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Activation of Face Expertise and the Inversion Effect

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Abstract

We used a contextual priming paradigm to examine top-down influences on the face-inversion effect. Adult participants were primed with either faces or Chinese characters and then tested on ambiguous figures that could be perceived as either faces or Chinese characters, dependent on the priming condition. The ambiguous figures differed from one another in their configural information, which is crucial for processing faces but not Chinese characters. The inversion effect was observed in the face-priming condition, but not in the character-priming condition. The present results provide the first direct evidence that top-down activation of the face-processing expertise system plays a crucial role in the face-inversion effect.

The recognition of faces is disproportionally impaired, relative to nonface stimuli (e.g., houses, cars), when they are seen inverted rather than upright (Yin, 1969). This phenomenon is referred to as the face-inversion effect. Conclusive evidence has shown that this effect is primarily due to disruption of the processing of configural, rather than featural, information in faces (e.g., Farah, Tanaka, & Drain, 1995; Freire, Lee, & Symons, 2000; Leder & Bruce, 2000; Rhodes, Brake, & Atkinson, 1993; Searcy & Bartlett, 1996; see Rossion & Gauthier, 2002, for a review).

Why is the processing of face configurations more vulnerable to inversion than the processing of such visual stimuli as houses and cars? We hypothesize that the face-inversion effect occurs because of the top-down activation of a specialized expertise system. This system has been tuned through experience to (a) process upright stimuli at the individual level (e.g., Gauthier & Tarr, 1997) and (b) rely heavily on configural information to discriminate between individuals (e.g., Diamond & Carey, 1986; Maurer, Le Grand, & Mondloch, 2002). When faces are presented in an orientation for which the face-expertise system is not tuned, observers fail to efficiently extract configural information in the faces, and an inversion effect results. In contrast, because the processing of many nonface stimuli does not take place at the individual level or does not rely on configural information to discriminate between individuals the inversion effect for these stimuli is either nonexistent or significantly smaller than that for faces.

To test this hypothesis, one must overcome two methodological challenges. First, one must control for differences in physical characteristics between faces and comparison stimuli. To address this issue, we employed a contextual priming paradigm that has previously been

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shown to be useful for examining the effect of top-down mechanisms on visual processing (e.g., Jonides & Gleitman, 1972; Taylor & Hamm, 1997). We first engaged participants in processing either faces or nonfaces and then tested them using ambiguous stimuli that could be perceived as faces or nonfaces depending on the priming condition. With this method, any performance difference between the two conditions can be unambiguously attributed to the top-down activation of face-processing versus nonface-processing systems.

Second, one must utilize comparison stimuli that are ecologically and experientially comparable to faces. Finding such comparison stimuli is extremely difficult because faces are a unique class of visual stimuli. First, people have extensive and long-term experience with faces from daily exposure to them. Second, faces are seen far more frequently upright than inverted. Third, by adulthood, people have become experts at processing faces at an extremely high level of proficiency. Fourth, unlike many other visual stimuli, faces are processed not only at the categorical level (e.g., race), but also at the individual level, with the latter as the primary focus. Fifth, faces contain both featural and configural information that can be used for discriminating between individuals.

Chinese written symbols (i.e., characters) may be ideal comparison stimuli because they are highly similar to faces on most of these dimensions. Chinese characters are omnipresent in Chinese societies, and Chinese people are exposed to them from early childhood. They have a canonical upright orientation and are processed primarily at the individual-character level (because each character carries specific meanings). Literate Chinese adults are experts at processing thousands of individual characters.

