Psychophysiology, 43 (2006), 292–296. Blackwell Publishing Inc. Printed in the USA.

DOI: 10.1111/j.1469-8986.2006.00402.x

BRIEF REPORT

Intentional modulation of emotional responding to unpleasant pictures: An ERP study

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Abstract

Intentionally altering responses to unpleasant stimuli affects physiological and hemodynamic activity associated with emotional and cognitive processing. In the present experiment, we measured the late-positive potential (LPP) of the visually evoked event-related brain potential to examine the effects of intentional emotion modulation on electrophysiological correlates of emotional and cognitive processing. Seventeen participants received instructions to view, suppress, and enhance emotional responses to unpleasant stimuli. Results revealed significantly decreased electrophysiological activity during suppression of emotional responses beginning around 250 ms poststimulus and lasting several hundred milliseconds. These data suggest that ERPs are sensitive to emotion modulation/regulation processes.

Descriptors: Late-positive potential, LPP, Unpleasant pictures, Emotion modulation/regulation, Attention

Researchers have begun to examine the effects of instructions to alter responding to emotional stimuli on physiological and neural indices of emotional and cognitive processing (cf. Ochsner & Gross, 2005). Decreases and increases in physiological measures such as startle eyeblink magnitude have been reported during suppression and enhancement of responses to unpleasant pictures, respectively (Gross & Levenson, 1993, 1997; Jackson, Malmstadt, Larson, & Davidson, 2000). Likewise, results from functional imaging studies suggest that suppression of responses to unpleasant images results in decreased amygdala activity and enhancement results in increased amygdala activity (Ochsner et al., 2004; Phan et al., 2005).

Although studies to date have demonstrated that instructions to purposefully modulate emotional responding to unpleasant stimuli affect physiology and brain activity, none have specifically examined the effects of such instructions on event-related brain potentials (ERPs). One ERP component that seems particularly well suited for this type of research is the late positive potential (LPP), a centro-parietally maximal broad positive deflection that reaches its maximum amplitude between 300 and 800 ms after stimulus onset and can last for several hundred milliseconds (Cuthbert, Schupp, Bradley, Birbaumer, & Land, 2000; Schupp et al., 2000). Numerous studies have shown that the LPP is enhanced for motivationally relevant stimuli such as highly arousing unpleasant (e.g., mutilations) and pleasant (e.g., erotic) pictures (Cuthbert et al., 2000; Schupp et al., 2000; Schupp, Junghofer, Weike, & Hamm, 2004). Like other late positive potentials in cognitive tasks (Donchin & Coles, 1988; Ritter & Ruchkin, 1992), the LPP is thought to index increased attention to, and facilitated perceptual processing of, motivationally relevant stimuli (Schupp et al., 2000; Schupp, Junghofer, Weike, & Hamm, 2003).

In the present study, we measured the LPP to determine whether this electrophysiological measure would be modulated by instructions to suppress and enhance responding to arousing unpleasant stimuli. Unpleasant stimuli were presented under three instructional conditions: passive viewing or with instructions to either decrease or increase emotional intensity. We hypothesized that the magnitude of the LPP would vary as a function of the degree to which participants were engaged in the processing of the unpleasant stimuli. That is, the amplitude of the LPP would be decreased during instructions to suppress emotional responding to unpleasant pictures and increased during instructions to enhance emotional responding to unpleasant pictures.

Method

Participants

Nineteen undergraduate students (16 female) in an upper level psychology class participated in the current study for extra credit. Participants were told that the top two enhancers and suppressers, as measured by brain activity, would be awarded $20 in bonus money. At the completion of the study, individual ERP averages were calculated for each participant and the two students who evidenced the largest emotion regulation effects on ERP measures were awarded $20. Data from 2 female participants were excluded due to data acquisition malfunction.

Stimuli and Procedures

The stimulus set comprised 60 unpleasant, high arousing and 20 neutral, low arousing color images taken from the Interna-

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tional Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 1999).[1] The unpleasant picture set included images of mutilation and threat (human and animal). The neutral picture set included images of household items and neutral faces. Unpleasant and neutral images differed significantly from each other in IAPS normative valence ($M = 2.03$ and 5.14) and arousal ($M = 6.24$ and 2.96) ratings.

