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Attending to Affect: Appraisal Strategies Modulate the Electrocortical Response to Arousing Pictures

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Arousing (unpleasant and pleasant) pictures elicit increased neurophysiological measures of perceptual processing. In particular, the electrocortical late positive potential (LPP) is enhanced for arousing, compared with neutral, pictures. To determine whether the magnitude of the LPP is sensitive to the way stimuli are appraised, 16 participants viewed both pleasant and unpleasant pictures and categorized them along an affective or nonaffective dimension. Results indicate that the LPP was reduced for both pleasant and unpleasant pictures when participants made nonaffective, compared with affective, judgments. These results are consistent with previous studies that have used functional neuroimaging to investigate the role of appraisal on emotional processing. The results are further discussed in terms of the utility of using the LPP to study emotion regulation.

Keywords: late positive potential, emotion regulation, appraisal, event-related brain potential, emotion

Motivationally significant stimuli automatically capture attention and receive increased perceptual processing resources (cf. Bradley, Sabatinelli, Lang, Fitzsimmons, King, & Desai, 2003). For instance, studies using functional neuroimaging techniques have found that both pleasant and unpleasant stimuli elicit increased activity in the visual cortex (Bradley et al., 2003; Lane, Reiman, Bradley, et al., 1997) and amygdala (Bradley et al., 2003; Phan, Taylor, Welsh, et al., 2003). On the basis of animal neuroanatomy (Amaral & Price, 1984) and human lesion data (Anderson & Phelps, 2001), it has been suggested that the increased perceptual processing of emotional stimuli indexed by sustained activation of the visual cortex results from reentrant processes from anterior brain sites such as the amygdala (cf. Sabatinelli, Bradley, Fitzsimmons, & Lang, 2005; Vuilleumier, Richardson, Armony, Driver, & Dolan, 2004).

The facilitated processing of arousing stimuli has also been reported in studies using event-related brain potentials (ERPs). These studies consistently find that both pleasant and unpleasant pictures elicit a larger late positive potential (LPP) than neutral pictures (Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000; Keil et al., 2002; Lang, Bradley, & Cuthbert, 1997; Schupp, Cuthbert, Bradley, Cacioppo, Ito, & Lang, 2000; Schupp, Junghofer, Weike, & Hamm, 2003). Given its topographical and morphological characteristics, the LPP may index similar attention and orienting processes as the classic P300 wave (Donchin & Coles, 1988). Functionally, then, the enhanced LPP may relate to augmented attention to arousing stimuli, much the way in which attended stimuli evince larger amplitude P300 than unattended stimuli (Schupp et al., 2003). Likewise the LPP might, like increased blood flow in visual cortex, index the facilitated perceptual processing that results from the activation of structures such as the amygdala (cf. Bradley et al., 2003; Keil et al., 2002).

Recent studies have begun to investigate whether this facilitated processing varies with how emotional stimuli are evaluated and interpreted. In fact, there is now evidence that such cognitive-control variables can modulate neural and physiological responses to emotional stimuli (for a review, see Ochsner & Gross, 2005). In some studies, participants are simply instructed to voluntarily modify their response to emotional stimuli. For example, Schaefer et al. (2002), using functional magnetic resonance imaging (fMRI), found that when participants were instructed to maintain their emotional response to an unpleasant picture, amygdala activity was sustained compared with when they were simply instructed to view unpleasant pictures. Similarly, Ochsner et al. (2002) found that activity in the amygdala was reduced when participants reinterpreted unpleasant stimuli in a less negative way.

Other studies have investigated the influence of appraisal and evaluation on neural indices of emotional processing in a more covert fashion. For instance, Hariri et al. (2003) and Keightley et al. (2003) asked participants to make speeded categorizations of unpleasant stimuli on either an affective or nonaffective dimension. These researchers reported reduced activity in both amygdala and visual cortex when participants made nonaffective judgments about unpleasant pictures. These data suggest that the nonaffective appraisal of unpleasant stimuli may effectively diminish the enhanced amygdala response and facilitated perceptual processing typically elicited by motivationally significant stimuli.

