Effects of high and low spatial filtering and spatial location of fearful faces on amygdala and fusiform gyrus activity

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Introduction

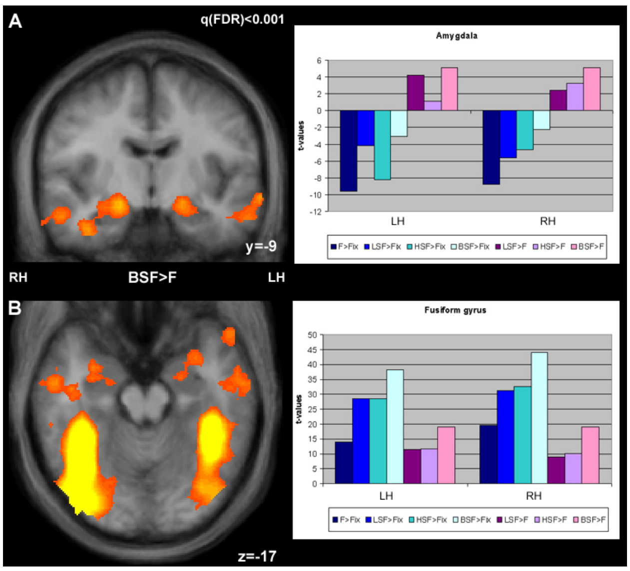
Faces provide complex visual information at multiple spatial frequencies: Low-spatial frequency (LSF) components reveal global configurational properties sufficient to supply coarse emotional cues, whereas fine grained features important for precise recognition of identity and for more detailed analysis of facial traits are conveyed by high-spatial frequency (HSF) components[1-4]. A recent neuroimaging study found that the amygdala is preferentially activated in response to LSF filtered faces in contrast to HSF images presented foveally[5]. Such a preference to LSF information in the amygdala is supported by the indirect connection via the superior colliculus and pulvinar to the M-pathway[6,7]. As the M-cells have large receptive fields making them sensitive to peripheral stimuli, it has been proposed that the amygdala might be especially sensitive to affective stimuli in the periphery in order to direct attention to emotionally relevant stimuli, which are not in the current focus of attention. In the present study we aimed to investigate the impact of stimulus eccentricity and different spatial frequencies on face processing in the amygdala using functional MRI.

Methods

15 healthy volunteers (4 males, mean age: 27 years) participated in the study. Greyscale faces with fearful expressions from the Karolinska Directed Emotional Faces set[8] were presented within an oval frame excluding the hair and non-facial contours. Faces were bandpass filtered using a radially symmetric filter and normalized in luminance. Spatial frequency (SF) content in the original stimuli (broad-band, BSF) was filtered (high-pass cut-off: 24 cycles/image for HSF stimuli; low-pass cut-off: 8 cycles/image for the LSF stimuli). Pairs of images, one face (LSF, HSF or BSF) and one Fourier transformed image, were presented either 1.7° (height: 3.8°; central location) or 9.5° (height: 8.2°; peripheral location) from central fixation for 500ms. Subjects had to indicate via button press on which side the face appeared. As control condition two Fourier images (F) were displayed, one containing a black oval-shaped circle as target. The photographs were scaled by the human cortical magnification factor to activate an approximately equivalent portion of early visual cortex at all stimulated eccentricities[9]. The four task conditions were implemented in a blocked design and were separated from each other by a fixation condition (fixation cross in the middle of a white screen; Fix). The fusiform gyrus was localized in a separate run by presenting blocks of greyscale face or house images interleaved with Fourier images, which were all fit behind an oval mask. BOLD fMRI was performed at 3 Tesla (Siemens TRIO, whole-brain EPI, TR 2s, TE 36ms, 2x2x2mm³). Analysis was performed using the general linear model approach (BrainVoyager QX). Regions of interest (ROIs) were determined on a single subject level either anatomically (amygdala) or functionally (fusiform gyrus) on the basis of the localizer experiment contrasting the face versus the house stimuli.

