Featural and configural face processing strategies: evidence from a functional magnetic resonance imaging study

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We explored the processing mechanisms of featural and configural face information using event-related functional magnetic resonance imaging. Featural information describes the information contained in the facial parts; configural information conveys the spatial interrelationship between parts. In a delayed matching-to-sample task, participants decided whether an intact test face matched a precedent scrambled or blurred cue face. Scrambled faces primarily contain featural information whereas blurred faces preserve configural information. Scrambled cue faces evoked enhanced activation in the left fusiform gyrus, left parietal lobe, and left lingual gyrus when viewing intact test faces. Following blurred cue faces, test faces enhanced activation bilaterally in the middle temporal gyrus. The results suggest that featural and configural information is processed by following distinct neural pathways. *NeuroReport* 19:287–291 © 2008 Wolters Kluwer Health | Lippincott Williams & Wilkins.

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Introduction

The processes underlying human face recognition have been the subject of numerous behavioural and neuroimaging studies. Most neuroimaging studies revealed a region in the fusiform gyrus of the brain that responds specifically to human faces, termed fusiform face area (FFA) (e.g. [1–5]). Faces are reported to be processed on the basis of configural information [6–8], as opposed to objects, which are thought to be processed more on the basis of parts [9]. Configural information is understood as the information contained in the spatial interrelationship of the features (e.g. eyes, nose, mouth). Recent studies on face perception have pointed out that both configurations and features play a role in the processing of facial information [10,11]. Further findings suggest that configural and featural information are processed by following separate pathways [10–13]. In a positron emission tomography study, Rossion and colleagues [12] found hemispheric differences when their participants attended to featural or configural information. When faces had to be matched according to their configuration, the right middle fusiform gyrus showed more activation than the left homologous region. In featural processing, the activation in the right middle fusiform gyrus was reduced, but enhanced in the left middle fusiform gyrus. For objects, no such double dissociation could be found in these face-specific regions. In a study on patients with unilateral right or left lesions centered in temporal–parietal regions, Robertson and colleagues [14] found an asymmetry in local and global features. Patients with right hemisphere lesions showed better performance when processing local features, and patients with lesions in the left hemisphere performed better when processing global features. In this study, we scrutinize whether configural and featural face processing mechanisms can be dissociated. In the study by Rossion and colleagues [12], participants had to attend to either featural or configural information. The task was to match face pairs in a block-design study. These face pairs either differed in the spacing of the features (configural block) or in the features themselves (featural block). The participants knew what information they had to look for in each block. Therefore, the results could be the effect of different *a priori* attention strategies, rather than differences related to the actual processing of the stimuli. In this study, we directly compared the featural and configural processing of a face.

We used a delayed same–different task by applying an event-related design. Participants first saw either a scrambled or a blurred face (cue face) and they had to decide whether a subsequent intact face (test face) was the same or not. Scrambling a face into its constituent parts reduces global configural information, whereas local featural information remains intact. Sufficient blurring of the faces hampers detailed information of the features, whereas the overall configuration of the face is unrestricted [11]. By keeping the test face intact, the visual input of the crucial stimulus remained the same. To solve the task, participants had to rely on either configural or featural

information provided in the cue face. On the basis of existing theories on face recognition [10,11,13], we hypothesized that featural and configural information is processed by following two distinct pathways. Different assumptions can be made about these pathways. First, it could be expected that configural (metrical) information is processed via dorsal pathways, whereas featural information is processed via ventral pathways analogous to the 'what' and 'where' system [15,16]. Second, a hemispherical difference could be expected for featural and configural processing [12,17]. If faces are processed purely holistically (i.e. featural and configural information is not processed by following distinct pathways) no differential activation would, however, be expected between test faces following scrambled faces and test faces following blurred faces. With this study, we test these possible outcomes and attempt to elucidate the nature of configural and featural face processing.

Methods

Participants

Fourteen right-handed participants ranging in age between 24 and 32 years (mean 27.1 years) took part in this study. All gave written informed consent and were treated according to the declaration of Helsinki. The study was approved by the local ethical committee. All participants received payment at the end of the experiment.

