



Emotional targets: Evaluative categorization as a function of context and content

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ABSTRACT

Event-related potential (ERP) studies of early evaluative categorization have often used variants of an oddball paradigm to assess attention to target stimuli as a function of content (i.e., valence) and context (e.g., presentation among non-targets differing in valence). However, most previous studies have not fully crossed content and context, and have not examined the time-course of these effects. The purpose of the current study was to investigate these two issues in an effort to further clarify the nature of evaluative categorization as reflected in the late positive potential (LPP). Pleasant, neutral, and unpleasant images served as both targets and non-targets in an emotional oddball task. Results indicate additive effects of emotional content and target status on the early portion of the LPP; however, the LPP did not differ between pleasant and unpleasant stimuli. Only target status modulated the later portion of the LPP, suggesting different contributions of cognitive–affective processes over time during evaluative categorization.

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1. Introduction

The late positive potential (LPP) is a neural index of sustained attention (Weinberg and Hajcak, 2011), and has been used as a marker of evaluative categorization (Ito et al., 1998; Schupp et al., 2004). The LPP is increased in response to motivationally-salient stimuli, defined either through content or task relevance; it is larger for emotional compared to neutral content (Bradley et al., 2001; Cuthbert et al., 2000; Ferrari et al., 2008, 2010; Foti et al., 2009; Weinberg and Hajcak, 2010), and it is increased for target compared to nontarget stimuli (Azizian et al., 2006; Ferrari et al., 2008, 2010). Moreover, there is evidence that the influence of content and task-relevance is independent and additive, rather than interactive (Ferrari et al., 2008).

There is also some evidence that the LPP is particularly sensitive to valence. Specifically, unpleasant stimuli may capture attention more effectively than both neutral and pleasant stimuli (i.e., a “negativity bias”; Delplanque et al., 2004; Huang and Luo, 2006; Ito et al., 1998; Smith et al., 2003). However, many studies have failed to find evidence for a negativity bias in the magnitude of the LPP (e.g., Briggs and Martin, 2009; Ferrari et al., 2008; Schupp et al., 2004, 2007; Weinberg and Hajcak, 2010). In a previous report using a passive viewing paradigm, (Weinberg and Hajcak, 2010), we demonstrated that a negativity bias in the LPP may emerge in large part because pleasant images of exciting sports – which are used heavily in the negativity bias literature (Delplanque et al., 2004; Huang and Luo,

2006; Ito et al., 1998; Smith et al., 2003) – elicit a very small LPP, thereby reducing the average LPP elicited by pleasant stimuli (perhaps because these images are less directly relevant to basic biological imperatives than, for example, erotic or mutilation images; Briggs and Martin, 2009; Franken et al., 2008; Schupp et al., 2004).

However, another possible explanation for the apparent discrepancies between these studies is that research which has demonstrated a negativity bias has primarily used variations on an emotional oddball paradigm (e.g., Ito and Cacioppo, 2000; Ito et al., 1998; Smith et al., 2003; Wood and Kisley, 2006), in which participants view a stream of images from a specific valence category (e.g., pleasant or unpleasant), each presented for 1000 ms, and respond to an infrequently presented target image from a different category—thus, the emotional content of a picture determines its status as target or nontarget (Cacioppo et al., 1993; Ito et al., 1998; Rossignol et al., 2007). In contrast, studies in which a negativity bias has failed to emerge have often used other types of viewing paradigms, such as random or blocked passive viewing designs (e.g., Schupp et al., 2004; Weinberg and Hajcak, 2010).

Insofar as bottom-up (i.e., exogenous, related to properties of the visual stimuli themselves) and top-down (i.e., endogenous, reflecting ongoing goals and intentions of the individual) processes can interact to determine the salience of stimuli in specific contexts (e.g., Pessoa, 2008, 2010; Pessoa and Adolphs, 2010), task differences might impact evidence for a negativity bias. For example, it is possible that salience defined in a bottom-up fashion (i.e., emotional content) is amplified by salience defined in a top-down manner (i.e., through task instructions). In other words, if unpleasant images are inherently subject to increased bottom-up processing compared to pleasant images, this effect might be heightened by an interaction with top-down manipulations of attention. Likewise, neutral targets, to the extent that

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they are less intrinsically salient than emotional targets, might not be subject to the same elaborated processing that emotional targets are (Schupp et al., 2007). To date, however, no studies using a modified oddball paradigm have fully crossed emotional content and target status (e.g., neutral pictures have not been presented as targets within an emotional context). Thus, the majority of extant studies have not addressed the potential additive, interactive, or even valence-specific effects of target status and picture valence in an oddball design.

