Peripheral vision and preferential emotion processing

Andrea De Cesarei[a], Maurizio Codispoti[a] and Harald T. Schupp[b]

This study investigated the preferential processing of emotional scenes, which were presented in the periphery of the visual field. Building on well-established affective modulations of event-related potentials, which were observed for foveal stimuli, emotional and neutral images were presented at several locations in the visual field, while participants either viewed the pictures or were engaged by a distractor task. The findings clearly show that emotional processing varied with picture eccentricity, with emotional effects being maximal in the center and absent in the far periphery. Moreover, near-peripheral emotional stimuli modulated event-related potentials only when participants were passively viewing them. These results suggest that perceptual processing resources are needed for identification and emotional processing of peripheral stimuli. ***NeuroReport*** **20:1439–1443 © 2009 Wolters Kluwer Health | Lippincott Williams & Wilkins.**

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[a]Department of Psychology, University of Bologna, Bologna, Italy and [b]Department of Psychology, University of Konstanz, Konstanz, Germany

Correspondence to Dr Andrea De Cesarei, Department of Psychology, University of Bologna, Viale Berti Pichat 5, Bologna 40128, Italy
Tel: +39 051 2091460; fax: +39 051 243086; e-mail: andrea.decesarei@unibo.it

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Introduction

The preferential processing of high-priority stimuli is an essential function of selective attention [1–4]. Studies investigating event-related potentials (ERPs) in response to pleasant, neutral, and unpleasant pictures are particularly informative with regard to the temporal dynamics of emotion processing. Among the ERP components modulated by picture emotionality is a late positive potential (LPP) measured over centro-parietal scalp regions that is enhanced when viewing emotionally arousing compared with neutral pictures [5,6]. Picture emotionality is also reflected in a negative ERP difference between emotional (pleasant and unpleasant) and neutral stimuli, which is observed in an earlier time window (approximately 150–300 ms) over occipito-temporal scalp regions [5,6]. The selective processing of pleasant and unpleasant cues has been suggested to reflect the inherent salience of life-threatening or life-sustaining stimuli [1,4].

Building on the preferential processing of affective stimuli, previous studies explored emotional processing under challenging conditions. Presenting unmasked emotional pictures as short as 24 ms was sufficient to elicit early and late ERP modulations, whereas in the presence of a masking pattern a longer exposure time (approximately 80 ms) was necessary to achieve affective ERP modulation [7,8] and stimulus identification [9]. Furthermore, a reduction in picture size was shown to dampen early, but not late, emotional ERP modulation [10]. Overall, these studies suggest a remarkable efficiency for the decoding of emotional stimuli and specify boundary conditions. However, under natural conditions, emotionally significant stimuli may often arise in the peripheral visual field, rather than in the fovea. Here we investigate whether the position of an emotional picture in the visual field, whether central or peripheral, is reflected in affective modulation of early and late ERPs.

In addition, we investigate the effects of task set on peripheral emotion processing. Varying processing demands of a distractor task, previous studies showed that the preferential processing of emotional pictures is influenced by the availability of processing resources [11,12]. Extending these findings, we examined whether the effects of task set on emotion processing vary for pictures presented at central or peripheral locations.

Methods

Participants

Thirty-two students (16 females, mean age = 25.33, SD = 4.46) from the University of Konstanz participated in the study for either course credits or money reward. The study was approved by the local ethical committee, and participants signed an informed consent form. Half of participants (eight females) passively viewed the pictures, while the remaining 16 participants performed an active discrimination task.

Stimulus materials and procedure

Two hundred and sixteen pictures were chosen from the IAPS [13], depicting pleasant (e.g. erotica, sports), unpleasant (threat, mutilations) and neutral (people in neutral contexts, household objects) contents. In data analysis, household objects were not included to avoid confounds with features specific to this particular picture category (e.g. reduced perceptual complexity, nonliving items) and to focus on biologically relevant stimuli [14]. Pictures were selected to vary according to normative ratings (valence mean = 6.9, 5.0, and 2.3; arousal mean = 6.2, 3.3, and 6.3, for pleasant, neutral, and unpleasant images, respectively).

