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Original article:

EXPERTISE ACCOUNTS FOR INVERSION EFFECT: NEW BEHAVIORAL EVIDENCE

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ABSTRACT

A contextual priming paradigm was used to investigate the influence of processing of configural/featural information and activation of expertise upon inversion effect. 32 participants were divided into Faces group (Faces priming vs. English letters priming) and Chinese characters group (Chinese characters priming vs. English letters priming). Pair matching tasks were performed in the processing of configural and featural information respectively. Participants were primed with either Face/Chinese characters or Combination of English letters, and then tested on ambiguous, undefined, but identical stimuli that could be interpreted as either faces/Chinese characters or combination of English letters in terms of different contextual priming. The presence of inversion effect in Faces and Chinese characters priming (only in the processing of configural information) and the absence of such effect in the English letters priming demonstrated that inversion effect should be attributed not only to the processing of configural information but also to the specific top-down priming mechanism. However, inversion effect of Chinese characters priming was distinct from that induced in the faces priming, and such effect of inversion in Chinese characters couldn't be explained by the recruitment of face-specific mechanisms, which justified the explanation of inversion effect by expertise.

Keywords: Inversion effect, expertise effect, priming effect

INTRODUCTION

The ability to recognize and discriminate between different faces is one of the most important human social skills. While adults are experts at processing upright faces, their performance is attenuated when faces are presented upside down. This well-established observation is called the face "inversion effect" (Yin, 1969; Valentine, 1988), and is much more pronounced for faces than objects (Yovel and Kanwisher, 2004). This finding is regarded as the evidence that special perceptual processing is adopted by the visual system for faces different from for other non-face objects (Farah et al., 1998). However, whether or not the face inversion effect demonstrates the specificity of face perception is still a controversial issue (de Gelder and Rouw, 2000; Farah et al., 1995). Accumulative evidences actually show that the mechanisms of the face processing are 'special', but very few researchers can come to an agreement of what these mechanisms are definitely specialized for (Bentin and Carmel, 2002; Kanwisher, 2000; Liu and Chaudhuri, 2003; Rossion et al., 2002a; Tarr and Gauthier, 2000).

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In terms of expertise effect, those mechanisms that appear to be selectively involved in face perception are employed more generally in the identification of any type of visual stimuli that share the common basic configuration and for which subjects have obtained sufficient visual expertise (Diamond and Carey, 1986; Gauthier et al., 2000). It is proposed that the specialized expertise system can account for inversion effect (Gauthier and Tarr, 1997), namely, inversion effect occurs in processing of faces as well as other non-face objects with long-term perceptual training. New inversion effects have been investigated by some studies (Reed et al., 2003; Stekelenburg and de Gelder, 2004; Epstein et al., 2006; Bosbach et al., 2006). Particularly, other studies provide the evidences to confirm the existence of expertise for birds, dogs, cars, and the Greebles so as to justify the explanation of inversion effect by expertise (Gauthier et al., 2003; Rossion et al., 2002 b; Tanaka and Curran, 2001). However, Xu et al. (2005) refute such explanation of these findings. They suggest that these so-called "non-face stimuli" employed in those experiments are processed, actually to some extent, as faces. Inversion effect of these non-face stimuli simply reflects capability of face mechanisms to be recruited for these 'facelike stimuli'. So a critical question should be solved at present: is there any evidence to justify a non-face inversion effect without the possible recruitment of face-specific mechanisms mentioned above?

To address these issues, Chinese written symbols (i.e., characters) are referred to as the ideal comparison stimuli in the present study. Chinese characters contain featural and configural information like faces. It has been reported the 'Visual Word Form Area' (VWFA) in left fusiform gyrus is particularly in charge of processing visual words (McCandliss et al., 2003), and literate Chinese adults possess visual expertise that allows their visual system to process words efficiently. Chinese characters often share a similar configuration shown in Figure 1a: 'Pin' (品) and 'Lei' (磊). Noticeably, the inverted 'Pin' (品) obtains the physiognomic information and looks like an upright schematic face, and vice versa. So it's easier for us to induce subjects to recognize inverted 'Pin' (品) as an upright schematic face by showing them photographic faces ahead of time (Figure 1b), which is named contextual priming and activating pattern (Gong et al., 2008; Bentin and Carmel, 2002). So when the identical stimuli (upright and inverted 品) are processed in different contextual priming and activation (Chinese characters or Faces), we can predict that, if expertise takes effect, inversion effect should be triggered not only in the faces priming but also in the Chinese characters priming. What's more, inversion effect of Chinese characters 'Pin' (品) should be opposite to that of schematic faces, which could refute the argument that inversion effect of Chinese characters would be due to the recruitment of face-specific processing mechanisms.