Yet, there is evidence that addressing these effects provides a better avenue to understand how evaluative categorization works, and specifically how images differing in valence impact the magnitude of the LPP under different salience conditions. For example, Ferrari et al. (2008) fully crossed target status and content, albeit in a semantic categorization task that differed from the emotional oddball paradigm in two ways: the emotional nature of images in their task was unrelated to target status, and pictures were presented for just 30 ms. This study reported independent and additive effects of target status and valence, but reported no evidence for a negativity bias when valence and target status were fully crossed. Similarly, Schupp et al. (2007) presented pleasant, neutral, and unpleasant targets in a rapid serial visual presentation task; they found evidence for an interaction between valence and target status, but no evidence for a negativity bias. However, neither of these two studies utilized an emotional oddball task, leaving open the question of the extent to which task differences may have impacted the failure to find a negativity bias in the LPP (see Schupp et al., 2000).

In the present study, we sought to further investigate emotional and target effects on the LPP, using a modified emotional oddball task similar to what has been employed in previous research in which a negativity bias has been reported (e.g., Ito and Cacioppo, 2000; Ito et al., 1998; Smith et al., 2003; Wood and Kisley, 2006). The task was modified such that a) emotional content and target status were fully crossed (per Ferrari et al., 2008), and b) exciting sports photographs were excluded from the pleasant picture category (Briggs and Martin, 2009; Schupp et al., 2004; Weinberg and Hajcak, 2010). In line with Ferrari et al. (2008), we hypothesized that the magnitude of the LPP would be enhanced for both emotional compared to neutral images, and for targets compared to standards—and that these effects would be additive rather than interactive. We anticipated that emotional pictures would be associated with a larger LPP than neutral pictures, but that the magnitude of the LPP elicited by pleasant and unpleasant pictures would be equivalent. Based on our previous work, we did not expect to find evidence for a negativity bias despite the use of an emotional oddball task.

In addition, and in contrast to previous studies (Ferrari et al., 2008; Schupp et al., 2007), we presented images for 1000 ms in order to examine earlier versus later portions of the LPP. There is reason to believe that the cognitive-affective processes reflected in the earlier LPP (i.e., 400–600 ms) differ from the slow-wave activity occurring after 600 ms (Dunning and Hajcak, 2009; Foti and Hajcak, 2008; MacNamara et al., 2009; Olofsson et al., 2008; Weinberg and Hajcak, 2011). Indeed, an emerging body of evidence indicates that earlier activity reflects the relatively obligatory capture of attention, while the later component is instead indicative of the increasing influence of top-down attentional processes (Dunning and Hajcak, 2009; Foti and Hajcak, 2008; MacNamara et al., 2009; Olofsson et al., 2008; Weinberg et al., in press; Weinberg and Hajcak, 2011). We therefore predicted that the later portion of the LPP would only be sensitive to targets compared to standards, and would be insensitive to picture valence. Furthermore, if top-down influences work cooperatively with the intrinsic salience of images to produce the negativity bias evident in modified oddball tasks, then it is possible that biased attention toward unpleasant images might be evident in early activity but not in the later time-window, where top-down processes predominate.

2. Method

2.1. Participants

A total of 19 Stony Brook University undergraduates (7 female) participated in the study for course credit. The mean age of participants was 19 ($SD = .84$) years. 63.2% were Caucasian, 5.3% were Hispanic, 15.8% were Asian, and 10.5% were African-American. 5.3% did not indicate any race.

