Emotion
2010, Vol. 10, No. 6, 767–782

1528-3542/10/$12.00 DOI: 10.1037/a0020242

Beyond Good and Evil: The Time-Course of Neural Activity Elicited by Specific Picture Content

Anna Weinberg and Greg Hajcak
Stony Brook University

The present study examined electrocortical evidence for a negativity bias, focusing on the impact of specific picture content on a range of event-related potentials (ERPs). To this end, ERPs were recorded while 67 participants viewed a variety of pictures from the International Affective Picture System. Examination of broad categories (i.e., pleasant, neutral, unpleasant) found no evidence for a negativity bias in two early components, the N1 and the Early Posterior Negativity (EPN), but revealed that unpleasant images did elicit a larger late positive potential (LPP) than pleasant pictures. However, images of erotica and mutilation elicited comparable LPP responses, as did affiliative and threatening images. Exciting (i.e., sports) images and disgusting images elicited smaller LPPs than other emotional images, similar to neutral images containing people—which were associated with the largest LPPs among neutral pictures. When these three anomalous categories (exciting, disgusting, and scenes with people) were excluded, unpleasant images no longer elicited a larger LPP than pleasant images. Thus, including exciting images in pleasant ERP averages disproportionately reduces the LPP. The present findings are discussed in light of the motivational significance of specific picture subtypes.

Keywords: emotion, IAPS, late positive potential, early posterior negativity, negativity bias

Although multiple stimuli compete for our attention, the majority will go unnoticed; in fact, only a small percentage of all stimuli reach conscious awareness (Most, Smith, Cooter, Levy, & Zald, 2007; Mack & Rock, 1998; Neisser, 1979). Stimuli that most efficiently capture our attention tend to be those critical to survival; for instance, those pertaining to reproduction or danger (e.g., Bradley, Codispoti, Cuthbert, & Lang, 2001; Lang, Bradley, & Cuthbert, 1997). Emotional stimuli, which signal the need to fight, flee, procreate, or affiliate, initiate relatively automatic responses, including transient changes in experienced affect, dispositions to act, and changes in central and peripheral physiology (Frijda, 1986, 1987; Lang, 1979, 1985).

Compared to affectively neutral stimuli, both appetitive and aversive emotional stimuli more effectively capture and hold attention (Armony & Dolan, 2002; Mogg, Bradley, De Bono, & Painter, 1997; Öhman, Flykt, & Esteves, 2001; Schupp et al., 2007; Vuilleumier, 2005), and receive increased processing even when presented in unattended locations (Anderson & Phelps, 2001; Esteves, Parra, Dimberg, & Öhman, 1994). Emotional stimuli, regardless of valence, are more likely to be recalled (Buchanan & Adolphs, 2002; Hamann, 2001; Hamann, Cahill, McGaugh, & Squire, 1997; Phelps, LaBar, & Spencer, 1997) and are viewed for longer (Lang, Bradley, & Cuthbert, 1997) than nonemotional stimuli. A variety of physiological systems appear to be uniquely sensitive to emotional stimuli: compared to neutral stimuli, both pleasant and unpleasant pictures elicit larger electrodermal responses (Bradley, 2009; Codispoti, Bradley, & Lang, 2001), enhanced spinal reflexes (Bonnet, Bradley, Lang, & Requin, 1995; Both, Everaerd, & Laan, 2003; Dolan, 2002), and increased excitability in the motor cortex (Hajcak, Molnar, et al., 2007).

In addition, multiple ERP components are sensitive to the emotional content of visual images, increasing in amplitude to both positively and negatively valenced stimuli compared to neutral (Cacioppo, Crites, Gardner, & Berntson, 1994; Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000; Keil et al., 2002; Schupp, Cuthbert, et al., 2004), which may be useful in tracking the temporal course of emotional processing. For example, early negativities (e.g., 100–300 ms) have been utilized to index early selective attention for emotional stimuli (Foti et al., 2009; Keil et al., 2002; Schupp, Flaisch, Stockburger, & Junghöfer, 2006; Schupp, Junghöfer, Weike, & Hamm, 2003a2004, 2003b, 2004). One such component is the N1, a central-parietal negative deflection of the ERP waveform, which peaks around 130 ms after stimulus onset (Foti et al., 2009; Keil et al., 2002). The N1 is sensitive to the emotional content of visual stimuli, and is larger for emotional compared to neutral images (e.g., Foti et al., 2009; Keil et al., 2002), suggesting greater early visual processing of emotional content. Likewise, the EPN, a temporo-occipital negativity maximal at around 230 ms, is also larger for emotional compared to neutral images (Foti et al., 2009; Schupp, Flaisch, et al., 2006; Schupp et al., 2003a, 2003b; Schupp et al., 2004; Schupp, Stockburger, et al., 2006; Weinberg & Hajcak, under review).

Recently, a number of electrocortical studies of emotional responding have focused on a P300-like positive modulation of the ERP referred to as the late positive potential (LPP). The LPP has a centro—parietal scalp distribution and is observed as early as

This article was published Online First November 8, 2010.

Anna Weinberg and Greg Hajcak, Department of Psychology, Stony Brook University.

Correspondence concerning this article should be addressed to Greg Hajcak, Department of Psychology, Stony Brook University, Stony Brook, NY 11794-2500. E-mail: greg.hajcak@stonybrook.edu

200 ms following stimulus onset (Codispoti, Bradley, & Lang, 2001; Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000; Foti, Hajcak, & Dien, 2009; Schupp et al., 2000; Schupp, Cuthbert, et al., 2004), and for as much as 1,000 ms after stimulus offset (Hajcak & Olvet, 2008). The LPP has been shown to be sensitive to the emotional content of visual images, such that its amplitude is enhanced by both positively- and negatively valenced stimuli compared to neutral (Cuthbert et al., 2000; Hajcak, Dunning, & Foti, 2009; Schupp et al., 2000; Schupp et al., 2004). The magnitude of the LPP can also be modified by online manipulations that direct attention toward more or less arousing portions of aversive stimuli (Dunning & Hajcak, 2009; Hajcak et al., 2009); along similar lines, manipulations of stimulus meaning impact the amplitude of the LPP (Foti & Hajcak, 2008; Hajcak & Nieuwenhuis, 2006; MacNamara, Foti, & Hajcak, 2009), suggesting that it integrates both top-down and bottom-up imperatives in affective evaluation.

Negativity Bias

ERPs associated with emotional processing have also been used to examine the hypothesis that negative information might hold a further privileged status among emotional content. Some argue that negative events and information evoke stronger physiological and emotional reactions compared to both neutral *and* positive events and information (Cacioppo & Gardner, 1999; Öhman, 1992; Peeters & Czapinski, 1990; Taylor, 1991). This "negativity bias" is thought to have resulted from evolutionary pressure favoring outcomes in response to threat versus rewards (Cacioppo, Gardner, & Berntson, 1999).

Indeed, people appear to use negative information more readily than positive when it comes to impression formation (e.g., Anderson, 1965; Fiske, 1980; Peeters & Czapinksi, 1990; Skowronski & Carlston, 1989). A range of behavioral data also suggests the existence of a negativity bias: locating a negative face among positive distracters takes less time than the converse (e.g., Hansen & Hansen, 1988; Öhman et al., 2001); additionally, negative compared to positive stimuli have been associated with greater interference on emotional stroop tasks (Pratto & John, 1991; for a review, see Baumeister, Bratslavsky, Finkenauer, & Vohs, 2001).

Studies utilizing ERPs have provided mixed support for the existence of a negativity bias. Some research suggests, for example, that the N1 may be particularly sensitive to unpleasant (compared to pleasant) visual stimuli, in that it appears uniquely resistant to habituation to a single highly arousing unpleasant image presented repeatedly (Carrieté, Hinojosa, & Mercado, 2003). However, other studies have failed to replicate this finding (Codispoti et al., 2007; Olofsson & Polich, 2007). In addition, a number of studies suggest that the EPN is in fact larger for *pleasant* compared to unpleasant stimuli (Franken, Muris, Nijs, & van Strien, 2008; Schupp, Junghöfer, et al., 2004; Schupp, Stockburger, et al., 2006).

Likewise, while many examinations of the LPP in response to picture content have demonstrated larger magnitudes elicited by images falling into the broad pleasant and unpleasant semantic categories (e.g., Schupp et al., 2000; Hajcak & Olvet, 2008; Hajcak, Dunning, & Foti, 2007), a number have also demonstrated that unpleasant images elicit larger LPPs than pleasant images—and these data have been interpreted in terms of a negativity bias in affective evaluation (e.g., Delplanque, Silvert, Hot, & Sequeira, 2005; Foti, Hajcak & Dien, 2009; Hajcak & Olvet, 2008; Huang & Luo, 2006; Ito, Larsen et al., 1998).

However, in many of the studies that have provided evidence for increased attentional allocation to unpleasant images (e.g., Ito, Larsen, Smith, & Cacioppo, 1998; Foti et al., 2009; Hajcak & Olvet, 2008; Kisley, Wood, & Burrows, 2007; Delplanque et al., 2005; Delplanque et al., 2006; Wood & Kisley, 2006), the composition of the broad semantic categories (i.e., pleasant and unpleasant) was much more heterogeneous than the labels imply. Within the broad "pleasant" category are images of couples in erotic embrace, fireworks, ice cream, sunsets, rollercoasters, and images of people skydiving; "neutral" is composed of images of household objects, images of abstract art, scenes with and without people in them, and so on; and "unpleasant" is composed of images of mutilated bodies, images of guns pointed at the camera and at others in the scene, images of attacking snakes or leopards, and images of vomit.

Importantly, recent studies have demonstrated very different patterns of physiological activity for specific semantic categories (Bradley, Codispoti, Cuthbert, & Lang, 2001; Bradley, Codispoti, Sabatinelli, & Lang, 2001). In particular, erotic, mutilation, and threat images—the image categories most directly relevant to primary motivational imperatives—appear to elicit the strongest electrodermal response; erotic elicit greater startle blink inhibition, and threat and mutilation greater startle blink potentiation, than other images in their respective broad (i.e., "pleasant" and "unpleasant") semantic categories. Another study of electrodermal responding to IAPS images showed the largest responses to erotic images, followed by threat and mutilation, followed by images of extreme sports, which elicited an only slightly—though significantly—larger response than neutral images (Sarlo, Palomba, Buodo, Minghetti, & Stegagno, 2005). Erotic images have also been found to elicit "emotion-induced blindness" similar to that elicited by highly arousing aversive images (Most, Smith, Cooter, Levy, & Zald, 2007).

Likewise, two recent examinations of brain potentials in response to specific semantic categories found LPPs of larger magnitude elicited by erotic and mutilation images than other images in their respective broad semantic categories (Briggs & Martin, 2009; Schupp, Cuthbert, et al., 2004). Moreover, images of sports and rollercoasters, which in this paper we will refer to as *exciting*, elicited responses that appeared similar to those elicited by neutral images (Schupp et al., 2004), though exciting and neutral pictures were not directly compared. In their seminal work on brain processes underlying the negativity bias, Ito and colleagues (1998) used either exclusively exciting images in their pleasant category (images 8490, a rollercoaster, and 8510, a race car) or food images (images 7340, pizza, and 7350, ice cream), while the unpleasant category consisted of mutilation and threat (images 3030 and 6230, respectively) or disgust (images 9140 and 9571, respectively; data also used in Smith et al., 2003).[1] In the studies from Delplanque et

[1] The finding that negative images elicit LPPs of larger magnitude than positive images was replicated in a subsequent study (Ito & Cacioppo, 2000) using 16 pleasant images with people, 16 pleasant images without people, 16 unpleasant images with people, and 16 unpleasant images without people. However, the specific IAPS images used in this study were not indicated.

al., (2005, 2006), 27 of the 40 pleasant images were exciting; in Smith et al. (2003), five of the 20 pleasant images were exciting; in Hajcak and Olvet (2008), 15 of the 40 pleasant images were exciting; in Foti, Dien, and Hajcak (2009), 17 of the 40 pleasant were exciting; and in Huang and Luo (2006), nine of the 25 pleasant were exciting. Collectively, these data suggest the somewhat paradoxical possibility that the existence of a negativity bias in the LPP may be driven by a dilution of the pleasant average by the inclusion of exciting stimuli.

