary suppression of negative affect: A functional magnetic resonance imaging study. *Biological Psychiatry*, *57*, 210–219.
- Phelps, E. A. (2006). Emotion and cognition: Insights from studies of the human amygdala. *Annual Review of Psychology*, *57*, 27–53.
- Postle, B. R., Zarahn, E., & D’Esposito, M. (2000). Using event-related fMRI to assess delay-period activity during performance of spatial and nonspatial working memory tasks. *Brain Research Protocols*, *5*, 57–66.
- Preston, A. R., Thomason, M. E., Ochsner, K. N., Cooper, J. C., & Glover, G. H. (2004). Comparison of spiral-in/out and spiral-out BOLD fMRI at 1.5 and 3 T. *Neuroimage*, *21*, 291–301.
- Procyk, E., Tanaka, Y. L., & Joseph, J. P. (2000). Anterior cingulate activity during routine and non-routine sequential behaviors in macaques. *Nature Neuroscience*, *3*, 502–508.
- Richards, J. M., & Gross, J. J. (2000). Emotion regulation and memory: The cognitive costs of keeping one’s cool. *Journal of Personality and Social Psychology*, *79*, 410–424.
- Rusting, C. L. (1998). Personality, mood, and cognitive processing of emotional information: Three conceptual frameworks. *Psychological Bulletin*, *124*, 165–196.
- Scherer, K. R., Schorr, A., & Johnstone, T. (2001). *Appraisal processes in emotion: Theory, methods, research*. New York: Oxford University Press.
- Seminowicz, D. A., & Davis, K. D. (2007). Interactions of pain intensity and cognitive load: The brain stays on task. *Cerebral Cortex*, *17*, 1412–1422.

- Sheppes, G., & Meiran, N. (2007). Better late than never? On the dynamics of online regulation of sadness using distraction and cognitive reappraisal. *Personality & Social Psychology Bulletin*, *33*, 1518–1532.
- Stein, J. L., Wiedholz, L. M., Bassett, D. S., Weinberger, D. R., Zink, C. F., Mattay, V. S., et al. (2007). A validated network of effective amygdala connectivity. *Neuroimage*, *36*, 736–745.
- Taylor, S. F., & Liberzon, I. (2007). Neural correlates of emotion regulation in psychopathology. *Trends in Cognitive Sciences*, *11*, 413–418.
- Teasdale, J. D., Howard, R. J., Cox, S. G., Ha, Y., Brammer, M. J., Williams, S. C. R., et al. (1999). Functional MRI study of the cognitive generation of affect. *American Journal of Psychiatry*, *156*, 209–215.
- Telch, M. J., Valentiner, D. P., Ilai, D., Young, P. R., Powers, M. B., & Smits, J. A. J. (2004). Fear activation and distraction during the emotional processing of claustrophobic fear. *Journal of Behavior Therapy and Experimental Psychiatry*, *35*, 219–232.
- Totterdell, P., & Parkinson, B. (1999). Use and effectiveness of self-regulation strategies for improving mood in a group of trainee teachers. *Journal of Occupational Health Psychology*, *4*, 219.
- Tsukiura, T., Fujii, T., Fukatsu, R., Otsuki, T., Okuda, J., Umetsu, A., et al. (2002). Neural basis of the retrieval of people's names: Evidence from brain-damaged patients and fMRI. *Journal of Cognitive Neuroscience*, *14*, 922–937.
- Urry, H. L., van Reekum, C. M., Johnstone, T., Kalin, N. H., Thurow, M. E., Schaefer, H. S., et al. (2006). Amygdala and ventromedial prefrontal cortex are inversely coupled during regulation of negative affect and predict the diurnal pattern of cortisol secretion among older adults. *Journal of Neuroscience*, *26*, 4415–4425.
- Van Overwalle, F. (2008). Social cognition and the brain: A meta-analysis. *Human Brain Mapping*, *9999*, NA.
- Wager, T. D., Davidson, M. L., Hughes, B. L., Lindquist, M. A., & Ochsner, K. N. (2008). Prefrontal-subcortical pathways mediating successful emotion regulation. *Neuron*, *59*, 1037–1050.
- Wager, T. D., Jonides, J., & Reading, S. (2004). Neuroimaging studies of shifting attention: A meta-analysis. *Neuroimage*, *22*, 1679–1693.
- Wager, T. D., Keller, M. C., Lacey, S. C., & Jonides, J. (2005). Increased sensitivity in neuroimaging analyses using robust regression. *Neuroimage*, *26*, 99–113.
- Wager, T. D., & Smith, E. E. (2003). Neuroimaging studies of working memory: A meta-analysis. *Cognitive, Affective & Behavioral Neuroscience*, *3*, 255–274.
- Whalen, P. J., Kagan, J., Cook, R. G., Davis, F. C., Kim, H., Polis, S., et al. (2004). Human amygdala responsivity to masked fearful eye whites. *Science*, *306*, 2061.
- Wiech, K., Seymour, B., Kalisch, R., Enno Stephan, K., Koltzenburg, M., Driver, J., et al. (2005). Modulation of pain processing in hyperalgesia by cognitive demand. *Neuroimage*, *27*, 59–69.
- Wrase, J., Klein, S., Gruesser, S. M., Hermann, D., Flor, H., Mann, K., et al. (2003). Gender differences in the processing of standardized emotional visual stimuli in humans: A functional magnetic resonance imaging study. *Neuroscience Letters*, *348*, 41–45.