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BRIEF REPORT

Overlapping Neural Substrates Between Intentional and Incidental Down-Regulation of Negative Emotions

Doris E. Payer, Kate Baicy, Matthew D. Lieberman, and Edythe D. London
University of California, Los Angeles

Emotion regulation can be achieved in various ways, but few studies have evaluated the extent to which the neurocognitive substrates of these distinct operations overlap. In the study reported here, functional magnetic resonance imaging (fMRI) was used to measure activity in the amygdala and prefrontal cortex of 10 participants who completed two independent tasks of emotion regulation—reappraisal, measuring intentional emotion regulation, and affect labeling, measuring incidental emotion regulation—with the objective of identifying potential overlap in the neural substrates underlying each task. Analyses focused on *a priori* regions of interest in the amygdala and inferior frontal gyrus (IFG). For both tasks, fMRI showed decreased amygdala activation during emotion regulation compared with emotion conditions. During reappraisal, this decrease in amygdala activation was accompanied by a proportional decrease in emotional intensity ratings; during affect labeling, the decrease in amygdala activation correlated with self-reported aggression. Importantly, across participants, the magnitude of decrease in amygdala activation during reappraisal correlated with the magnitude of decrease during affect labeling, even though the tasks were administered on separate days, and values indexing amygdala activation during each task were extracted independently of one another. In addition, IFG–amygdala connectivity, assessed via psychophysiological interaction analysis, overlapped between tasks in two regions within the right IFG. The results suggest that the two tasks recruit overlapping regions of prefrontal cortex, resulting in similar reductions in amygdala activation, regardless of the strategy employed. Intentional and incidental forms of emotion regulation, despite their phenomenological differences, may therefore converge on a common neurocognitive pathway.

Keywords: emotion regulation, cognitive reappraisal, affect labeling, amygdala, prefrontal cortex

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Humans routinely engage in emotion regulation (ER)—"the initiation of new, or alteration of ongoing, emotional responses through the action of regulatory processes" (Ochsner & Gross, 2005, p. 242)—in an effort to modify their emotional trajectories. This regulation can be achieved in numerous ways (Hartley & Phelps, 2010; Koole, 2009), and although once assumed only to be initiated intentionally, evidence now suggests that some forms can occur automatically, without explicit intentions to modify emotions (Mauss, Bunge, & Gross, 2007). That is, under certain conditions, regulatory processes analogous to those elicited intentionally can be elicited incidentally (when individuals are not *trying* to regulate emotions; Lieberman et al., 2007; Lieberman, Inagaki, Tabibnia, & Crockett, 2011), challenging prevailing assumptions. Overlap in neurobiological mechanisms across phenomenologically distinct forms of ER can offer some insight into commonalities in underlying processes. To this end, neuroimaging studies have compared neural processes across intentional ER strategies (Goldin, McRae, Ramel, & Gross, 2008; McRae et al., 2009), but commonalities with unintentional forms of ER remain unexplored. As understanding such commonalities can refine and expand the definition of ER and encourage new avenues for research, we compared neural processes involved in intentional and incidental forms of ER, with the objective of determining whether processes overlap across this distinction.

The most commonly studied form of intentional ER is cognitive reappraisal, generally assumed to involve the deliberate transformation of negative stimuli into less distressing terms by reinterpreting, rationalizing, or objectifying the material (but see Mauss

Doris E. Payer and Kate Baicy, Department of Psychiatry & Biobehavioral Sciences, University of California, Los Angeles; Matthew D. Lieberman, Department of Psychiatry & Biobehavioral Sciences and Department of Psychology, University of California, Los Angeles; Edythe D. London, Department of Psychiatry & Biobehavioral Sciences, Department of Molecular & Medical Pharmacology, David Geffen School of Medicine, University of California, Los Angeles.

