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Visual scanning and recognition of Chinese, Caucasian, and racially ambiguous faces: Contributions from bottom-up facial physiognomic information and top-down knowledge of racial categories

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ABSTRACT

Recent studies have shown that participants use different eye movement strategies when scanning own- and other-race faces. However, it is unclear (1) whether this effect is related to face recognition performance, and (2) to what extent this effect is influenced by top-down or bottom-up facial information. In the present study, Chinese participants performed a face recognition task with Chinese, Caucasian, and racially ambiguous faces. For the racially ambiguous faces, we led participants to believe that they were viewing either own-race Chinese faces or other-race Caucasian faces. Results showed that (1) Chinese participants scanned the nose of the true Chinese faces more than that of the true Caucasian faces, whereas they scanned the eyes of the Caucasian faces more than those of the Chinese faces; (2) they scanned the eyes, nose, and mouth equally for the ambiguous faces in the Chinese condition compared with those in the Caucasian condition; (3) when recognizing the true Chinese target faces, but not the true target Caucasian faces, the greater the fixation proportion on the nose, the faster the participants correctly recognized these faces. The same was true when racially ambiguous face stimuli were thought to be Chinese faces. These results provide the first evidence to show that (1) visual scanning patterns of faces are related to own-race face recognition response time, and (2) it is bottom-up facial physiognomic information that mainly contributes to face scanning. However, top-down knowledge of racial categories can influence the relationship between face scanning patterns and recognition response time.

1. Introduction

How we process the faces of own- and other-races similarly and differently is a topic of intense interest in psychology and neuroscience (Hugenberg, Young, Bernstein, & Sacco, 2010; Meissner & Brigham, 2001; Sporer, 2001). The question has received extensive empirical investigation since the early 1900s (Feingold, 1914), in part, because the answers may elucidate a host of important issues in cognitive and social psychology, such as the role of experience in the formation of visual processing expertise and in the emergence of racial prejudice and stereotyping (Hugenberg et al., 2010; Meissner & Brigham, 2001; Shutts & Kinzler, 2007; Sporer, 2001).

It is now well established that individuals process faces from different races differentially. One of the manifestations of such differential processing is the so-called other-race effect (ORE) of face recognition: individuals generally recognize own-race faces more accurately and faster than other-race faces (for reviews, see Anzures et al., 2013; Hugenberg et al., 2010; Meissner & Brigham, 2001). Using event-related potential (ERP) and functional magnetic resonance imaging (fMRI) methodologies, researchers have also observed differences in neural responses when processing own- and other-race faces, such as differences in occipito-temporal N170 amplitude and latency (Stahl, Wiese, & Schweinberger, 2008; Vizioli, Foreman, Rousselet, & Caldara, 2010; Walker, Silvert, Hewstone, & Nobre, 2008), P2 potentials (Lucas, Chiao, & Paller, 2011; Stahl et al., 2008), N200 potentials (Lucas et al., 2011), responsiveness of a broad range of ventral temporal areas (Natu, Raboy, & O'Toole, 2011), and the activation of the ventral occipital temporal cortex including the fusiform face area (Feng et al., 2011; Golby, Gabrieli, Chiao, & Eberhardt, 2001; Natu, Raboy, & O'Toole, 2011).

In recent years, studies have also shown that participants use different eye movement strategies when scanning own- and

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other-race faces, which we would refer to as the other-race scanning effect (ORSE). This effect has been observed among individuals from not only adults (Brielmann, Bülthoff, & Armann, 2014; Brielmann et al., 2014; Fu, Hu, Wang, Quinn, & Lee, 2012; Goldinger, He, & Papesh, 2009; Wu, Laeng, & Magnussen, 2012), but children (Hu, Wang, Fu, Quinn, & Lee, 2014; Kelly et al., 2011) and even infants (Liu et al., 2011; Wheeler et al., 2011; Xiao, Xiao, Quinn, Anzures, & Lee, 2012). For example, Fu et al. (2012) recently demonstrated that the race of a face can influence participants' scanning patterns such that Chinese participants spend more time looking at the eye region of Caucasian faces relative to Chinese faces, and more time looking at the nose and mouth of Chinese faces relative to Caucasian faces. However, not all studies have found this ORSE. For example, Blais and her colleagues reported no differences between fixation patterns on own- and other-race faces (Blais, Jack, Scheepers, Fiset, & Caldara, 2008). It should be noted that they were mainly concerned with differences in face scanning strategies between Asian and Caucasian observers rather than scanning differences between own- and other-race face stimuli within one racial group of participants. However, in the face categorization task of Blais et al., a difference between fixation patterns in Asian compared with Caucasian faces for both Western and Asian observers was in fact apparent but not discussed (see Blais et al., 2008; Fig. 3).