This possibility is consistent with the notion that the LPP tracks motivational salience: though both erotic and exciting images may be rated as *arousing* by participants, erotic images convey information more directly relevant to survival and other biological imperatives and may therefore be more likely to activate an appetitive motivational system (Anokhin et al., 2006; Bradley, Codispoti, Cuthbert, & Lang, 2001; Bradley, Codispoti, Sabatinelli, & Lang, 2001; Briggs & Martin, 2009; Franken et al., 2008; Schupp, Cuthbert, et al., 2004). With this in mind, subjects viewed a wide array of images from the IAPS in the present study (Lang, Bradley, & Cuthbert, 2005). As in previous studies, the pictures fell into three broad categories (pleasant, neutral, and unpleasant), but within those categories, images pertaining to more specific semantic categories were selected. Within the broad pleasant category, erotic images of heterosexual couples, affiliative pictures (e.g., cuddly animals, babies, and smiling families), and exciting images (e.g., exciting sports) were selected. Within the broad neutral category, images of common household objects (e.g., a fork), images of scenes without people (e.g., landscapes) and images of scenes with people (e.g., women standing before a church), were selected. Finally, within the broad unpleasant category, images of mutilation (e.g., a mutilated hand), images of threat (e.g., a gun pointed toward the camera), and disgusting images (e.g., an overflowing toilet) were selected.

In order to examine the time course over which valence-related processing biases might emerge, two early components, the N1 and the EPN, were examined. Consistent with previous literature, we hypothesized that the N1 would be enhanced to emotional compared to neutral, but that no negativity bias would emerge at this early stage (Codispoti et al., 2007; Olofsson & Polich, 2007). In addition, we hypothesized that the EPN would display a positivity bias (i.e., be enhanced to pleasant pictures), as has been previously demonstrated (Franken et al., 2008; Schupp, Junghöfer, et al., 2004; Schupp, Stockburger, et al., 2006). However, the present study is novel in that, to date, there has been little work to examine the impact of multiple *specific* picture contents on these early negativities. We hypothesized that the magnitude of these early components would vary with the evolutionary significance of specific picture content, such that they would be enhanced for more motivationally salient images (e.g., mutilation and erotic; Schupp, Cuthbert, et al., 2004; Franken et al., 2008).

Further, it was anticipated that, when examining broad valence-based categories (pleasant, neutral, and unpleasant), previous findings would be replicated; that is, the magnitude of the LPP would be larger for emotional (pleasant and unpleasant) than neutral images, and that the magnitude of the LPP would be larger for unpleasant than pleasant images (e.g., Delplanque et al., 2005; Ito, Larsen et al., 1998; Hajcak & Olvet, 2008). However, it was also hypothesized that variation would exist within the broad semantic categories; specifically, it was anticipated that erotic and mutilation images would also elicit the largest LPPs (per Schupp et al., 2004), and that, consistent with previous research (Ito & Cacioppo, 2000) neutral images with people would elicit larger LPPs than neutral images without people.

Finally, we anticipated that, when directly compared, exciting images would not elicit significantly different LPPs from neutral images. Our primary hypothesis built on this, and sought to examine the notion that the inclusion of sports photographs might result in a dilution of pleasant picture LPPs; we hypothesized that by excluding exciting images from the pleasant category ERP averages, the negativity bias in the LPP would be reduced or eliminated.

Methods

Participants

A total of 67 Stony Brook University undergraduates (41 female) participated in the study for course credit. Three were excluded from analysis due to poor quality of recordings. Data from 64 participants (39 female) were therefore included in final analysis of EEG. Self-report data for six participants were lost as a result of computer error; for self-report, data for 61 (39 female) subjects were therefore included.

Visual Stimuli

One hundred and 35 images were selected from the IAPS (Lang et al., 2005). Forty-five were pleasant, 45 neutral, and 45 unpleasant images. Within each of the three broad semantic categories, images were further subdivided into three specific semantic categories (pleasant: 15 erotic, 15 affiliative, 15 exciting; neutral: 15 objects, 15 scenes without people, 15 scenes with people; unpleasant: 15 mutilation, 15 threat, and 15 disgusting). Normative ratings indicated that unpleasant pictures (M = 1.90, SD = .68) were less pleasant, $t(44) = 22.77$, $p < .001$, than neutral pictures (M = 5.03, SD = .31) which were less pleasant, $t(44) = 24.23$, $p < .001$ than pleasant pictures (M = 7.43, SD = .50; higher numbers indicate more pleasant ratings). Both unpleasant (M = 6.26, SD = .71; $t(44) = 20.00$, $p < .001$) and pleasant (M = 5.84, SD = .93; $t(44) = 16.11$, $p < .001$) images were more emotionally arousing than neutral images (M = 2.98, SD = .54; higher numbers indicate higher arousal). However, normative ratings of arousal for unpleasant and pleasant images were not significantly different from one another, $t(44) = 1.76$, $p = .09$. Specific images used in the study appear in the Appendix.

All visual stimuli were presented on a Pentium D computer, using Presentation software (Neurobehavioral Systems, Inc.; Albany, CA). Prior to each trial, participants viewed a white fixation cross on a black background. Each picture was displayed in color at the full size of the monitor, 48.26 cm. Participants were seated approximately 60.96 cm from the screen and the images occupied about 40° of visual angle horizontally and vertically.

Procedure

Subsequent to verbal instructions indicating that they would be passively viewing pictures of varying emotional quality, participants were seated and electroencephalograph sensors were attached. Participants then viewed three blocks of images, with each block consisting of pleasant-only, unpleasant-only, and neutral-only images. Some studies on affective picture processing have utilized a modified oddball task, in which a single emotional target is presented infrequently within a stream of images representing a different affective context; for example, a single pleasant picture may be presented in a stream of unpleasant pictures. However, these studies have always presented either unpleasant or pleasant pictures as target stimuli—that is, neutral pictures have not been targets within an emotional context (e.g., Ito, Caciopo, & Lang, 1998; Rosenkrants & Polich, 2008). Thus, these studies have not addressed the potential additive, interactive, or even valence-specific effects of target status and picture type. To avoid some of these issues in the current study, images were presented in valence-specific blocks to rule out possible differences resulting from target effects, local probability, and violations of valence-related expectations or surprise (Ito, Larsen et al., 1998), as well as to preclude any potential impact of decision-making or motor response demands. The order of the blocks was counterbalanced between subjects, and between each block, participants were given a short break. Within each block, the order of stimulus presentation was random for each participant, and each image was presented twice; blocks lasted approximately five minutes each. Each image was presented for 1.5 seconds, with 2-second intervals between image presentations.

Following the completion of electroencephalographic recording, participants were again asked to view each image, and were instructed to rate each image on the valence and arousal dimensions using a visual analog scale, the self-assessment manikin (SAM; Lang, 1980). The arousal scale consists of five characters depicting a range of visceral responses from calm to excited; the numbers 1 through 9 were presented below the characters, with 1 corresponding to a strong bodily response and 9 corresponding to no bodily response. Participants were told to rate only their level of arousal on this scale (e.g., stimulated, jittery, wide awake, or relaxed, calm, dull, or sleepy), rather than the affective quality of their response. The valence scale also consisted of five characters depicting a range from happy to unhappy, with the numbers 1 through 9 again presented below the characters. The number 1 corresponded to the happiest figure, and 9 corresponded to the most unhappy figure. Participants were instructed to use this scale to rate the extent to which they felt pleasant or unpleasant emotions in response to the picture. On both of the scales, 5 represented the midpoint, and participants were encouraged to use any point on the scale. For presentation purposes here, both sets of ratings have been reverse-scored so that a score of 9 represents pleasant valence and high arousal.

Electroencephalographic Recording and Data Processing

Continuous EEG recordings were collected using an elastic cap and the ActiveTwo BioSemi system (BioSemi, Amsterdam, Netherlands). Sixty-four electrode sites were used, based on the 10/20 system, as well as two electrodes on the right and left mastoids. Electrooculogram (EOG) generated from eye movements and eyeblinks was recorded using four facial electrodes: horizontal eye movements were measured via two electrodes located approximately 1 cm outside the outer edge of the right and left eyes. Vertical eye movements and blinks were measured via two electrodes placed approximately 1 cm above and below the right eye. The EEG signal was preamplified at the electrode to improve the signal-to-noise ratio and amplified with a gain of 16× by a BioSemi ActiveTwo system (BioSemi, Amsterdam). The data were digitized at 24-bit resolution with a sampling rate of 512 Hz using a low-pass fifth order sinc filter with a half-power cutoff of 102.4 Hz. Each active electrode was measured online with respect to a common mode sense (CMS) active electrode producing a monopolar (nondifferential) channel. Offline, all data was referenced to the average of the left and right mastoids, and band-pass filtered with low and high cutoffs of 0.1 and 30 Hz, respectively; eyeblink and ocular corrections were conducted per Gratton, Coles, and Donchin (1983).

A semiautomatic procedure was employed to detect and reject artifacts. The criteria applied were a voltage step of more than 50.0 μV between sample points, a voltage difference of 300.0 μV within a trial, and a maximum voltage difference of less than 0.50 μV within 100-ms intervals. These intervals were rejected from individual channels in each trial. Visual inspection of the data was then conducted to detect and reject any remaining artifacts.

The EEG was segmented for each trial beginning 200 ms prior to picture onset and continuing for 1,700 ms (i.e., for the entire picture presentation duration). For each trial, the baseline was defined as the 200 ms prior to picture onset. ERPs were constructed by separately averaging the 12 picture types (Pleasant, Neutral, and Unpleasant, and then the three more specific subcategories within each of those broad categories). The N1 appears maximal around 100 ms at central sites (e.g., Foti et al., 2009); therefore, the N1 was scored as the average activity from Cz and CPz between 100 and 150 ms. Following this, the EPN is maximal at approximately 240 ms at occipital recording sites (Foti et al., 2009), and it was scored as the average activity at Iz, P9, and P10, between 200 and 280 ms.

Because the LPP is maximal at centro-parietal sites (Foti & Hajcak, 2008; Hajcak, Dunning, & Foti, 2007; Keil et al., 2002; Schupp et al., 2000), it was scored as the average activity from five centro-parietal sites (Pz, CPz, Cz, CP1, and CP2). Previous research (Foti & Hajcak, 2008; Foti et al., 2009; Weinberg & Hajcak, under review) has demonstrated that important information about the time course of emotional responding may be reflected in differences between early and later windows of the LPP. In order to examine this, the LPP was evaluated in two windows following stimulus onset: 400–1,000 ms (early window) and 1,000–1,500 ms (late window).

In all cases, the N1, EPN, and LPP were statistically evaluated using SPSS (Version 15.0) General Linear Model software, with gender entered as a between-subjects factor. Differences between the broad categories (pleasant, neutral, and unpleasant) were examined first, followed by differences between specific semantic categories. Where applicable, main effects of, and interactions with, gender are reported. Greenhouse-Geisser correction was applied to p values associated with multiple-df repeated measures comparisons when necessitated by violation of the assumption of sphericity; p values were adjusted with the Bonferroni correction for multiple post hoc comparisons. In several analyses, and in order to create the scalp distributions, an average of all neutral picture types was used as a comparison point when there were differences only between the broad categories (not within); objects were used as a comparison point when differences also emerged among the specific picture types.

