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Functional overlap of top-down emotion regulation and generation: An fMRI study identifying common neural substrates between cognitive reappraisal and cognitively generated emotions

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Abstract One factor that influences the success of emotion regulation is the manner in which the regulated emotion was generated. Recent research has suggested that reappraisal, a top-down emotion regulation strategy, is more effective in decreasing self-reported negative affect when emotions were generated from the top-down, versus the bottom-up. On the basis of a process overlap framework, we hypothesized that the neural regions active during reappraisal would overlap more with emotions that were generated from the top-down, rather than from the bottom-up. In addition, we hypothesized that increased neural overlap between reappraisal and the history effects of top-down emotion generation would be associated with increased reappraisal success. The results of several analyses suggested that reappraisal and emotions that were generated from the top-down share a core network of prefrontal, temporal, and cingulate regions. This overlap is specific; no such overlap was observed between reappraisal and emotions that were generated in a bottom-up fashion. This network consists of regions previously implicated in linguistic processing, cognitive control, and self-relevant appraisals, which are processes thought to be crucial to both reappraisal and top-down emotion generation. Furthermore, individuals with high reappraisal success demonstrated greater neural overlap between reappraisal and the history of top-down emotion generation than did those with low reappraisal success. The overlap of these key regions, reflecting overlapping processes, provides an initial insight into the mechanism by which generation history may facilitate emotion regulation.

Keywords Emotion regulation · Emotion generation · Cognitive reappraisal · Transfer appropriate processing · Medial prefrontal cortex · Face · fMRI · History effects

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Functionalist approaches to the study of emotion emphasize that even negative emotions can promote adaptive responding. In situations that require rapid, automatic responses, such as a threat in one's environment, emotional responses can facilitate useful behavior (Öhman, Flykt, & Lundqvist, 2000). However, there are times when our emotional responses do not lead to optimal responding, such as when emotion distracts us from an important task, or when the expression of an emotion is socially inappropriate. In these cases, the ability to change or regulate our emotions can be a crucially adaptive skill.

One commonly used emotion regulation strategy is reappraisal, which has been shown to be an effective way to diminish negative emotion (Gross, 1998b; Jackson, Malmstadt, Larson, & Davidson, 2000; Kalisch, 2009; McRae et al., 2010; Ochsner, Silvers, & Buhle, 2012). Reappraisal involves reinterpreting the emotional meaning of potentially emotional stimuli or events in a way that changes the emotional response (Gross, 1998b; Lazarus & Alfert, 1964). Experimental studies of reappraisal have demonstrated that reappraisal can successfully decrease several measures of negative emotion (Eippert et al., 2007; Gross, 1998a, 2002; McRae et al., 2010; McRae, Misra, Prasad, Pereira, & Gross, 2011; Ray, McRae, Ochsner, & Gross, 2010), and observational studies have indicated that reappraisal use is associated with adaptive outcomes (Gross & John, 2003; Nezlek & Kuppens, 2008). Furthermore, the processes underlying reappraisal are thought to be similar to those targeted by cognitive behavioral therapy (CBT; Beck & Dozois, 2011).

Given the effectiveness of reappraisal and its potential as an intervention, it is important to understand the circumstances under which reappraisal is the most and least effective.

One potential variable that might influence reappraisal success is the history of how the emotion that is being regulated by reappraisal was generated. To date, one study has demonstrated that reappraisal is more effective in decreasing negative affect when emotion is generated in a top-down, versus a bottom-up, manner (McRae et al., 2011). This report demonstrated the emotional effects of reappraisal on top-down- versus bottom-up-generated emotions, but did not present direct evidence for the proposed neural mechanism through which reappraisal reduced emotions that were generated from the top-down to a greater degree than emotions that were generated from the bottom-up. To better understand the relationship between reappraisal and emotions with a history of top-down generation, we propose a process overlap framework in which reappraisal facilitation is characterized by the overlapping neural processes recruited by reappraisal and emotions with a history of top-down generation. In support of this process overlap framework, we review the neural regions typically engaged during reappraisal and top-down emotion generation, focusing on regions likely to be engaged by both processes. We performed several conjunction analyses to assess the degree of neural overlap between reappraisal and emotions with a history of top-down generation, and explored whether greater neural overlap is associated with greater reappraisal success.

Emotion regulation

Experimental research suggests that reappraisal is a helpful, adaptive emotion regulation strategy. Reappraisal effectively decreases self-reported negative affect (Eippert et al., 2007; Gross, 1998a, 2002; McRae et al., 2010; McRae et al., 2011; Ray et al., 2010) and associated peripheral physiological arousal, as well as amygdala activation (Dillon & LaBar, 2005; Eippert et al., 2007; Gross, 1998a; Jackson et al., 2000; Kalisch, 2009; S. H. Kim & Hamann, 2007; Ray et al., 2010; Urry, van Reekum, Johnstone, & Davidson, 2009; Walter et al., 2009), and may even be an effective strategy in the reduction of the cravings associated with addictive substances (Kober et al., 2010). Reappraisal allows one to remain engaged with an emotional stimulus or event during regulation, and thus memory for the stimulus or event is retained (Dillon, Ritchey, Johnson, & LaBar, 2007; Richards & Gross, 2000). Furthermore, the frequent use of reappraisal relates to greater levels of positive emotion, lesser negative emotion, better interpersonal functioning, and higher levels of well-being (Aldao & Nolen-Hoeksema, 2010; Gross & John, 2003; McRae, Jacobs, Ray, John, & Gross, 2012).

Reappraisal involves several cognitive processes supported by a complex network of brain regions. This network includes prefrontal, parietal, limbic, and temporal regions typically associated with broader cognitive-control processes. Lateral prefrontal regions include the dorsolateral prefrontal cortex (DLPFC), supporting goal orientation and working memory (Barbey, Koenigs, & Grafman, 2013; Kanske, Heissler, Schönfelder, Bongers, & Wessa, 2011; MacDonald, Cohen, Stenger, & Carter, 2000), and the ventrolateral prefrontal cortex (VLPFC), implicated in the cognitive control of memory and the expectation of emotional stimuli (Badre & Wagner, 2007; Bender, Hellwig, Resch, & Weisbrod, 2007; Boettiger & D'Esposito, 2005; Hornak et al., 2004; McRae et al., 2010). Additional cognitive-control regions include the anterior cingulate cortex (ACC), thought to be involved in conflict monitoring (Hutcherson et al., 2005; Kalisch, 2009; Miller & Cohen, 2001), and the inferior parietal lobule (IPL), involved in spatial attention (Mayer et al., 2007; McRae et al., 2010).

In concert with regions associated with cognitive control, reappraisal also recruits a network of regions associated with the recontextualization of emotional stimuli using self-relevant information. This network includes the medial prefrontal cortex (MPFC), implicated in the evaluation of emotional stimuli, self-referential memory, and theory of mind (Fletcher et al., 1995; Gilbert et al., 2006; Kelley et al., 2002; Mechias, Etkin, & Kalisch, 2010; Olsson & Ochsner, 2008; Teasdale et al., 1999; Urry et al., 2009); several temporal regions associated with recognizing social cues and semantic memory processing (Britton et al., 2006; McRae et al., 2010; Visser, Jefferies, & Lambon Ralph, 2010); and the posterior cingulate cortex (PCC), implicated in the integration of emotion and episodic memory retrieval (Maddock, Garrett, & Buonocore, 2003; Ochsner et al., 2004).

