Emotion
2008, Vol. 8, No. 1, 132–137

1528-3542/08/$12.00 DOI: 10.1037/1528-3542.8.1.132

Modulations of the Electrophysiological Response to Pleasant Stimuli by Cognitive Reappraisal

Jason W. Krompinger, Jason S. Moser, and Robert F. Simons
University of Delaware

Research indicates that individuals successfully regulate their emotions to negatively valenced stimuli using cognitive, antecedent-focused techniques (cf. Gross, 1998). Event-related potential studies have elucidated candidate neural correlates, particularly modulations of the late positive potential (LPP) to index emotion regulation processes. The present study attempted to extend prior demonstrations of emotion regulation effects on the LPP to the domain of positively valenced stimuli. Twenty participants completed a blocked emotion regulation task: The first block consisted of passively viewing pleasant and neutral pictures, whereas the last two blocks consisted of either decreasing or increasing emotions to pleasant pictures. Results replicated our previous findings with negatively valenced stimuli, demonstrating an attenuated LPP during decrease instructions and no effect of increase instructions. Modulation of the ERP as a function of instruction was most prominent during the positive-going slow-wave time window of the LPP, indicating that attentional resources allocated to the perceptual processing of pleasant stimuli may be manipulated using emotion regulation strategies.

Keywords: emotion regulation, late positive potential, LPP, pleasant emotions, attention

Successful regulation of emotion is critical to optimizing psychological well-being (Gross & John, 2003; Gross & Levenson, 1993). Although strategies used to regulate emotion vary, those that involve stimulus or contextual (i.e., cognitive) reappraisal have received the most study of late because of their favorable effects on physiological and psychological functioning (Gross & John, 2003; Ochsner & Gross, 2005). Studies of cognitive reappraisal generally demonstrate that significant regulation effects are evident within seconds after individuals are instructed to decrease or increase their responses to negative emotion-evoking stimuli in the laboratory setting (Jackson, Malmstadt, Larson, & Davidson, 2000).

Most studies of reappraisal have focused on elucidating the mechanisms underlying regulation of negative emotions (cf. Ochsner & Gross, 2005). This focus on negative emotion seems to be driven by the fact that models of psychopathology emphasize the dysregulation of negative affect (cf. *Diagnostic and Statistical Manual of Mental Disorders,* fourth edition; American Psychiatric Association, 2000), and negative emotions are those that people seem most concerned with regulating (cf. Gross, 1998). These studies have demonstrated that several correlates of negative emotion processing can be down-regulated during instructions to cognitively decrease emotional responses, including corrugator electromyography and heart rate, sympathetic nervous system activity, amygdala activity, and self-report (Gross, 1998; Jackson et al., 2000; Ochsner et al., 2004). Regarding instructions to cognitively increase negative emotional responses, some of these same studies have found increases in peripheral physiological measures (Jackson et al., 2000) and in amygdala activation (Ochsner et al., 2004).

In light of this research, our own investigations of emotion regulation followed suit and also focused primarily on responses to unpleasant stimuli. To examine modulations of electrophysiological responses to emotional stimuli under reappraisal conditions, we used event-related potential (ERP) measurement. Specifically, we studied the effects of instructions to cognitively decrease (or "suppress"; see also Jackson et al., 2000) and cognitively increase (or "enhance"; see also Jackson et al., 2000) emotional responses to unpleasant pictures on the late positive potential (LPP). The LPP, an attention-sensitive positive-going slow wave with a centroparietal maximum, has been shown in many studies to be responsive to the arousal aspects of both positive and negative emotion-evoking pictures (Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000; Schupp, Cuthbert, Bradley, Cacioppo, Ito, & Lang, 2000) and has been described as an index of motivated attention (Cuthbert et al., 2000; Schupp et al., 2004). Because of its sensitivity to the affective properties of pictoral stimuli, the LPP seems to be a good candidate for exploring the electrophysiological correlates of emotion regulation by means of cognitive reappraisal manipulation, and in the two studies we have conducted thus far (Hajcak & Nieuwenhuis, 2006; Moser, Hajcak, Bukay, & Simons, 2006) we have shown that the LPP is reduced while participants view unpleasant stimuli following decrease instructions.