Stimuli

Blurred, scrambled, and intact faces were created from 40 grey-scale photographs of Caucasian faces (20 men, 20 women). The faces were cut out with the elliptic tool provided by Adobe Photoshop 7.0 using soft contours (5 pixel feather). Thus, the outer features of the faces such as head shape and hairline were discarded and all the faces appeared the same in size and shape (296 pixels wide, 385 pixels high). The blurred stimuli were created by applying a Gaussian filter with a σ of 0.025 of image width in frequency space, using the equation $\exp[-f^2/(2*\sigma^2)]$. For the scrambled stimuli, eyes, mouth, and nose were cut out using the elliptic tool reported above (eyes: 131-pixels wide and 95-pixels high, mouth 160×82, nose 98×145 pixels). These features were arranged on a black background (600×800 pixels), so that no part was situated in its natural position with reference to its neighbouring part. Four different scrambled versions were created ensuring that the location of each feature was not predictable. The features were placed within the same area as the blurred and intact stimuli, so that they subtended to the same visual angle. In the control condition, lines in four different orientations were used, either placed on a black background or on an array with the same size as that of the faces. This array was a special scrambled version of a stimulus face, where an intact face was cut into small parts and rearranged so that it contained no featural and no configural information while at the same time preserving the overall luminance information. Examples of the stimuli can be seen in Fig. 1. The stimulation was presented via magnetic resonance-compatible video goggles (MAVision 2000 fMRI, Resonance Technology, Inc. Northridge, California, USA).

Task

The experiment was conducted using Presentation software (www.neurobs.com). Trials started with the presentation of a fixation cross (3 s). In the experimental conditions, either a blurred (cueblr) or a scrambled face (cuescr) was presented for 5 s, followed by fixation cross (5 s), and an intact test face. The test face disappeared after 2 s or as soon as the participants responded. Depending on the cue face this test face was coded as testscr, or testblr. The task was to decide whether test and cue face were identical. In the control condition, a line appeared instead of the cue face. Instead of the test face another line was presented on the scrambled

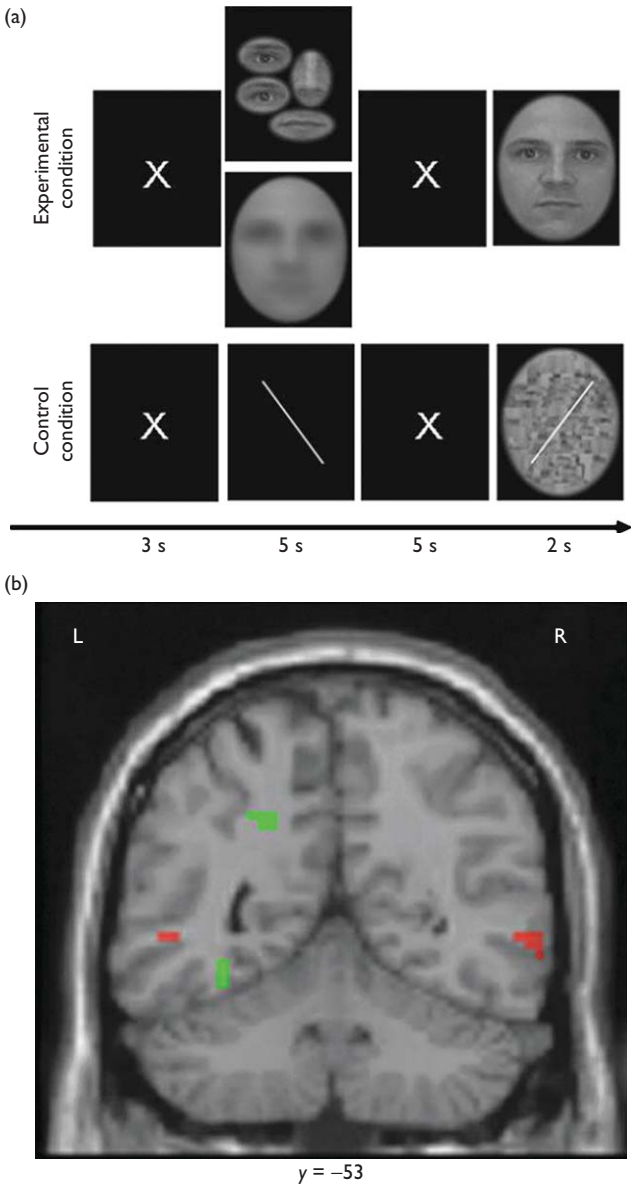

Fig. 1 Design. (a) After a fixation cross, either a scrambled or blurred face (experimental condition) or a line (control condition) was presented for 5 s (cue). After a delay, an intact face or control stimulus was presented (test stimulus). The task was to decide whether the test stimulus was the same as the cue stimulus. (b) Differential processing of featural (green) and configural (red) face information. The activation map ($P < 0.001$, uncorrected, minimal cluster size 5 voxels) is shown superimposed onto a selected coronal slice of the EPI-template provided by SPM2. The section was taken coronally; the anterior–posterior level is based on MNI coordinates.

array described above. Participants judged whether the two lines had the same orientation. Participants indicated their response with the right or left index finger for same or different stimuli, respectively. The procedural order of a trial can be seen in Fig. 1a.