Emotion generation

Reappraisal has been compared to other emotion regulation strategies, such as distraction or suppression (Goldin, McRae, Ramel, & Gross, 2008; Hayes et al., 2010; Kanske et al., 2011; McRae et al., 2010), but little attention has been given to the success of reappraisal when it is used on emotions with various properties that might interact with emotion regulation (e.g., Mühlberger, Neumann, Lozo, Müller, & Hettinger, 2012). Emotions can be elicited in a variety of ways, from reflexive responses to simple physical stimuli (bottom-up) to more complex stimuli requiring interpretation (top-down). Everyday emotions likely consist of a blend of bottom-up processing of emotional stimuli and the top-down interpretation of self-relevant situations. However, these types of emotion generation recruit different neural systems, and this history of generation may be reflected in the recruitment of neutral regions that could interact with downstream processes like emotion regulation.

Bottom-up emotion generation Bottom-up emotion generation occurs when the perceptual features of relatively simple emotional stimuli, often considered "biologically prepared," are detected in the environment (LeDoux, 2000; Luo, Holroyd, Jones, Hendler, & Blair, 2007; Öhman & Mineka, 2001; Seligman, 1971). In the laboratory, bottom-up emotions are typically generated using stimuli that represent real-life, biologically prepared elicitors perceptually, via sight, sound, or touch. For example, many laboratory studies use images of emotional faces, threatening animals, or pain-inducing methods (H. Kim, Somerville, Johnstone, Alexander, & Whalen, 2003; McRae et al., 2011; Öhman & Soares, 1998). The processing of bottom-up stimuli, as evidenced by amygdala activation, can be unconscious and relatively automatic (Anderson et al., 2003; Phelps & Ledoux, 2005; Spezio, Adolphs, Hurley, & Piven, 2007; Vuilleumier, Armony, Driver, & Dolan, 2003; Whalen et al., 2004; but see Pessoa, 2005).

Top-down emotion generation Top-down-generated emotions are marked by a high-level appraisal of a situation as being relevant to one's goals (Frijda, 1988; Ochsner et al., 2009; Scherer, Schorr, & Johnstone, 2001). For example, a hurried voice message from an individual's employer may be interpreted as curt and a sign of disapproval, eliciting fear of employment termination. In the laboratory, language-based stimuli are typically used to elicit emotion from the top-down by providing scripts or captions containing emotional content (H. Kim et al., 2004; McRae et al., 2011; Ochsner et al., 2009; Phelps et al., 2001; Teasdale et al., 1999).

The complex, self-relevant cognition central to top-down emotion generation has been shown to rely on a core network consisting of prefrontal, temporal, and limbic regions. Top-down emotion generation elicits a pattern of prefrontal activation similar to that of reappraisal, including the MPFC, which has been implicated in the evaluation of emotional stimuli (Mechias et al., 2010; Urry et al., 2009), theory of mind (Fletcher et al., 1995; Gilbert et al., 2006), and self-referential memory (Kelley et al., 2002; Ochsner et al., 2009; Olsson & Ochsner, 2008; Teasdale et al., 1999), and has been shown to engage in comodulation with the amygdala, a structure associated with emotional salience that can modulate emotion-related physiological responses (H. Kim et al., 2004; McRae et al., 2011; Olsson, Nearing, & Phelps, 2007). The VLPFC has been implicated in the expectation and evaluation of emotional stimuli (Bender et al., 2007; Boettiger & D'Esposito, 2005; Hornak et al., 2004) and the cognitive control of memory (Badre & Wagner, 2007; Ochsner et al., 2009). Finally, the DLPFC has been associated with goal orientation and working memory (Barbey et al., 2013; MacDonald et al., 2000).

Like reappraisal, top-down emotion generation has also been associated with neural activation in limbic and temporal regions. These regions include the ACC, implicated in conflict monitoring (Miller & Cohen, 2001; Ochsner et al., 2009); the PCC, associated with the integration of emotion and episodic memory retrieval (Maddock et al., 2003; Teasdale et al., 1999); and several temporal regions, implicated in recognizing social cues and semantic memory processing (Britton et al., 2006; Ochsner et al., 2009; Visser et al., 2010).

The interaction between emotion regulation and emotion generation

Little research has focused on the interaction of emotion regulation and emotion generation history. There is some evidence that reappraisal is more effective in decreasing self-reported negative affect when emotions were generated in a top-down, versus a bottom-up, manner (McRae et al., 2011). This interaction is hypothesized to be due to the overlap between cognitive and neural processes, outlined above, that are recruited by reappraisal and emotions that were generated in a top-down fashion. This hypothesized process overlap may be similar to a property of memory known as *transfer-appropriate processing* (TAP; Roediger, Weldon, & Challis, 1989). TAP theory rests on the notion that some types of cognitive performance—namely, memory—are state-dependent. For memory, when the processes involved in the encoding of information overlap with the processes involved in the recall of information, retrieval is facilitated. Several fMRI studies have provided neural evidence for TAP by observing greater overlap in the neural regions that are recruited when memory encoding and retrieval processes are congruent, versus incongruent (Butler & James, 2011; Rugg, Johnson, Park, & Uncapher, 2008; Vaidya, Zhao, Desmond, & Gabrieli, 2002). A process overlap hypothesis might apply to other types of cognitive processing, such as those shared by reappraisal and emotions generated in a top-down manner. If, like memory, emotion regulation is state-dependent, reappraisal should be more effective under emotional conditions of greater process overlap, and therefore greater neural overlap.

The present study

In the present study, our goal was to conduct a novel test for a process overlap between reappraisal and emotions that were generated in a top-down manner. To do this, we examined the overlap of the neural regions recruited by reappraisal and emotions generated from the-top down using fMRI. We evaluated top-down emotion generation as a history effect by temporally shifting our analysis forward to the poststimulus period, thereby eliminating low-level differences between the top-down and bottom-up conditions. We evaluated reappraisal for only bottom-up-generated emotions, thereby eliminating the hypothesized overlapping top-down emotion generation processes.

We predicted a strong overlap of regions previously implicated in the support of both reappraisal and emotions generated from the top-down, including DLPFC, VLPFC, MPFC, PCC, and broad temporal regions. We predicted that no such overlap would be observed between reappraisal and emotions generated from the bottom-up. In addition, we predicted that an increase in neural overlap would be associated with an increase in reappraisal success, demonstrating an analogue to the TAP literature, where increased neural overlap during memory encoding and retrieval is associated with better retrieval performance.

Method

The present study extends the analysis of data collected from the participants reported in McRae et al. (2011). This prior report, which focused on simple differences between conditions, reported results from an a priori region-of-interest analysis of the amygdala and self-reported negative affect. In the present study, we focused on performing conjunction analyses to characterize whole-brain overlap between conditions.

Participants

Participants were recruited via online advertising from the San Francisco Bay Area community. The participants were screened via e-mail to exclude those with past or current mood/anxiety disorders, current use of psychoactive medications, or fMRI rule-outs (e.g., pregnancy, metal in body, tattoos on head or neck). We recruited only women, to reduce the heterogeneity of emotional reactivity and regulation previously observed between men and women (Kring & Gordon, 1998; McRae, Ochsner, Mauss, Gabrieli, & Gross, 2008). A total of 26 women, ages 18–35, completed the entire experimental procedure (mean age = 24.88, *SD* = 5.58, 15 Caucasian, five Asian American, two Hispanic, and four of other or multiple ethnicities). The participants provided written informed consent and were compensated for their participation. This project was approved by the institutional review board at Stanford University.