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Correspondence concerning this article should be addressed to Edythe D. London, UCLA Semel Institute for Neuroscience and Human Behavior, 760 Westwood Plaza, Los Angeles, CA 90095. E-mail: elondon@mednet.ucla.edu

et al., 2007). This strategy decreases self-reported negative emotion and physiological markers of stress and arousal (Ochsner & Gross, 2008), and is associated with activation of prefrontal cortex (PFC) accompanied by decreased amygdala activity (Berkman & Lieberman, 2009; Ochsner & Gross, 2005, 2008). A particularly consistent finding across studies is involvement of ventrolateral PFC (Berkman & Lieberman, 2009), including inferior frontal gyrus (IFG). The IFG, particularly on the right, has been implicated in inhibitory control (Aron, Robbins, & Poldrack, 2004), spanning emotional as well as cognitive domains (Berkman, Burklund, & Lieberman, 2009; Tabibnia et al., 2011), and thus provides a possible neural mechanism underlying the decreased emotional experience with reappraisal.

In contrast, affect labeling—the verbal labeling of emotional stimuli or one's reaction to them, that is, "putting feelings into words"—is an incidental, unintentional form of ER. Like reappraisal, emotion conditions of this task can elicit markers of negative affect, including self-reported distress (Lieberman et al., 2011) and autonomic reactivity (Hariri, Mattay, Tessitore, Fera, & Weinberger, 2003; Tabibnia, Lieberman, & Craske, 2008). Engaging in affect labeling diminishes these markers, and, like reappraisal, is associated with recruitment of right IFG and accompanying decreases in amygdala activity (Hariri, Bookheimer, & Mazziotta, 2000; Hariri et al., 2003; Lieberman et al., 2007; Payer, Lieberman, & London, 2011), that is, neural activation patterns consistent with ER. This decreased amygdala activity was recently shown to relate to aggression (Payer et al., 2011), suggesting that despite being elicited incidentally, it may index an individual's capacity for ER.

Analogous neurobiological findings between reappraisal and affect labeling (i.e., IFG recruitment accompanied by reduced amygdala activation) suggest commonalities between tasks, yet no neuroimaging investigation has examined them in the same study. The only study to directly address their overlap measured self-reported distress, and found a correlation between reductions in distress achieved through reappraisal and affect labeling (Lieberman et al., 2011). The present study sought to explore commonalities at a neural systems level, using data from two functional magnetic resonance imaging (fMRI) studies: one investigating reappraisal (Baicy, 2008), the other, affect labeling (Payer et al., 2011; also see Supplemental Materials) after identifying a subset of participants who completed both tasks. Here, we compared amygdala and IFG activation across these participants, with the expectation of revealing overlap in the neural substrates recruited by each task.

Method

Participants

The sample consisted of 10 participants who completed independent studies of reappraisal (Baicy, 2008) and affect labeling (Payer et al., 2011) in the same laboratory, as part of a larger investigation of emotion processing in methamphetamine dependence (see Supplemental Materials). The participants described here were among the age- and education-matched healthy control group to which methamphetamine-dependent participants were compared. Participant overlap was assessed following conclusion of both studies, preventing expansion of the sample.

Inclusion-exclusion criteria are described in detail in Payer et al. (2011) and Baicy (2008). Briefly, volunteers aged 18–55 years provided written informed consent, and were screened for eligibility using questionnaires, psychiatric diagnostic interviewing (SCID-IV; First, Spitzer, Gibbon, & Williams, 1995), and a medical examination. All participants were right-handed, fluent in English, in good general health, and had no current Axis I diagnosis (except nicotine dependence), use of psychotropic medications or substances (except alcohol or marijuana use, not qualifying for abuse or dependence), or positive urine drug screens on test days. Following completion of all sessions, participants were compensated in cash or vouchers. All procedures were approved by the UCLA Office of the Human Research Protection Program.

The 10 participants described here (6 female) were on average 27.6 years old ($SD = 8.09$, range = 21–43 years), and had completed an average of 14.6 years of education ($SD = 1.27$). They completed reappraisal and affect labeling tasks on separate test days, 1–61 days apart ($M = 24.3$ days, $SD = 24.5$).

Tasks

For the reappraisal task (Figure 1B), participants were presented with images from the IAPS stimulus set (Lang, Bradley, & Cuthbert, 2005), each preceded by instructions to either experience the associated emotional response naturally ("look" condition), or to decrease its intensity through reappraisal ("decrease" condition). Participants confirmed their understanding via verbal description of their strategy on a practice trial. The stimulus set consisted of 32 highly aversive and 16 neutral images, matched for number of people/faces and visual complexity. Each trial consisted of a 2-s instruction cue (look or decrease), 8 s of stimulus presentation, 7 s to rate emotional intensity on a scale from 1 (*least intense*) to 7 (*most intense*), and a 2-s intertrial interval. The task contained a total of 96 trials, counterbalanced for instruction (look or decrease) across participants, and presented over two sequential functional runs.

