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Reprint of "Affective picture processing as a function of preceding picture valence: An ERP analysis"

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ABSTRACT

Event-related brain potential (ERP) studies consistently revealed that a relatively early (early posterior negativity; EPN) and a late (late positive potential; LPP) ERP component differentiate between emotional and neutral picture stimuli. Two studies examined the processing of emotional stimuli when preceded either by pleasant, neutral, or unpleasant context images. In both studies, distinct streams of six pictures were shown. In Study 1, hedonic context was alternated randomly across the 180 picture streams. In Study 2, hedonic context sequences were blocked, resulting in 60 preceding sequences of pleasant, neutral, and unpleasant context valence, respectively. The main finding was that the valence of the preceding picture sequence had no significant effect on the emotional modulation of the EPN and LPP components. However, previous results were replicated in that emotional stimulus processing was associated with larger EPN and LPP components as compared to neutral pictures. These findings suggest that the prioritized processing of emotional stimuli is primarily driven by the valence of the current picture.

1. Introduction

In a world where various stimuli compete for attentional resources, the fast and reliable detection of positive and negative reinforcers facilitates adaptive behavior (Lang et al., 1997; Öhman et al., 2000). Thus, functional and evolutionary considerations suggest the preferential processing of emotional cues. Over the past decade, numerous neuroimaging studies have confirmed that emotional cues guide selective visual attention. Functional magnetic resonance imaging (fMRI) revealed increased BOLD (blood oxygen level dependent) signals in associative visual regions (extrastriate, occipito-parietal, and inferior temporal cortex) and subcortical limbic structures when viewing emotionally arousing pictures compared to neutral pictures (e.g., Bradley et al., 2003; Costafreda et al., 2008; Junghöfer et al., 2006; Sabatinelli et al., 2007, 2011). Furthermore, event-related brain potential (ERP) studies revealed the temporal dynamics of emotion processing at the level of distinct processing stages and demonstrated that emotional stimuli receive enhanced processing early in the processing stream (Schupp et al., 2006).

Two ERP components, referred to as early posterior negativity (EPN) and late positive potential (LPP), have consistently been found to be modulated by emotional picture valence. The EPN component is observed as a relative negative difference in processing emotional pictures (pleasant and unpleasant) compared to neutral pictures over temporo-occipital sites in a time window between 150 and 350 ms (e.g., Junghöfer et al., 2001; Schupp et al., 2003, 2006). The late positive potential, measured over centro-parietal regions between 300 and 700 ms, is larger for emotional, compared to neutral, stimuli (e.g., Palomba et al., 1997; Schupp et al., 2000; Sabatinelli et al., 2007). Studies relying on stimuli from the International Affective Picture System (IAPS, Lang et al., 2008) observed that EPN and LPP modulations are most accentuated for pictures depicting evolutionarily relevant stimulus contents, such as reproduction- and defense-related scenes (Schupp et al., 2003, 2006), which also provoke reliable somatic, autonomic and humoral responses (Bradley et al., 2001). Recent research demonstrated the emotional modulation of these ERP components across a broader array of emotional stimuli including emotional facial expressions (Mühlberger et al., 2009; Sato et al., 2001; Schupp et al., 2004; Wieser et al., 2010), emotional words (Kissler et al., 2006), symbolic gestures (Flaisch et al., 2009, 2011), and clashing moral statements (Van Berkum et al., 2009). These findings have been considered from the perspective of 'natural selective attention', which holds that under naturalistic conditions stimulus perception and evaluation are often directed by underlying motivational systems of avoidance and approach (Bradley, 2009; Lang et al., 1997; Schupp et al., 2006).