After participants received a general description of the experiment, EEG/EOG sensor electrodes were attached and participants were seated approximately 0.5 m directly in front of the computer monitor and then given detailed task instructions. Participants performed a blocked picture viewing task administered on a Pentium I class computer, using Presentation software (Neurobehavioral Systems, Inc.) to control the presentation and timing of all stimuli. During the task, pictures from the IAPS were displayed for 1000 ms and occupied the entire screen of a 17-in. monitor. The order of pictures was random within each block.

In the first block of the task, participants viewed 20 unpleasant and 20 neutral randomly presented IAPS pictures and were instructed to simply view the pictures as they were presented and pay close attention to each one (hereafter referred to as the view condition). This condition was designed as a baseline for comparing the effects of the regulation instructions given in the last two blocks. The view block was not counterbalanced with the other two instruction blocks in an attempt to reduce any contamination of the view block by regulation instructions. A fixation mark (+) was presented for 2000 ms at the beginning of each trial to orient participants to the center of the screen. IAPS pictures appeared 500 ms after the offset of the fixation cross. The interval between the offset of the IAPS picture and the following fixation cross was 1000 ms.

The second and third blocks of the task each consisted of 20 different unpleasant IAPS images. In one block, participants received instructions to suppress their emotional response to the pictures and in the other block participants received instructions to enhance their emotional response to the pictures (hereafter referred to as the *suppress* and *enhance* conditions, respectively). The order of these two emotion modulation blocks was counterbalanced across subjects. The word "SUPPRESS" or "ENHANCE" was presented for 2000 ms at the beginning of each trial to remind subjects what to do. IAPS pictures appeared 500 ms after the offset of the instruction word. The interval between the offset of the IAPS picture and the following instruction word was 1000 ms. Following the third and final block, physiological sensors were removed and participants were asked to fill out a questionnaire regarding their experiences in each of the experimental blocks as a manipulation check.

Emotion Modulation Instructions

Instructions for the emotion modulation conditions were adapted from Jackson et al. (2000) because they were found to be effective in modulating physiological responses to unpleasant pictures. Thus, participants were not restricted in using any particular emotion modulation strategy during the second and third blocks. For the suppress condition, participants were given the following verbatim instructions:

> During this block, you will see only negative pictures and be instructed to suppress the emotion you are currently feeling in response to the picture. Before each picture, the word **SUPPRESS** will be presented on the screen to remind you what to do. By suppress we mean that we would like you to decrease the intensity of the emotion you feel in response to the picture. Try to feel the emotion less strongly. For example, think of how a doctor enters an emergency room. The doctor knows that he/she will be entering a negative environment and prepares him/herself to deal with that by decreasing the negative emotions he/she might feel when he/she enters the room. So, when you see the word SUPPRESS, prepare yourself to decrease the intensity of whatever negative emotion you might feel in response to the picture. Prepare yourself to feel the negative emotion less strongly. Suppression of an emotion is not equivalent to replacing that emotion with a different one. Do not generate thoughts and images that are completely unrelated to the presented stimulus in order to produce a different emotion to compete with or replace your initial emotional response to the picture. For example, if you are asked to suppress the fear you feel in response to a picture of a poisonous snake, do not think of something unrelated that generates a positive emotion, e.g., the end of finals week and beginning of winter holiday! However, feel free to focus on a positive aspect of the picture or on a possible positive outcome of the situation in the picture. For example, you can imagine that the poisonous snake is about to be killed, which may help you to decrease the fear you may feel in response to the picture.

For the *enhance* condition, participants were given the following verbatim instructions:

> During this block, you will see only negative pictures and be instructed to enhance the emotion you are currently feeling in response to the picture. Before each picture, the word **ENHANCE** will be presented on the screen to remind you what to do. By enhance we mean we would like you to increase the intensity of the emotion you feel in response to the picture. Try to feel the emotion more strongly. For example, think of how someone who likes scary movies enters a movie theatre to see a scary movie. This person knows that he/she will see something scary and wants to feel as scared as he/she possibly can to get the most out of the movie. So, when you see the word **ENHANCE**, prepare yourself to increase the intensity of whatever negative emotion you feel in response to the picture. Prepare yourself to feel the negative emotion more strongly.

Following these instructions, participants were given the chance to ask questions and provided with additional examples until the experimenter felt the participant completely understood the emotion regulation instructions. As an additional manipulation check, the experimenter reviewed participants' responses on the postexperiment questionnaire to determine whether or not participants understood the instructions and reported using strategies typical of what previous research has shown (see Jackson et al., 2000; Ochsner & Gross, 2005).