The affect label task (Figure 1C) included three conditions in which participants matched a target item at the top of the display to one of two choice items at the bottom: (a) affect matching ("match"), where participants matched faces (Tottenham et al., 2009) by emotional expression; (b) affect labeling ("label"), where participants chose one of four verbal labels describing the facial expression (i.e., "angry," "scared," "happy," "surprised"); and (c) shape matching ("shapes"), where participants matched forms (10 possible geometric shapes). The task contained four blocks per condition, each consisting of five 5-s trials (trial order randomized within blocks), presented over two sequential functional runs (order counterbalanced across participants). Each block was preceded by a 2-s cue indicating the condition, and followed by 16 s of fixation. For match and label conditions, 40 stimulus displays were chosen from the set used in Lieberman et al. (2007) so that half the target faces for each condition displayed fear and half anger, and half were female. A total of 25 individuals comprised the stimulus set, and although some individuals appeared in more than one stimulus display, no individual-emotion combination was repeated across trials.

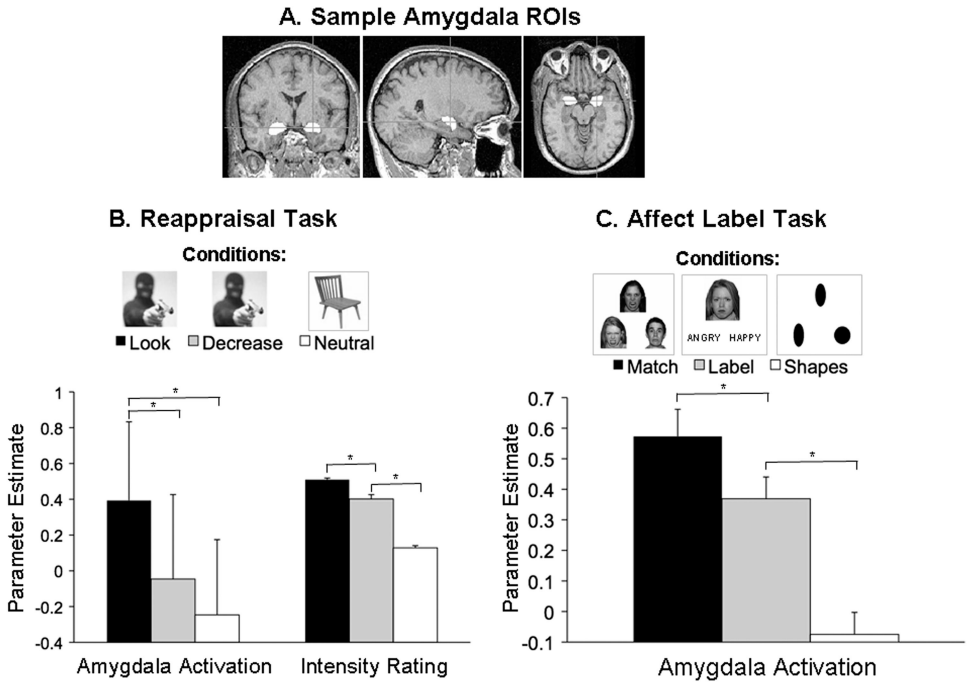

Figure 1. Amygdala activation and emotional intensity ratings are lowered during both reappraisal and affect label tasks**.** Panel A: Sample amygdala tracings from FSL FIRST (Patenaude, 2007). Voxels within these masks were used to calculate amygdala activation during each condition of the two tasks. Panel B: The figure legend displays sample stimuli from the reappraisal task. Bars represent means and standard errors for amygdala activation (left and right amygdala combined), as well as emotional intensity ratings following image presentation (divided by 10 for display purposes). For both measures, values were lower during the Decrease than the Look condition of the task. Panel C: The figure legend displays sample stimuli from the affect label task. Amygdala activation (left and right amygdala combined) was lower during the affect labeling (Label) than the affect matching (Match) condition of the task.