In the aforementioned studies, neural measures of emotional processing were obtained seconds after affective stimulus presentation. Because the hemodynamic response is relatively slow, it is difficult to examine the earlier time course of cognitive control and

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emotional processing using fMRI. However, ERPs have excellent temporal resolution and can be sampled on the order of milliseconds; accordingly, this methodology may be ideally suited for such a task. Given the fact that the LPP, like the amygdala and visual cortex, appears sensitive to arousing stimuli, the LPP may be useful for investigating early indices of cognitive control over emotional responding.

To test this possibility, we measured the LPP while participants made both affective and nonaffective appraisals of arousing pictures. On the basis of fMRI studies that show decreased amygdala and visual cortex response to arousing unpleasant pictures during nonaffective versus affective evaluation (Hariri et al., 2003; Keightley et al., 2003), we hypothesized that the LPP would be similarly decreased when picture appraisal was nonaffective. Additionally, we sought to investigate whether affective versus nonaffective appraisal would also influence the LPP for arousing pleasant pictures. We hypothesized that nonaffective evaluation would also reduce the LPP observed after viewing pleasant arousing pictures. Considering that arousal-related effects on the LPP are evident nearly 300 ms after stimulus onset, modulation of the LPP by top-down cognitive control would suggest relatively early cognitive influences on neural indices of emotion processing and that the LPP might be a useful tool for future studies of cognitive/affective relationships.

Method

Participants

Sixteen undergraduate students (10 women, 6 men) in an upper-level psychology class at the University of Delaware participated in the present experiment for extra credit.

Stimulus Materials

A total of 120 pictures were selected from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 1999); of these, 40 depicted unpleasant scenes (e.g., threat and mutilation scenes), 40 depicted pleasant scenes (e.g., smiling families, sporting events, nudes), and 40 depicted neutral scenes (e.g., household objects, leaves, trees).[1] The three categories differed on normative ratings of valence ($M = 7.01$, $SD = 0.65$, for pleasant picture content; $M = 5.03$, $SD = 0.38$, for neutral picture content; and $M = 2.22$, $SD = 0.43$, for unpleasant picture content); additionally, the emotional pictures were reliably higher on normative arousal ratings ($M = 5.49$, $SD = 1.17$, for pleasant picture content; $M = 2.74$, $SD = 0.50$, for neutral picture content; and $M = 6.16$, $SD = 0.61$, for unpleasant picture content).[2] Pleasant and unpleasant pictures were selected such that an equal number of each contained 2 or more persons, and these were equated for arousal and valence.

We administered the task on a Pentium I 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 17–in. (43.18-cm) monitor. At a viewing distance of approximately 24 in. (60.96 cm), each picture occupied nearly 35° of visual angle horizontally and vertically.

Procedure

After a brief description of the experiment, electroencephalograph (EEG) sensors were attached and the participant was given detailed task instructions. In the first block, participants viewed the 40 pleasant, 40 unpleasant, and 40 neutral IAPS pictures; the participants did not have to make any decisions about these pictures and were only instructed to view the pictures naturally. Pictures were presented for 1000 ms with a 1500-ms intertrial interval (ITI) during which a blank screen was presented. The second and third experimental blocks involved participants making affective and nonaffective decisions and only used the pleasant and unpleasant pictures from the first experimental block.

