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Differential effects of object-based attention on evoked potentials to fearful and disgusted faces

Isabel M. Santos [a,*], Jaime Iglesias [b], Ela I. Olivares [b], Andrew W. Young [c]

[a] *Universidade de Aveiro, Departamento de Ciências da Educação, Campus Universitário de Santiago, 3810-193 Aveiro, Portugal*
[b] *Universidad Autónoma de Madrid, Facultad de Psicología, Departamento de Psicología Biológica y de la Salud, Campus de Cantoblanco, 28049 Madrid, Spain*
[c] *University of York, Department of Psychology and York NeuroImaging Centre, York YO10 5DD, UK*

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Abstract

Event-related potentials (ERPs) were used to investigate the role of attention on the processing of facial expressions of fear and disgust. Stimuli consisted of overlapping pictures of a face and a house. Participants had to monitor repetitions of faces or houses, in separate blocks of trials, so that object-based attention was manipulated while spatial attention was kept constant. Faces varied in expression and could be either fearful or neutral (in the fear condition) or disgusted or neutral (in the disgust condition). When attending to faces, participants were required to signal repetitions of the same person, with the facial expressions being completely irrelevant to the task. Different effects of selective attention and different patterns of brain activity were observed for faces with fear and disgust expressions. Results indicated that the perception of fear from faces is gated by selective attention at early latencies, whereas a sustained positivity for fearful faces compared to neutral faces emerged around 160 ms at central–parietal sites, independent of selective attention. In the case of disgust, ERP differences began only around 160 ms after stimulus onset, and only after 480 ms was the perception of disgust modulated by attention allocation. Results are interpreted in terms of different neural mechanisms for the perception of fear and disgust and related to the functional significance of these two emotions for the survival of the organism.

Keywords: Event-related potentials; Emotion; Attention; Fear; Disgust

1. Introduction

Selective attention is a mechanism which permits stimuli of importance to guide our behaviour (Luck, Woodman, & Vogel, 2000). The human face can be considered a highly important stimulus and facial expressions are often thought to be a privileged vehicle for signals of emotion. Given that recognition of emotions from faces is fundamental in the regulation of our social behaviour (Ekman, 1982), facial expressions are likely to be capable of gaining attention in a preferential way. Providing support for this assumption, studies using event-related potentials (ERP) and MEG confirm that emotional information from faces is registered and discriminated at early stages of processing (Pizzagalli, Lehmann, Koenig, Regard, & Pascual-Marqui, 2000; Pizzagalli, Regard, & Lehmann, 1999; Pourtois, Grandjean, Sander, & Vuilleumier, 2004; Rhodes & Palermo, 2007; Williams, Palmer, Liddell, Song, & Gordon, 2006). In ERP studies, effects of facial emotion have been described for the N170 component (Caharel, Courtay, Bernard, Lalonde, & Rebai, 2005; Caharel et al., 2007; Campanella, Quinet, Bruyer, Crommelinck, & Guerit, 2002), which is assumed to reflect early stages of the structural encoding of faces (Bentin, Allison, Puce, Perez, & McCarthy, 1996; Bentin & Deouell, 2000; Eimer, 2000). Emotion effects were also observed for the P1 component with an implicit emotional task, suggesting an early automatic encoding of emotional facial expression (Batty & Taylor, 2003). Moreover, Pourtois et al. (2004) have reported an emotional modulation effect of the early visual component C1 around 90 ms, whereby this component was greater for fearful faces than for neutral faces. Therefore there are indications that at least certain emotional expressions, such as fear, seem to be perceived in a rapid and preferential way. Less clear, however, is the influence of attention on these early processing stages. This topic is of recent growing interest, in particular

* Corresponding author. Tel.: +351 234370353; fax: +351 234370640.
E-mail address: isabel.m.b.santos@gmail.com (I.M. Santos).

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in relation to the specific neural bases of the different emotions.