Previous studies have mostly presented emotional stimuli in temporal isolation and used carefully planned presentation

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schemes to avoid confounds due to sequence effects (Flaisch et al., 2008a,b). However, in the natural environment, stimuli typically do not occur in isolation; instead, emotional stimuli may cluster in time and space. Accordingly, people may encounter congruent streams or contexts of pleasant or unpleasant stimuli. This raises the question of how the repeated engagement of either the appetitive or aversive motivational system affects the processing of individual emotional cues. One recent study addressed this issue by presenting emotional IAPS pictures either in an intermixed fashion or as streams of 8 pictures of the same stimulus type (Pastor et al., 2008). Results indicate that emotional modulation of the LPP and positive slow wave was comparable in both mixed and repeated presentation conditions. On the other hand, research using a modified oddball paradigm suggests that hedonic contexts may indeed modulate affective stimulus processing. For instance, positive and negative personality adjectives elicit larger LPP amplitudes when presented in a sequence of adjectives of opposite valence contexts than same valence contexts (Cacioppo et al., 1993, 1994; Crites et al., 1995). A number of methodological differences may account for the divergent findings obtained in previous studies. For instance, studies differed with regard to the type of emotional stimuli (words vs. pictures) or the duration of stimulus presentation (1.5 vs. 12 s). Further research is thus needed to elucidate the effects of hedonic contexts upon emotional stimulus processing. Accordingly, the present study investigated the processing of emotional pictures presented with the experimental parameters of the modified oddball paradigm.

The main aim of the present studies was to investigate the emotional ERP modulation, indexed by EPN and LPP components, as a function of the valence of preceding images. To this end, stimuli were presented in streams of six pictures, in which a sequence of pleasant, neutral, or unpleasant context pictures preceded pleasant, neutral, or unpleasant target pictures (i.e., same valence context vs. opposite valence context). Studies 1 and 2 differed with respect to the presentation of the hedonic context sequences. In Study 1, picture streams containing different valence contexts alternated randomly (cf. Cacioppo et al., 1993). In Study 2, 60 sequences of each valence context were presented in succession, counterbalancing their order across participants. As a result, both studies allowed a comparison of emotional picture processing in the context of the same, a neutral, or the opposite valence picture sequence. Accordingly, the first aim was to determine whether hedonic context modulates emotion processing indexed by the EPN and LPP component. On the one hand, it has been suggested that the discrimination of emotional and neutral stimuli may represent an obligatory process, which is not modulated by hedonic context (Pastor et al., 2008). On the other hand, previous research revealed hedonic context effects on emotion processing (Cacioppo et al., 1993). Furthermore, several distinct hypotheses may be derived from previous research regarding the interaction of hedonic context and current picture processing. For instance, from an affective priming perspective, congruent valence contexts may facilitate the processing of emotional pictures if they are of the same valence as the hedonic context (cf. Avero and Calvo, 2006). Alternatively, if an emotional picture is incongruent with the hedonic context, it may be particularly salient and accordingly efficient in drawing attentional resources (Cacioppo et al., 1993). Furthermore, repeatedly presenting pictures from the same valence category may lead to sensitization effects, particularly for the processing of unpleasant images, as seen in the EMG corrugator response (Bradley et al., 1996). Accordingly, if the context would modulate processing of current emotional stimuli, the second goal of the study was to reveal the direction of this modulation with respect to the EPN and LPP components (general sensitization vs. facilitation by the same or opposite hedonic context).

2. Methods

2.1. Participants

Participants in Study 1 were seventeen (11 females) students from the University of Greifswald. Participants were between the ages of 19 and 26 years. In Study 2, participants were a second group of seventeen (11 females) students from the University of Greifswald, who were between the ages of 19 and 27 years. All participants received course credit towards their research requirements and provided written informed consent for the protocol, which was approved by the Review Board of the University of Greifswald.

2.2. Stimulus materials and design

Sixty target pictures were taken from the International Affective Picture System (IAPS; see Lang et al., 2008) depicting 20 unpleasant scenes (e.g., spiders, mutilations), 20 pleasant scenes (e.g., attractive infants, opposite sex nudes), and 20 neutral scenes (e.g., neutral faces, household objects).[1] The three categories differed significantly from each other in their normative valence ratings ($M = 7.3$, 4.9, and 2.3 for pleasant, neutral, and unpleasant contents, respectively; scale range: 1–9). Mean arousal levels for both emotional categories were significantly higher than for neutral contents ($M = 5.4$, 2.8, and 6.8 for pleasant, neutral, and unpleasant contents, respectively). These target pictures were the focus of the analysis and were presented embedded in a sequence of context pictures.

