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The Negativity Bias in Affective Picture Processing Depends on Top-Down and Bottom-Up Motivational Significance

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Abstract

It is widely believed that negative information is psychologically more meaningful than positive information, a phenomenon known generally as the negativity bias. However, findings concerning the possibility of a negativity bias in emotional picture processing have been mixed, with recent studies indicating the lack of such a bias in event-related brain potentials (ERPs) when pleasant and unpleasant images are equated for motivational relevance. Here, we investigated two factors that could influence the detection of a negativity bias: picture presentation paradigm and specific picture content. Across two studies, participants viewed pleasant-affiliative, pleasant-thrilling, unpleasant-threatening and neutral images presented in the context of oddball, blocked and random viewing paradigms. Across paradigms, emotional images elicited larger responses in the late positive potential (LPP) than did neutral images. A negativity bias was detected in the oddball paradigm and when thrilling, rather than affiliative, pleasant stimuli were used. Findings are discussed in terms of factors known to influence LPP amplitude and their relevance to differential effects across picture viewing paradigms.

Keywords

Negativity bias; late positive potential; LPP; P300; motivational significance

The emotional evaluation of people and objects is among the most rapid and automatic processes in the mind, often preceding conscious awareness (see Zajonc, 1980, 1984). Rapid evaluations of whether a stimulus is helpful or dangerous are crucial to the correct and timely execution of motivated behavior; for example, to approach a potential reward or flee from a potential threat. However, despite the obvious value in appraising both rewarding and harmful stimuli, whether positive and negative evaluations are given equivalent weight in judgments has been a matter of considerable debate (Briggs & Martin, 2008, 2009; Cacioppo, Berntson, Norris, & Gollan, 2011; Radilova, 1982). The current study was aimed at testing whether differences in the specific context in which affect-related stimuli are

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encountered plays a role in determining their motivational significance, as determined by the amplitude of late positive event-related brain potentials (ERPs).

The Negativity Bias

The Negativity Bias is the psychological phenomenon that, simply put, “bad is stronger than good” (Baumeister, Bratslavsky, Finkenauer, & Vohs, 2001). That is, negative events tend to have larger and longer-lasting effects than do positive events of equal magnitude, an effect thought to reflect an evolutionary adaptation to the relatively greater relevance of threat compared to reward (see Cacioppo, Gardner, & Berntson, 1999). Whereas an insufficient response to positive information could lead to regrets over missed opportunities, an insufficient response to negative information could lead to injury or death. The negativity bias appears pervasive, as evidence has been found in a number of domains. For example, in determining long-term life satisfaction, the effects of positive events tend to wear off more quickly than the effects of negative events (Brickman & Campbell, 1971; Brickman, Coates, & Janoff-Bulman, 1978). Similarly, close relationship satisfaction seems to be more strongly influenced by the presence of negative behaviors and interactions than positive ones (Gottman, 1979, 1994; Gottman & Krokoff, 1989). Also, negative information is weighted more heavily than positive information when forming impressions of others (e.g., Riskey & Birnbaum, 1974; Fiske, 1980; Peeters & Czapinksi, 1990; Skowronski & Carlston, 1989). Analogous effects also have been found at a more basic level of evaluative categorization, in that arousal ratings more strongly predict valence ratings for unpleasant than for pleasant images (Ito, Cacioppo, & Lang, 1998). In summarizing this literature, Taylor (1991) concluded that negative events tend to result in greater mobilization of cognitive, emotional and social responses than do positive events.

In order to specify the temporal dynamics of evaluative processing, a number of researchers have investigated whether the negativity bias in behavior has a psychophysiological counterpart in the ERP (e.g., Bartholow, Fabiani, Gratton, & Bettencourt, 2001; Briggs & Martin, 2008; Carretié, Mercado, Tapia, & Hinojosa, 2001; Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000; Delplanque, Silvert, Hot, & Sequeira, 2005; Delplanque, Silvert, Hot, Rigoulot, & Sequeira, 2006; Ito, Larsen, Smith, & Cacioppo, 1998; Schupp et al., 2000; Smith et al., 2006). Typical paradigms in this domain involve participants viewing sets of pleasant, unpleasant, and neutral stimuli (often pictures) while ERPs are recorded, with the pleasant and unpleasant sets matched for arousal and extremity in valence (e.g., Ito et al., 1998b; Radilova, 1982; Schupp et al., 2000). Most such studies have focused on the amplitude of the P300 (P3) and/or late positive potential (LPP), which are highly sensitive to the motivational significance of eliciting stimuli (e.g., Nieuwenhuis, Aston-Jones, & Cohen, 2005; Weinberg & Hajcak, 2010). Evidence for a negativity bias in the P3/LPP has been mixed, with some studies finding larger amplitudes to unpleasant than to pleasant stimuli (e.g., Bartholow et al., 2001; Cuthbert et al., 2000; Delplanque et al., 2005, 2006; Foti, Hajcak, & Dien, 2009; Hajcak & Olvet, 2008; Huang & Luo, 2006; Ito et al., 1998b; Rozenkrants & Polich, 2008), and others finding that unpleasant and pleasant stimuli elicit equally large (relative to neutral) P3/LPP responses (Briggs & Martin, 2008, 2009; Diedrich, Naumann, Maier, & Becker, 1997; Palomba, Angrilli, & Mini, 1997; Radilova, 1982;

Schupp et al., 2000; Schupp, Junghöfer, Weike, & Hamm, 2003; Weinberg & Hajcak, 2010).