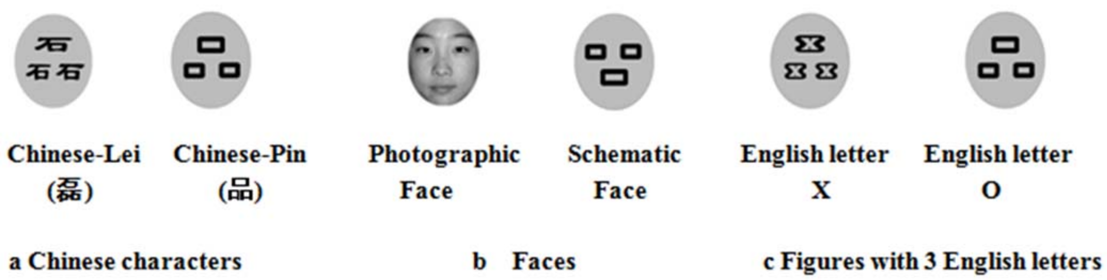

Figure 1: Stimuli used in different contextual priming

Participants were divided into two groups: Faces group and Chinese characters group. Noticeably, the comparison stimuli (Figure 1c) were introduced both in the Faces group and in the Chinese characters group in which subjects were induced to recognize the undefined visual stimulus 'Pin' (品) as the unmeaning combination with three English letters 'O' by means of presenting subjects the priming stimuli----combination with three English letters 'X'. With the identical ambiguous stimuli, the patterns of responses in two groups could be compared with each other. In addition, the influence of configural/featural information processing upon inversion effect was also investigated in the present study.

EXPERIMENT 1

FACES VS. ENGLISH LETTERS PRIMING

MATERIALS AND METHODS

Participants

16 Chinese male undergraduate students in medical school (all Chinese native speakers, mean age 20.4 years, range 18-23), with normal eyesight and right handedness, participated in the experiment. Written consents were obtained before the experiment. Subjects got payment for their participation. The experiment was approved by the Academic Committee of School of Aerospace Medicine, Fourth Military Medical University, China.

Materials and procedure

A total of subjects were primed with either faces or combination of English letters. In each contextual priming condition, there were two types of stimuli, the priming stimuli and the ambiguous stimuli ('Pin' as schematic faces in Face priming, as Eng-O in English letters priming). At first, half of participants were instructed verbally to complete face pair matching task before the formal test. Then 48 pairs of photographic faces with two orientations (24 upright and 24 inverted images) were presented randomly to prime participants to recognize the following 48 pairs of ambiguous stimuli as schematic faces. Subjects were required to judge whether the pairs of faces were identical or not by pressing the 'A' (same) or 'L' (different) key (keys were counterbalanced across subjects). These 48 pairs of photographic faces and 48 pairs of schematic faces were different in terms of changes of configural information. Half a minute later, another 48 pairs of photographic faces and 48 pairs of schematic faces were presented to subjects in which featural information of faces was changed (orders of presence of configural or featural information were also counterbalanced across subjects). One month later, the English letters priming was performed by these participants who were induced verbally to complete the pair matching tasks of English letters. 96 pairs of English letters (48 pairs of English letters X and 48 pairs of English letters O) with configural difference were followed by 96 pairs with variation of features (see Figure 2). Similarly, the other half of subjects were primed with English letters first, and then with faces one month later.

