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Research Article

Not All Visual Expertise Is Holistic, but It May Be Leftist

The Case of Chinese Character Recognition

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ABSTRACT—*We examined whether two purportedly face-specific effects, holistic processing and the left-side bias, can also be observed in expert-level processing of Chinese characters, which are logographic and share many properties with faces. Non-Chinese readers (novices) perceived these characters more holistically than Chinese readers (experts). Chinese readers had a better awareness of the components of characters, which were not clearly separable to novices. This finding suggests that holistic processing is not a marker of general visual expertise; rather, holistic processing depends on the features of the stimuli and the tasks typically performed on them. In contrast, results for the left-side bias were similar to those obtained in studies of face perception. Chinese readers exhibited a left-side bias in the perception of mirror-symmetric characters, whereas novices did not; this effect was also reflected in eye fixations. Thus, the left-side bias may be a marker of visual expertise.*

People have extensive exposure to faces beginning at birth. As a result, all people are experts in face recognition. Researchers have identified several behavioral markers of expertise in face processing, such as holistic processing, although it remains controversial whether these effects are expertise markers that apply to both faces and objects (e.g., Bukach, Gauthier, & Tarr, 2006; Gauthier & Bukach, 2007) or only to faces (e.g., McKone, Kanwisher, & Duchaine, 2007; McKone & Robbins, 2007; Robbins & McKone, 2007). People also have extensive exposure to words, although in this case the exposure begins slightly later, in childhood. Nevertheless, it remains unclear whether the markers of expertise found for face processing also are markers of expertise in visual word processing. Unlike faces, words in alphabetic languages, such as English, do not have a homogeneous configuration, and word processing relies on identifying the serial order of a restricted set of letters that form combinations of varying length (Wong & Gauthier, 2006). These differences make direct comparison between face processing and English word processing difficult.

In contrast, Chinese orthography is a logographic writing system, in which graphemes, rather than series of letters, represent words. Characters can be regarded as the perceptual units of the orthography. They consist of individual strokes, and combinations of strokes compose individual stroke patterns, which are the recurrent constituent units of characters. The stroke patterns stack in several different formats to form different characters (see Fig. 1). There are more than a thousand stroke patterns in Chinese orthography (Hsiao & Shillcock, 2006), and unlike letters in English words, these stroke patterns do not usually correspond to particular phonemes. To recognize a character, Chinese readers have to identify its constituent stroke patterns, which may look like an integral whole to non-Chinese readers. It has been shown that these stroke patterns are indeed the smallest functional units in Chinese character recognition (Chen, Allport, & Marshall, 1996).

Chinese characters share many properties with faces (McCleery et al., 2008). Like faces, they must be recognized at the individual level; research on expertise in reading Chinese characters has shown that experts' recognition is quicker at the individual character level than at the font level (subordinate; i.e., recognizing the font of a character) or at the lexical (superordinate) level (e.g., recognizing whether the stimulus is a Chinese character or an English word). This suggests that the individual character is the entry level for Chinese character

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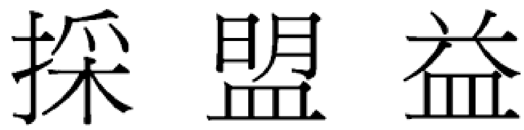

Fig. 1. Examples of Chinese characters with different configurations: left-right configuration (left), top-bottom configuration (middle), and mirror-symmetric configuration (right).

recognition in experts (Wong & Gauthier, 2006).[1] Literate Chinese must know 3,000 to 4,000 characters. Characters have a homogeneous shape (square) and a canonical, upright orientation. Some characters have a mirror-symmetric configuration, as faces do. For Chinese readers, characters are highly learned, and must be recognized regardless of font variation (much as faces must be identified regardless of their specific expressions). Featural information is also critical for character recognition.

However, there are also some differences between face and character recognition. For example, configural information, which has been shown to be important for face processing, is not important for character recognition (Ge, Wang, McCleery, & Lee, 2006); Chinese readers have to pay attention to the relationships among stroke patterns while deemphasizing their exact spacing in order to recognize characters efficiently. In addition, although every adult has ample experience in face processing, not every adult has experience in reading Chinese characters. Therefore, it is possible to directly compare adult experts and novices by comparing native readers and nonreaders. Such examinations will enable researchers to identify markers of expertise. In the study reported here, we examined two face-expertise effects, holistic processing and left-side bias, to determine whether they also characterize expertise in Chinese character recognition.

