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Implicit emotional processing in peripheral vision: Behavioral and neural evidence

Simon Rigoulot[a,b,*,1], Fabien D'Hondt[a,b,d,2], Jacques Honoré[a,b,c], Henrique Sequeira[a,b,d,3]

[a] Université de Lille Nord de France, F-59000, France
[b] Neurosciences Fonctionnelles et Pathologies, Université de Lille 2, F-59000, France
[c] Centre National de la Recherche Scientifique (CNRS), F-59000, France.
[d] Neurosciences, Université de Lille 1, F-59000, France

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ABSTRACT

Emotional facial expressions (EFE) are efficiently processed when both attention and gaze are focused on them. However, what kind of processing persists when EFE are neither the target of attention nor of gaze remains largely unknown. Consequently, in this experiment we investigated whether the implicit processing of faces displayed in far periphery could still be modulated by their emotional expression. Happy, fearful and neutral faces appeared randomly for 300 ms at four peripheral locations of a panoramic screen (15 and 30° in the right and left visual fields). Reaction times and electrophysiological responses were recorded from 32 participants who had to categorize these faces according to their gender. A decrease of behavioral performance was specifically found for happy and fearful faces, probably because emotional content was automatically processed and interfered with information necessary to the task. A spatio-temporal principal component analysis of electrophysiological data confirmed an enhancement of early activity in occipito-temporal areas for emotional faces in comparison with neutral ones. Overall, these data show an implicit processing of EFE despite the strong decrease of visual performance with eccentricity. Therefore, the present research suggests that EFE could be automatically detected in peripheral vision, confirming the abilities of humans to process emotional saliency in very impoverished conditions of vision.

1. Introduction

Among environmental stimulations, faces have a privileged status, as first shown by Yarbus (1967) who found that ocular fixations were more likely to be directed towards faces than to any other part of a scene. Indeed, in an evolutionary perspective, quick detection and analysis of facial expressions are seen as an important behavioral advantage (e.g., Darwin, 1872), particularly in social communication (Adolphs, 2003). In agreement with the necessity to process such crucial information, the skills of human observers to make reliable judgments about emotional facial expressions (EFE) persist with poorly informative stimulations, such as faint changes in facial expression (Edwards, 1998) or in experimentally degraded conditions of processing, like in attentional blink (De Jong, Koster, van Wees & Martens, 2009), binocular rivalry (Alpers & Gerdes, 2007) or masking (Morris, Ohman, & Dolan, 1998) paradigms.

Behavioral and imaging studies have explored the specificities of the implicit processing of EFE and have found that even when emotional cues are not relevant for the task, EFE still modulate the behavioral performance (Frühholz, Jellinghaus, & Herrmann, 2011) and the activity of cerebral structures (e.g., Critchley et al., 2000). Despite task instructions, emotional information can automatically capture a portion of the attentional resources (see Fox, Russo, Bowles, & Dutton, 2001 for discussion) and influence performance. In the literature, this influence has been described in two different ways. First, the automatic capture of attention could help the participants in their task and lead to enhanced behavioral performance. This was demonstrated in dot-probe paradigms, when an emotional stimulation in one point of the visual field improved the detection and the identification of a target subsequently appearing in the same location (Armony & Dolan, 2002; Brosch, Sander, & Scherer, 2007; Lipp & Derakshan, 2005). Second, in an opposite way, automatic capture of

* Correspondence to: Laboratoire de Neurosciences Fonctionnelles et Pathologies, Hôpital R. Salengro, Service EFV, CHRU de Lille, 59037 Lille Cedex, France.
E-mail addresses: simon.rigoulot@mcgill.ca (S. Rigoulot), fabien.dhondt@gmail.com (F. D'Hondt), ja-honore@chru-lille.fr (J. Honoré), henrique.sequeira@univ-lille1.fr (H. Sequeira).
[1] Currently at: McGill University/School of Communication Sciences and Disorders 1266 avenue des Pins Ouest; H3G 1A8, Montreal, QC, Canada; http://www.mcgill.ca/pell_lab/. Tel.: +1 514 398 8496; fax: +1 514 398 8123.
[2] Tel.: +0033 0 3 20 44 62 81; fax: +0033 0 3 20 44 67 32.
[3] Tel.: +0033 (0)3 20 43 69 29.

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emotional information could disrupt the processing of information relevant to the task. This is the case in emotional Stroop tasks (Frühholz et al., 2011; Williams, Mathews, & MacLeod, 1996) or when the occurrence of an emotional item delayed responses to the target, which has been interpreted as reflecting a difficulty of disengaging from emotional information (Fox et al., 2001; Koster, Crombez, Verschuere, & De Houwer, 2004; Mathews, Fox, Yiend, & Calder, 2003).

The ability of EFE to mobilize attentional resources was further confirmed by imaging studies using Event-Related brain Potentials (ERP) or functional MRI analyses. Sato, Kochiyama, Yoshikawa, and Matsumura (2001), in a gender discrimination task, found that faces with fearful and happy emotional expressions, compared to faces with neutral expression, elicited a larger negative peak at about 270 ms (N270) over the posterior temporal areas. Vuilleumier, Armony, Driver, and Dolan (2001) observed that the activity of the amygdala, a key structure of emotional processing, was similar both when spatial attention was directed towards fearful faces and when it was not. Using pictures of natural scenes, Carretié, Hinojosa, Martin-Loeches, Mercado, and Tapia (2004) showed emotional modulations of early event-related components (P1, P2 and N2) in an oddball paradigm with neutral, pleasant and unpleasant deviant pictures, while the participants had to focus on the color of the frame surrounding the pictures.