Concerning the variation of configural information, a gray-scale picture of schematic face (original image), for example, was modified to create another three facial images, one by moving the eyes 6 pixels apart and moving the mouth up 6 pixels (A), another by moving the eyes apart 6 pixels only (B), and the third by moving the mouth up 6 pixels (C). Then the original schematic face was paired either with itself or with another 3 newly created facial images so as to make 24 upright pairs of schematic faces (12 same vs. 12 different). Finally, the inverted pairs of schematic faces were made by turning the 24 upright pairs up-side down. A similar procedure was used to create 48 pairs of the photographic faces. To sum up, subjects in the faces priming would be presented with a total of 96 pairs of stimuli: 48 pairs of photographic faces and 48 pairs of schematic faces; 48 inverted pairs and 48 upright pairs; 48 identical pairs and 48 different

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pairs (see Table 1). The English letters priming were just dealt with in the same way. With regard to the processing of featural information in faces priming, for instance, another three gray-scale schematic faces for pairing were made by thickening eye lines or/and the mouth line. We just thickened the lines from inside so as to keep the metric distance between features.

All pairs of stimuli, measured 354 pixels×595 pixels, were presented on a black background, centered on a computer screen 60 cm in front of the participants. A central cross on the screen between stimuli helped subjects maintain fixation. Subjects were required to respond as accurately as possible, and performed a practice before the formal task.

Data analysis

Accuracy and reaction time (RTs) were recorded (accuracy was measured in terms of percent correct responses) for each task, and they were analyzed by Repeated-measures ANOVAs using Greenhouse-Geisser degrees of freedom. Post hoc *t* tests were performed when necessary. When the configural information was processed, between-subjects factor was the Orders of priming presentation (2 levels, from Faces to English letters vs. From English letters to Faces), and within subjects factors were Types of priming (2 levels, Faces priming vs. English letters priming), Types of stimuli (Priming stimuli vs. Ambiguous stimuli), and Orientations (2 levels, Inverted and Upright). Data were analyzed similarly during the processing of featural information.

