Similarities in neural activations of face and Chinese character discrimination

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This study compared Chinese participants' visual discrimination of Chinese faces with that of Chinese characters, which are highly similar to faces on a variety of dimensions. Both Chinese faces and characters activated the bilateral middle fusiform with high levels of correlations. These findings suggest that although the expertise systems for faces and written symbols are known to be anatomically differentiated at the later stages of processing to serve face processing or written-symbol-specific processing purposes, they may share similar neural structures in the ventral occipitotemporal cortex at the stages of visual processing. *NeuroReport* 00:000–000 © 2009 Wolters Kluwer Health | Lippincott Williams & Wilkins.

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Introduction

Humans are remarkably adept at processing visual information. In some visual categories, because of either their functional significance or long-term exposure to them or both, our abilities at processing are at the expert level. Faces and written symbols are the most prominent examples of such visual categories.

Functional MRI (fMRI) research [1] on face processing has identified a number of areas in the extrastriate cortex that are highly active when the face expertise system is engaged. The area that has received the most attention is the lateral middle fusiform gyrus – often referred to as the fusiform face area [1,2] because of its preferential response to faces. Although it remains highly controversial whether the fusiform face area's responsiveness to faces is biologically preordained or acquired through learning, it is commonly accepted that face-processing expertise is associated with activity in this area [3–7].

There has also been an extensive neuroimaging research on written word processing. Most of the existing studies have, however, focused on semantic, syntactical, and phonetic processing of written symbols [8]. Limited fMRI research has examined the written symbol processing from the visual expertise perspective, which has revealed strong left-lateralized responses in the fusiform gyrus [9–11]. This finding seems to suggest that the visual expertise for processing faces and written symbols may have separate neural bases in the ventral occipitotemporal cortex.

This suggestion may, however, be premature because the existing studies have mainly compared face processing with the processing of letters or words from alphabetical languages. fMRI studies with nonalphabetical languages such as Chinese characters show strong responses in the right fusiform regions that are on or near the right fusiform face area [12–14]. These findings suggest that the processing of written symbols and that of faces may involve common neural structures in the ventral occipitotemporal cortex. More specifically, the fusiform face area may play an important role in the visual processing of both faces and written symbols. Most of the existing studies on Chinese character processing, however, examine linguistic tasks [8]. None has directly compared the processing of faces and Chinese written symbols in the ventral occipitotemporal cortex using a comparable visual-processing task.

Comparing Chinese character processing with face processing is ideal because although they are highly distinctive in both form and function, they are nonetheless remarkably similar on a number of dimensions. First, Chinese characters are derived from ancient logographs that are iconic in nature. In contrast to written alphabetical languages that represent words phonetically and thus rely strongly on phonemic decoding, Chinese characters represent words graphically and rely on visual form decoding. Second, both faces and characters are seen far more frequently upright than inverted. Third, faces and characters contain both featural and configural information. Fourth, we often process faces and Chinese characters at the individual level (i.e. their identities). Fifth, Chinese adults are experts at processing faces and Chinese characters because of daily exposure to them since early childhood. These similarities between faces and Chinese characters provide an ideal situation to test

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the hypothesis that visual expertise for faces and written symbols may involve common neural structures in the ventral occipitotemporal cortex.

This study addressed this issue. Using fMRI methodology, we recruited Chinese adults who were experts at processing both Chinese faces and characters. We specifically focused on activation similarities and differences for faces and Chinese characters in the fusiform regions because they have been shown to be responsive to faces and written words.

Methods

Participants

Eleven right-handed Chinese undergraduates (five men, 21.3 ± 1.76 years) participated with informed consent.

Stimuli

The character and face stimuli consisted of 60 characters and 60 Chinese adult faces (half males), respectively, each of which centred on a gray background (Fig. 1a and b). Sixty noise images created with the Matlab software (Mathworks Inc., Sherborn, Massachusetts, USA) were used as baseline (Fig. 1c). To ensure physical comparability, both faces and character stimuli were matched with each other in terms of luminance, color, and gray intensity level.

Procedure

Participants participated in four block-design runs. Two runs were the face tasks and the other two were the character tasks. In each task, participants judged whether a pair of sequentially presented faces or characters were the same or different (50% same and 50% different). The orders of the four runs were counter balanced between participants. Each run included three 30-s experimental stimulus epochs interleaved by three 28-s noise picture epochs serving as a baseline. Each face or character epoch began with a 2-s task cue followed by six trials (5 s each trial, 32 s in total). Each experimental trial began with a 500-ms fixation followed by the first stimulus for 500 ms, then 1500-ms fixation followed by the second stimulus for 1000 ms, finally 1500-ms fixation during which the participants judged whether the two stimuli in this trial were identical. During each noise picture epochs, participants only fixated on the centre of each picture. Each face or character run lasted for 180 s.

