Deconstructing Reappraisal: Descriptions Preceding Arousing Pictures Modulate the Subsequent Neural Response

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Abstract

■ The late positive potential (LPP) is a sustained positive deflection in the event-related potential that is larger following the presentation of emotional compared to neutral visual stimuli. Recent studies have indicated that the magnitude of the LPP is sensitive to emotion regulation strategies such as reappraisal, which involves generating an alternate interpretation of emotional stimuli so that they are less negative. It is unclear, however, whether reappraisal-related reductions in the LPP reflect reduced emotional processing or increased cognitive demands following reappraisal instructions. In the present study, we sought to examine whether a more or less negative description preceding the presentation of unpleasant images would similarly modulate the LPP. The LPP was recorded from 26 subjects as they viewed unpleasant and neutral International Affective Picture System images. All participants heard a brief description of the upcoming picture; prior to unpleasant images, this description was either more neutral or more negative. Following the more neutral description, the magnitude of the LPP, unpleasant ratings, and arousal ratings were all reliably reduced. These results indicate that changes in narrative are sufficient to modulate the electrocortical response to the initial viewing of emotional pictures, and are discussed in terms of recent studies on reappraisal and emotion regulation. ■

INTRODUCTION

Emotions may be conceptualized as multisystem responses to stimuli that compel attention, have personal meaning, and have undergone some form of appraisal (Gross & Thompson, 2007). Emotion regulation, then, refers to the set of controlled and automatic strategies that influence the direction of attention or the meaning and subsequent appraisal of stimuli. Researchers have begun to examine and compare specific cognitive strategies relevant to emotion regulation (for a review, see Ochsner & Gross, 2005). At a broad level, emotion regulation strategies can be classified as either response- or antecedent-focused (Gross & Thompson, 2007; Gross, 2002). Response-focused strategies occur relatively late in the emotion-generation process and would include suppressing the behavioral expression of emotion. Ironically, expressive suppression is ineffective in decreasing the experience of negative emotions, and has been associated with memory impairment and increased physiological reactivity (Richards & Gross, 2000; Gross & Levenson, 1997).

On the other hand, antecedent-focused regulation strategies occur relatively early within the emotion-generation process. Techniques that would fall under this category include detachment (i.e., taking on a more impersonal, third-person perspective) and reappraisal (i.e., reinterpreting an unpleasant stimulus to be less negative). These emotion regulation strategies, as contrasted with suppression, appear to be effective in decreasing the experience of negative emotions (Hajcak & Nieuwenhuis, 2006; Gross, 2002; Ochsner, Bunge, Gross, & Gabrieli, 2002) and have no adverse effects on memory (Richards & Gross, 2000). The specific neural systems associated with antecedent-focused emotion regulation have been the target of numerous functional magnetic resonance imaging (fMRI) studies. Schaefer et al. (2002) first reported that the increased amygdala activity in response to unpleasant stimuli could be prolonged if subjects were given an explicit instruction to maintain their emotional response. Since then, multiple studies that utilize the specific strategies of detachment (Kalisch, Wiech, Critchley, & Dolan, 2006; Beauregard, Levesque, & Bourgouin, 2001) and reappraisal (Urry et al., 2006; Phan et al., 2005; Levesque et al., 2003; Ochsner et al., 2002) have demonstrated that it is possible to consciously inhibit amygdala activation when instructed to decrease emotional response. Collectively, these findings have shed a great deal of light on the systems implicated in the successful regulation of emotion and suggest that multiple antecedent-focused emotion regulation strategies rely on a similar network of neural activity: Diminished processing in emotion-related (i.e., limbic) regions are reported in the context of increased

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activity in areas of the brain implicated in cognitive control (i.e., prefrontal cortex).

In addition to fMRI, event-related brain potentials (ERPs) have been used to investigate the processes of emotion regulation in recent studies. The excellent temporal resolution of ERPs has allowed for greater insight into the time course of emotion regulation processes, and these studies suggest that reappraisal modulates ERPs following unpleasant pictures (Hajcak & Nieuwenhuis, 2006; Moser, Hajcak, Bukay, & Simons, 2006). These studies have focused on the late positive potential (LPP) in particular, which has been shown to be reliably increased in magnitude following both pleasant and unpleasant compared to neutral stimuli (Schupp, Junghofer, Weike, & Hamm, 2004; Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000; Schupp et al., 2000). In one combined fMRI/ERP study, the LPP was found to be correlated with neural activity in the lateral occipital, inferotemporal, and parietal visual areas, supporting the notion that it reflects facilitated perceptual processing of motivationally relevant, emotional stimuli (Sabatinelli, Lang, Keil, & Bradley, 2007). Instructions to reappraise unpleasant stimuli have been shown to decrease the magnitude of the LPP and, importantly, reappraisal modulates the LPP just 300 msec after stimulus onset (Hajcak & Nieuwenhuis, 2006; Moser et al., 2006).

The reduced LPP following reappraisal has been interpreted as reflecting a diminished emotional response following emotion regulation instructions (Hajcak & Nieuwenhuis, 2006; Moser et al., 2006)—this interpretation is consistent with findings that relate the magnitude of the LPP to subjective ratings of emotion intensity (Cuthbert et al., 2000). In this view, reappraisal-related reductions in the LPP reflect changes in emotional processing resulting from a shift in meaning (Lazarus, 1991). As previous neuroimaging studies have reported, however, reappraisal recruits areas of the prefrontal cortex implicated in effortful cognitive control (Phan et al., 2005; Levesque et al., 2003; Ochsner et al., 2002). Increased effort and cognitive control may reflect the fact that subjects must generate their own alternative interpretation of images (Hajcak & Nieuwenhuis, 2006; Moser et al., 2006; Phan et al., 2005; Levesque et al., 2003; Ochsner et al., 2002; Jackson, Malmstadt, Larson, & Davidson, 2000). Thus, it is unclear whether it is the shift in narrative itself, increased task difficulty associated with reappraisal, or some other process that is responsible for changes in the LPP following reappraisal instructions.