Chinese characters also contain both featural and configural information. Featural information contributes crucially to the processing of individual Chinese characters, as it does to the processing of individual faces. For example, the word shown in Figure 1a means “forest,” but changing its lower features transforms it into another word, “plum” (Fig. 1b). However, although Chinese characters contain configural information, changing this information does not alter their identities. For example, the character in Figure 1c still means “forest” despite the displacement of its features from their original location (Fig. 1a). Similar displacement of major facial elements would result in perception of faces with different identities (Freire et al., 2000). This unique difference between faces and Chinese characters offers an ideal situation for testing our hypothesis that the face-inversion effect is due to top-down activation of the face-expertise system. More specifically, despite the important similarities between Chinese characters and faces, participants should not show an inversion effect for Chinese characters, because of the relative unimportance of configural information (regardless of orientation) in processing individual Chinese characters, but they should show an inversion effect with faces, because upright configural information plays a crucial role in face processing (Carey & Diamond, 1977).

In the present study, Chinese adults participated in either a face or a character condition and were asked to make same/different judgments about a pair of upright or inverted stimuli. In the face condition (see Fig. 2), the first priming task (the real-face task) involved pairs of faces that were either identical or different from each other in the distances between the eyes, nose, and mouth. The nonidentical faces shared the same internal face features and face contour. Thus, they differed from each other primarily in their configural information. In the second priming task (the schematic-face task), participants saw line drawings of schematic faces, and again, the nonidentical faces differed from each other in the distances between the features. The priming task with line-drawing faces was used to ensure that the priming effect from the first task, with gray-scale faces, would be maintained in the subsequent critical condition (described later in this section), in which line-drawing stimuli were used.

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In the character condition (see Fig. 2), the first priming task (the real-character task) used real Chinese characters, and characters in nonidentical pairs differed from each other in the distances between features. The second priming task (the nonsense-character task) used nonsense Chinese characters; again, the nonidentical characters differed from each other in the distances between the features.

A third, crucial task (the ambiguous-figure task) followed the two priming tasks in both conditions. Participants saw pairs of ambiguous figures that could be perceived as either faces or nonsense Chinese characters (see Fig. 2). The nonidentical pairs again differed from each other in the distances between the internal elements. Because the ambiguous figures were identical in the two conditions, any differences in performance between the face and character conditions could be attributed only to the expertise systems that the participants were primed to engage. Thus, if the face-inversion effect is indeed due to the top-down activation of the face-expertise system, an inversion effect would be expected in the face condition and not in the character condition.

METHOD

Participants

Sixteen Chinese college students participated (8 males).

Materials and Procedure

For the real-face task, a gray-scale photograph of a male face was used to create three additional faces, one by moving the eyes apart six pixels and moving the mouth and nose up six pixels, another by moving the eyes closer together by six pixels and the mouth and nose up six pixels, and the third by moving only the eyes apart six pixels. A similar procedure was used to create four schematic faces for the schematic-face task, four real Chinese characters for the real-character task, four nonsense Chinese characters for the nonsense-character task, and four ambiguous figures for the ambiguous-figure task. The stimuli within each set thus differed from each other primarily in their configural information. All stimuli measured 8.5 cm × 11.5 cm (Fig. 2).

Participants were randomly assigned to either the face or the character condition. They performed the real-face or real-character task first, followed by the schematic-face or nonsense-character task, and finally the ambiguous-figure task, with 2-min breaks between tasks. On each trial, a stimulus was paired either with itself or with another member of its set. For each task, 144 pairs were presented, 72 that were identical and 72 that were different; stimuli were upright on 72 trials and inverted on the other 72 trials. Pairs were presented in random order on a 14-in. computer monitor 55 cm from the participants. Stimulus presentation and data collection were controlled by experimental software. Participants were instructed to indicate whether “the two stimuli were the same or different” by pressing the “same” or “different” key (keys were counterbalanced across subjects), and received no feedback. To avoid a trade-off between accuracy and latency, we asked participants to take their time to respond and respond as accurately as possible. Thus, the latency data were the main focus of interest.

RESULTS

Table 1 shows the means and standard errors for accuracy and latency of correct responses for each task in each condition. As expected given the experimental instructions, participants were highly accurate, showing no significant effect of inversion on accuracy in any of the tasks, as confirmed by a 2 (condition: face vs. character) × 2 (orientation: inverted vs.

upright) × 3 (task: first vs. second vs. third) repeated measures analysis of variance (ANOVA).

