



Sensitivity to emotional scene content outside the focus of attention



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ABSTRACT

We investigated whether the emotional content of visual scenes depicting people is processed in peripheral vision. Emotional or neutral scene photographs were paired with a matched scrambled image for 150 ms in peripheral vision ($\geq 5^\circ$). The pictures were immediately followed by a digit or letter in a discrimination task. Interference (i.e., slowed reaction times) with performance in this task indexed the processing resources drawn by the pictures. Twelve types of specific emotional scene contents (e.g., erotica or mutilation) were compared. Results showed, first, that emotional scenes caused greater interference than neutral scenes, in the absence of fixations. This suggests that emotional scenes are processed and draw covert attention outside the focus of overt attention. Second, interference was similar for female and male participants with pleasant scenes (except for erotica), but females were more affected by all types of unpleasant scenes than males. This reveals that sensitivity to peripheral vision is modulated by sex and affective valence. Third, low-level image properties, visual saliency, and size of bodies and faces, were generally equivalent for emotional and neutral scenes. This rules out the alternative hypothesis of a contribution of non-emotional, purely perceptual factors.

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1. Introduction

Most visual stimuli in natural environments and social settings appear for an observer beyond the foveal and parafoveal boundaries of the retina ($\sim 5^\circ$ away from fixation), where the object details fade out (see Wandell, 1995). This implies that most visual stimuli occur outside the current focus of overt spatial attention. To overcome these biological constraints, the visual system relies on saccades to bring peripheral stimuli into the fovea. Given the adaptive importance of emotional stimuli—as related to well-being and survival—it is, however, possible that sensitivity to affective visual cues in the visual periphery is enhanced. This would facilitate early detection of potential benefit and harm cues prior to eye fixations, and also ensure selective gathering of important information for further analysis, in the service of increasing adaptive function. To address this issue, we investigated whether emotional visual scenes have a processing advantage over neutral scenes appearing in peripheral vision, in the absence of overt attention; and whether sensitivity in such conditions depends on type of emotional scene content and sex of the viewer.

1.1. Attention to emotional stimuli in central vision

In most prior research on the processing of emotional pictures,¹ they were presented in central vision. In such conditions, emotional stimuli typically receive heightened attention in the cognitive and neural systems, relative to neutral stimuli (see Bradley, Keil & Lang, 2012; Carretié, 2014; Domínguez-Borrás & Vuilleumier, 2013; Lang & Bradley, 2010; Mohanty & Sussman, 2013; Pessoa, Oliveira & Pereira, 2013). First, significant differences between pleasant and unpleasant scenes, as well as among various specific emotional scene contents (e.g., erotica, romance, human attack, and accidents), have been found in valence (pleasantness–unpleasantness) and arousal (calm–tension) ratings (see Bradley & Lang, 2007; Calvo & Avero, 2009; Gomez, von Gunten & Danuser, 2013; Moltó et al., 2013), psychophysiological measures (e.g., skin conductance, startle reflex, facial corrugator activity; Bradley, Codispoti, Cuthbert & Lang, 2001a; Schupp et al., 2004), and brain activity (ERPs, event-related potentials: Briggs & Martin, 2009; Keil et al., 2009; Schupp et al., 2004; Weinberg & Hajcak, 2010; fMRI, functional-magnetic-resonance imaging: Sabatinelli, Bradley, Fitzsimmons & Lang, 2005; Sabatinelli, Bradley, Lang, Costa & Versace,

¹ In prior research, the attentional processing of two main types of emotional pictures, i.e., facial expressions and visual scenes, has been widely investigated. While the former depict single faces, the latter involves more complex images with multiple elements. We chose emotional scenes because they produce stronger subjective experience and ERP responses than facial expressions (Thom et al., 2014), and thus the influence of emotion in peripheral vision should be more easily detected for scenes.

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2007), with erotica and mutilation contents often producing the strongest reactions.

Second, the processing of emotional scenes varies as a function of sex of the viewers. Relative to men, women typically judge unpleasant pictures as more negative (Bradley, Codispoti, Sabatinelli & Lang, 2001b; Calvo & Avero, 2009; Gomez et al., 2013; Moltó et al., 2013), and are more reactive both psychophysiologicaly (Bianchin & Angrilli, 2012; Bradley, Codispoti, et al., 2001b; Gard & Kring, 2007) and neurophysiologicaly (ERPs: Bianchin & Angrilli (2012) and fMRI: Sabatinelli, Flaisch, Bradley, Fitzsimmons & Lang (2004)). In contrast, for pleasant pictures, sex differences are less likely to appear, except for erotic images (couples and opposite-sex erotica), with men being typically more reactive than women (Bradley, Codispoti, et al., 2001b; Gomez et al., 2013; Sabatinelli et al., 2004). Accordingly, sex of the viewer, affective valence, and content specificity produce interactive effects when emotional scenes are available to processing in central vision.