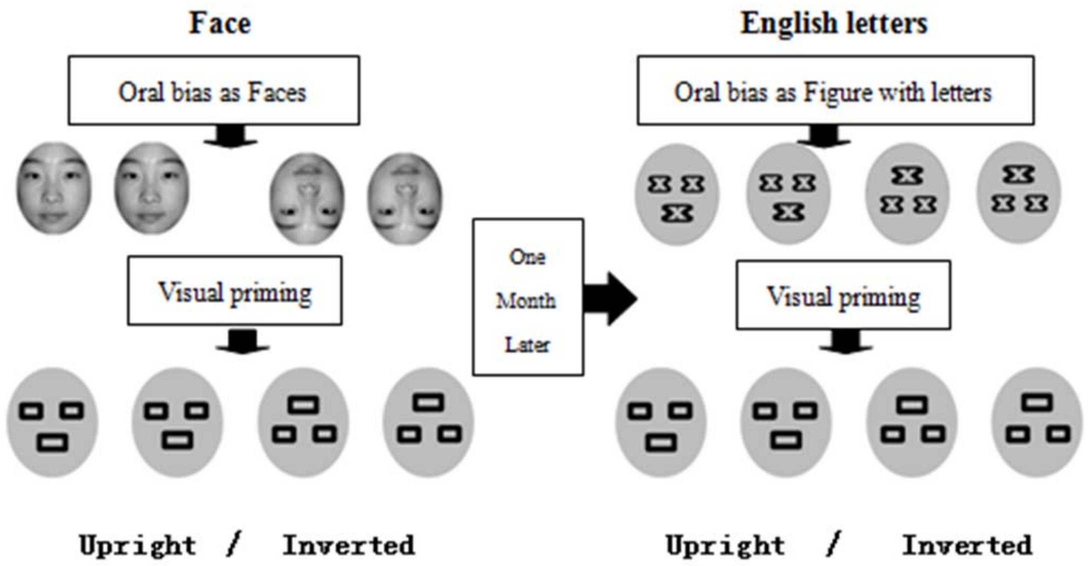

Figure 2: The process of matching in Face and English letters contextual priming

Table 1: The number of the pairs of stimuli in Face

Type	Orientation	Judgment	Pairs of stimuli
PFace (48)	Upright (24)	Same (12)	OO×3, AA×3, BB×3, CC×3
		Different (12)	OA×2, OB×2, OC×2, AB×2, AC×2, BC×2
	Inverted (24)	Same (12)	OO×3, AA×3, BB×3, CC×3
		Different (12)	OA×2, OB×2, OC×2, AB×2, AC×2, BC×2
SFace (48)	Upright (24)	Same (12)	OO×3, AA×3, BB×3, CC×3
		Different (12)	OA×2, OB×2, OC×2, AB×2, AC×2, BC×2
	Inverted (24)	Same (12)	OO×3, AA×3, BB×3, CC×3
		Different (12)	OA×2, OB×2, OC×2, AB×2, AC×2, BC×2

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RESULTS

Accuracy in processing of configural information

There were significant main effects of Orientation ($F_{1, 14}$=8.51, *p*=0.011), Types of stimuli ($F_{1, 14}$=4.66, *p*=0.048), an interaction between Types of Priming and Orientation ($F_{1, 14}$=17.96, *p*=0.00083), and an interaction between Types of priming and Types of stimuli ($F_{1, 14}$=6.06, *p*=0.027). Post hoc *t* test revealed there were significant differences of accuracy between upright and inverted stimuli in photographic faces (*p*=0.05) and schematic faces (*p*<0.01). However, in English letters priming, there was no statistical difference of accuracy between upright and inverted English letter X (*p*>0.05), neither was English letter O (*p*>0.05) (see Table 2).

Reaction time in processing of configural information

There were main effects of Types of priming ($F_{1, 14}$=9.43; *p*=0.0083) and Orientation ($F_{1, 14}$=27.94; *p*=0.00012), and there was an interaction between Types of priming and Orientation ($F_{1, 14}$=47.35; *p*=0.000008). Post hoc *t* test revealed recognition of photographic faces and schematic faces were both retarded by inversion (*p*<0.01). Nevertheless, such delay was not observed in English letters X or English letters O (*p*>0.1) (see Table 2).

Accuracy in processing of featural information

The main effect of Types of stimuli ($F_{1, 14}$=8.06, *p*=0.013) and an interaction between Types of Priming and Types of Stimuli ($F_{1, 14}$=4.81; *p*=0.045) were statistically significant. Further tests demonstrated that the changes of accuracy were independent of orientation in both Faces and English letters Priming (*p*>0.05) (see Table 3).

Reaction time in processing of featural information

There was only a significant main effect of Types of Priming ($F_{1, 14}$=7.70; *p*=0.015). Reaction time for Faces was longer than English letters (3062.2 ms vs. 2510.3 ms, *p*<0.05). However, the changes of reaction time were independent of orientation in both Face and English letters Priming (*p*>0.05) (see Table 3).

Table 2: Mean percent correct responses and RTs (and S.D.) of configural processing in Face and English letters priming

Type	Orientation	Accuracy (%)		Reaction time (ms)	
		Face	English letters	Face	English letters
Priming stimuli	Upright Inverted	92.41±8.20 85.29±9.06	88.80 ±6.76 91.67 ±6.27	2998.33±544.02* 3720.40±607.71*	3016.40±1195.37 2971.67±1065.61
Comparison Stimuli	Upright Inverted	89.43±9.98* 79.03±10.53*	91.15±5.24 91.41±8.26	2750.87±867.13* 3521.80±1038.20*	3102.13±758.32 3145.27±747.07

* P < 0.01

Table 3: Mean percent correct responses and RTs (and S.D.) of featural processing in Face and English letters priming

Type	Orientation	Accuracy (%)		Reaction time (ms)	
		Face	English letters	Face	English letters
Priming stimuli	Upright Inverted	95.05±6.84 96.61±3.79	96.06 ±4.62 95.31 ±5.46	2918.69±447.75 3092.19±519.79	2281.24±732.48 2298.71±809.82
Comparison Stimuli	Upright Inverted	94.01±7.75 93.97±6.63	89.58±8.61 88.80±6.03	3080.87±712.52 3156.88±436.92	2754.84±831.28 2706.24±929.52

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Speed-accuracy trade-off

Speed-accuracy trade-off was measured by correlating accuracy with RTs. In processing of configural information, all correlations but two were positive, ranging from 0.063 to 0.399, but no correlations reached statistical significance. In processing of featural information, no correlations but three were positive, ranging from 0.021-0.418, and none of them reached statistical significance (see Table 4).

