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Research article

Electrophysiological evidence for attentional capture by irrelevant angry facial expressions: Naturalistic faces

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HIGHLIGHTS

- Participants were asked to judge the gender of a neutral target face.
- Angry or happy distractor faces increased reaction times.
- The P_D component suggests that angry distractors were attentionally suppressed.
- Angry distractors elicited a larger N450 component, reflecting conflict detection.
- The results support the idea that angry faces are attentionally prioritized.

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ABSTRACT

Recently, research on lateralized event related potentials (ERPs) in response to irrelevant distractors has revealed that angry but not happy schematic distractors capture spatial attention. Whether this effect occurs in the context of the natural expression of emotions is unknown. To fill this gap, observers were asked to judge the gender of a natural face surrounded by a color singleton among five other face identities. In contrast to previous studies, the similarity between the task-relevant feature (color) and the distractor features was low. On some trials, the target was displayed concurrently with an irrelevant angry or happy face. The lateralized ERPs to these distractors were measured as a marker of spatial attention. Our results revealed that angry face distractors, but not happy face distractors, triggered a P_D, which is a marker of distractor suppression. Subsequent to the P_D, angry distractors elicited a larger N450 component, which is associated with conflict detection. We conclude that threatening expressions have a high attentional priority because of their emotional value, resulting in early suppression and late conflict detection.

1. Introduction

There are few studies showing that threatening expressions, such as angry faces, capture attention when they are irrelevant to the task. However, this would be crucial evidence for the threat-capture hypothesis [1] which suggests that angry expressions grab attention automatically. Preferential attentional selection of threatening over positive expressions, called the *anger superiority effect*, has been observed in visual search only when angry faces were task-relevant [2]. This effect has been taken to support the threat-capture hypothesis, which states that threatening faces are processed faster than non-threatening faces and detected before attentional deployment [3]. However, visual search tasks in which the anger superiority effect was observed have used angry faces as targets and not as distractors. Typically, capture of attention by irrelevant distractors disrupts search, resulting in an increase in reaction times (RTs) [4]. Preferential processing of threatening stimuli would predict larger bottom-up capture by threatening than non-threatening face distractors. Studies which have required participants to search for a target in competition with an irrelevant facial expression are scarce. In previous research using natural or schematic facial expressions, increased RTs were observed for emotional distractor expressions, which was attributed to the affective significance of the distractor [5,6]. However, no difference between RTs to happy and angry distractors was established, which contradicts the threat-capture hypothesis.

Despite the lack of behavioral evidence for the threat-capture hypothesis, electrophysiological data has provided evidence in its

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favor. In this context, the N2pc has been used as a marker of spatial selective attention [7,8]. The N2pc occurs between 200 and 300 ms after stimulus onset at parietal electrodes and may be dissociated into two subcomponents [9]: a contralateral negativity, the Nt, associated with attentional selection, and a contralateral positivity, the P_D, associated with suppression of irrelevant stimuli [10]. When the distractor is shown at a lateral position and the target is on the vertical midline, the N2pc component reflects involuntary attentional capture by the distractor while the P_D reflects active attentional filtering of the distractor [11–14].

Because the N2pc and P_D constitute electrophysiological markers of attentional processing, they are useful measures for investigating the capture of attention by threatening facial expressions. For lateralized target expressions, the N2pc is larger for angry as compared to happy face targets [15,16]. Similarly, the N2pc to lateralized distractor expressions occurred in response to threatening, but not in response to happy expressions [17], which supports the threat-capture hypothesis. The N2pc to angry distractors demonstrates an early attentional deployment toward threatening emotional content, even though the stimuli were task-irrelevant.

It is currently unknown whether this effect can be generalized to conditions involving pictures of real facial expressions, rather than schematic pictures. Indeed, to be biologically relevant, the threat-capture hypothesis [1] must apply to natural faces and not only to schematic faces [18]. Evidence of attentional capture by real faces is crucial in the framework of the evolutionary relevance of threat. Threat is thought to activate a dedicated "fear module" that was forged in our phylogeny [19] before the advent of schematic drawings. Critically, the investigation of lateralized ERPs to natural angry faces as irrelevant distractors would provide information about the temporal dynamics of the activation of the fear module and its consequences on attentional and post-attentional processing.