Several possible explanations can be offered for these apparently discrepant sets of findings. First, beyond simple valence and arousal ratings, specific picture content may determine how emotional pictures are evaluated (see Anokhin et al., 2006; Franken, Muris, Nijs, & van Strien, 2008). That is, even if certain pleasant and unpleasant pictures are rated as equally arousing and extreme in valence, the meaning of the depicted scenes varies considerably, which could influence the magnitude of affective, motivational or attentional responses—and, hence, brain activity—they elicit. Findings from two recent studies highlight this issue. McGraw, Larsen, Kahneman, & Schkade (2010, Study 3) found that participants judged unpleasant images to be more intense than pleasant images, despite both categories of images having been rated as equally arousing and extreme in valence using standard bipolar rating scales. Weinberg and Hajcak (2010) provided direct evidence for the notion that self-reported valence and arousal ratings do not adequately capture the extent to which emotional images influence underlying motivational and attentional responses. These authors found that images depicting exciting sports and thrill rides elicited smaller LPP amplitude than images depicting erotic and affiliative scenes, despite equivalently high positive valence ratings for both categories, and that pleasant and unpleasant images most related to motivational imperatives (i.e., images of mutilated bodies and erotic images implying procreation) elicited the largest LPP amplitudes, which did not differ in magnitude across valence categories. Weinberg and Hajcak concluded that the apparent negativity bias in the LPP observed in previous studies (e.g., Ito et al., 1998b) was likely due to the use of a particular category of less evocative pleasant stimuli (exciting sports and thrill rides) rather than a broad bias towards enhanced processing of unpleasant stimuli.

A second possibility is that the use of different experimental paradigms across studies contributes to the likelihood of finding a negativity bias in the LPP. To date, the question of picture presentation paradigm has received very little systematic attention in the literature (but see Schupp et al., 2000). In theory, differences across paradigms in certain structural features known to influence LPP amplitude might interact with picture valence to influence the likelihood of a negativity bias emerging. In particular, whereas the question of specific picture contents relates to evaluations of the inherent or “bottom-up” motivational significance of emotional pictures (Franken et al., 2008; Weinberg & Hajcak, 2010), other features, such as whether or not participants are required to respond to the pictures and the relative frequency and predictability of various picture types can also influence the LPP, through variation in top-down motivational significance (see Nieuwenhuis et al., 2005) and novelty-induced orienting responses (see Bradley, 2009), features that often differ across paradigms.

The majority of studies investigating P3/LPP responses to emotional pictures have used one of three types of paradigms: a visual oddball paradigm, a random presentation paradigm, or a blocked presentation paradigm. An important difference between the oddball paradigm on the one hand and randomized or blocked presentations on the other is the relative salience of specific image types. In the oddball paradigm, presentation of frequent nontarget stimuli of invariant (usually neutral) valence is punctuated by infrequent stimuli of a different valence, such that targets are both more novel and more unpredictable than nontargets. In contrast, in the random presentation paradigm the valence of images is randomly determined across trials, and blocked presentation paradigms involve images of only a single valence category presented in sequence. These differences could have implications for the motivational salience of specific image types. For example, in an oddball paradigm, an emotional target is particularly salient because it stands in contrast to the neutral non-targets preceding it. Similarly, individual targets within a random presentation paradigm are likely to be more salient than those presented in a blocked paradigm, since the valence of current targets cannot be predicted and will often differ from preceding targets in random paradigms.

To the extent that the salience of targets within paradigms interacts with the valence of specific images, a negativity bias might be more likely in the oddball than in either the random or blocked paradigms, and more likely in the random than in the blocked paradigm. Consistent with this idea, several studies in which the LPP was found to be larger to unpleasant than to pleasant images have used some version of an oddball paradigm. For example, Ito et al. (1998b) constructed stimulus sets in which pictures were presented in sequences of five, four of which were affectively neutral and one – the oddball or target – represented a positive or negative valence category. Using this paradigm, Ito et al. found that unpleasant oddballs elicited larger LPPs than pleasant oddballs (see also Delplanque et al., 2005; Rozenkrants & Polich, 2008; but see Weinberg, Hilgard, Bartholow, & Hajcak, 2012). In contrast, studies reporting equivalent LPP amplitudes in response to pleasant and unpleasant images generally have used randomized (e.g., Schupp et al., 2000) or blocked picture presentation (e.g., Cuthbert et al., 2000; Franken et al., 2008; Weinberg & Hajcak, 2010).

The purpose of this research was to test the extent to which parameters differing across viewing paradigms influence evaluative picture processing and contribute to the likelihood of a negativity bias in the P3/LPP. Previous research has pointed specifically to the parameters of the oddball paradigm as possibly contributing to such a bias (Schupp et al., 2000), and to the specific contents of the pleasant images themselves (Weinberg & Hajcak, 2010), but no previous study has systematically varied picture presentation paradigms (oddball, random and blocked) and pleasant picture contents to directly compare their effects on LPPs elicited from affective pictures. To the extent that a negativity bias is more likely to emerge within the context of an oddball than in random or blocked viewing paradigms, it is possible that unpleasant images will elicit larger LPP than pleasant images even when pictures in the two categories are matched for motivational imperatives (cf., Weinberg & Hajcak, 2010). The primary goal of the first experiment was to test this hypothesis. The primary goal of the second experiment was to evaluate whether the negativity bias emerges in other paradigms when the pleasant and unpleasant image categories are matched for valence extremity but not matched for bottom-up motivational significance (see Weinberg & Hajcak, 2010).

General Method

Overview

Methodological details were very similar for the two experiments reported here. In both, participants viewed color pictures varying in affective valence (pleasant, unpleasant and neutral), selected from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 1999), while ERPs were recorded. All participants viewed the images in blocked, random, and oddball viewing paradigms (details in the following section). The only methodological difference between the two experiments was in the contents of the pleasant images (affiliative in Experiment 1; thrilling in Experiment 2). The following sections describe procedures common to both experiments. Details concerning image contents and participants for each experiment are provided in subsequent sections.

Picture Presentation Paradigms

Each participant completed three picture presentation paradigms, with paradigm order counter-balanced across participants. In each paradigm, images were presented for 1000ms each, with a jittered inter-stimulus interval of 900 or 1200ms. In both studies, 60 IAPS images were used (20 each of neutral, pleasant, and unpleasant valence; the neutral and unpleasant images were identical across studies[1]).