2.2. Visual stimuli

Sixty images were selected from the International Affective Picture System (Lang et al., 2005) to serve as both targets and standards in the emotional oddball; of these, 20 were pleasant, 20 neutral, and 20 unpleasant (specific images are listed in Appendix A). Based on previous work examining electrocortical response to specific picture categories (Schupp et al., 2004; Weinberg and Hajcak, 2010), the pleasant category consisted of affiliative images (e.g., babies, smiling families), the unpleasant category consisted of threat images (e.g., a man pointing a gun toward the camera), and the neutral category consisted of neutral scenes containing people (e.g., a woman seated at a desk). Because there is evidence that images containing human faces may potentiate the LPP independent of emotional content (Ferri et al., under review; Ito and Cacioppo, 2000; Weinberg and Hajcak, 2010), each of the three categories consisted primarily of images of people in order to control for potential effects driven by the presence of faces. Normative ratings indicated that unpleasant pictures were less pleasant (valence $M = 3.28$, $SD = .55$) than neutral pictures ($M = 5.11$, $SD = .48$), which were less pleasant than pleasant pictures ($M = 7.31$, $SD = .47$; larger numbers indicate more pleasant ratings). Unpleasant ($M = 5.45$, $SD = .27$) and pleasant ($M = 5.43$, $SD = .27$) images were matched on arousal and were more emotionally arousing than neutral images ($M = 2.98$, $SD = .21$; larger numbers indicate higher arousal).

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 70 cm from the screen and the images occupied about 40° of visual angle horizontally and vertically, and were instructed to fixate on the center of the screen.

2.2. Procedure

Subsequent to verbal instructions indicating that they would be engaging in a target detection task while viewing pictures of varying emotional quality, participants were seated and electroencephalograph sensors were attached. Prior to the start of the task, participants were familiarized with exemplars of images from each valence category. These images were not included in the experiment. Each trial then consisted of a sequence of five images: four “standard” images, all drawn from the same affective category (i.e., either pleasant, neutral, or unpleasant), and one “target” image drawn from a different affective category. Participants were instructed to respond as quickly as possible to targets by pressing a key when they saw an image that differed in valence from the others within the same trial (per Rozenkrants and Polich, 2008). Only ERP responses associated with correctly-identified targets were retained for analysis. The average accuracy rate was 94.56% ($SD = 3.80$).

Each image was presented for 1000 ms. Consistent with previous studies that have employed this type of task (Ito and Cacioppo, 2000; Ito et al., 1998; Smith et al., 2003), the target image appeared in the 4th position in the sequence on half the trials, and in the 5th position on the remaining half. Between each picture presentation

was a random inter-stimulus interval (ISI) that ranged from 500 ms to 550 ms. Following the fifth image in the trial, a fixation cross was displayed for an interval that varied randomly between 1000 and 1500 ms. A total of 120 trials were presented randomly. There were 20 trials for each of six conditions: pleasant targets with unpleasant standards, pleasant targets with neutral standards, unpleasant targets with pleasant standards, unpleasant targets with neutral standards, neutral targets with unpleasant standards, or neutral targets with pleasant standards. Each image in the set served as a target once and as a standard stimulus four times.

2.3. Electroencephalographic recording and data processing

Continuous EEG recordings were collected using an elastic cap and the ActiveTwo BioSemi system (Amsterdam, Netherlands). Sixty-four Ag–AgCl active electrodes 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 pre-amplified at the electrode to improve the signal-to-noise ratio and amplified with a gain of 1x by a BioSemi ActiveTwo system. The data were digitized at 24-bit resolution with a LSB value of 31.25 nV and a sampling rate of 512 Hz, using a low-pass fifth order sinc filter with -3 dB cutoff point at 104 Hz. Each active electrode was measured online with respect to a common mode sense (CMS) active electrode, located between PO3 and POz, producing a monopolar (non-differential) channel. CMS forms a feedback loop with a paired driven right leg (DRL) electrode, located between POz and PO4, to form the active recording reference. Offline, all data were 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; eye-blink and ocular corrections were conducted per Gratton et al. (1983).

Following this, a semi-automatic procedure was employed to detect and reject artifacts. Data from individual channels were rejected if a voltage step of more than 50.0 μ V between sample points or a voltage difference of 300.0 μ V within a segment existed. In addition, data were identified as artifacts if a voltage difference of less than .50 μ V within 100 ms intervals was present. Visual inspection of the data was then conducted to detect and reject any remaining artifacts, including any remaining ocular artifacts that might have survived correction.

The EEG was segmented for each stimulus beginning 200 ms prior to picture onset and continuing for 1200 ms (i.e., for the entire picture presentation duration). For each stimulus-locked response, the baseline was defined as the 200 ms prior to picture onset. ERPs were constructed by separately averaging 6 picture types (pleasant targets, pleasant standards, neutral targets, neutral standards, unpleasant targets, and unpleasant standards).