Magnetic resonance imaging and functional magnetic resonance imaging data analysis

Gradient echo, echoplanar imaging was performed using a GE Signa 3 Tesla scanner (GE Medical Systems, Milwaukee, Wisconsin, USA), obtaining volumes of 32 3.5-mm thick axial images, which were recorded in an interleaved manner (TR=2.4 s, TE=32 ms, FA=90, FOV=26 cm, 96×96 matrix). Two runs consisting of 306 volume scans each were obtained using an event-related design.

The scans were aligned along the AC/PC axis and were then processed and analysed using SPM2 (Wellcome Department of Cognitive Neurology, London, UK). To correct for their different acquisition times, the signal measured in each slice was shifted with respect to the acquisition time of the first slice using a sync interpolation in time. The images of each participant were realigned to the first image to correct for head movement. Then the images were normalized into stereotaxic anatomical Montreal Neurological Institute (MNI) space by using the transformation matrix calculated from the first volume of each participant and the EPI template provided by SPM2. Afterwards, the normalized data with a resliced voxel size of $3 \times 3 \times 3$ mm were smoothed with a Gaussian kernel (full-width at half-maximum, 6 mm) to accommodate interparticipant variation in brain anatomy. All analyses were restricted to trials in which responses were correct. The expected hemodynamic response at stimulus onset for each event type was modelled by two response functions, a canonical hemodynamic response function [18] and its temporal derivative. The functions were convolved with the stimulus onsets to create covariates in a general linear model. Parameter estimates for the hemodynamic response function regressor were calculated from the least mean squares fit of the model to the time series. Parameter estimates for the temporal derivative were not considered in any contrast. Incorrect responses were calculated as a parameter estimate of no interest. As we were interested in areas in the dorsal and ventral stream, we masked brain activity for the occipital, parietal, and temporal lobes and calculated the contrasts testblr > testscr and testscr > testblr within this mask, separately for each participant. In a random effects group analysis, these contrasts were subjected to a paired *t*-test between the scrambled (testscr) and blurred (testblr) variables. Voxels with a significance level of $P < 0.001$ uncorrected, belonging to clusters with at least 5 voxels are reported. The control condition was not included in any analyses reported here.

Results

Behavioural data

The mean accuracy rate was 70.54% (*SD*=16.8) in the blurred condition, 80.58% (*SD*=10.4) in the scrambled condition, and 90.18% (*SD*=9.7) in the control condition. One-way analysis of variance revealed an effect of condition. Pairwise comparison of the scrambled and blurred conditions revealed only a marginal difference (P=0.064). Participants performed significantly better in the control condition than in the blurred ($P < 0.001$) and also the scrambled conditions ($P < 0.05$). The mean reaction time (RT) for blurred trials was 1133 ms (*SD*=459), for scrambled trials mean RT was 1184 ms (*SD*=503), in the control condition the mean RT was 916 ms (*SD*=351). Pairwise comparisons showed no difference between scrambled and blurred conditions (P=0.670), but the RTs of the control condition were marginally shorter than those in the experimental conditions (blurred: P=0.058, scrambled: P=0.073).

Table 1 Peak activations

Cerebral area	Side	BA	*Z* value	MNI-coordinates (*x*, *y*, *z*)	Cluster size
Blurred-to-scrambled contrast					
Middle temporal gyrus	L	39	3.53	−51, −57, 3	6
	R	21	3.39	60, −54, 0	9
Scrambled-to-blurred contrast					
Precuneus	L	7	3.91	−15, −63, 36	8
Insula	R	13	3.79	36, −42, 21	5
Fusiform gyrus	L	37	3.75	−33, −54, −12	10
Parietal lobe	L	31	3.74	−21, −51, 36	10
Lingual gyrus	L	19	3.64	−27, −69, −3	6

Cerebral area with corresponding Brodman area (BA), *Z*-values and MNI coordinates for peaks. L, left; MNI, Montreal Neurological Institute; R, right.