Although we have begun to examine ERP modulations associated with the regulation of negative emotion, we are aware of no studies to date that have used ERPs to evaluate the neural markers associated with the regulation of emotional responses to pleasant, approach-based cues. Developing a better understanding of the common and distinct neural mechanisms involved in regulating positive emotions

Jason W. Krompinger, Jason S. Moser, and Robert F. Simons, Department of Psychology, University of Delaware.

Portions of this article were presented at the 46th Annual Meeting of the Society for Psychophysiological Research, Vancouver, BC, Canada, October 2006.

Correspondence concerning this article should be addressed to Jason W. Krompinger, Department of Psychology, University of Delaware, Newark, DE 19716. E-mail: jkrompi@psych.udel.edu

is especially important given the increasing evidence that dysregulation of positive, as well as negative, affect is thought to be characteristic of some mental disorders (Brown, Chorpita, & Barlow, 1998; Kashdan, 2007; Watson et al., 1995). Therefore, the aim of the current study was to address this gap in the literature by examining ERP correlates of positive emotion regulation.

Studies by Lang et al. (e.g. Cuthbert et al., 2000) have demonstrated that a number of highly arousing stimulus categories spanning appetitive valences, such as erotic and adventure-related images, can bring about LPPs of equal magnitude to those evoked by unpleasant stimuli. This is consistent with the suggestion that the LPP indexes motivated attention to biologically salient information whether it signals the need to approach or withdraw (Cuthbert et al., 2000; Schupp et al., 2000, 2004). Data from our own laboratory, using similar pictures, were used to examine LPP responses to both pleasant and unpleasant stimuli in the context of a directed attention task (Hajcak, Moser, & Simons, 2006). It was found that the LPP was reliably reduced when individuals attended to nonemotional versus emotional aspects of a stimulus. There was no difference in this reduction between positive and negative pictures. Considering these similarities in LPP modulation across stimulus valence, it might be reasonable to expect that decreasing emotional responses to pleasant stimuli might yield an LPP response decrement similar to that found when decreasing emotions to unpleasant stimuli.

Although both Hajcak and Nieuwenhuis (2006) and Moser et al. (2006) showed LPP reductions when instructed to decrease negative emotion, we have not yet been successful in demonstrating up-regulation as indexed by increased LPP magnitude. We speculated that this failure to up-regulate may have been due to a ceiling effect on the LPP (Moser et al., 2006). That is, highly arousing, highly negative pictures may automatically capture all available attentional resources (cf. Hoffman, Simons, & Houck, 1983) indexed by the LPP, thereby creating a ceiling that is inconsistent with up-regulation. Similar deductions have been made by Pratto and John (1991) and echoed more recently by Ito, Larsen, Smith, and Cacioppo (1998).

An alternative explanation for the absence of up-regulation relates to the behavioral ecology of the task. Instructing study participants to increase a negative emotional reaction would require that they engage, or approach stimuli that automatically elicit avoidance. It is possible that in the context of our ERP experiments, this approach–avoidance conflict could not be resolved or at least not resolved within the time constraints of our experimental procedures. Such an incompatibility should not be an issue when individuals are instructed to enhance a positive emotional reaction. In point of fact, prior work indicates that pleasant stimuli facilitate approach behavior. For example, pleasant stimuli seem to elicit faster behavioral responses than do unpleasant stimuli (Hare, Tottenham, Davidson, Glover, & Casey, 2005; Schultz et al., 2007). Perhaps with appetitive, pleasant stimuli eliciting greater congruency between the up-regulation instructions and participants' inherent approach motivations, enhancement of the LPP by instruction might be achieved. Although the literature examining the up-regulation of positive emotions is sparse, Demaree, Schmeichel, Robinson, and Everhart (2004) did demonstrate increased heart rate and skin conductance during instructions to increase positive emotions.