Because the LPP is maximal at centro-parietal sites (Cuthbert et al., 2000; Foti and Hajcak, 2008), it was scored as the average activity from five sites (Pz, CPz, Cz, CP1, and CP2). Previous research (Foti et al., 2009; Weinberg and Hajcak, 2011) 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 three time windows following stimulus onset: early (400–600 ms), middle (600–800 ms), and late (800–1000 ms).

2.4. Statistical analyses

All statistics were conducted using SPSS (Version 17.0) General Linear Model software. A 3-way (valence category) repeated-

measures ANOVA was conducted to examine the effect of valence category on reaction time to targets. The three time windows of the LPP were statistically evaluated using a 2 (target vs. standards) \times 3 (valence category: pleasant, neutral, and unpleasant) \times 3 (time window: early, middle, late) repeated-measures ANOVA, in order to evaluate the effect of target and emotion in the three windows of the LPP. Following this, and in order to examine differences across the full time-window of the LPP, each time-window was then considered separately using three 2 (target vs. standards) \times 3 (valence category: pleasant, neutral, and unpleasant) repeated-measures ANOVAs. 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. Finally, Pearson's r was also used to examine the relationship between reaction time to targets and the magnitude of the LPP to targets in each window.

3. Results

3.1. Electrocortical response

Grand average stimulus-locked ERPs for targets and standards in each valence category (e.g., pleasant, neutral, and unpleasant) are presented in Fig. 1 (top), as well as the target minus standard difference for each valence category. Mean LPP area measures for each of the three time windows are presented in Table 1; a graphic depiction of these means is presented in Fig. 1 (bottom). As suggested by Fig. 1, LPP amplitude varied across time windows ($F(2,36) = 9.53, p = .001; \eta_p^2 = .35$; Greenhouse-Geisser $\epsilon = 0.64$), as a function of target ($F(1,18) = 21.41, p = .001; \eta_p^2 = .54$; Greenhouse-Geisser $\epsilon = 1.00$), and as a function of picture content ($F(2,36) = 9.39, p = .001; \eta_p^2 = .34$; Greenhouse-Geisser $\epsilon = 0.81$). The effect of target was consistent across time-windows ($F(2,36) = 2.65, p = .08; \eta_p^2 = .13$; Greenhouse-Geisser $\epsilon = 0.81$) and across valence category ($F(2,36) < 1, p = .62; \eta_p^2 = .03$; Greenhouse-Geisser $\epsilon = 0.80$). However, the effect of valence category differed significantly as a function of time-window ($F(4,72) = 14.42, p = .001; \eta_p^2 = .45$; Greenhouse-Geisser $\epsilon = 0.68$). Furthermore, there was a three-way interaction between time-window, valence category and target ($F(4,72) = 3.58, p = .01; \eta_p^2 = .17$; Greenhouse-Geisser $\epsilon = 0.66$).

In the early window, picture content impacted the magnitude of the LPP ($F(2,36) = 21.56, p = .001; \eta_p^2 = .55$; Greenhouse-Geisser $\epsilon = 0.91$), such that pleasant ($t(18) = 5.47, p = .001$; critical p -value = .017 for three contrasts) and unpleasant images ($t(18) = 6.41, p = .001$) elicited a larger LPP than neutral images. There was no difference between the magnitude of the LPP elicited by pleasant and unpleasant images ($t(18) = .63, p = .54$). Because comparisons of the pleasant and unpleasant categories amount to an attempt to support the null hypothesis, a Bayes-factor one-sample t -test was also conducted (Rouder et al., 2009), in which r was set *a priori* to 1.0; setting r to a lower value can unduly favor small effect sizes, while a higher value of r risks overlooking modest but significant effects (Rouder et al., 2009). In the early LPP window, the odds of Null: Alternative hypothesis were greater than 4:1 favoring the null hypothesis (JZS Bayes Factor [null/alternative] = 4.74), suggesting that the LPP elicited by pleasant pictures did not differ from the LPP elicited by unpleasant pictures.

The magnitude of the LPP also varied as a function of target in the early window ($F(1, 18) = 12.75, p = .002; \eta_p^2 = .42$; Greenhouse-Geisser $\epsilon = 1.00$), such that targets elicited a larger response than standards. However, the effect of targets did not vary by valence category ($F(2, 36) = 2.18, p = .13; \eta_p^2 = .11$; Greenhouse-Geisser $\epsilon = .81$).