Apparatus and MRI Parameters

Functional MRI was performed on a 3.0 Tesla Siemens Allegra scanner (Erlangen, Germany), using a standard T2*-weighted gradient-echo echo-planar imaging pulse sequence to collect the blood oxygen level-dependent signal. Acquisition parameters for reappraisal were: TR = 1500 ms, TE = 30 ms; flip angle = 70°; matrix = 64 × 64; voxel size = 3.1 × 3.1 × 4.0 mm. Each volume (608 total) consisted of 26 interleaved slices with a 25% distance factor, aligned parallel to the anterior–posterior commissural plane. Acquisition parameters for affect labeling were: TR = 2500 ms, TE = 28 ms; flip angle = 80°; matrix = 64 × 64; voxel size = 3.1 × 3.1 × 2.5 mm. Each volume (420 total) consisted of 36 interleaved slices with a 25% distance factor, aligned parallel to the anterior–posterior commissural plane. All images were later resampled into 3.125 mm isotropic voxels. Participants viewed stimuli through magnet-compatible video goggles (Resonance Technology, Northridge, CA), and indicated their choices through button press on a magnet-compatible keypad under their right hand. T2-weighted anatomical images in the same planes as the functional scans and a high-resolution magnetization-prepared rapid gradient echo (MPRAGE) image were also acquired for region-of-interest (ROI) generation and spatial normalization of functional images.

Data Analysis

MRI preprocessing was performed using SPM5 (Wellcome Trust Centre for Neuroimaging, London, U.K.). Images were spatially realigned to the mean of the functional images (using a least squares approach and 6-parameter rigid-body spatial transformation) to correct for movement, and spatially coregistered with individual structural templates.

Amygdala activation. Individual amygdala ROI masks were delineated using the FIRST tool (Patenaude, 2007) of the FSL Software Package (FMRIB Analysis Group, Oxford, United Kingdom), which uses an automated procedure to fit shape-and-appearance models of subcortical regions to individual MPRAGE images (Figure 1A). Following ROI generation for each participant, functional scans were spatially smoothed with a 5-mm full width at half maximum (FWHM) Gaussian kernel, and masked with the spatially coregistered amygdala ROIs. For each task, a general linear model (GLM) was applied at each voxel within the ROI mask, using the MarsBaR toolbox for SPM (Brett, Anton, Valabregue, & Poline, 2002).

For the reappraisal task, the GLM consisted of regressors for instruction cues, each condition—look (negative images with LOOK instructions), decrease (negative images with DECREASE instructions), and neutral (neutral images collapsed across LOOK

and DECREASE instructions)—and the emotional intensity rating phase. Fixation between trials was the implicit baseline. Individual trials were modeled as 8-s boxcar functions, convolved with the hemodynamic response function (HRF) provided by SPM. The GLM for the affect label task consisted of regressors for instruction cues and each condition (match, label, and shapes). Fixation between blocks was the implicit baseline. Blocks were modeled as 25-s boxcar functions, convolved with the standard HRF.

After fitting the models at each voxel within the ROI masks, the resulting parameter estimates were averaged across all voxels in the mask, providing an index of amygdala activation during each condition of each task. These values were exported to SPSS 16.0 (Chicago, IL) for further analysis.

IFG recruitment. To investigate effective connectivity between the amygdala and PFC, we used psychophysiological interaction (PPI) analysis, which employs multiple regression to isolate regions showing differential relationships with one another, depending on psychological context. Results can be interpreted as the context-specific influence one brain region exerts over another (Friston et al., 1997). To isolate PFC regions showing the desired connectivity patterns (greater negative relationship with the amygdala during "regulation" than "emotion" conditions), we used individual FIRST-generated amygdala ROIs as seed regions from which activity time courses were extracted, conditions of the two tasks as the manipulated context, and IFG as a potential region for connectivity.

For each participant, functional images were smoothed with an 8-mm FWHM Gaussian kernel, and activation time courses during each task were extracted from their amygdala ROIs. These time courses, along with a regressor for task conditions of interest (look vs. decrease for reappraisal, match vs. label for affect labeling) and the amygdala × condition interaction (product of the two time courses), were entered into whole-brain multiple regression analyses. Given our *a priori* hypotheses and small sample size, analyses were restricted to left and right IFG, using anatomic masks defined by the PickAtlas toolbox for SPM (Tzourio-Mazoyer et al., 2002). After estimating the models and assessing the interaction for each participant, statistical maps were spatially normalized to the standard Montreal Neurological Institute (MNI) template, using a 12-parameter affine transformation.