In the present study, we sought to more precisely identify the underlying processes of reappraisal and determine whether narratives could modulate the electrocortical responses to the initial viewing of emotional stimuli. We used the LPP as an electrophysiological measure of emotional intensity and collected self-report ratings of valence and arousal after each trial. Both neutral and unpleasant stimuli were preceded by brief descriptions: 50% of unpleasant stimuli were preceded by a negative description, whereas the remaining unpleasant stimuli were preceded by a more neutral description; neutral stimuli were always preceded by a neutral description. On all trials, participants were simply instructed to view the pictures. In this way, subjects were provided narratives that could influence the meaning of the upcoming stimuli, rather than being left to generate their own reinterpretation. Therefore, there were no differences in task difficulty. In addition, the narratives were given before subjects ever viewed the stimuli, so that the potential modulation of the initial emotional response could be observed. Although the very first study of reappraisal used a similar approach and found reduced autonomic activity to emotionally arousing film clips (Lazarus & Alfert, 1964), to our knowledge, such a procedure has yet to be used in conjunction with either ERPs or fMRI to examine neural activity related to emotional processing.

We hypothesized that more neutral descriptions preceding unpleasant stimuli would reduce emotional responses to those stimuli. In particular, we expected that the LPP for unpleasant stimuli preceded by neutral descriptions would be reduced compared to unpleasant stimuli preceded by negative descriptions. We also hypothesized that neutral compared to negative descriptions preceding unpleasant stimuli would be associated with less negative and less arousing self-report ratings. In addition, to assess for any early effects of emotion and reappraisal, we scored the frontal P2 and the posterior N1 components. Although both are related to attention, the N1 has been found to index stimulus discrimination (Vogel & Luck, 2000), and the P2 has been found to be enhanced for unpleasant images (Huang & Luo, 2006). We predicted that the P2 would be enhanced for unpleasant compared to neutral images; however, insofar as both the P2 and the N1 are relatively early ERP components, we hypothesized that they would not be influenced by reappraisal, and would therefore not differ according to narrative type.

METHODS

Participants

Twenty-nine undergraduate students (14 men, 15 women) participated in the current study. Three subjects were excluded from analysis due to poor quality recordings, leaving 26 subjects (12 men, 14 women) for the final sample. No subjects discontinued their participation in the experiment once the procedures had begun. All participants received course credit for their participation.

Stimulus Materials

A total of 75 pictures were selected from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2005); of these, 25 depicted neutral scenes (e.g., neutral faces, household objects) and 50 depicted unpleasant scenes (e.g., sad faces, violent images). The two categories differed on normative ratings of valence (M = 5.05, SD = 1.21, for neutral picture content; M = 2.82, SD = 1.64, for unpleasant picture content); additionally, the emotional pictures were reliably higher on normative arousal ratings (M = 5.71, SD = 2.16, for unpleasant picture content; and M = 2.91, SD = 1.93, for neutral picture content). Prior to each picture, a brief auditory description of the upcoming picture was played through headphones. Every participant heard the same neutral description for the 25 neutral images. For each of the 50 unpleasant images, participants heard one of two descriptions: One description highlighted the negative aspects of the image, whereas the other described the image in more neutral terms. Our goals were to mimic the type of reappraisals that have been suggested in studies of emotion regulation and to provide individuals with these descriptions prior to their viewing the images. A complete list of the IAPS image number and associated descriptions are presented in Appendix A and Appendix B.

The task was administered on a Pentium D class computer, using Presentation software (Neurobehavioral Systems, Albany, CA) to control the presentation and timing of all stimuli. Prior to each picture, a white fixation cross was presented on a black screen for 6 sec. During this period, a brief (3–5 sec) description of the upcoming picture was played through headphones. Each picture was then displayed in color for 3 sec and occupied the entirety of a 19-in. (48.26 cm) monitor. At a viewing distance of approximately 24 in. (60.96 cm), each picture occupied approximately 40° of visual angle horizontally and vertically. After the offset of each picture, participants rated the picture on the dimensions of valence and arousal. After a 1000-msec delay, the next trial began.

Procedure

After a brief description of the experiment, electroencephalograph (EEG) sensors were attached and the subject was given detailed task instructions. Participants were told that they would be viewing pictures; additionally, that they would hear a brief description played over the headphones prior to each picture, which would describe what is being depicted in the upcoming picture. Following each picture, participants were instructed to rate each picture on two visual analog scales that assessed valence and arousal (Lang, 1980). The valence scale depicted five characters who ranged from happy to unhappy; below this scale were the numbers "1" through "9" ("1" corresponded to the happiest figure, "3" to next-most happy figure, and "2" was located between the previous two, and so on). Participants were told to use this scale to indicate how pleasant or unpleasant they felt about the preceding picture. The second scale depicted five characters who appeared to have a very strong visceral response to no visceral response; again, the numbers "1" through "9" were presented below this scale, and participants were told to rate the picture, but this time based on the *strength* of their emotional response to the picture. On both the arousal and valence dimension, a score of 5 represented the midpoint between the two extreme ratings, and participants were encouraged to use any point on the scale even if it fell between two of the five figures on the analogue scales. For presentation purposes, valence and arousal ratings were reverse-scored so that a score of 9 represented pleasant valence and high arousal.

All participants performed one practice trial to ensure that the sequence of events was clear, and that they understood the rating scales. After the practice trial, all participants performed 75 trials, with breaks after every 15 trials. Of these, 25 were neutral pictures and 50 were unpleasant pictures. For 25 of the unpleasant pictures, a less negative description preceded the image, whereas a more negative description preceded the other 25 unpleasant images. The order of trials and the description that preceded each unpleasant image were determined randomly for each subject.

Psychophysiological Recording, Data Reduction, and Analysis

The continuous EEG was recorded using an ECI Electrocap and the ActiveTwo BioSemi system (BioSemi, Amsterdam, Netherlands). Recordings were taken from 64 scalp electrodes based on the 10–20 system, as well as two electrodes placed on the left and right mastoids. The electrooculogram (EOG) generated from blinks and eye movements was recorded from four facial electrodes: two approximately 1 cm above and below the subject's left eye, one approximately 1 cm to the left of the left eye, and one approximately 1 cm to the right of the right eye. As per BioSemi's design, the ground electrode during acquisition was formed by the Common Mode Sense active electrode and the Driven Right Leg passive electrode.

All bioelectric signals were digitized on a laboratory microcomputer using ActiView software (BioSemi). The EEG was sampled at 500 Hz. Off-line analysis was performed using Brain Vision Analyzer software (Brain Products). All data were re-referenced to the average of the two mastoids and band-pass filtered with cutoffs of 0.1 and 30 Hz. The EEG was segmented for each trial, beginning 500 msec before each picture onset and continuing for 3500 msec. The EEG for each trial was corrected for blinks and eye movements using the method developed by Gratton, Coles, and Donchin (1983). Specific intervals for individual channels were rejected in each trial using a semiautomated procedure, with physiological artifacts identified by the following criteria: a voltage step of more than 50.0 μV between sample points, a voltage difference of 300.0 μV within a trial, and a maximum voltage difference of less than 0.50 μV within 100-msec intervals.