Functional MRI data acquisition

During each run, 60 whole brain T2*-weighted axial images were acquired by a 3.0 T MRI scanner (USA) using standard echo planar imaging sequence (36 contiguous axial slices, slice thickness 4 mm, repetition time = 3000 ms, echo time = 30 ms, field of view = 240 mm, flip angle = 90°, matrix size 64 × 64).

Functional magnetic resonance imaging data analysis

Image data analysis was performed using SPM2 [The Wellcome Trust Centre for Neuroimaging, University College London (UCL), London UK, *www.fil.ion.ucl.ac.uk/spm/spm2.html*] [15]. After spatial realignment and normalization, all scans were resampled into $2 \times 2 \times 2\,mm^3$ voxels, and then spatially smoothed with an isotropic Gaussian kernel (full width at half-maximum = 6 mm) and temporally high-pass filtered (high-pass filter = 128 s) [15]. For each participant, the image data of four runs were combined and analyzed using general linear model, where the regressor was created by convolving a canonical hemodynamic response function with a δ-function corresponding with the presentation sequence of each stimulus type.

Results

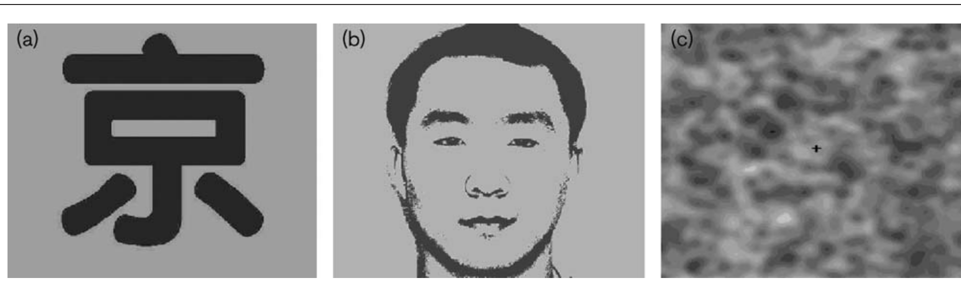
Behavior results

Participants were highly accurate in the face and character conditions (96.3 ± 3.4 and 96.6 ± 3.2%). Paired *t*-tests showed no significant differences in accuracy between the face and character tasks.

Functional MRI results

The individual response patterns underwent a group analysis using participants as a random variable. Four contrasts were used: face minus baseline, character minus baseline, face minus character, and character minus face. The whole-brain analyses showed that response patterns elicited by the face and character stimuli relative to baseline were highly similar (Table 1). The stronger

Fig. 1



Stimuli used in this experiment. Chinese character (a), face (b), and noise image (c).

Table 1 The peak activation loci and *Z* scores for each condition of whole-brain analysis ($P<0.001$, uncorrected)

	Talairacb coordinates				
Brain region	*x*	*y*	*z*	*Z*	Voxel
Face minus base					
Cuneus	14	−101	5	4.62	147
Lingual G	2	−90	−4	4.41	51
Middle occipital G	−34	−76	2	4.56	1367
Fusiform G	44	−61	−11	4.59	1070
Inferior parietal L	38	−52	47	4.76	352
Inferior parietal L	−40	−45	41	5.17	690
Middle frontal G	53	17	30	4.43	601
Middle frontal G	−12	4	48	5.50	951
	−44	30	26	3.94	34
Inferior frontal G	32	27	−5	4.55	67
Postcentral G	51	−33	48	4.81	303
Chinese character minus base					
Cuneus	18	−99	9	4.51	141
Cuneus	−16	−91	5	3.90	163
Lingual G	12	−86	−6	3.90	22
Lingual G	−6	−78	−8	3.96	27
Inferior occipital G	42	−72	−5	4.32	78
Fusiform G	−34	−50	−19	4.52	565
Anterior L	40	−38	−22	4.99	217
Posterior L	46	−58	−24	4.99	313
Cingulate G	−10	14	38	4.77	356
Superior frontal G	4	6	51	4.60	437
Middle frantal G	34	−3	60	4.14	48
Medial frontal G	−16	−2	48	4.58	259
Face minus Chinese character					
Inferior frontal G	51	18	12	4.05	50
Fusiform G	42	−49	−14	3.99	61
Precuneus	16	−70	39	3.65	20
Chinese character minus face					
Ventral prefrontal L	18	50	−9	3.33	17
Posterior L	18	−69	−20	3.26	26
Occipital L	18	−96	20	3.05	29
Inferior temporal G	−57	−55	−4	2.95	55

G, gyrus; L, lobe.

activities elicited by faces relative to baseline were observed in the bilateral fusiform gyrus with superiority in the right ($P<0.001$ uncorrected, $k=16$). Similarly, significant activities elicited by characters relative to baseline were also observed in bilateral fusiform gyrus ($P<0.001$ uncorrected, $k=16$). These activations were not significantly related to behavioral performance.