Results

N1

Grand average stimulus-locked ERPs for each broad picture category (e.g., pleasant, neutral, and unpleasant) are presented in Figure 1. Figure 1 also presents topographic maps depicting voltage differences (in μV) for pleasant minus neutral images, and unpleasant minus neutral images in the time-range of the N1. Mean N1 measures are presented in Table 1. As indicated in Figure 1, the N1 peaked between 100 and 150 ms, and was maximal over central sites. Confirming the impression from Figure 1, the overall magnitude of the N1 differed as a function of picture content, $F(2, 124) = 6.89$, $p < .001$. Likewise, the N1 varied by gender, $F(1, 62) = 6.60$, $p < .05$, such that females ($M = -2.40$, $SD = 1.19$) had larger N1s compared to males ($M = -1.63$, $SD = 1.13$). However, picture type did not vary as a function of gender, $F(2, 124) = 1.70$, $p = .19$. Post hoc comparisons confirmed that the N1 was larger following pleasant, $t(63) = 3.72$, $p < .001$; critical p value $= .017$ for three contrasts, and unpleasant, $t(63) = 2.91$, $p < .001$, compared to neutral pictures. However, there was no significant difference in the magnitude of the N1 elicited by unpleasant and pleasant pictures, $t(63) = 1.02$, $p = .31$.

Further, within each broad picture category, there were no significant differences in the magnitude of the N1. The N1 did not significantly differ as a function of specific picture type within the pleasant category (erotic, affiliative, exciting; $F(2, 126) = 1.59$, $p = .21$), or the unpleasant category (mutilation, disgust, threat; $F(2, 126) = .45$, $p = .64$). Finally, the N1 did not differ significantly as a function of picture type within the neutral category [objects, scenes with people, scenes without people; $F(2, 126) = 1.08$, $p = .34$].

EPN

Grand average stimulus-locked ERPs for specific picture types within each broad picture category (e.g., pleasant, neutral, and unpleasant) are presented in Figure 2 and mean EPN area measures are presented in Table 1. Like the N1, the overall magnitude of the EPN differed as a function of picture content, $F(2, 124) = 19.38$, $p < .001$ and gender, $F(1, 62) = 7.76$, $p < .01$, such that females ($M = 5.68$, $SD = 3.18$) had smaller EPNs compared to males ($M = 3.60$, $SD = 2.43$). Like the N1, the effect of picture type did not vary as a function of gender, $F(2, 124) = 1.09$, $p = .34$. Post hoc comparisons confirmed that the EPN was larger (i.e., more negative) for pleasant, $t(63) = 7.44$, $p < .001$; critical p value $= .017$, for three contrasts and unpleasant, $t(63) = 3.49$, $p < .001$, pictures compared to neutral. Moreover, the EPN elicited by pleasant was significantly larger than the EPN elicited by unpleasant pictures, $t(63) = 2.83$, $p < .01$.

Within each broad picture category, there were also differences in the magnitude of the EPN. Stimulus-locked ERPs and topographic maps depicting voltage differences (in μV) for erotic minus objects, affiliative minus objects, mutilation minus objects, and threat minus objects after picture onset in the time-range of the EPN (i.e., 200–280 ms) are presented in Figure 2. Within the pleasant category (Figure 2, top), the EPN differed as a function of specific picture type, $F(2, 126) = 57.84$, $p < .001$. Post hoc comparisons revealed that the EPN was larger for erotic than both exciting, $t(63) = 11.14$, $p < .001$; critical p value $= .017$ for three contrasts, and affiliative pictures, $t(63) = 7.76$, $p < .001$; in addition, affiliative pictures elicited a larger EPN than exciting pictures, $t(63) = 2.70$, $p < .01$.

Within the unpleasant category (Figure 2, bottom), the EPN again differed as a function of specific picture type, $F(2, 126) = 14.28$, $p < .001$. Post hoc comparisons revealed that the EPN elicited by mutilation pictures was larger than that elicited by disgusting pictures, $t(63) = 5.40$, $p < .001$; critical p value $= .017$

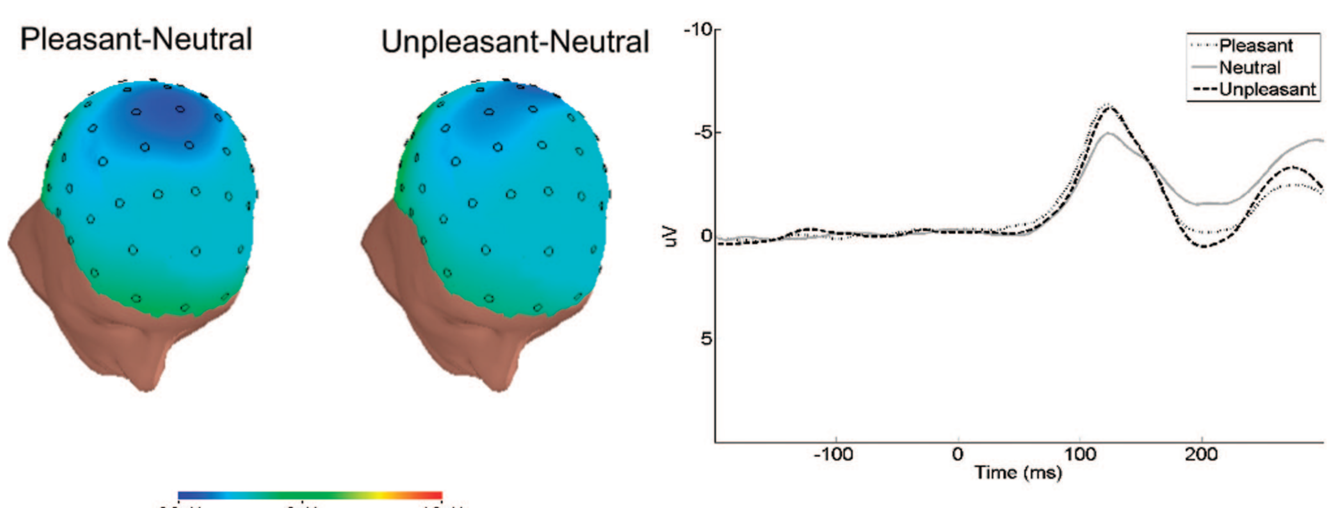

Figure 1. Topographic maps (left) depicting voltage differences (in μV) for pleasant minus neutral images and unpleasant minus neutral images in the time range of the N1 (100–150 ms following picture onset). Also shown (right) are stimulus-locked ERPs averaged at Cz and CPz for the broad semantic categories (Pleasant, Neutral, Unpleasant).

Table 1
Mean Arousal and Valence Ratings (Self-Report) for Broad and Specific Semantic Categories, as Well as Mean Area Measures (μV) for the N1, EPN, Early LPP (400–1,000 ms), and Late LPP (1000–1,500 ms) When Viewing Specific Semantic Categories (SDS in Parentheses)

Picture type	Arousal	Valence	N1	EPN	Early LPP	Late LPP
Pleasant	4.73 (1.39)	7.06 (.74)	−2.34 (1.48)	4.13 (3.19)	3.73 (3.83)	2.29 (3.30)
Exciting	4.22 (1.65)	6.78 (.92)	−2.28 (1.71)	5.35 (3.51)	−.62 (3.98)	−1.14 (3.16)
Affiliative	4.48 (1.67)	7.63 (.82)	−2.14 (2.11)	4.54 (3.65)	4.37 (5.30)	4.24 (5.23)
Erotic	5.63 (1.60)	6.80 (1.32)	−2.60 (1.92)	2.51 (3.19)	7.42 (4.77)	3.77 (4.85)
Pleasant without exciting	5.05 (1.40)	7.22 (.83)	−2.37 (1.73)	3.53 (3.22)	5.89 (4.43)	4.00 (4.29)
Neutral	1.74 (.85)	5.07 (.57)	−1.75 (1.32)	5.67 (3.23)	−.48 (4.03)	−.43 (3.29)
Objects	1.43 (.79)	4.94 (.70)	−1.52 (1.78)	5.10 (3.61)	−1.51 (4.18)	−1.33 (3.61)
Scenes w/out people	1.85 (.96)	5.21 (.69)	−1.78 (2.00)	6.17 (3.32)	−1.47 (4.34)	−1.83 (4.01)
Scenes with people	1.96 (1.03)	5.06 (.60)	−1.94 (1.86)	5.75 (3.51)	1.54 (5.71)	1.88 (5.08)
Neutral without scenes with people	1.64 (.82)	5.08 (.62)	−1.65 (1.46)	5.64 (3.30)	−1.49 (3.79)	−1.58 (3.17)
Unpleasant	5.84 (1.55)	2.22 (.88)	−2.20 (1.39)	4.80 (3.31)	5.10 (4.50)	3.38 (3.76)
Disgusting	5.44 (1.77)	2.14 (.85)	−2.08 (1.63)	5.60 (3.60)	2.79 (5.22)	1.39 (4.75)
Threatening	5.35 (1.66)	2.80 (1.17)	−2.36 (2.10)	4.56 (3.39)	5.53 (5.04)	3.58 (4.54)
Mutilation	6.78 (1.70)	1.70 (.90)	−2.17 (2.10)	4.22 (3.63)	7.02 (5.30)	5.19 (5.10)
Unpleasant without disgusting	6.06 (1.56)	2.25 (.94)	−2.27 (1.78)	4.39 (3.35)	6.28 (4.69)	4.38 (3.99)

for three contrasts. Threat pictures also elicited a larger EPN than disgusting pictures, $t(63) = 3.62$, $p < .01$. However, the EPNs elicited by threat and mutilation images were not significantly different, $t(63) = 1.28$, $p = .20$.

The EPN also differed as a function of picture type within the neutral category [Figure 2, middle; $F(2, 126) = 7.25$, $p < .01$]. Post hoc comparisons revealed that the EPN elicited by images of objects was larger than that elicited by scenes without people, $t(63) = 3.98$, $p < .001$; critical p value = .017 for three contrasts. The difference between scenes with people and objects did not reach significance, $t(63) = 2.08$, $p = .04$, nor did the difference between the EPNs elicited by scenes with people and scenes without people, $t(63) = 1.59$, $p = .12$.

Erotic and mutilation elicited the largest EPN within the broad categories of pleasant and unpleasant, respectively; moreover, the EPN elicited by erotic pictures was significantly larger than that elicited by mutilation pictures, $t(63) = 5.37$, $p < .001$; critical p value = .008 for six contrasts. Comparisons to neutral images of objects indicate that the EPN elicited by erotic pictures was larger than that elicited by objects, $t(63) = 8.07$, $p < .001$. Comparisons between affiliative and threat, $t(63) < 1$, did not reach significance, nor did comparisons of the EPN elicited by mutilation pictures and objects, $t(63) = 2.44$, $p < .02$, affiliative and object, $t(63) = 1.83$, $p = .07$, or threat and object, $t(63) = 1.77$, $p = .08$.

LPP (Early Window)

Grand average stimulus-locked ERPs for each broad picture category (e.g., pleasant, neutral, and unpleasant) are presented in Figure 3 and mean LPP area measures are presented in Table 1. As suggested by Figure 3, the overall magnitude of the LPP differed as a function of picture content, $F(2, 124) = 111.15$, $p < .001$. The magnitude of the LPP did not vary as a function of gender $F(1, 62) = 3.82$ $p = .06$, and gender and picture type did not interact to determine the magnitude of the LPP, $F(2, 124) = 2.27$, $p = .11$. Post hoc comparisons confirmed that the LPP elicited by unpleasant pictures was larger than that elicited by pleasant pictures, $t(63) = 3.87$, $p < .001$; critical p value = .017 for three contrasts. Further, the LPP elicited by unpleasant pictures was larger than that elicited by neutral images, $t(63) = 14.19$, $p < .001$, as was the LPP elicited by pleasant pictures, $t(63) = 11.41$, $p < .001$.