A 2 (condition) × 2 (orientation) × 3 (task) repeated measures ANOVA on latency of correct responses revealed significant effects of task and condition, as well as a task-by-condition interaction, $F(2, 28) = 22.19$, $p < .001$, $\varepsilon^2 = .61$; $F(1, 14) = 14.03$, $p < .001$, $\varepsilon^2 = .50$; and $F(2, 28) = 20.90$, $p < .001$, $\varepsilon^2 = .60$, respectively. Table 1 shows that this significant interaction was mainly due to the fact that as the experiment progressed, latencies did not change much in the face condition, but decreased significantly in the character condition. The effect of orientation and the orientation-by-condition interaction were also significant, $F(1, 14) = 8.29$, $p < .05$, $\varepsilon^2 = .37$, and $F(1, 14) = 4.67$, $p < .05$, $\varepsilon^2 = .25$, respectively. There was a significant and consistent inversion effect in the face condition, but not in the character condition, and the effect in the face condition became less pronounced as the stimuli became increasingly dissimilar to real faces (Table 1). In the crucial ambiguous-figure task, the inversion effect was still significant in the face condition, paired *t* test, $t(7) = -2.58$, $p < .05$, $\varepsilon^2 = .49$, but was not significant in the character condition, $t(7) = -0.46$, $p > .05$, $\varepsilon^2 = .03$.

DISCUSSION

The results were consistent with our predictions: Inversion significantly increased the latency to discriminate gray-scale or schematic faces that differed from each other in configuration, but had no significant effect on the latency of processing real and nonsense Chinese characters that also differed from each other in configuration. More important, after the face-priming tasks, participants showed a significant inversion effect when processing the ambiguous stimuli. However, after the character-priming tasks, the same ambiguous stimuli did not produce a significant inversion effect.

Because the face and character conditions used identical stimuli in the ambiguous-figure task, the fact that there was an inversion effect in the face condition but not in the character condition must be attributed to the priming tasks. In other words, activation of a particular expertise system during the first two tasks carried over to the ambiguous-figure task, yielding differential effects depending on whether it was the face-expertise system or the character-expertise system that was activated. Furthermore, because the ambiguous figures differed from each other only in their configural information, the inversion effect observed in the face condition must have been related to the processing of configural information after the face-expertise system was activated.

Similarly, the failure to observe an inversion effect in the character condition must be related to the activation of the system for expertise in Chinese characters. Because configural information serves no purpose in the discrimination of individual Chinese characters, this system is indifferent to whether configural information is viewed upright or inverted. As a result, no inversion effect was observed in this condition.

The present study provides the first direct evidence regarding whether the top-down activation of the face-expertise system plays a crucial role in the face-inversion effect. Previous studies that have compared the effect of inversion on the processing of faces and nonfaces (e.g., Yin, 1969) could not address this question because the face and nonface stimuli used in these studies differed from each other not only in physical characteristics, but also in the associated level of expertise. In the present study, because the ambiguous figures were physically identical, and the Chinese participants were experts at processing both faces and Chinese characters, the presence of the inversion effect in the face condition and the absence of this effect in the character condition provide clear evidence that the face-inversion effect is related not only to the processing of configural information, but also to the specific activation of the face-expertise system. This finding is consistent with the results of Tanaka and Farah (1991), who found that the processing of configural information alone was insufficient to explain the face-inversion effect.