Psychophysiological Recording, Data Reduction, and Analysis

The electroencephalogram (EEG) was recorded using an ECI electrocap. Recordings were taken from four locations along the midline: frontal (Fz), frontocentral (FCz), central (Cz), and parietal (Pz). In addition, Med-Associates tin electrodes were placed on the left and right mastoids (M1 and M2, respectively). During the recording, all activity was referenced to Cz. The electrooculogram (EOG) generated from blinks and vertical

[1]The numbers of the IAPS pictures used were the following: neutral (2480, 2880, 5390, 5500, 5531, 5740, 5800, 5900, 7000, 7002, 7009, 7010, 7025, 7035, 7140, 7175, 7190, 7224, 7560, 7950) and unpleasant (2205, 2800, 2900, 3000, 3010, 3030, 3051, 3053, 3060, 3061, 3062, 3064, 3071, 3080, 3100, 3102, 3110, 3130, 3140, 3150, 3170, 3180, 3230, 3261, 3350, 3400, 3500, 3530, 6212, 6230, 6243, 6260, 6350, 6360, 6370, 6510, 6540, 6560, 6570, 6821, 9006, 9040 9050, 9140, 9220, 9405, 9410, 9420, 9421, 9500, 9560, 9570, 9800, 9910, 9911).

eye movements was also recorded using Med-Associates miniature electrodes placed approximately 1 cm above and below the subject'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 by a Grass Model 78D polygraph with Grass Model 7P511J preamplifiers (bandpass = 0.1–100 Hz).

All bioelectric signals were digitized on a laboratory microcomputer using VPM software (Cook, 1999). The EEG was sampled at 200 Hz. Data collection began 500 ms prior to picture onset and continued for 1500 ms. Off-line, 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 A/D values on any channel that equaled that converter's minimum or maximum values). Based on this rejection criteria, the four conditions did not significantly differ with respect to the number of rejected trials (neutral view $M = 0.24$, $SD = 0.75$; unpleasant view $M = 0.18$, $SD = 0.53$; unpleasant suppress $M = 0.29$, $SD = 0.85$; unpleasant enhance $M = 0.12$, $SD = 0.33$; $F[3,48] < 1$). Single-trial EEG data were lowpass filtered at 20 Hz with a 51-weight FIR digital filter as per Cook and Miller (1992).

ERPs were constructed by separately averaging unpleasant and neutral picture trials in the view condition; separate averages were also created for unpleasant picture trials in the suppress and enhance conditions. The number of trials included in each average did not significantly vary by condition (neutral view $M = 19.77$, $SD = 0.75$; unpleasant view $M = 19.82$, $SD = 0.53$; unpleasant suppress $M = 19.71$, $SD = 0.85$; unpleasant enhance $M = 19.88$, $SD = 0.33$; $F[3,48] < 1$). For each ERP average, the average activity in the 0–200-ms window prior to picture onset served as the baseline. The LPP was quantified at the site of its maximum as determined by ANOVA with orthogonal polynomial contrasts conducted on the four midline electrode sites. The LPP was then defined as the average activity in the 350–600-ms window following stimulus onset.

The LPP was statistically evaluated using SPSS (Version 13.0) General Linear Model software with Greenhouse–Geisser correction applied to p values associated with multiple df repeated measures comparisons. After conducting the omnibus ANOVA, the Newman–Keuls procedure (cf. Sheskin, 1997) was used to test for significant post hoc comparisons at alpha = .05.