Figure 4 presents topographic maps depicting voltage differences (in μV) for eight specific picture types minus objects after picture onset in the time-range of both the early LPP (i.e., 400–1,000 ms) and the late LPP (i.e., 1,000–1,500). Stimulus-locked ERPs for the specific content categories are presented in Figure 5. Consistent with the impression from Figures 4 and 5, there were also differences in the magnitude of the LPP within each broad picture category. Within the pleasant category (Figure 5, top), the LPP differed as a function of specific picture type, $F(2, 126) = 93.49$, $p < .001$. As suggested by Figure 4, post hoc comparisons confirmed that the LPP elicited by erotic pictures was larger than that elicited by exciting, $t(63) = 13.48$, $p < .001$; critical p value = .017 for three contrasts, and affiliative, $t(63) = 5.07$, $p < .001$, pictures. The LPP elicited by affiliative pictures was also larger than that elicited by exciting pictures, $t(63) = 8.55$, $p < .001$.

Within the unpleasant category (Figure 5, bottom), the LPP again differed as a function of specific picture type, $F(2, 126) = 30.37$, $p < .001$. Post hoc comparisons revealed that the LPP elicited by mutilation pictures was larger than that elicited by threat, $t(63) = 2.74$, $p < .01$; critical p value = .017 for three contrasts, and disgusting pictures, $t(63) = 7.69$, $p < .001$. Likewise, the LPP elicited by threat images was larger than that elicited by disgusting images, $t(63) = 4.92$, $p < .001$, as demonstrated in Figure 4.

Finally, the LPP also differed as a function of picture type within the neutral category [Figure 5, middle; $F(2, 126) = 19.4$, $p < .001$]. Post hoc comparisons revealed that scenes with people elicited a larger response than both objects, $t(63) = 5.40$, $p < .001$; critical p value = .017 for three contrasts, and scenes without people, $t(63) = 4.83$, $p < .01$, as suggested by Figure 4. However, images of objects and scenes without people did not differ from one another, $t(63) = .07$, $p = .95$.

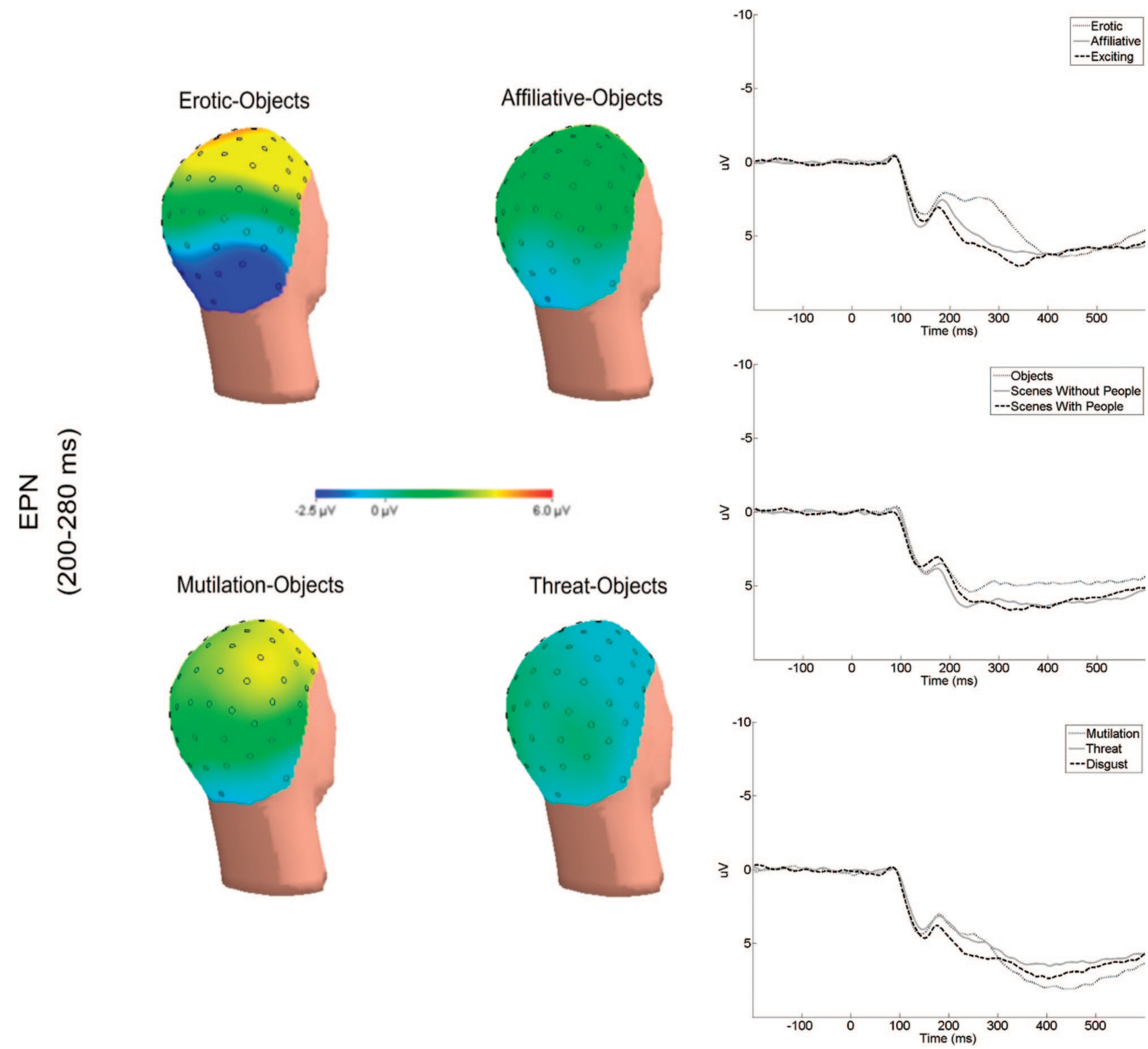

Figure 2. Topographic maps (left) depicting voltage differences (in µV) for pleasant minus neutral images (top) and unpleasant minus neutral images (bottom) in the time range of the EPN (200–280 ms following picture onset). Also shown (right) are stimulus-locked ERPs averaged at Iz, P9, and P10 for the specific semantic categories within Pleasant (top), Neutral (center), and Unpleasant (bottom).

Erotic, mutilation, and scenes with people elicited the largest LPP within the broad categories of pleasant, unpleasant, and neutral pictures, respectively. Although both erotic and mutilation images elicited the largest LPP in their respective picture content categories, the two did not differ significantly from one another, $t(63) = .63$, $p = .53$. Likewise, threat and affiliative images did not differ significantly from one another, $t(63) = 2.03$, $p = .05$; critical p value $= .01$ for five contrasts. However, neutral scenes with people elicited a larger response than exciting images, $t(63) = 2.98$, $p < .01$. Along similar lines, disgusting images, which elicited the smallest LPP in the unpleasant category, did not elicit a reliably larger LPP compared to neutral scenes with people, $t(63) = 1.72$, $p = .09$, but were associated with larger LPPs than exciting images, $t(63) = 6.34$, $p < .001$. Overall then, both exciting and disgusting images were anomalous within the broad pleasant and unpleasant categories, respectively—both contents elicited relatively small LPPs. Moreover, exciting pictures appeared to elicit a uniquely small LPP—smaller than the LPP elicited by both disgusting pictures and neutral pictures containing people.

LPP (Late Window)

In the later window, the overall magnitude of the LPP differed as a function of broad-category picture content, $F(2, 124) = 47.48$,

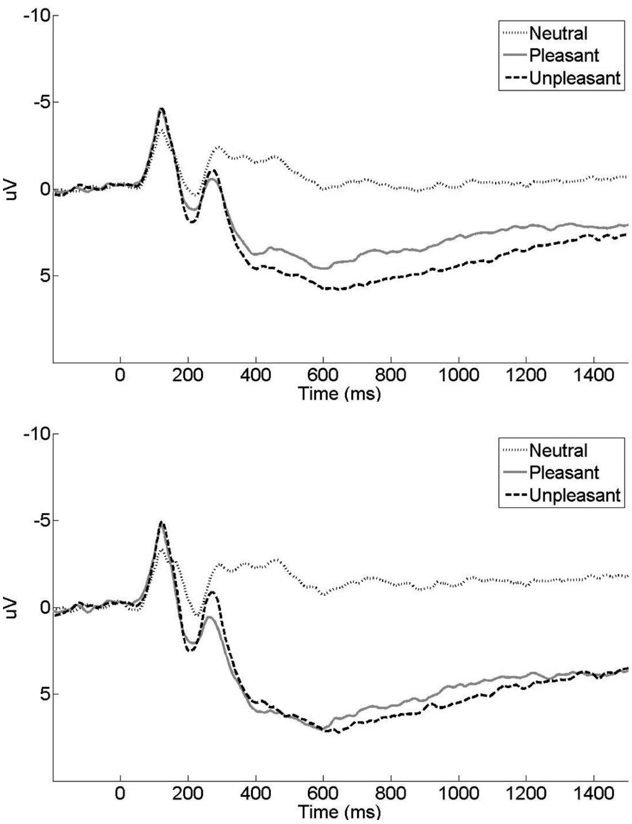

Figure 3. Stimulus-locked ERPs averaged from five centro-parietal sites (Pz, CPz, Cz, CP1, & CP2) for the original broad semantic categories (Pleasant, Neutral, Unpleasant; top). On the bottom are stimulus-locked ERPs for reconstituted broad semantic categories (Pleasant minus exciting images, Neutral minus scenes with people, Unpleasant minus disgusting images).

$p < .001$. The late LPP did not vary by gender, $F(1, 62) = 2.22$, $p = .14$, nor was there a significant interaction between gender and picture type, $F(2, 126) = 1.68$, $p = .19$. Post hoc comparisons confirmed that the LPP elicited by unpleasant pictures remained larger than that elicited by pleasant pictures, $t(63) = 2.71$, $p < .017$; critical p value $= .017$ for three contrasts. Both unpleasant, $t(63) = 9.28$, $p < .001$, and pleasant pictures, $t(63) = 8.23$, $p < .001$, remained larger than that elicited by neutral pictures.

As above, the late LPP differed as a function of specific picture type within the pleasant category, $F(2, 126) = 39.81$, $p < .001$. Post hoc comparisons revealed that the late LPP elicited by erotic pictures was larger than that elicited by exciting pictures, $t(63) = 7.72$, $p < .001$; critical p value $= .017$ for three contrasts. Affiliative pictures also elicited a larger response than exciting pictures, $t(63) = 7.78$, $p < .001$. However, in this later window, the LPP elicited by erotic was no longer larger than that elicited by affiliative, $t(63) = .69$, $p = .49$; see Figures 4 and 5.

Within the unpleasant category, the LPP again differed as a function of specific picture type [mutilation, disgust, threat; $F(2, 126) = 17.71$, $p < .001$]. Post hoc comparisons revealed that the LPP elicited by mutilation pictures was larger than that elicited by disgusting images, $t(63) = 6.55$, $p < .001$; critical p value $= .017$ for three contrasts. Mutilation images also elicited a larger response than threat images, though this effect only approached significance, $t(63) = 2.36$, $p = .02$. Threat images also elicited a larger LPP than disgusting images, $t(63) = 3.33$, $p < .001$.

Finally, the late LPP continued to differ as a function of specific picture type within the neutral category, $F(2, 126) = 23.15$, $p < .001$. Post hoc comparisons revealed that scenes with people elicited a larger response than both objects, $t(63) = 5.38$, $p < .001$; critical p value $= .017$ for three contrasts and scenes without people, $t(63) = 5.76$, $p < .01$. However, the responses elicited by images of objects and scenes without people did not differ from one another, $t(63) = .96$, $p = .34$.