Oddball paradigm—Following previous emotional oddball tasks (e.g., Bartholow, Lust, & Tragesser, 2010; Ito et al., 1998b), each trial consisted of five stimuli presented sequentially. Four of these stimuli were neutral standards (i.e., context), while one was an emotional target of either positive or negative valence. To ensure the establishment of the neutral context, targets always appeared in the fourth or fifth position in the sequence. The valence of the oddball stimulus was determined randomly on each trial. Participants were asked to press a button with their right index finger when they saw an emotional deviant and to withhold the button press for all neutral standards. Each pleasant and unpleasant stimulus in the set served as the oddball four times. Participants received a brief break after every 16 trials (80 stimuli). Participants completed 80 trials in total.

Blocked paradigm—In this paradigm, participants passively viewed blocks of images from one valence category in sequence (i.e., a block of all pleasant images, a block of all neutral images, and a block of all unpleasant images). Within each block, each stimulus from the respective valence category was displayed four times (i.e., 80 trials per block). Upon completing one block, participants received a brief break, and then pressed a button to begin the next block. The order of the stimulus valence categories was chosen at random for each participant, as was the order of the stimuli within each block. Participants completed a total of 240 trials.

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[1] The IAPS picture numbers for the images used in this study were as follows: Neutral images were 2036, 2038, 2102, 2104, 2200, 2210, 2221, 2381, 2393, 2397, 2411, 2440, 2480, 2495, 2499, 2513, 2518, 2570, 2580, and 2620. Threatening images were 1301, 1303, 2120, 2130, 2694, 6190, 6200, 6242, 6244, 6555, 6561, 6562, 6571, 6825, 6832, 6836, 9423, 9426, 9427, and 9428. Affiliative images were 1710, 2045, 2071, 2075, 2150, 2155, 2160, 2208, 2209, 2303, 2345, 2347, 2352, 4597, 4599, 4623, 4624, 4625, 4626, and 4640. Thrilling images were 8021, 8031, 8034, 8080, 8130, 8180, 8185, 8190, 8200, 8208, 8210, 8250, 8300, 8350, 8370, 8380, 8400, 8470, 8490, and 8496. Of the thrilling images used in experiment 2, thirteen had been used by Weinberg and Hajcak (2010): 8031, 8080, 8180, 8185, 8190, 8200, 8210, 8300, 8380, 8400, 8470, 8490, and 8496.

Random paradigm—In this paradigm, participants passively viewed stimuli chosen at random from all three valence categories. Each stimulus was displayed four times, for a total of 240 trials. Participants received a break after the first 120 images.

Electrophysiological Recording

All participants were outfitted with a 28-channel electrode cap (Electrode Arrays, El Paso, TX) containing Ag/AgCl electrodes placed according to the expanded 10/20 electrode placement system (Electrode Position Nomenclature Committee, 1994). The online recording was referenced to the right mastoid, with an average bilateral mastoid reference derived offline. Impedance was kept below 10kΩ at all electrode locations. Electrooculogram (EOG) activity caused by eye movements was recorded with bipolar electrodes placed about 2cm lateral to each outer canthus (horizontal EOG) and additional electrodes placed about 1cm above and below the left eye (vertical EOG). Recordings were amplified with a Neuroscan Synamps amplifier (Compumedics, Inc., Charlotte, NC) and filtered online at .10 to 30 Hz with a sampling rate of 1000 Hz.

Blinks measured at the vertical EOG electrodes were removed from the EEG at all other channels using a regression-based procedure (Semlitsch, Anderer, Schuster, & Preesslich, 1986). Stimulus-locked epochs of 200 ms pre-stimulus to 1000ms post-stimulus were defined for each trial. Artifact rejection eliminated trials with deflections of more than 100μV. Trials were then averaged according to electrode and stimulus conditions within each presentation paradigm. Finally, averages were low-pass filtered at 12Hz. Consistent with previous reports, visual inspection of the ERP waveforms indicated that the LPP emerged between approximately 350 and 800 ms post-stimulus at centro-parietal and parietal scalp locations (e.g., Ferrari et al., 2008; Franken, Nijs, Muris, & Van Strien, 2007; Ito et al., 1998b; Schupp et al., 2000). Therefore, and consistent with recent studies differentiating earlier and later portions of the LPP (Dunning & Hajcak, 2009; Foti & Hajcak, 2008; MacNamara, Foti, & Hajcak, 2009; Olofsson, Nordin, Sequeria, & Polich, 2008; Weinberg &Hajcak, 2010; Weinberg et al., 2012), we measured the early and late LPP as the average amplitudes measured at centro-parietal and parietal electrodes over left, midline, and right scalp locations (CP3, CPz, CP4, P3, Pz, and P4) between 350-500ms and 550-800 ms post-stimulus, respectively, in each paradigm.

Procedure

After providing informed consent, participants were escorted to the sound-attenuated recording room where electrodes were placed and tested. Participants then were seated in a comfortable chair approximately 60cm from a 12″ × 9″ video monitor on which task instructions and all stimulus images were presented. The experimenter read the instructions along with participants and ensured that they understood, after which the experimenter left the room. Before each presentation paradigm, the experimenter provided an additional reminder of which task the participant was about to perform and what the task required. The experimenter monitored all sessions via video camera from an adjacent control room to ensure that participants remained awake and on task. Sessions lasted approximately 90 minutes.

Experiment 1

Participants

Thirty-five healthy undergraduates (16 women) participated in exchange for partial course credit. Participants ranged in age from 18 to 22 years old (*M* = 19.5, *SD* = 1.67); 28 reported their ethnicity as White, 4 as Asian, 1 as Black, 1 as biracial Black and White, and 1 did not provide demographic information. Six participants had to be excluded due to poor EEG recording quality, excessive movement artifact, or falling asleep during the session, leaving the final sample for data analysis at 29 (14 women).