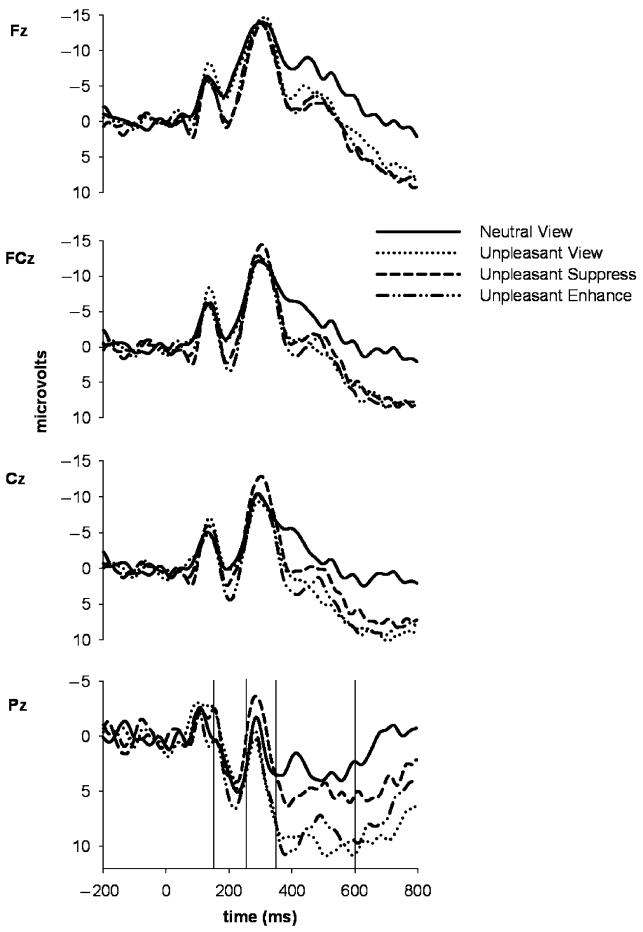

Figure 1. Stimulus-locked ERPs at Fz, FCz, Cz, and Pz for the view, enhance, and suppress conditions. The vertical lines at Pz indicate the time windows submitted to statistical analysis (i.e., 150–250, 250–350, and 350–600 ms).

Results

Late Positive Potential: View Condition

Consistent with the literature and as illustrated in Figure 1, the trend analysis on Electrode Site revealed a highly significant linear trend across the four sites, $F_{lin}(1,16) = 22.10$, $p < .001$, suggesting that the LPP grew consistently larger from anterior to posterior recording sites. The subsequent analysis of the Pz data, where the LPP was maximal, confirmed the impression gleaned from Figure 1 that unpleasant images elicited larger LPPs than neutral images, $t(16) = 5.74$, $p < .001$ (see also Table 1).

Late Positive Potential: Emotion Modulation Effects

Again, the linear trend accounted for most of the variance in the analysis of Electrode Site, $F_{lin}(1,16) = 25.53$, $p < .001$, reflecting a parietal distribution of the LPP (see Figure 1). A one-way ANOVA conducted on Emotion Modulation Condition (view, enhance, suppress) at the Pz site revealed that the LPP varied significantly as a function of condition, $F(2,32) = 5.86$, $p < .01$. The Newman–Keuls test confirmed that the LPP was significantly smaller in the suppress condition than in the view and enhance conditions, and that the LPPs in the enhance and view conditions did not differ from one another (see Figure 1; Table 1).

Table 1. *Mean (Standard Deviation) ERP Magnitudes (in Microvolts) at Pz for Unpleasant Pictures in the View, Suppress, and Enhance Conditions and Neutral Pictures in the View Condition*

Measure	Neutral view condition	Unpleasant view condition	Unpleasant suppress condition	Unpleasant enhance condition
LPP	3.14 (6.50)	9.67 (6.40)	5.17 (5.65)	9.01 (6.63)
Averaged ERP 150–250 ms	—	1.95 (6.90)	1.94 (6.98)	3.96 (6.05)
Averaged ERP 250–350 ms	—	3.30 (7.29)	− 1.05 (7.26)	2.72 (7.02)

As illustrated in Figure 1, electrophysiological activity elicited among the three conditions appeared to differ prior to onset of the LPP window (i.e., 350 ms) at the Pz electrode site. To test the time course of emotion modulation, activity in two earlier time windows (150–250 and 250–350 ms) was measured. As with the LPP, the largest positivity was observed at Pz for the 150–250-ms and 250–350-ms time windows, $F_{lin}(1,16) = 20.25$, $p < .001$ and $F_{lin}(1,16) = 47.82$, $p < .001$, respectively.

No significant differences among conditions were found in the 150–250-ms window, $F(2,32) = 1.73$, $p > .15$. In the 250–350-ms time window, on the other hand, the same pattern of results was found as for the LPP. A one-way ANOVA conducted on Emotion Modulation Condition (view, enhance, suppress) at the Pz site revealed that the averaged activity in the 250–350-ms time window varied significantly as a function of condition, $F(2,32) = 5.67$, $p < .01$. The Newman–Keuls test confirmed that the averaged activity in the 250–350-ms time window was significantly smaller in the suppress condition than in the view and enhance conditions, and that this activity was similar in magnitude for the enhance and view conditions (see Figure 1; Table 1).