Task

The experimental task consisted of two main parts, "background" and "instruction" (see Fig. 1). In the background portion of the task, participants saw a piece of background information (top-down negative sentences, bottom-up fearful faces, or scrambled faces or sentences) for 4 s. Participants then saw a fixation cross for a variable duration between 0 and 4 s, averaging 2 s. The instruction portion of the task then began, with a neutral face (Tottenham et al., 2009) being presented for 6 s (with a matching identity to the background fearful face in the bottom-up condition). A colored frame bordered the neutral face, and participants were trained to look and respond naturally when one frame color appeared, and to use reappraisal to decrease their emotional response when the other color appeared. The assignment of background information and neutral faces to the look or reappraise condition was counterbalanced across participants. Following the instruction portion of the task, participants responded to the question "How negative do you feel?" on a 5-point rating scale (labeled *not at all negative* to *very negative*). Finally, a fixation cross appeared for a variable duration between 2 and 6 s, averaging 4 s, between trials.

Task training

Participants were trained on the experimental task before entering the scanner. The experimenter explained that during the task, the participant would see a series of faces. Before each face, the participant would be provided a piece of background information (a negative sentence, face, or a neutral scrambled face or sentence), which would inform the participant as to what was going on for that person at that point in time. Participants were encouraged to consider the background information while viewing the neutral face that followed it. They were instructed to think of the scrambled faces and sentences as not containing significant background information, and these were combined to form our lowest-level common control condition, which contained elements of both types of emotional background information.

Participants were then told that when they viewed these neutral faces, they would also be asked to either (1) look and have their natural response to the person and their situation (look) or (2) try to think about the person and their situation in a way that made it less negative (reappraise). Several examples of reappraisals were provided, and the participant was required to generate at least two appropriate reappraisals during this training. Examples of appropriate reappraisals were: The situation is not as bad as it first seemed, this person has special skills to get him- or herself out of the situation, or he or she is feeling better now.

Scan parameters

A total of 24 axial slices (4.4 mm thick) were collected on a 3-T (GE Signa LX Horizon Echospeed) scanner with a T2* sensitive gradient echo spiral-in-out pulse sequence (TR = 2.00, TE = 40 ms, 80° flip angle, 24-cm field of view, 64 × 64 data acquisition matrix), which has been shown to effectively reduce signal dropout at high field strengths (Preston, Thomason, Ochsner, Cooper, & Glover, 2004). In all, 230 whole-brain images were taken in each of four 7-min 40-s runs. High-resolution SPGR scans were acquired and coregistered with functional scans for anatomical normalization.

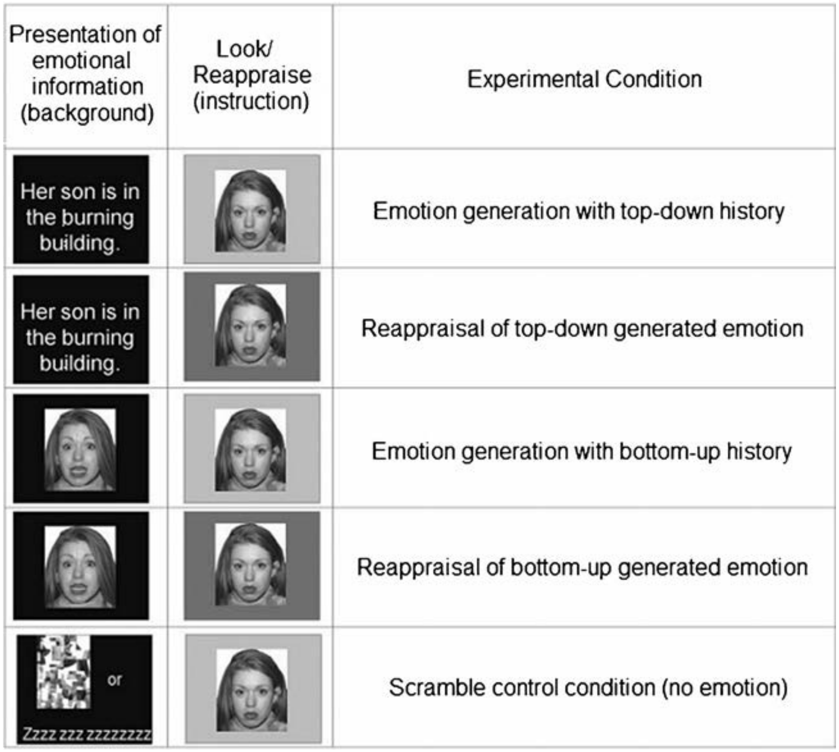

Fig. 1 Emotion generation and regulation task. Participants were first presented with either fearful faces (bottom-up emotion generation) or negative sentences (top-down emotion generation), followed by the instruction to look or reappraise. The instruction to look or reappraise was delivered via the color of the frame surrounding the neutral face (light gray = pink, dark gray = blue). *Emotion generation* refers to the look instruction, or the presentation of the neutral face with the instruction to look and respond naturally, considering the relevant background information. *Emotion regulation* refers to the reappraisal instruction, or the presentation of the neutral face with the instruction to decrease negative affect using reappraisal, considering the relevant background information. Also presented were either scrambled pictures or scrambled words (pictured together to save space) presented before the instruction to look, combined and used as a control condition

Data analysis

Standard preprocessing steps were completed in AFNI. The functional images were corrected for motion across scans using an empirically determined baseline scan and then manually coregistered to each subject's high-resolution anatomical image. Anatomical images were then normalized to a structural template image, and normalization parameters were applied to the functional images. Finally, the images were resliced to a resolution of $2 \times 2 \times 2$ mm and smoothed spatially with a 4-mm filter. We then used a GLM (3dDeconvolve) in AFNI to model two different task parts: the emotion presentation period, when top-down, bottom-up, or scrambled information was presented (background); and the emotion generation/regulation period, when individuals were either looking and responding naturally or using reappraisal to try to decrease their negative affect toward a neutral face (instruction). This resulted in ten conditions: two task parts during five conditions (see Fig. 1). Linear, whole-brain contrasts were then computed using joint voxel and extent thresholds determined by 3dClustSim, an AFNI program that estimates the probability of false-positive clusters at different voxel and extent thresholds. For each cluster of 1,000 voxels or more, subpeaks were calculated with a minimum separation of 20 mm.