ERPs were constructed by separately averaging trials in the three conditions: neutral pictures following a neutral description, unpleasant picture following a negative description, and unpleasant picture following a more neutral description. For each ERP average, the average activity in the 500-msec window prior to picture onset served as the baseline. To reduce the spatial dimensions of the dataset, we created eight clusters of electrodes with five electrodes in each. In accordance with Dien and Santuzzi's (2005) suggestion, we employed three 2-level regional clusters: left versus right hemisphere, anterior versus posterior, and inferior versus superior. The left–right anterior–superior clusters included electrodes AF3/4, F1/2, F3/4, FC1/2, and FC3/4; the left–right anterior–inferior clusters were defined by electrodes AF7/8, F5/6, F7/8, FC5/6, and FT7/8; the left–right posterior–superior clusters included CP1/2, CP3/4, P1/2, P3/4, and PO3/4; the left–right posterior–inferior clusters included CP5/6, P5/6, P7/8, PO7/8, and TP7/8.

The LPP was evaluated as a function of condition and site in three windows following stimulus onset: 400–1000 msec (early window), 1000–2000 msec (middle window), and 2000–3000 msec (late window). For each window, the LPP was quantified as the average activity in the window and was evaluated with a 3 (condition) × 2 (hemisphere) × 2 (anterior–posterior) × 2 (inferior–superior) repeated measures analysis of variance (ANOVA).

The N1 component was scored as the peak amplitude between 50 and 150 msec after stimulus onset at posterior recording sites (CP1/2, CP3/4, P1/2, P3/4, PO3/4, CP5/6, P5/6, P7/8, PO7/8, and TP7/8), and the P2 component was scored as the peak amplitude between 150 and 250 msec at anterior recording sites (AF3/4, F1/2, F3/4, FC1/2, FC3/4, AF7/8, F5/6, F7/8, FC5/6, and FT7/8). Each of these components was evaluated with a three-level (condition) repeated measures ANOVA.

In all cases, the LPP, N1, and P2 were statistically evaluated using SPSS (Version 14.0) General Linear Model software, with Greenhouse–Geisser correction applied to p values associated with multiple df, repeated measures comparisons; p values were adjusted with the Bonferroni correction for multiple post hoc comparisons.

RESULTS

Behavioral Data

Valence and arousal ratings are presented in Figure 1. Consistent with the impression from Figure 1, both valence [$F(2, 50) = 155.31$, $p < .001$] and arousal [$F(2, 50) = 89.11$, $p < .001$] ratings varied as a function of condition. Post hoc comparisons indicated that unpleasant images following both negative ($M = 2.73$, $SD = 1.02$) and neutral ($M = 3.92$, $SD = 1.18$) descriptions were rated as less pleasant than neutral images [$M = 5.24$, $SD = 1.19$; $t(25) = 16.27$, $p < .001$ and $t(25) = 8.11$, $p < .001$, respectively]; additionally, unpleasant images that followed negative descriptions were rated as less pleasant than unpleasant images that followed neutral descriptions [$t(25) = 11.45$, $p < .001$]. In terms of arousal ratings, unpleasant images following both unpleasant ($M = 5.23$, $SD = 1.65$) and neutral ($M = 3.84$, $SD = 1.65$) descriptions were rated as more emotionally arousing than neutral pictures [$M = 1.95$, $SD = 0.89$; $t(25) = 10.25$, $p < .001$ and $t(25) = 8.84$, $p < .001$, respectively]; unpleasant pictures following negative descriptions were rated as more arousing compared to unpleasant pictures that followed neutral descriptions [$t(25) = 7.50$, $p < .001$]. Consistent with previous studies, unpleasant images were rated as more unpleasant and arousing compared to neutral pictures from the IAPS; however, the description that preceded the unpleasant picture also reliably influenced both valence and arousal ratings: Negative descriptions decreased valence and increased arousal ratings compared to more neutral descriptions.

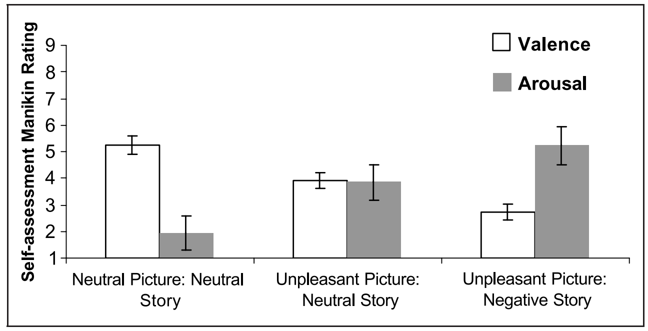

Figure 1. Valence and arousal ratings obtained using the self-assessment manikin rating scales after each trial. Higher ratings reflect more positive valence and increased ratings of arousal; error bars represent ±2.13 standard errors, the 95% confidence interval.

Early Components: N1 (50–150 msec) and P2 (150–250 msec)

Mean amplitudes for each component in each condition are presented in Figure 2. For the N1 component, a significant effect of condition was found [$F(2, 50) = 4.02$, $p < .05$]. One-tailed follow-up t tests confirmed the trends that are apparent in the graph, using a critical p value of .017 after Bonferroni correction. Unpleasant pictures preceded by negative stories ($M = -2.88$ μV, $SD = 2.64$ μV) were associated with a larger N1 than either unpleasant pictures preceded by neutral stories [$M = -1.72$ μV, $SD = 2.53$ μV; $t(25) = 2.38$, $p < .017$] or neutral pictures [$M = -1.68$ μV, $SD = 2.77$ μV; $t(25) = 2.93$, $p < .01$]. The amplitude of the N1 did not significantly differ between neutral pictures and neutrally described unpleasant pictures ($p = .47$).