Thus, the current study was designed to make further contributions to both the LPP modulation and emotion regulation literature by demonstrating that ERP responses to appetitive stimuli can be modulated by means of cognitive reappraisal. Toward this end, we first instructed participants to passively view pleasant and neutral pictures. In two counterbalanced blocks that followed, participants were instructed to use cognitive reappraisal strategies to either decrease (suppress) or increase (enhance) emotional responses to the pleasant pictures as they were in our previous study with unpleasant pictures (Moser et al., 2006). We expected to observe the standard emotion effect when the LPP was assessed during passive viewing: enhanced LPP to positive pictures. In terms of emotion regulation, we expected to see an attenuated LPP when individuals were to decrease their emotional response, indicating a withdrawal of attention from the appetitive aspects of the evocative stimulus. With regard to modulations of the LPP when individuals were asked to increase their emotional response, we took an exploratory approach, entertaining both possibilities that (a) given the similarities in LPPs normally elicited by positive and negative stimuli, there would be little room for up-regulation or (b) to the extent that subtle motivations are relevant and that positive emotion could result in more flexible regulation strategies, increases in LPP magnitude during up-regulation might be observed.

Method

Participants

Twenty-two undergraduate students (10 women) in an upper level psychology class participated in the current study for extra credit. As an additional incentive, a $20 prize was awarded to the top two regulators, as measured by their brain activity. Two participants (1 woman and 1 man) were excluded as a result of data collection malfunction.

Stimuli and Procedures

The stimulus set was composed of 60 pleasant, high-arousal and 20 neutral, low-arousal color images taken from the International Affective Picture System[1] (IAPS; Lang, Bradley, & Cuthbert, 1999). The pleasant picture set included three general categories of images: children and animals, triumphant sports moments, and nudity and eroticism. The neutral picture set included images of household items and neutral faces. Pleasant and neutral images differed significantly from each other in IAPS normative valence ratings ($M = 6.92$ and 5.77, respectively) and arousal ratings ($M = 5.85$ and 3.81, respectively).

After participants received a general description of the experiment, electroencephalogram/electro-oculogram (EEG/EOG) sensor electrodes were attached and participants were seated approximately 0.5 m directly in front of a 17-in computer monitor. Participants performed a blocked picture-viewing task administered on a Pentium III class computer, using Presentation software

[1] The numbers of the IAPS pictures used were the following: neutral (4611, 4653, 4658, 5390, 5500, 5510, 5623, 5731, 5740, 5800, 5900, 7000, 7002, 7009, 7034, 7060, 7080, 7140, 8161, 8380) and pleasant (1650, 4220, 4290, 4490, 4599, 4607, 4608, 4650, 4651, 4652, 4659, 4660, 4664, 4670, 4672, 4680, 4690, 4800, 4810, 5260, 5450, 5460, 5470, 5621, 5626, 5629, 5700, 5910, 7010, 7025, 7035, 7040, 7090, 7100, 7270, 7501, 7502, 8021, 8030, 8031, 8034, 8040, 8080, 8090, 8170, 8180, 8190, 8200, 8210, 8260, 8300, 8340, 8370, 8400, 8470, 8490, 8496, 8500, 8501, 8502).

(Neurobehavioral Systems, Inc., Albany, CA) to control the presentation and timing of all stimuli. During the task, full-screen pictures (visual angle = 18.2°) from the IAPS were displayed for 1,000 ms. The order of pictures was random within each block. In the first block of the task, participants viewed 20 pleasant and 20 neutral IAPS pictures and were instructed to simply view the pictures as they were presented and respond naturally (the view condition). This condition was designed to serve as a baseline for comparison to the effects of the 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 previous regulation instructions. A fixation mark (+) was presented for 2,000 ms at the beginning of each trial to orient participants to the center of the screen as well as to maintain a constant interstimulus interval across the three blocks of trials. 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 1,000 ms.

The second and third blocks of the task consisted of 20 pleasant IAPS images each. In one block, participants received instructions to cognitively decrease their emotional response to the pictures and in the other block, to cognitively increase their emotional response to the pictures (suppress and enhance blocks, respectively[2]). The order of these two emotion regulation blocks was counterbalanced across participants. The word "SUPPRESS" or "ENHANCE" was presented for 2,000 ms at the beginning of each trial as a reminder. 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 1,000 ms. Following the third and final block, physiological sensors were removed and participants were asked to complete a questionnaire indicating the strategies they used to regulate their emotions in each of the two regulation blocks.