When comparing specific semantic categories, the pattern of results in the later window was identical to results in the early window. Erotic, mutilation, and scenes with people elicited the largest LPP within the broad categories of pleasant, unpleasant, and neutral pictures, respectively. Scenes with people elicited a significantly larger LPP than exciting images, $t(63) = 4.11$, $p < .001$; critical p value $= .01$ for five contrasts, as did disgusting images, $t(63) = 4.29$, $p < .001$. However, scenes with people did not significantly differ from disgusting images, $t(63) = .71$, $p = .48$. Likewise, erotic and mutilation images did not differ significantly from one another, $t(63) = 2.07$, $p = .04$, nor did threat and affiliative, $t(63) = 1.00$, $p = .32$.

Reexamining the Broad Emotional Categories

Because there appeared to be one subcategory in each of the broad emotional categories which elicited a relatively small electrocortical response—exciting images, which elicited a *smaller* LPP than neutral scenes with people, and disgust, which did not reliably differ from neutral scenes with people—new broad semantic categories were created in order to examine the impact of including these pictures in ERP averages. For the new averages of pleasant and unpleasant pictures, the specific semantic category eliciting the smallest LPP was excluded. So that the new ERP averages were based on a similar number of trials, the anomalous subtype within the neutral category (i.e., scenes with people) was also excluded.[2] Pleasant thus consisted of erotic and affiliative images, neutral of images of objects and scenes without people, and unpleasant consisted of mutilation and threat images.

Grand average stimulus-locked ERPs for each reconstituted category are presented in Figure 3 (bottom). A repeated-measures analysis indicated that the magnitude of the early LPP still varied as a function of picture type, $F(2, 124) = 176.72$, $p < .001$. In this time window, the LPP also varied as a function of gender, $F(1, 62) = 4.68$, $p < .05$. Post hoc analyses demonstrated that both pleasant, $t(63) = 16.30$, $p < .001$; critical p value $= .006$ for eight contrasts and unpleasant, $t(63) = 16.55$, $p < .001$ images elicited significantly larger LPPs than neutral images. However, the LPPs elicited by pleasant and unpleasant images no longer differed

[2] When compared to a broad neutral category which contained all three specific subtypes (including scenes with people), the new pleasant, $t(63) = 15.23$, $p < .001$, and unpleasant, $t(63) = 16.16$, $p < .001$, categories still elicited significantly larger LPPs. This was also true in the later window for pleasant compared to neutral, $t(63) = 11.11$, $p < .001$, and unpleasant compared to neutral, $t(63) = 10.76$, $p < .001$.

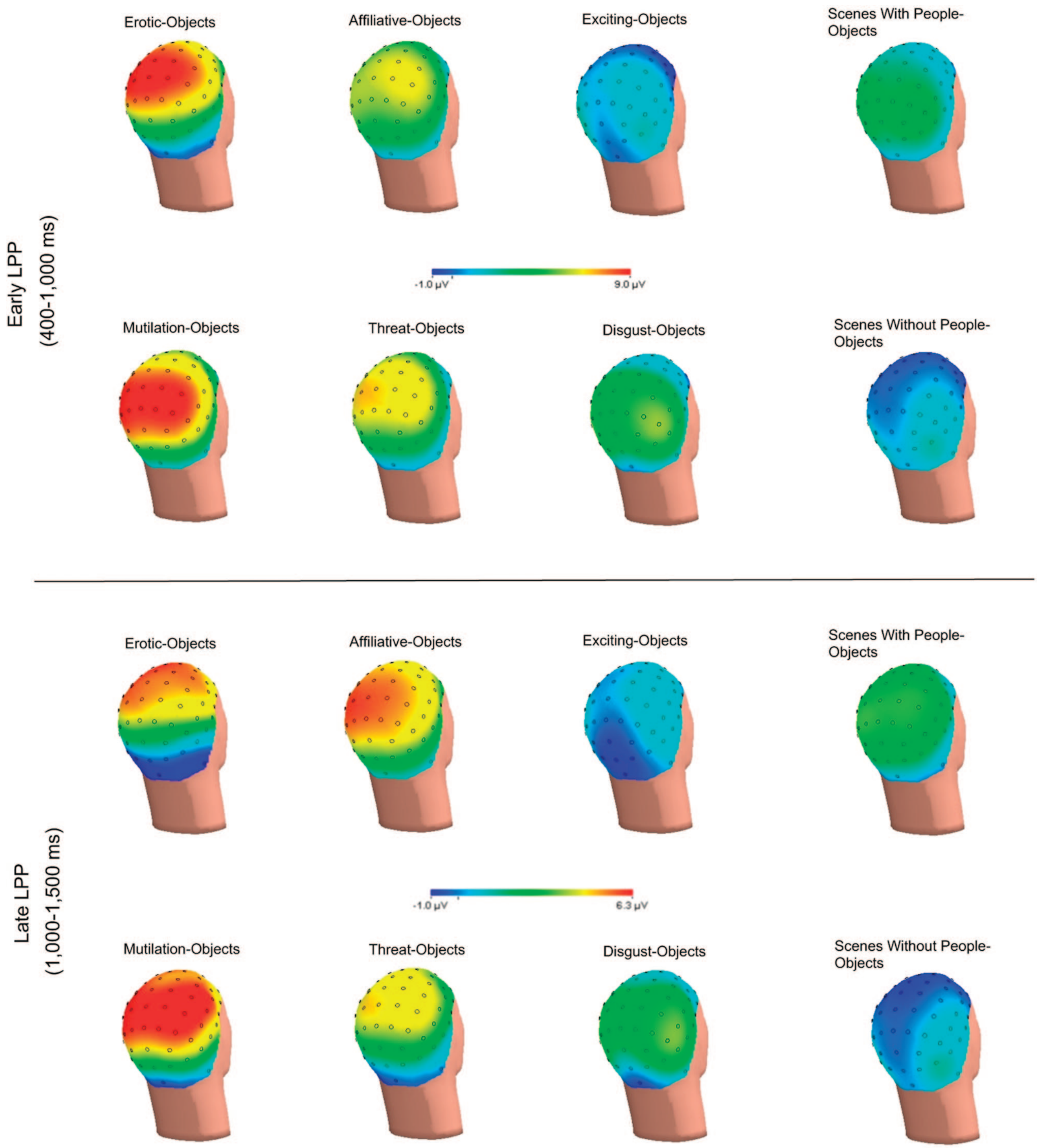

Figure 4. Topographic maps depicting voltage differences (in μV) for eight specific semantic categories minus objects in the time range of the early LPP (400–1,000 ms following picture onset; top) and late LPP (1,000–1,500 ms following picture onset; bottom).

significantly in magnitude from one another, $t(63) = .91$, $p = .37$. Finally, in this time-window, gender and picture type interacted to determine response, $F(2, 124) = 3.17$, $p < .05$. This interaction appeared to be driven by a trend such that females had larger LPPs to pleasant, $t(62) = 2.49$, $p = .02$ and unpleasant images, $t(62) = 2.30$, $p = .03$ than males, though these comparisons did not reach significance. There was no significant difference between males and females in the magnitude of the LPP elicited by neutral images, $t(62) = .74$, $p = .46$. Further, there was no significant difference between the LPPs elicited by pleasant and unpleasant

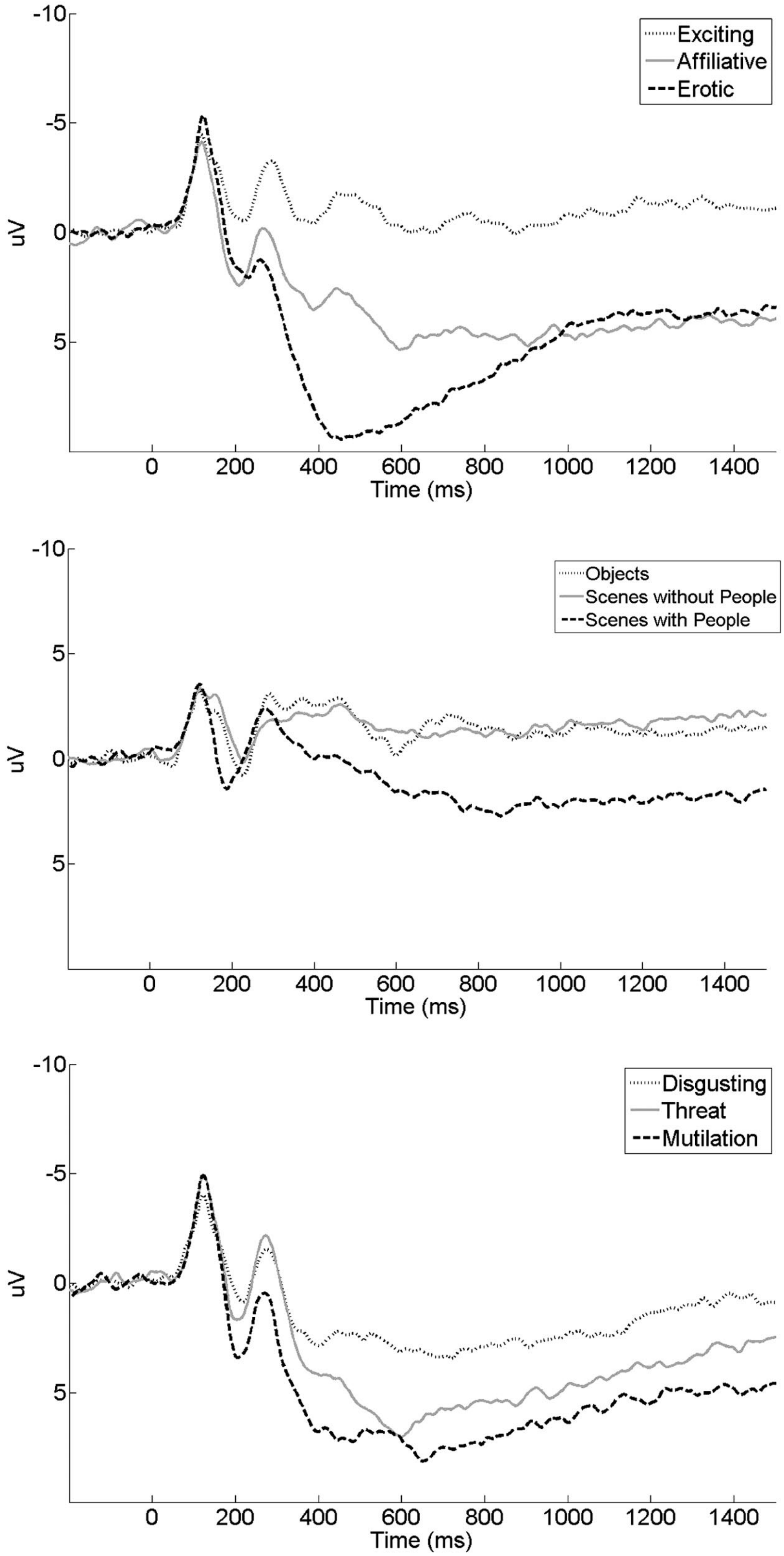

Figure 5. Stimulus-locked ERPs for specific semantic categories within Pleasant (top) Neutral (center), and Unpleasant (bottom).

images for either males, $t(24) = .65$, $p = .52$ or females, $t(38) = .65$, $p = .52$.

In the later window, LPP magnitude again varied as a function of picture type, $F(2, 124) = 86.44$, $p < .001$. However, in this time window, the LPP did not vary by gender, $F(1, 62) = 2.20$, $p = .14$, nor did gender and picture type interact significantly, $F(2, 124) = 1.69$, $p = .19$. Again, both pleasant, $t(63) = 11.55$, $p < .001$ and unpleasant, $t(63) = 11.67$, $p < .001$ images elicited significantly larger LPPs than neutral images. However, once again, the LPPs elicited by pleasant and unpleasant images no longer differed significantly from one another in magnitude, $t(63) = .79$, $p = .43$; critical p value = .017 for three contrasts.

