Psychophysiology, 46 (2009), 28–33. Wiley Periodicals, Inc. Printed in the USA.

DOI: 10.1111/j.1469-8986.2008.00723.x

See no evil: Directing visual attention within unpleasant images modulates the electrocortical response

JONATHAN P. DUNNING AND GREG HAJCAK

Abstract

The late positive potential (LPP) is larger for emotional than neutral stimuli, and reflects increased attention to motivationally salient stimuli. Recent studies have shown that the LPP can also be modulated by stimulus meaning and task relevance. The present studies sought to determine whether the magnitude of the LPP can be manipulated by directing attention to more or less arousing aspects *within* an emotional stimulus. To this end, trials included a passive viewing and directed attention portion. In both Studies 1 and 2, unpleasant compared to neutral images were associated with an increased LPP during passive viewing; additionally, directing attention to non-arousing compared to highly arousing areas of unpleasant images resulted in a decreased LPP. Results are discussed in terms of the utility of using the LPP to understand emotion–cognition interactions, especially with regard to directed visual attention as an emotion regulation strategy.

Descriptors: Attention, Emotion, LPP, ERP, IAPS

Emotional compared to affectively neutral stimuli are more likely to capture and sustain attention (Lang, Bradley, & Cuthbert, 1997; Schupp et al., 2007; Vuilleumier, 2005). Due to their remarkable temporal resolution, event-related potentials (ERPs) are increasingly being used to investigate attentional processing in the context of emotion. For instance, several studies have examined the late positive potential (LPP) as a dependent measure of attention to emotional stimuli. The LPP is a sustained positive deflection in the ERP that begins approximately 250 ms after stimulus onset and is more pronounced for both pleasant and unpleasant compared to neutral visual stimuli (Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000; Schupp et al., 2000; Schupp, Junghofer, Weike, & Hamm, 2004). The LPP is believed to reflect increased attention to, and facilitated processing of, motivationally relevant stimuli (Schupp et al., 2000; Schupp, Junghofer, Weike, & Hamm, 2003). Just as the P300 is larger for attended compared to unattended stimuli, the increased LPP appears to reflect increased attention to emotional stimuli. The notion that emotional stimuli might automatically capture attention has been referred to as "motivated attention" (Lang et al., 1997).

Several recent studies have begun to examine how motivated attention interacts with more "top down"—and controlled—information processing. For instance, when emotional and neutral pictures served as targets in a rapid viewing task, the P300 was enhanced when targets were emotional compared to non-emotional (Schupp et al., 2007). Other studies have examined whether the LPP is sensitive to emotion regulation instructions. In particular, paradigms that utilize voluntary suppression (Moser, Hajcak, Bukay, & Simons, 2006) and reappraisal instructions (Hajcak & Nieuwenhuis, 2006) report a decreased magnitude of the LPP to unpleasant pictures. A recent study found that when unpleasant pictures were described in more neutral than negative terms prior to picture presentation, the LPP was also reduced (Foti & Hajcak, 2008). Finally, using a manipulation similar to Hariri, Mattay, Tessitore, Fera, and Weinberger (2003) and Keightley et al. (2003), Hajcak and colleagues (2006) found that evaluating pleasant and unpleasant pictures along a nonaffective dimension resulted in a reliably reduced LPP. Collectively, these results indicate that the emotional modulation of the LPP is responsive to manipulations of stimuli relevance and meaning and can be used to study processes relevant to emotion regulation.

Functional neuroimaging studies have begun to explicate the neural architecture supporting the modulation of responses to emotional stimuli through emotion regulation (for a review, see Ochsner & Gross, 2005). Specifically, cognitive change techniques such as reappraisal result in decreased amygdala activation and increased lateral and medial prefrontal activation (Ochsner, Bunge, Gross, & Gabrieli, 2002; Ochsner et al., 2004; Phan et al., 2005). Along similar lines, Hariri et al. (2003) and Keightley et al. (2003) found reduced activity in the amygdala and visual cortex when participants made nonaffective judgments about unpleasant pictures. Overall, then, the cognitive control of emotion appears to depend on activation of prefrontal control regions and the deactivation of emotion-related regions, including the amygdala.