Emotion Regulation Instructions

Instructions for the emotion regulation conditions were adapted from Jackson et al. (2000) and Moser et al. (2006) for use with pleasant images. Thus, participants were not explicitly restricted to using any specific emotion regulation strategy during the second and third blocks, although the instructions emphasized cognitively reframing the event being viewed in such a way as to decrease or increase positive emotional responses. For example, during down-regulation, participants were instructed to view the pleasant image from a detached, uninvolved perspective or to imagine that the pictured event gets worse (e.g., the erotic pictures depict individuals engaging in risky behavior), and during up-regulation participants were instructed to imagine that they were partaking in the pleasant event or that the pictured event gets even better. Broadly, these techniques reflect those described in prior emotion regulation experiments, emphasizing both self- and situation-focused approaches to reframing the context of the scene (e.g., Ochsner et al., 2004). As a manipulation check, the experimenter reviewed participants' responses on the emotion regulation strategies questionnaire to determine whether or not participants understood the instructions.[3]

Psychophysiological Recording, Data Reduction, and Analysis

The 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, tin electrodes were placed on the left and right mastoids (M1 and M2, respectively). During the recording, all activity was referenced to Cz. A vertical EOG generated from blinks and eye movements was also obtained using Med-Associates (St. Albans, VT) miniature electrodes placed approximately 1 cm above and 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 by a Grass Model 78D polygraph with Grass Model 7P511J preamplifiers (bandpass = 0.1–100 Hz; Grass Instruments, Quincy, MA).

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 before picture onset and continued for 1,500 ms. Off-line, the EEG for each trial was corrected for vertical EOG artifacts using the method developed by Gratton, Coles, and Donchin (1983) and then rereferenced 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 values on any channel that equaled that converter's minimum or maximum values). Single-trial EEG data were low-pass filtered at 20 Hz with a 51-weight finite impulse response digital filter as per Cook and Miller (1992).

ERPs were constructed by separately averaging pleasant and neutral picture trials in the view condition; separate averages were also created for pleasant picture trials in the suppress and enhance conditions. ERP averages from the view condition were constructed to serve three purposes: (a) to confirm our first hypothesis concerning differentiations in LPP magnitude between pleasant and neutral stimuli, (b) to provide a baseline condition for pleasant pictures that could be compared with the emotion regulation conditions, and (c) to determine the location and time windows demonstrating the largest LPP to be used in the statistical analyses of our emotion regulation effects. For each ERP, the average activity in the 0- to 200-ms window before picture onset served as the baseline. On visual inspection of grand-averaged waveforms obtained from the initial passive viewing condition, and using the method of Cuthbert et al. (2000), four time windows were defined as reflecting LPP modulation. Windows measuring the average activity between 175 and 225 ms and 225 to 325 ms after stimulus onset captured the P2–N2 deflection and N2–P3 deflection, respectively. A time window measuring average activity between 325 and 475 ms after stimulus onset captured the peak and subsequent resolution of the P3 component. Finally, the positive-going slow wave that developed following

[2] In the interest of keeping consistent with terms used in prior studies from our laboratory, we use the term *suppress* here to indicate cognitive reframing as a means for down-regulating emotion. It should be noted that prior studies (e.g., Gross & Levenson, 1993) have used the term *suppress* to refer to the behavioral inhibition of overt emotional expression.

[3] In the enhance condition, 18 of the 20 participants (90%) indicated that they typically placed themselves in the context of the picture to carry out this regulation. The remaining 2 participants indicated that they tried to attend only to positive aspects of the stimuli and ignore neutral or negative features. For suppression, 16 of the 20 participants (80%) indicated that they would typically focus on negative or unappealing aspects of the stimuli. Three of the remaining participants stated that they attempted to emotionally detach from or "numb" themselves to the stimuli.

the resolution of the P3 was measured as the average activity in the time window of 475 to 675 ms.

ERP measures were statistically evaluated using SPSS (Version 13.0) General Linear Model software with orthogonal polynomial contrasts conducted on the electrode site factor and Greenhouse–Geisser correction applied to p values associated with multiple degree of freedom repeated measures comparisons. After conducting the omnibus analysis of variance (ANOVA), the Hochberg's sequential Bonferroni procedure was used to test for significant post hoc comparisons with a family wise $\alpha = .05$ (cf. Hochberg, 1988).