HOLISTIC PROCESSING

We used the complete composite paradigm to examine holistic-processing effects (Gauthier & Bukach, 2007). In this paradigm, two stimuli are presented briefly, either sequentially or simultaneously. Participants are told to attend to either the top or the bottom halves of the stimuli and judge whether they are the same or different. In congruent trials, the attended and irrelevant halves lead to the same response (i.e., both are the same or both are different). In incongruent trials, the attended and irrelevant halves lead to different responses. Holistic processing is indicated by interference from the irrelevant halves in matching the attended halves; it can be assessed by the performance difference between congruent and incongruent trials (i.e., a congruency effect; Fig. 2a).[2] If holistic processing is a marker of expertise, the effect should be observed among experts, but not novices.

[1]What the basic level of word recognition is remains controversial. Rosch (1978) proposed that the basic level of categorization is the level at which objects show the most increase in shape similarity. Wong and Gauthier (2006) thus defined individual letters as structural basic-level categories (e.g., letter "K" category) because different letters do not share structural parts. In Chinese character recognition, characters with the same specific structure (e.g., top-bottom structure; see Fig. 1) may be considered to belong to the same basic-level category.

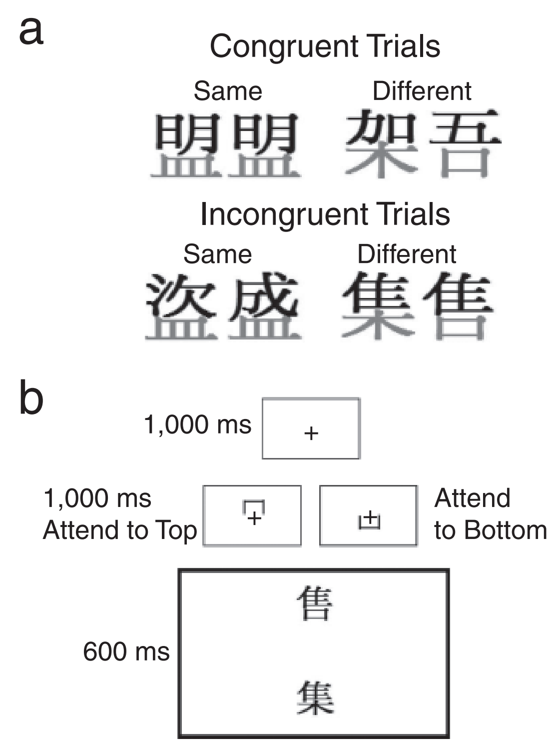

Fig. 2. Illustration of the stimulus pairs in the complete composite paradigm (a) and the trial sequence (b). In (a), gray shading indicates the components to be attended; in this illustration, the attended halves are the bottom halves, but in the experiment, the top and bottom halves were attended equally often. Each trial (b) started with a 1,000-ms central fixation cross, which was followed by a cue either above or below the cross. The location of the cue indicated whether participants should attend to the top or bottom halves of the characters that were presented in the following display.

Method

Materials

The materials consisted of 80 pairs of Chinese characters that have a top-bottom configuration (i.e., characters that can be horizontally divided into two components; see the middle example in Fig. 1). Twenty of these pairs were presented in each of the four conditions illustrated in Figure 2a. We selected characters such that each pair of components to be attended and compared appeared in one congruent and one incongruent trial (Fig. 2a shows two examples). All the characters used were existing characters of medium to high frequency (Huang, 1994). Frequency did not differ significantly between the characters used in the congruent trials and the characters used in the in-

[2]This design avoids response-bias effects that can lead to incorrect conclusions in the partial composite design, in which the irrelevant halves are always different (Robbins & McKone, 2007).

congruent trials (as determined by t test). The characters were presented in Ming font.

Participants

We recruited 8 male and 8 female native Chinese readers from Taiwan (i.e., international students) as experts, and 8 male and 8 female participants who did not have any experience in any Asian languages as novices. They were all students at the University of California, San Diego (mean age = 25 years 3 months). All were right-handed, according to the Edinburgh handedness inventory (Oldfield, 1971), and had normal or corrected-to-normal vision. They participated for course credit or received a small honorarium for their participation.

Design

The design had a within-subjects variable, congruency (congruent vs. incongruent), and a between-subjects variable, expertise (expert vs. novice). The dependent variable was discrimination performance measured by A', a bias-free nonparametric measure of sensitivity. The value of A' varies from .5 to 1.0; a higher value indicates better discrimination. Unlike d', A' can be computed when cells with zero responses are present.[3]

Procedure

In each trial, after 1,000 ms of central fixation, participants were cued with a symbol indicating which half (top or bottom) of each character they should attend to in making the same/different judgment (Fig. 2b); the two characters were then presented above and below the initial fixation, respectively, about 5° of visual angle away from each other. Each character subtended about 1.5° of visual angle. Participants were told to look at each character once during the 600-ms presentation time (cf. Robbins & McKone, 2007) and to respond as quickly and accurately as possible by pressing the button indicating their judgment. Before the experiment, they performed a practice session with characters not used in the experiment proper.