In each trial, a picture measuring 7.67 (horizontal) × 5.95° (vertical) was presented either 16.4° left of the monitor center (far left, 16.5% of trials), 8.2° left (near left, 16.5%

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of trials), 0° (center, 33% of trials), 8.2° right (near right, 16.5% of trials), or 16.4° right of the center (far right, 16.5% of trials). Distances are taken from the center of the monitor to the horizontal center of the picture. Together with the picture, a gray box subtending 8.8 (horizontal) × 6.9° (vertical) was presented in the center of the screen. The box was either closed or could contain a gap in the middle upper or lower side, measuring 0.6°. Participants in the active task condition were asked to indicate, as fast and as accurate as possible, whether the box contained a gap or not. Response hand was balanced across participants. Participants were told that the picture presented with the box was irrelevant to the task.

Each trial began with a blank screen lasting 1 s. Then, the picture was presented for 24 ms, followed by a black screen, which lasted on average 1.25 s before the next trial began. The experiment consisted of 1296 trials, delivered in four blocks, which were separated by a short break.

Apparatus and data analysis

Brain activity was measured using a 256 channels sensor net (EGI, Eugene, Oregon, USA). Signal was online referenced to the vertex sensor and sampled at 250 Hz, with high-pass and low-pass filters set at 0.1 and 100 Hz. Off-line analyses were performed using EMEGS [15] and included low-pass filtering at 30 Hz, artifact detection, sensor interpolation, baseline correction (100 ms), and conversion to an average reference. Time windows and scalp regions of interest were determined for emotion sensitive ERP components based on previous research and visual inspection. The early ERP component was scored between 200 and 280 ms at occipito-temporal sensors (left: 93–95, 102–107, 112–117, 121–126, 134–137, 146, 147; center: 138, 148; right: 139, 149–151, 157–161, 166–171, 175–179, 188–191, 200, 201, 209). The late ERP component was scored as mean activity between 400 and 800 ms at centro-parietal sensors (left: 9, 17, 42–44, 51, 52, 59, 78, 79, 88; center: 8, 80, 89, 100, 257; right: 131–133, 144, 145, 185–187, 198, 199).

Accuracy and latency of behavioral response were measured in the active task condition. To correct for very fast or slow responses, response times within each participant and condition were analyzed using the median as index of central tendency.

Data were submitted to repeated measures analyses of variances (ANOVA) including the factor valence (pleasant, neutral, unpleasant) and position (far left, near left, central, near right, far right). Quadratic contrasts were carried out to characterize significant effects of valence (pleasant > neutral < unpleasant) and position (far left < near left < center > near right > far right). A Huynh–Feldt correction was applied to the degrees of freedom when appropriate.

Results

Early emotional event-related potential modulation (200–280 ms)

A significant main effect of picture valence was observed, $F(2,30) = 5.72$, $P < 0.01$, $\eta_p^2 = 0.28$. The early positivity was smaller for pleasant and unpleasant compared with neutral pictures, that is, a negative ERP difference to emotional stimuli (Fig. 1), $F_{quad}(1,15) = 6.88$, $P < 0.05$, $\eta_p^2 = 0.32$. However, this effect was qualified by a significant quadratic interaction of valence by position, $F_{quad}(1,15) = 9.9$, $P < 0.01$, $\eta_p^2 = 0.40$. Separate follow-up tests for each of the five locations revealed significant emotional modulation at the central and near-left position, main effect valence $F(2,30) = 10.21$ and 5.2, all $Ps < 0.05$, $\eta_p^2s = 0.41$ and 0.26, $F_{quad}(1,15) = 11.99$ and 6.7, all $Ps < 0.01$, $\eta_p^2s = 0.44$ and 0.31, and a close to significant effect at near-right location, $F(2,30) = 3.33$, $P = 0.06$, $\eta_p^2 = 0.18$, $F_{quad}(1,15) = 4.07$, $P = 0.06$, $\eta_p^2 = 0.21$. In contrast, no reliable emotional modulation was seen at far-lateral locations. Furthermore, a significant effect of position was observed, $F(4,60) = 30.81$, $P < 0.001$, $\eta_p^2 = 0.67$, indicating that early ERP positivity was reduced by picture eccentricity, $F_{quad}(1,15) = 54.47$, $P < 0.001$, $\eta_p^2 = 0.78$.