Results

Emotion Effects

The ERP waveforms at each recording site obtained during the passive viewing condition are presented in Figure 1. To determine the location and timing of maximal LPP effects, an initial 2 (emotion) × 4 (time window) × 4 (site) ANOVA was conducted.[4] Emerging from this analysis were significant main effects for each of these factors: emotion, $F(1, 18) = 29.75$, $p < .0001$; time window, $F(3, 54) = 9.69$, $p < .0001$; site, $F(3, 54) = 38.54$, $p < .0001$. Additionally, significant interactions were observed between time window and electrode site, $F(9, 162) = 7.33$, $p < .0001$, and time window and emotion, $F(3, 57) = 11.47$, $p < .0001$. The significant emotion effect confirmed that LPP magnitude was larger for pleasant than for neutral pictures. Post hoc tests revealed that the ERP was more positive during the P3 and sustained slow-wave windows (3 and 4) than it was during the earlier two windows but that Windows 3 and 4 did not differ from one another. Analyses also indicated that the magnitude of the LPP increased in a linear fashion from anterior to posterior sites achieving maximum positivity at Pz.

Regarding the more important Time Window × Emotion interaction, post hoc comparisons confirmed that the emotion effect, when quantified as the difference in the ERP to the pleasant and neutral stimuli, was present during Time Windows 2, 3, and 4 and was not evident during the first window. This emotion effect was larger during Time Windows 3 and 4 than it was during each of the two earlier windows, but its magnitude did not change from Window 3 to Window 4. Lastly, the Time Window × Site interaction revealed that the parietal maximum developed during the second time window and, like the emotion effect, remained consistent throughout the remaining two windows.

Emotion Regulation Effects

Because the effect of emotion began during the second time window and was maximal at Pz, emotion regulation of the LPP was analyzed by means of a 3 (time windows: 2, 3, and 4) × 3 (condition: view, enhance, suppress) ANOVA conducted at electrode site Pz.[5] A significant main effect of condition was evident, $F(2, 38) = 6.16$, $p < .01$. The Bonferroni procedure revealed that suppress condition differed significantly from both view and enhance conditions and that view and enhance conditions did not differ from one another (Figure 2). There was also a significant effect of time, $F(2, 38) = 24.04$, $p < .0001$, as before, with significantly greater positivity in Windows 3 and 4 than in Window 2. Finally, there was a significant Time × Condition interaction, $F(4, 76) = 6.38$, $p < .01$, with post hoc comparisons indicating that regulation of the LPP was reliable only during the P3 and slow-wave portions of the LPP, and the size of this effect grew larger as the LPP progressed over time (ds = .43 and .95 for the P3 and slow-wave time windows, respectively).

Discussion

As expected, pleasant pictures elicited larger LPPs than neutral pictures under normal viewing conditions, indicating that the emotional pictures were engaging participants' attentional resources in such a way as to differentiate them from stimuli with little motivational significance. Second, LPP magnitudes to pleasant pictures were significantly attenuated when individuals were instructed to decrease their emotional response. Third, no effect of instruction on LPP magnitude was observed during the enhance block; the LPPs in this condition were comparable in size to those observed during the initial passive viewing block.

The down-regulation of the LPP observed in this study replicated that which was found in our previous experiment using an identical design save for the use of unpleasant instead of pleasant stimuli (Moser et al., 2006). This result lends further credence to the notion that an observable neural response thought to reflect attentional processing can be modulated when participants are instructed to actively reframe emotional aspects of a stimulus. Furthermore, together with our previous findings using unpleasant stimuli, the result of the current study indicates that such an effect is evident across valences when each stimulus type is regulated in isolation. The LPP modulation during down-regulation, then, might reflect a more general disengagement of attentional–perceptual processing from the arousing aspects of the motivationally relevant stimuli. It is interesting to speculate on the timing of this disengagement or regulation process. Using our time windows as benchmarks, we observed that the emotional aspects of the stimuli impacted on the ERP during the 225- to 325-ms window and regulation was apparent as early as 100 ms later. That is, emotion regulation, at least in terms of LPP reductions, is evident within 325 ms of stimulus delivery and within 100 ms of the ERP modulation by emotional content. The fact that we used a cued instruction task in the current study, however, leaves open the possibility that regulation effects may emerge earlier during instruction–word processing.