EXPERIMENT 2

CHINESE CHARACTERS VS. ENGLISH LETTERS PRIMING

MATERIALS AND METHODS

Participants

16 Chinese male undergraduate students in medical school (all Chinese native speakers, mean age 21.2 years, range 19-24) participated in the experiment, with the same inclusion criteria as experiment 1.

Materials and procedure

The procedure in experiment 2 was almost identical with that of experiment 1 except that subjects in this experiment were primed with Chinese characters in comparison with faces in experiment 1 (see Figure 3). It is noteworthy in the ambiguous stimuli that the upright Chinese character 'Pin' (品) was induced to be recognized as an inverted schematic face in faces priming.

Table 4: Spearman correlations between accuracy and RTs in configural and featural processing (r, n=16) in Faces and English Letters priming

Condition	Configural			Featural	
	Comparison Stimuli	Priming Stimuli		Comparison Stimuli	Priming Stimuli
Inverted Faces	0.160	0.063		-0.090	0.418
Upright Faces	0.215	0.148		-0.021	-0.084
Inverted English letters	-0.189	0.339		0.045	0.093
Upright English letters	-0.153	0.399		0.218	0.131

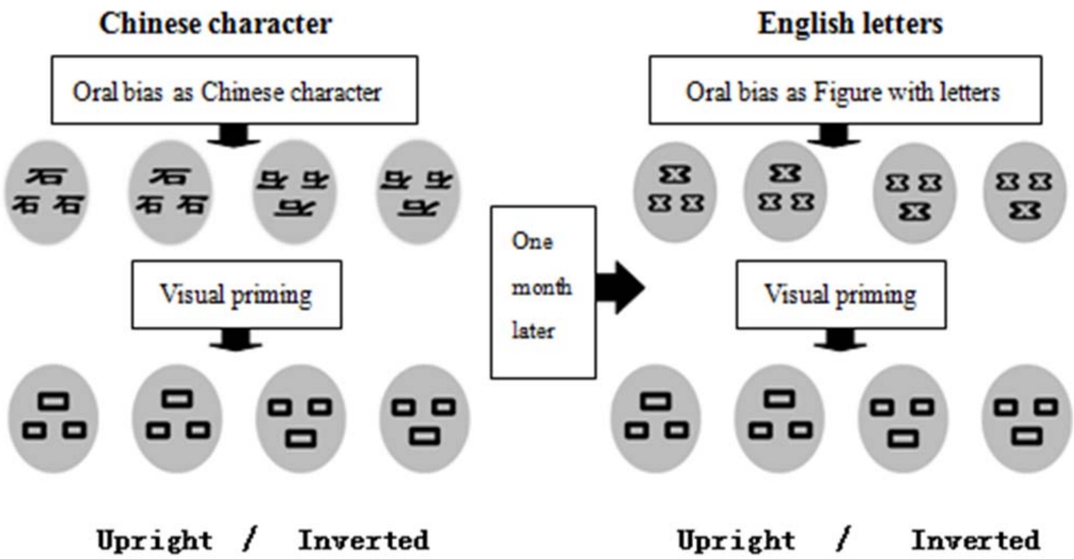

Figure 3: The process of matching in Chinese character and English letters contextual priming

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Data analysis

Accuracy and reaction time (RTs) were also recorded for each task, and the same statistical measure was repeated as the measure mentioned in experiment 1.

RESULTS

Accuracy in processing of configural information

There were main effects of Types of stimuli ($F_{1, 14}$=4.15; p=0.061) and Orientation ($F_{1, 14}$=18.87; p=0.00067), and there was an interaction between Types of priming and Orientation ($F_{1, 14}$=15.41; p=0.0015). Further test indicated that subjects responded more accurately to upright Chinese character Lei/Pin than inverted Chinese character Lei/Pin in Chinese characters priming (p<0.05) (see Table 5), while there was no statistical difference of accuracy between upright and inverted English letter X / O (p>0.05) (see Table 5).