Results

The results showed a congruency effect among the novices, $F(1, 15) = 10.667$, $p = .005$, $p_{\text{rep}} = .966$, $\eta_p^2 = .416$, but not the experts; the interaction between expertise and congruency was significant, $F(1, 30) = 4.774$, $p < .05$, $p_{\text{rep}} = .897$, $\eta_p^2 = .137$ (Fig. 3). This finding shows that novices perceive Chinese characters more holistically than experts, and suggests that holistic processing is not a marker of expertise. Compared with non-Chinese readers, Chinese readers have a better awareness of character components; thus, it is easier for them to attend to specific parts of characters. In contrast, non-Chinese readers may have difficulty separating the components and tend to group them according to similarity or continuity of features.

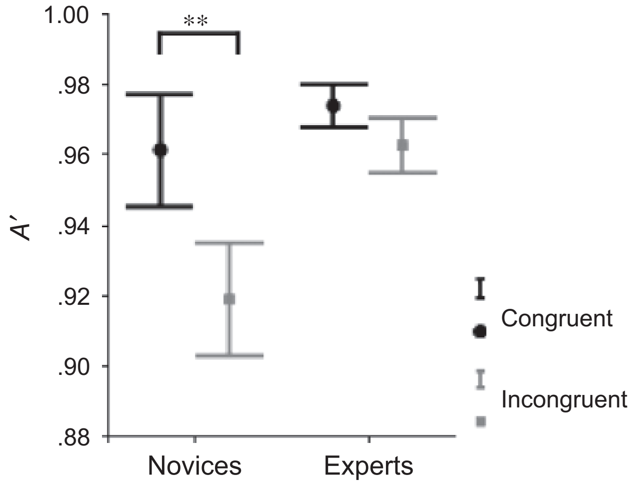

Fig. 3. Results from the first holistic-processing experiment: experts' and novices' discrimination performance on congruent and incongruent trials. Asterisks indicate a significant congruency effect, $p < .01$. Error bars show standard errors.

Our results could have been due to a ceiling effect, as the experts had a very high A' (average = .978). To eliminate this possibility, we conducted a follow-up experiment, in which we aimed to bring the experts' performance down to the level of the novices' performance in the first experiment. We made the task harder by reducing the contrast level of the stimuli and shortening the presentation time to 500 ms. We also split the characters with a red horizontal line (Fig. 4) to match previous experiments with faces and objects (e.g., Robbins & McKone, 2007). In addition, we included misaligned- and inverted-character conditions (Fig. 4): If the holistic-processing effect in novices is indeed due to interference from the irrelevant halves, the effect should be reduced by misalignment; if the absence of the holistic-processing effect in experts is indeed due to their expertise, experts should become like novices when characters are inverted and process them holistically.

For the follow-up experiment, we recruited 7 male and 8 female experts, and 7 male and 8 female novices. All were

Fig. 4. Examples of the stimulus pairs in the three conditions of the follow-up holistic-processing experiment: upright (aligned), misaligned, and inverted. The horizontal lines shown here in gray were red in the experiment.

[3] A' is calculated as follows:

$$A' = 0.5 + \left[sign(H - F) \frac{(H - F)^2 + |H - F|}{4\max(H, F) - 4HF} \right],$$

where H and F are the hit rate and false alarm rate, respectively. The d' measure may be affected by response bias when assumptions of normality and equal standard deviations are not met (Stanislaw & Todorov, 1999). In this experiment, novices had a bias toward "same" responses ($p = .07$). In a follow-up experiment (see Results), novices also had this bias ($p < .01$ for all conditions), and experts had this bias only with inverted characters ($p = .02$).

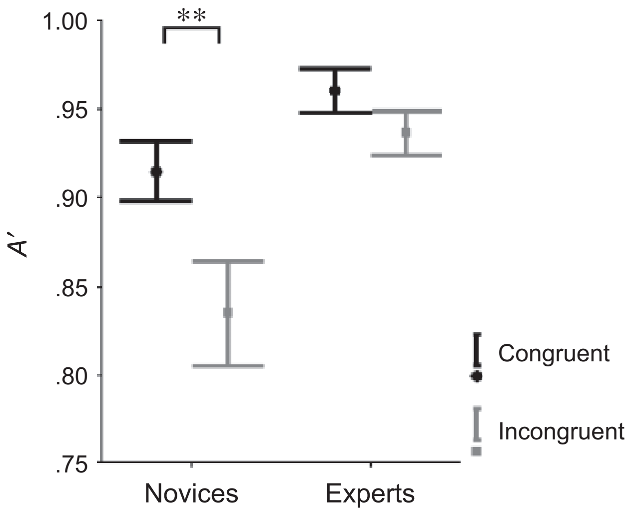

Fig. 5. Results from the upright-character condition in the follow-up holistic-processing experiment: experts' and novices' discrimination performance on congruent and incongruent trials. Asterisks indicate a significant congruency effect, $p < .01$. Error bars show standard errors.