The parameter map for face or character in each run was obtained by computing the parameters of regressors corresponding with face or character voxel by voxel, respectively. Such parameter map was defined as response patterns. For each participant, similarity of activations between face and character was quantitatively measured by correlation coefficients of response patterns of them in the fusiform gyrus. The correlation coefficients were calculated between response patterns of either the two face runs or the two character runs (within-category correlation), and between a face run and a character run (between-category correlation). The computation of correlation was limited to bilateral fusiform gyrus.

Both within-category and between-category correlations were all significant ($P<0.001$, Fig. 2). A 2 (hemisphere: right vs. left fusiform gyrus) $\times$ 2 (Stimulus type: faces vs. characters) repeated measures analysis of variance on the within-category correlation data showed only a significant interaction [$F(1,10)=5.68$, $P<0.05$]. This effect was because of the fact that in the right fusiform gyrus the within-category correlations for faces were significantly larger than those for characters [$t(10)=5.50$, $P<0.001$], whereas this was not the case in the left fusiform gyrus [$t(10)=0.54$, $P=0.6$].

A 2 (hemisphere: right vs. left fusiform gyrus) $\times$ 4 (between-category pairs: face task 1 or 2) and on the between-category correlation data showed no significant effects, which suggests that the response patterns between face and characters runs were highly similar and not affected by the hemispheric or task order factors.

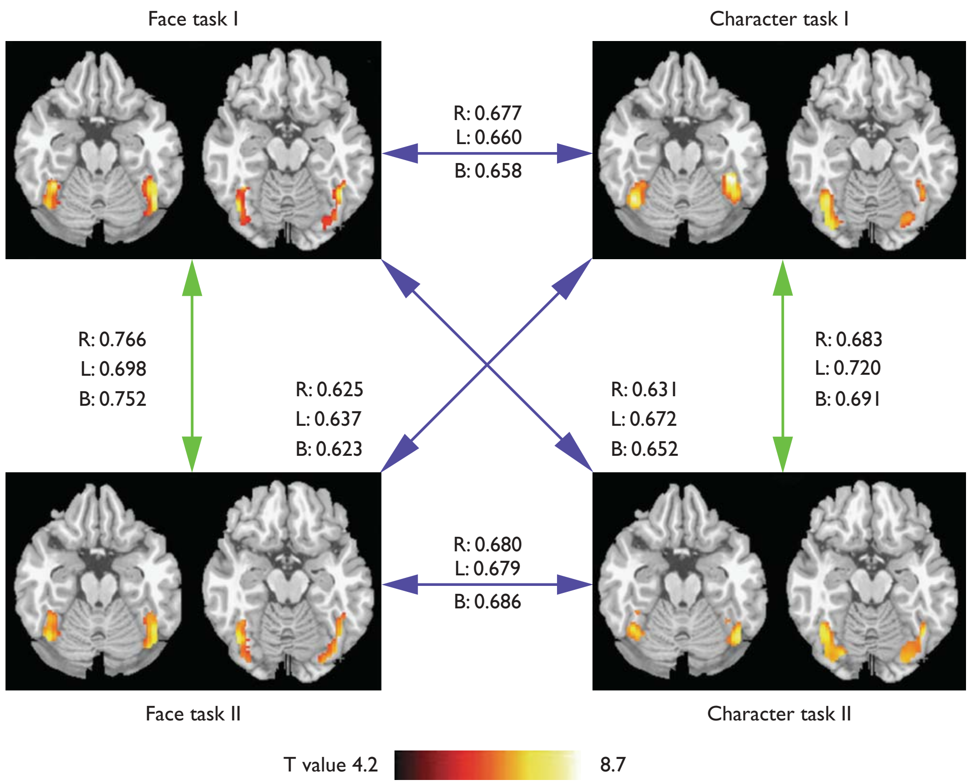
The whole-brain contrasts between faces and characters showed greater responses to faces in the right middle fusiform gyrus, right inferior frontal gyrus, and right precuneus ($P<0.001$ uncorrected, $k=16$), and greater activities elicited by character relative to faces in the right prefrontal lobe, right posterior lobe, right cuneus, and left inferior temporal gyrus ($P<0.001$ uncorrected, $k=16$) (Fig. 3, Table 1).

Discussion

Here, we compared neural activations associated with processing faces and Chinese characters in a visual discrimination task. Both stimulus types activated a highly similar network of brain regions. More specifically, face and character processing showed overlapping response patterns in the bilateral fusiform areas – especially in the right hemisphere.