Reaction time in the processing of configural information

The main effect of Orientation ($F_{1, 14}$=8.015; p=0.013) was significant, so was an interaction among Types of Stimuli, Types of priming, and Orientation ($F_{1, 14}$=7.24; p=0.018). Post hoc t test was indicative of the fact that responses to Chinese character Lei and Pin were both delayed by inversion effect (p<0.01). By comparison, the recognition of English letters X or O were uninfluenced by inversion (p>0.05) (see Table 5).

Accuracy in processing of featural information

There was only an interaction between orders of priming presentation and Orientation ($F_{1, 14}$=4.26; p=0.058). The changes of accuracy were independent of orientation in both Chinese character and English letters priming (see Table 6).

Reaction time in the processing of featural information

No significant main effect or interaction was found, and further analysis suggested that no changes of reaction time were observed when the stimuli were turned upside down (p>0.05) (see Table 6).

Table 5: Mean percent correct responses and RTs (and S.D.) of configural processing in Chinese character and English letters priming

Type	Orientation	Accuracy (%)		Reaction time (ms)	
		Chinese character	English letters	Chinese character	English letters
Priming stimuli	Upright Inverted	92.88±5.73* 86.73±6.73*	92.44 ±7.33 92.45 ±8.77	2961.87±530.38** 3342.57±532.71**	2924.84±502.24 3064.95±531.94
Comparison Stimuli	Upright Inverted	91.14±8.85* 85.05±7.93*	90.88±10.01 90.36±8.96	3080.24±635.77** 3272.40±645.98**	2988.63±579.25 2991.08±458.16

* P < 0.05, ** P < 0.01

Table 6: Mean percent correct responses and RTs (and S.D.) of featural processing in Chinese character and English letters priming

Type	Orientation	Accuracy (%)		Reaction time (ms)	
		Chinese character	English letters	Chinese character	English letters
Priming stimuli	Upright Inverted	92.96±8.01 92.45±6.31	91.87 ±8.53 92.66 ±7.83	2452.94±634.48 2311.73±552.84	2449.03±530.96 2392.10±748.39
Comparison Stimuli	Upright Inverted	91.15±8.03 92.19±8.18	92.34±7.32 82.71±8.64	2459.41±676.19 2479.82±648.06	2474.03±442.59 2478.10±573.33

Speed-accuracy trade-off

In processing of configural information, all correlations ranged from 0.006-0.452, and they failed to reach statistical significance. In processing of featural information, no correlations reached statistical significance, ranging from 0.056-0.473 (see Table 7).

DISCUSSION

Priming effect and configural information processing

When the identical, ambiguous, and undefined stimuli in the present study were processed in Faces group and Chinese characters group, the presence of inversion effect in the faces / Chinese characters priming and the absence of such effect in the English letters priming testified the contextual priming effect, especially in the processing of configural information. Notably, the presence of inversion effect in processing of configural information and the absence of that in processing of featural information reinforced the direct evidence that inversion effect is related to the processing of configural information other than featural information after face-expertise or Chinese character-expertise mechanisms are activated. Additionally, it could be found that the contextual activation of specific perceptual system plays a crucial role in the processing of visual stimuli, for example, only oral bias is sufficient to elicit a priming effect (Bentin et al., 2000). In conclusion, the present findings suggested that configuration information processing alone was insufficient to account for effect of inversion, and inversion effect of faces and Chinese characters should be attributed not only to the processing of configural information but also to top-down priming effect.

Further, Bentin et al. (2002) argue that two types of mechanisms can account for the priming effect---conceptual priming and perceptual priming. Logically, general perceptual mechanisms would be adopted to process the undefined stimuli. It was notable that the visual feature of the ambiguous stimuli, responding modes, and procedures were carefully controlled, which ensured that the salientness and task performance were comparable across different priming. So the difference among these priming only reflected the distinctive activation of processing mechanism. In English letters priming, the ambiguous stimuli were induced to be referred to as the unmeaning combination of three English letters O. Subjects were encouraged to process these stimuli as novices, and no specific networks could be activated in such contextual condition. By comparison, Chinese subjects were experts at processing faces as well as Chinese characters. As we know, facial stimuli activate the occipito-temporal cortex (posterior and middle fusiform gyrus), with a right hemisphere advantage (Hasson et al., 2002; Rossion et al., 2003; Anaki et al., 2007). Similarly, a specific network is also activated when individuals process Chinese characters (Chen et al., 2002), and the left lateralization pattern for words has been confirmed in most cases (Polk and Farah, 2002; Dehaene et al., 2002; Tarkiainen et al., 2002).