Materials

Sixty images chosen from the IAPS served as stimuli in this study. These images consisted of 3 sets of twenty images each: pleasant affiliative images (e.g., cute babies, romantic couples, hugging children), unpleasant threatening images (e.g., armed robbery, public riots), and neutral scenes with people (e.g., old men playing chess, people standing with arms crossed). The images were matched across categories on a variety of dimensions, including extremity of valence, arousal, number of racial minority persons, and numbers of nonhuman stimuli. Neutral pictures were allowed to be less arousing than the emotional pictures because arousing neutral pictures are a limited set of peculiar, perhaps anxiety-inducing images (e.g., a construction worker eating lunch on a skyscraper I-beam). All images involved people except for two threatening and one affiliative image that contained dogs. Mean valence ratings for the pleasant, neutral, and threatening images were 7.3, 5.1, and 3.3, respectively; mean arousal ratings were 5.4, 3.0, and 5.5, respectively. Image selection was guided by Weinberg & Hajcak (2010) to ensure that the pleasant and unpleasant categories contained images matched on bottom-up motivational relevance in addition to similarity in arousal and valence extremity ratings.

Results and Discussion

Analytic Approach

Although use of univariate repeated-measures analysis of variance (ANOVA) is commonplace in ERP research, this approach has a number of shortcomings that can limit its applicability (see Vasey & Thayer, 1987). For one, ANOVA requires that the data meet an assumption of sphericity (i.e., that the variances of differences between factor levels are equal), which frequently is violated (Jennings & Wood, 1976), and corrections for violations of this assumption within ANOVA (e.g., Greenhouse-Geisser or Huynh-Feldt *p*-value adjustments) result in loss of statistical power. In addition, inter-individual variability in both baseline and stimulus-elicited EEG activity often is greater than variability attributable to variables of interest (see Gratton, 2007). Given the assumption in ANOVA that the mean response is representative of all individuals within a group (or condition) and that differences among individuals are considered error, this variability contributes to inflated error variance estimates in ANOVA (further reducing power) and ignores the often stable and reliable individual differences in psychophysiological response patterns across individuals (see Hammond, McClelland, & Mumpower, 1980; Marwitz & Stemmler, 1998). Thus, numerous scholars have advised the use of various multivariate approaches for psychophysiological data (see Gratton, 2007; Kristjansson, Kircher, & Webb, 2007; Vasey & Thayer, 1987), such as multilevel modeling. Advantages of multilevel modeling include relaxed assumptions concerning sphericity or compound symmetry, the ability to simultaneously estimate both within-participant and between-participants effects (see Raudenbush & Bryk, 1992), and the ability to specify separate error terms at each level of nesting. Multilevel modeling also is robust to missing observations (e.g. bad electrodes), whereas repeated-measures ANOVA requires that missing values be interpolated or that the subject's data be discarded. Thus, assuming reasonably large samples ($n > 10 + k$), this approach generally yields greater power than ANOVA (Baguley, 2004). Based on these considerations, the current data were analyzed with hierarchical linear modeling (HLM) using SAS PROC MIXED (see Raudenbush & Bryk, 1992). Measurements of voltage at each electrode site for each valence and paradigm were nested within subjects. Nuisance variance between subjects was modeled by including a random intercept of subject.

The primary hypothesis for this study was that a negativity bias is more likely to emerge in the oddball than in the random or blocked viewing paradigms. To test this hypothesis, we first submitted the LPP amplitudes to overall 3 (Valence) x 3 (Paradigm) x 3 (Coronal scalp location) x 2 (Sagittal scalp location) HLMs, separately for the early and late LPP windows. Effects of interest did not differ across scalp locations, so further analyses collapsed across those factors. Mean LPP amplitudes as a function of picture valence category, picture presentation paradigm, and epoch for Experiment 1 are shown in the upper panel of Table 1. ERP waveforms displaying the LPPs elicited by target images in Experiment 1 are given in Figure 1.

Early LPP Window (300-550 ms)

The HLM on the early portion of the LPP revealed a significant effect of Paradigm, $F(2, 1528) = 1077$, $p < .0001$, indicating larger amplitudes overall in the oddball ($M = 7.17$ μV) compared to the blocked ($M = 1.66$ μV) and random paradigms ($M = 1.81$ μV); a main effect of Valence, $F(2, 1528) = 285.31$, $p < .0001$, indicating larger overall amplitudes for emotional (i.e., pleasant and unpleasant) images compared to neutral images (Ms = 4.47 and 1.69 μV, respectively); and a Paradigm x Valence interaction, $F(4, 1528) = 75.83$, $p < .0001$. To test the hypothesis that a negativity bias is more likely in the oddball compared to the random and blocked paradigms, this interaction was further explored through the use of planned contrasts testing for significant differences between the affiliative and threatening images within each paradigm. In the oddball paradigm, threatening images ($M = 9.25$ μV) elicited somewhat larger amplitude than affiliative images ($M = 8.90$ μV), but this difference was not reliable, $t(1475) = 1.45$, $p > 0.10$, $d = 0.09$. There was no evidence of a negativity bias in either of the other paradigms. In the blocked paradigm, affiliative ($M = 2.06$ μV) and threatening images ($M = 2.16$ μV) elicited comparable LPP amplitudes, $t(1475) = 0.40$, $p > 0.10$, $d = 0.04$. Similarly, in the random paradigm the LPPs elicited by affiliative ($M = 2.24$ μV) and threatening images ($M = 2.23$ μV) did not differ, $t(1475) = -0.02$, $p > .10$, $d = 0.00$. Collapsing across paradigms, an overall negativity bias was not apparent in this epoch, as threatening images ($M = 4.55$ μV) elicited comparable activity to affiliative images ($M = 4.40$ μV), $t(1475) = 1.06$, $p > .10$, $d = 0.05$.