Two important issues remain unresolved. First, it is unclear whether the differential scanning patterns of own- and other-race faces are related to participants' face recognition performance or are epiphenomenal and thus have nothing to do with our encoding and recognition of own- or other-race faces. It has been suggested that the nose centric scanning pattern of Asian observers might facilitate holistic processing for faces in general and own-race faces in particular (Blais et al., 2008; Kelly, Miellet, & Caldara, 2010). To date, no evidence exists to support this speculation. In fact, there is little evidence even to support the idea that Asian observers' nose centric scanning strategies facilitates their face recognition performance. A major goal of the present study was to address this significant gap in the literature.

To this end, we asked Chinese participants without any direct contact with foreign individuals to remember and then recognize own-race Chinese faces and other-race Caucasian faces. We used a high-temporal resolution eye tracker to observe participants' eye movements during encoding and recognition of the faces and then correlated their eye movement patterns during encoding and recognition to their recognition performance. We expected to replicate the more nose-centric pattern for the own-race Chinese faces and the more eye-centric pattern for Caucasian faces. If such scanning patterns are epiphenomenal with respect to face encoding, we would not expect to obtain any significant correlations between participants' eye movement patterns and their recognition performance. However, if participants are indeed scanning faces for critical information to encode, we should observe significant correlations between face recognition performance and the way in which participants' scanned the faces. Further, such correlations should differ for own- and other-race faces.

The second outstanding issue in the literature is the mechanism underlying Chinese observers' differential scanning of own- and other-race faces. Several possibilities could account for this effect. One possibility, the facial physiognomy hypothesis, is that Chinese faces have a different face morphology in terms of their physiognomic features relative to Caucasian faces. This explanation offers a highly bottom-up account, suggesting that the difference in own- and other-race face scanning is mainly governed by the physical features of faces. By this account, higher-level cognition should not influence significantly how individuals scan own- and other-race faces. Indeed, it has been shown that Chinese faces tend to have wider noses and smaller mouth widths than Caucasians (Le, Farkas, Ngim, Levin, & Forrest, 2002). In addition, it is possible that diagnostic physiognomic features differentiating individual Chinese faces may lie in the nose region, whereas those differentiating Caucasian faces may lie in the eye region. Also, Chinese eyes are less variable than Caucasian eyes (e.g., Le et al., 2002). For example, nearly all Chinese have black eyes, whereas Caucasian eye colors vary greatly. Thus, Chinese observers may scan more the Chinese nose region because this region affords more optimal information to differentiate individual Chinese faces than Caucasian faces, whereas they scan more the Caucasian eye region because it affords more optimal information to differentiate individual Caucasian faces than Chinese faces.

Another possibility is the so-called enculturation hypothesis. It has been suggested that in the west, making eye contact is an important social behavior one must learn in order to ensure successful social interaction (Argyle & Cook, 1976). Failure to maintain appropriate eye contact is associated with various problems such as autism and social anxiety. For this reason, westerners tend to scan the eyes of a face. In contrast, Asian societies including Chinese ones discourage direct eye contact with another interlocutor during face-to-face interaction (Li, 2004). This is because staring at the eyes of another has long been considered to be socially inappropriate. Such behavior is considered impolite and immodest. In particular, when one does so to a person of a higher social hierarchy, the former might be construed as showing disrespect to the latter. For this reason, there is evidence to show that Asian children and even infants are socialized not to have sustained eye contact with another person (Kisilevsky et al., 1998). It has been suggested by Fu and his colleagues (2012) that due to such early enculturation of gaze norms, when Chinese adults are presented with static faces of their own race, they continue their adherence to their culture's gaze norm. Because the gaze norm is learned to govern interactions among in-group members, when looking at out-group Caucasian faces, Chinese adults do not feel obliged to abide by this norm and therefore show increased visual attention towards Caucasian eyes. It should be noted, however, that Asians generally display less attention to the eye regions of both Asian and Caucasian faces than Caucasian observers (Blais et al., 2008; Kelly et al., 2010).