As in the early window, the overall magnitude of the LPP differed as a function of picture content in the middle window ($F(2,36) = 5.93, p = .006; \eta_p^2 = .25$; Greenhouse-Geisser $\epsilon = 0.80$), such that pleasant ($t(18) = 2.83, p = .01$; critical p -value = .017 for three contrasts) and unpleasant images ($t(18) = 4.07, p = .001$) elicited a larger LPP compared

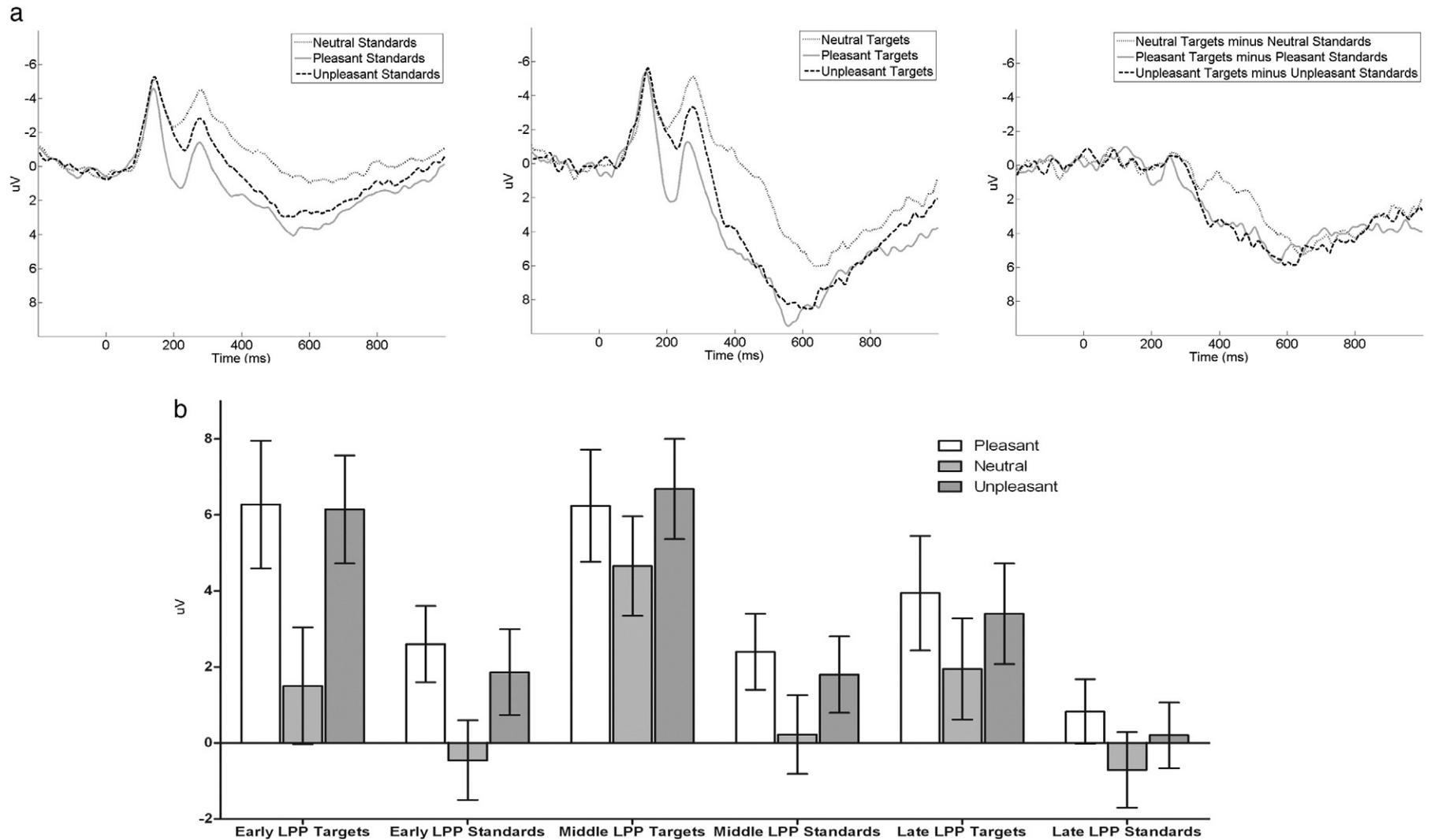


Fig. 1. a) Stimulus-locked ERP waveforms reflecting the average activity at Pz, CPz, Cz, CP1, and CP2. In each panel, targets and standards for each valence category are compared. Stimulus onset occurred at 0 ms and negative is plotted up. b) A bar graph depicting average activity for each picture type (e.g., pleasant targets, pleasant standards, etc.) in each time-window of the LPP (early window: 400–600 ms, middle window: 600–800 ms, late window: 800–1000 ms). Bars denote standard errors.