We did not observe any effect on the LPP as a result of instructions to increase the emotional response. This result contradicts other findings in the literature that have demonstrated up-

[4] As noted in the description of our method, our three conditions were not fully counterbalanced in that all participants received the view condition first. To test whether LPP reductions seen under suppress instructions were simply a result of habituation over the course of time, we conducted an additional analysis of emotion regulation by including condition order as a between-groups factor (i.e., the suppress-first participants and the enhance-first participants). These analyses yielded no significant effect of order or significant interaction between order and condition (ps > .80) as would be expected if the LPP simply grew smaller with repeated exposures.

[5] For exploratory purposes, participant gender was included as a between-groups factor, along with within-groups factors time window, emotion regulation condition, and electrode site in the initial repeated measures ANOVA. This analysis yielded no significant between-groups effect of gender or a significant interaction with any within-groups factor (ps > .10).

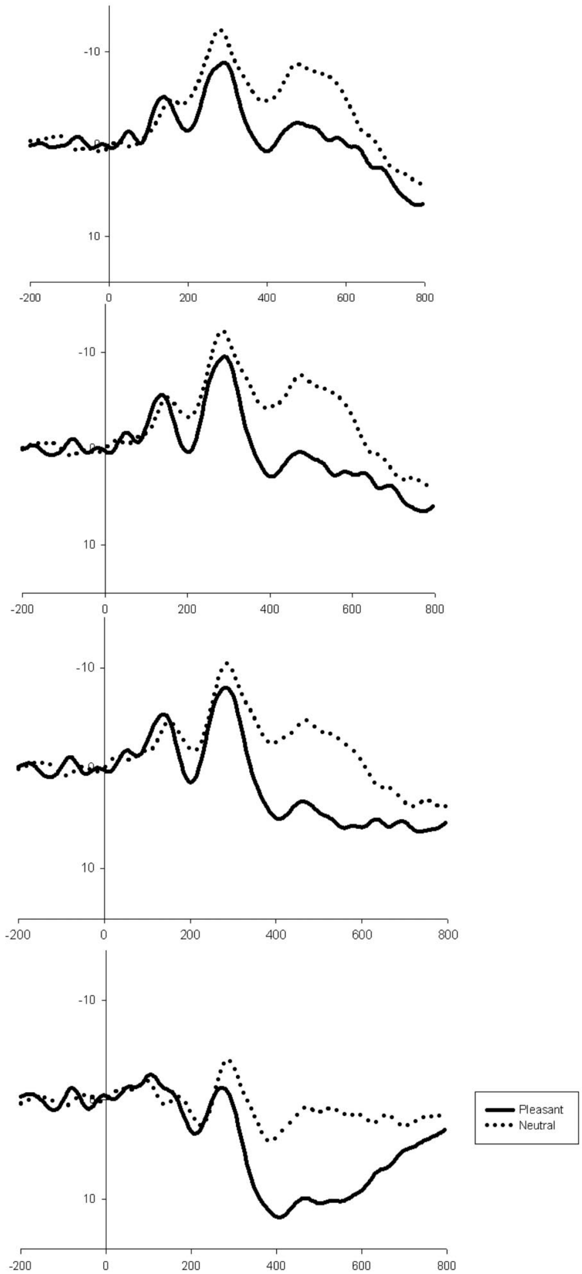

Figure 1. Stimulus-locked event-related potentials for the view condition at (from top) Fz, Fcz, Cz, and Pz. The *y*-axis is in microvolts; the *x*-axis is time in milliseconds.

regulation of physiological responses as a function of increase instructions (e.g., Jackson et al., 2000), but it is consistent with results from our previous ERP study using unpleasant stimuli (Moser et al., 2006). This failure to increase the LPP to either pleasant or unpleasant stimuli may reflect a ceiling as a result of the automatic capture of free attentional resources by motivationally relevant stimuli regardless of valence (Pratto & John, 1991), and is inconsistent with our speculation that up-regulation requires a match between stimulus valence and normal response dispositions (i.e., approach and avoidance). We are continuing to examine these issues in ongoing experiments.

It is important to note in this regard that the current experiment exposed participants to the evocative stimuli for a relatively brief duration compared with other studies of emotion regulation (e.g., Oschner et al., 2004) that were more successful in producing emotion enhancement. Extended stimulus presentation may allow individuals more time to carry out the up-regulation instructions. That is, it is possible that cognitive up-regulation has a different time course than cognitive down-regulation, at least as reflected in ERPs, and that our exposure time was not adequate to allow enhancement processes to unfold. Longer picture presentation studies will be necessary to test this hypothesis.