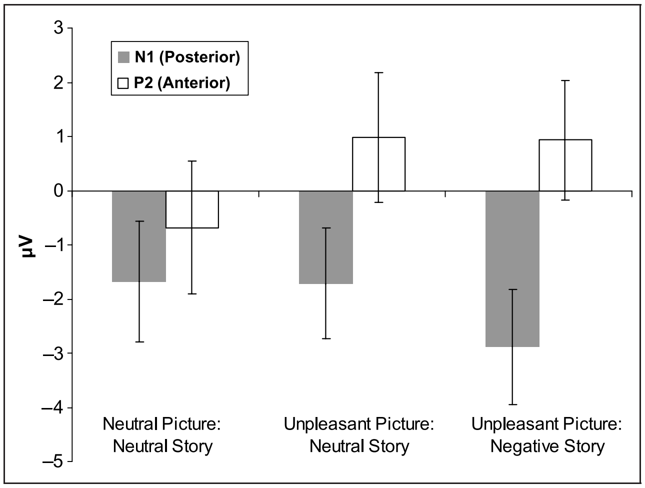

Figure 2. N1 and P2 amplitudes in each condition. The N1 component was scored as the peak amplitude 50–150 msec after picture onset at posterior clusters. The P2 component was scored as the peak amplitude 150–250 msec after picture onset at anterior clusters. Error bars represent ±2.13 standard errors, the 95% confidence interval.

For the P2 component, once again, a significant effect of condition was found [$F(2, 50) = 5.24$, $p < .05$]. Confirming the trends that are apparent in Figure 2, unpleasant pictures were associated with a larger P2 than neutral pictures ($M = -0.68$, $SD = 3.06$), whether preceded by neutral stories [$M = 0.98$, $SD = 2.99$; $t(25) = 2.49$, $p < .01$] or negative stories [$M = 0.93$, $SD = 2.75$; $t(25) = 2.75$, $p < .01$]. The amplitude of the P2 did not significantly differ between unpleasant pictures described neutrally and negatively ($p = .46$).

LPP: Early Window (400–1000 msec)

Stimulus-locked ERPs in each condition (neutral picture, unpleasant picture following negative description, and unpleasant picture following neutral description) are presented in Figure 3 at each electrode cluster collapsing across hemisphere. In the early window, the overall magnitude of the LPP (collapsing across condition) was larger at posterior [$F(1, 25) = 90.79$, $p < .001$] and superior [$F(1, 25) = 15.02$, $p < .001$] recording sites;

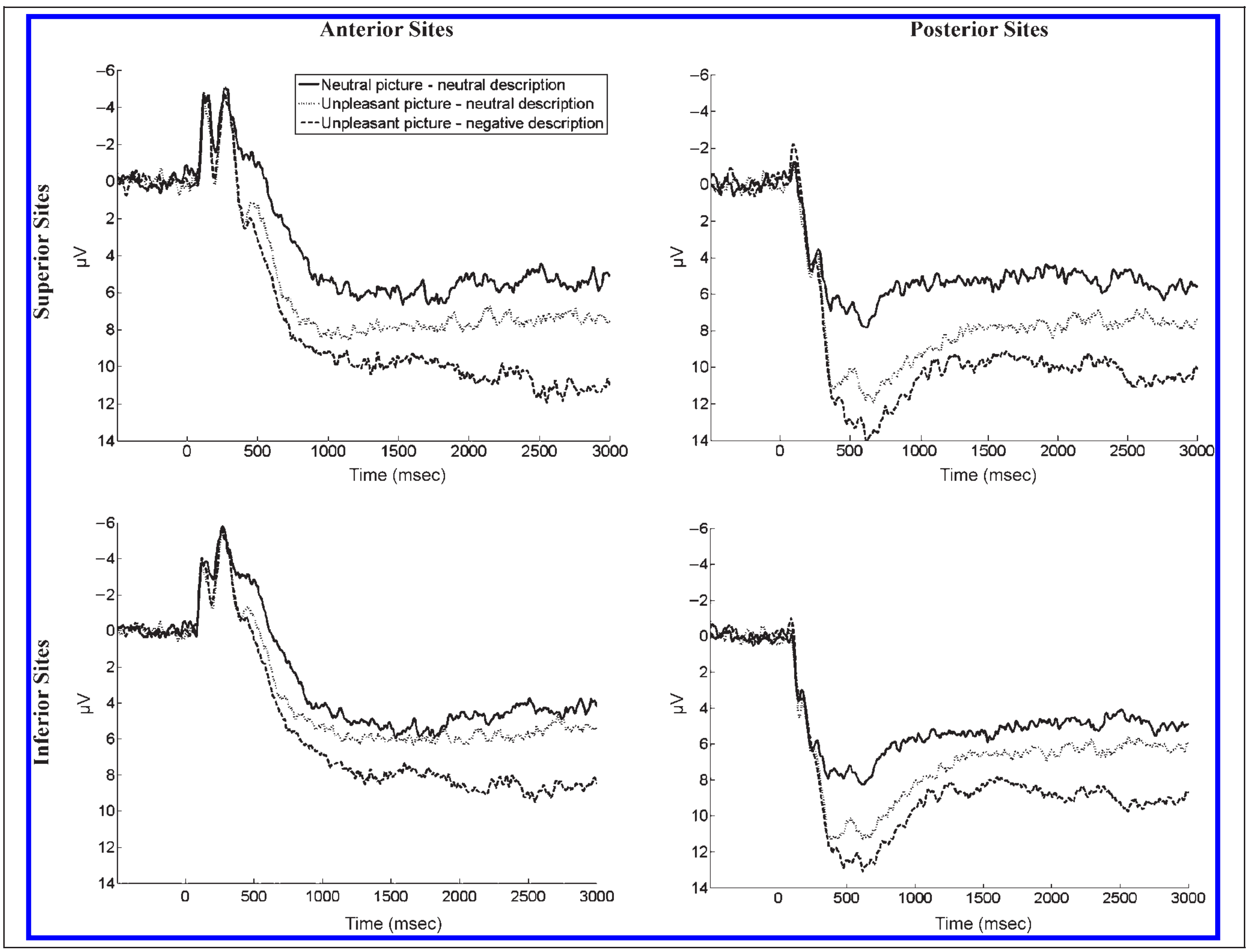

Figure 3. ERPs in all three conditions at anterior–superior (top, left), anterior–inferior (bottom, left), posterior–superior (top, right), and posterior–inferior (bottom, right) electrode clusters collapsing across hemisphere. Picture onset occurred at 0 msec.

in fact, the difference between superior and inferior sites was largest at posterior sites [$F(1, 25) = 23.28$, $p < .001$]. Importantly, the LPP also varied as a function of condition [$F(2, 50) = 26.74$, $p < .001$], which was qualified by interactions between condition and the inferior–superior [$F(2, 50) = 29.57$, $p < .001$] and anterior–posterior [$F(2, 50) = 9.41$, $p < .001$] locations. The LPP did not vary by hemisphere [$F(1, 25) < 1$], and all other two-, three-, and four-way interactions did not reach significance (all ps > .15).