Functional magnetic resonance imaging data

The paired *t*-test of testblr and testscr faces elicited a significant fMRI bold signal difference. Blurred trials as opposed to scrambled trials revealed activation in the middle temporal gyrus bilaterally (Table 1).

Contrasting scrambled trials with blurred trials activated the left posterior fusiform gyrus, left precuneus, areas of the left parietal lobe, the left lingual gyrus, and the right insula (Table 1). Figure 1b illustrates the differential activation between blurred and scrambled conditions.

Discussion

In this study, we traced brain regions that were activated in configural (blurred trials) and featural (scrambled trials) face processing. We found bilateral activation of the middle temporal gyrus during configural face processing. Featural processing selectively activated the left fusiform gyrus, parietal lobe, lingual gyrus, and precuneus. Furthermore, the right insula was activated during featural face processing. As the visual information contained in the stimuli was identical, this difference of activation can only be a result of a different mechanism used for processing featural and configural information. The differential neural activation of featural and configural processing found in this study is compatible with the dual-code view of face processing often suggested in earlier studies [10,11,13]. Left hemisphere activation when a featural processing mode is applied is in line with findings of Martinez and colleagues [17], who found more activation in the left hemisphere when participants attended to local features compared with when they attended to the global pattern (see Ref. [12]).

Andrews and Ewbank [19] found evidence for the fact that face-selective regions within the inferior temporal lobe are involved in the perception and recognition of faces,

whereas processing of changeable aspects of faces (e.g. different viewpoints of faces and facial expression) is associated with superior temporal face-selective regions. These data suggest that the regions in the brain associated with configural and featural processing are situated posterior to the FFA. These findings are in line with the idea that featural and configural information is extracted from the input representation of a face in the primary visual cortex in the bottom–up course of the visual stream before they are combined to 'holistic' face representations in the FFA [11].

In contrast to other brain imaging studies on face processing, we found no activation in the FFA. Because intact faces were contrasted with intact faces, regions selective for faces *per se* were subtracted. Only the activation that was selective for featural or configural processing remained because the task could be solved only by using either configural or featural information provided by the cue face. Thus, the activation revealed by the present contrasts constitutes the processing mode adopted to encode the test face, suggesting that the FFA is not involved in the differential processing of configural and featural information. This assumption is not consistent with the findings of Rossion and colleagues [12], who reported a double dissociation between configural and featural processing modes within the FFA. This discrepancy may be the consequence of different paradigms. In the study of Rossion and colleagues, participants were explicitly instructed to attend to either eyes and mouth or the whole face, and indicate whether the parts or the whole faces were the same. Possibly, the findings of Rossion and colleagues [12] reflect different attentional strategies instead of configural and featural processing (cf. [20]). Our participants had to recognize an intact face on the basis of either configural or featural information that they saw just before. A further difference between these two studies is that Rossion and colleagues [12] used a block design in a positron emission tomography study, whereas here we used fMRI using an event-related design. In the study by Rossion and colleagues, participants were told to attend to one type of information during the whole block. Their results may therefore be biased in a way, as they measured *a priori* attention strategies instead of processing strategies. In our event-related design participants had to change strategies several times within the same run. Finally, Rossion and colleagues analysed the percentage of blood flow changes only within the right and left FFA whereas we analysed activation in the whole posterior cortex (occipital, parietal, and temporal lobes).

Please note that we found a correlation across participants between brain activity and task performance in the blurred and scrambled conditions (data not shown). This result, however, did not confound with our findings, as the brain areas where both conditions correlated with performance did not overlap with each other, nor did they overlap with the areas reported here. This suggests that activations found for featural and configural processing were not mediated by task difficulty.

The data presented here clearly suggest a dual-code view, where featural and configural information is processed following separate pathways. Our findings indicate that these pathways partly coincide with the ventral stream ('what system') and dorsal stream ('where system') [15,16]. Some of the regions processing featural information are located ventral to the middle temporal gyrus, which showed more activation for configural processes, but at the same time featural processing activated a region in the parietal lobe, which lies dorsal to the middle temporal gyrus. We found hemispheric differences associated with featural and configural processing as well. Specifically, the data suggest that featural processing occurs comparatively left lateralized whereas configural processing activates bilateral regions.

Conclusion

In this study, we demonstrate that featural and configural face processing evoke differential activation in brain areas closely associated with visual processing, indicating that featural and configural face information is processed following two distinct pathways. These findings challenge the concept that faces are processed as unparsed wholes.

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