In the affective decision block, participants were instructed to categorize each picture as pleasant or unpleasant by pressing the left or right “ctrl” key; participants were also instructed to be both fast and accurate. Before the presentation of each picture, the words “pleasant” and “unpleasant” were presented either to the left or right of the screen to remind participants both about the decision that they were making and about the appropriate response button. This instruction was presented for 1000 ms. In the nonaffective decision block, participants were instructed to categorize each picture in terms of the number of persons present in the picture. Specifically, they were instructed to press one “ctrl” key if the picture contained two or more people and press the other “ctrl” key if the picture contained one or fewer people (cf. Keightley et al., 2003, for similar methods). Participants were explicitly told that a close-up photograph of a person’s leg or arm should be categorized as “1 or fewer” people; on the other hand, a close-up photograph of two faces should be categorized as “2 or more” people. Before the presentation of each picture, “1 or fewer” and “2 or more” were presented either to the left or right of the screen for 1000 ms to remind participants both about the decision that they were making and about the appropriate response button. The correspondence between responses and “ctrl” keys was counterbalanced across participants, as was the ordering of the affective and nonaffective blocks (8 participants performed the affective decision block before the nonaffective decision block); however, all participants simply viewed pictures in the first block. Pictures in the second and third blocks were again presented for 1000 ms, and there was a 1500-ms blank screen that preceded the onset of the next trial.

Psychophysiological Recording, Data Reduction, and Analysis

We recorded the EEG using an Electro-Cap International (ECI; Eaton, OH) Electro-Cap. Recordings were taken from four locations along the midline: frontal (Fz), frontocentral (FCz), central (Cz), and parietal (Pz). In addition, ECI electrodes were placed on the left and right mastoids (M1 and M2, respectively). During the recording, all activity was referenced to Cz. The electro-oculogram (EOG) generated from blinks and vertical eye movements was also recorded with ECI miniature electrodes placed approximately 1 cm above and 1 cm below the participant’s right eye. The right earlobe served as a ground site. All EEG/EOG electrode impedances were below 10 kΩ, and the data from all channels were recorded with a Grass Model 7PCM8 polygraph with Grass Model 7P511 preamplifiers (bandpass = 0.1–100 Hz).

All bioelectric signals were digitized on a laboratory microcomputer with VPM software (Cook, 1999). The EEG was sampled at 200 Hz, and

[1] The numbers of the IAPS pictures used were the following: pleasant (1601, 2000, 2070, 2080, 2091, 2092, 2165, 2311, 2340, 4002, 4180, 4220, 4290, 4532, 4572, 4608, 4658, 4659, 4660, 4664, 4800, 4810, 5470, 5621, 5626, 5628, 7325, 8021, 8032, 8080, 8200, 8210, 8280, 8320, 8330, 8370, 8400, 8465, 8490, 8540), neutral (2190, 2480, 2570, 2840, 2880, 5390, 5500, 5510, 5532, 5534, 5731, 5740, 5800, 5900, 7000, 7002, 7004, 7006, 7009, 7010, 7025, 7030, 7034, 7035, 7040, 7040, 7060, 7080, 7090, 7100, 7140, 7150, 7175, 7190, 7217, 7224, 7233, 7235, 7491, 7950), and unpleasant (2800, 2900, 3051, 3102, 3110, 3261, 3530, 3550, 6230, 6242, 6250, 6260, 6313, 6350, 6370, 6510, 6540, 6560, 6570, 6571, 6821, 9040, 9050, 9253, 9300, 9400, 9405, 9410, 9421, 9433, 9490, 9520, 9530, 9570, 9800, 9810, 9910, 9911, 9920, 9921).

[2] These means are nearly identical to those reported in other studies of the LPP (e.g., Cuthbert et al., 2000; Keil et al., 2002).

data collection began 500 ms before picture onset and continued for 1500 ms. Offline, the EEG for each trial was corrected for vertical EOG artifacts using the method developed by Gratton, Coles, and Donchin (1983; Miller, Gratton, & Yee, 1988) and then re-referenced to the average activity of the mastoid electrodes. Trials were rejected and not counted in subsequent analysis if there was excessive physiological artifact (i.e., 25 ms of invariant analog data on any channel or analog-to-digital (A/D) values on any channel that equaled that converters minimum or maximum values). Single-trial EEG data were lowpass filtered at 20 Hz with a 51-weight finite impulse response (FIR) digital filter as per Cook and Miller (1992).