students at the University of California, San Diego (mean age = 24 years 7 months), were right-handed, and had normal or corrected-to-normal vision. The design and procedure were the same as in the first experiment. Each participant performed three experimental blocks: upright, misaligned, and inverted; the order of the blocks was counterbalanced across participants.

The results with upright characters again showed a significant interaction between expertise and congruency, $F(1, 28) = 4.602, p < .05, p_{rep} = .891, \eta_p^2 = .141$ (Fig. 5). The congruency effect was evident among the novices, $F(1, 14) = 12.526, p = .003, p_{rep} = .974, \eta_p^2 = .472$, but not the experts, even though the experts' performance decreased to about the level of the novices' performance in the first experiment; that is, the experts' average A' decreased from .978 to .948 (an A' value of .95 indicates about 90% accuracy); the novices had a larger drop: from .940 to .875. The results from this condition suggest that the absence of a congruency effect among the experts in the first experiment was unlikely to have been due simply to a ceiling effect.

The results also showed that misalignment significantly reduced the congruency effect among the novices; there was a significant interaction between congruency and misalignment (aligned vs. misaligned), $F(1, 14) = 4.909, p < .05, p_{rep} = .886, \eta_p^2 = .260$. There was no misalignment effect among the experts (Fig. 6). In contrast, inversion led to a congruency effect among the experts; there was a significant interaction between congruency and inversion (upright vs. inverted), $F(1, 14) = 5.517, p < .05, p_{rep} = .902, \eta_p^2 = .283$. There was no inversion effect among the novices (Fig. 7). These results confirm that the observed congruency effect was due to the inability of novices to selectively attend to character parts.

LEFT-SIDE BIAS

In face perception, a left-side bias has been reported consistently: A chimeric face made from two left half-faces from the viewer's perspective is usually judged more similar to the original face than is a chimeric face made from two right half-faces (Brady, Campbell, & Flaherty, 2005; Gilbert & Bakan, 1973; see Fig. 8a). It has been argued that this phenomenon is an indicator of right-hemisphere (RH) involvement in face perception (Burt & Perrett, 1997). Studies examining eye movements in face processing also have shown a preference to look at the left side of the gaze field (e.g., Butler et al., 2005; Everdell, Marsh, Yurick, Munhall, & Paré, 2007; Hsiao & Cottrell, 2008; Mertens, Siegmund, & Grusser, 1993) and an initial saccade bias, mostly to the left, for viewing faces (Leonards & Scott-Samuel, 2005). These effects have never been observed in the perception of other types of objects.

We examined whether a left-side bias can also be observed in Chinese character perception. The materials consisted of mir-

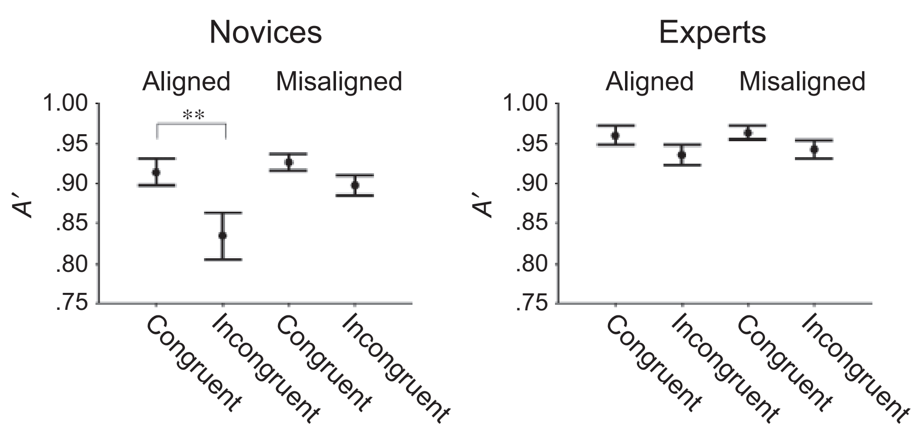

Fig. 6. Effects of alignment in the follow-up holistic-processing experiment. Experts' and novices' discrimination performance on congruent and incongruent trials is shown separately for the upright (aligned) and misaligned conditions. Asterisks indicate a significant congruency effect, $p < .01$. Error bars show standard errors.