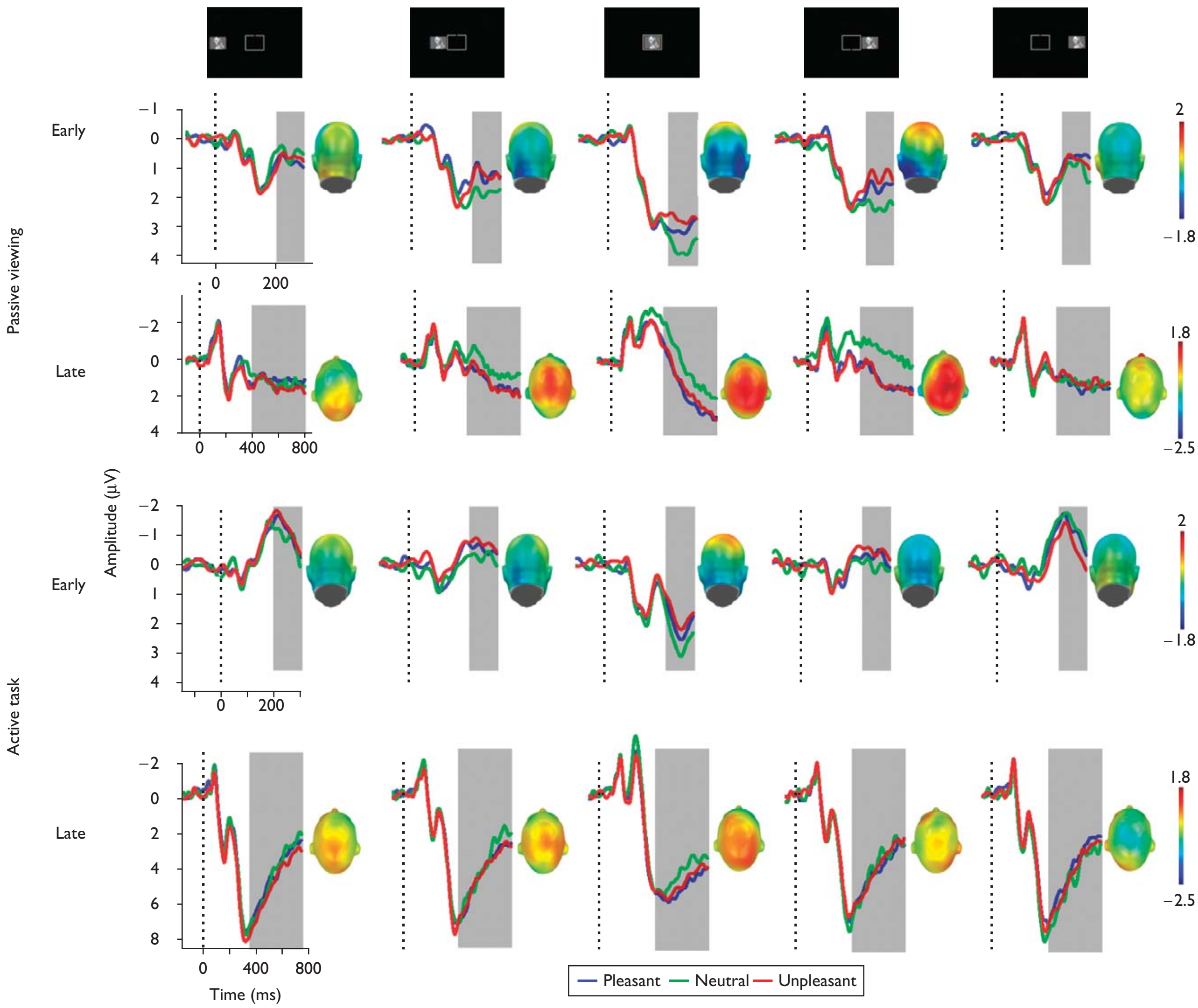
Similar effects were observed while participants performed the active task condition. The main difference to the passive viewing condition was that significant effects of valence were only observed for central stimuli, valence $F(2,30) = 9.69$, $P < 0.01$, $\eta_p^2 = 0.39$, $F_{quad}(1,15) = 12.9$, $P < 0.01$, $\eta_p^2 = 0.46$. Similar to the passive viewing condition, positivity of early ERP was reduced by picture eccentricity, position $F(4,60) = 35.55$, $P < 0.001$, $\eta_p^2 = 0.7$, $F_{quad}(1,15) = 51.62$, $P < 0.001$, $\eta_p^2 = 0.78$, and by picture valence, $F(2,30) = 5.84$, $P < 0.01$, $\eta_p^2 = 0.28$, $F_{quad}(1,15) = 8.45$, $P < 0.05$, $\eta_p^2 = 0.36$, and these effects were qualified by a significant quadratic interaction of valence by position, $F_{quad}(1,15) = 7.73$, $P < 0.05$, $\eta_p^2 = 0.34$.