ERPs were constructed by separately averaging pleasant, unpleasant, and neutral trials in the view condition; separate averages were also created for unpleasant and pleasant pictures in the affective and nonaffective decision conditions. Only trials on which participants responded correctly were included in the analyses. For each ERP average, the mean activity in the 0–200-ms window before picture onset served as the baseline. The LPP was quantified at the site of its maximum amplitude, where amplitude was based on the difference between the baseline and the average activity in a 500–650-ms window that followed stimulus onset. The site of the maxima was determined by analysis of variance (ANOVA), with orthogonal polynomial contrasts conducted on the four midline electrode sites. The LPP at this site was then statistically evaluated with SPSS (Version 10.1) general linear model software.

Results

Behavioral Data

The average reaction time (RT) on pleasant and unpleasant trials in the affective decision block were 1195 ms ($SD = 77$) and 1175 ms ($SD = 79$), respectively. In the nonaffective decision block, the RT on pleasant and unpleasant trials was 1178 ms ($SD = 84$) and 1199 ms ($SD = 92$), respectively. A 2 (decision type) × 2 (picture valence) repeated measures ANOVA on RT indicated that participants were equivalently fast to make both affective and nonaffective decisions regarding pictures, $F(1, 15) < 1$; additionally, RT was comparable on pleasant and unpleasant pictures, $F(1, 15) < 1$. However, the Decision Type × Picture Valence interaction was significant, $F(1, 15) = 19.50$, $p < .001$. Post hoc t tests confirmed that in the affective decision block, participants were faster to categorize unpleasant pictures, $t(15) = 2.27$, $p < .05$; however, in the nonaffective decision block, participants were faster to categorize pleasant pictures, $t(15) = 2.33$, $p < .05$.

Performance accuracy in the affective decision block was 96.6% ($SD = 3.4$) and 97.2% ($SD = 2.9$) on pleasant and unpleasant trials, respectively; in the nonaffective block, performance accuracy was 95.3% ($SD = 3.3$) and 95.1% ($SD = 3.6$) on pleasant and unpleasant trials, respectively. A comparison of performance accuracy indicated that performance was comparable when the picture was pleasant and unpleasant, $F(1, 15) < 1$. Although participants tended to make fewer mistakes in the affective decision block, this difference did not reach statistical significance, $F(1, 15) = 4.27$, $p > .05$; finally, the Decision Type × Picture Valence interaction was not significant, $F(1, 15) < 1$.

The LPP–View Condition

The trend analysis on electrode site revealed a significant linear trend across the four sites, suggesting that the LPP grew larger moving from anterior to posterior recording sites, $F_{\text{lin}}(1, 15) = 11.88$, $p < .001$. This linear trend accounted for 94% of the variance across electrode sites. Consistent with the literature and as illustrated in the top panel of Figure 1, the largest LPPs were recorded at the Pz site. The subsequent analysis of the Pz data confirmed the impression gleaned from the bottom panel of Figure 1 that the LPPs after viewing pleasant and unpleasant pictures did not differ from one another, $t(15) = 1.30$, $p > .20$, but the LPP associated with both pleasant ($M = 8.63$, $SD = 6.18$) and unpleasant ($M = 7.20$, $SD = 6.02$) pictures was enhanced compared with the LPP associated with the neutral ($M = 2.35$, $SD = 5.16$) pictures; $t(15) = 7.79$, $p < .001$, and $t(15) = 5.68$, $p < .001$, respectively. Thus, like previous studies, the arousing pictures used in the present study were characterized by an enhanced LPP, compared with nonarousing pictures, and the LPP did not vary by valence.

