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Nonemotional features suppress early and enhance late emotional electrocortical responses to negative pictures☆

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ABSTRACT

Neural processing of emotional pictures is often indexed by two electrocortical responses: the early posterior negativity (EPN) and the late positive potential (LPP). Because emotional pictures vary in nonemotional features (e.g., composition, human content, and spatial frequency), researchers often match pictures on nonemotional features to avoid their confounding effects on the EPN and LPP. However, this matching is tedious and might be unnecessary if the confounding effects could be shown to be negligible. In an item-analysis of mean amplitudes to 400 negative to neutral pictures from the International Affective Picture System (IAPS), nonemotional features had larger effects on EPN than LPP. Picture composition suppressed the relationship between emotion and EPN. Further, data simulations showed that for small picture sets, nonemotional features inflated the correlation between emotion and LPP. Therefore, nonemotional features suppress the EPN and enhance the LPP, particularly so in small picture sets.

1. Introduction

Research on event-related potentials (ERPs) to emotional pictures has found two peaks that appear to code emotional value for both positive and negative valence along the visual processing stream (Olofsson et al., 2008). Specifically, when ERPs to emotional pictures are subtracted from those to neutral pictures, an early posterior negativity (EPN) and a late positive potential (LPP) are commonly observed (Schupp et al., 2006). Both peaks can also be obtained by emotional words (Kissler et al., 2009; Schacht and Sommer, 2009). The EPN refers to a bilateral temporal-occipital negativity about 200 ms after picture onset. Source localization studies suggest that potential sources reside in the occipital cortex with parietal contributions (Junghöfer et al., 2001). Although the EPN to pictures appears superimposed on the N1 in several studies (Junghöfer et al., 2001; Keil et al., 2001), it can also occur later than the N1 (Foti et al., 2009; Schupp et al., 2003b). Because the topography and timing is similar to the selection negativity in studies of directed attention (Codispoti et al., 2006), the EPN may reflect a call for attentional resources that is triggered by emotional stimuli because of their intrinsic relevance for the organism (motivated attention, Schupp et al., 2006).

The LPP is a central-parietal positivity about 300 ms after picture onset (Cuthbert et al., 2000; Palomba et al., 1997). Research emphasizes that the traditional P300 or P3b peak (Bashore and Van Der Molen, 1991; Sutton et al., 1965) is similar to the LPP in that both index the allocation of attentional resources to salient events (Bradley, 2009; Hajcak et al., 2010; Olofsson et al., 2008). Traditionally, the term P300 refers to the ERPs that are elicited by top-down, explicit attention to neutral stimuli, whereas the term LPP refers to ERPs that are elicited by bottom-up, motivated attention to emotional stimuli (Ferrari et al., 2008). The LPP is associated with activations in lateral occipital, inferotemporal, and parietal visual areas (Sabatinelli et al., 2007). Although the LPP can last several seconds, research suggests that later slow wave responses represent processes different from the initial response around 300 ms (Foti et al., 2009). The LPP has been used to index attentional processes in aging (Kisley et al., 2007), spider phobia (Leutgeb et al., 2009; Norberg et al., 2010), drug abuse (Franken et al., 2008), and emotion regulation (Hajcak et al., 2010).

Emotional pictures often differ from neutral pictures not only on emotional variables (e.g., valence and arousal) but also on many other features such as spatial frequency (Delplanque et al., 2007) and human content (Colden et al., 2008). These features may not carry any emotional information yet influence and, thus, confound emotional responses. To reduce or eliminate these potential confounds, many previous studies have either matched emotional and

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neutral pictures on nonemotional features or compared responses between different participant groups (e.g., phobics vs. controls). Although picture matching is a valid strategy, it seems tedious, particularly so because people respond emotionally to a wide variety of visual stimuli that vary greatly on many nonemotional features and, thus, seem difficult to match. In fact, strong emotions can be elicited by pictures of sporting events, traffic accidents, erotic scenes, hospital scenes, landscapes, and action scenes (Britton et al., 2006; Lang and Bradley, 2010). Clearly, studies that sample broadly from these real-life situations enhance the ecological and external validity of their results.

So, although emotion shows effects on EPN and LPP when pictures are matched on nonemotional features, it is unresolved how large the confounding effects of nonemotional features are on EPN and LPP if emotional pictures are not matched for nonemotional features. In other words, if it could be shown that the confounding effects of nonemotional features are small or average out relative to effects of emotion, such results would suggest that it may be unnecessary to match pictures on nonemotional features.

