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Emotional event-related potentials are reduced if negative pictures presented at fixation are unattended☆

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ABSTRACT

Viewing of emotional pictures elicits two event-related potentials (ERPs) to emotional versus neutral pictures: an early posterior negativity (EPN) and a late positive potential (LPP). Because it is unresolved whether these indexes of emotional processing are reduced to task-irrelevant pictures at fixation, negative and neutral pictures from the International Affective Picture Set (IAPS) were shown at fixation together with 6 letters that surrounded the pictures. In separate tasks, participants were instructed to attend either the pictures or the letters. When the pictures were task relevant, results showed an EPN and LPP. In contrast, when the pictures were task irrelevant, the EPN was eliminated and the LPP reduced. Performance was high in both tasks (hit rates > 87%), but somewhat better when the pictures were relevant. However, analyses showed no relationship between this performance difference and the differences in EPN and LPP between tasks. These results suggest that emotional processing of strong, negative pictures is sensitive to manipulations of attention even if the pictures are shown at fixation.

Emotional pictures guide attention [31], as shown by better performance to emotional than neutral pictures in various tasks [20,22]. However, because attention has limited capacity, emotion needs to guide attention somewhat independently of top-down, directed attention. To study this question, one approach has been to overlay neutral stimuli with task-irrelevant emotional pictures [1,2], or to present series of neutral pictures intermixed with irrelevant emotional pictures [8,27]. Another common approach has been to present task-relevant stimuli at one location together with task-irrelevant emotional pictures at another location. This approach allows one to study whether emotional pictures are processed even at task-irrelevant locations. In a classic fMRI study [30], participants viewed stimuli that consisted of simultaneous pairs of faces and houses: two fearful or neutral faces were shown left and right of fixation and two houses were shown above and below fixation (or vice versa). Participants were instructed to attend either the horizontal or vertical picture pairs. Importantly, results showed greater amygdala activation to fearful than neutral faces even if the faces were unattended. Although these findings suggest that emotion is processed even if it is shown in task-irrelevant locations, subsequent research suggests that these effects can be eliminated if the main task is more demanding [23], consistent with Lavie's load theory [15]. Nonetheless, other fMRI studies with emotional faces or emotional pictures from the International Affective Picture Set (IAPS; e.g., [14]) have confirmed that when the main task is rather simple, irrelevant emotional pictures elicit amygdala activation even if they are shown in the periphery [23,24,28,29].

In contrast, most event-related potential (ERP) studies suggest that electrocortical correlates of emotional processing are eliminated if the irrelevant emotional pictures are shown in the periphery [7,10,12,16]. Viewing of emotional pictures typically elicits two ERP responses: An early posterior negativity (EPN) and a late positive potential (LPP) that index greater attention to emotional than neutral pictures (motivated attention) [6,13,25,26]. The EPN refers to a relative negativity to emotional versus neutral pictures at temporal-occipital sites after about 200 ms, and the LPP refers to a relative positivity to emotional versus neutral pictures at central-parietal sites after about 300 ms. Research found that when the main task was easy and the task-irrelevant emotional pictures were shown in the periphery, the LPP to emotional faces [10,12] and the EPN and LPP to emotional IAPS pictures [7,16] were eliminated.

Although emotional ERPs may be eliminated if the task-irrelevant emotional pictures are shown in the periphery, the same may not be true for pictures at fixation. First, even neutral stimuli act as stronger distracters at fixation than in the periphery [3]. Second, because emotional pictures produce larger EPN and LPP at fixation than in the periphery [7], emotional ERPs to pictures at fixation may be more resistant to manipulations of attention. In support, when fearful and neutral faces were shown at fixation, a greater ERP positivity to attended fearful versus neutral faces after

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160 ms was eliminated only after 220 ms when the faces were unattended; thus, the initial differential response to the fearful faces remained although the faces were unattended [11]. Third, because emotional pictures are more arousing than emotional faces [5] and EPN and LPP correlate positively with arousal [6,26,33], the EPN and LPP to emotional pictures may be more resistant to manipulations of attention than those to emotional faces. Indeed, two recent studies found evidence for enduring LPP to task-irrelevant, negative pictures at fixation [17,19]. In one study [17], mutilated bodies were shown at fixation, and participants performed a matching task on bars on either side of the pictures. The LPP to the mutilation pictures remained significant when participants were instructed that the pictures showed real scenes but not when they were instructed that the pictures showed fictional scenes. In another study of spider fear [19], participants viewed spiders and mushrooms at fixation that were surrounded by a ring of 3 or 6 letters. Participants performed a task on the letter ring and were instructed to ignore the pictures. Nonetheless, spider-fearful participants showed a greater LPP to unattended spiders than mushrooms compared to non-fearful participants.

However, these findings of enduring LPP to emotional pictures at fixation might be limited to particular instructions (e.g., pictures are real scenes [17]) or to spider fear [19]. To study whether task-irrelevant emotional pictures at fixation are processed, participants were shown negative IAPS pictures at fixation and each picture was surrounded by a ring of six letters. To manipulate attention, participants attended either the pictures or the letter ring during different tasks. Both EPN and LPP were recorded because effects of attention might differ for early and late processing. For example, when fearful and neutral faces were unattended, the initial differential ERP response to fearful versus neutral faces was retained but the LPP was eliminated [11].

