



Adaptive attunement of selective covert attention to evolutionary-relevant emotional visual scenes

Andrés Fernández-Martín^{a,d}, Aída Gutiérrez-García^b, Juan Capafons^c,
Manuel G. Calvo^{c,*}

^a Universidad Internacional de La Rioja, Logroño, Spain

^b Universidad de Burgos, Burgos, Spain

^c Universidad de La Laguna, Tenerife, Spain

^d Instituto Universitario de Neurociencia (IUNE), Universidad de La Laguna, Spain

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ABSTRACT

We investigated selective attention to emotional scenes in peripheral vision, as a function of adaptive relevance of scene affective content for male and female observers. Pairs of emotional-neutral images appeared peripherally—with perceptual stimulus differences controlled—while viewers were fixating on a different stimulus in central vision. Early selective orienting was assessed by the probability of directing the first fixation towards either scene, and the time until first fixation. Emotional scenes selectively captured covert attention even when they were task-irrelevant, thus revealing involuntary, automatic processing. Sex of observers and specific emotional scene content (e.g., male-to-female-aggression, families and babies, etc.) interactively modulated covert attention, depending on adaptive priorities and goals for each sex, both for pleasant and unpleasant content. The attentional system exhibits domain-specific and sex-specific biases and attunements, probably rooted in evolutionary pressures to enhance reproductive and protective success. Emotional cues selectively capture covert attention based on their bio-social significance.

1. Introduction

Humans live in a complex environment with multiple stimuli occurring simultaneously around. For an observer, however, most visual stimuli appear beyond the foveal boundaries of central vision, outside the focus of overt attention, which limits their access to conscious information processing. Further, the capacity of working memory in the cognitive system is narrow, and therefore attention must be allocated selectively and sequentially for conscious processing. All this implies that viewers could miss critical information for adaptive demands. Nevertheless, emotional stimuli have a special adaptive value because they are related to pain and pleasure, punishment and reward, survival and well-being, and thus they are biologically and socially relevant. To guarantee that such stimuli are perceived from amongst many others, evolution must have equipped humans with parallel processing mechanisms that can automatically detect cues of potential danger and benefit. An implication is that individuals should be able to process emotional stimuli in extrafoveal vision, before they are foveally fixated. This mechanism is assumed to involve initial preattentive evaluation of emotional stimuli, with neural and cognitive encoding prior to or in the absence of (but subsequently guiding) overt attention, and an underlying brain network (mainly, amygdala and ventral prefrontal cortex, vPFC) (see Carretié, 2014). Through early covert

* Corresponding author at: Department of Psychology, University of La Laguna, 38205 Tenerife, Spain.

E-mail addresses: andres.fernandez@unir.net (A. Fernández-Martín), aidagg@ubu.es (A. Gutiérrez-García), jcapafon@ull.es (J. Capafons), mcalvo@ull.es (M.G. Calvo).

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attention, prior to consciousness, parallel processing would bring such stimuli into overt attention and conscious analysis, and thus facilitate appropriate responses. In this way, extrafoveal processing would secure early attention to adaptively relevant stimuli, thus preparing the organism for anticipatory defensive and appetitive behavior (Bradley, Keil, & Lang, 2012).

1.1. Processing of emotional scenes in peripheral vision

Within this adaptive approach to cognition, evidence of emotional processing of extrafoveally presented visual scenes has been obtained in studies of brain activity (Carretié et al., 2013; De Cesare, Codispoti, & Schupp, 2009; D'Hondt et al., 2013; Keil, Moratti, Sabatinelli, Bradley, & Lang, 2005; Rigoulot et al., 2008), recognition and categorization responses (Calvo & Lang, 2005; Calvo, Nummenmaa, & Hyönä, 2008; D'Hondt, Szaffarczyk, Sequeira, & Boucart, 2016), affective priming paradigms (Calvo & Avero, 2008; Calvo & Nummenmaa, 2007), and eye-movement studies (Alpers, 2008; Calvo et al., 2008; Kissler & Keil, 2008; McSorley & van Reekum, 2013; Nummenmaa, Hyönä, & Calvo, 2006, 2009). Relatedly, evidence of processing of extrafoveally presented emotional facial expressions has been obtained with both behavioral measures (Bayle, Schoendorff, Hénaff, & Krolak-Salmon, 2011; Calvo, Fernández-Martín, & Nummenmaa, 2014; Goren & Wilson, 2006) and neurophysiological measures (Bayle, Hénaff, & Krolak-Salmon, 2009; Calvo, Beltrán, & Fernández-Martín, 2014; Rigoulot, D'Hondt, Honoré, & Sequeira, 2012). Facial expressions convey information about the feelings and intentions of expressers, and therefore their detection in the visual periphery has high adaptive value. Altogether, this suggests that affective significance—at least a coarse impression or gist—is perceived prior to fixation on emotional visual images (scenes and faces).