Table 7: Spearman correlations between accuracy and RTs in configural and featural processing (r, n=16) in Chinese characters and English Letters priming

Condition	Configural		Featural	
	Comparison Stimuli	Priming Stimuli	Comparison Stimuli	Priming Stimuli
Inverted Chinese character	-0.452	-0.145	-0.473	-0.056
Upright Chinese character	-0.344	-0.270	-0.441	-0.041
Inverted English letters	0.006	-0.029	0.056	0.070
Upright English letters	0.346	0.133	0.302	0.468

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So when the ambiguous stimuli were primed to be interpreted as faces or Chinese characters, face-specific or Chinese character-specific perceptual processes should be triggered. So to speak, the results seemed to corroborate the fact that inversion effect should be correlated with expertise closely.

Inversion effect and expertise

Inversion effect of ambiguous stimuli observed in the Chinese characters priming was distinct from that induced in the faces priming, and such effect of inversion in Chinese characters group couldn't be attributed to the recruitment of face-specific mechanisms mentioned above, which justified the explanation of inversion effect by expertise.

As Diamond and Carey (1986) found, the effort of long term experience in discriminating within a stimulus class would lead to inversion effect. They proposed three prerequisites for a disproportionate effect of stimulus inversion to occur. The prerequisites indicated that the inversion effect upon face recognition should not be considered as the evidence of a process unique to face recognition. On the contrary, it demonstrated that the recognition of any extremely familiar stimuli with a common configuration would show the inversion effect. As a matter of fact, there is little reported effect of inversion in other non-face objects. The advocators of expertise also argued that such non-face objects as Houses were unfit for acting as comparison stimuli in this manner (Valentine, 1988). To further investigate the expertise theory, the key point was to find an ideal stimulus class that was of equal familiarity, psychological significance and similar visual properties (e.g. complexity, symmetry) to faces. It is proved extremely difficult to find favorable stimuli, because faces are a unique class of visual stimuli. People have extensive and long-term experience with faces. The facial images are seen far more frequently upright than inverted. By adulthood, people have become experts at processing faces at an extremely high level of proficiency. Fortunately for us, comparable to faces, Chinese characters could be ideal comparison stimuli because of their ecologically similarity. Literate Chinese adults are experts at identifying thousands of Chinese characters from early childhood. Considering the hardship to possess a special form of visual expertise, it demands the course of many years of extensive experience, training, much intensity and even the substantial social burden (Busey and Vanderkolk, 2005).

The present findings confirmed our prediction and indicated that, when inversion effect of the identical undefined stimuli were triggered not only in the faces priming but also in the Chinese characters priming, the two types of inversion effect were not similar but opposite to each other. Therefore, such possibility should be excluded that explanation of so called 'facelike stimuli' account for the inversion effect in Chinese characters priming. Generally speaking, if face-specific mechanisms were activated in Chinese characters priming, it should lead to completely same inversion effect as that of faces. What's more, it is noticeable that perception of visual words and pseudowords reliably activates areas restricted to the left lateral fusiform gyrus and occipitotemporal sulcus (Hasson et al., 2002; Polk et al., 2002), which is different from the location of face-expertise system.

As accumulative studies of perceptual expertise were initially motivated by the domain-specificity dispute, namely, whether the mechanisms underlying face recognition are domain specific or domain general (Bosbach et al., 2006). The inherent distinction of activation between faces and words mentioned above, along with the opposite inversion effects between faces and Chinese characters in the present study, allowed us to hypothesize that the mechanisms of the two expertise systems may originate from different domains, which demand further studies in the future.

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