Not only are EFE processed despite the decrease of focused attentional resources, but also they recruit a specific neural network, at least partially different from the one recruited when the processing of EFE is explicit. Critchley et al. (2000) reached this conclusion from fMRI experiments where the participants had to judge the emotional expression of happy, angry and neutral faces or the facial gender of the same faces. In a recent investigation, Van Strien, De Sonneville, and Franken (2010) found a difference in the location of the late positive potential (LPP) as amplitudes were larger at centro-frontal electrodes during valence ratings (explicit processing) and at midline parietal electrodes during gender identification (implicit processing of emotional content).

It is noteworthy that the investigation of the implicit processing of emotional facial expressions relies on studies focused on stimulations projected to the center of the visual field. Yet, most visual events occur in the peripheral visual field and cause saccades which displace targets of interest into central vision where detailed visual analysis can be performed (Liversedge & Findlay, 2000). This implies that some features are selected in peripheral vision (PV) for saccadic capture. Furthermore, despite the ability of emotional information to automatically capture a portion of attentional resources in implicit conditions, the persistence of this ability in visual impoverished situations such as PV has never been studied. In fact, a few studies investigated the emotional processing in PV but only in explicit conditions (see Rigoulot et al. 2008, 2011). In addition, some studies investigated the implicit processing of EFE in parafoveal locations (around 5° of eccentricity) with dot-probe tasks (e.g., Fox, Derakshan, & Shoker, 2008; Pourtois, Grandjean, Sander, & Vuilleumier, 2004; Pourtois, Dan, Grandjean, Sander, & Vuilleumier, 2005) and showed that threatening faces, but not happy ones, enhanced early electrophysiological components in comparison with neutral ones (C1 and P100; Pourtois et al., 2004, at 4.1° of eccentricity). Another study (Bayle, Henaff, & Krolak-Salmon, 2009) used magnetoencephalography to investigate the processing of emotional facial expressions. Neutral and fearful faces, very briefly presented at 5° of eccentricity, were followed by target faces without facial expressions and the brain responses after the onset of the first faces were analyzed. The authors observed increased cerebral activations in the amygdala and the fusiform gyrus in response to fearful expressions, in line with the alleged role of these structures in the processing of emotional expressions (Adolphs, 2002).

Altogether, these data suggest that EFE can be processed in parafoveal vision and outside the attentional focus. However, the question of the persistence of an implicit processing of EFE in far periphery, where most visual events first occur, remains unanswered. Here we investigated how EFE influence the neurobehavioral activity of participants involved in a discrimination task in which emotional information is useless. We also ensured that the emotional faces were really outside the central visual field by projecting them in far periphery (up to 30° of eccentricity) because responses evoked by parafoveal stimuli, as in Bayle and colleague's study, did not differ from those obtained in central vision (see Kaplan, 2004; Martin & Grünert, 2004). Finally, we addressed the question of the ability of happy faces to mobilize as efficiently as fearful faces attentional resources in PV (see Pourtois et al., 2004, 2005).

Our hypothesis is that fearful and happy expressions modulate behavioral and electrophysiological responses to faces appearing in PV, even when the attention of the participants is not directed towards the emotional content of faces. Accordingly, we projected in peripheral vision fearful, neutral and happy faces of which participants had to categorize the gender. The behavioral and cerebral modulations related to the emotional expression of faces were evaluated by means of reaction times and ERPs recordings. Considering the rare available electrophysiological data related to peripheral vision, in addition to a baseline to peak analysis, an exploratory spatio-temporal principal component analysis (PCA) was chosen to determine the spatial and temporal features of interest in the ERPs data. Indeed, PCA techniques have already demonstrated their relevance to explore ERPs in response to emotional stimuli (Delplanque, Lavoie, Hot, Silvert, & Sequeira, 2004; Delplanque, Silvert, Hot, & Sequeira, 2005; Delplanque, Silvert, Hot, Rigoulot, & Sequeira, 2006; Hot, Saito, Mandai, Kobayashi, & Sequeira, 2006; Kayser & Tenke, 2003; Rigoulot et al., 2008).

2. Methods

2.1. Participants

Two experiments were designed. Sixteen women (all right-handed; mean age: 19.1 ± 3.5 years) were included in the first experiment and 16 other (15 right-handed and 1 left-handed; mean age: 19.9 ± 1.7 years) in the second one. Only women were included in these experiments because an important body of literature suggests that women are more reactive to emotional information than men (Bradley, Codispoti, Sabatinelli, & Lang, 2001; Campanella et al., 2004; Collignon et al., 2010; Larsen & Diener, 1987). They all had normal or corrected to normal vision and none of them had a history of neurological or psychiatric disorder, or drug consumption. Prior to the experiment, participants were given forms in order to get their consent, to test their handedness (Hécaen, 1984), and were paid 20 Euros for their participation. The study was approved by the ethics committee of the Centre National de la Recherche Scientifique (CNRS).

2.2. Apparatus and stimuli

Three projectors (SONY CS5, Tokyo, Japan) displayed the stimuli on a panoramic semi-circular light-grey (68 cd/m^2) screen covering almost the entire visual field (180°). The projectors were connected to a computer devoted to the presentation of the stimuli (Hewlett-Packard Pentium III, 1000 MHz).