Because comparisons of the reconstituted pleasant and unpleasant categories amount to an attempt to support the null hypothesis, two Bayes-factor one-sample t tests were also conducted (per Rouder et al., 2009; see also Gallistel, 2009), in which r was set a priori to 1.0. In the early LPP window, the odds of Null: Alternative hypothesis were greater than 6:1 favoring the null hypothesis, JZS Bayes Factor (null/alternative) = 6.78. This was also true of the late window, JZS Bayes Factor (null/alternative) = 7.49. Because the odds favor the null hypothesis, we cautiously conclude that there may in fact be no difference between the LPP elicited by the reconstituted pleasant and unpleasant categories, in either the early or the late window. At the least, we conclude that a previously significant negativity bias was no longer apparent once anomalous categories were excluded from analyses.

Self-Reported Arousal

Table 1 presents means and standard deviations for self-report ratings of valence and arousal for each picture type. Within the broad semantic categories (pleasant, neutral, unpleasant), self-report of arousal varied as a function of picture type, $F(2, 124) = 248.78$, $p < .001$. Arousal ratings did not vary by gender, $F(1, 62) < 1$; however, gender and picture type did interact to determine self-report of arousal, $F(2, 132) = 5.39$, $p < .01$. Post hoc comparisons confirmed that neutral pictures were less arousing than pleasant, $t(66) = 20.83$, $p < .001$ and unpleasant, $t(66) = 19.89$, $p < .001$ pictures. Further, unpleasant pictures were rated as more arousing than pleasant pictures, $t(66) = 5.64$, $p < .001$. Thus, the pattern of overall self-reported arousal ratings exactly mirrored the LPP findings across broad picture categories. Examination of the interaction between gender and picture type revealed that the tendency to report unpleasant pictures as more arousing than pleasant characterized female, $t(38) = 6.53$, $p < .001$ but not male, $t(24) = 1.15$, $p = .26$ respondents. Both males and females reported pleasant and unpleasant to be more arousing than neutral, however ($p < .001$ in all cases).

Within each broad semantic category, there were also differences in self-reported arousal. Within the pleasant category, arousal did not vary by gender, $F(1, 62) = 3.22$, $p = .08$. However, arousal ratings differed as a function of specific picture type, $F(2, 124) = 29.42$, $p < .001$, and picture type and gender again interacted to determine self-report of arousal $F(2, 124) = 3.28$, $p < .05$). Post hoc comparisons revealed that erotic pictures were rated as significantly more arousing than both exciting, $t(66) = 7.48$, $p < .001$ and affiliative, $t(66) = 5.55$, $p < .001$ images. On the other hand, exciting and affiliative images were not rated significantly differently in terms of their arousal ratings, $t(66) = 1.39$, $p = .17$. In addition, males rated erotic images as significantly more arousing than females, $t(62) = 2.39$, $p < .05$.

Within the unpleasant category, arousal ratings differed as a function of specific picture type, $F(2, 124) = 47.24$, $p < .001$. However, arousal again did not vary by gender, $F(1, 62) = 2.15$, $p = .15$, and no interaction between gender and picture type, $F(2, 124) < 1$. Post hoc comparisons revealed that mutilation images were rated as significantly more arousing than both disgusting, $t(66) = 10.35$, $p < .001$; critical p value = .017 for three contrasts and threatening images, $t(66) = 9.23$, $p < .001$. However, disgusting and threatening images were not rated significantly different from one another in terms of their arousal ratings, $t(66) = .44$, $p = .67$.

Within the neutral category, arousal ratings differed as a function of specific picture type, $F(2, 132) = 25.49$, $p < .001$. Again arousal did not vary by gender, $F(1, 62) = 1.70$, $p = .20$, and no interaction between picture type and gender, $F(2, 124) < 1$. Post hoc comparisons revealed that both scenes with people, $t(66) = 6.39$, $p < .001$; critical p value = .017 for three contrasts and scenes without people were rated as significantly more arousing than images of objects, $t(66) = 5.60$, $p < .001$. However, scenes with and without people were not rated significantly different in terms of their arousal ratings, $t(66) = 1.42$, $p = .16$.

Self-Reported Valence

Like arousal, valence also varied as a function of broad semantic categories, $F(2, 132) = 641.26$, $p < .001$. It also varied as a function of gender, $F(1, 62) = 7.42$, $p < .01$, such that males reported pictures to be more pleasant overall ($M = 4.95$, $SD = .81$) than females ($M = 4.69$, $SD = .73$). However, there was no significant interaction between gender and picture type, $F(2, 124) = 2.73$, $p = .07$. Post hoc comparisons confirmed that pleasant pictures were rated as more pleasant than neutral, $t(63) = 17.63$, $p < .001$, which were more pleasant than unpleasant pictures, $t(63) = 24.45$, $p < .001$. In addition, pleasant pictures were rated as more pleasant than unpleasant pictures, $t(63) = 28.36$, $p < .001$; critical p value = .017 for three contrasts.

Valence also varied as a function of the specific semantic category within the pleasant category, $F(2, 124) = 17.91$, $p < .001$. Post hoc comparisons revealed that affiliative images were rated as more pleasant than both exciting, $t(63) = 7.57$, $p < .001$ and erotic, $t(63) = 4.58$, $p < .001$ images. Erotic and exciting images did not differ significantly from one another in terms of valence, $t(63) = .02$, $p = .98$.

Likewise, within the neutral category, valence varied as a function of the specific semantic category, $F(2, 126) = 5.94$, $p < .01$. Post hoc comparisons revealed that scenes without people were rated as more pleasant than images of objects, $t(63) = 3.92$, $p < .001$; critical p value = .017 for three contrasts. However, scenes without people did not differ significantly from scenes with people, $t(63) = 1.74$, $p = .08$. Scenes with people and images of objects also did not differ significantly from one another, $t(63) = 1.52$, $p = .14$.

Finally, valence varied as a function of the specific semantic category within the unpleasant category, $F(2, 126) = 65.24$, $p < .001$. Post hoc comparisons revealed that mutilation images were rated as more unpleasant than both threat, $t(63) = 9.77$, $p < .001$; critical p value = .017 for three contrasts, and disgusting, $t(63) =$

7.24, $p < .001$ images. In addition, disgusting images were more unpleasant than threat images, $t(63) = 6.04$, $p < .001$.

Self-Report for New Broad Semantic Categories

Because unpleasant pictures were rated by participants to be more arousing than pleasant pictures, new broad semantic categories were also created to examine self-report of arousal and valence, such that the anomalous specific semantic category from each broad category was dropped (see contents of categories above). A repeated-measures analysis indicated that self-report of arousal still varied as a function of broad semantic category, $F(2, 124) = 275.88$, $p < .001$. Self-report of arousal did not vary by gender, $F(1, 62) < 1$, though gender and picture type did interact, $F(2, 124) = 3.37$, $p < .05$. Unpleasant images continued to be rated as more arousing than pleasant images, $t(24) = 4.97$, $p < .001$. However, as above, men did *not* report the new unpleasant category to be more arousing than the new pleasant category, $t(24) = 1.21$, $p = .24$, whereas women continued to report the new unpleasant category to be significantly more arousing than the new pleasant category, $t(38) = 5.85$, $p < .001$, a result that was not reflected in the magnitude of any ERP component.

Self-report of valence also continued to vary as a function of broad semantic category, $F(2, 124) = 520.56$, $p < .001$. Valence also varied as a function of gender, $F(1, 62) = 7.78$, $p < .01$, such that males reported pictures to be more pleasant overall ($M = 5.03$, $SD = .75$) than females ($M = 4.74$, $SD = .81$). However, gender and picture type did not interact to determine self-report of valence, $F(2, 124) = 1.57$, $p = .21$. Post hoc comparisons confirmed that pleasant pictures were rated as more pleasant than neutral, $t(63) = 15.99$, $p < .001$; critical p value = .017 for three contrasts, and unpleasant pictures, $t(63) = 26.99$, $p < .001$. In addition, neutral pictures were rated as more pleasant than unpleasant pictures, $t(63) = 22.53$, $p < .001$.

Discussion

The current study examined the time-course of electrocortical processing of emotional stimuli—both as a function of broad affective categories (i.e., pleasant, neutral, and unpleasant) and more specific content-based categories of pictures. As in previous research (e.g., Cuthbert et al., 2000; Schupp et al., 2000; Schupp et al., 2004; Hajcak, Dunning, & Foti, 2007), the magnitude of the N1, EPN, and LPP elicited by broadly defined emotional pictures (both pleasant and unpleasant) was larger than that elicited by neutral pictures. This was also reflected in self-report of arousal—pleasant and unpleasant images were rated as more arousing than neutral images.

Although the N1 was enhanced for both pleasant and unpleasant compared to neutral images, the N1 did not differentiate specific picture subtypes. The first hint of more specific content-based differentiation was evident in the time window of the EPN, which appeared to distinguish among picture types; this was particularly true within the pleasant category, for which each of the three subcategories differed from one another. Within the unpleasant category, the EPN also appeared to distinguish more from less motivationally salient categories (i.e., mutilation and threat from disgusting), though mutilation and threat were not reliably different from one another. The EPN appeared particularly enhanced for erotic images. These data suggest that the N1 and EPN may be sensitive to distinct visual features that broadly differentiate emotional from neutral pictures in the former case, but begin to make more precise distinctions in the latter.

Following these early negativities, both the early and late LPPs displayed a graded response to pictures—differentiating both emotional categories from neutral pictures, and further demonstrating specificity within these broad categories. In general, LPP patterns were identical in early and late portions of the LPP, with two exceptions: erotic images elicited a significantly larger LPP than affiliative images in the early window, but by the later window, the response to the two picture types was no longer different. Likewise, while mutilation elicited a larger early LPP than threat images, the difference was not significant in the later window.

Previous research has suggested a distinction between early, relatively obligatory attentional capture by emotional images (<300 ms), and later, more elaborative processes (>300 ms) which may reflect continued processing and encoding (e.g., Azizian & Polich, 2007; Codispoti et al., 2007; Foti et al., 2009; Hajcak & Olvet, 2008; Mecklinger & Pfeifer, 1996; Olofsson & Polich, 2007; Olofsson et al., 2008; Ruchkin et al., 1988, 1995; Weinberg & Hajcak, under review). The results of the present study support this distinction; while early components may make broad distinctions between emotional and nonemotional images, (e.g., the N1), or respond preferentially to the most-arousing emotional categories, (e.g., the EPN), the LPP appears to index a process of finer-grained distinction between picture subtypes, and one that may change over time as more deliberative processes come into play (e.g., Foti & Hajcak, 2008; Hajcak & Nieuwenhuis, 2006; MacNamara, Foti, & Hajcak, 2009).

When considering the broad semantic categories of pictures, there was no evidence of a negativity bias in the magnitude of the N1, and in fact, there was evidence for a positivity bias in the time window of the EPN, such that pleasant pictures (particularly erotic images), elicited a larger EPN than unpleasant pictures. This is consistent with previous research on the EPN and emotional stimuli (Schupp, Junghöfer, et al., 2004; Schupp, Stockburger, et al., 2006). However, evidence *was* found for a negativity bias in the magnitude of the LPP: when considering all emotional pictures, unpleasant images elicited a larger LPP than pleasant images in both the early (400–1,000 ms) and late (1,000–1,500 ms) windows. This negativity bias was also reflected in participant self-report of arousal: although we chose pleasant and unpleasant pictures that were relatively well-matched on *normative* arousal ratings, unpleasant images were rated as more arousing than pleasant images *by our subjects*.

However, it was clear that there was substantial variation in the LPP within the broad categories of pleasant, neutral, and unpleasant pictures. Erotic- (e.g., nude couples) and mutilation-themed images (e.g., bomb victims) elicited the largest LPPs within pleasant and unpleasant pictures, respectively—and the LPPs elicited by erotic and mutilation pictures were of comparable magnitude to one another. Previous work has also suggested larger LPPs for mutilation and erotic content within unpleasant and pleasant images, respectively (Schupp, Cuthbert, et al., 2004). In addition, we found that affiliative and threat images elicited LPPs of comparable magnitude to one another, though smaller than both erotic and mutilation images, respectively.