Therefore, we investigated attentional effects of realistic threatening distractors in a visual search task. Participants were instructed to first locate a face surrounded by a color singleton and subsequently discriminate the gender of this face. On some trials, one of the remaining faces conveyed an emotional expression. We measured the lateralized ERPs to the irrelevant distractor when the distractor was on a lateral position and the target was on the vertical midline [11–14]. Because the vertical target is equally represented in both hemispheres, the lateralized ERPs only reflect processing of the distractor. Importantly, this spatial configuration enabled us to compare attentional processing of non-threatening (happy) and threatening (angry) distractor expressions. Behaviorally, we expected to find longer RTs in the distractor-present conditions than the distractor-absent condition, but no difference between facial expressions [5,6,17]. Additionally, we analyzed the electrophysiological signal occurring irrespectively of the distractor location in the N450 time interval. This measure will allow us to evaluate post-attentional effects.

2. Materials and methods

2.1. Participants

Twenty-four University of Geneva students (five males) without any neurological or psychiatric conditions participated in this experiment. All participants reported normal or corrected-to-normal vision. One participant was rejected because fewer than 50% of his trials remained after artifact rejection, mainly due to saccadic eye movements. Two participants were excluded because they produced excessive saccades toward the target or the distractor (average horizontal EOG outside $\pm 3\,\mu V$). Thus, the following analyses were conducted on the 21 remaining participants (three males). All participants were naive as to the purpose of the experiment. The local ethics committee of the University of Geneva had approved the study, and informed consent was obtained from participants prior to the experiment. Students received class credit in exchange for their participation.

2.2. Stimuli

The Cogent toolbox (www.vislab.ucl.ac.uk/Cogent2000) for Matlab was used to display the stimuli. As depicted in Fig. 1, six stimuli were presented at 6° of eccentricity on a black background. An oval of 1.8° horizontal by 2° vertical was shown as the contour of the faces. Faces were cropped at the hairline (see Fig. 1c) and selected from the NimStim [20] and the Karolinska Directed Emotional Faces database [KDEF; 21]. Critically, all faces with visible teeth were discarded in order to avoid any low-level capture by the resulting salient bright region [22,23]. We used 12 different identities (6 male and 6 female), each with a neutral, happy, and angry expression. In each visual search display, those identities were divided in sets of three males and three females, changing randomly every 96 trials. All pictures were gray-scale. Pictures of facial expressions are prone to low-level confounds [23]. Therefore, the contrast and the luminance histograms of the pictures were equalized using the SHINE toolbox [24], which reduces the variation of low-level perceptual features potentially influencing the lateralized ERPs.

2.3. Apparatus and procedure

Participants were seated in a comfortable chair in a dimly lit room. All stimuli were displayed on a CRT screen with a luminance of ~7.9 cd/m^2. The target consisted of a face surrounded by an unfilled oval whose color was different from the remaining ovals. The target face varied unpredictably between green among blue and blue among green. A distractor expression was present on two-thirds of the trials as in our previous studies [for more details,see 11,12,17].

Each trial began with a gray fixation cross on a black background for a random interval between 600 and 1600 ms. Participants were instructed to report the gender of the face inside the color singleton as quickly as possible while maintaining accuracy better than 90%. Responses were given with the right hand, and participants were instructed to respond using one of two keys of a standard keyboard. Incorrect responses were indicated by visual feedback. The stimulus remained on the screen until a response was given. Before the experiment, participants completed 96 trials of the task in which they were trained to avoid moving their eyes in the direction of the target. The three male and three female identities of the practice session were not used in the main experiment. Each participant performed 12 blocks of 96 experimental trials for a total of 1152 trials. Following the experiment, participants evaluated the valence and the intensity of each face using a continuous scale (respectively −100 to +100, from highly negative to highly positive, and 0–200, from low to high intensity, rescaled to 0–100).

2.4. Electrophysiological recording and analysis

EEG signals were recorded using an actiCHamp amplifier (Brain Products, Gilching, Germany) with active Ag/AgCl electrodes sampled at 1000 Hz. Twenty-seven electrodes were fixed on the scalp, one on the outer canthi of each eye (HEOG), one above and below the right eye (VEOG), and one on each earlobe. Cz served as online reference and AFz as ground. Electrode impedance was kept below 5 kΩ for EEG and H/VEOG.

Using BrainVision Analyzer 2.1 (Brain Products, Gilching, Germany), data were filtered with a zero phase-shift, low-pass But-