Using a novel approach to shed light on potential mechanisms of these emotion regulation effects, van Reekum and colleagues (2007) measured patterns of gaze fixation after participants were

---

Address reprint requests to: Greg Hajcak, Department of Psychology, Stony Brook University, Stony Brook, NY 11794-2500, USA. E-mail: greg.hajcak@stonybrook.edu

instructed to increase or decrease their emotional response to affective images in a recent fMRI investigation. In line with previous research, emotion regulation was associated with neural activation in the prefrontal cortex and amygdala. Importantly, when instructed to decrease negative emotion, participants directed their visual attention to irrelevant or non-emotional areas of the picture; these gaze fixations accounted for a significant amount of variance in brain areas responsive to the regulation instruction (van Reekum et al., 2007). Consequently, van Reekum and colleagues emphasized the importance of *where* participants fixate and attend following emotion regulation instructions.

If the LPP indexes increased motivated attention to emotional compared to neutral stimuli and is also sensitive to top-down attentional control, it stands to reason that directing attention to arousing compared to non-arousing aspects of the *same* emotional stimuli might dynamically influence its amplitude. Based on the work by van Reekum and colleagues (2007), the present studies sought to determine whether directing participants' visual attention to certain areas within unpleasant pictures could modulate the amplitude of the LPP. Participants were shown neutral and unpleasant pictures for 6000 ms while their EEG was recorded. During the first half of each trial in Study 1, participants' visual attention was directed to specific areas of the picture; at that point, participants were able to freely view the picture for the remainder of the trial. Fifty percent of the unpleasant pictures had attention directed to highly arousing areas, whereas the other 50% had attention directed to non-arousing areas. All neutral pictures had attention directed to non-arousing locations.

To determine whether responses to unpleasant images might differ depending on the time point at which attention is directed, a second study was conducted in which participants freely viewed images for the first half of each trial, and then visual attention was directed for the remainder of the trial. Study 1 and Study 2 were identical except for the reversed order of the directed attention and passive viewing conditions. We hypothesized that unpleasant compared to neutral pictures would elicit a more pronounced LPP during passive viewing, and that the LPP would be reduced when attention was directed to non-arousing compared to highly arousing areas of unpleasant pictures.

STUDY 1

Method

Participants

Twenty-eight undergraduates (18 women, 10 men) participated in Study 1, none of whom withdrew from the experiment once it had begun. Four participants' data were excluded due to poor quality physiological recordings (excessive EEG artifacts), leaving 24 participants (16 women, 8 men) to be included in analyses. All participants received course credit for their participation in the study. This research was approved by the Stony Brook University Institutional Review Board.

Stimuli

A total of 60 pictures were selected from the International Affective Picture System (IAPS; Lang, Bradley & Cuthbert, 2005); of these, 40 depicted unpleasant scenes (e.g., sad faces, violent images) and 20 depicted neutral scenes (e.g., neutral faces, household objects).[1] The two categories differed on normative ratings of valence ($M = 2.09$, $SD = 0.41$, for unpleasant pictures; $M = 5.11$, $SD = 0.50$, for neutral pictures) $t(58) = -24.84$, $p < .001$; additionally, the unpleasant pictures were higher on normative arousal ratings ($M = 6.13$, $SD = 0.61$) than the neutral pictures ($M = 2.94$, $SD = 0.79$), $t(58) = 17.26$, $p < .001$.

To direct attention to a part of each picture, a transparent blue circle was placed over each IAPS image. For the neutral IAPS, a circle was placed on some neutral portion of each picture. However, each of the 40 unpleasant IAPS images was modified to create *both* a version with an arousing focus *and* a version with a non-arousing focus. Thus, for each unpleasant IAPS used, a circle was placed on an arousing area and a non-arousing area. Both the arousing and non-arousing conditions, therefore, used the exact same IAPS pictures—they simply differed according to which version of the pictures were selected. Significant effort was made to balance potential visual complexity differences within circles such that the non-arousing focused areas contained meaningful objects similar to the arousing focused areas of the same pictures. In other words, non-arousing areas of focus included objects for participants to look at and were not simply placed on irrelevant, empty background areas of the picture. As an example, in a picture with a man holding a gun to his head, the arousing focused circle was placed around the man's ear where the point of the gun touches his head. For the non-arousing version of the same picture, the non-arousing focused circle was placed on the man's other ear (where no gun was present).