A different set of 50 pleasant, 50 neutral, and 50 unpleasant IAPS pictures was selected to create the hedonic contexts. The three context categories differed significantly from each other in their normative valence ratings ($M = 7.2$, 5.4, and 2.5 for pleasant, neutral, and unpleasant contents, respectively). Mean arousal levels for both emotional categories were significantly higher than for neutral contents ($M = 5.3$, 3.4, and 5.8 for pleasant, neutral, and unpleasant contents, respectively).

The pictures were presented in streams of 6 pictures (cf. Cacioppo et al., 1993). Five of the six pictures were drawn from the context picture set. The target picture was drawn from the target picture set and appeared third, fourth, or fifth within the picture stream. Presenting pictures from one of the three valence categories realized the pleasant, neutral, or unpleasant hedonic context. Furthermore, pictures subsequent to target pictures varied in valence to increase the likelihood that participants paid attention to the picture streams (Cacioppo et al., 1993, 1994). A total of 180 distinct picture streams occurred since each stimulus of the target picture set ($N = 60$) was presented within each of the three hedonic context categories ($N = 20$ for each of the nine context by target valence combinations). The participants pressed a button to initiate each of the 180 picture streams. Each picture was displayed for 1.5 s and preceded by a warning dot (.5 s) to ensure that the participants were attending to the screen. After picture offset, participants were asked to rate the valence of the pictures using a three-way response button. The inter-trial interval was 3 s. One stream of 6 pictures served as a practice trial.

Study 1 and Study 2 differed in the arrangement of the hedonic context sequences. In Study 1, picture streams containing pleasant, neutral, or unpleasant context sequences were presented in random order. In Study 2, context picture valence was blocked so that the sixty streams of each context picture valence were presented in succession. This resulted in 3 consecutive experimental blocks, each consisting of 60 picture streams with pleasant, neutral, or unpleasant context sequences, respectively. The order of presentation was counterbalanced across participants in Study 2.

2.3. ERP recordings and analysis

Brain and ocular scalp potential fields were measured with a 129 lead geodesic sensor net, on-line bandpass filtered from 0.1 to 100 Hz, and sampled at 250 Hz using Netstation acquisition software and EGI amplifiers (Electrical Geodesics, Inc., Eugene, OR). Electrode impedance was kept below 30 kΩ, as recommended for this type of amplifier by EGI guidelines. Data were recorded continuously with the vertex sensor as the reference electrode. A 35 Hz digital low pass filter was applied off-line to the continuous EEG data. Single-trial epochs were corrected for vertical and horizontal eye movements (Miller et al., 1988). Data editing and artifact rejection were based on an elaborate method for statistical control of artifacts, specifically tailored for the analyses of dense sensor ERP recordings (Junghöfer et al., 2000). Data were baseline-corrected (100 ms prestimulus) and converted to an average reference. Finally, separate average waveforms were calculated for the 9 experimental cells (*Target Valence* by *Context Valence*) for each sensor and participant. Applying strict artifact criteria, 8.7 (SD = 1.6) and 9.8 (SD = 1.4) trials were used to calculate average waveforms in Study 1 and Study 2, respectively. Trial numbers were not

[1] The IAPS slide numbers were as follows: pleasant – 4670, 4658, 4660, 4690, 4650, 4680, 4651, 4652, 4664, 4659, 2311, 2341, 2165, 2170, 2050, 2080, 2360, 2070, 2340, 2160: neutral – 2850, 2570, 2440, 2480, 2381, 2230, 2210, 2200, 2190, 9070, 7020, 7175, 7235, 7233, 7010, 7030, 7080, 7040, 7002, 7009: unpleasant – 1201, 1120, 1300, 1050, 1930, 3530, 6510, 6260, 6350, 6540, 9405, 3130, 3080, 3110, 3060, 3102, 3053, 3000, 3071, 3010.