Post hoc analyses confirmed that condition reliably influenced the magnitude of the LPP at both anterior [$F(2, 50) = 14.19$, $p < .001$] and posterior [$F(2, 50) = 38.71$, $p < .001$] recording sites. Post hoc comparisons at posterior sites confirmed that the LPP was larger for unpleasant pictures following negative descriptions compared to both neutral pictures [$t(25) = 8.52$, $p < .001$] and unpleasant pictures following a neutral description [$t(25) = 2.94$, $p < .01$]; the LPP elicited by unpleasant pictures following a neutral description was also larger than the LPP observed on neutral pictures [$t(25) = 5.55$, $p < .001$]. At anterior sites, unpleasant pictures described negatively and neutrally had larger LPPs than neutral pictures [$t(25) = 4.84$, $p < .001$ and $t(25) = 3.24$, $p < .01$, respectively]; however, unpleasant pictures described negatively did not differ from unpleasant pictures described neutrally after Bonferroni correction [$t(25) = 2.10$, $p = .05$, critical p value = .017 for three contrasts].

Similar post hoc comparisons indicated that condition influenced the LPP at both inferior [$F(2, 50) = 20.26$, $p < .001$] and superior [$F(2, 50) = 30.95$, $p < .001$] recording sites. Paired-samples t tests at superior sites revealed a pattern of results identical to that found at posterior recording sites: Neutral images had smaller LPPs than unpleasant pictures described negatively [$t(25) = 6.85$, $p < .001$] and unpleasant pictures described neutrally [$t(25) = 5.05$, $p < .001$]; additionally, unpleasant images described negatively differed from unpleasant pictures described neutrally [$t(25) = 2.93$, $p < .01$]. The pattern of results at inferior sites was identical to what was obtained at anterior sites: Unpleasant pictures (described both negatively and neutrally) had larger LPPs than neutral pictures [$t(25) = 6.45$, $p < .001$ and $t(25) = 3.70$, $p < .001$, respectively], however, the LPP did not differ between the unpleasant picture conditions after Bonferroni correction [$t(25) = 2.39$, $p = .02$, critical p value = .017].

Overall then, consistent with the impression from Figure 3, the LPP in the early window was larger following the presentation of unpleasant compared to neutral pictures, regardless of the preceding description at anterior, posterior, inferior, and superior recording sites. Additionally, the LPP elicited by unpleasant pictures was larger when preceded by negative compared to more neutral descriptions at posterior and superior recording sites. These results are consistent with the scalp distribution of the unpleasant minus neutral and unpleasant (negative description) minus unpleasant (neutral description) differences in the early window, presented in Figure 4 (top): Both differences revealed a positive difference that was maximal at posterior-superior recording sites, as has been consistently found in other LPP studies (Hajcak & Nieuwenhuis, 2006; Moser et al., 2006; Schupp et al., 2000, 2004; Cuthbert et al., 2000).

To further examine the timing of these effects, the LPP was divided into three 200-msec windows (400–600, 600–800, and 800–1000 msec poststimulus onset) at superior–posterior sites, where condition effects were maximal. A 3 (condition) × 3 (segment) repeated measures ANOVA was performed. As expected, a significant main effect of condition was found [$F(2, 50) = 44.60$, $p < .001$], as was a main effect of segment [$F(2, 50) = 5.74$, $p < .05$]. The interaction between condition and segment, however, was not significant ($p > .50$). Post hoc paired-sample t tests demonstrated that the overall magnitude of

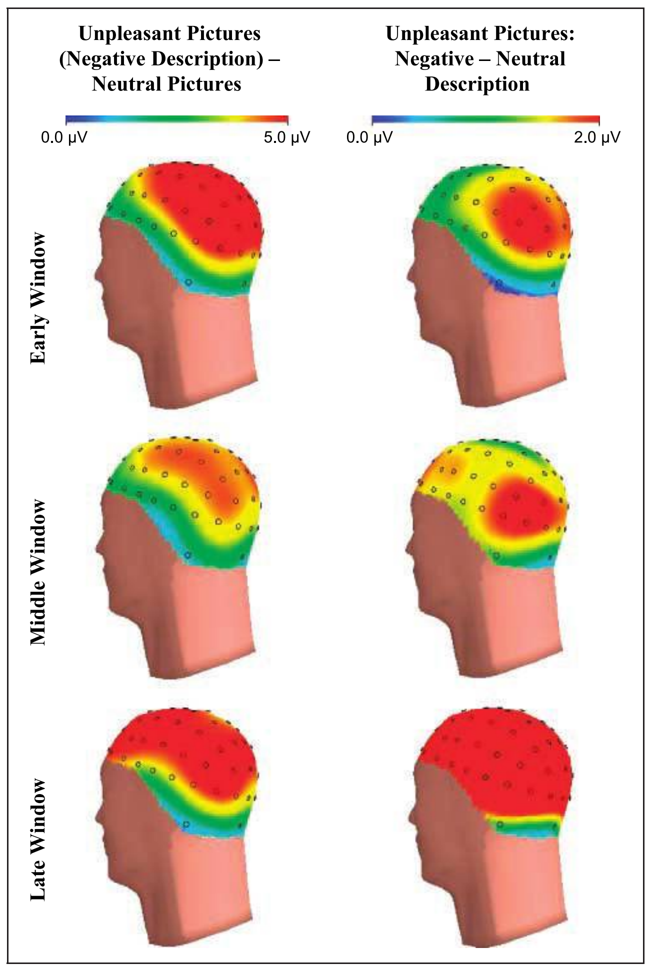

Figure 4. Scalp topography of the difference between unpleasant pictures following a negative description and neutral pictures (left) as well as the difference between unpleasant pictures that followed both negative and neutral descriptions (right) in the early (top), middle (middle), and late (bottom) windows.

the LPP (averaged across condition) was larger in the 600–800 msec segment than in the 800–1000 msec segment [$t(25) = 4.32$, $p < .001$], but neither of the other two contrasts reached significance (both *p*s > .05). Thus, the pattern of results for condition at superior–posterior clusters obtained above did not vary as a function of time across the early window.

LPP: Middle Window (1000–2000 msec)

In the middle window, the overall magnitude of the LPP (collapsed across condition) was again larger at superior than inferior recording sites [$F(1, 25) = 13.39$, $p < .001$], and did not vary by hemisphere [$F(1, 25) < 1$]. The LPP in the middle window was comparable between anterior and posterior recording sites [$F(1, 25) < 1$]. As in the early window, the LPP was modulated by condition [$F(2, 50) = 8.40$, $p < .001$], and the influence of condition varied by superior–inferior sites [$F(2, 50) = 9.00$, $p < .001$]. All other interaction terms did not reach significance (*p*s > .10).