To assess whether IFG recruitment overlapped between tasks, we used a conjunction approach, searching for voxels that showed a significant effect during both tasks simultaneously. We performed one-sample *t* tests for effects of each task, and used the resulting maps of *t*-values to create a third map, consisting of the lower of the two *t*-values at each voxel. This map was then subjected to a voxelwise threshold of $p = .0025$ (effective conjoint probability after subjecting each map to a threshold of $p = .05$, using Fisher's methods of combining probabilities (see Kampe, Frith, & Frith, 2003; McRae et al., 2009), with the assumption that surviving clusters would indicate areas in which both tasks produced effects.

Results

Reappraisal Task

Parameter estimates from left and right amygdala ROIs correlated with each other during all conditions of the task, all $r(8) > .86$, all $p \leq .001$, and were combined by calculating their mean. A one-way repeated-measures ANOVA assessing differences in these values between task conditions (look, decrease, neutral) showed a significant effect of condition, $F(2, 18) = 8.96$, $p = .002$, and, as expected, follow-up paired-samples *t* tests revealed lower amygdala activation during the decrease than the look condition, $t(9) = 3.41$, $p = .008$, $d = 1.12$ (Figure 1A). Activation during the neutral condition was lower than during the look condition, $t(9) = 3.97$, $p = .003$, $d = 1.27$, but not the decrease condition, $t(9) = 1.17$, $p = .271$.

A one-way repeated-measures ANOVA assessing emotional intensity ratings also showed a significant effect of condition, $F(2, 18) = 169.64$, $p < .001$, echoing findings from the original study (Baicy, 2008; Supplementary Materials). In the present sample, follow-up paired-samples *t* tests revealed parallel patterns to those in the amygdala: Ratings were lower during the decrease than the look condition, $t(9) = 4.53$, $p = .001$, $d = 1.67$, and ratings during the neutral condition were lower than during both look, $t(9) = 23.17$, $d = 8.98$ and decrease, $t(9) = 11.90$, $d = 4.19$, both $p < .001$ (Figure 1A).

To confirm that the observed decrease in amygdala activation indexed a change in emotional state, we assessed its relationship with emotional intensity ratings. Across participants, reduction in amygdala activation (difference between look and decrease conditions) marginally correlated with reduction in emotional intensity ratings, $r(8) = .549$, $p = .100$, suggesting a relationship between reduced amygdala activation and emotional state. When separated by hemisphere, reduced right amygdala activation significantly correlated with reduced emotional intensity, $r(8) = .678$, $p = .031$. The correlation was not statistically significant on the left, $r(8) = .402$, $p = .250$.

Affect Label Task

Parameter estimates from left and right amygdala ROIs correlated with each other during match and label conditions, both $r(8) > .88$, both $p \leq .001$, and were combined by calculating their mean. A one-way repeated-measures ANOVA assessing differences in these values between task conditions (match, label, shapes) showed a significant effect of condition, $F(2, 18) = 17.37$, $p < .001$, and, as expected, follow-up paired-samples *t* tests revealed lower amygdala activation during the label than the match condition, $t(9) = 3.04$, $p = .014 < .05$, $d = .99$ (Figure 1B), echoing findings from the original sample (Payer et al., 2011; Supplementary Materials). Activation during the shapes condition was lower than during the match condition, $t(9) = 4.79$, $p = .001$, $d = 1.52$, and the label condition, $t(9) = 3.62$, $p = .006$, $d = 1.14$.

Due to the incidental nature of the task, it was not possible to collect ratings of emotional intensity and measure changes in emotional state. However, we previously reported an inverse correlation between reduced amygdala activation and self-reported aggression (presumably indexing ER capacity; Payer et al., 2011), and the correlation held true in the present sample, $r(8) = -.801$, $p = .017$.