Our primary analyses used contrasts providing the most conservative test of the process overlap hypothesis, meaning that trials containing both reappraisal instructions and emotions generated from the top-down did not contribute to the conjunction. To identify regions active during reappraisal, the contrast of reappraise > look for only bottom-up trials during the instruction portion of the task was selected, to avoid the history effects of top-down emotion generation. To identify regions associated with a history of top-down emotion generation, the contrast of top-down > bottom-up for only look trials during the instruction portion of the task was selected. This contrast eliminated low-level differences between the top-down and bottom-up conditions by evaluating top-down emotion generation as a history effect. In addition, to examine the overlap between the neural engagement during the emotion generation period itself, we performed an additional conjunction analysis (top-down > bottom-up during the background portion of the task, masked with reappraisal > look during the instruction portion of the task). In the interest of allowing comparisons between the component contrasts and the conjunctions, the component contrasts of the conjunction analyses were computed with a voxel threshold of $t = 3.08$ (corresponding to $p < .005$) and an extent threshold of 35, resulting in a quite liberal threshold of $p < .2$ when corrected for multiple comparisons (one-tailed). These independent component contrasts, when conjoined, resulted in an overall alpha of $p < .04$.[1]

To explore regions of overlap between reappraisal and the history of top-down emotion generation, a conjunction analysis was performed using the contrasts above (i.e., reappraise > look for only bottom-up trials during the instruction portion of the task, masked with top-down > bottom-up for only look trials during the instruction portion of the task). The conjunction analyses were performed by saving a binary mask of the first contrast at our component contrast threshold, and then displaying the second contrast at that same threshold after being multiplied by the binary mask. Therefore, only voxels exceeding this component threshold in both component contrasts survived our joint threshold. To increase the specificity of our results, we performed all three alternative combinations of the contrasts as conjunction analyses, where overlapping neural regions would not be expected. These contrasts were (1) look > reappraise for only bottom-up trials during the instruction portion of the task, masked with top-down > bottom-up for only look trials during the instruction portion of the task; (2) reappraise > look for only bottom-up trials during the instruction portion of the task, masked with bottom-up > top-down for only look trials during the instruction portion of the task; and (3) look > reappraise for only bottom-up trials during the instruction portion of the task, masked with bottom-up > top-down for only look trials during the instruction portion of the task.

To determine whether greater neural overlap between regulation and a history of generation is associated with greater reappraisal success, an exploratory reappraisal success analysis was performed. Reappraisal success was scored by calculating the difference between self-reported negative affect during look trials and reappraise trials in the top-down generation condition. Using a simple high–low split, these continuous data were used to create two groups for which separate conjunctions were performed: one for subjects demonstrating high reappraisal success, and one for subjects demonstrating low reappraisal success. Finally, conjunctions were computed using individual-level contrasts, and a Pearson's correlation coefficient was used to determine the relationship between the number of voxels that survived the conjunction procedure at the individual level, and reappraisal success scores as defined above.

[1] For those who are only interested in activation in component contrasts that meet significance on their own, clusters larger than 44 voxels at a voxel threshold for $p < .005$ have an overall alpha of .05.

Results

Emotion regulation

Consistent with previous findings, the regions associated with reappraisal (reappraise > look for only bottom-up trials during the instruction portion of the task) included DLPFC, VLPFC, MPFC, ACC, PCC, and several regions of temporal cortex (see Table 1 and Fig. 2).

Top-down emotion generation

The regions identified for emotions that were generated from the top-down (top-down > bottom-up for only look trials during the instruction portion of the task) coincided with those from previous top-down emotion generation findings, including DLPFC, VLPFC, MPFC, ACC, PCC, and several regions of temporal cortex (see Table 2 and Fig. 3).

Conjunction analyses

To examine the neural overlap of reappraisal and the history effects of top-down emotion generation, a conjunction analysis was performed (reappraise > look for only bottom-up trials during the instruction portion of the task, masked with top-down > bottom-up for only look trials during the instruction portion of the task). The regions of overlap were generally left lateralized, and included DLPFC, VLPFC, MPFC, ACC, PCC, and temporal cortex broadly (see Table 3 and Fig. 4). Three alternative conjunction analyses were performed at an even more liberal voxelwise threshold of $p < .01$. No significant activation was observed for the conjunction of look > reappraise for only bottom-up trials during the instruction portion of the task, masked with top-down > bottom-up for only look trials during the instruction portion of the task, or for the conjunction of reappraise > look for only bottom-up trials during the instruction portion of the task, masked with bottom-up > top-down for only look trials during the instruction portion of the task. For the contrast of look > reappraise for only bottom-up trials during the instruction portion of the task, masked with bottom-up > top-down for only look trials during the instruction portion of the task, we observed significant activation in the right inferior parietal lobule (extent of 82) and right parahippocamal gyrus (extent of 53). These clusters of significant activation likely reflect low-level features common to the component contrasts. The results of the secondary conjunction, which included contrasts from the

Table 1 Activations for reappraise versus look contrast

Region	Extent	*T*	*X*	*Y*	*Z*	Hemisphere
A. Reappraise > look for only bottom-up trials during the instruction portion of the task						
Inferior occipital gyrus	1,327	5.04	35	–81	–2	Right
Subpeaks:						
Declive		4.97	33	–65	–20	Right
Fusiform gyrus		4.85	33	–41	–18	Right
Inferior frontal gyrus	829	5.59	–59	21	20	Left
Superior frontal gyrus	525	5.92	–5	9	66	Left
Precuneus	410	5.08	–3	–47	36	Left
Fusiform gyrus	354	5.01	–35	–51	–10	Left
Lingual gyrus	283	4.69	–19	–81	–8	Left
Superior temporal gyrus	214	4.39	–39	–55	16	Left
Medial frontal gyrus	204	4.80	–9	41	38	Left
Precentral gyrus	114	4.59	–47	–1	52	Left
Cingulate gyrus	104	4.78	–5	–19	38	Left
Middle temporal gyrus	88	5.44	–53	–47	2	Left
Superior frontal gyrus	81	4.80	–39	19	48	Left
Cingulate gyrus	70	4.76	–13	27	28	Left
Inferior frontal gyrus	62	4.19	45	21	14	Right
Thalamus	59	3.99	–1	–23	6	Left
Middle temporal gyrus	45	4.83	49	3	–18	Right
Middle temporal gyrus	39	4.20	–51	–65	20	Left
Caudate	36	4.82	39	–33	2	Right
B. Look > reappraise for only bottom-up trials during the instruction portion of the task						
Posterior cingulate	2,345	8.42	13	–65	16	Right
Subpeaks:						
Cuneus		6.20	–17	–67	8	Left
Culmen		4.76	13	–51	–2	Right
Parahippocampal gyrus		4.21	31	–45	8	Right
Insula	142	5.21	45	–13	12	Right
Inferior parietal lobule	106	4.19	–43	–45	44	Left
Inferior parietal lobule	64	4.24	53	–41	50	Right
Superior temporal gyrus	43	4.26	57	–11	4	Right

Whole-brain voxel threshold of $p < .005$, extent threshold of 35. For each cluster of 1,000 voxels or more, subpeaks were calculated with a minimum separation of 20 mm

emotion generation period, were similar, but broader than in the main conjunction (Table 4, Fig. 5). These results suggest that the effects that we report reflect an overlap in either the neural systems engaged during different types of emotion generation or those engaged when the history of emotion regulation differs.