Later LPP Window (550-800 ms)

The HLM on the later portion of the LPP revealed a significant effect of Paradigm, *F*(2, 1528) = 400.67, $p < .0001$, indicating larger amplitudes overall in the oddball ($M = 4.88$ μV) compared to the blocked ($M = 1.56$ μV) and random paradigms ($M = 2.09$ μV); a main effect of Valence, *F*(2, 1528) = 117.73, $p < .0001$, indicating larger overall amplitudes for emotional images compared to neutral images (*M*s = 3.40 and 1.73 μV, respectively); and a Paradigm x Valence interaction, *F*(4, 1528) = 59.27, $p < .0001$. As with the early window amplitudes, we tested the hypothesis that a negativity bias would be more likely to emerge within the oddball paradigm than in the blocked or random paradigms by testing for significant differences between the affiliative and threatening images within each paradigm elicited in this later window. A significant negativity bias was apparent in the oddball paradigm, as threatening images elicited greater LPP amplitude ($M = 6.43$ μV) than did affiliative images ($M = 5.96$ μV), *t*(1475) = 2.09, $p < 0.05$, $d = 0.12$. In the blocked paradigm, affiliative images ($M = 2.16$ μV) actually elicited greater amplitudes than did threatening images ($M = 1.44$ μV), *t*(1475) = −3.20, $p < .01$, $d = -0.31$. In the random paradigm the LPPs elicited by affiliative ($M = 2.14$ μV) and threatening images ($M = 2.28$ μV) did not differ, *t*(1475) = −0.63, $p > .10$, $d = -0.06$. Collapsing across paradigms, an overall negativity bias was not evident in this epoch, as threatening images ($M = 3.34$ μV) did not elicit greater LPP than did affiliative images ($M = 3.47$ μV), *t*(1475) = −1.00, $p > 0.10$, $d = -0.04$.

Data from this experiment provided some evidence that a small negativity bias may emerge even when pleasant and unpleasant images are equated on bottom-up motivational significance. This finding has important implications for understanding boundary conditions of the negativity bias in affective picture processing. In particular, it recently was proposed (Weinberg & Hajcak, 2010) that a negativity bias is likely to emerge only when pleasant and unpleasant images are not matched for relevance to essential approach and avoidance drives, what some have called *biological imperatives* (see Franken et al., 2008). The current results suggest that even when pleasant and unpleasant images are equated on that dimension, a negativity bias can still emerge if such images are relatively unpredictable and infrequent. As argued previously, these factors contribute to evaluations of top-down motivational significance, which both amplify the overall strength of the neural signal elicited by affective pictures (as evidenced by the main effect of Paradigm in both LPP epochs) and interact with considerations of bottom-up significance to produce a modest relative increase in aversive activation (see Cacioppo et al., 2011).

If the presence of a negativity bias is indeed dependent upon the interaction of picture contents and picture presentation paradigm, then the magnitude of the bias should increase when thrilling, rather than affiliative, pleasant images are used. Moreover, use of thrilling images should increase the likelihood of observing a bias in the other (blocked and random) paradigms. The purpose of the second experiment was to test these hypotheses, thereby providing additional evidence pertaining to the conditions under which a negativity bias is likely to emerge in the LPP during affective picture processing.

Experiment 2

Participants

Participants were 48 healthy undergraduates ranging in age from 18 to 32 years (*M* = 19.5, *SD* = 2.6). Data from 8 participants were lost when a computer hard drive crashed. Data from 6 additional participants were excluded due to poor recording quality or excessive movement artifact, leaving a final sample of 29 (10 female).

Materials

The neutral and unpleasant images were identical to those used in Experiment 1. The pleasant images depicted thrilling activities involving people (i.e., white-water rafting, ski-jumping, gymnastics, athletes winning medals), 13 of which also were used by Weinberg and Hajcak (2010). Mean ratings of bipolar valence (*M* = 7.25, *SD* = 0.48) and arousal (*M* = 6.07, *SD* = 0.60) for these images were positive and approximated the extremity of valence and arousal of the affiliative images used in Experiment 1. ERP waveforms displaying the LPPs elicited by target images in Experiment 2 are given in Figure 2.

Results and Discussion

The primary hypothesis for this experiment was that, with stimuli not equated for bottom-up motivational significance, a negativity bias would be evident in all paradigms, and that the size of this effect in the oddball paradigm would be larger than that observed in Experiment 1. As in the first experiment, amplitudes from the early and late epochs of the LPP were each submitted to separate 3 (Paradigm) x 3 (Valence) x 3 (Coronal) x 2 (Sagittal) HLMs with a random effect of subject. Effects of interest did not differ across scalp locations.[2] Mean LPP amplitudes as a function of picture valence category, picture presentation paradigm, and epoch for Experiment 2 are given in the lower panel of Table 1.

Early LPP Window (300-550 ms)

The HLM for the early epoch LPP showed a significant main effect of Paradigm; *F*(2, 1484) = 883.53, *p* < .0001, with LPP amplitudes being larger in the oddball paradigm (*M* = 5.79 μV) than in the blocked (*M* = 0.77 μV) and random paradigms (*M* = 0.73 μV); a main effect of Valence, *F*(2, 1484) = 184.59, *p* < .0001, with LPP amplitudes being larger for emotional (i.e., pleasant and unpleasant) images than for neutral images (*M*s = 3.20 and 0.9 μV, respectively); and a Paradigm x Valence interaction, *F*(4, 1484) = 48.86, *p* < .0001. To decompose this complex interaction, planned contrasts were computed comparing the amplitudes elicited by threatening and thrilling stimuli within each paradigm. No evidence for a negativity bias in this early window was found for either the oddball paradigm, *t*(1484) = 0.91, *p* > .20, *d* = 0.05, or the random paradigm, *t*(1484) = −0.33, *p* > .20, *d* = −0.04. Evidence for a modest negativity bias in the early window was seen for the blocked paradigm, though this difference was not reliable, *t*s(1484) = 1.77, *p* < .10, *d* = .18. Collapsing across paradigms, an overall negativity bias was not evident in this epoch, as

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[2] The overall HLM did show significant main effects of Coronal location and Sagittal location, and a significant Paradigm x Sagittal location interaction. However, these effects are irrelevant to the primary hypotheses being investigated here and therefore will not be discussed.

threatening images ($M = 3.29$ μV) elicited similar early LPP amplitudes as did thrilling images ($M = 3.10$ μV), $t(1484) = 1.36$, $p > 0.10$, $d = 0.06$.