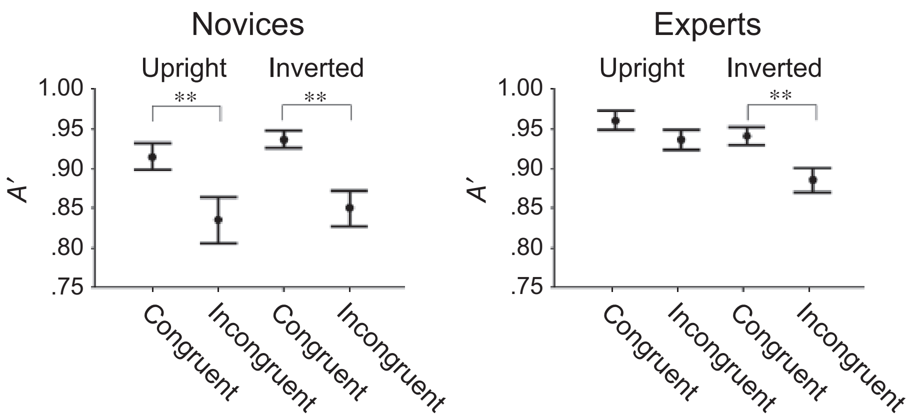

Fig. 7. Effects of inversion in the follow-up holistic-processing experiment. Experts' and novices' discrimination performance on congruent and incongruent trials is shown separately for the upright and inverted conditions. Asterisks indicate a significant congruency effect, $p < .01$. Error bars show standard errors.

ror-symmetric characters in the most common fonts (Ming and Kai). Much like faces, these characters are symmetric in configuration, but have some asymmetric features due to the shapes of strokes. Thus, we were able to create chimeric characters in the same fashion as chimeric faces are created (Fig. 8b). We presented these chimeric characters to both Chinese and non-Chinese readers and asked them to judge whether chimeric characters made from two left half-characters or chimeric characters made from two right half-characters looked more similar to the original characters (Fig. 8c).

Method

Materials

We selected 30 Chinese mirror-symmetric characters (see the example on the right in Fig. 1) for use in this experiment; all were high-frequency characters according to Huang (1994). Each character was presented twice, in Ming and Kai fonts, respectively; in total, there were 60 trials. To counterbalance the differences between the two sides of the characters, we presented the mirror-images of the original stimuli in half of the trials; if a character was presented in Ming font in its original form, it was presented in its mirror-image form in Kai font, and vice versa. For each character, the font used for the original and the font used for the mirror image were counterbalanced across participants. In each trial, a character stimulus was presented together with its corresponding chimeric characters (Fig. 8b).

Participants

We recruited 14 male and 14 female native Chinese readers from Taiwan as experts, and another 14 male and 14 female participants who do not have any experience in any Asian languages as novices. They were all students at the University of California, San Diego (mean age = 25 years 4 months). All were right-handed, according to the Edinburgh handedness inventory (Oldfield, 1971), and had normal or corrected-to-normal vision. They participated for course credit or received a small honorarium for their participation.

Design

The design had a between-subjects variable: expertise (expert vs. novice). The dependent variable was preference for the left chimeric character (i.e., the character created from two left halves of an original character), defined as the number of trials on which the left chimeric character was judged more similar to the original character, divided by the total number of trials.

Procedure

In each trial, the original character was presented next to either the left or the right edge of the screen; this position was counterbalanced across participants (cf. Brady et al., 2005; see Fig. 8c). Along with the original character, two chimeric characters (one created from two left halves of the original character and the other created from two right halves of the original character) were presented above and below the arrow, respectively; each was about 2.5° of visual angle away from the center and subtended about 1.5° of visual angle. Participants were told to follow the arrow at the center of the screen to look at the original character first and then indicate which of the two chimeric characters looked more similar to the one on the side by pressing the corresponding button. The characters stayed on the screen until a response was made.

Results

The results showed a strong effect of expertise, $F(1, 56) = 14.896$, $p < .001$, $p_{\text{rep}} = .992$, $\eta_p^2 = 0.216$: The experts had a significant preference for the left chimeric character (56.7%), $F(1, 27) = 15.489$, $p = .001$, $p_{\text{rep}} = .986$, $\eta_p^2 = .365$, whereas the novices did not have a preference (48.3%; n.s.; Fig. 9). This result supports the expertise account for the left-side bias in face perception and suggests RH involvement in expertise in Chinese character recognition.