Post hoc analyses indicated a main effect of condition at both superior [$F(1, 50) = 9.69$, $p < .001$] and inferior [$F(1, 50) = 6.68$, $p < .01$] electrode clusters. Paired-sample *t* tests confirmed that at both superior and inferior recording sites, the only reliable difference in LPP magnitude was between neutral pictures and unpleasant pictures preceded by a negative description [$t(25) = 3.98$, $p < .001$ and $t(25) = 3.49$, $p < .001$, respectively]. Unpleasant pictures that were preceded by a neutral description no longer elicited a reliably larger LPP than neutral pictures, at both superior and inferior sites [$t(25) = 2.48$, $p = .02$ and $t(25) = 1.39$, $p > .15$, respectively, critical *p* value = .017]. Although the LPP to unpleasant pictures described neutrally was reduced compared to unpleasant pictures described negatively at both superior and inferior sites, this difference was not reliable [$t(25) = 2.15$, $p = .04$, and $t(25) = 2.35$, $p = .03$, respectively, critical *p* value = .017]. As can be seen in Figures 3 and 4, during the middle window (1000–2000 msec after stimulus onset), the difference between neutral pictures and unpleasant pictures preceded by a negative description was evident at all recording clusters; in this window, however, the LPP elicited by unpleasant pictures preceded by neutral descriptions no longer differed from that observed following neutral pictures. In addition, unlike the early window, the LPP enhancement for unpleasant pictures described negatively was also more broadly distributed and was not confined to only superior–posterior recording sites.

To assess the timing of these results, the LPP was scored at all superior recording sites, where condition effects were maximal, and divided into five equal segments (1000–1200, 1200–1400, 1400–1600, 1600–1800, and 1800–2000 msec). A 3 (condition) × 5 (segment) repeated measures ANOVA was performed. As expected, a main effect of condition was found [$F(2, 50) = 9.68$, $p < .001$], but neither the main effect of segment ($p > .40$) nor the interaction between segment and condition ($p > .60$) reached significance. This suggests that neither the overall magnitude of the LPP nor the effects of condition varied across time in the middle window.

LPP: Late Window (2000–3000 msec)

In the late window, analyses revealed a pattern of results similar to that obtained in the middle window, with the important difference that LPPs to unpleasant pictures described neutrally were now significantly reduced compared to unpleasant pictures described negatively. As in the middle window, the overall magnitude of the LPP (collapsed across condition) was larger at superior than inferior recording sites [$F(1, 25) = 11.84$, $p < .001$], but did not vary by hemisphere [$F(1, 25) < 1$] or between anterior and posterior sites [$F(1, 25) < 1$]. Condition modulated the amplitude of the LPP [$F(2, 50) = 15.22$, $p < .001$], and interacted with the inferior–superior electrode clusters [$F(2, 50) = 4.62$, $p < .05$]. No other interaction term reached significance (*p*s > .15).

At both superior [$F(2, 50) = 15.26$, $p < .001$] and inferior [$F(2, 50) = 14.14$, $p < .001$] electrode clusters, condition modulated the LPP. Paired-sample *t* tests at superior sites confirmed that unpleasant pictures preceded by a negative description were characterized by larger LPPs than both neutral pictures [$t(25) = 5.44$, $p < .001$] and unpleasant pictures preceded by more neutral descriptions [$t(25) = 3.11$, $p < .01$]; additionally, neutral and unpleasant preceded by neutral descriptions did not differ from one another after Bonferroni correction [$t(25) = 2.36$, $p = .03$, critical *p* value = .017]. Similarly, at inferior sites, unpleasant pictures preceded by neutral descriptions no longer differed from neutral pictures [$t(25) = 1.91$, $p > .05$], but both were characterized by LPPs that were smaller than unpleasant pictures that were described negatively [$t(25) = 3.27$, $p < .01$ and $t(25) = 4.92$, $p < .001$, respectively]. Like the middle window, then, LPPs differed between unpleasant and neutral images, but only when the unpleasant picture was described negatively; unpleasant pictures that were described more neutrally no longer differed from neutral pictures, and were characterized by a reliably smaller LPP than unpleasant pictures described negatively. Finally, as in the middle window, the LPP enhancement for unpleasant pictures described negatively was found to be broadly distributed and not confined to superior–posterior recording sites.

To assess for effects of time, the LPP was scored at superior sites, the late window was divided into five equal segments (2000–2200, 2200–2400, 2400–2600, 2600–2800, and 2800–3000 msec), and a 3 (condition) × 5 (segment) repeated measures ANOVA was performed. As expected, a main effect of condition was found [$F(2, 50) = 15.27$, $p < .001$], but neither the main effect of segment ($p > .60$) nor the interaction between condition and segment ($p > .25$) reached significance. As found for the middle window, this suggests that neither the overall magnitude of the LPP nor the effects of condition varied across time in the late window.

The LPP and Self-report Ratings

To determine whether the regulatory effects of narrative type on self-report ratings of valence and arousal related to differences in LPP magnitude, bivariate correlations were performed. The LPP was scored at superior–posterior recording sites in the early window and at all superior sites in the middle and late windows, and the difference between the LPP after negatively described and neutrally described unpleasant pictures was calculated. The analogous differences for valence and arousal self-report ratings were also calculated. Neither arousal differences nor valence differences were significantly predictive of LPP shifts by narrative type (all ps $> .20$).[1]

DISCUSSION

Although numerous studies have demonstrated the effectiveness of reappraisal as an emotion regulation technique using both fMRI (Phan et al., 2005; Levesque et al., 2003; Ochsner et al., 2002; Jackson et al., 2000) and ERPs (Hajcak & Nieuwenhuis, 2006; Moser et al., 2006), the underlying mechanisms of reappraisal have yet to be directly examined. In previous studies, subjects have typically been asked to generate their own alternative interpretations after viewing an emotional stimulus, an experimental manipulation which leaves open two important questions: (a) whether the shift in narrative is responsible for subsequent changes in brain activity, rather than increased task difficulty or some other cognitive process; and (b) whether narratives are capable of influencing the response upon first viewing emotional stimuli.