1.2. Attentional capture by emotional visual scenes in extrafoveal vision

Few studies have investigated attention to emotional scenes in extrafoveal vision (generally, $\geq 5^\circ$; see Carretié (2014)). Eye-movement research has found that emotional scenes selectively attract overt attention. When an emotional and a neutral scene are presented simultaneously, the first fixation is more likely to be directed to the emotional image (Alpers, 2008; Calvo & Lang, 2004; Calvo, Nummenmaa & Hyönä, 2008; but see Acunzo & Henderson, 2011), and saccade latencies can be shorter for emotional scenes (Calvo, Nummenmaa & Hyönä, 2007). This reveals selective orienting, and occurs even when viewers are instructed to look first at the neutral picture (Nummenmaa, Hyönä & Calvo, 2006). Relatedly, when viewers are asked to perform a saccade to an exogenous (non-emotional) cue, trajectories deviate towards the emotional scene (McSorley & van Reekum, 2013), and latencies are longer when the image opposite to the instructed direction is emotional (Nummenmaa, Hyönä & Calvo, 2009). Similarly, anti-saccade responses show more errors towards emotional than to neutral images (Kissler & Keil, 2008). ERP studies have also provided relevant evidence. Emotional scenes in the near periphery (8.2° ; but not farther: 16.4°) elicited a negative ERP differential (relative to neutral scenes) over temporo-occipital scalp regions (200–280 ms), and a later positivity over centro-parietal areas (400–800 ms) (De Cesarei, Codispoti & Schupp, 2009). An affective modulation of early ERPs (145 ms) in lateral occipital and infero-temporal cortices has also been reported for emotional pictures at a 30° eccentricity (Rigoulot et al., 2008). Altogether, in the absence of low-level image differences between emotional and neutral scenes, these findings suggest that emotional content is perceived and captures attention extrafoveally.

1.3. The current study: Attentional capture and interference

The current study adds to prior research by extending emotional scene processing from central to peripheral vision. We investigated a logical consequence of the enhanced processing of emotional scenes: If they capture and draw attention, this will interfere with the encoding of concurrent non-emotional stimuli (see Carretié, 2014). To address this issue, a scene (either emotional or neutral; or a meaningless scrambled image with the same low-level image properties) was presented peripherally ($\geq 5^\circ$) or centrally (as a control condition) for 150 ms. This was immediately followed by a digit or letter which participants had to discriminate as even vs. odd, or vowel vs. consonant. Importantly, the scene was task-irrelevant and the digit/letter was task-relevant. Interference with performance in the digit/letter task (i.e., slower discrimination times when the emotional scene was presented, relative to the neutral scene or the scrambled image) indexed the processing resources allocated to the emotional scene. The more it draws attention, the more performance in digit/letter task will be impaired.

The logic of this paradigm relies on the generally accepted premise that attentional processing draws on a limited pool of cognitive resources to be shared with concurrent tasks. As a result, as long as motivationally relevant cues (e.g., emotional scene contents) activate appetitive or aversive reactions or goals, such cues will have priority in recruiting the limited processing resources, and this attentional engagement will result in a reduction of available resources for concurrent stimuli. From a neurophysiological view, this trade-off can be conceptualized as reflecting competition in dedicated neural circuits (Shafer et al., 2012), with motivationally relevant cues having dominance. As a consequence, the processing of concurrent or immediately following motivationally non-relevant cues should be impaired when competing with emotionally significant stimuli (see Bradley et al., 2012; Carretié, 2014).

To determine whether sensitivity to emotional scenes in peripheral vision is modulated by affective valence, scene content, and sex of the viewer, we distinguished 12 specific content categories (e.g., erotica attack) within the pleasant and the unpleasant valence dimensions, and they were presented to young adult females and males. In addition, to explore potential lateralization effects of emotional processing (see Gianotti, 2012), the emotional scenes were displayed in the left or the right visual field. Importantly, to ensure that emotional processing occurred in truly peripheral vision, eye-movements were monitored to identify trials with saccades, and eventually remove them. Furthermore, to rule out alternative, non-emotional explanations of the hypothesized effects of emotional scenes, perceptual factors were controlled (mainly, low-level image properties, visual saliency, and human face and body size).

2. Method

2.1. Participants

Forty-eight undergraduates (24 females; between 20 and 30 years of age) gave informed consent and received course credit or monetary incentive (5 €) for their participation. They were informed in advance that they would be presented with emotional, either pleasant or unpleasant, and non-emotional photographs. The study was approved by the local ethics committee, and was conducted in accordance with the WMA Declaration of Helsinki 2008.

2.2. Stimuli

We used 72 pleasant and 72 unpleasant scene images, and 144 neutral images, all of them in their original, natural colors. To use a homogeneous format, their resolution was adjusted to 700×500 pixels. Most (91.5%) of the emotional stimuli were photographs from the International Affective Picture System (IAPS; Lang, Bradley & Cuthbert, 2008). Within the pleasant dimension, the following six categories of scenes were formed, each containing 12 pictures: babies/families, romance, erotica-female, erotica-male, erotica-couples (heterosexual), and adventure/sports. Pictures showing genitals or sexual intercourse were excluded as they could be regarded as too sexually explicit. Within the unpleasant dimension, the following six categories were established, each containing 12 pictures: accidents, loss/illness, human attack with or without weapons, mutilation, and male-to-female aggression. The IAPS image numbers are shown in the Appendix A.

Our distinction of specific content categories was generally based on those established by prior research (e.g., Bradley, Codispoti, et al., 2001a; see above). Bernat, Patrick, Benning, and Tellegen (2006) have underscored the importance of classifying emotional pictures of different types into meaningful content categories, to determine the possible content specificity of emotional processing. All our scene stimuli depicted people, in order to keep some homogeneity across the variety of contents. By using people scenes, we also aimed to enhance emotional perception and reaction (Thom et al., 2014). Various studies have

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