Findings from both lesion and brain imaging studies indicate that the perception of different facial emotions relies to some extent on different neural substrates (Calder, Lawrence, & Young, 2001; Phillips et al., 2004). Localised amygdalar lesions in humans can produce particularly severe deficits in the recognition of fearful facial expressions (Adolphs, Tranel, Damasio, & Damasio, 1995; Adolphs et al., 1999; Broks et al., 1998; Calder et al., 1996), whereas circumscribed impairment to the insula and putamen selectively impaired recognition and experience of disgust (Calder, Keane, Manes, Antoun, & Young, 2000). These findings have been amply corroborated by neuroimaging studies with normal participants (Morris et al., 1996, 1998; Phillips et al., 1997; Sprengelmeyer, Rausch, Eysel, & Przuntek, 1998; Whalen et al., 1998; Williams, Morris, McGlone, Abbott, & Mattingley, 2004) and are often taken to suggest the existence of neural systems that have evolved especially for the perception of emotional stimuli with survival relevance to the individual. However, it is not yet clear whether the detection of such stimuli is pre-attentive, and neuroimaging studies present conflicting evidence regarding the effect of attention on the perception of emotional material (Anderson, Christoff, Panitz, De Rosa, & Gabrieli, 2003; Pessoa, 2005; Pessoa & Ungerleider, 2003; Vuilleumier, Armony, Driver, & Dolan, 2001). Altogether, fMRI studies suggest that attention may modulate the processing of different emotions in different ways, such that fear processing can proceed, at least initially, outside the focus of attention, whereas the processing of disgust seems to be more dependent on focal attention (Anderson et al., 2003). Moreover, it seems that under conditions of high attentional load (Lavie, 1995), emotional processing may be annulled (Pessoa, McKenna, Gutierrez, & Ungerleider, 2002). Given their higher temporal resolution, ERP studies potentially present a fruitful approach to further explore these issues.

Several ERP studies have already examined the effect of attention during emotional perception. Consistent with Pessoa et al. (2002), ERP correlates of facial expression processing were shown to be modulated by spatial attention (Eimer, Holmes, & McGlone, 2003; Holmes, Vuilleumier, & Eimer, 2003) using a task very similar to that used by Vuilleumier et al. (2001). Emotion effects in the form of an enhanced positivity at frontocentral sites for emotional faces compared to neutral faces were found starting around 100 ms (Holmes et al., 2003) and 160 ms (Eimer et al., 2003), which were eliminated when the focus of attention was directed away from the faces towards a concurrent perceptual discrimination task. Differences in late latency ERPs between emotional and neutral faces, and among different facial expressions (fear, happiness, disgust and surprise) were observed during an expression discrimination task but disappeared during a gender discrimination task (Krolak-Salmon, Fischer, Vighetto, & Mauguiere, 2001). Additionally, selective attention effects in a similar task were found in the ventral anterior insula to facial expressions of disgust (Krolak-Salmon et al., 2003) and in the amygdala to facial expressions of fear (Krolak-Salmon, Henaff, Vighetto, Bertrand, & Mauguiere, 2004) when recording intracranial ERPs. In a recent ERP study, however, which presented facial stimuli foveally, an initial stage of fear processing between 160 and 220 ms after stimulus onset was unaffected by attention, whereas emotional expression effects beyond 220 ms were eliminated when attention was directed to a concurrent task, implying that only later stages of emotion processing are dependent on attention (Holmes, Kiss, & Eimer, 2006). These results are compatible with evidence from backward masking paradigms, which support the existence of two stages in fear perception. The first, an early, automatic, and relatively unconscious stage of processing, which was associated with enhanced responses for the N2 component for fearful relative to neutral faces, and a later, more controlled and conscious stage of processing that was associated with enhanced responses for the late P3 component (Liddell, Williams, Rathjen, Shevrin, & Gordon, 2004).

These findings relate to a long-standing question in studies of attention, concerning how attention modulates information processing at early and late stages (Luck et al., 2000). This differentiation seems particularly important in studies of emotion processing, not only because the different stages of emotion processing might be differently affected by selective attention (Holmes et al., 2006), but also because there might be differences between the pattern of attention modulation for the various emotions. Moreover, it seems important to distinguish between conscious attention allocation, which determines voluntary selection of one stimulus or another and is normally manipulated by task instructions, and involuntary early selection, which might occur independently of the participant's conscious processing strategies.

In order to address these issues, the present study used ERPs to investigate the role of attention on the processing of facial expressions of fear and disgust. These particular emotions were chosen because they are the ones whose neural bases have been most extensively investigated to date, and the present study aimed to complement knowledge derived from other neuroimaging techniques, giving it a more detailed temporal dimension. As in the fMRI studies of Anderson et al. (2003) and Williams, McGlone, Abbott, and Mattingley (2005), the stimuli used consisted of overlapping pictures of a face and a house transparently superimposed, so that object-based attention could be manipulated (with the participant attending to faces or to houses) while spatial attention was kept constant (because the faces and houses were presented at the same location). With this type of overlapping stimulus, the segregation of attended and unattended stimuli necessarily involves processes at the level of object recognition. Neuroimaging studies have provided evidence that a particular object in a display where two objects are spatially superimposed can be individually perceived and used as the unit of attentional selection, and that attending to a single stimulus in such conditions selectively activates specialised extrastriate cortical areas (O'Craven, Downing, & Kanwisher, 1999).

In the present ERP study, participants had to perform a one-back repetition task, attending either to the faces or to the houses, in separate blocks of trials. In this way, the predictability and continuity of the task ensured that attention could be effectively allocated to the relevant type of stimulus. Moreover, an item from the relevant stimulus category had to be held in working memory