Moreover, both exciting images (e.g., sky-diving, wind-surfing) and disgusting images (e.g., overflowing toilets) elicited significantly smaller LPPs than other pleasant and unpleasant images, respectively. Within the neutral category, scenes with people elicited significantly larger LPPs than both images of objects and scenes without people—consistent with previous work indicating that images of people attract more attention and elicit larger LPPs than images which do not contain people (Ito & Cacioppo, 2000). Notably, exciting images elicited a significantly *smaller* LPP than both disgusting images and neutral scenes with people, whereas disgusting images did not differ from neutral images that contained people.

In light of the unusually small LPPs elicited by exciting images, we subsequently created new broad categories, dropping the anomalous content from each category (with "pleasant" consisting of only erotic and affiliative, "neutral" consisting of objects and scenes without people, and "unpleasant" consisting of threat and mutilation), in order to test the hypothesis that the inclusion of exciting images might dilute the LPP of the pleasant category. Analyses of the LPP elicited by these redefined categories suggested that, although the magnitude of the LPP differed for emotional compared to neutral images, the magnitude of the LPP elicited by pleasant and unpleasant images was no longer different in either the early or late window.

Previous support for a negativity bias in neural activity might be considered in light of these findings. Evidence from this and other (Briggs & Martin, 2009; Schupp, Cuthbert, et al., 2004) studies demonstrates that exciting images elicit smaller ERPs than other emotional images, and, in the present study, smaller ERPs even than neutral images that include people. In addition, when comparing erotic images to mutilation images, and when comparing affiliative images to threat images, there was no evidence for a bias toward unpleasant stimuli in terms of the LPP. Thus, our study points to the possibility that an apparent negativity bias evident in the LPP is due to the inclusion of exciting/sports pictures in the pleasant category. Importantly, studies examining the negativity bias have often used either exclusively exciting images within the pleasant category (Ito, Larsen et al., 1998, study one), or have intermixed a high percentage of exciting images with erotica and/or other pleasant images (e.g., Delplanque et al., 2005; Foti et al., 2009; Hajcak & Olvet, 2008; Smith et al., 2003). In light of the current data, it is certainly possible that the observed negativity bias in these studies is driven by a subset of pleasant pictures that elicit a small LPP, rather than a specific bias toward negatively valenced stimuli that determine a large LPP.

These results further suggest that the selection of affective stimuli in psychophysiological studies should be conducted with more than just self-reported arousal in mind. Though the pattern of LPP response was frequently reflected in the pattern of self-reported arousal for the specific picture content, there was not always perfect agreement. For example, while the reconstituted broad categories of pleasant and unpleasant no longer differed from one another in terms of the LPP, this pattern was not reproduced in the self-report data: within the reconstituted broad semantic categories, unpleasant images were still rated as more arousing than pleasant images. If anything, such a bias in self-reported arousal to unpleasant pictures should make it easier to detect a negativity bias in the electrocortical data. However, no such bias was evident in the LPP. Moreover, the difference between unpleasant and pleasant ratings may be explained, at least in part, by gender differences in self-report to *specific* picture content. In particular, men reported pleasant and unpleasant categories to be equally arousing, demonstrating no bias for these unpleasant images. Women, however, continued to report unpleasant images to be more arousing than pleasant images—and this difference appeared to be due primarily to the fact that women rated erotic images as significantly *less* arousing than men (Bradley, Codispoti, Sabatinelli, & Lang, 2001)—again this was an arousal-related difference that was not reflected in the LPP.

In addition, there were notable similarities and discrepancies in terms of the LPP and arousal ratings with respect to specific picture content. For example, erotic, mutilation, and scenes with people were each rated as the most arousing in their respective categories, and also elicited the largest LPPs. Exciting images elicited the smallest LPP of all the emotional categories, and were also rated as the least arousing category of all the *emotional* images. A disconnect between self-report and LPP measures, however, is evident in several instances. For instance, scenes with and without people were not significantly different in terms of their arousal ratings, but scenes with people elicited a substantially larger LPP. Also, exciting pictures *were* rated as more arousing than neutral scenes with people—but scenes with people again elicited a *larger* LPP than exciting images. Finally, though significantly different from one another, erotic and exciting images were both rated as relatively arousing. Yet erotic images elicited an LPP several orders of magnitude larger than that elicited by exciting images. Such findings may be understood in terms of arguments that the magnitude of the LPP is related not just to self-reported arousal, but also to the motivational salience of stimulus content. Because erotic images convey information directly relevant to survival, they are more likely to activate an appetitive motivational system than exciting images (Briggs & Martin, 2009; Franken et al., 2008). Exciting images, though rated as highly arousing, do not convey survival-relevant information, and are therefore less likely to engage motivational systems.

Limitations of the present study suggest avenues for future research. While many studies have presented images of opposite sex nudes as a part of the erotic category, all of the erotic images presented here were of heterosexual couples. In the present study, however, no record was made of participants' sexual orientation. Examining the interactions between gender, sexual preference, and response to a wider variety of erotic stimuli would be an important consideration in future research. In addition, while images within the specific semantic categories were carefully selected and matched on normed arousal ratings, the coverage of emotional imagery was by no means complete. For instance, examining responses to pleasant images of food and unpleasant images related to loss might further contribute to the current findings. Kisley, Wood, and Burrows (2007) and Ito, Larsen et al., (1998, study two) found a negativity bias in the LPP using two food-related pictures compared to two images of decomposing animals. Importantly, our current results did not find evidence for the negativity bias, but only when affiliative and erotic images were compared to threat and mutilation pictures. In light of the Kisley et al. (2007) and Ito, Larsen et al. (1998) findings, these data raise interesting questions regarding how motivationally salient food-related images would compare to pleasant images with affiliative and erotic content. In addition, given the pattern of attentional allocation for images of people (e.g., Ito & Cacioppo, 2000), it could be informative to separately examine human and animal photos within the affiliative category.

To date, ERP work on the negativity bias has been taken as evidence that this bias operates automatically at the stage of stimulus evaluation (e.g., Delplanque et al., 2005; Foti et al., 2009; Hajcak & Olvet, 2008; Huang & Luo, 2006; Ito, Larsen et al., 1998). We found no evidence of this in either early (i.e., N1, EPN) or later (i.e., LPP) ERP components. In contrast, the EPN results appeared to indicate a positivity bias, while the current LPP results indicate that the presence of negativity bias in evaluative categorization may be due to the inclusion of exciting/sports pictures. However, the current data do not rule out the possibility that a negativity bias is evident at the level of response output (e.g., Anderson, 1965; Fiske, 1980; Hansen & Hansen, 1988; Öhman, Lundqvist, & Esteves, 2001; Peeters & Czapinksi, 1990; Pratto & John, 1991; Skowronski & Carlston, 1989). Moreover, the current data do not speak to developmental changes (Kisley et al., 2007; Charles, Mather, & Carstensen, 2003), individual differences (Ito & Cacioppo, 2005), or mood-related changes (Chen, Yuan, Huang, Chen, & Li, 2008) in the processing of unpleasant compared to pleasant stimuli. Finally, the present study does not address whether losses mean more than gains of equivalent magnitude (Kahneman & Tversky, 1984). Detailed examination of the multiple processes that occur between early automatic evaluative categorization and later behavioral output, as well as the various effects of intra-, extra-, and interpersonal contexts influencing both categorization and output, will be essential to our understanding of emotional experience.

References

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

Anderson, N. (1965). Averaging versus adding as a stimulus-combination rule in impression formation. *Journal of Experimental Psychology, 70,* 394–400.

Anokhin, A., Golosheykin, S., Sirevaag, E., Kristjansson, S., Rohrbaugh, J., & Heath, A. (2006). Rapid discrimination of visual scene content in the human brain. *Brain research, 1093,* 167–177.

Armony, J., & Dolan, R. (2002). Modulation of spatial attention by fear-conditioned stimuli: An event-related fMRI study. *Neuropsychologia, 40,* 817–826.

Azizian, A., & Polich, J. (2007). Evidence for attentional gradient in the serial position memory curve from event-related potentials. *Journal of Cognitive Neuroscience, 19,* 2071–2081.

Baumeister, R., Bratslavsky, E., Finkenauer, C., & Vohs, K. (2001). Bad is stronger than good. *Review of General Psychology, 5,* 323–370.

Bonnet, M., Bradley, M., Lang, P., & Requin, J. (1995). Modulation of spinal reflexes: Arousal, pleasure, action. *Psychophysiology, 32,* 367–372.

Both, S., Everaerd, W., & Laan, E. (2003). Modulation of spinal reflexes by aversive and sexually appetitive stimuli. *Psychophysiology, 40,* 174–183.

Bradley, M. (2009). Natural selective attention: Orienting and emotion. *Psychophysiology, 46,* 1–11.

Bradley, M., Codispoti, M., Cuthbert, B., & Lang, P. (2001). Emotion and motivation I: Defensive and appetitive reactions in picture processing. *Emotion, 1,* 276–298.

Bradley, M., Codispoti, M., Sabatinelli, D., & Lang, P. (2001). Emotion and motivation II: Sex differences in picture processing. *Emotion, 1,* 300–319.

Briggs, K., & Martin, F. (2009). Affective picture processing and motivational relevance: Arousal and valence effects on ERPs in an oddball task. *International Journal of Psychophysiology, 72,* 299–306.

Brosschot, J., & Thayer, J. (2003). Heart rate response is longer after negative emotions than after positive emotions. *International Journal of Psychophysiology, 50,* 181–187.

Buchanan, T., & Adolphs, R. (2002). The role of the human amygdala in emotional modulation of long-term declarative memory. *Emotional cognition: From Brain to Behaviour,* 9–34.

Cacioppo, J., Crites, S., Gardner, W., & Berntson, G. (1994). Bioelectrical echoes from evaluative categorizations. I: A late positive brain potential that varies as a function of trait negativity and extremity. *Journal of Personality and Social Psychology, 67,* 115–125.

Cacioppo, J., & Gardner, W. (1999). Emotion. *Annual Review of Psychology, 50,* 191–214.

Cacioppo, J., Gardner, W., & Berntson, G. (1999). The affect system has parallel and integrative processing components: Form follows function. *Journal of Personality and Social Psychology, 76,* 839–855.

Carretié, A., Hinojosa, J. A., & Mercado, F. (2003). Cerebral patterns of attentional habituation to emotional visual stimuli. *Psychophysiology, 40,* 381–388.

Charles, S., Mather, M., & Carstensen, L. (2003). Aging and emotional memory: The forgettable nature of negative images for older adults. *Journal of Experimental Psychology-General, 132,* 310.

Chen, J., Yuan, J., Huang, H., Chen, C., & Li, H. (2008). Music-induced mood modulates the strength of emotional negativity bias: An ERP study. *Neuroscience Letters, 445,* 135–139.

Codispoti, M., Bradley, M., & Lang, P. (2001). Affective reactions to briefly presented pictures. *Psychophysiology, 38,* 474–478.

Codispoti, M., Ferrari, V., & Bradley, M. (2007). Repetition and event-related potentials: Distinguishing early and late processes in affective picture perception. *Journal of Cognitive Neuroscience, 19,* 577–586.

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

Delplanque, S., Silvert, L., Hot, P., Rigoulot, S., & Sequeira, H. (2006). Arousal and valence effects on event-related P3a and P3b during emotional categorization. *International Journal of Psychophysiology, 60,* 315–322.

Delplanque, S., Silvert, L., Hot, P., & Sequeira, H. (2005). Event-related P3a and P3b in response to unpredictable emotional stimuli. *Biological Psychology, 68,* 107–120.