Later LPP Window (550-800 ms)

The HLM examining mean amplitudes in the later portion of the LPP showed a significant main effect of Paradigm, $F(2, 1484) = 517.87$, $p < .0001$, indicating that the LPP was larger overall in the oddball ($M = 5.17$ μV) than in the blocked ($M = 1.46$ μV) or random paradigms ($M = 1.94$ μV), and a significant main effect of Valence, $F(2, 1484) = 94.03$, $p < .0001$, indicating larger amplitudes for emotional images than for neutral images (*M*s = 3.30 and 1.97 μV, respectively). A planned contrast comparing LPPs elicited by threatening and thrilling images across presentation paradigms also indicated that threatening images elicited larger LPP ($M = 3.68$ μV) than thrilling images ($M = 2.92$ μV), $t(1484) = 6.07$, $p < 0.0001$, $d = 0.26$. These effects were qualified by a significant Paradigm x Valence interaction, $F(4,1484) = 65.92$, $p < 0.0001$. As before, this interaction was explored through the use of planned contrasts comparing LPP amplitudes elicited by thrilling versus threatening images, separately within each paradigm. These contrasts showed that a negativity bias was evident in all three paradigms during this later epoch. Specifically, in the oddball paradigm, threatening stimuli ($M = 7.06$ μV) elicited larger amplitude than did thrilling stimuli ($M = 5.80$ μV), $t(1484) = 5.83$, $p < 0.0001$, $d = 0.30$. A significant bias also emerged in the blocked condition (*M*s = 1.65 and 1.18 μV for threatening and thrilling images, respectively), $t(1484) = 2.17$, $p < 0.05$, $d = 0.23$. Finally, a significant bias also was apparent in the random paradigm, (*M*s = 2.33 and 1.79 μV for threatening and thrilling images, respectively), $t(1484) = 2.51$, $p < .05$, $d = 0.26$.

Data from this experiment support the thesis that a negativity bias is more likely to be found, regardless of paradigm, when stimuli are matched for valence and arousal but not motivational significance (see Franken et al., 2008; Weinberg & Hajcak, 2010). In particular, studies in which thrilling/adventure or sports-related images comprise the pleasant category seem especially likely to find larger LPP to unpleasant than pleasant images (Ito et al., 1998). Thus, it seems fair to conclude that such images are not as motivationally significant as threatening images or as pleasant-affiliative images, likely because thrilling stimuli do not represent biological imperatives (Franken et al., 2008; Weinberg & Hajcak, 2010).

Despite the fact that unpleasant stimuli elicited larger LPP than pleasant stimuli in the later epoch in each viewing paradigm, the presence of a significant Paradigm x Valence interaction and the general pattern of *d*-scores suggest that the negativity bias remains larger in the oddball paradigm than in the random and blocked viewing paradigms, consistent with one of the main hypotheses of this research. Thus, even when a negativity bias can be attributed primarily to differences in bottom-up motivational significance across the pleasant and unpleasant image categories, a role for top-down factors associated with target infrequency and unpredictability is still apparent. That the bias was primarily apparent in the later LPP epoch is also consistent with this idea, suggesting that the processes responsible for the negativity bias are slower and may be attributable to the *duration* rather than the overall magnitude of attention allocation (see Hajcak & Olvet, 2008).

General Discussion

The current research sought to clarify the nature of the negativity bias in affective picture processing by testing the extent to which the LPP elicited by pleasant and unpleasant images is influenced by both bottom-up and top-down motivational significance, represented here by the contents of pleasant images and variation in picture viewing paradigms, respectively. Findings were largely consistent with the main hypotheses that a negativity bias is more likely to emerge within the context of an oddball paradigm, in which valenced targets are relatively infrequent and unpredictable and required (in the paradigm used here) a behavioral response, than in blocked or random viewing paradigms, and when the specific contents of unpleasant and pleasant images is not equated for relevance to biological imperatives. That the negativity bias was more apparent later in the LPP in both experiments is generally consistent with previous work showing that unpleasant stimuli tend to sustain attention longer than pleasant stimuli, as indexed by the duration of LPP activity (see Hajcak & Olvet, 2008).

The data from Experiment 1 provide evidence of a modest negativity bias, particularly in the later LPP epoch, but only within the oddball paradigm. Although the bias was smaller (and not statistically reliable) in the earlier epoch, the fact that the analysis of the early epoch data showed a significant Paradigm x Valence interaction still supports the general idea that a negativity bias is more likely to emerge in the oddball than in either the random or blocked paradigms. Unexpectedly, data from the blocked paradigm showed a reverse bias (i.e., positivity bias) in the later LPP epoch. While not predicted, this finding is consistent with the general idea that, when affiliative images are used as the pleasant comparison, a negativity bias is unlikely to emerge (Franken et al., 2008; Weinberg & Hajcak, 2010).

When the pleasant and unpleasant picture categories were not matched for depictions of biological imperatives (i.e., Experiment 2), the negativity bias was both more prevalent (i.e., across paradigms) and was larger in the oddball paradigm in comparison with Experiment 1. This finding underscores the significance of this factor in contributing to the presence (or absence) of a negativity bias in the LPP across studies (see Franken et al., 2008; Weinberg & Hajcak, 2010), and more importantly highlights the importance of this factor in determining the activation of the underlying motivational systems thought to contribute to the LPP and to drive approach and avoidance behaviors (see Cacioppo et al., 2011; Cacioppo et al., 1999; Nieuwenhuis et al., 2005). This finding also is consistent with the conclusions of McGraw et al. (2010, Experiment 3), who demonstrated that pleasant and unpleasant images equated on self-report ratings of bipolar valence and arousal can still differ on other psychological dimensions, thereby raising serious questions about reliance on such ratings alone for testing hypotheses about potential similarities and differences in the processing of valenced information.