The LPP–Decision Conditions

The top panel of Figure 2 presents the averaged LPP amplitudes at Fz, FCz, Cz, and Pz when participants made affective and nonaffective decisions. The ANOVA with orthogonal trends revealed significant linear, $F_{\text{lin}}(1, 15) = 7.91$, $p < .05$, and quadratic, $F_{\text{quad}}(1, 15) = 6.94$, $p < .05$, trends across the four recording sites. In this case, however, it was the quadratic trend

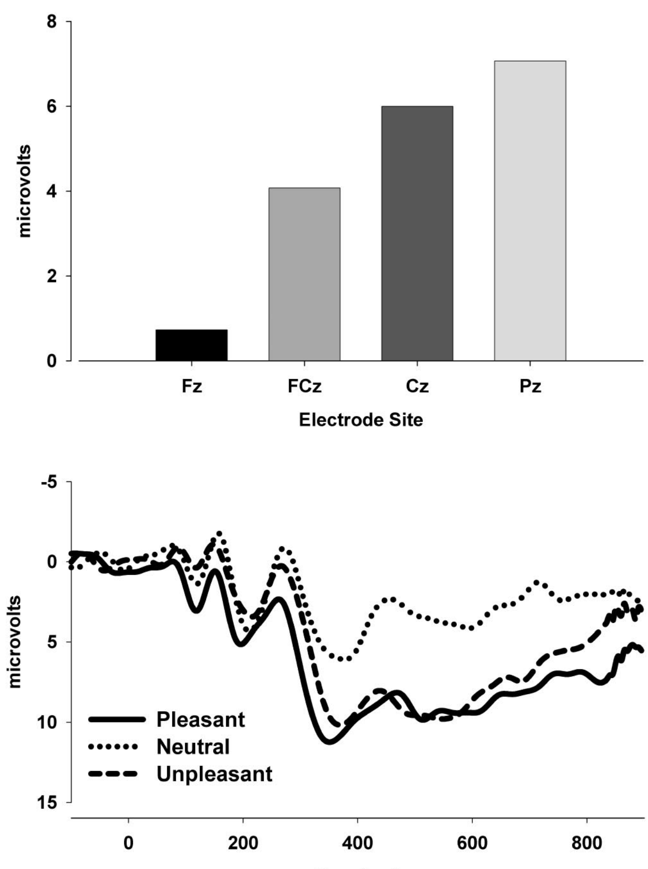

Figure 1. Overall magnitude of the late positive potential (LPP) at frontal (Fz), frontocentral (FCz), central (Cz), and parietal (Pz) during the view condition (top), and stimulus-locked event-related brain potentials (ERPs) at Pz where the LPP was maximal (bottom).

that accounted for most of the variance (63%) and reflected a more central distribution of the LPP.

In the affective decision block, the LPP magnitude observed on pleasant and unpleasant trials was 18.3 μV ($SD = 10.1$) and 18.1 μV ($SD = 8.3$), respectively. The LPP magnitude in the nonaffective decision block was 14.1 μV ($SD = 6.6$) and 15.0 μV ($SD = 8.1$) on pleasant and unpleasant trials, respectively. A 2 (Decision Type) × 2 (Picture Valence) repeated measures ANOVA on the Cz data again failed to reveal a main effect of picture valence, $F(1, 15) < 1$, but did reveal a main effect of decision type, $F(1, 15) = 4.54$, $p < .05$. Figure 2 (bottom panel) illustrates that the LPP was significantly smaller when participants made nonaffective decisions, compared with affective decisions. The significant effect of decision type was independent of picture valence, $F(1, 15) < 1$.

To verify that the scalp topography truly differed between the view and decision blocks, we averaged the ERPs to positive and negative stimuli within each block, and a 2 (block) × 4 (electrode site) repeated measures ANOVA was conducted on LPP magnitude. Because the LPP elicited by arousing stimuli were larger in the decision blocks than the viewing block, $F(1, 15) = 32.80$, $p < .001$, we scaled the ERP data as recommended by McCarthy and Wood (1985).[3] As expected, the effect of electrode site was highly significant, $F(3, 45) = 30.03$, $p < .001$, but more important, the scaled scores revealed a significant Block × Electrode Site interaction, $F(3, 45) = 26.43$, $p < .001$. These results confirmed the impression from Figures 1 and 2 that the LPP was generally larger toward more posterior recording sites but that the distribution of the LPP differed between the viewing and decision blocks, reflecting a more central distribution during the decision block than during the view-only block.