Results

The ROI-analysis revealed a different modulation of activity in the amygdala (**Fig. A**) and the fusiform gyrus (**Fig. B**). The spatial frequency of the emotional stimuli had an effect on the responses in the amygdala and the fusiform gyrus whereas the latter one was also affected by the eccentricity of the faces. A decrease in response was observed in the amygdala for all task conditions in contrast to fixation (Fix), regardless of the position of the stimuli. However, contrasting the faces against the control condition (F) was associated with an increase in activity in the amygdala. BSF faces activated the amygdala significantly stronger than LSF and HSF faces. Corresponding t-values of all contrasts are depicted in the bar graph in **Figure A**. The location of the emotional stimuli had no significant effect on amygdala responses (not shown).



In the fusiform gyrus increased activity was found during all task conditions compared to fixation (Fix). The face tasks lead to significantly higher activity in the fusiform gyrus than the control task (F). The BSF face task resulted in significantly higher responses in the fusiform gyrus than the face stimuli only containing either LSF or HSF visual information. Corresponding t-values of all contrasts are depicted in the bar graph in **Figure B**. The spatial location of the faces also had an effect on the activity in the fusiform gyrus as faces presented in the central location rather than the peripheral one were associated with a significantly stronger response (not shown).

Discussion

In contrast to previous results[5] amygdala responses were not selectively driven by LSF cues. On the contrary, it could be demonstrated that the amygdala responds most to naturalistic (BSF) images of faces. While the contrast between the different tasks and the fixation condition revealed a decrease in amygdala activity, the contrast between faces and Fourier transformed images resulted in increase in activity. This latter contrast does not reflect non-specific visual dissimilarities between two different visual displays (one containing faces, the other one just a fixation cross) such as energy, contrast, luminance etc., but rather relates directly to any face- or identity-specific information within one or another SF range. Therefore, it can be assumed that a coarse analysis of emotional stimuli like the extraction of SF cues in faces is performed in the amygdala, though it is not preferentially tuned to neither HSF nor LSF cues in faces. In the fusiform gyrus an increased response to faces of all SF ranges was found. However, a predominant influence of BSF faces was observed in the fusiform gyrus, which indicates the equal importance of low and high SF cues for face detection and identification. LSF as well as HSF faces produce optimal activation of the fusiform gyrus in contrast to fixation and Fourier transformed images and provide visual details about faces that can be associated with specific emotional expressions.

The hypothesis that the amygdala might be especially sensitive to emotional stimuli in the visual field periphery could not be supported by the data as no effect of stimulus location was observed. However, in agreement with previous reports[10,11] fusiform gyrus was activated more by faces presented in the central compared to the peripheral location.

Overall, these findings support the notion that the amygdala as well as the fusiform gyrus are not preferentially engaged in the processing of high or low SF aspects of emotional expressions in faces as both frequency ranges are equally implicated in face perception.

References

1 Calder et al. (2000). J. Exp. Psychol. Hum. Percept. Perform. 26, 527-551; 2 Liu et al. (2000). J. Exp. Psychol. Hum. Percept. Perform. 26, 956-979; 3 Hayes et al. (1986). Perception 12, 595-602; 4 Fiorentini et al. (1983). Perception 12, 195-201; 5 Vuilleumier et al. (2003). Nature Neuroscience 6, 624-631; 6 Morris et al. (1999). Proc. Natl. Acad. Sci. USA 96, 1680-1685; 7 de Gelder et al. (1999). Neuroreport 10, 3759-3763; 8 KDEF, Lundqvist, D., Flykt, A. & Ohman, A.; Dept. of Neurosciences, Karolinska Hospital, Stockholm, Sweden, 1998; 9 VanEssen et al. (1984). Vision Res. 24, 429-448; 10 Levy et al. (2001). Nat. Neurosci. 4, 533-539; 11 Liu & Ioannides (2006). Neuroimage 31, 1726-1740.