The task was administered on a Pentium D class computer, using Presentation software (Neurobehavioral Systems, Inc., Albany, CA) to control the presentation and timing of all stimuli. Each picture was displayed in color 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 roughly 40° of visual angle horizontally and vertically. The blue circle used to direct attention during the first half of each trial measured approximately 3 in. in diameter (about 7° of visual angle).

Procedure

After a brief description of the experiment, electroencephalograph (EEG) sensors were attached and participants were given detailed task instructions. Participants were told that they would be viewing a series of pictures; a circle would be present on the picture for the first 3 s and then it would disappear for the last 3 s of each trial. Participants were instructed to focus their attention and look only at the area within the circle while it remained on the screen. Then, when the circle disappeared, participants were told that they could freely view the picture.

All participants performed three practice trials to ensure that they understood the instructions. A total of 60 trials were equally divided into four blocks, with breaks between each block. Of the 60 trials, 20 were neutral pictures and 40 were unpleasant pictures. For 20 of the unpleasant pictures, highly arousing areas were highlighted within the blue circle, whereas non-arousing areas were highlighted within the blue circle for the other 20

---

[1] The numbers of the IAPS pictures used were the following: unpleasant (1525, 2053, 2095, 2141, 2352.2, 2703, 2717, 2811, 3005.1, 3010, 3015, 3016, 3017, 3030, 3053, 3063, 3181, 3225, 3261, 3266, 3530, 6312, 6313, 6315, 6415, 6550, 6570.1, 6571, 6831, 9252, 9253, 9300, 9405, 9410, 9420, 9430, 9433, 9570, 9635.1, 9810) and neutral (2102, 2190, 2206, 2235, 2320, 2383, 2580, 2745.1, 2980, 5390, 5740, 7000, 7002, 7004, 7010, 7140, 7175, 7491, 7560, 7595).

unpleasant pictures. All participants viewed the same 60 IAPS pictures; importantly, unpleasant pictures were randomly assigned to either the arousing or non-arousing condition for each participant. The order of trials was also randomized for each participant. Each picture was presented for 6000 ms (3000 ms with the circle, 3000 ms without the circle), and a fixation mark (+) was presented for 2000 ms between each picture.

Psychophysiological Recording, Data Reduction, and Analysis

The continuous EEG was recorded using the ActiveTwo BioSemi system (BioSemi, Amsterdam, Netherlands). Recordings were taken from 64 scalp electrodes based on the 10/20 system. In addition, two electrodes were placed on the left and right mastoids (M1 and M2, respectively). The electrooculogram (EOG) generated from blinks and eye movement was recorded from four 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 designed by BioSemi, 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) and analyzed offline using Brain Vision Analyzer (Brain Products, Germany). The EEG was sampled at 512 Hz. Off-line, all data were rereferenced to the numeric mean of the mastoids and band-pass filtered between 0.1 and 30 Hz; the EEG was corrected for blinks and eye movements using the method developed by Gratton, Coles, and Donchin (1983). In addition, a semiautomated procedure was used to identify and reject physiological artifacts according to the following criteria: a voltage step of more than 50.0 μV between sample points, a voltage difference of more than 300.0 μV within a trial, and a maximum voltage difference of less than 0.50 μV within 100-ms intervals.

ERPs were constructed by separately averaging trials in the three conditions: neutral pictures, unpleasant pictures with attention directed to arousing foci, and unpleasant pictures with attention directed to non-arousing foci. For each ERP average, the average activity in the 200-ms window prior to picture onset served as the baseline. Based on previous research indicating that the LPP is typically maximal at posterior and parietal sites (Foti & Hajcak, 2008; Hajcak, Dunning, & Foti, 2007; Keil et al., 2002; Schupp et al., 2000), the LPP was scored as the average activity at Pz, P1, P2, and POz.