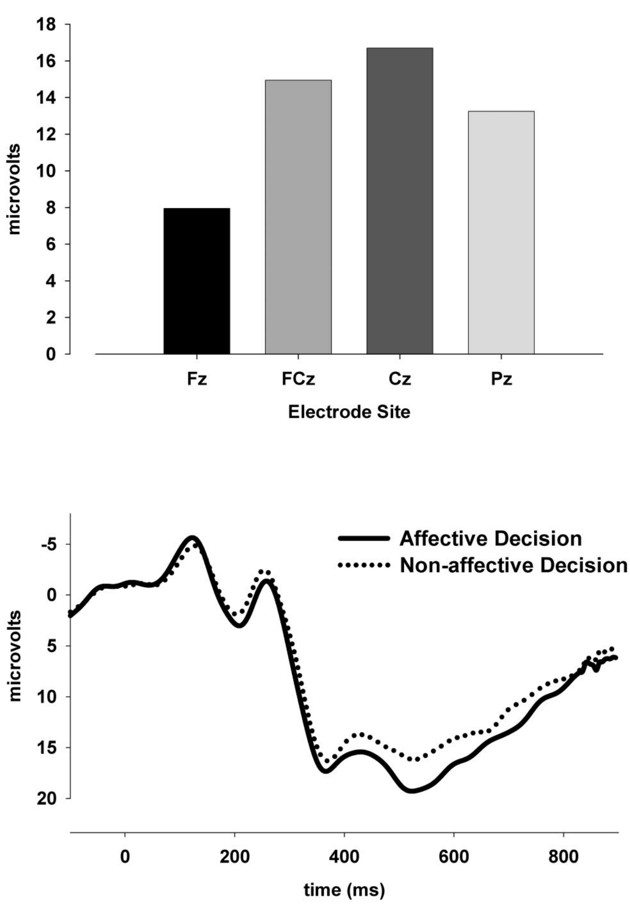

Figure 2. Overall magnitude of the late positive potential (LPP) at frontal (Fz), frontocentral (FCz), central (Cz), and parietal (Pz) during the affective and nonaffective decision conditions (top), and stimulus-locked event-related brain potentials (ERPs) at Cz where the LPP was maximal (bottom).

Discussion

Consistent with data from previous studies, the LPP was enhanced after the presentation of both unpleasant and pleasant pictures compared with neutral pictures; however, the magnitude of the LPP did not differ between pleasant and unpleasant pictures (Cuthbert et al., 2000; Keil et al., 2002; Lang et al., 1997; Schupp et al., 2000, 2003; however, see Ito & Cacioppo, 2000, for evidence of a possible negativity bias). The present study extends the results of previous studies by demonstrating that the magnitude of the LPP is not only sensitive to the emotional content of pictures but also to the way in which this emotional content is appraised. Specifically, when participants evaluated pleasant and unpleasant pictures along a nonaffective dimension, the LPP was reliably reduced in comparison with when the same pictures were appraised in terms of their affective valence. The reduction in the LPP based on the type of appraisal was not modulated by the valence of the picture with similar reductions during the nonaffective decision block occurring for both unpleasant and pleasant pictures.

The present study used a manipulation similar to that used by Keightley et al. (2003) and Hariri et al. (2003), who investigated neural correlates of affective and nonaffective appraisal using fMRI. Both fMRI studies found that the nonaffective appraisal of unpleasant stimuli led to reduced activity in the amygdala and the fusiform area of the ventral visual cortex. Insofar as the LPP was also reduced in the present study when participants made nonaffective evaluations of arousing stimuli, the present results dovetail well with the results of Hariri et al. (2003) and Keightley et al. (2003) and indicate that how a stimulus is appraised also influences the electrocortical response to emotional stimuli—a modulation evident just 400 ms after stimulus presentation.