The enculturation hypothesis emphasizes more the role of top-down processes in the differential patterns of own- and other-race scanning. This hypothesis is in line with the socio-cognitive theoretical framework which proposes that individuals adopt different processing strategies depending on whether faces are categorized as own- or other-race (Hugenberg, Miller, & Claypool, 2007; MacLin & Malpass, 2003). Recent studies have supported the socio-cognitive theoretical perspective and found that cues which indicate membership in a particular group can not only influence encoding strategies, but also later recognition accuracy of the faces. For example, Michel, Corneille, and Rossion (2007) and Michel, Corneille, and Rossion (2010) found that Caucasian participants processed ambiguous Asian/Caucasian faces more holistically when they were categorized or perceived as own-race faces rather than other-race faces. Several studies also found that participants showed better recognition memory for racially ambiguous faces that were categorized or encouraged to be categorized as own-race faces compared to other-race faces (MacLin & Malpass, 2001; Pauker et al., 2009; Shutts & Kinzler, 2007).

To date, no clear evidence exists to support either the facial physiognomic hypothesis or the enculturation hypothesis. Thus, the second major goal of the present study aimed to test these two hypotheses directly. In particular, we used a novel design to avoid a major confound in some of the existing studies (e.g., Fu et al., 2012) where the Chinese and Caucasian faces used in those studies were different in various aspects of their physiognomy (e.g., the shape and size of the eyes, nose, and mouth). In our design, we morphed Chinese and Caucasian faces to create composite faces that were 50% Chinese and 50% Caucasian (50% Chinese–50% Caucasian); thus, the morphed faces had 50% Chinese and 50% Caucasian physiognomy. In addition, we presented these 50% faces with 100% Chinese faces in a Chinese face condition. We also led the Chinese participants to believe that all the faces were Chinese. In a Caucasian face condition, we presented the 50% faces with 100% Caucasian faces and led Chinese participants to believe that all faces were Caucasian. This manipulation is similar to that used by Michel et al. (2007).

We reasoned that if the enculturation hypothesis is correct, we should observe more nose scanning patterns for both 100% Chinese faces and 50% Chinese–50% Caucasian faces by the Chinese participants in the Chinese condition, whereas the Chinese participants would display more eye scanning patterns for both the 100% Caucasian faces and 50% Chinese–50% Caucasian faces in the Caucasian condition. However, if the physiognomic hypothesis is correct, we should observe a more nose-centric pattern for the 100% Chinese faces and a more eye-centric pattern for the 100% Caucasian faces. For the 50% Chinese–50% Caucasian faces in the Chinese and Caucasian conditions, no scanning difference should be observed.

2. Method

2.1. Participants

The participants were 40 right-handed Han Chinese undergraduate students (20 males) living in Zhejiang province aged from 18 to 23 years ($M = 20.10$ years, $SD = 1.85$ years). All were native Chinese without any direct contact with Caucasian or other non-Chinese individuals. The study was conducted according to the Ethical Guidelines and Regulations of NIH, the Code of Ethics of the World Medical Association (Declaration of Helsinki), and was approved by Zhejiang Normal University Research Ethics Review Committee. Participants gave written informed consent prior to their participation and were compensated for their participation.

2.2. Materials

12 photos of 100% Caucasian faces (6 male), 12 photos of 100% Chinese faces (6 male) and 24 racially ambiguous 50% Chinese–50% Caucasian faces (12 male) were used (width: 500 pixels, 13.5 cm, 12.7 degrees of visual angle, height: 700 pixels, 18.9 cm, 17.9 degrees of visual angle, resolution: 72 pixels per inch). They were all normalized to be the same shape and size. All faces were also aligned in terms of the center of the eyes and nose. All face images were frontal view and rendered grey to prevent any differences in skin tone among the Chinese, Caucasian, and racially ambiguous faces from affecting participants' scanning of the faces. To control for hairstyle differences, all face images appeared within the same elliptical shape. Furthermore, to control for the influence of low-level stimulus attributes such as luminance and contrast, the images were matched in overall luminance using Shine Matlab toolbox (Willenbockel et al., 2010). Sample faces are shown in Fig. 1.

Racially ambiguous 50% Chinese–50% Caucasian faces were created from an Asian 'parent' face and a Caucasian 'parent' face (the same sex) using a Morph software (FantaMorph, Abrosoft Co., Beijing, China). The software automatically and digitally morphed the Chinese and Caucasian faces in equal proportions (50% Chinese–50% Caucasian). The faces used to create the morphs were different from the 100% faces used in the experiment.

The faces used in our study were chosen according to the results of a prior experiment in which Caucasian and Chinese faces were matched in terms of attractiveness and distinctiveness as judged by Chinese and Caucasian adults (Ge et al., 2009). Gaze direction was also not significantly different between the Chinese ($M = 4.06$, $SD = .44$), and Caucasian ($M = 4.13$, $SD = .46$) faces, as rated from 1 (look averted) to 5 (look direct) by 15 Chinese participants, $p = .494$.