When attention was directed to specific portions of the pictures, the LPP was defined as the average activity in 1000–2000-ms (early) and 2000–3000-ms (late) windows. During passive viewing, the LPP was similarly defined as the average activity in 4000–5000-ms (early) and 5000–6000-ms (late) windows. The LPP was evaluated using a 3 (Trial Type: unpleasant pictures with an arousing focus, unpleasant pictures with a non-arousing focus, neutral pictures with a non-arousing focus) × 2 (Window) repeated-measures analysis of variance (ANOVA) during the directed attention portion of the trial; during passive viewing, the LPP was evaluated using a 2 (Trial Type: unpleasant, neutral) × 2 (Window) repeated-measures ANOVA. In all cases, the LPP was statistically evaluated using SPSS (Version 15.0) 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

The grand average ERPs elicited by each picture type are presented in Figure 1. When attention was directed to specific portions of the pictures, the LPP was larger in the early compared to late window, $F(1,23) = 6.35, p < .05$; additionally, the LPP varied as a function of Trial Type, $F(2,46) = 6.36$, $p < .01$, and Trial Type interacted with Window, $F(2,46) = 4.93, p < .05$. To further examine the effect of Trial Type, LPP amplitude was collapsed across Windows and submitted to post hoc paired samples *t* tests. Analyses revealed that the LPP elicited by unpleasant pictures with arousing foci ($M = -0.69$ μV, $SD = 2.89$ μV) was significantly larger than both neutral ($M = -2.79$ μV, $SD = 3.66$ μV) $t(23) = -3.15, p < .01$, and unpleasant images with a non-arousing focus ($M = -2.79$ μV, $SD = 3.41$ μV) $t(23) = 3.61, p < .005$. Importantly, the LPP elicited by neutral and non-arousing focused unpleasant images did not differ, $t(23) = -0.002, p > .90$. Consistent with the impression from Figure 1, directing participants' attention to non-arousing compared to arousing areas of unpleasant pictures resulted in a reduced LPP; in fact, the LPP for unpleasant pictures was similar to that elicited by neutral pictures when attention was directed to non-arousing foci.

To examine the interaction between Trial Type and Window, post hoc paired samples *t* tests were conducted to examine the effects of Trial Type separately at the early and late windows. In the early window (1000–2000 ms), analyses revealed that the LPP elicited by unpleasant pictures with arousing foci ($M = -0.03$ μV, $SD = 3.06$ μV) was significantly larger than both neutral pictures ($M = -2.72$ μV, $SD = 3.69$ μV) $t(23) = -3.80, p < .005$, and non-arousing focused unpleasant images ($M = -2.59$ μV, $SD = 3.07$ μV) $t(23) = 4.38$, $p < .001$; the LPP elicited by neutral and non-arousing focused unpleasant images did not differ, $t(23) = -0.19$, $p > .80$. In the late window (2000–3000 ms), a similar pattern emerged in that LPPs elicited by arousing focused unpleasant pictures ($M = -1.35$ μV, $SD = 2.96$ μV) were larger than non-arousing focused images ($M = -3.00$ μV, $SD = 3.96$ μV) $t(23) = 2.63, p < .05$. Furthermore, the LPPs elicited by non-arousing focused and neutral ($M = -2.86$ μV, $SD = 3.76$ μV) pictures did not differ, $t(23) = .15, p > .85$. However, unique to the second window, the difference between arousing focused unpleas-

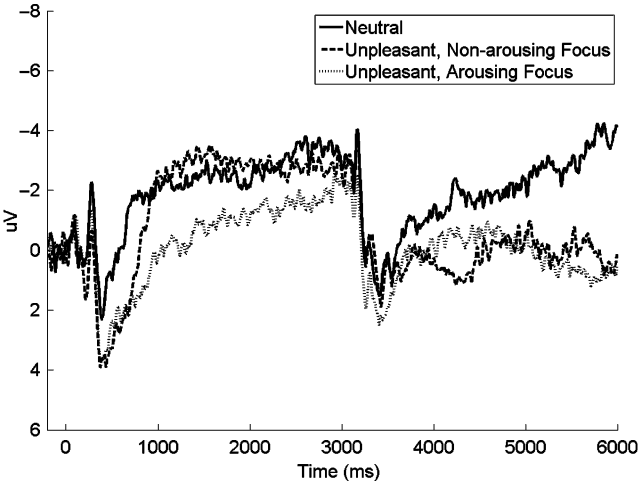

Figure 1. Grand averaged ERPs elicited by each picture type (neutral pictures, unpleasant pictures with non-arousing foci, and unpleasant pictures with highly arousing foci) in Study 1. Circle onset occurred at 0 ms.

ant and neutral pictures did not survive Bonferroni correction, $t(23) = -2.19$, $p < .05$. Taken together, and as evidenced by Figure 1, examination of the interaction revealed that the experimental effect of directed visual attention was more robust in the first window compared to the second.