The reviewed evidence thus far supports the hypothesis that perception is attuned to emotional visual stimuli outside the focus of attention, to secure and enhance their processing. In this regard, an important question is whether perception of emotional images in extrafoveal vision involves *selective* encoding when they are presented simultaneously with neutral images—and therefore *competing* for attentional resources. If so, this would suggest that biological evolution must have shaped the perceptual, cognitive, and neural systems to facilitate *preferential* detection of adaptively important stimuli. An underlying mechanism would involve initial perception of emotional visual stimuli through covert attention—prior to or in the absence of fixations—followed by attraction of overt attention for further processing. Within this conceptualization, we had two aims in the current study. First, we examined differences in selective attentional capture by emotional scenes in peripheral vision depending on their specific content. Second, we investigated differences in selective attentional capture in peripheral vision as a function of sex of the observers. Given that, for evolutionary reasons, some emotional stimuli may have acquired a special adaptive relevance for human females vs. males, we were particularly interested in the possible interactions between scene content and sex of the observers. Extrafoveal vision processing should be enhanced for types of emotional content that are most relevant for the adaptive function of each sex group.

1.2. Role of emotional scene content and sex of viewers

Prior research has found significant differences among various emotional image *contents* (e.g., erotica, romance, human attack, accidents, etc.) in valence and arousal ratings (see Bradley & Lang, 2007; Calvo & Avero, 2009; Gomez, von Gunten, & Danuser, 2013), eye-movements and pupillometry (Bradley, Costa, & Lang, 2015), psychophysiological reactivity (e.g., skin conductance, startle reflex; Bradley, Codispoti, Cuthbert, & Lang, 2001; Schupp et al., 2004), and brain measures (Briggs & Martin, 2009; Keil et al., 2009; Sabatinelli, Bradley, Fitzsimmons, & Lang, 2005; Sabatinelli, Bradley, Lang, Costa, & Versace, 2007; Schupp et al., 2004; Weinberg & Hajcak, 2010), with erotica and mutilation contents often producing the strongest reactions. In addition, such emotional picture processing varies as a function of *sex of viewers*. Women generally show greater defensive activation than men when viewing unpleasant images, as shown by subjective evaluation (Bradley, Codispoti, Sabatinelli, & Lang, 2001; Calvo & Avero, 2009; Gomez et al., 2013), psychophysiological (Bradley, Codispoti, Sabatinelli, et al., 2001; Gard & Kring, 2007), and brain activity (Bianchin & Angrilli, 2012; Gardener, Carr, MacGregor, & Felmingham, 2013; Groen, Wijers, Tucha, & Althaus, 2013; Sabatinelli, Flaisch, Bradley, Fitzsimmons, & Lang, 2004). When viewing pleasant images, men are more reactive than women to erotica (Bradley, Codispoti, Sabatinelli, et al., 2001; Gomez et al., 2013; Sabatinelli et al., 2004; Sarlo, Palomba, Boudo, Minghetti, & Stegagno, 2005; Whittle, Yücel, Yap, & Allen, 2011), and women are more reactive to images of babies and affection (Bradley, Codispoti, Sabatinelli, et al., 2001; Charles, Alexander, & Saenz, 2013; Cárdenas, Harris, & Becker, 2013).

In these studies, however, the stimuli were generally presented singly (one at a time) and at fixation, i.e., directly available to overt attention in central vision. Research on this issue can be extended by assessing attentional *selection* in *extrafoveal* vision. In this vein, three recent studies (Bradley et al., 2015; Calvo, Gutiérrez-García, & Del Líbano, 2015; Calvo, Rodríguez-Chinea, & Fernández-Martín, 2015) presented male (22–24) and female (22–24) observers with pairs of neutral-emotional scenes in peripheral vision, with variable emotional scene content categories. This approach allows for addressing the issue of attentional selection in extrafoveal vision as a function of type of emotional content and sex of viewers. Nevertheless, Bradley et al. (2015) assessed gaze duration after the pictures entered foveal vision, but measures were not obtained in peripheral vision. Calvo et al. (2015) and Calvo et al. (2015) assessed processing while the scenes were in peripheral vision and in the absence of fixations, and found gist recognition of affective scene valence and interference with a concurrent on-going task at fixation, respectively. This suggests that emotional scenes drew covert attention. Further, in all three studies, the effects varied depending on type of scene content and sex of viewers. These findings constitute the starting point for the current study, in which we used an alternative, presumably more informative paradigm.

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