Biological Psychology 119 (2016) 91–100

Contents lists available at ScienceDirect

Biological Psychology

journal homepage: www.elsevier.com/locate/biopsycho

Explicit and implicit emotional processing in peripheral vision: A saccadic choice paradigm

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ARTICLE INFO

Article history:
Received 22 October 2015
Received in revised form 12 July 2016
Accepted 12 July 2016
Available online 14 July 2016

Keywords:
Peripheral vision
Eye movement
Emotion
Visual scenes
International affective picture system

ABSTRACT

We investigated explicit and implicit emotional processing in peripheral vision using saccadic choice tasks. Emotional-neutral pairs of scenes were presented peripherally either at 10, 30 or 60° away from fixation. The participants had to make a saccadic eye movement to the target scene: emotional vs neutral in the explicit task, and oval vs rectangular in the implicit task. In the explicit task, pleasant scenes were reliably categorized as emotional up to 60° while performance for unpleasant scenes decreased between 10° and 30° and did not differ from chance at 60°. Categorization of neutral scenes did not differ from chance. Performance in the implicit task was significantly better for emotional targets than for neutral targets at 10° and this beneficial effect of emotion persisted only for pleasant scenes at 30°. Thus, these findings show that explicit and implicit emotional processing in peripheral vision depends on eccentricity and valence of stimuli.

1. Introduction

Sensory systems are constrained by their limited capacity of processing while they have to deal with an enormous flow of stimuli. Among the different brain mechanisms allowing to cope with these limitations, emotional processes are critical, by enabling prioritization of affective stimuli over neutral cues in order to react adaptively to potentially advantageous or harmful stimuli. Indeed, converging evidence suggests that emotional information captures attentional resources and disrupts ongoing goal-oriented processing (e.g., see Bradley, Keil, & Lang, 2012; Ohman & Mineka, 2001; Pourtois, Schettino, & Vuilleumier, 2013; Vuilleumier & Huang, 2009; Vuilleumier, 2005, 2015). In fact, numerous studies have shown that the emotional content of visual stimuli can have an influence at the behavioral and neural levels when the attention is focused on a non-emotional aspect of these stimuli (i.e. in implicit conditions) as often in daily life (e.g., Cohen, Moyal, Lichtenstein-Vidne, & Henik, 2016; Critchley et al., 2000; Hariri, Bookheimer, & Mazziotta, 2000). However, although affective cues probably arise mainly in the periphery of the visual field in everyday life, only a few studies have investigated the ability of human observers to process emotional stimuli either explicitly or implicitly when they are not the target of the gaze. Yet, the properties of the retina constrain visual perception in such a way that visual acuity is not uniform across the visual field (see Livingstone & Hubel, 1987 Livingstone & Hubel, 1988; Nassi & Callaway, 2009; Wandell, 1995). Consequently, peripheral vision is far less capable of fine discrimination than central vision (Boucart, Moroni, Thibaut, Szaffarczyk, & Greene, 2013). This loss of spatial resolution in the periphery has several physiological reasons: (1) the considerable drop of the density of cone photoreceptors as eccentricity increases from the fovea (Curcio et al., 1991); (2) the reduced receptor density in peripheral retina (Chui, Song, & Burns, 2008); and (3) the larger receptive fields in periphery. Moreover, since retinotopic projection to cortex prioritizes foveal inputs, there is a disproportionately large representation of central retinal locations in the visual cortex (e.g., Horton & Hoyt, 1991) whereas the cortical representation of peripheral parts of the retina decreases as eccentricity increases (Azzopardi & Cowey, 1993; Duncan & Boynton, 2003; Popovic & Sjostrand, 2001). Despite these physiological limitations, peripheral vision allows coarse discriminations such as object and scene categorization, even at very large eccentricities (up to 70°; Boucart et al., 2013; Thorpe, Gegenfurtner, Fabre-Thorpe, & Bulthoff, 2001).

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http://dx.doi.org/10.1016/j.biopsycho.2016.07.014
0301-0511/