Once attention was no longer directed toward arousing or non-arousing portions of unpleasant images (i.e., after circles were removed from pictures), analyses revealed a significant effect of Trial Type, $F(1,23) = 12.12$, $p < .005$, but not Window, $F(1,23) = 1.94$, $p > .15$. A significant interaction was also present, $F(1,23) = 13.09$, $p < .005$. To further examine this interaction, the LPP amplitude across Trial Type was examined in both Windows separately. Analyses revealed that in the first window (1000–2000 ms), the LPP was larger following unpleasant ($M = -0.20$ µV, $SD = 4.07$ µV) compared to neutral pictures ($M = -1.98$ µV, $SD = 3.75$ µV), $t(23) = -2.51$, $p < .05$. Similarly, in the second window (2000–3000 ms), unpleasant ($M = 0.04$ µV, $SD = 4.32$ µV) compared to neutral pictures ($M = -2.97$ µV, $SD = 3.60$ µV) also elicited larger LPPs, $t(23) = -4.26$, $p < .001$. Therefore, throughout passive viewing, unpleasant ($M = -0.08$ µV, $SD = 4.13$ µV) compared to neutral pictures ($M = -2.48$ µV, $SD = 3.58$ µV) elicited significantly larger LPPs; the interaction indicated that this difference was slightly greater in the second window compared to the first (see Figure 1).

Overall, findings from Study 1 indicated that directing participants' attention to non-arousing compared to arousing areas within unpleasant pictures resulted in a reduced LPP. When participants were allowed to freely view the images, unpleasant compared to neutral pictures elicited larger LPPs. To extend these results, we sought to determine whether the results from Study 1 would replicate if attention was directed *after* an initial passive viewing period. Thus, we wanted to examine whether the LPP could be modulated by a directed attention manipulation that followed passive viewing.

STUDY 2

Method

Participants

Seventeen undergraduates (10 women, 7 men) participated in the present study, none of whom withdrew from the experiment once it had begun. All participants received course credit for their participation in the study. This research was approved by the Stony Brook University Institutional Review Board.

Stimuli, Procedure, Data Reduction, and Analysis

The stimuli, procedures, and quantification and analyses of the LPP for Study 2 were identical to Study 1 with one exception: Participants were instructed to freely view the pictures for the *first* 3000 ms, and then participants' visual attention was directed for the *final* 3000 ms of each trial. In other words, the order of experimental conditions (passively viewing pictures compared to directed visual attention) was reversed.

Although the order of conditions was changed, we expected the same pattern of results to emerge in Study 2 as in Study 1. Therefore, we hypothesized a priori that directing attention to non-arousing compared to arousing areas of unpleasant images would elicit a reduced LPP. Similarly, during passive viewing, unpleasant compared to neutral pictures should elicit larger LPPs.

Results

The grand average ERPs elicited by each picture type in Study 2 are presented in Figure 2. During initial passive viewing, analyses revealed a significant effect of Trial Type, $F(1,16) = 13.55$, $p < .005$, and Window, $F(1,16) = 4.86$, $p < .05$, but not an interaction, $F(1,16) < 1$. Thus, when participants were freely viewing pictures, the LPP was larger following unpleasant ($M = 4.05$ µV, $SD = 3.92$ µV) compared to neutral pictures ($M = 0.74$ µV, $SD = 3.23$ µV) and was larger in the early ($M = 2.86$ µV, $SD = 2.80$ µV) compared to the later window ($M = 1.94$ µV, $SD = 3.54$ µV).

Once attention was directed toward arousing or non-arousing aspects of the pictures, analyses revealed a significant effect of Trial Type, $F(2,32) = 6.44$, $p < .05$, but not Window, $F(1,16) = 1.97$, $p > .15$, or an interaction between Trial Type and Window, $F(2,32) < 1$. To further examine the effect of Trial Type, LPP amplitude was collapsed across both windows and submitted to paired samples t tests. Analyses confirmed our a priori hypotheses such that the LPP elicited by unpleasant pictures with arousing foci ($M = 1.83$ µV, $SD = 6.50$ µV) was significantly larger than both neutral ($M = -3.05$ µV, $SD = 3.11$ µV) $t(16) = -3.27$, $p < .01$, and unpleasant pictures with a non-arousing foci ($M = -2.00$ µV, $SD = 5.14$ µV) $t(16) = 2.20$, $p < .05$. The LPP elicited by neutral and unpleasant images with a non-arousing focus did not differ from one another, $t(16) = -1.12$, $p > .25$. Taken together, these results replicate the findings of Study 1: LPP amplitude was reduced when directing visual attention to non-arousing compared to arousing areas of unpleasant pictures.[2]