Ochsner and Gross (2004) highlight a number of strategies for modifying emotional experience. Particularly relevant to the present study is their idea of *attentional deployment*, which refers to the process of selectively attending to aspects of stimuli that either heighten or dampen emotional experience (Ochsner & Gross, 2004). In terms of the neural architecture supporting attentional/cognitive modulations of emotional processing, a number of studies have reported corresponding changes in areas of the brain that are typically involved in cognitive control, such as the prefrontal cortex (cf. Hariri et al., 2003; Northoff, Heinzel, Bermpohl,

[3] The minimum and maximum value across all electrode sites was determined for each condition. The minimum was then subtracted from the LPP value at each site, and this value was divided by the difference between the maximum and minimum. This scaling procedure controls for the type of between-condition difference evident in the present study (cf. McCarthy & Wood, 1985).

et al., 2004; Ochsner & Gross, 2004). Within this framework, the results of the present study suggest that the LPP may also be a viable dependent measure of the interaction between cognitive and affective processing.

In fact, we have recently found that other attentional/cognitive strategies such as intentional suppression (Moser, Hajcak, Bukay, & Simons, in press) and reappraisal (Hajcak & Nieuwenhuis, in press) also attenuate the magnitude of the LPP. These data provide converging evidence that the LPP is useful for studying emotional processing and its regulation during the viewing of affective pictures. Through future studies, it will be important to better understand the relationship between various emotion regulation strategies. For instance, is the ability to modulate emotional processing through reappraisal related to the type of appraisal-related differences reported in the present study?

The present study raises other questions for future research. To begin with, the LPP was maximal at Pz during the viewing block and maximal at Cz during the decision blocks. Additionally, the LPP was larger during the decision blocks. Both the LPP and P300 are centroparietally maximal ERP components that reflect processes related to attention and orienting; furthermore, the P300 is enhanced when participants must respond to stimuli. The fact that the LPP was larger when emotional stimuli required a response is also consistent with these similarities. Because the decision blocks involved a response requirement, it is possible that the topographic shift reflects processes related to motor planning and/or execution. Future studies could examine, for instance, the topographical differences in LPP between appraisal strategies that require a response and those that do not to examine the specific effects of motor processes and mental processes involved in modifying affective experience.

The modulation of the LPP was observed in the emotional decision condition relative to the nonemotional decision condition; thus, it is possible that this difference reflects an enhancement of the LPP in the latter condition or a reduction in the former condition. Existing studies on this type of emotion regulation strategy would suggest that the difference is down-regulatory in nature; however, the particular design used in the present study does not allow for this specific conclusion.

In summary, the present study found that the LPP was modulated by appraisal strategy (i.e., cognitive control) as predicted. More specifically, these results show that the enhanced electrocortical response to emotional stimuli can be modulated by appraisal processes (i.e., by directing attention to emotional vs. nonemotional aspects of stimuli) fairly early after stimulus presentation. It will be valuable if future studies directly compare the modulation of neural activity across multiple emotion regulation strategies, with multiple neuroimaging techniques. Given the relationship between emotion regulation deficits and a variety of psychopathologies, it will also be important to determine whether modulations of measures such as the LPP are sensitive to individual differences in self-reported emotionality and emotion regulation.

References

Amaral, D. G., & Price, J. L. (1984). Amygdalo-cortical projections in the monkey (*Macaca fascicularis*). *Journal of Computational Neurology, 230,* 465–496.

Anderson, A. K., & Phelps, E. A. (2001). Lesions of the human amygdala impair enhanced perception of emotionally salient events. *Nature, 411,* 305–308.