Comparison of Reappraisal and Affect Label Tasks

Amygdala activity. To test for a relationship between the magnitudes of decrease in amygdala activation achieved through reappraisal and affect labeling, we assessed their correlation. The two difference measures (look minus decrease for reappraisal, match minus label for affect labeling) were significantly correlated across participants, $r(8) = .765$, $p = .010$ (Figure 2A). A follow-up "leave-

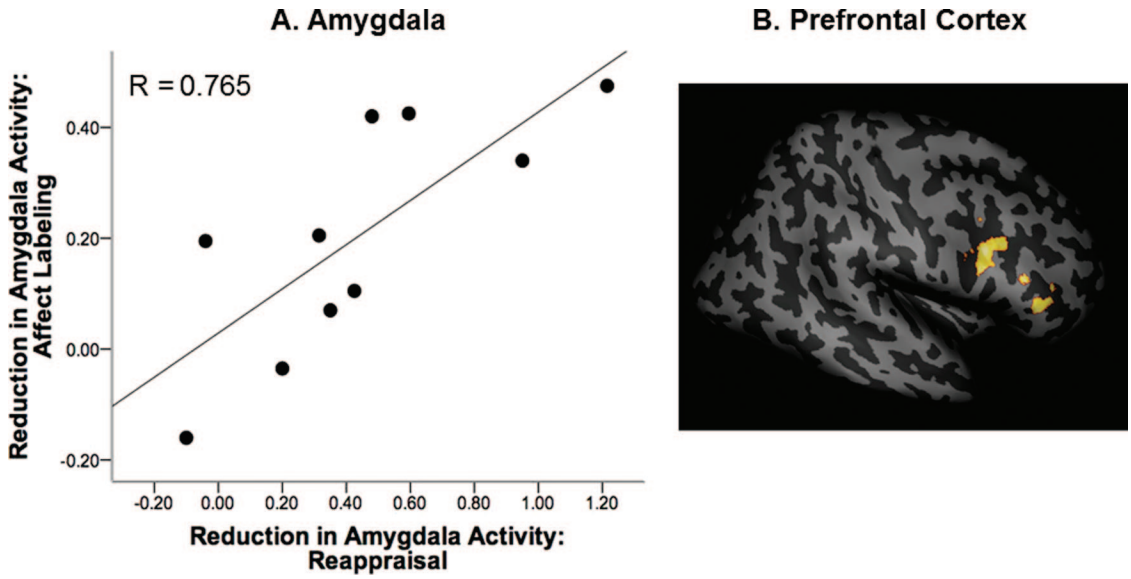

Figure 2. Overlap between neural correlates of emotion regulation during reappraisal and affect labeling. Panel A: Across participants, reduced amygdala activation achieved through reappraisal (look–decrease) correlated with reduced amygdala activation achieved through affect labeling (match–label). Panel B: Regions of IFG associated with these decreases in amygdala activation (assessed with PPI) overlapped in the right IFG, coordinates (x, y, z) = 54, 34, 20 mm, cluster size = 139 voxels; coordinates (x, y, z) = 38, 10, 28 mm, cluster size = 118 voxels. Data are rendered onto a structural template provided by SPM using the SurfRend toolbox (written by I. Kahn; http://spmsurfrend.sourceforge.net).

one-out" analysis, iteratively removing one participant and assessing correlations among the remaining data points, ensured that this correlation was not driven by any single participant or outlier (for all iterations, $.685 < r < .834$, $.005 < p < .042$).

IFG recruitment. To examine whether IFG recruitment overlapped between reappraisal and affect labeling, we performed a "minimum *t*-value" conjunction analysis between PPI maps from the two tasks (each map showing IFG regions that had greater connectivity with the amygdala during regulation than emotion conditions). Task-related IFG recruitment overlapped in two clusters in the right IFG (Figure 2B), with a peak minimum *t*-value of 3.44.

Discussion

The results provide evidence that intentional and incidental ER share neural substrates. Specifically, the magnitude of decrease in amygdala activation achieved through reappraisal was related to that achieved through affect labeling, and both tasks recruited common areas in right IFG. To our knowledge, this study is the first to show this relationship in a within-subjects design, and provides a neural basis for the recently reported correlation between subjective emotional consequences of reappraisal and affect labeling (Lieberman et al., 2011).