A between-conditions comparison indicated a more negative ERP between 200 and 280 ms in the active task compared with the passive viewing condition, $F(1,30) = 9.8$, $P < 0.01$, $\eta_p^2 = 0.25$. No other main effects or interaction reached significance.

Late emotional event-related potential modulation (400–800 ms)

Pleasant and unpleasant as compared with neutral pictures elicited a more positive LPP amplitude (Fig. 1), $F(4,60) = 9.22$, $P < 0.001$, $\eta_p^2 = 0.38$, $F_{quad}(1,15) = 14.16$, $P < 0.01$, $\eta_p^2 = 0.49$. However, this effect was qualified by a significant quadratic interaction of valence by position, $F_{quad}(1,15) = 17.9$, $P < 0.001$, $\eta_p^2 = 0.54$. Follow-up tests indicate a significant emotional modulation at the central, near-left, and near-right positions, main effect valence $F(2,30) > 4.56$, $P < 0.05$, η_p^2 values > 0.23, $Fs_{quad}(1,15) > 9.8$, $P < 0.01$, $\eta_p^2 > 0.4$. In contrast, no reliable

Fig. 1



Event-related potential waveforms and topography of the effects of picture valence and eccentricity, in the passive viewing and the active task condition. Waveforms are shown at occipito-temporal (early) and centro-parietal (late) scalp regions. Negative is plotted upwards. Topographies display the arousing-neutral differential, from a back head view (early) and a top head view (late).

emotional modulation was seen at far-lateral locations. Furthermore, a significant effect of position was observed, $F(4,60) = 4.59$, $P < 0.01$, $\eta^2_p = 0.23$, indicating least positive LPP amplitudes for near-lateral pictures.

In the active task condition, similar effects were observed. The main difference to the passive viewing condition was that emotional effects were only observed for central pictures, as indicated by the significant quadratic interaction of valence by position, $F_{quad}(1,15) = 3.32$, $P < 0.05$, $\eta^2_p = 0.37$, and by the effect of valence for central stimuli, $F(2,30) = 5.66$, $P < 0.05$, $\eta^2_p = 0.27$, $F_{quad}(1,15) = 7.36$, $P < 0.05$, $\eta^2_p = 0.33$. No reliable emotional modulation was seen at near or far-lateral locations, and the overall effect of valence failed to reach significance, $F(2,30) = 2.1$, not significant. A significant effect of position was also observed, $F(4,60) = 3.15$, $P < 0.05$, $\eta^2_p = 0.17$, indicating least positive LPP amplitudes for near-lateral stimuli.

A large task-related LPP was observed in the active task compared with the passive viewing, effect condition $F(1,30) = 34.98$, $P < 0.001$, $\eta^2_p = 0.54$. Moreover, affective LPP modulation was attenuated at near-lateral as well as central picture positions during the active task compared with the passive viewing condition. A 3 (position: near-left, central, and near-right) × 3 (valence) × 2 (condition) supports this observation by revealing a significant valence × condition interaction, $F(2,60) = 5.4$, $P < 0.05$, $\eta^2_p = 0.15$.