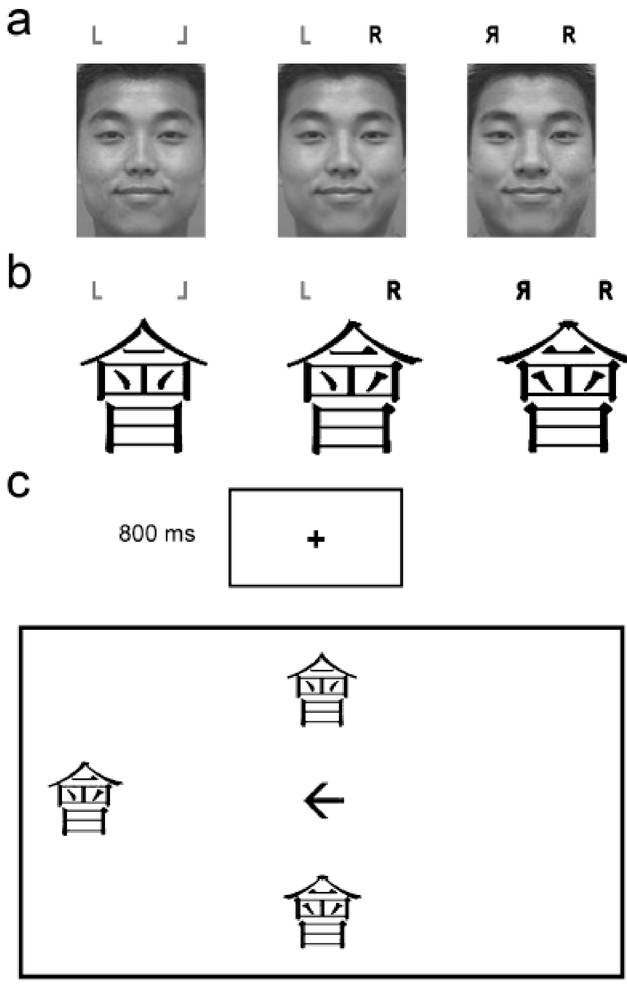

Fig. 8. Examples of chimeric stimuli and the trial sequence in the left-side-bias experiment. Left-side bias in face perception has been demonstrated using chimeric stimuli (a). Two left halves of an original face (center) are combined to form a left chimeric face, and two right halves of the face are combined to form a right chimeric face. The letters ''L'' (left) and ''R'' (right) are shown to indicate the halves that are in their original and mirror-image orientations. We tested for left-side bias in Chinese character perception using analogous chimeric characters, shown here in Ming font (b). On each trial (c), participants were shown an original character (shown here on the left of the display) and were asked to judge whether the left or the right chimeric character created from that original character (above and below the central arrow) was more similar to the original.

Previous studies had shown that the left-side bias in face perception is also reflected in eye movements (e.g., Butler et al., 2005). Thus, during the experiment, we recorded eye movements from 12 novices and 12 experts (half males and half females) using an EyeLink II eye tracker. The tracking mode was pupil only, with a sample rate of 500 Hz; the resolution was 0.01° of visual angle. A chin rest was used to reduce head movements. In data acquisition, the saccade motion threshold was 0.1° of visual angle, the saccade acceleration threshold was $8000°/s^2$, and the saccade velocity threshold was 30°/s (EyeLink II defaults for cognitive research). The standard nine-point calibration procedure was administered in the beginning and repeated whenever the drift correction error was larger than 1° of visual angle. Drift correction was performed at the beginning of every trial. The data of the eye with less calibration error were used for analysis.

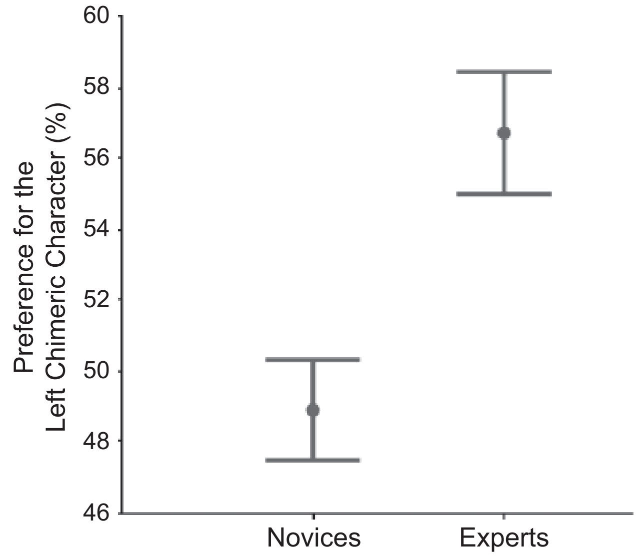

Fig. 9. Results from the left-side-bias experiment: preference for the left chimeric character in experts and novices. Error bars show standard errors.