Discussion

In this study, we examined the effects of instructions to intentionally modulate emotional responses on electrophysiological activity elicited by highly arousing unpleasant stimuli. Consistent with previous reports, LPPs were larger for highly arousing unpleasant stimuli than for neutral stimuli (Cuthbert et al., 2000; Schupp et al., 2000). More important to the primary aims of the current study, results revealed significant modulation of the LPP as a result of the experimental instructions. Specifically, the LPP was reduced during intentional suppression of responses to highly arousing unpleasant stimuli. We also observed that earlier electrophysiological activity (between 250 and 350 ms after stimulus onset) elicited by the unpleasant stimuli was decreased in the suppress condition. This reduction was evident relative to the activity found in both the passive viewing and enhance conditions, and the LPP and earlier activity also did not differ between the passive view and enhance conditions.

Because LPPs in the suppress condition were also significantly smaller than those in the enhance condition, the difference between passive view and suppress is likely not due to the fact that the latter condition always followed the former condition (e.g., habituation). Future research, however, should consider counterbalancing all conditions or randomizing the presentation of emotion modulation instructions in an unblocked design to protect against possible confounds related to ordering instructions. Additionally, the fact that electrophysiological activity was only reduced during suppression suggests that the intentional modulation of emotional responses does not simply draw resources from the primary picture viewing task; if this were the case, one would expect a reduced LPP in both the suppress and enhance conditions. Rather, the present study suggests that only instructions to suppress influenced the LPP.

The current findings fit nicely with other studies suggesting reductions in physiological and hemodynamic activity during instructions to suppress responses to unpleasant images (Jackson et al., 2000; for a review, see Ochsner & Gross, 2005) and extend this phenomena to include electrophysiological activity associated with attentional/perceptual processing. Thus, decreasing emotional responding to unpleasant stimuli seems to decrease the activity of multiple peripheral and central systems. The fact that we found suppression of electrophysiological activity beginning around 250 ms after stimulus presentation suggests that suppression instructions affect perception/attention rather early and that the positivity that is most evident in the LPP (i.e., 350–600 ms after stimulus onset) most likely begins substantially earlier and that this positivity contributes to multiple ERP components. It will be important to further examine the time course of this suppression effect in future studies.

We did not, however, find increased activity during instructions to enhance emotional responding. There are a number of possible reasons why subjects were unable to enhance their electrocortical responses in the context of the current study. First, it is possible that the lack of enhancement may be a function of our stimulus selection. By selecting pictures that were at the extreme end of both the valence and arousal dimension we may have "stacked the deck" against the subjects by eliciting near maximal responses. A variant on this ceiling hypothesis would be that it may not be the particular pictures per se, but that enhancing perceptual/attentional processing, as indexed by the LPP, of any emotional stimulus may be difficult to accomplish because emotional stimuli by their very nature claim substantial processing resources. This may be analogous to an earlier finding from our laboratory in which large late positive activity (i.e., the P300) continued to be associated with simple targets even when the target detection task had met strict criteria for automaticity (cf. Hoffman, Simons, & Houck, 1983). Second, the stimulus duration and ERP epoch length may not have been sufficiently long to capture an enhancement effect if one occurs later in time (cf. Ochsner et al., 2004). Last, the instructions and/or experimental design employed in the current study might not have allowed for optimal engagement in enhanced processing of the stimuli. For example, it is possible that the generic instructions used in this study were not specific enough to demonstrate enhancement or perhaps the use of only unpleasant stimuli in a blocked instructional design limited the range of response. Future studies can explore these issues and begin to tease these possibilities apart by increasing picture exposure, measuring affective reactions—through self-report, autonomic activity, and so forth—simultaneously with EEG, using more specific instructions, and including other classes of emotional stimuli (e.g., pleasant pictures).

In sum, the present study suggests that the electrophysiological response to highly arousing unpleasant stimuli can be changed by intentionally modulating one's emotional reaction. Specifically, we found that electrophysiological activity between 250 and 650 ms poststimulus was decreased during intentional suppression of responses to unpleasant stimuli. This study represents a first step in determining the utility of ERPs in studying emotion modulation/regulation processes. Future studies will be needed to illuminate the temporal dynamics of this modulation, how modulation of responses to other stimuli (e.g., pleasant) are reflected in ERPs, and how different types of instructions and manipulations might best be used to down- and up-regulate electrophysiological responses to motivationally relevant stimuli.

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(Received October 31, 2005; Accepted April 5, 2006)