Dolan, R. (2002). Emotion, cognition, and behavior. *Science, 298,* 1191.

Dunning, J., & Hajcak, G. (2009). See no evil: Directing visual attention within unpleasant images modulates the electrocortical response. *Psychophysiology, 46,* 28–33.

Esteves, F., Parra, C., Dimberg, U., & Öhman, A. (1994). Nonconscious associative learning: Pavlovian conditioning of skin conductance responses to masked fear-relevant facial stimuli. *Psychophysiology, 31,* 375–385.

Fiske, S. (1980). Attention and weight in person perception: The impact of negative and extreme behavior. *Journal of Personality and Social Psychology, 38,* 889–906.

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

Foti, D., Hajcak, G., & Dien, J. (2009). Differentiating neural responses to emotional pictures: Evidence from temporal-spatial PCA. *Psychophysiology, 46,* 521–530.

Franken, I., Muris, P., Nijs, I., & van Strien, J. (2008). Processing of pleasant information can be as fast and strong as unpleasant information:

Implications for the negativity bias. *Netherlands Journal of Psychology, 64,* 168–176.

Frijda, N. (1986). *The emotions*. Ed. de la Maison des Sciences de l'Homme.

Frijda, N. (1987). Emotion, cognitive structure, and action tendency. *Cognition & Emotion, 1,* 115–143.

Gallistel, C. (2009). The importance of proving the null. *Psychological Review, 116,* 439–453.

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

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

Hajcak, G., Dunning, J., & Foti, D. (2009). Motivated and controlled attention to emotion: Time-course of the late positive potential. *Clinical Neurophysiology, 120,* 505–510.

Hajcak, G., Molnar, C., George, M., Bolger, K., Koola, J., & Nahas, Z. (2007). Emotion facilitates action: A transcranial magnetic stimulation study of motor cortex excitability during picture viewing. *Psychophysiology, 44,* 91–97.

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

Hajcak, G., & Olvet, D. (2008). The persistence of attention to emotion: Brain potentials during and after picture presentation. *Emotion, 8,* 250–255.

Hamann, S. (2001). Cognitive and neural mechanisms of emotional memory. *Trends in Cognitive Sciences, 5,* 394–400.

Hamann, S., Cahill, L., McGaugh, J., & Squire, L. (1997). Intact enhancement of declarative memory for emotional material in amnesia. *Learning & Memory, 4,* 301–309.

Hansen, C., & Hansen, R. (1988). Finding the face in the crowd: An anger superiority effect. *Journal of Personality and Social Psychology, 54,* 917.

Huang, Y., & Luo, Y. (2006). Temporal course of emotional negativity bias: An ERP study. *Neuroscience Letters, 398,* 91–96.

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

Ito, T., & Cacioppo, J. (2005). Variations on a human universal: Individual differences in positivity offset and negativity bias. *Cognition & Emotion, 19,* 1–26.

Ito, T., Cacioppo, J., & Lang, P. (1998). Eliciting affect using the International Affective Picture System: Trajectories through evaluative space. *Personality and Social Psychology Bulletin, 24,* 855.

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

Kahneman, D., & Tversky, A. (1984). Choices, values, and frames. *American Psychologist, 39,* 341–350.

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

Kisley, M., Wood, S., & Burrows, C. (2007). Looking at the sunny side of life: Age-related change in an event-related potential measure of the negativity bias. *Psychological Science, 18,* 838–843.

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

Lang, P. (1980). *Self-assessment manikin*. Gainesville, FL: University of Florida.

Lang, P. (1985). The cognitive psychophysiology of emotion: Fear and anxiety. *Anxiety and the Anxiety Disorders, 3,* 3–62.

Lang, P., Bradley, M., & Cuthbert, B. (1997). Motivated attention: Affect, activation, and action. *Attention and orienting: Sensory and motivational processes,* 97–135.

Lang, P., Bradley, M., & Cuthbert, B. (2005). International affective picture system (IAPS): Affective ratings of pictures and instruction manual. Gainesville, FL: University of Florida.

Mack, A., & Rock, I. (1998). Inattentional blindness: Perception without attention. *Visual Attention, 8,* 55–76.

MacNamara, A., Foti, D., & Hajcak, G. (2009). Tell me about it: Neural activity elicited by emotional pictures and preceding descriptions. *Emotion, 9,* 531–543.

Mecklinger, A., & Pfeifer, E. (1996). Event-related potentials reveal topographical and temporal distinct neuronal activation patterns for spatial and object working memory. *Cognitive Brain Research, 4,* 211–224.

Mogg, K., Bradley, B., De Bono, J., & Painter, M. (1997). Time course of attentional bias for threat information in non-clinical anxiety. *Behaviour Research and Therapy, 35,* 297–303.

Most, S., Smith, S., Cooter, A., Levy, B., & Zald, D. (2007). The naked truth: Positive, arousing distractors impair rapid target perception. *Cognition and Emotion, 21,* 964–981.

Neisser, U. (1979). The control of information pickup in selective looking. *Perception and its development: A tribute to Eleanor J. Gibson,* 201–219.

Öhman, A. (1992). Orienting and attention: Preferred preattentive processing of potentially phobic stimuli. In B. A. Campbell, H. Haynes, & R. Richardson (Eds.), *Attention and information processing in infants and adults. Perspectives from human and animal research.* Hillsdale, NJ: Erlbaum.

Öhman, A., Flykt, A., & Esteves, F. (2001). Emotion drives attention: Detecting the snake in the grass. *Journal of Experimental Psychology General, 130,* 466–478.

Öhman, A., Lundqvist, D., & Esteves, F. (2001). The face in the crowd revisited: A threat advantage with schematic stimuli. *Journal of Personality and Social Psychology, 80,* 381–396.

Olofsson, J., Nordin, S., Sequeira, H., & Polich, J. (2008). Affective picture processing: An integrative review of ERP findings. *Biological Psychology, 77,* 247–265.

Olofsson, J., & Polich, J. (2007). Affective visual event-related potentials: Arousal, repetition, and time-on-task. *Biological Psychology, 75,* 101–108.

Peeters, G., & Czapinski, J. (1990). Positive-negative asymmetry in evaluations: The distinction between affective and informational negativity effects. In W. Stroebe & M. Hewstone (Eds.), *European Review of Social Psychology* (Vol. 1, pp. 33–60). New York: Wiley.

Phelps, E., LaBar, K., & Spencer, D. (1997). Memory for emotional words following unilateral temporal lobectomy. *Brain and Cognition, 35,* 85–109.

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

Rouder, J., Speckman, P., Sun, D., Morey, R., & Iverson, G. (2009). Bayesian t tests for accepting and rejecting the null hypothesis. *Psychonomic Bulletin & Review, 16,* 225.

Rozenkrants, B., & Polich, J. (2008). Affective ERP processing in a visual oddball task: Arousal, valence, and gender. *Clinical Neurophysiology, 119,* 2260–2265.

Ruchkin, D. S., Canoune, H. L., Johnson, R., & Ritter, W. (1995). Working-memory and preparation elicit different patterns of slow-wave event-related brain potentials. *Psychophysiology, 32,* 399–341.

Ruchkin, D. S., Johnson, R., Mahaffey, D., & Sutton, S. (1988). Toward a functional categorization of slow waves. *Psychophysiology, 25,* 339–353.

Sarlo, M., Palomba, D., Buodo, G., Minghetti, R., & Stegagno, L. (2005). Blood pressure changes highlight gender differences in emotional reactivity to arousing pictures. *Biological Psychology, 70,* 188–196.

Schupp, H., Cuthbert, B., Bradley, M., Cacioppo, J., Ito, T., & Lang, P. (2000). Affective picture processing: The late positive potential is modulated by motivational relevance. *Psychophysiology, 37,* 257–261.
Schupp, H., Cuthbert, B., Bradley, M., Hillman, C., Hamm, A., & Lang, P. (2004). Brain processes in emotional perception: Motivated attention. *Cognition & Emotion, 18,* 593–611.
Schupp, H., Flaisch, T., Stockburger, J., & Junghöfer, M. (2006). Emotion and attention: Event-related brain potential studies. *Progress in Brain Research, 156,* 31–51.
Schupp, H., Junghöfer, M., Weike, A., & Hamm, A. (2003a). Attention and emotion: An ERP analysis of facilitated emotional stimulus processing. *Neuroreport, 14,* 1107.
Schupp, H., Junghöfer, M., Weike, A., & Hamm, A. (2003b). Emotional facilitation of sensory processing in the visual cortex. *Psychological Science,* 7–13.
Schupp, H., Stockburger, J., Bublatzky, F., Junghöfer, M., Weike, A., & Hamm, A. (2007). Explicit attention interferes with selective emotion processing in human extrastriate cortex. *BMC Neuroscience, 8,* 16.
Schupp, H. T., Junghöfer, M., Weike, A. I., & Hamm, A. O. (2004). The selective processing of briefly presented affective pictures: An ERP analysis. *Psychophysiology, 41,* 441–449.
Schupp, H. T., Stockburger, J., Codispoti, M., Junghöfer, M., Weike, A. I., & Hamm, A. O. (2006). Stimulus novelty and emotion perception: The near absence of habituation in the visual cortex. *NeuroReport, 17,* 365–369.
Skowronski, J., & Carlston, D. (1989). Negativity and extremity biases in impression formation: A review of explanations. *Psychological Bulletin, 105,* 131–142.
Smith, N., Cacioppo, J., Larsen, J., & Chartrand, T. (2003). May I have your attention, please: Electrocortical responses to positive and negative stimuli. *Neuropsychologia, 41,* 171–183.
Taylor, S. (1991). Asymmetrical effects of positive and negative events: The mobilization-minimization hypothesis. *Psychological Bulletin, 110,* 67–85.
Vuilleumier, P. (2005). How brains beware: Neural mechanisms of emotional attention. *Trends in Cognitive Sciences, 9,* 585–594.
Weinberg, A., & Hajcak, G. (under review). Reaction Time, Interrupted: Neural activity elicited by task-irrelevant pictures predicts subsequent behavioral interference.
Wood, S., & Kisley, M. (2006). The negativity bias is eliminated in older adults: Age-related reduction in event-related brain potentials associated with evaluative categorization. *Psychology and Aging, 21,* 815–820.

Appendix

IAPS Images Used in the Present Study

Pleasant Images

Exciting: 8030, 8080, 8180, 8185, 8190, 8200, 8210, 8300, 8496, 8370, 8380, 8400, 8470, 8490, 8031.

Affiliative: 1441, 1463, 1710, 1750, 1920, 2040, 2070, 2071, 2080, 2091, 2150, 2165, 2340, 2345, 2550.

Erotic: 4608, 4650, 4652, 4658, 4659, 4660, 4664, 4670, 4676, 4680, 4687, 4689, 4690, 4694, 4695.

Neutral Images

Objects: 7000, 7002, 7004, 7006, 7010, 7025, 7034, 7035, 7040, 7041, 7056, 7090, 7100, 7150, 7175.

Scenes with People: 2102, 2190, 2191, 2200, 2214, 2280, 2305, 2357, 2381, 2383, 2385, 2393, 2512, 2570, 7550.

Scenes without People: 5390, 5471, 5510, 5530, 5531, 5731, 5740, 7490, 7491, 7500, 7546, 7547, 7590, 7595, 7700.

Unpleasant Images

Disgusting: 2730, 2981, 7380, 9008, 9040, 9140, 9181, 9300, 9301, 9320, 9373, 9561, 9570, 9571, 9830.

Threat: 1120, 1300, 1301, 1930, 2811, 3530, 6250, 6312, 6313, 6315, 6370, 6550, 6560, 6571, 9425.

Mutilation: 3015, 3016, 3030, 3051, 3101, 3102, 3110, 3120, 3140, 3168, 3170, 3190, 3261, 3266, 3400.

Received May 14, 2009
Revision received April 14, 2010
Accepted May 3, 2010 ■