An Eyelink 1000 Eye tracker (1000 Hz sample rate) was used to record participants' fixations on the face images. The SR Research Experiment Builder program was used to control stimulus presentation. The screen used for presenting the stimuli was set to 1024×768 pixels resolution.

2.3. Procedure

Participants took part in the study individually. They were positioned about 60 cm from the screen. Fixation data were recorded by the EyeLink 1000 eye-tracker automatically only when faces were presented. Each trial started with a fixation cross (1000 ms), followed by a target face appearing for 2 s. The participants were instructed to inspect the target face carefully and remember it (encoding period). After a 16 ms 'mask' stimulus (white noise mask) and a 2000 ms blank screen, a test face appeared. The test face was either the same as (target face) or different from (foil face) the target face in the encoding period. The race and sex of the test face were always the same as the target face in the encoding period. Participants were asked to judge as accurately and as fast as possible whether the test face was the same as the target face in the encoding period or if it was different using the left or right key on the computer keyboard (test period). The key assignment was counter-balanced between participants. As soon as participants responded, a prompt showing "next trial" appeared for 1 s and then the next trial began. All stimuli were presented at the center of the computer screen.

After 6 practice trials (1 "same" and 1 "different" trial with 100% Chinese, 100% Caucasian, and 50% Chinese and 50% Caucasian female faces; the faces used in the practice phase were never shown again in the experimental phase), participants performed two experimental blocks of 48 trials (12 Chinese or Caucasian faces and 12 racially ambiguous faces were both presented 2 times in encoding and test period) presented randomly with an inter-trial interval of 1 s. In one block, participants were told that they were to remember and recognize a series of Chinese faces (the Chinese condition). However, in fact, half of the faces were 100% Chinese and the other half were 50% Chinese and 50% Caucasian. Among all the trials, 24 were "same" trials and 24 were "different" trials. As a result, this condition contained 12 "same" and 12 "different" trials with 100% Chinese faces and 12 "same" and 12 "different" trials with faces that were 50% Chinese and 50% Caucasian. All trials were randomized.

In the Caucasian condition, participants were told that they were going to remember and recognize Caucasian faces, half of which were 100% Caucasian and the other half of which were 50% Chinese and 50% Caucasian. Thus, they performed the same task as in the Chinese condition but there were 24 trials with 100% Caucasian faces and 24 trials with 50% Chinese–50% Caucasian faces (12 Caucasian and another 12 racially ambiguous faces were both presented 2 times in the encoding and test periods).

The Chinese and Caucasian conditions were within-subject with the order of the conditions counter-balanced between participants. Crucially, the trials with 50% Chinese–50% Caucasian faces included in the Chinese and Caucasian conditions were not the same for one participant, but they were counterbalanced across participants.

Before each experimental block, the eye movements of participants were calibrated. Only the left eye was recorded during the experiment. Participants were instructed to fixate a dot at the center of the screen to perform an automatic drift correction using a nine-point fixation procedure. The calibration was then validated

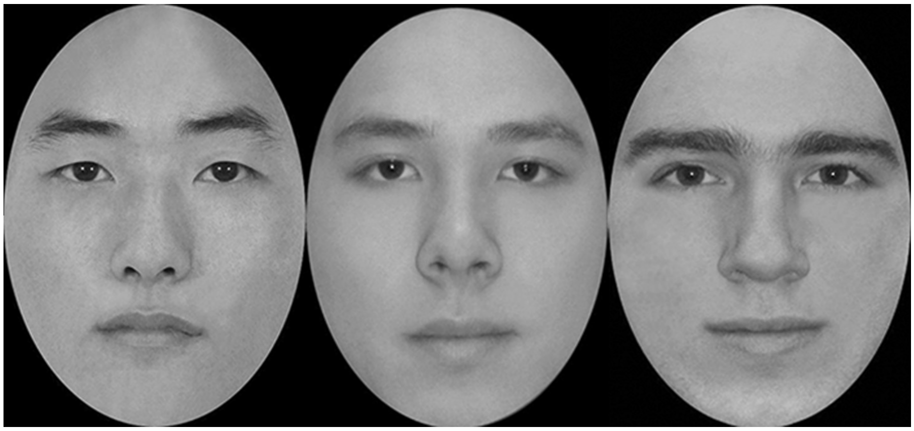

Fig. 1. Sample faces used in the present study. The left one is a Chinese male face, the right one is a Caucasian male face, and the middle one is a racially ambiguous male face.

and repeated when necessary until the optimal calibration criterion was reached. We recorded eye movement data during the encoding period and the test period of each trial.