We analyzed the fixations on the characters with a linear mixed model; the fixed factors were expertise (expert vs. novice) and character location (left, right, top, and bottom; see Fig. 8c), and the random factors were subject and image identities. The results showed a strong effect of expertise on fixation location in the x direction, $F(1, 1354.818) = 11.554, p = .001, p_{rep} = .986$: The experts' fixations were more to the left than the novices' (Fig. 10). On average, the experts' fixations shifted leftward from the center of the character about 5.6% of the whole character in pixels, $F(1, 6152.939) = 12.735, p < .001, p_{rep} = .992$, whereas the novices' fixations were shifted only about 1.5%.[4] This result again suggests that the left-side bias is related to visual expertise.

DISCUSSION

We examined whether holistic processing and the left-side bias observed in face processing can also be observed in expert-level Chinese character processing. We have shown that novices process Chinese characters more holistically than experts; this result suggests that holistic processing is not a marker of general

[4]The novices' fixations were also very slightly away from the center (p = .018), which may reflect pseudoneglect: Right-handed subjects systematically tend to bisect lines to the left of the center (Bowers & Heilman, 1980). This pseudoneglect effect has often been linked to stronger activation of the right than the left hemisphere in response to the visuospatial nature of a task (Vingiano, 1991).

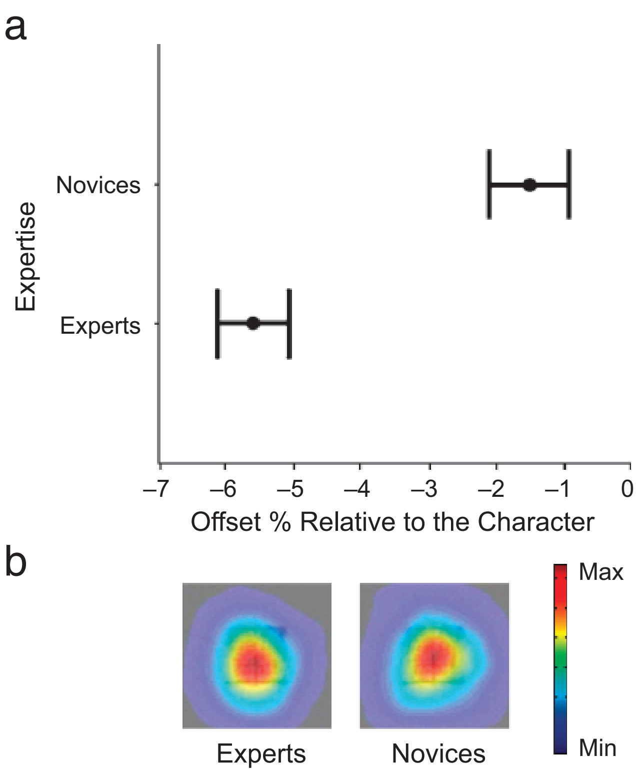

Fig. 10. Eye movements in the left-side-bias experiment. The graph (a) shows experts' and novices' mean eye fixations relative to the center of the characters. Error bars show standard errors. The color illustrations (b) show the relative distribution of fixations (from minimum to maximum density) across the spatial area where the characters were displayed (collapsed over the four character locations on the screen). Fixation locations from all trials and from all subjects were combined for the calculation of these distributions. The blurry lines in the center of each illustration portray the average of all character images presented. On each fixation, a Gaussian distribution with a standard deviation equal to eight pixels was applied to smooth the distribution (the image width is 81 pixels).

visual expertise. Hence, whether holistic processing is employed depends on the stimulus features and the task typically performed on the stimuli. Chinese characters consist of features that are not clearly separable to novices; what Chinese readers have been trained for is the ability to separate and group individual features of the characters into discernible components (Chen et al., 1996) and to ignore some configural information (e.g., relative distances between features; Ge et al., 2006). Chinese characters thus provided a unique opportunity to show reduced holistic processing in experts. This effect may be less clear in alphabetic languages, such as English, because novices can already discern the separation of letters.

We have also shown that misalignment of character halves significantly reduces holistic processing in novices; this result is consistent with the holistic-processing effect in the literature on face recognition in experts. It confirms that novices' holistic processing of Chinese characters is due to the inability to selectively attend to character parts; when the parts are misaligned, the effect is reduced because the interference from the irrelevant parts is reduced. In addition, we have shown that inversion of characters leads to holistic processing in experts; this result is also consistent with the face and object recognition literature, which shows that expert processing is tuned by experience. For example, it has been shown that the congruency effect is stronger for own-race than for other-race faces (Michel, Rossion, Han, Chung, & Caldara, 2006). In our study, experts may have had difficulty isolating and detecting constituent stroke patterns in the inverted characters; hence, the holistic-processing effect emerged. These results show that expertise in Chinese character recognition develops a skill that is opposite to the skill used in recognition of faces: the ability to perceive the stimuli less holistically. In other words, holistic processing is not a marker of general visual expertise; rather, holistic processing depends on the stimulus features and the task typically performed on the stimuli.