While the present research used physiological measurements (i.e., the LPP) to assess emotion elicitation and modulation, we did not collect self-report information from participants regarding their subjective emotional experience. Although evidence indicates a strong correlation between LPP magnitude and verbal report (Hajcak & Nieuwenhuis, 2006) of emotional experience, we can only infer at this point that the experience of negative emotion decreased when participants down-regulated the LPP and was unchanged when they were instructed to enhance. A more detailed three-systems assessment (i.e., including recording overt behavioral and verbal responses in addition to our psychophysiological assessment; cf. Gross, 1998; Lang, 1979) might offer more insight into subjective experience and further flesh out differences between up- and down-regulation.

Another issue to consider regarding our design was the utilization of an initial passive viewing block for all participants before the counterbalanced emotion regulation blocks. As indicated previously,

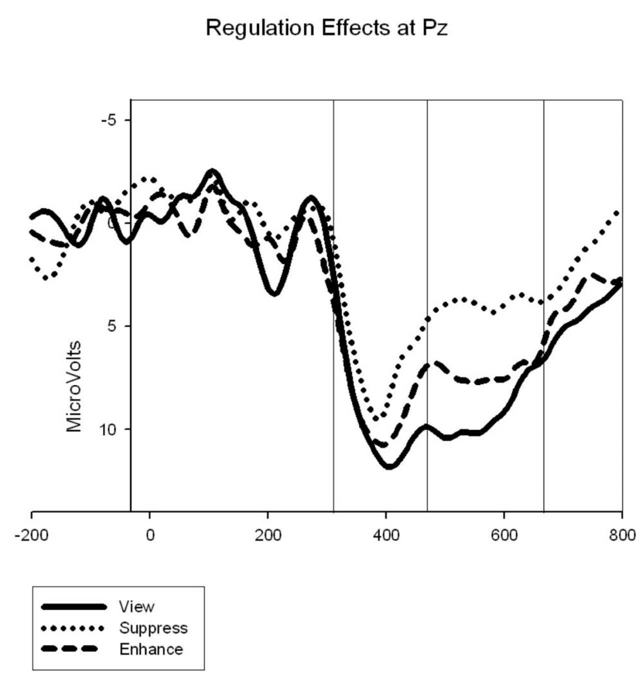

Figure 2. Stimulus-locked event-related potentials for view, enhance, and suppress conditions at Pz. The *y*-axis is in microvolts; the *x*-axis is time in milliseconds. P3 time window is marked by vertical lines (325–475 ms), followed by the slow-wave time window (475–675 ms).

this approach was chosen to ensure that the passive viewing block elicited ERPs that were representative of emotional stimulus processing in the absence of any systematic or instructed emotion regulation on the part of the participant. We felt that using a fully counterbalanced approach (i.e., with some participants performing the passive viewing block after a suppress or an enhance block) would have led to the contamination of the view ERPs through participants' spontaneous use of the just-acquired regulation techniques, even when instructed to refrain from doing this. However, the present design leaves open the possibility that our participants might have habituated to the pictures over time, thus complicating the interpretation of the suppress and enhance manipulations. Given, however, that the LPPs in response to suppress and enhance instructions differed significantly even though these specific blocks were completely counterbalanced, it seems unlikely that simple habituation can account for the down-regulation of the LPP. Nonetheless, additional experimentation that uses a more thoroughly counterbalanced approach to stimulus and condition presentation might provide additional information on the trial-by-trial ability to regulate emotions.

Our results bolster the idea that ERPs can be a useful tool in observing psychophysiological correlates of emotion regulation and indicate that ERP correlates of pleasant picture viewing can be manipulated in a fashion similar to that for unpleasant picture viewing. Future research can expand on these findings and further take advantage of the temporal precision of ERPs by using more complex experimental designs that emphasize more fine-grained time-course examination of emotion regulation processes.

References

American Psychiatric Association. (2000). *Diagnostic and statistical manual of mental disorders* (4th ed., text rev.). Washington, DC: Author.