Reappraisal success analysis

To determine whether an increase in neural overlap between reappraisal and the history effects of top-down emotion generation is associated with increased reappraisal success, each participant was assigned to either the high-reappraisal-success group ($N = 13$, mean of reappraisal success score = –.48, $SD = .10$) or the low-reappraisal-success group ($N = 13$, mean of reappraisal success score = –.22, $SD = .16$). The results of a conjunction analysis on each group demonstrated substantial overlap for the high-performing group, whereas no such overlap was observed for the low-performing group at the same joint threshold (see Table 5 and Fig. 6). Consistent with these between-group findings, the correlation between reappraisal success and the number of

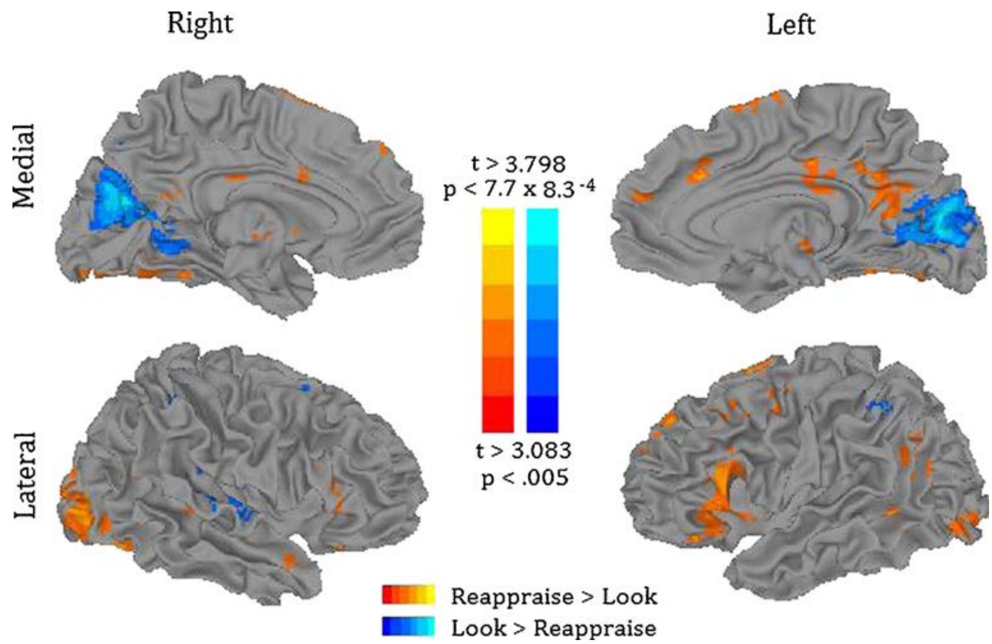

Fig. 2 Medial and lateral views of whole-brain activations for the contrast of reappraise versus look for only bottom-up trials during the instruction portion of the task. The whole-brain voxel threshold is $p < .005$, with an extent threshold of 35

significant overlapping voxels at the individual level was significant [$r(24) = .36$, $p = .04$; see Fig. 7].[2]

Discussion

Emotion regulation and emotion generation: A process overlap perspective

The present article reports for the first time the overlapping neural processes between top-down emotion regulation and emotions that were generated from the top-down. This overlap in processes likely reflects a neural network supporting a complex appraisal process that determines the affective value of emotional stimuli. This appraisal process is common to both emotions that were generated from the top-down, reflecting how the emotion was first established, and reappraisal, through which the emotion can be altered. In addition, an exploratory analysis suggests that the individuals who most successfully use reappraisal to decrease their negative affect show a greater neural overlap between reappraisal and top-down-generated emotion.

Regions of overlap between reappraisal and the history effects of top-down emotion generation include prefrontal, temporal, and cingulate regions. Two lateral prefrontal regions were identified. First, the DLPFC, associated with general cognitive control, likely plays a role in the appraisal process by protecting against distractions and, in an experimental context, keeping the current instructions for the study in mind (Barbey et al., 2013; Kanske et al., 2011; MacDonald et al., 2000). The second lateral prefrontal region, the VLPFC, is associated with the expectation and evaluation of emotional stimuli (Bender et al., 2007; Boettiger & D'Esposito, 2005; Hornak et al., 2004), the cognitive control of memory (Badre & Wagner, 2007), and language processing (Grodzinsky & Santi, 2008). VLPFC activation may reflect processes related to retrieving episodic memories in pursuit of the contextualization of emotional stimuli.

Another prefrontal region of overlap, the MPFC, has been previously implicated in cognitive processes that likely play a role in the complex appraisal process common to reappraisal and emotion generation, including the evaluation of emotional stimuli (Mechias et al., 2010; Teasdale et al., 1999), self-referential memory (Kelley et al., 2002), and the attribution of mental states to one's self and others, supporting processes related to empathy (Carrington & Bailey, 2009; Fletcher et al., 1995; Gilbert et al., 2006; Mitchell, Banaji, & Macrae, 2005; Olsson & Ochsner, 2008; Singer, 2006). The MPFC has been shown to engage in comodulation with the amygdala, a limbic structure associated with emotional salience that can modulate emotion-related physiological responses (H. Kim et al., 2004; McRae et al., 2011; Phelps, 2004; Urry et al., 2009).

[2] To ensure our results are not merely specific to our selection of the history effect contrast, we also calculated the reappraisal success analyses using the nonhistory effect conjunction (top-down > bottom-up during the background portion of the task masked with reappraise > look during the instruction portion of the task). Similarly, reappraisal success still correlated, although to a lesser degree, with the number of significant voxels [$r(24) = .31$, $p = .06$].

Table 2 Activations for top-down versus bottom-up contrast

Region	Extent	*T*	*X*	*Y*	*Z*	Hemisphere
A. Top-down > bottom-up for only look trials during the instruction portion of the task						
Middle temporal gyrus	3,172	8.56	–51	–3	–18	Left
Subpeaks:						
Inferior frontal gyrus		7.34	–39	31	–2	Left
Inferior frontal gyrus		6.80	–55	19	2	Left
Medial frontal gyrus	1,974	11.27	–5	45	32	Left
Subpeaks:						
Superior frontal gyrus		5.68	9	31	48	Right
Middle frontal gyrus		4.05	–23	23	44	Left
Middle temporal gyrus	1,130	6.46	–53	–69	18	Left
Subpeaks:						
Middle temporal gyrus		6.46	–53	–69	18	Left
Precuneus		4.28	–29	–83	40	Left
Precuneus	745	7.24	–5	–59	26	Left
Inferior frontal gyrus	552	6.25	39	17	–16	Right
Superior frontal gyrus	427	5.80	–3	15	62	Left
Middle temporal gyrus	354	5.93	–57	–47	2	Left
Middle temporal gyrus	247	5.44	49	3	–18	Right
Culmen	159	3.98	–1	–35	–8	Left
Superior temporal gyrus	158	5.29	61	–61	22	Right
Midbrain, parahippocampal gyrus, and amygdala	148	4.54	–1	–15	–18	Left
Uvula	97	5.61	21	–71	–26	Right
Lingual gyrus	57	4.78	–17	–99	–16	Left
Medial frontal gyrus	46	4.81	1	67	6	Right
Parahippocampal gyrus	46	4.22	–33	–31	–10	Left
Middle frontal gyrus	44	5.07	–47	7	50	Left
Superior temporal gyrus	44	4.27	41	9	–26	Right
B. Bottom-up > top-down for only look trials during the instruction portion of the task						
Middle occipital gyrus	378	5.35	27	–65	4	Right
Middle frontal gyrus	317	5.88	41	43	24	Right
Inferior parietal lobule	312	6.42	45	–39	50	Right
Middle temporal gyrus	120	6.77	51	–49	–2	Right
Middle frontal gyrus	119	5.18	–47	39	26	Left
Precuneus	113	5.16	25	–55	36	Right
Cuneus	41	4.15	15	–99	12	Right
Middle occipital gyrus	36	4.19	–31	–59	4	Left
Postcentral gyrus	35	4.03	–51	–23	58	Left

Whole-brain voxel threshold of $p < .005$, extent threshold of 35. For each cluster of 1,000 voxels or more, subpeaks were calculated with a minimum separation of 20 mm

Although the results of the conjunction analysis did not include the amygdala, two other limbic structures, the ACC and PCC, were found to be common to reappraisal and emotion that was generated from the top-down. The ACC is thought to be involved in conflict monitoring and attention to emotion (Hutcherson et al., 2005; Kalisch, 2009; Miller & Cohen, 2001), whereas the PCC has been implicated in the integration of emotion and episodic memory retrieval (Maddock et al., 2003; Teasdale et al., 1999) and may play a role in accessing emotionally relevant, self-referential contextual information (Touryan et al., 2007).

