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Research Report

The role of spatial frequency information for ERP components sensitive to faces and emotional facial expression

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Abstract

To investigate the impact of spatial frequency on emotional facial expression analysis, ERPs were recorded in response to low spatial frequency (LSF), high spatial frequency (HSF), and unfiltered broad spatial frequency (BSF) faces with fearful or neutral expressions, houses, and chairs. In line with previous findings, BSF fearful facial expressions elicited a greater frontal positivity than BSF neutral facial expressions, starting at about 150 ms after stimulus onset. In contrast, this emotional expression effect was absent for HSF and LSF faces. Given that some brain regions involved in emotion processing, such as amygdala and connected structures, are selectively tuned to LSF visual inputs, these data suggest that ERP effects of emotional facial expression do not directly reflect activity in these regions. It is argued that higher order neocortical brain systems are involved in the generation of emotion-specific waveform modulations. The face-sensitive N170 component was neither affected by emotional facial expression nor by spatial frequency information.

Theme: Neural Basis of Behaviour
Topic: Cognition

Keywords: Emotional expression; Event related potential; Face processing; Spatial frequency

1. Introduction

A growing literature exists on the ability of humans to rapidly decode the emotional content of faces [2,30]. Perceived facial expressions are important social and communicative tools that allow us to determine the emotional states and intentions of other people. Such skills are critical for anticipating social and environmental contingencies, and underlie various cognitive and affective processes relevant to decision-making and self-regulation [18,19,23].

Electrophysiological investigations have contributed in important ways to our understanding of the time course of emotional facial expression processing in the human brain, with human depth electrode and magnetoencephalography (MEG) studies revealing discriminatory responses to emotional faces as early as 100 to 120 ms post-stimulus onset [34,35,43]. One of the most reliable findings from scalp electrode studies is that emotional relative to neutral faces elicit an early positive frontocentral event-related potential (ERP) component. This effect occurs reliably within 200 ms of face onset [7,27,28,37], and has been found as early as 110 ms in a study by Eimer and Holmes [27]. A more broadly distributed and sustained positivity has been identified at slightly later time intervals (after approximately 250 ms: [7,27,40,45,60]). Whereas the early frontocentral positivity may reflect an initial registration of facial expression, the later broadly distributed sustained positivity, or late positive complex (LPC), has been linked to extended attentive processing of emotional faces [27].

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In addition to findings relating to the temporal parameters of expression processing, neuroimaging and lesion studies indicate that distinct brain regions subserve facial emotion perception [1]. Amygdala, cingulate gyrus, orbitofrontal cortex, and other prefrontal areas are all activated by emotional expressions in faces [11,14,24,48,52]. Little is known, however, about the relationships between these brain areas and electrophysiological correlates of emotional expression analysis.

One compelling finding from neuroimaging is that amygdala and connected structures, such as superior colliculus and pulvinar, are preferentially activated by low spatial frequency (LSF), but not high spatial frequency (HSF), representations of fearful faces [64]. Selective activation from LSF stimuli is consistent with anatomical evidence that these brain areas receive substantial magnocellular inputs [9,42,61], possibly as part of a phylogenetically old route specialised for the rapid processing of fear-related stimuli [21,41,50,56,59].

Magnocellular cells are particularly sensitive to rapid temporal change such as luminance flicker and motion, and have large receptive fields making them sensitive to peripheral and LSF stimuli. They produce rapid, transient, but coarse visual signals, and have a potential advantage in the perception of sudden appearance, location, direction of movement, and stimuli signalling potential danger. Conversely, parvocellular neurons are responsive to stimuli of low temporal frequencies, are highly sensitive to wavelength and orientation, and have small receptive fields that show enhanced sensitivity to foveal, HSF information. Parvocellular channels provide inputs to ventral visual cortex, but not to subcortical areas, and are crucial for sustained, analytic, and detailed processing of shape and colour, which are important for object and face recognition [15,39,44].

Given the heightened sensitivity of amygdala and connected structures to coarse (LSF) signals, driven by magnocellular afferents, and the capacity for the amygdala to modulate activation in higher cortical brain regions [40,49], it is of interest to see whether the early face emotion-specific frontocentral positivity and subsequent LPC would also reveal this sensitivity. Differential sensitivities to emotional expression information at high and low spatial scales are also apparent in tasks examining facial expression processing, with LSF information found to be important for expression discrimination, and HSF information found to be important for emotional intensity judgements [17,62,64]. The dissociation of low relative to high spatial frequency components of faces is also evident in the production of rapid attentional responses to LSF but not HSF fearful facial expressions [38].

An ERP investigation into the differential tunings for LSF and HSF information in facial expression processing may provide further indications of the possible functional significance and time course of these processes. To examine this issue, ERPs were recorded while participants viewed photographs of single centrally presented faces (fearful versus neutral expressions), houses, or chairs. Stimuli were either unfiltered and thus contained all spatial frequencies (broad spatial frequency or BSF stimuli), or were low-pass filtered to retain only LSF components ($\leq$6 cycles/image; $\leq$2 cycles/deg of visual angle), or high-pass filtered to retain only HSF components ($\geq$26 cycles/image; $\geq$4 cycles/deg of visual angle). To preclude possible confounds relating to differences between these stimuli in terms of their brightness or contrast, all stimuli were normalised for their luminance and average contrast energy.

If LSF cues are more important than HSF cues in producing ERP modulations to fearful facial expressions, ERP effects of emotional expression triggered by fearful relative to neutral LSF faces should be more pronounced than effects observed for HSF faces. LSF faces might even elicit emotional expression effects comparable to the effects observed with unfiltered BSF faces. Alternatively, if such ERP effects were dependent on the availability of full spatial frequency information, they should be present for BSF faces, but attenuated or possibly even entirely absent for HSF as well as LSF faces.

Another aim of the present study was to investigate effects of both spatial frequency and emotional facial expression on the face-sensitive N170 component, which is assumed to reflect the structural encoding of faces prior to their recognition [8,25,26,58]. One recent study [33] has found enhanced N170 amplitudes for faces relative to non-face objects with LSF, but not HSF stimuli, suggesting that face processing might depend primarily on LSF information. We investigated this issue by measuring the N170 as elicited by faces relative to houses, separately for BSF, LSF, and HSF stimuli. With respect to the link between the N170 and emotional processing, several previous ERP studies using BSF faces have found that the N170 is not modulated by emotional facial expression [27,28,36,37], consistent with the suggestion that the structural encoding of faces and perception of emotional expression are parallel and independent processes [16]. Here, we investigated whether emotional facial expression might affect N170 amplitudes elicited by faces as compared to houses at different spatial scales.

2. Materials and methods

2.1. Participants

The participants were 14 healthy volunteers (9 men and 5 women; 24–39 years old; average age: 30.6 years). One participant was left-handed, and all others were right-handed by self-report. All participants had normal or corrected-to-normal vision. The experiment was performed in compliance with relevant institutional guidelines, and was approved by the Birkbeck School of Psychology ethics committee.