Bradley, M. M., Sabatinelli, D., Lang, P. J., Fitzsimmons, J. R., King, W., & Desai, P. (2003). Activation of the visual cortex in motivated attention. *Behavioral Neuroscience, 117,* 369–380.

Cook, E. W., III. (1999). *VPM reference manual.* Birmingham, AL: Author.

Cook, E. W., III, & Miller, G. A. (1992). Digital filtering—Background and tutorial for psychophysiologists. *Psychophsyiology, 29,* 350–367.

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.

Donchin, E., & Coles, M. G. H. (1988). Is the P300 component a manifestation of context updating? *Behavioral and Brain Sciences, 11,* 355–372.

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

Hajcak, G., & Nieuwenhuis, S. T. (in press). *Reappraisal modulates the electrocortical response to unpleasant pictures.* Cognitive, Affective, and Behavioral Neuroscience.

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.

Ito, T. A., & Cacioppo, J. T. (2000). Electrophysiological evidence of implicit and explicit categorization processes. *Journal of Experimental Social Psychology, 36,* 660–676.

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.

Lane, R. D., Reiman, E. M., Bradley, M. M., Lang, P. J., Ahern, G. L., Davidson, R. J., & Schwartz, G. E. (1997). Neuroanatomical correlates of pleasant and unpleasant emotion. *Neuropsychologia, 35,* 1437–1444.

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: Sesnory and motivational processes* (pp. 97–135). Hillsdale, NJ: Erlbaum.

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (1999). *International Affective Picture System: Instruction manual and affective ratings* (Tech. Rep. No. A-4). Gainesville, FL: Center for Research in Psychophysiology, University of Florida.

McCarthy, G., & Wood, C. C. (1985). Scalp distributions of event-related potentials: An ambiguity associated with analysis of variance models. *Electroencephalography and Clinical Neurophysiology, 62,* 203–208.

Miller, G. A., Gratton, G., & Yee, C. M. (1988). Generalized implementation of an eye movement correction procedure. *Psychophysiology, 25,* 241–243.

Moser, J. S., Hajcak, G., Bukay, E., & Simons, R. F. (in press). Intentional modulation of emotional responding to unpleasant pictures. *Psychophysiology.*

Northoff, G., Heinzel, A., Bermpohl, F., Niese, R., Pfenning, A., Pascual-Leone, A., & Schlaug, G. (2004). Reciprocal modulation and attenuation in the prefrontal cortex: An fMRI study on emotional–cognitive interaction. *Human Brain Mapping, 21,* 202–212.

Ochsner, K. N., Bunge, S. A., Gross, J. J., Gabrieli, J. D. E. (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. (2004). Thinking makes it so: A social cognitive neuroscience approach to emotion regulation. In R. F. Baumeister & K. D. Vohs (Eds.), *Handbook of self-regulation: Re-*

search, theory, and applications (pp. 229–255). New York: Guilford Press.

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

Phan, K. L., Taylor, S. F., Welsh, R. C., Decker, L. R., Noll, D. C., Nichols, T. E., et al. (2003). Activation of the medial prefrontal cortex and extended amygdala by individual ratings of emotional arousal: A fMRI study. *Biological Psychiatry, 53,* 211–215.

Sabatinelli, D., Bradley, M. M., Fitzsimmons, J. R., & Lang, P. J. (2005). Parallel amygdala and inferotemporal activation reflect emotional intensity and fear relevance. *Neuroimage, 24,* 1265–1270.

Schaefer, S. M. Modulation of amygalar activity by the conscious regulation of negative emotion. *Journal of Cognitive Neuroscience, 14,* 913–921.

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,* 4–13.

Vuilleumier, P., Richardson, M. P., Armony, J. L., Driver, J., & Dolan, R. J. (2004). Distant influences of amygdala lesion on visual cortical activation during emotional face processing. *Nature Neuroscience, 7,* 1271–1278.

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