The precise neurocognitive mechanisms underlying this differential effect of inversion are yet to be specified. Neuroimaging studies have shown that face and character processing produce differential activations in the brain. Face stimuli activate a core network in the extrastriate cortex, including the lateral middle fusiform gyrus (fusiform face area, or FFA), the inferior occipital gyrus, and the posterior superior temporal sulcus (Haxby, Hoffman, & Gobbini, 2002). The activations in the FFA are bilateral but often stronger in the right than the left hemisphere, and are reduced when nonface control stimuli are used (Haxby et al., 1999). Recent functional magnetic resonance imaging (fMRI) studies have shown that a specific network is also activated when individuals process Chinese characters (e.g., Chen, Fu, Iversen, Smith, & Mathews, 2002). As in the case of face processing, the extrastriate cortex is activated (a result, perhaps, of word-form encoding). However, activations for Chinese characters, unlike faces, are greater in the left occipital and posterior temporal regions (fusiform gyrus included) than in the corresponding areas in the right hemisphere. Furthermore, the additional regions activated by linguistic symbols are distinct from those activated by faces. For example, during Chinese-character processing, the inferior frontal, middle, and inferior temporal gyri and the inferior and superior parietal lobules are activated, perhaps owing to phonological and semantic processing.

It is premature to infer from the findings of the present study that priming with faces will induce a brain activation pattern that is different from that induced by priming with Chinese characters, because the tasks and stimuli used in the existing fMRI studies on face and Chinese-character processing are not directly comparable. It remains to be seen whether the ambiguous figures we used, despite being physically identical, will selectively activate two distinct cortical networks depending on whether participants are primed with faces or characters. This possibility has important implications for elucidating the brain basis of the face-inversion phenomenon, as well as the current debate regarding the functional role of brain areas recruited for face processing (Gauthier, Tarr, Anderson, Skudlarski, & Gore, 1999; Grill-Spector, Knouf, & Kanwisher, 2004; Kanwisher, Tong, & Nakayama, 1998). Because face processing and Chinese-character processing are matched so closely except for the role of configural information in discrimination of individuals, the present priming paradigm is ideally suited for testing this intriguing hypothesis.

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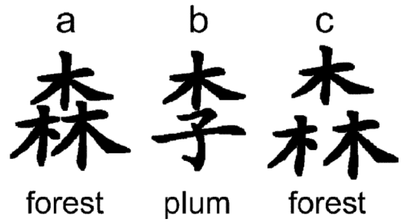

Fig. 1.
Examples of Chinese characters.

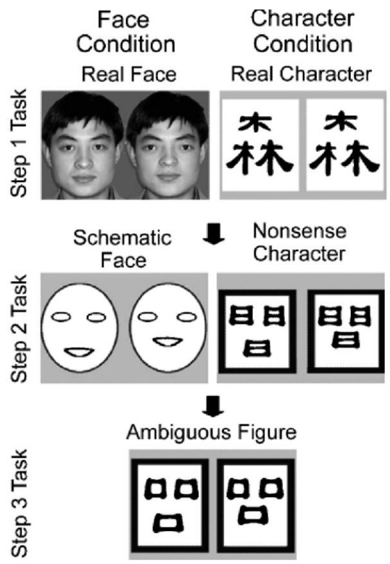

Fig. 2.
Design of the face and character conditions. In all three tasks, half the pairs were presented upright (as shown here), and the other half were inverted.

TABLE 1

Mean Accuracy and Correct-Response Latency for Each Task in the Face and Character Conditions

	Accuracy (%)		Correct latency (ms)	
Task	**Face condition**	**Character condition**	**Face condition**	**Character condition**
1: Real-face or real-character				
Upright	93.8 (2.5)	84.4 (3.0)	1,792.6 (263.2)	3,756.6 (167.1)
Inverted	90.3 (3.7)	85.2 (2.7)	1,993.9 (308.1)	3,821.4 (160.7)
2: Schematic-face or nonsense-character				
Upright	83.0 (3.3)	93.4 (2.1)	1,889.2 (200.5)	2,545.5 (160.3)
Inverted	85.8 (2.4)	93.7 (2.2)	2,009.3 (173.3)	2,522.3 (170.8)
3: Ambiguous-figure				
Upright	91.3 (1.9)	95.8 (1.7)	1,786.5 (250.5)	2,100.3 (142.5)
Inverted	89.4 (2.8)	96.9 (1.4)	1,890.9 (264.4)	2,119.4 (144.8)

Note. Standard errors are in parentheses.