The fact that LPP amplitudes elicited by all picture types were much larger in the oddball paradigm may contribute to the emergence of a negativity bias by magnifying subtle differences between pleasant and unpleasant categories. That is, an increase in meaningful variation in the oddball paradigm, potentially due to infrequency and unpredictability more effectively engaging top-down attentional mechanisms (see Bradley, 2009), may increase the signal-to-noise ratio, thereby causing small differences to become more apparent and more statistically reliable. This observation is supported by the way the negativity bias diminished as overall LPP amplitude decreased across paradigms. Considering the late epoch data from Experiment 2, LPP amplitudes were greatest overall (M = 5.17 μV), and the difference in amplitude between threatening and thrilling images most apparent (Δ = 1.26 μV), in the oddball task. Overall amplitudes were considerably smaller (M = 1.94 μV) in the random paradigm, as was the magnitude of the amplitude difference between threatening and thrilling images (Δ = 0.54 μV). In the blocked paradigm, amplitudes were smallest overall (M = 1.46 μV), and the negativity bias was also smallest (Δ = 0.47 μV). By enhancing potentially important differences between the pleasant and unpleasant categories, the oddball task permits stronger tests of the negativity bias hypothesis than do other picture viewing paradigms.

Along with other recent reports, the current research suggests that some modification of the general negativity bias framework might be appropriate. In particular, the current results and those of Weinberg and Hajcak (2010) highlight the importance of motivational relevance in determining the strength of neural activation elicited by pleasant and unpleasant images. Although theories of the negativity bias also underscore the importance of the intrinsic relevance of stimuli (Cacioppo, Crites, Gardner, & Berntson, 1994; Crawford & Cacioppo, 2002; Öhman & Mineka, 2001), they generally hold that for any two pleasant and unpleasant stimuli similar in valence extremity and arousal, especially at relatively high levels, the unpleasant stimulus will be more motivationally relevant and, thus, more strongly engage basic motivational drives. (Note, however, that very mild unpleasant stimuli are thought to be less motivationally engaging than mild pleasant stimuli, i.e., the “positivity offset;” see Cacioppo, Gardner, & Bertson, 1997). This postulate appears not to hold in all circumstances, but appears to depend on the extent to which the unpleasant and pleasant stimuli represent biological imperatives (see Franken et al., 2008; Weinberg & Hajcak, 2010; Weinberg et al., 2012). The current results go beyond those of these other recent studies by showing that the specific context in which pleasant and unpleasant images is viewed can determine the extent to which they engage basic motivational systems as reflected in the amplitude of the LPP. Although previous researchers have speculated about this possibility (see Schupp et al., 2000), the current results are the first to empirically demonstrate it by directly comparing effects of different picture viewing paradigms.

Despite the novelty of the current data and their importance for understanding the negativity bias, this study had a number of limitations that should be noted. First, the fact that the oddball paradigm required an evaluative behavioral response (as in similar previous studies; Ito et al., 1998b; Smith, Cacioppo, Larsen, & Chartrand, 2003; Smith et al., 2006; Wood & Kisley, 2006), whereas the other two paradigms did not, introduces some method variance that makes it difficult to directly compare the data across paradigms. It is noteworthy that in at least one previous study (Ito & Cacioppo, 2000), a negativity bias was found (in an oddball task) even though the behavioral response participants made was semantic (“Are people present in the picture?”) rather than evaluative, suggesting the possibility that any behavioral response might increase the odds of a negativity bias emerging. In future studies, researchers should consider eliminating the behavioral response requirement so as to better equate the task demands of various paradigms. Second, given that participants in the current study completed three viewing paradigms, the number of trials within each paradigm was reduced to avoid fatigue. Although at least 24 trials were included in each cell for comparison, more than enough to ensure a stable LPP during affective picture processing (see Moran, Jendrusina, & Moser, 2013), future researchers should consider increasing the number of trials per condition to better represent estimates of neural response across valence categories and viewing paradigms.

In addition to these limitations, it is important to bear in mind that the overall magnitude of the negativity bias seen in the current research was quite modest overall. Use of multilevel modeling arguably allowed us to detect statistically reliable differences in LPP amplitude that would have been classified as nonsignificant using more traditional univariate approaches. Indeed, a recent study by this same research team (Weinberg et al., 2012), in which participants (N = 19) completed an oddball paradigm using affiliative and threatening images, reported no effects of picture valence (pleasant vs. unpleasant) on the amplitude of the LPP elicited by infrequent targets using repeated-measures ANOVA. However, a closer inspection of the data from that study shows that unpleasant targets presented among neutral nontargets (matching the procedure used in the current oddball paradigm) elicited larger LPPs than pleasant targets presented among neutral nontargets across epochs similar to those used here (400-600 and 600-800 ms), and that the magnitude of the unpleasant-pleasant amplitude differences were comparable (Ms = 1.46 and 2.28 μV, respectively) to those seen in the current study. It seems likely that, had those previous data been analyzed using HLM, the conclusions would have supported a negativity bias in that study as well.

In sum, the current research generally supports the idea that a negativity bias in the LPP during affective picture processing is more likely to be found within the context of an oddball paradigm, where emotional pictures are relatively infrequent and unpredictable, compared to viewing paradigms in which these factors do not differentiate valenced from neutral images (e.g., random and blocked designs). This bias is especially likely to emerge when the oddball viewing paradigm is combined with an imbalance in the bottom-up motivational significance of the images representing the pleasant and unpleasant picture categories (e.g., when responses to thrilling pleasant images are compared with responses to threatening unpleasant images). Perhaps more important, by better specifying the conditions under which a negativity bias is likely to emerge, the current results have implications for theories of evaluative processing more generally (e.g., Cacioppo et al., 2009, 2011; Schupp et al., 2004).