Regarding emotion, there is no consensus on the basis of the available data concerning the processing of emotional scenes (see Bayle, Schoendorff, Henaff, & Krolak-Salmon, 2011; Calvo, Fernandez-Martin, & Nummenmaa, 2014; Rigoulot et al., 2011; Rigoulot, D'Hondt, Honore, & Sequeira, 2012 for studies on emotional facial expressions processing). On the one hand, several data suggest that emotional scenes are explicitly processed in near peripheral vision. For instance, eye-tracking studies have shown that emotional scenes presented concurrently with neutral scenes in the visual periphery (the centre of the pictures was located approximately between 8° and 12° away from initial fixation) are more likely to attract the first fixation. This emotional effect is observed during tasks requiring to determine whether the scenes are either similar or different in valence (Calvo & Lang, 2004; Nummenmaa, Hyona, & Calvo, 2006). Nummenmaa et al. (2006) also observed that emotional stimuli were more likely to be fixated first than neutral pictures, simultaneously presented, when participants were told to attend to the neutral picture first, which suggests that emotional content captures visual attention exogenously. However, this result was nuanced by the fact that the probability of a first eye fixation on an emotional picture in this condition remained lower than when they had to attend to the emotional picture first. Thus, as concluded by the authors, participants were to some extent able to inhibit their first eye fixation on an emotional picture in this latter condition. Moreover, Calvo, Rodriguez-Chinea, & Fernandez-Martin, 2015 have recently found that emotional scenes were reliably discriminated from simultaneously presented neutral scenes in near peripheral vision (at 12.75° eccentricity) in a task where participants had to judge on wich side the emotional picture was located. In the same study, participants were also more accurate and faster when the emotional scenes appeared in the left than in the right visual field, in line with the "right hemisphere hypothesis" postulating a dominance of this hemisphere in emotional processing (e.g., Demaree, Everhart, Youngstrom, & Harrison, 2005; Gainotti, 2012; Heller, Nitschke, & Miller, 1998). On the other hand, few studies investigated implicit emotional processing (i.e. when the attention is not focused on the emotional content of the visual stimuli) in near peripheral vision. Eye-tracking studies have found that, in these conditions too, the emotional scenes are more likely to attract the first fixation than the simultaneously presented neutral scenes (during recognition tasks using these scenes as primes; (Calvo & Lang, 2005); Calvo, Nummenmaa, & Hyona, 2007,Calvo, Nummenmaa, & Hyona, 2008). In agreement with this privileged status of emotional pictorial stimuli, we recently provided behavioral and magnetoencephalographic evidence that non-predictive emotional information in peripheral vision at 12° eccentricity interferes with subsequent responses to foveally presented targets (D'Hondt et al., 2013). Moreover, Keil, Moratti, Sabatinelli, Bradley, and Lang (2005) also observed a right hemisphere dominance for implicit emotional processing at 3.9° eccentricity. In their study, participants had to count silently occasional random-dot patterns embedded in a 10 Hz flicker of colored pictures presented to both hemifields. They found that unpleasant scenes, as compared to neutral scenes, increased steady-state visual evoked potentials (ssVEPs) amplitude in the occipito-temporal and parietal cortex and that this effect was most pronounced at right temporal electrodes when these pictures were presented to the left visual field. Taken as a whole, these results suggest that the processing of emotional scenes could be effective in peripheral vision both in explicit and implicit conditions. However, these results were obtained for relatively low eccentricities.

To the best of our knowledge, only two event-related potentials (ERP) studies have investigated the processing of emotional scenes at larger eccentricities. Rigoulot et al. (2008) explored the affective (unpleasant vs neutral) categorization of natural scenes in central vision (0°) and at 30° eccentricity. The authors found that response latency was delayed for unpleasant pictures compared to neutral pictures and affective modulation of early ERP components existed whatever the eccentricity. While these results suggest that emotional pictures were discriminated from neutral pictures, the behavioral performance in terms of accuracy did not differ from the chance level for unpleasant pictures in peripheral vision. De Cesarei, Codispoti, and Schupp (2009) also performed a study comparing emotional processing between central (0°) and peripheral vision but at smaller eccentricities (8.2° and 16.4° eccentricity) and in passive viewing conditions as well as during a non-emotional active task (aiming at indicating whether a box presented in central vision contained a gap or not). When pictures were presented in central vision, they found, both during passive viewing and active task conditions, similar effects than previous studies using explicit emotional categorization tasks (e.g., Codispoti, Ferrari, De Cesarei, & Cardinale, 2006; Schupp, Junghofer, Weike, & Hamm, 2003, Schupp, Junghofer, Weike, & Hamm, 2004; Schupp, Flaisch, Stockburger, & Junghofer, 2006): emotional scenes, as compared to neutral scenes, induced larger early ERP components recorded at occipito-temporal sites, which may reflect perceptual encoding, and a larger late positive potential (LPP), indexing stimulus representation in working memory. At 8.2° eccentricity, similar results were found for the LPP in the passive viewing condition but the emotional effect on the early ERP components was observed only in the left visual field. No emotional modulations of early and late ERP components were observed in the active task. At 16.4° eccentricity, there were no emotional modulations in both conditions. Thus, the ability to process emotional stimuli might decline with increasing eccentricity and even though this has not been tested yet, we can suppose that effect of eccentricity could differ between explicit and implicit conditions.

Several data show that emotional stimuli differ in the way they influence task performance and associated brain activity as a function of whether their emotional content is explicitly or implicitly processed (e.g., Cohen et al., 2016; Critchley et al., 2000; Habel et al., 2007; Hariri et al., 2000; Scheuerecker et al., 2007; see also Codispoti et al., 2006; Schupp et al., 2006). Interestingly, in a recent study by Schupp, Schmälzle, & Flaisch, 2014, participants were presented with central target pictures (animal images or images depicting non-animal content) that were overlaid upon emotional or neutral background pictures. Emotional modulations of early and late ERP components, similar to those classically observed during the explicit emotional processing of natural scenes in central vision, were found in the passive viewing condition but not when participants were engaged in the animal-/non-animal-categorization task. Furthermore, the valence of the background pictures did not modulate the performance (both for speed and accuracy) in the task. In line with the results found by De Cesarei et al. (2009) in peripheral vision, this study reinforces the idea that implicit emotional processing in the peripheral visual field might be not possible if no sufficient resources are available. Another relevant line of evidence comes from the study by De Cesarei and Codispoti (2006) in which the authors investigated emotional modulations induced by pictures presented in different sizes during an animal/person categorization task. Indeed, given that size reduction also reduces discriminability because of the loss of fine details in the scene (e.g., Loftus & Harley, 2005), one can assume that modulation of picture size can give some insights about how the processing of emotional scenes is performed in conditions of low spatial resolution. De Cesarei and Codispoti (2006) observed that LPP amplitude was larger for both unpleasant and pleasant stimuli compared to neutral stimuli and these emotional effects were stable across all sizes. Pleasant pictures also elicited higher LPP amplitude than unpleasant pictures. However, emotional effect on the early ERP component was found only for pleasant pictures and was both reduced in amplitude and delayed with decreasing picture size.