Discussion

The present studies confirmed that directing participants' visual attention to arousing versus non-arousing portions within unpleasant images could modulate the LPP. In fact, in both studies, we found that directing participants' attention to non-arousing compared to arousing areas of unpleasant pictures resulted in a LPP similar in magnitude to that elicited by neutral pictures. Importantly, during passive viewing, unpleasant compared to neutral pictures elicited markedly larger LPPs. Thus, under normal passive viewing instructions, the increased LPP appears to reflect the relatively automatic increase in attention toward emotional stimuli—what has been referred to as motivated attention (Lang et al., 1997). However, the LPP was also sensitive to whether visual attention was directed toward more or less arousing portions of unpleasant stimuli—indicating that the LPP is also sensitive to more top-down, or controlled, processes such as directed attention. Insofar as the LPP elicited by unpleasant stimuli did not differ from the LPP elicited by neutral stimuli when attention was directed toward non-arousing foci, these results suggest that the effect of *motivated attention* can be overcome by *directed attention*.

---

[2] Although the attentional focus on unpleasant pictures was randomized for each participant, the LPP in Study 2 appeared somewhat smaller toward the end of the free-viewing condition that preceded non-arousing focused attention (i.e., the 2500–3000-ms window in Figure 2). To ensure that this was not accounting for our effect, we reanalyzed the LPP amplitude during the directed attention condition using a premanipulation baseline correction (defined as the average amplitude in the 2500–3000-ms window). Results still indicated that arousing focused pictures elicited larger LPPs ($M = -2.04$ µV, $SD = 3.66$ µV) than non-arousing focused pictures ($M = -4.30$ µV, $SD = 4.03$ µV) $t(16) = 2.11$, $p < .05$.

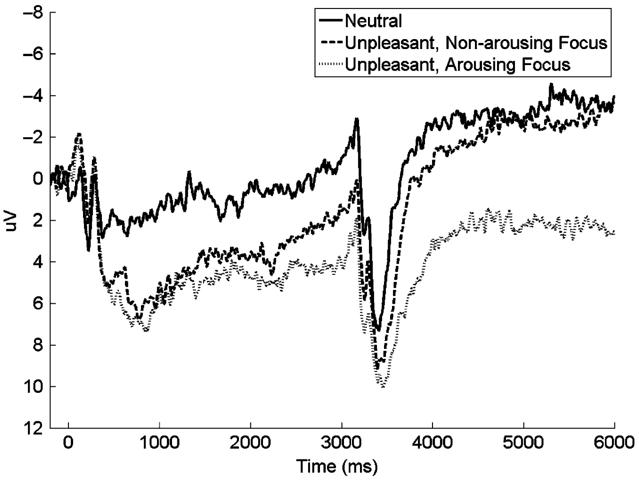

Figure 2. Grand averaged ERPs elicited by each picture type (neutral pictures, unpleasant pictures with non-arousing foci, and unpleasant pictures with highly arousing foci) in Study 2. Circle onset occurred at 3000 ms.

Although a previous report confirmed that the LPP elicited by emotional stimuli could be larger or smaller depending on whether stimuli were targets or not, respectively (Schupp et al., 2007), the current studies demonstrate that the LPP is also sensitive to directed visual attention *within* emotional stimuli. These results can be situated in the broader context of Gross' process model of emotion regulation, which highlights the relative effectiveness of antecedent-focused emotion regulation strategies such as attentional deployment and reappraisal (Gross & Thompson, 2007). In this context, the present studies indicate that the LPP is sensitive to the cognitive emotion regulation strategy of attentional deployment (Gross & Thompson, 2007). In fact, several recent studies have found that the LPP is sensitive to *other* cognitive-based regulation strategies such as reappraisal (Foti & Hajcak, 2008; Hajcak & Nieuwenhuis, 2006; Moser et al., 2006). Interestingly, one study also found that the LPP was not influenced by concurrent task difficulty (Hajcak et al., 2007). The current results, in conjunction with the aforementioned studies, imply that the LPP may be a useful tool in teasing apart the possible mechanisms responsible for successful emotion regulation, investigating the time course of emotion regulation, and identifying similarities and differences across emotion regulation strategies.