Our electrophysiological measures of emotion intensity provided evidence that changes in narrative are sufficient to induce modulations in the LPP. In the early time window, unpleasant pictures described neutrally were associated with reduced LPPs as compared with unpleasant pictures described negatively at posterior–superior recording sites, and this difference was prominent at both superior and inferior recording sites in the late window. In addition, unpleasant pictures preceded by neutral descriptions were associated with enhanced LPPs as compared with neutral pictures in the early time window, but this difference was no longer present during the middle and late time windows; that is, 1000 msec after stimulus onset, the pattern of brain activity associated with unpleasant pictures preceded by neutral descriptions was no longer consistently distinguishable from that associated with neutral pictures. These results are in agreement with previous ERP studies (Hajcak & Nieuwenhuis, 2006; Moser et al., 2006) and suggest that the shift in narrative could be directly responsible for the changes in brain activity found to occur during reappraisal.

Previous fMRI studies have demonstrated that assigning labels to emotionally arousing stimuli can be used to decrease amygdala activity (Lieberman, Hariri, Jarcho, Eisenberger, & Bookheimer, 2005; Hariri, Mattay, Tessitore, Fera, & Weinberger, 2003). Using ERPs, Hajcak, Moser, and Simons (2006) found that labeling pictures in terms of a nonaffective dimension reduced the LPP compared to labeling them along an affective dimension. The present findings build upon this earlier work and demonstrate that, when interpreting an emotional stimulus, the mere presence of a description is not sufficient for down-regulating emotion; rather, it is the nature of that description that determines its regulatory potential.

In addition to changes in the LPP, differences in early, attention-related components were also found. The posterior N1 (50–150 msec peak) was enhanced for negatively described unpleasant pictures, as compared to both neutrally described unpleasant pictures and neutral pictures. This suggests that there was an early effect of narrative type, facilitating subjects' attention toward upcoming stimuli that were known to be unpleasant in nature. This can be contrasted with the frontal P2 (150–250 msec peak), which was found to be sensitive not to narrative but to emotion, with all unpleasant pictures associated with enhanced P2s compared to neutral pictures. It appears that attention may be driving the earliest processes, as indexed by the N1, followed soon after by early emotional responses that appears to be automatic and insensitive to reappraisal. It is not until approximately 300 to 400 msec later that the narratives appear to modulate the effect of emotion on ERPs.

Although ERPs have only limited spatial resolution, the temporal nature of these results suggests that there may be multiple neural systems relevant to reappraisal, including an early pathway between the amygdala and the visual cortex (Sabatinelli et al., 2007; Phan et al., 2005; Levesque et al., 2003; Ochsner et al., 2002), as well as a later pathway which incorporates the influence of the lateral and ventromedial prefrontal cortex (Urry et al., 2006; Ochsner et al., 2004). It is also worth noting that the LPP, in general, appeared to become more frontally distributed over time, with the enhancement effects of emotion beginning in posterior–superior sites (early window) and then spreading to include all superior sites (middle and late windows). Such a shift may be important for constructing neural models to better represent both emotional processing and regulation.

Analysis of self-report ratings generally fit well with the ERP findings. Specifically, unpleasant pictures preceded by relatively neutral descriptions were found to be more unpleasant and more arousing than neutral pictures, but they were also less unpleasant and less arousing than unpleasant pictures preceded by negative descriptions. As hypothesized, this pattern provides evidence for a direct effect of narrative on multiple responses to emotional stimuli. However, it should be noted that the changes in self-report ratings across conditions were not significantly correlated with shifts in the LPP across subjects; it will be important for future studies to further consider the relationship between ERP and self-report measures in the context of emotion regulation.

The fact that each description was given before subjects viewed the corresponding picture also demonstrates the potential for specific narratives to influence *the initial* processing of emotional stimuli—not just processing following reappraisal. One possible interpretation of these results is that the descriptions that subjects were given altered their expectations about the upcoming pictures, which in turn modulated their emotional response. Conscious adjustment of expectations about stimuli may then represent a powerful antecedent-focused strategy for the cognitive control of emotion. In this regard, we may have been tapping into the *controlled generation* of emotional responses, as opposed to the *controlled regulation* that is thought to underlie the strategy of reappraisal (Ochsner & Gross, 2005). Another view of emotion regulation, however, posits that all emotional responses are regulated in some fashion, and that a more appropriate question may not be whether regulation occurs but rather what type of regulation and to what degree (Gross & Thompson, 2007). We are currently conducting follow-up studies to isolate the effects of expectations about stimuli on subsequent emotional responses.

If narrative shift is a relevant mechanism in the emotion regulation strategy of reappraisal, this would indicate that various antecedent-focused strategies may operate through unique mechanisms and not a single, broad cognitive process. Indeed, one fMRI study directly comparing the strategies of detachment and reappraisal found distinct patterns of activation in the medial and lateral prefrontal regions, respectively (Ochsner et al., 2004). Future work might focus on identifying the relevant mechanisms for other emotion regulation strategies, with the ultimate goal of being able to distinguish between strategies and to specify the contexts in which each would be most appropriate.

Another remaining question is the degree to which reappraisal can be used to enhance or up-regulate emotional responses. Although fMRI evidence suggests that instructions to enhance can increase both amygdala activity and subjective ratings of stimuli (Kim & Hamann, 2007; Urry et al., 2006; Ochsner et al., 2004), at least one ERP study has failed to find the LPP to be sensitive to enhancement effects (Moser et al., 2006). In the current study, although the negative narratives to unpleasant stimuli were designed primarily to be descriptive, it is possible that these narratives may have actually enhanced subjects' emotional and electrocortical responses. This could be directly assessed in future studies by including irrelevant narratives to unpleasant stimuli or by comparing responses to stimuli in which there was no narrative at all.

In sum, the present study provides further evidence that reappraisal is a viable strategy of emotion regulation by demonstrating that descriptions of stimuli are capable of influencing both patterns of brain activity and self-reports of emotional experiencing. We found that unpleasant pictures preceded by neutral descriptions were associated with reduced electrophysiological activity as compared with negative descriptions—a difference evident beginning 400 msec after stimulus onset. Further, we found that activity associated with unpleasant pictures preceded by neutral descriptions was not consistently distinguishable from activity associated with neutral pictures 1000 msec after picture presentation. The type of description was also found to influence ratings of valence and arousal, with unpleasant pictures preceded by neutral descriptions being reported as less unpleasant and less arousing than those with negative descriptions. Future studies will be needed to determine how this effect of narrative shift distinguishes reappraisal from other emotion regulation strategies, as well as disentangling the effects of expectations on emotional experiencing.