The conjunction analysis also included several temporal regions. These regions may represent cognitive processes related to semantic memory and recognizing social cues, especially in facial expressions (Britton et al., 2006; Narumoto, Okada, Sadato, Fukui, & Yonekura, 2001; Visser

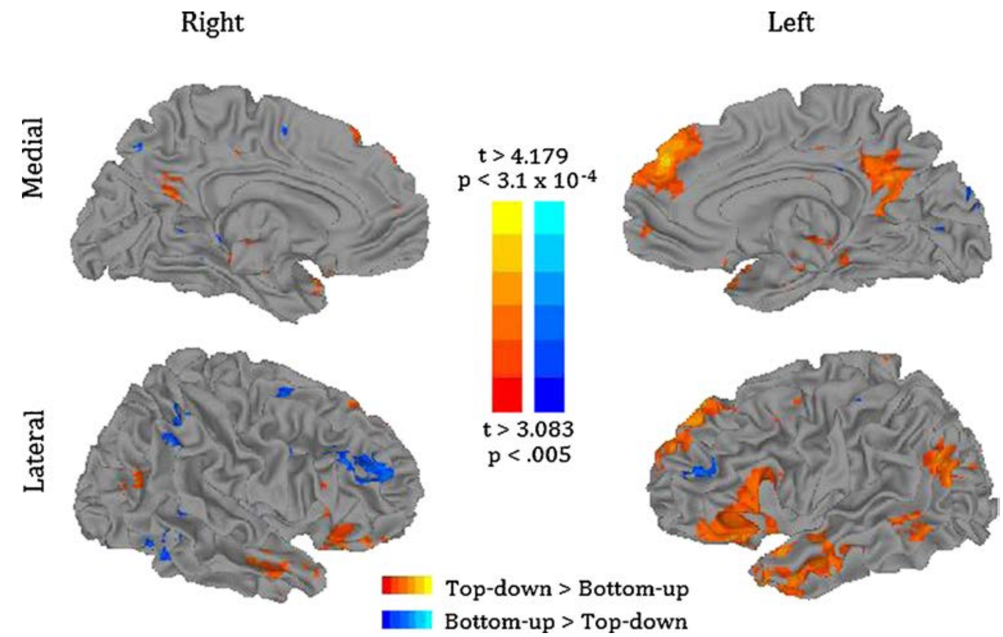

Fig. 3 Medial and lateral views of whole-brain activations for the contrast of top-down > bottom-up for only look trials during the instruction portion of the task. The whole-brain voxel threshold is $p < .005$, with an extent threshold of 35

et al., 2010)—an unsurprising result, given the use of faces in the experimental task.

Finally, the emotion generation contrast presented above suggests that the neural circuits engaged during the retention of emotional information in working memory may be dissociable in terms of the types of emotion being retained (see Table 2 and Fig. 3). Activation related to emotions generated from the bottom-up peaks in the region of Brodmann's area (BA) 46, whereas top-down activation peaks in the region of BA 8, extending into BA 9. This differential DLPFC activation may be the result of holding emotional information in working memory, from when it was presented in the background portion of the task, to when it was measured in the instruction portion of the task. This distinct pattern of activation may reflect processes related to the maintenance of emotional information in working memory (Barbey et al., 2013).

Table 3 Activations for conjunction of reappraise > look and top-down > bottom-up contrasts during instruction

Region	Extent	*T*	*X*	*Y*	*Z*	Hemisphere
Inferior frontal gyrus	843	6.85	–45	27	–8	Left
Precuneus	423	7.24	–5	–59	26	Left
Superior frontal gyrus	268	8.66	–9	39	48	Left
Middle temporal gyrus	238	6.46	–53	–69	18	Left
Superior frontal gyrus	198	5.80	–3	15	62	Left
Middle temporal gyrus	100	5.93	–57	–47	2	Left
Middle temporal gyrus	84	7.36	–51	–11	–10	Left

Top-down > bottom-up for only look trials during the instruction portion of the task, masked with reappraise > look for only bottom-up trials during the instruction portion of the task. Each component contrast's whole-brain voxel threshold was set at $p < .005$, and the extent threshold was 35. The overall combined probability of the conjunction was $p < .04$

The exploratory reappraisal success analysis more closely aligns our process overlap framework with the TAP literature (wherein increased neural overlap between memory encoding and retrieval is associated with increased memory performance; see, e.g., Rugg et al., 2008) by providing evidence that an increase in neural overlap between reappraisal and emotions with a top-down generation history is correlated with reappraisal success. Furthermore, this overlap is specific. The PFC overlap observed for only the high-reappraisal-success group aligns well with prior research showing that the engagement of multiple PFC regions is characteristic of both reappraisal and top-down emotion generation.

Theoretical and clinical implications

If process facilitation applies to emotion regulation, it is possible that the history of emotion generation is only one of the many state variables likely to influence reappraisal-related success. As one example, the degree to which an emotional stimulus fits one's motivational state or goals, known as *regulatory focus*, may also influence reappraisal success. Regulatory focus theory differentiates between promotion focus (hopes and aspirations) and prevention focus (duties and obligations; Higgins, 1998). In an fMRI study measuring memory retrieval of emotional words, focus-consistent trials (positive words in the promotion-focused

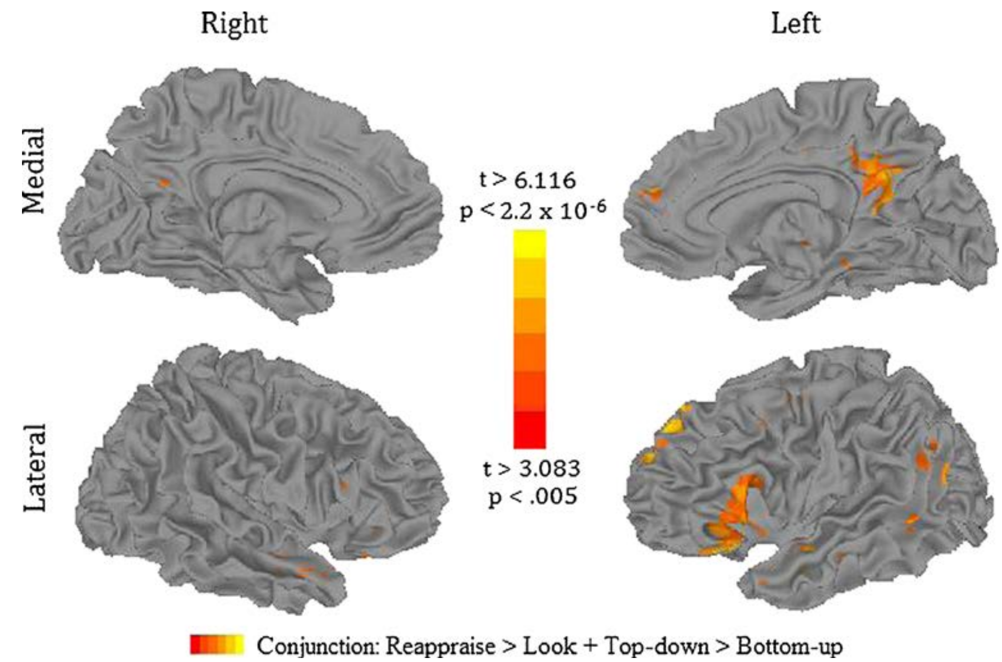

Fig. 4 Medial and lateral views of whole-brain activations for the conjunction of top-down > bottom-up for only look trials during the instruction portion of the task, masked with reappraise > look for only bottom-up trials during the instruction portion of the task. Each component contrast's whole-brain voxel threshold was set at $p < .005$, with an extent threshold of 35. The overall combined probability of the conjunction was $p < .04$.

group and negative words in the prevention-focused group) were associated with self-referential memory processes in the PCC (Touryan et al., 2007). As we reported above, both the generation of self-relevant appraisals, so critical to reappraisal, and top-down emotion generation likely rely on similar processes. Therefore, the current regulatory focus of the person using reappraisal may impact the success of reappraisal, or potentially the interaction between reappraisal success and the history of emotion generation.