The current findings also dovetail nicely with van Reekum et al.'s (2007) study that demonstrated the importance of accounting for a participant's visual gaze following emotion regulation instructions. Van Reekum et al. (2007) suggested that successful modulation of emotion in previous ERP studies (Hajcak & Nieuwenhuis, 2006; Moser et al., 2006) may have been due to reduced viewing of arousing areas of affective stimuli. Explicitly testing this possibility, the current studies suggest that this may, in fact, be a central mechanism used by participants to modulate their emotional response. Based on this work, future research might continue pursuing the role of visual gaze and attentional deployment in emotion regulation across both ERP and functional imaging studies.

One limitation of the present investigation was that no independent behavioral or physiological measure was utilized to ensure task compliance. Further studies could use eye-tracking techniques to ensure that participants look at expected locations. Future investigations would also benefit from including a separate measure of affective responding or arousal, such as skin conductance, corrugator response, or emotion-modulated startle. Inclusion of such a measure could help delineate whether the LPP attenuation is driven more by a reduced emotional response, by reduced attention, or both.

It is likely that processes of cognitive reappraisal and attentional deployment are interwoven. For instance, previous studies have shown that reappraising, or changing the meaning of a stimulus, results in a reliably reduced LPP (Foti & Hajcak, 2008; Hajcak et al., 2006; Hajcak & Nieuwenhuis, 2006). Yet, as demonstrated by van Reekum and colleagues (2007), it is possible that participants may be using techniques such as attentional deployment as a means of reappraisal. The present research suggests that the LPP can also be modulated by directing visual attention toward or away from arousing areas of emotional pictures; however, it is possible that directing attention to more or less arousing areas of emotional pictures led to reappraisal-related changes in stimulus meaning. In other words, it is difficult to determine which process, or both, is responsible for modulation of the LPP—and teasing apart these mechanisms should be a primary focus of future investigations. As an example, future studies might combine ERP and eye tracking in the context of meaning-based manipulations (cf. Foti & Hajcak, 2008; Hajcak & Nieuwenhuis, 2006) to examine how (re)appraisal processes influence attentional focus.

From a broader perspective, a goal of the present studies was to demonstrate how the temporal resolution of ERPs can inform research on emotion regulation. It could be argued that by focusing on ERP waveforms that span several seconds (such as the LPP), the temporal resolution of ERPs is compromised. However, the manipulation used in Study 1 provides insight regarding how the temporal resolution of ERPs may be used to better understand emotion regulation strategies in future investigations. Specifically, Figure 1 suggests that modulation of the LPP elicited by both arousing and non-arousing foci did not differ from one another until around 700 ms following stimulus onset—before then, it appears as if attention is automatically increased in the presence of emotional stimuli.

In summary, the current results highlight the utility of the LPP for studying cognition–emotion interactions, especially the bidirectional influence of attention on emotion. The LPP continues to be a promising tool both for understanding the time course of attention to emotional stimuli and for examining emotion regulation, whereby top-down control processes modulate attentional allocation and emotional processing (Foti & Hajcak, 2008; Hajcak & Nieuwenhuis, 2006; Moser et al., 2006). In particular, attentional focus is important to consider in the context of other reappraisal-related manipulations of the LPP.

REFERENCES

Cuthbert, B. N., Schupp, H. T., Bradley, M. M., Birbaumer, N., & Lang, P. J. (2000). Brain potentials in affective picture processing: Covariation with autonomic arousal and affective report. *Biological Psychology*, *52*, 95–111.

Foti, D., & Hajcak, G. (2008). Deconstructing reappraisal: Descriptions preceding arousing pictures modulate the subsequent neural response. *Journal of Cognitive Neuroscience*, *20*, 977–988.

Gratton, G., Coles, M. G., & Donchin, E. (1983). A new method for offline removal of ocular artifact. *Electroencephalography and Clinical Neurophysiology*, *55*, 468–484.

Gross, J. J., & Thompson, R. A. (2007). Emotion regulation: Conceptual foundations. In J. J. Gross (Ed.), *Handbook of emotion regulation* (pp. 3–24). New York: Guilford Publications.