APPENDIX A

IAPS Numbers and Corresponding Descriptions for Unpleasant Pictures

IAPS #	*Negative Description*	*Neutral Description*
1050	This poisonous snake is about to attack.	This snake is harmless and is in a zoo exhibit.
1201	A poisonous tarantula is about to bite this man.	This is a harmless pet tarantula sitting on his owner's shoulder.
1302	This is an angry attack dog trained to bite strangers.	This is a dog that has been trained to show its teeth on command.
1930	This is a shark that attacked and killed a diver.	This is the mechanical shark from the movie "Jaws."
2120	This is a violent and angry man.	This man has just held his breath for 2 minutes.
2130	This angry woman is yelling at her children.	This woman is about to sneeze.
2141	This woman has just found her mother dead.	These are actresses in a movie called "The Funeral."

APPENDIX A *(continued)*

IAPS #	*Negative Description*	*Neutral Description*
2205	This man has just lost his wife to cancer.	This man's wife was ill but is fully recovering.
2399	This woman suffers from intense migraine headaches.	This is an actress posing for an aspirin commercial.
2661	This premature baby may not live more than a couple of days.	Thanks to early care, this baby develops into a healthy toddler.
2683	This is a bloody clash between soldiers and protestors.	These are actors in a movie about tension in the Middle East.
2688	The poacher is shooting the bear to sell its fur.	A vet is tranquilizing this bear to give him medicine.
2691	This is a protester during a riot where 50 people were killed.	This is a scene from a movie about a riot in the Middle East.
2700	These women are mourning the loss of their close friend.	These women are overwhelmed with joy at a friend's wedding.
2710	This man was found dead from an overdose in a halfway house.	This is an actor from the 1970s film called ''Drug Smuggle.''
2716	This man is addicted to crack cocaine.	This man is an actor in a movie about addiction.
2750	This is a homeless man who lives under a bridge in London.	This is an actor who is playing the role of a homeless man.
2810	This boy suffers from intense anger problems.	This boy is yelling ''Ready or not, here I come.''
3168	This man suffers from a number of deformities from birth.	The costume worn in this horror film won an Academy Award in 1982.
3220	This man is dying in a hospital.	This man is recovering from illness in a hospital.
3301	This child was severely injured in a car accident.	This child was injured but makes a full recovery.
6020	This is an electric chair used to execute prisoners on death row.	This is a prop from a movie about a man who is on death row.
6190	This woman is about to pull the trigger on her husband.	This is a picture from a training video on gun safety.
6212	This child is about to be shot and killed by a solider.	This solider notices the child and does not shoot.
6250	This is a serial killer who has murdered 6 people.	This is a poster for an upcoming action movie.
6312	This woman is being abducted by a rapist.	This is an actress in a self-defense training video.
6313	This man has attacked and mugged this woman.	This woman is in a scene from a TV show about inner-city violence.
6570.1	This man is about to commit suicide.	This man ends up not committing suicide.
6571	This man is having his car stolen by a thief.	This is a scene from a movie about an undercover cop.
6830	This man is preparing to rob a bank.	This is an actor in bank robbery film.
6831	This is a police officer investigating the scene of a murder.	This is the set of a 1960s crime show.
8230	This boxer is being sent into a coma.	This is a scene from the movie about boxing.
9042	This man has been punished by his tribe.	This tradition is a rite of passage and is actually not painful.
9050	This is a terrible plane crash in which many people were killed.	This plane veered off the runway, but no one was seriously hurt.
9250	These workers have found a war victim.	These doctors will save the woman's life.
9400	This solider was killed in Vietnam.	This is a scene from a movie about Vietnam.
9421	This solider has just lost his best friend in an attack.	This solider is on his way to receive medical attention.
9425	This man has just been taken hostage by terrorists.	This is a scene from a movie called ''The Terrorists.''
9470	This building was bombed and 6 people were killed.	This building was condemned and is being demolished.
9490	This man was burned alive in an explosion.	This is a prop from a monster film.
9520	These abandoned children are near a nuclear reactor.	These children are actors in a movie about poverty.
9584	This man is undergoing painful dental surgery.	The man is having a routine dental checkup.

APPENDIX A (*continued*)

IAPS #	Negative Description	Neutral Description
9600	This ship sinks and no one survives.	This is a scene from a movie much like "Titanic."
9611	All passengers were killed in this plane crash.	This fake plane crash was put together for a movie.
9635.1	This man was set on fire during a civil war.	This daredevil sets himself on fire as a stunt.
9800	This is a photo of a German Nazi.	This is an actor in a movie about neo-Nazis.
9901	The victims in this accident could not be saved in time.	No one was in this car when it was totaled at a construction site.
9911	The driver in this accident was killed before help could arrive.	This is contrived scene from an educational film about drunk driving.
9920	Two people died in this horrendous car crash.	No one was seriously injured in this car accident.
9921	The firefighters do not save this woman in time.	The firefighters get this woman to safety just in time.

APPENDIX B

IAPS Numbers and Corresponding Descriptions for Neutral Pictures

IAPS #	Neutral Description
2102	This man reads the stock report every morning.
2393	These workers are checking the settings of a complicated machine.
2575	This propeller will be used on a small cargo ship.
2580	These men play chess three times a week.
2593	This café has outdoor seating.
5530	This is an edible mushroom.
5740	This plant is common to the northern United States.
7002	This towel was used to clean the floor.
7004	This spoon is from a 1970s collection.
7010	This woven basket was made to hold fruit.
7056	This wire cutter has many settings.
7090	This book was written in 1950.
7130	This truck has been used by five different companies.
7140	This bus travels a route from Boston to Atlanta.
7150	This is a blue umbrella.
7175	This lamp takes a 60-Watt bulb.
7211	This clock is in the lobby of an office building.
7217	This coat rack is used by three people.
7491	This building was used in a TV sitcom.
7500	This is the office of a large law firm.
7550	This man is working on an old engineering program.
7595	These types of cars were popular in the 1970s.
7700	This is a poster from a work-training video.
7705	This cabinet can hold up to 500 file folders.
7950	These tissues sell for 99 cents.

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Note

1. All 26 subjects demonstrated the predicted shift in valence ratings (i.e., rating unpleasant pictures preceded by neutral stories as less negative than those preceded by negative stories), and 25 subjects demonstrated the predicted shift in arousal ratings (with the 26th subject giving both types of pictures equivalent ratings). On the other hand, the predicted LPP shift by narrative type was evident in 19 subjects in the early window, 15 in the middle window, and 20 in the late window. Future studies could investigate individual differences to identify possible moderators and better explain why the shift in self-report ratings was more consistent across subjects than the shift in the LPP.

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