Table 1Mean amplitudes (μV) for the early (400–600 ms), middle (600–800 ms), and late (800–1000 ms) LPP (SDs in parentheses).

	Pleasant targets	Pleasant standards	Pleasant grand mean	Neutral targets	Neutral standards	Neutral grand mean	Unpleasant targets	Unpleasant standards	Unpleasant grand mean	Targets grand mean	Standards grand mean
Early LPP	6.27 (7.31)	2.60 (4.37)	4.44 (5.27)	1.50 (6.69)	−.46 (4.58)	.52 (5.14)	6.14 (6.20)	1.86 (4.91)	4.00 (5.26)	4.64 (6.10)	1.34 (4.48)
Middle LPP	6.24 (6.43)	2.40 (4.37)	4.32 (4.89)	4.65 (5.71)	.22 (4.52)	2.44 (4.53)	6.68 (5.75)	1.80 (4.37)	4.24 (4.59)	5.86 (5.31)	1.47 (4.25)
Late LPP	3.94 (6.56)	.83 (3.71)	2.39 (4.78)	1.95 (5.80)	−.71 (4.34)	.62 (4.55)	3.40 (5.77)	.20 (3.77)	1.80 (4.43)	3.10 (5.19)	.11 (3.72)

to neutral images. As before, pleasant and unpleasant images did not differ from one another significantly ($t(18) = .11, p = .92$), and the odds of Null: Alternative hypothesis were greater than 5:1 favoring the null hypothesis (JZS Bayes Factor [null/alternative] = 5.69). The LPP also varied as a function of target in this window ($F(1, 18) = 24.80, p = .001; \eta_p^2 = .58$; Greenhouse-Geisser $\epsilon = 1.00$), such that targets elicited a larger response than standards. This effect was not modulated by valence category ($F(2,36) < 1, p = .66; \eta_p^2 = .02$; Greenhouse-Geisser $\epsilon = .78$).

In the late window, the overall magnitude of the LPP no longer differed reliably as a function of picture content ($F(2,36) = 3.17, p = .07; \eta_p^2 = .15$; Greenhouse-Geisser $\epsilon = 0.76$). However, the LPP remained larger for targets than standards in this time window ($F(1, 18) = 16.27, p = .001; \eta_p^2 = .48$; Greenhouse-Geisser $\epsilon = 1.00$); in addition, as in the previous two windows of the LPP, the effect of target did not vary by valence category ($F(2,36) < 1, p = .90; \eta_p^2 = .01$; Greenhouse-Geisser $\epsilon = .91$).

3.2. Reaction time

Reaction time was significantly impacted by valence category ($F(2,36) = 7.94, p = .001; \eta_p^2 = .31$; Greenhouse-Geisser $\epsilon = 0.98$), such that participants were faster to identify unpleasant targets ($M = 640.85, SD = 79.43$) than neutral targets ($M = 681.46, SD = 71.46; t(18) = 4.13, p = .001$). However, participants were not significantly faster to identify pleasant ($M = 668.27, SD = 82.86$) compared to neutral targets ($t(18) = 1.29, p = .21$), nor did reaction time significantly differ for pleasant and unpleasant targets ($t(18) = 2.48, p = .02$; critical p -value = .017 for three contrasts), though the odds of Null: Alternative hypothesis .45:1 against the null hypothesis (JZS Bayes Factor [null/alternative] = .45). Finally, there was no significant relationship between reaction time and the magnitude of the LPP in any time window.

4. Discussion

Consistent with our hypotheses and previous research (Ferrari et al., 2008), the present study demonstrated that the early and middle portion of the LPP were sensitive to both target status and picture valence such that targets elicited an enhanced LPP compared to standards, as did emotional compared to neutral images. The present results suggest that the effects of emotion and target status were orthogonal; that is, though both targets and emotional content potentiated the LPP, the impact of emotion did not vary by target status, or vice-versa (Ferrari et al., 2008).