It has been shown that in face recognition, familiar faces induce stronger holistic-processing effects than unfamiliar faces (e.g., Harris & Aguirre, 2008); similarly, experts' reduced holistic processing of Chinese characters may also be modulated by familiarity. For example, the holistic-processing effect may reemerge in experts viewing low-frequency characters or pseudocharacters (by analogy with unfamiliar faces), rather than high-frequency characters. However, if experts' reduced holistic processing is due to familiarity with the constituent stroke patterns, the effect may be influenced by the frequency of stroke patterns, rather than characters. These issues require further examination.

Our experiment on the left-side bias in Chinese character perception showed that experts have a significantly stronger preference for the left chimeric character than novices do. Thus, the left-side bias observed in face perception is not face-specific; it is a marker of expertise in Chinese character processing. This finding also suggests RH involvement in Chinese character expertise and is consistent with the left-visual-field/RH advantage observed in Chinese orthographic processing (e.g., Tzeng, Hung, Cotton, & Wang, 1979; Yang & Cheng, 1999). RH processing has been argued to be more coarsely tuned than left-hemisphere (LH) processing (e.g., Jung-Beeman, 2005). Studies examining neural microcircuitry suggest that the cortical columns in the RH are in general more densely interconnected than those in the LH, which suggests a more functionally overlapped representation in the RH compared with the LH (e.g., Hutsler & Galuske, 2003). Behavioral data also suggest that the RH has an advantage over the LH in tasks requiring processing of low-frequency information (e.g., Ivry & Robertson, 1998). Thus, the current results suggest that the increase in processing efficiency after expertise is acquired may be due to extracting and integrating information from more functionally overlapped or low-frequency-biased representations in the RH.

Faces and Chinese characters have several fundamental differences in their features, their configurations, and the tasks typically performed on them. The left-side bias is nevertheless observed in both expert-level character perception and expert-level face perception; this suggests that this bias may be a marker of general visual expertise. This hypothesis is consistent with human functional magnetic resonance imaging studies of object processing showing that the increase in brain activity due to object-discrimination (expertise) training is larger in the RH than in the LH (e.g., Gauthier, Tarr, Anderson, Skudlarski, & Gore, 1999; Op de Beeck, Baker, DiCarlo, & Kanwisher, 2006). One exception to this relationship between RH processing and visual expertise is the classical right-visual-field/LH advantage in reading English words (e.g., Bryden & Rainey, 1963). According to the phonological mapping hypothesis (Maurer & McCandliss, 2007), the LH lateralization for word processing in alphabetic languages may be specifically related to the influence of grapheme-phoneme conversion established during learning to read. Further examination is required to determine the conditions under which visual processing will rely more on the LH than the RH representation.

We have also shown that this left-side bias in Chinese character perception is reflected in eye movements: Experts' fixations on the characters shift leftward compared with novices' fixations. This leftward bias in eye fixation has also been observed in face recognition, and it has been argued that this bias is related to the RH involvement in face processing (e.g., Hsiao & Cottrell, 2008). The current results suggest that RH processing may be important for the development of visual expertise. Because of the contralateral projection from the visual hemifields to the hemispheres, the left halves of stimuli may be constantly encoded and processed in the RH during learning (Hsiao, Shieh, & Cottrell, 2008). Thus, experts may direct their fixations more to the left, compared with novices, because the internal representation of the left stimulus-half is more informative than the internal representation of the right stimulus-half, and hence the left stimulus-half attracts their attention.

In conclusion, the current study suggests that the controversy about whether the purportedly face-specific effects are indeed face-specific or actually markers of expertise may partly be due to the confusion about what the real markers of expertise are. In Chinese character perception, holistic processing, assessed by the congruency effect in a composite paradigm, is stronger among novices than among experts, which suggests that holistic processing is stimulus and task dependent; it is not a marker of general visual expertise. In contrast, the left-side bias is observed in both face processing and expert-level Chinese character processing, but not in novice-level Chinese character processing. This suggests that the left-side bias may be a more general marker of visual expertise. Thus, the effects of visual expertise may reflect at least two components: a common component that involves an efficient coarse coding developed in the RH and a stimulus-dependent component. In face processing, features may be grouped (holistic processing) because of the homogeneous configuration of faces. In Chinese character processing, experts may show reduced holistic processing because they have learned to isolate and identify components that appear repetitively in different characters to facilitate character recognition.

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