Table 4 Activations for conjunction of reappraise > look and top-down > bottom-up during background

Region	Extent	*T*	*X*	*Y*	*Z*	Hemisphere
Superior temporal gyrus	820	6.67	–51	9	2	Left
Posterior cingulate	577	5.39	–5	–57	14	Left
Precentral gyrus	390	7.45	–47	–1	48	Left
Middle temporal gyrus	349	8.95	–53	–7	–8	Left
Middle temporal gyrus	299	7.44	–55	–67	20	Left
Superior temporal gyrus	223	8.41	57	–61	22	Right
Superior temporal gyrus	211	7.62	49	7	–14	Right
Middle temporal gyrus	207	7.66	–61	–39	2	Left
Caudate	168	5.28	7	15	10	Right
Middle temporal gyrus	104	6.26	43	–29	–4	Right
Superior frontal gyrus	79	5.57	–1	–3	70	Left
Superior frontal gyrus	59	5.32	–11	41	42	Left
Superior temporal gyrus	49	5.12	–59	–55	24	Left

Top-down > bottom-up during the background portion of the task, masked with reappraise > look during the instruction portion of the task. Each component contrast's whole-brain voxel threshold was set at $p <$ .005 (extent threshold of 35). Thus, the overall combined probability of the conjunction was $p < .04$

The interaction of processes supporting the way that emotions are generated and reappraisal may be relevant to the treatment of clinical disorders. Although many clinical disorders draw on a combination of bottom-up and top-down processes in terms of both emotion regulation and generation, some disorders are more heavily characterized by one or the other. Negative emotions generated by specific physical stimuli (e.g., specific phobia) may not respond to reappraisal as well as do methods of regulation that decrease awareness of the emotional stimuli (Johnson, 2009). In fact, the use of reappraisal on emotions that were generated from the bottom-up may be counterproductive, by bringing emotional content into conscious awareness (McRae et al., 2011). On the other hand, negative emotions that were generated via higher-level processes (e.g., ruminative depression; Disner, Beevers, Haigh, & Beck, 2011) may be more successfully regulated by top-down strategies (e.g., reappraisal) that directly change the top-down source of the negative emotion.

Limitations and future directions

In the present study, we tested a novel hypothesis of process overlap in emotion regulation and the way that emotions were generated, using strictly defined fMRI contrasts and demonstrating sufficient specificity. To reduce heterogeneity and

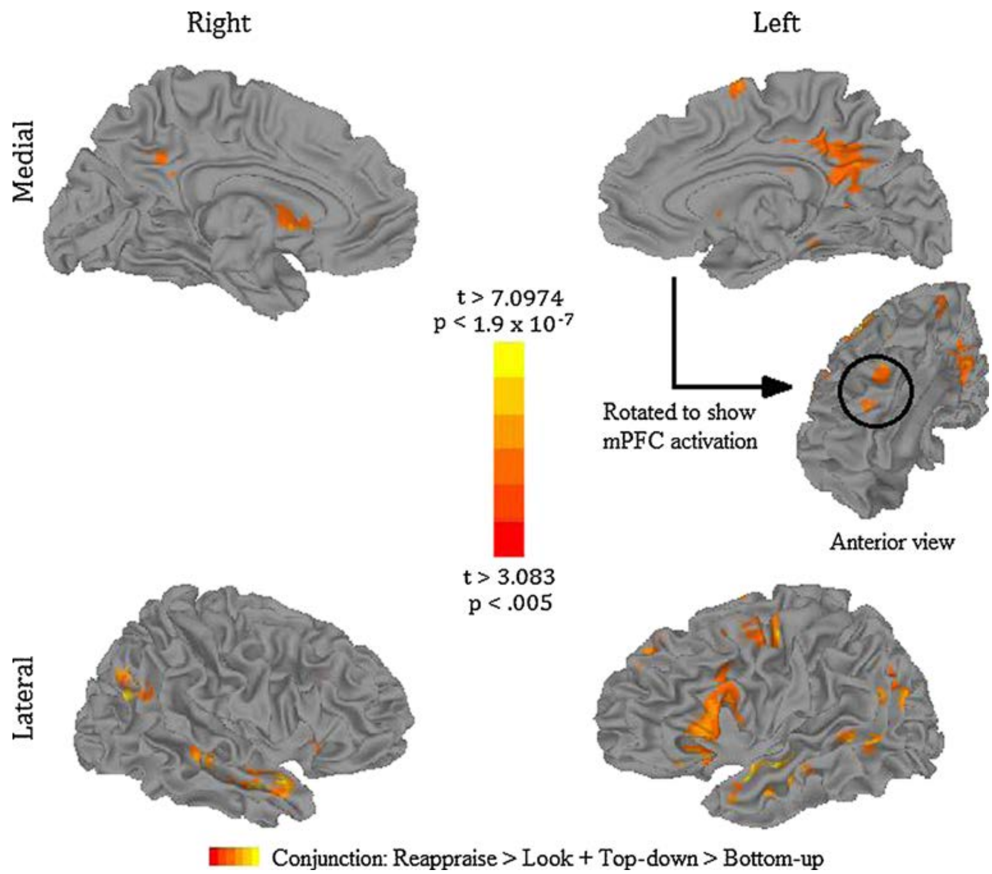

Fig. 5 Medial and lateral views of whole-brain activations for the conjunction of top-down > bottom-up during the background portion of the task, masked with reappraise > look during the instruction portion of the task. Each component contrast's whole-brain voxel threshold was set at $p < .005$ (extent threshold of 35). Thus, the overall combined probability of the conjunction was $p < .04$

remain consistent with the previous literature on reappraisal, the present study included only young, healthy, female volunteers. Future studies should test for a similar interaction of emotion regulation and generation in male participants. In addition, individuals with current or past mood or anxiety disorders were excluded from this study. As we proposed above, emotions generated from the top-down and the-bottom up may rely on distinct cognitive mechanisms, providing a possible neurological etiology for the dysregulation of specific types of emotion. The inclusion of individuals with these disorders might provide valuable information for treatment. Furthermore, measures of important trait and state variables, such as regulatory focus, should be included in future work.