Hajcak, G., Dunning, J., & Foti, D. (2007). Neural response to emotional pictures in unaffected by concurrent task difficulty: An event-related potential study. *Behavioral Neuroscience*, *121*, 1156–1162.

Hajcak, G., Moser, J. S., & Simons, R. F. (2006). Attending to affect: Appraisal strategies modulate the electrocortical response to arousing pictures. *Emotion*, *6*, 517–522.

Hajcak, G., & Nieuwenhuis, S. (2006). Reappraisal modulates the electrocortical response to negative pictures. *Cognitive and Affective Behavioral Neuroscience*, *6*, 291–297.

Hariri, A. R., Mattay, V. S., Tessitore, A., Fera, F., & Weinberger, D. R. (2003). Neocortical modulation of the amygdala response to fearful stimuli. *Biological Psychiatry*, *53*, 494–501.

Keightley, M. L., Winocur, G., Graham, S. J., Mayberg, H. S., Hevenor, S. J., & Grady, C. L. (2003). An fMRI study investigating cognitive modulation of brain regions associated with emotional processing of visual stimuli. *Neuropsychologia*, *41*, 585–596.

Keil, A., Bradley, M. M., Hauk, O., Rockstroh, B., Elbert, T., & Lang, P. J. (2002). Large-scale neural correlates of affective picture processing. *Psychophysiology*, *39*, 641–649.

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (1997). Motivated attention: Affect, activation and action. In P. J. Lang, R. F. Simons, & M. T. Balaban (Eds.), *Attention and orienting: Sensory and motivational processes* (pp. 97–135). Hillsdale, NJ: Erlbaum.

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (2005). *International Affective Picture System (IAPS): Affective ratings of pictures and instruction manual*. Technical Report A-6. Gainesville, FL: University of Florida.

Moser, J. S., Hajcak, G., Bukay, E., & Simons, R. F. (2006). Intentional modulation of emotional responding to unpleasant pictures: An ERP study. *Psychophysiology*, *43*, 292–296.

Ochsner, K. N., Bunge, S. A., Gross, J. J., & Gabrieli, J. D. (2002). Rethinking feelings: An FMRI study of the cognitive regulation of emotion. *Journal of Cognitive Neuroscience*, *14*, 1215–1229.

Ochsner, K. N., & Gross, J. J. (2005). The cognitive control of emotion. *Trends in Cognitive Sciences*, *9*, 242–249.

Ochsner, K. N., Ray, R. D., Cooper, J. C., Robertson, E. R., Chopra, S., Gabrieli, J. D., et al. (2004). For better or for worse: Neural systems supporting the cognitive down- and up-regulation of negative emotion. *NeuroImage*, *23*, 483–499.

Phan, K. L., Fitzgerald, D. A., Nathan, P. J., Moore, G. J., Uhde, T. W., & Tancer, M. E. (2005). Neural substrates for voluntary suppression of negative affect: A functional magnetic resonance imaging study. *Biological Psychiatry*, *57*, 210–219.

Schupp, H. T., Cuthbert, B. N., Bradley, M. M., Cacioppo, J. T., Ito, T., & Lang, P. J. (2000). Affective picture processing: The late positive potential is modulated by motivational relevance. *Psychophysiology*, *37*, 257–261.

Schupp, H. T., Junghofer, M., Weike, A. I., & Hamm, A. O. (2003). Emotional facilitation of sensory processing in the visual cortex. *Psychological Science*, *14*, 7–13.

Schupp, H. T., Junghofer, M., Weike, A. I., & Hamm, A. O. (2004). The selective processing of briefly presented affective pictures: An ERP analysis. *Psychophysiology*, *41*, 441–449.

Schupp, H. T., Stockburger, J., Codispoti, M., Junghofer, M., Weike, A. I., & Hamm, A. O. (2007). Selective visual attention to emotion. *The Journal of Neuroscience*, *27*, 1082–1089.

van Reekum, C. M., Johnstone, T., Urry, H. L., Thurow, M. E., Schaefer, H. S., Alexander, A. L., et al. (2007). Gaze fixations predict brain activation during the voluntary regulation of picture-induced negative affect. *NeuroImage*, *36*, 1041–1055.

Vuilleumier, P. (2005). How brains beware: Neural mechanisms of emotional attention. *Trends in Cognitive Sciences*, *9*, 585–594.

(Received February 13, 2008; Accepted April 17, 2008)