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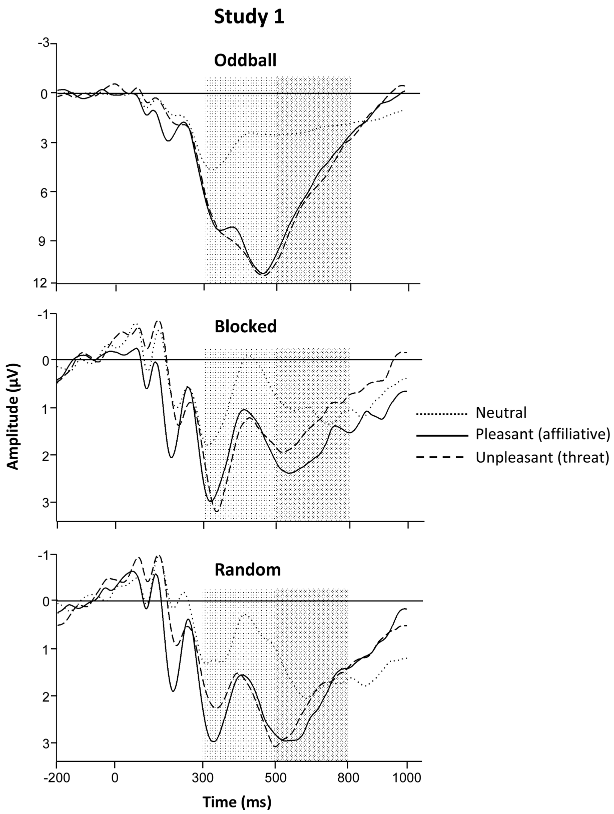

Figure 1.

Grand average waveforms for each picture type in each paradigm in Experiment 1. The shaded areas represent the time windows used for quantification of the LPP (300-550ms and 550-800ms post-stimulus). The waveforms represent a composite of the activity recorded at the six electrodes used in the analysis of mean LPP amplitude (CP3, CPz, CP4, P3, Pz, and P4).

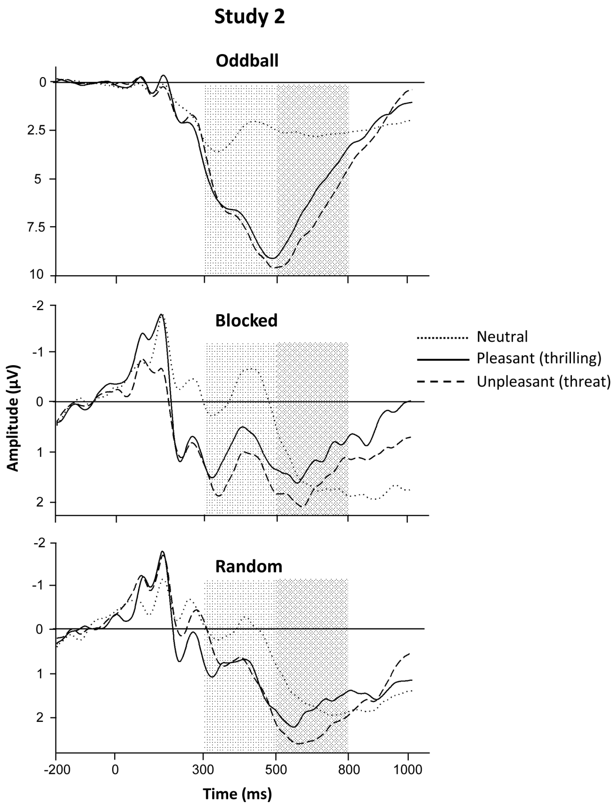

Figure 2.

Grand average waveforms for each picture type in each paradigm in Experiment 2. The shaded areas represent the time windows used for quantification of the LPP (300-550ms and 550-800ms post-stimulus). The waveforms represent a composite of the activity recorded at the six electrodes used in the analysis of mean LPP amplitude (CP3, CPz, CP4, P3, Pz, and P4).

Table 1

Mean LPP Amplitudes (in microvolts) Averaged Across Centro-parietal and Parietal Electrodes for Each Picture Type in Each Paradigm.

	Experiment 1		
Paradigm	Affiliative	Neutral	Threatening
Oddball			
Epoch 1	8.90_a (3.79)	3.35_b (1.87)	9.25_a (3.56)
Epoch 2	5.96_a (3.95)	2.26_b (2.33)	6.43_c (4.08)
Blocked			
Epoch 1	2.06_a (2.37)	0.77_b (2.40)	2.16_a (2.46)
Epoch 2	2.16_a (2.41)	1.06_b (2.09)	1.45_b (2.08)
Random			
Epoch 1	2.24_a (2.53)	0.95_b (2.39)	2.23_a (2.56)
Epoch 2	2.14_a (2.33)	1.86_a (2.32)	2.28_a (1.97)

	Experiment 2		
Paradigm	Thrilling	Neutral	Threatening
Oddball			
Epoch 1	7.23_a (4.34)	2.70_b (1.93)	7.45_a (4.00)
Epoch 2	5.80_a (3.90)	2.66_b (2.14)	7.06_c (4.42)
Blocked			
Epoch 1	1.01_a (2.34)	-0.14_b (2.80)	1.43_a (2.33)
Epoch 2	1.18_a (2.13)	1.56_{ab} (2.34)	1.65_b (1.98)
Random			
Epoch 1	1.07_a (2.07)	0.14_b (1.79)	0.99_a (2.13)
Epoch 2	1.79_a (2.01)	1.69_a (1.90)	2.33_b (2.25)

Note. Numbers in parentheses are standard deviations. Within each row, means with different subscripts differ at $p < .05$.