Taken separately, each task produced amygdala and IFG activation patterns that are consistent with ER. During reappraisal, participants decreased amygdala activation and reported proportional decreases in emotional intensity, consistent with previous neuroimaging studies (Berkman & Lieberman, 2009; Ochsner & Gross, 2005, 2008). Similarly, participants decreased amygdala activation through affect labeling, which correlated with self-reported aggression, consistent with studies suggesting affect labeling as a form of incidental ER (Hariri et al., 2000; Hariri et al., 2003; Lieberman et al., 2007; Payer et al., 2011).

Importantly, neural activation patterns during the two tasks showed commonalities with one another. Across participants, the extent to which amygdala activation was reduced through reappraisal correlated with the extent of reduction achieved through affect labeling. Further, PFC activity associated with these reductions overlapped between tasks in the right IFG. These findings suggest convergence of the disparate neurocognitive processes necessary to perform each task, resulting in similar amygdala regulation across individuals, regardless of strategy employed. Together, the results are consistent with the role of right IFG in cognitive and emotional inhibitory control (Berkman et al., 2009; Tabibnia et al., 2011), and provide the first direct evidence for the previously suggested neural overlap between intentional and incidental ER (Berkman & Lieberman, 2009).

Several limitations of the study should be noted. First, since reappraisal task instructions preceded stimulus onsets, the task measured *biased appraisal* (rather than initial appraisal/subsequent *re*-reappraisal) of stimuli, making "reappraisal" somewhat of a misnomer. However, we wished to remain consistent with the literature, and therefore adopted these traditional design and naming conventions (but see Eippert et al., 2007). Second, the affect labeling task does not allow for subjective emotional intensity ratings, preventing distinction between emotion-regulation and potential nonemotion effects (e.g., instruction sensitivity of the amygdala, participant inattention). However, we present evidence throughout that amygdala/IFG patterns associated with affect labeling at least in part reflect modulation of emotions. Further, it is possible that during affect labeling, participants spontaneously adopted intentional ER strategies.

However, the task was introduced as a "visual processing task," and did not require consideration of emotional content beyond task instructions. Third, the sample was small, limiting statistical power and enhancing the probability of beta errors (e.g., marginal correlations may have reached significance in a larger sample, as the smallest detectable correlation with $n = 10$ is $r = .63$). We took measures to minimize multiple comparisons, but recognize the importance of replicating the findings in a larger sample. Finally, the two tasks were completed on separate days, using differing task designs and MRI acquisition parameters. Although correlation and conjunction analyses allow for some comparison, the findings should be replicated using parallel designs during a single session.

These limitations notwithstanding, the present findings not only reinforce that affect labeling, like reappraisal, elicits PFC–amygdala connectivity patterns consistent with ER, but also show that these seemingly disparate approaches can recruit overlapping neural substrates and result in similar outcomes. Although the present results are specific to the down-regulation of negative emotions, and relationships to up-regulation or positive emotions (e.g., (Kim & Hamann, 2007; Ochsner et al., 2004) remain to be explored, the findings help refine the definition of emotion regulation, and lend support to the utility of putting feelings into words in alleviating negative affect.

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Appendix

Supplemental Material

Since the sample of participants who completed both the reappraisal and affect label tasks is small ($N = 10$), additional data are presented here in an effort to show that data from the present sample are representative of, and show similar patterns of effects to, the larger samples from which participants were drawn. In their individual studies, a total of 17 healthy participants completed the reappraisal task (control group in Baicy, 2008), and 23 healthy participants completed the affect label task (control group in Payer et al., 2011). Amygdala ROI and PPI analyses were performed for all participants as described in the Method Section. For the large samples, PPI analyses were assessed at a threshold of $p < .005$, uncorrected, with a 50-voxel cluster minimum. PPI analysis for the reappraisal task showed connectivity with the amygdala in a 60-voxel cluster in the right inferior frontal gyrus (IFG), x, y, z (mm) = 58, 24, 32; peak $t = 4.51$, $p < .001$. PPI analysis for the affect label task showed connectivity with the amygdala in two clusters in the right IFG, Cluster 1: 111 voxels; x, y, z (mm) = 54, 38, 16; peak $t = 4.81$, $p < .001$; Cluster 2: 209 voxels; x, y, z (mm) = 44, 20, 30; peak $t = 3.47$, $p < .001$. Within these clusters, effects shown by the present subsample were assessed. Results are presented in Supplementary Table 1, and suggest that subsample data are comparable to the original results.

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