Brown, T. A., Chorpita, B. F., & Barlow, D. H. (1998). Structural relationships among dimensions of the *DSM–IV* anxiety and mood disorders and dimensions of negative affect, positive affect, and autonomic arousal. *Journal of Abnormal Psychology, 107,* 179–192.

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

Cook, E. W., & Miller, G. A. (1992). Digital filtering: Background and tutorial for psychophysiologists. *Psychophysiology, 29*(3), 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*(2), 95–111.

Demaree, H. A., Schmeichel, B. J., Robinson, J. L., & Everhart, D. E. (2004). Behavioural, affective, and physiological effects of negative and positive emotional exaggeration. *Cognition and Emotion, 18*(8), 1079–1097.

Gratton, G., Coles, M. G., & Donchin, E. (1983). A new method for off-line removal of ocular artifact. *Electroencephalography and Clinical Neurophysiology, 55*(4), 468–484.

Gross, J. J. (1998). The emerging field of emotion regulation: An integrative review. *Review of General Psychology, 2*(3), 271–299.

Gross, J. J., & John, O. P. (2003). Individual differences in two emotion regulation processes: Implications for affect, relationships, and well-being. *Journal of Personality and Social Psychology, 85,* 348–362.

Gross, J. J., & Levenson, R. W. (1993). Emotional suppression: Physiology, self-report, and expressive behavior. *Journal of Personality and Social Psychology, 64,* 970–986.

Hajcak, G., Moser, J. S., & Simons, R. F. (2006). Attending to affect: Appraisal strategies modulate the electrocortical response to arousing pictures. *Emotion, 6*(3), 517–522.

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

Hare, T. A., Tottenham, N., Davidson, M. C., Glover, G. H., & Casey, B. J. (2005). Contributions of amygdala and striatal activity in emotion regulation. *Biological Psychiatry, 57,* 624–632.

Hochberg, Y. (1988). A sharper Bonferroni procedure for multiple tests of significance. *Biometrika, 75,* 800–802.

Hoffman, J. E., Simons, R. F., & Houck, M. R. (1983). Event-related potentials during controlled and automatic target detection. *Psychophysiology, 20*(6), 625–632.

Ito, T. A., Larsen, J. T., Smith, N. K., & Cacioppo, J. T. (1998). Negative information weighs more heavily on the brain: The negativity bias in evaluative categorizations. *Journal of Personality and Social Psychology, 75,* 887–900.

Jackson, D. C., Malmstadt, J. R., Larson, C. L., & Davidson, R. J. (2000). Suppression and enhancement of emotional responses to unpleasant pictures. *Psychophysiology, 37*(4), 515–522.

Kashdan, T. B. (2007). Social anxiety spectrum and diminished positive experience: Theoretical synthesis and meta-analysis. *Clinical Psychology Review, 27,* 348–365.

Lang, P. J. (1979). A bio-informational theory of emotional imagery. *Psychophysiology, 16,* 495–512.

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: Center for Research in Psychophysiology, 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., & Gross, J. J. (2005). The cognitive control of emotion. *Trends in Cognitive Sciences, 9*(5), 242–249.

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

Pratto, F., & John, O. P. (1991). Automatic vigilance: The attention-grabbing power of negative social information. *Journal of Personality and Social Psychology, 61,* 380–391.

Schultz, K. P., Fan, J., Madidina, O., Marks, D. J., Hahn, B., & Halperin, J. M. (2007). Does the emotional go/no-go task really measure behavioral inhibition? Convergence with measures on a non-emotional analog. *Archives of Clinical Neuropsychology, 22,* 151–160.

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*(2), 257–261.

Schupp, H. T., Cuthbert, B. N., Bradley, M. M., Hillman, C. H., Hamm, A. O., & Lang, P. J. (2004). Brain processes in emotional perception: Motivated attention. *Cognition & Emotion, 18*(5), 593–611.

Watson, D., Weber, K., Assenheimer, J. S., Clark, L. A., Strauss, M. E., & McCormick, R. A. (1995). Testing a tripartite model: I. Evaluating the convergent and discriminant validity of anxiety and depression symptom scales. *Journal of Abnormal Psychology, 104, 3*–14.

Received January 24, 2007
Revision received August 8, 2007
Accepted August 21, 2007 ■