Behavioral responses

Overall, performance in the gap detection task was good (mean correct responses = 95%, response time = 427 ms). However, position of the pictures modulated response times and accuracy with slower and less accurate responses for central compared with lateral positions, effect position on accuracy $F(4,60) = 5.33$, $P < 0.01$, $\eta_p^2 = 0.26$, $F_{quad}(1,15) = 10.94$, $P < 0.01$, $\eta_p^2 = 0.42$, effect position on response times $F(4,60) = 16.5$, $P < 0.001$, $\eta_p^2 = 0.52$, $F_{quad}(1,15) = 21.1$, $P < 0.001$, $\eta_p^2 = 0.59$.

Discussion

Previous studies revealed the preferential processing of pleasant and unpleasant pictures, shown in the center of the visual field. Here we investigated emotion processing when pictures are presented in the periphery of the visual field. The findings revealed a gradient of emotional processing from the center to the periphery of the visual field: while affective modulation of early and late ERPs was observed up to 8.2° eccentricity, no emotional effects were observed at higher eccentricities. As processing efficacy decreases with increasing eccentricity, stimulus identification seems to be critical for the preferential emotion processing of peripheral stimuli.

A large body of ERP studies revealed that foveally presented affective pictures modulate early and late processing stages, even under challenging conditions such as brief exposure time or small image size [5–8,10,11]. Briefly presenting small pictures, this study fully replicated these findings. Specifically, emotional compared with neutral pictures presented at 0° eccentricity elicited a negative differential ERP over occipito-temporal scalp regions, and a later positive differential LPP over centro-parietal scalp areas. Establishing these findings provided the foundation to investigate the preferential emotional processing of pictures presented in the periphery of the visual field.

The novel finding of this study is that peripheral vision supports preferential emotional processing of natural scenes. While participants fixated the center of the screen, and short exposure times prevented saccadic eye movements, pictures presented at 8.2° eccentricity were associated with early and late emotional ERP modulations. However, no significant ERP affective modulation was observed for pictures presented at 16.4° eccentricity. This pattern of findings presumably reflects a decrease in visual processing efficiency in the peripheral visual field compared with the fovea, which might be due to a decrease in receptor density and contour linking [16]. The present results are at odds with a previous study, which showed that the presentation of natural scenes at 15° supported visual categorization [17]. Specifically, participants could indicate with high accuracy whether a natural scene contained an animal or not. However, detection of a specific target category (e.g. animals vs. all other contents) relies on the matching of a top–down template with bottom–up information, which maximizes the categorization efficiency [18]. In contrast, a top–down template does not usually guide the understanding of natural scenes, and, accordingly, content identification may require a greater amount of processing to be achieved. In addition, efficient categorization of peripheral stimuli was demonstrated using pictures, which were almost three times larger than in this study [17]. As stimulus size seems critical for recognizing peripheral pictures [19], future studies should explore the preferential emotion processing in the periphery at various picture sizes.

The finding that peripheral pictures supported preferential emotion processing was further assessed in an active task context. While passive viewing allows revealing the spontaneous nature of the preferential processing of emotional pictures, an explicit distractor task introduced an explicit processing goal, taxed perceptual resources, and assured that attention was focused at central locations. Results clearly showed that ERP affective modulation to stimuli presented up to 8.2° eccentricity was reduced compared with the passive viewing condition. These results are consistent with previous studies suggesting that a demanding visual distractor task may interfere with preferential emotion processing [11,12], and extend them by showing that, under more demanding conditions, emotional processing was limited to the center of the visual field.

Conclusion

In this study, affective ERP modulation in response to emotional pictures was reduced by picture eccentricity, and no effects were observed for far-peripheral pictures. Moreover, near-peripheral emotional pictures modulated brain activity only when participants were passively viewing the pictures. These findings suggest that emotional response to peripheral stimuli relies on the availability of processing resources, which allow to identify picture contents and to engage motivational systems.

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