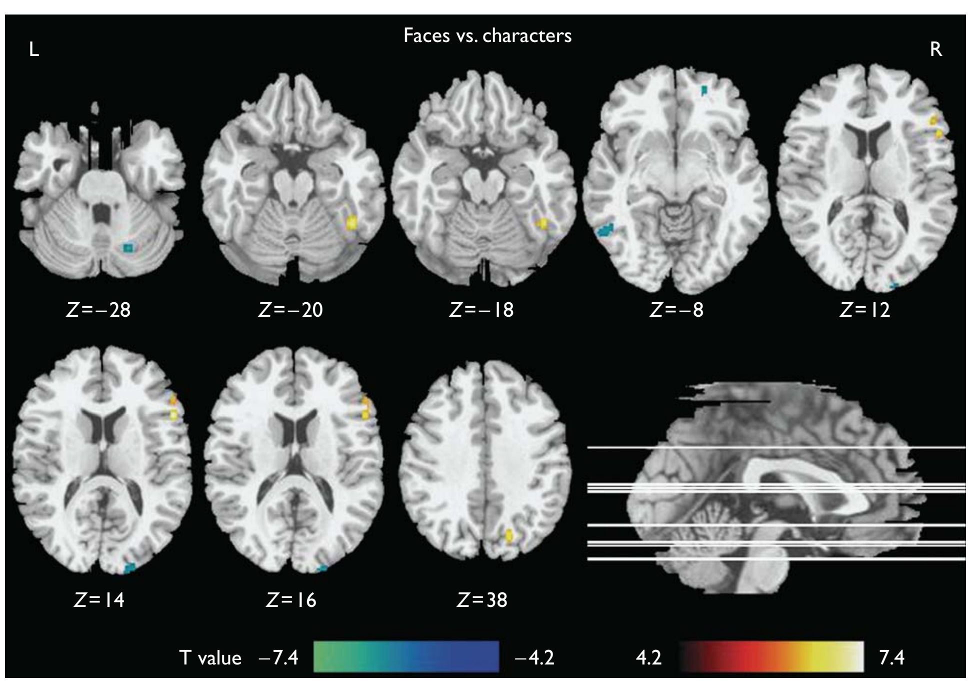
This similarity was further evidenced by the strong between-category correlations in bilateral fusiforms between face and character processing (Fig. 2). A similar study by Haxby *et al.* [16], however, found that the mean within-category correlations (0.81 for faces and 0.87 for house) were significantly greater than the mean negative between-category correlations (−0.40 and −0.47 for face and house). In contrast, the present between-category correlations were not only high (ranging from 0.623 to 0.686) but also approached those for the within-category correlations (ranging from 0.683 to 0.766). In the case of characters, but not faces, there was no significant difference between the between-category and within-category correlations. As described above, other than their physical characteristics and functions, characters are highly similar to faces on a variety of dimensions. Perhaps the strong correlations between response patterns for faces and characters may be a reflection of these similarities at the visual-processing level, suggesting that the processing of both stimuli may have similar neural bases during the early stage of visual processing.

Fig. 2



Correlation of whining-category runs (green line) and between-category runs (blue line).

Fig. 3



Comparison of activations between faces and Chinese characters. The hot and cold color indicated activation associated with faces and characters, respectively ($P<0.001$ uncorrected). Z was defined by Montreal Neurological Institute atlas.

We also found some differences between face and character processing. Within the right middle fusiform gyrus, we found greater activations for faces relative to characters, which was consistent with the large body of literature that has also found this area to be more responsive to faces relative to other nonface objects, including those for which one has acquired high-level processing expertise [2,5,7,17,18]. As mentioned earlier, whether the fusiform face area is biologically preordained to process faces is still hotly debated. Our finding is not entirely inconsistent with this face specificity hypothesis. One alternative possibility for the fusiform face area's greater response to faces than to characters is that expert level individuals may rely more on configural information for individuating faces [3,6,19,20], whereas they may rely more on featural information for individuating Chinese characters [21].

Beyond the fusiform areas, we observed stronger responses to faces relative to characters in the right inferior frontal gyrus and right precuneus. Right precuneus has been consistently associated with visual processing but its exact role in face processing remains unknown. The inferior frontal gyrus has been suggested to be involved in the semantic analysis of object-based visual information and generation of top-down expectations [22,23]. Relative to faces, characters elicited increased activities in the right ventral prefrontal lobe, and the right cuneus and left inferior temporal gyrus. The latter two structures are known to be part of a bottom-up network involved in the orthographic processing of characters [24], whereas the former may be part of a top-down character-processing network back projected to the ventral occipitotemporal cortex. The above differential findings between the face and character tasks may reflect differences in processing at a later stage that is functionally and anatomically differentiated to serve face processing and written-symbol-specific processing purposes, respectively.

Conclusion

Although the systems of faces and Chinese characters serve entirely different cognitive and social functions, responses to both types of stimuli in the ventral occipitotemporal cortex were highly similar, suggesting that the two systems may share neutral structures in the extrastriate regions at the early stage of processing.

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