Participants were 14 university students (7 women) with a mean age of 24 years (range between 18 and 29). They were recruited with ads on departmental bulletin boards and received either movie vouchers or credit. The study was approved by the regional review board and used informed consent.

From the 2008 IAPS [14], 280 pictures without black frames were selected to have mainly negative valence and high arousal (*negative* pictures, $n = 140$) or neutral valence and low arousal (*neutral* pictures, $n = 140$). Thus, the effects of high arousal and negative valence cannot be separated in the current picture set. The picture list can be obtained on request. Mean valence norms (across sex) were 2.55 ($SD = 0.76$) for negative pictures and 5.16 ($SD = 0.60$) for neutral pictures; $p < .001$, $\eta_p^2 = .78$. Mean arousal norms (across sex) were 5.98 ($SD = 0.71$) for negative pictures and 3.42 ($SD = 0.73$) for neutral pictures; $p < .001$, $\eta_p^2 = .76$. An additional 10 negative and 10 neutral pictures were selected for the practice tasks.

Visual stimuli were shown at a distance of 80 cm (chin rest) on a 21-inch 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 IAPS pictures were shown in landscape (13.2° × 9.4°), and letters were H, K, M, V, W, and Z as distracters and N as target. Letters were shown in capital bold (max 1.3° wide and 1.2° tall). The letters bordered the pictures and their middle positions fell on a frame of 15.0° × 10.7°.

The electroencephalogram (EEG) was recorded from 128 electrodes according to the ABC system (i.e., electrodes are arranged in circles with different radii from the vertex) with an Active Two Biosemi system (BioSemi, Amsterdam, Netherlands) at 512 Hz. The data were only filtered with a built-in low-pass filter at 104 Hz and an offline notch filter at 50 Hz.

Each trial comprised a picture of a small circle (1500 ms), a fixation cross (1000–1200 ms), the picture stimulus (200 ms), and a blank screen (1300 ms). The purpose of the small circle was to signal to the participants to blink (if necessary) and, thus, to avoid artifacts from eye blinks during the picture stimulus. The duration of the fixation cross was randomized on each trial to be 1000, 1100, or 1200 ms. The picture stimulus consisted of an IAPS picture at fixation and six letters around the picture. Two letters each were shown above and below the picture, and one letter each was shown left and right of the picture. On most trials, the letters were H, K, M, V, W, and Z, and their positions were random on each trial. The picture and letters were shown only for 200 ms to reduce risks for saccades.

Participants performed two tasks on separate blocks; task order was counterbalanced across participants. In the *picture task*, participants were instructed to push the space key if the picture was the same as that on the previous trial. They were further informed that they could ignore the letter ring and that the letter ring would never include N. In the *letter task*, participants were instructed that on most trials, the picture stimulus would include six different letters whereas on some trials, five of the six letters would be replaced by N. Their task was to push the space key if the letter N was shown. Participants were further told to ignore the pictures during this task. For both tasks, participants were instructed to keep their gaze on the center of the screen (i.e., position of fixation cross) throughout the task and to respond as quickly as possible while minimizing errors.

For each participant, half of the 140 negative and half of the 140 neutral IAPS pictures were assigned randomly to each task. Each task comprised 140 trials with the 70 negative and the 70 neutral pictures. Of the 70 trials for each emotion, 14 (20%) were target trials and required participants to push the space key. The remaining 56 (80%) were non-target trials and were identical on both tasks. So, on these non-target trials in both tasks, a negative or neutral picture was shown surrounded by six distracter letters, and no button press was required.

To familiarize participants with the tasks, participants completed 20 practice trials before each task with pictures different from those used in the actual task. The same pictures were used in both practice tasks.

The software BESA (version 5.3, MEGIS Software GmbH, Gräfelfing, Germany, www.BESA.de) was used for offline processing. Noisy electrodes (maximum of 2 for 6 participants) were interpolated with spherical splines. Eye blinks were corrected with a built-in algorithm (15 surrogate brain sources). To reduce confounding effects from motor responses, only non-target trials without button presses were analyzed. Epochs ranged from 100 ms before to 1000 ms after stimulus onset. Participants had more than 80% artifact-free trials. Epochs were baseline corrected (100 ms) and re-referenced to the linked electrodes D32 and B10 (see www.biosemi.com/headcap.htm). These electrodes are closest to the mastoids, which are commonly used as reference electrodes [21].

Across participants, the ERP difference waves to negative minus neutral pictures were used to identify, through visual inspection, electrode clusters and intervals that corresponded to the EPN and LPP. In these analyses, the difference waves between negative and neutral pictures were collapsed across tasks to detect the main effect of emotion (i.e., negative minus neutral). Across tasks, the EPN was evident between 230 and 300 ms across 6 electrodes (A13, A14, and A24–A27; these correspond to the area at and slightly above O9, Iz, and O10), and the LPP was evident between 400 and 1000 ms across 22 electrodes (A02–A08, A17–A21, A30–A32, B02–B05, B19, and D16–D17; these correspond to the area between Cz, P3, POz, and P4). Fig. 1 shows the mean ERP waves for negative and neutral pictures during each task across the relevant electrodes for EPN and LPP. Also, the insets in Fig. 1 show, for each task, the scalp topographies of negative minus neutral mean amplitudes across the relevant intervals for EPN and LPP.