In addition, despite the use of an oddball paradigm similar to that used in previous studies demonstrating a negativity bias in the LPP (e.g., Ito et al., 1998), pleasant and unpleasant images did not differ from one another in terms of the neural response they evoked. In our previous work, we demonstrated that an apparent negativity bias could result from including exciting sports pictures in the pleasant picture ERP averages (Weinberg and Hajcak, 2010). However, that study did not employ an emotional oddball paradigm. In the present study, we only used affiliative and threatening pleasant and unpleasant pictures, respectively, and again found no evidence for a negativity bias. These results are consistent with arguments that the negativity bias reflected in the LPP is not apparent when pleasant and unpleasant

images are matched for motivational salience (Briggs and Martin, 2009; Schupp et al., 2004; Weinberg and Hajcak, 2010). Although this does not preclude the possibility that a negativity bias occurs at later stages of evaluation (e.g., Hansen and Hansen, 1988; Öhman et al., 2001), data are accumulating to suggest that such a bias does not necessarily occur at these earliest stages of evaluative categorization, and may depend heavily on picture content rather than simply on arousal and valence ratings. Future studies might also vary the specific content of the broad picture categories of pleasant, neutral, and unpleasant (per Weinberg and Hajcak, 2010) within a modified oddball task to further explore the ways in which variation in intrinsic salience interacts with top-down attentional manipulations. For example, Schupp et al. (2007) did identify an interaction between valence and target status when examining highly-arousing stimulus categories (e.g., erotic and mutilation).

Though the present results do not reveal any evidence for a negativity bias in the magnitude of the LPP, the results from the behavioral analysis did suggest that participants were marginally faster to identify unpleasant targets, compared to both pleasant and neutral targets. This suggests the possibility of a negativity bias operating at a later processing stage, though this was not reflected in the neural response.

It is also worth noting that in many respects the early portion of the LPP identified in the present study closely resembles the P300, which, like the sustained LPP, appears sensitive to the motivational significance of stimuli, defined either through task parameters or the properties of the stimuli themselves (see Nieuwenhuis et al., 2005). For example, there is ample evidence that infrequent target stimuli elicit an enhanced P300 compared to frequent standard stimuli (see, e.g., Polich, 2007 for a review). Other research suggests that P300 amplitude is also sensitive to the valence of emotional stimuli (Johnston et al., 1986; Palomba et al., 1997; Radilova, 1982), suggesting that the content of the stimuli may also modulate the component. The scalp-recorded LPP is a broad and sustained positivity, which persists well beyond the time-frame of the P300. Based on previous evidence from Principal Components Analysis (PCA), we have argued that the LPP may reflect the activity of multiple overlapping components (Foti et al., 2009; MacNamara et al., 2009; Weinberg and Hajcak, 2011), one of which may indeed be a P300 or P300-like component.

Consistent with this understanding of the LPP, the results of the present study indicate that the later portion of the LPP was only sensitive to target status. An increasing amount of research suggests that early (i.e., <600 ms) components may reflect different processes in the allocation of attention to emotion than later components (i.e., >600 ms; Azizian and Polich, 2007; Foti et al., 2009; Olofsson et al., 2008; Weinberg and Hajcak, 2010, 2011). The present research supports this notion: Whereas the two earlier time-windows of the LPP were sensitive to both bottom-up and top-down influences on attention, the later portion of the LPP was uniquely sensitive to targets compared to standards. Later activity may reflect more flexible, sustained, and elaborative processes relevant to top-down task imperatives (Foti and Hajcak, 2008; MacNamara et al., 2009, 2011; Olofsson et al., 2008; Weinberg and Hajcak, 2011). Combined, these results suggest that the LPP serves as a useful index of in the study of how multiple motivational factors may influence sustained attention, and further that earlier and later portions of the LPP can be functionally dissociable (e.g., Weinberg and Hajcak, 2011).

Appendix A. Picture identification numbers from the IAPS for images used in this study

Pleasant Images: 1710, 2045, 2071, 2075, 2150, 2155, 2160, 2208, 2209, 2303, 2345, 2347, 2352, 4597, 4599, 4623, 4624, 4625, 4626, 4640.

Neutral Images: 2036, 2038, 2102, 2104, 2200, 2210, 2221, 2381, 2393, 2397, 2411, 2440, 2480, 2495, 2499, 2513, 2518, 2570, 2580, 2620.

Unpleasant Images: 1301, 1303, 2120, 2130, 2694, 6190, 6200, 6242, 6244, 6555, 6561, 6562, 6571, 6825, 6832, 6836, 9423, 9426, 9427, 9428.

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