Because no prior study has addressed this question (Olofsson et al., 2008), we selected 400 pictures in the range of neutral to negative valence from the International Affective Picture System (IAPS) that is a cross-culturally validated set of emotional and neutral pictures from various contexts and currently contains more than 1000 pictures (Lang et al., 2008). Although the IAPS is used in many ERP studies (Olofsson et al., 2008), the IAPS pictures vary substantially in many nonemotional features (Colden et al., 2008; Delplanque et al., 2007). For each picture, we determined the following nonemotional features:

- Picture composition: In a study by Bradley et al. (2007), ERPs to pictures with clear figure-ground organization (simple composition) were compared with ERPs to pictures with scenes (complex composition). The LPP to emotional (vs. neutral) pictures was relatively unaffected by composition. In contrast, the ERPs between 150 and 300 ms were strongly affected by composition: scenes elicited a stronger posterior positivity than did figure-ground compositions. Although no reliable EPN was obtained, effects of composition overlapped in time and location with those typically reported for the EPN (Schupp et al., 2006). These findings suggest that composition might confound EPN results obtained with IAPS. In fact, a recent study found a reverse EPN in that ERPs were more negative for neutral than negative IAPS pictures (Van Strien et al., 2009). To explain this reverse EPN, the authors argued that picture composition confounded their EPN results because negative pictures were more complex than neutral pictures and, thus, elicited a posterior positivity that suppressed the EPN.
- Human content: Colden et al. (2008) classified IAPS pictures as to whether they depicted something inanimate (i.e., objects), animal nonfaces, animal faces, human nonfaces, and human faces. Results showed that low-arousing, neutral pictures contained mainly objects, whereas high-arousing, emotional pictures contained mainly human faces and nonfaces. Although potentially confounding effects of content have yet to be determined, an effect on EPN might be predicted: faces elicit an N170 (Bentin et al., 1996), and this peak overlaps temporally and spatially with the EPN. Therefore, an apparent EPN to emotional versus neutral pictures might be enhanced by a greater proportion of faces in emotional than neutral pictures.
- Spatial frequency: As discussed by Delplanque et al. (2007), typical picture selections from the IAPS show clear differences in spatial frequency. For example, selections of pleasant and unpleasant pictures that were matched on arousal had more energy in all frequency bands than did neutral, low-arousing pictures. Therefore, confounding effects of spatial frequency on emotional ERPs cannot be ruled out (Boeschoten et al., 2005). Notably, the present question is whether energy in low and high spatial frequency bands per se affects EPN and LPP rather than whether effects of emotional content differ for different spatial frequencies. To illustrate, effects of emotional content for low frequencies would be studied with low-pass filtered emotional and neutral pictures that have identical energy in the low frequency bands (Alorda et al., 2007; Carretié et al., 2007; Pourtois et al., 2005).
- Luminance and contrast: In ERP studies, prime candidates for low-level confounds are luminance and contrast (Luck, 2005), but potentially confounding effects on emotional ERPs are unresolved.

In the present study, participants viewed IAPS pictures and rated the emotionality of each picture while ERPs were recorded. Data were aggregated over individual pictures to perform an item analysis over pictures. Multiple regression analyses with simultaneous and hierarchical models served to assess the independent or unique contributions (direct effects) of emotion and nonemotional features on EPN and LPP mean amplitudes. Subsequent mediation analyses served to determine whether correlations of emotion with EPN and LPP were mediated by nonemotional features (indirect effects of emotion). Because emotion studies commonly use fewer than 400 pictures, we also performed data simulations to determine whether stronger confounding effects of nonemotional features can be anticipated in studies with small picture sets, as might be expected because of greater random variation.

2. Method

2.1. Participants

Forty-three students (30 women) with a mean age of 24.0 (age range: 19–37 years) were recruited from Stockholm University and Karolinska Institute as part of another study on the effects of a low dose of a benzodiazepine on emotional memory (Olofsson et al., in press). The study used informed consent and was approved by the regional review board. In a double-blind design, 22 participants (15 women) received a pill of 20 mg oxazepam whereas 21 participants (15 women) received placebo. Results reported below were collapsed across treatment groups because treatment had nil effect on ERPs. First, treatment showed no effects in between-subjects ANOVAs on emotional ratings, EPN, and LPP (all $p > .20$, see Olofsson et al., in press). Second, when treatment and the interaction between treatment and emotion were entered as additional predictors in the multiple regression analyses reported below, their effects were negligible ($\beta < .05$, $p > .50$). Third, results for the placebo group by itself were similar to those reported below. Notably, these null findings for benzodiazepine treatment are consistent with reports of effects on emotional processes only on tonic rather than phasic emotional responses (Olofsson et al., in press).

2.2. Materials

We selected 400 negative to neutral pictures from the IAPS set (Lang et al., 2008). Pictures were sampled to have mainly negative valence and high arousal ($n = 200$) or neutral valence and low arousal ($n = 200$). Each participant viewed a pseudo-random selection of 100 negative and 100 neutral pictures; there were 30 selections that were counterbalanced across subjects (for details, see Olofsson et al., in press).

Pictures were shown at a distance of 80 cm on a 21-in. View Sonic P227f cathode ray-tube monitor at a 100-Hz refresh rate with a resolution of 1280 × 1024 pixels. Experiment software was Presentation 10.3 (Neurobehavioral Systems, Inc., Albany, CA).

The electroencephalogram (EEG) was recorded from 128 electrodes with an Active Two Biosemi system (BioSemi, Amsterdam, Netherlands) at 512 Hz with a 104 Hz lowpass filter.

2.3. Procedure

Participants were informed that they would receive either a mild dose of a sedative or placebo. About 1 h after treatment, participants viewed and rated the 200 individual pictures. The order of the 100 negative and 100 neutral pictures was pseudorandom (no more than four consecutive pictures from the same category). In this series, forty checkerboard images were randomly distributed. Because these data are irrelevant here, they are not discussed further. Emotion ratings and EEG were recorded to each picture. The session lasted 25 min.