Table 5 Performance analysis: Activations for conjunction of reappraise > look and top-down > bottom-up contrasts for the high-reappraisal-success group

Region	Extent	*T*	*X*	*Y*	*Z*	Hemisphere
Inferior frontal gyrus	123	4.83	–57	23	14	Left
Middle temporal gyrus	67	12.57	–57	–11	–10	Left
Superior frontal gyrus	44	5.15	5	11	64	Right
Middle frontal gyrus	42	6.34	–37	19	54	Left
Middle temporal gyrus	38	5.98	–57	–47	2	Left
Superior frontal gyrus	36	5.80	–13	47	36	Left

High-reappraisal-success group conjunction analysis: Top-down > bottom-up for only look trials during the instruction portion of the task, masked with reappraise > look for only bottom-up trials during the instruction portion of the task for the high-performing group. The whole-brain voxel threshold was set at $p < .005$, and the extent threshold at 35. The overall combined probability of the conjunction was $p < .04$. No significant activation was found for the low-reappraisal-success group at this threshold

In order to parallel an earlier design (H. Kim et al., 2004) and to stay within time and complexity restraints, we did not employ a fully crossed design that would have included a type of bottom-up emotion regulation. Future studies should employ a design to test the facilitation of other types of emotion regulation by emotions generated in multiple ways. Furthermore, replicating these results using more complex, mixed stimuli, such as those encountered more frequently in everyday life, should be pursued in future work.

Finally, novel experiments should be devised to explore the boundaries of the cognitive and neural conditions conducive

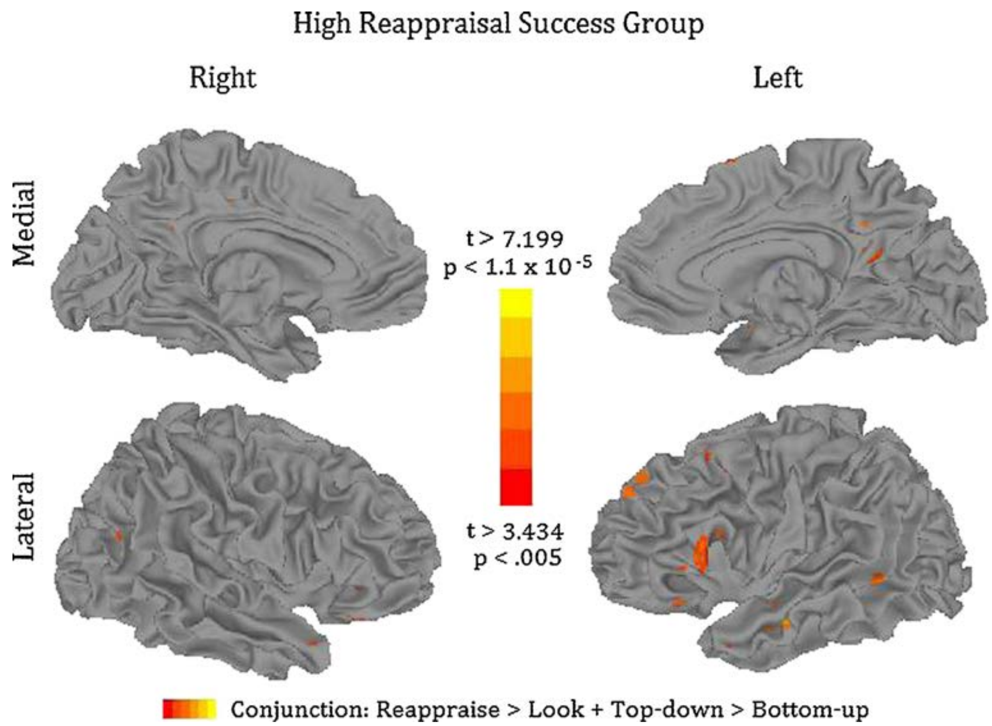

Fig. 6 High-reappraisal-success group conjunction analysis. Medial and lateral views of whole-brain activations for the conjunction of top-down > bottom-up for only look trials during the instruction portion of the task, masked with reappraise > look for only bottom-up trials during the instruction portion of the task. The whole-brain voxel threshold was set at $p < .005$, with an extent threshold of 35. The overall combined probability of the conjunction was $p < .04$. No significant activation was found for the low-reappraisal-success group at this threshold

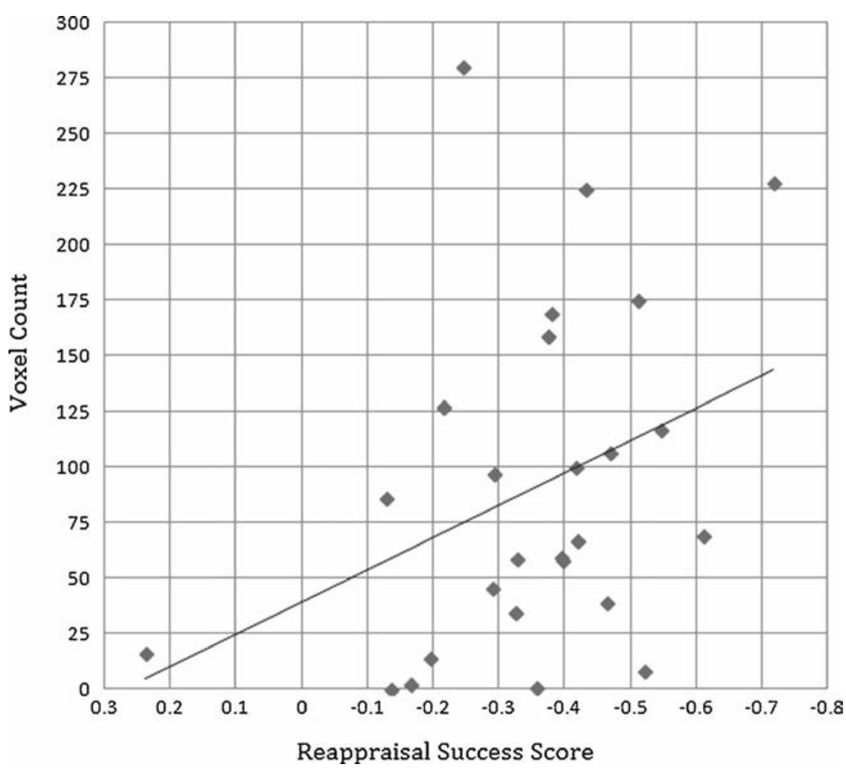

Fig. 7 Correlation scatterplot of the number of voxels that survived the conjunction procedure (top-down > bottom-up for only look trials during the instruction portion of the task, masked with reappraise > look for only bottom-up trials during the instruction portion of the task) at the individual level, and reappraisal success scores [$r(24) = .36$, $p = .04$]. A lower reappraisal success score represents greater reappraisal success

to the facilitation of emotion regulation. Not all theories predict that process overlap will result in facilitation. For example, an ego-depletion account of self-regulation posits that exhausting an overlapping process may hinder the success of emotion regulation (Baumeister, Bratslavsky, Muraven, & Tice, 1998; but see Iida, Nakao, & Ohira, 2012). Therefore, the efficiency of reappraisal might be sensitive to the duration of overlapping processes during top-down emotion generation. According to this view, if top-down emotion generation is carried out for a longer period of time, it is possible that subsequent reappraisal may be *less* effective. By varying the duration of top-down emotion generation and the onset of reappraisal, it may be possible to determine the time course under which reappraisal is most effective for distinct types of emotions. Furthermore, by including neuroimaging measures in the above experimental design, it may be possible to determine whether depletion is apparent when observing activation in the same neural regions identified here.

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