3. Results

We analyzed the data of the 100% Chinese and Caucasian faces and the 50% Chinese–50% Caucasian faces separately. We also compared the scanning differences between 50% and 100% faces in the Chinese and Caucasian conditions to further reveal the influences of physiognomy on face scanning.

3.1. Results of 100% faces

3.1.1. Accuracy (ACC)

The average ACC was high for 100% Chinese faces (M = .91, SD = .11) and 100% Caucasian faces (M = .94, SD = .09). This was likely due to the fact that the task was relatively easy as participants were only asked to remember one face and then recognize it. A pair wise t-test revealed that there was no significant difference between the 100% Chinese and 100% Caucasian faces, $t(39) = -1.37$, p = .178, Cohen's d = .299.

3.1.2. Correct response times (RTs)

Correct RTs that were two standard deviations above or below each participant's overall mean for each type of stimulus in each block were removed (4.8% of the correct trials). A pair wise t-test revealed that there was no significant difference between 100% Chinese (M = 1096 ms, SD = 326 ms) and 100% Caucasian faces (M = 1048 ms, SD = 288 ms), $t(39) = 1.70$, p = .097, Cohen's d = .156.

3.1.3. Fixation proportion on the eyes, nose, and mouth

A velocity threshold was used to generate fixations with 100 ms minimal fixation duration and 1° saccade amplitude. In order to examine participants' fixations on the areas of interest (eyes, nose, mouth), we used a proportional fixation time measure. This measure was obtained by dividing the sum of the fixation time on each of the areas of interest (AOIs) by the total fixation time on the whole face.

We first defined a number of AOIs for each face individually: the whole face (the area within the face contour), the eyes (right and left eyes combined), the nose, and the mouth (Fig. 2). The definition of these AOIs was the same as that used in prior studies (e.g. Fu et al., 2012; Hu et al., 2014), so that we could compare our results with those previous studies. The whole face included the eye, nose, and mouth regions. Second, we obtained the total fixation time on each of the AOIs. Third, we computed the proportional fixation time on the AOIs of the eyes, nose, and mouth for each face by dividing the total fixation time on the eyes, nose, or mouth of a particular face by the total fixation time on the whole face. Note that the proportions of eye, nose, and mouth fixations do not add to one, because some fixations fell outside of these AOIs, e.g. those that fell on the cheeks.

For the target faces in the encoding period, a 2 face race (Chinese vs. Caucasian) × 3 face region (eyes, nose, and mouth) repeated measures ANOVA was performed on the fixation proportion density measure. Note that the adjusted F value, p value, and degrees of freedom were used henceforth when the Mauchly's Test of Sphericity was significant. The effect of face region was significant, $F(1.74, 67.70) = 43.81$, $p < .001$, $\eta_p^2 = .529$. The interaction between face race and face region was also significant, $F(1.49, 58.20) = 12.84$, $p < .001$, $\eta_p^2 = .248$. Two simple effect tests were conducted to examine this interaction effect. False discovery rate (FDR) adjustment was used to do post hoc analysis henceforth. Within each AOI, participants spent significantly more time on the eyes of the 100% Caucasian faces (M = .373, SD = .180) than on the eyes of the 100% Chinese faces (M = .328, SD = .153), $t(39) = -2.51$, p = .024, Cohen's d = .269. In contrast, they spent significantly more time on the nose of the 100% Chinese faces (M = .284, SD = .151) than on the nose of the 100% Caucasian faces (M = .236, SD = .140), $t(39) = 4.24$, $p < .001$, Cohen's d = .330. The proportional time on the mouth was not significantly different between the 100% Chinese faces (M = .072, SD = .075) and the 100% Caucasian faces (M = .068, SD = .083), $t(39) = .51$, p = .617, Cohen's d = .051. Within each race of faces, participants spent more time scanning the region of the eyes

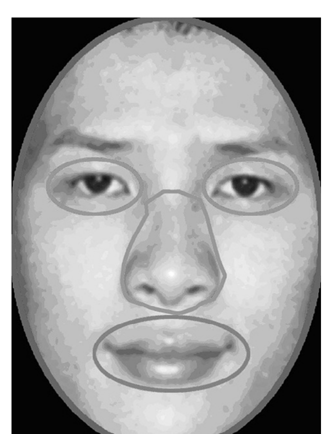

Fig. 2. Sample area of interest (AOI) plot.

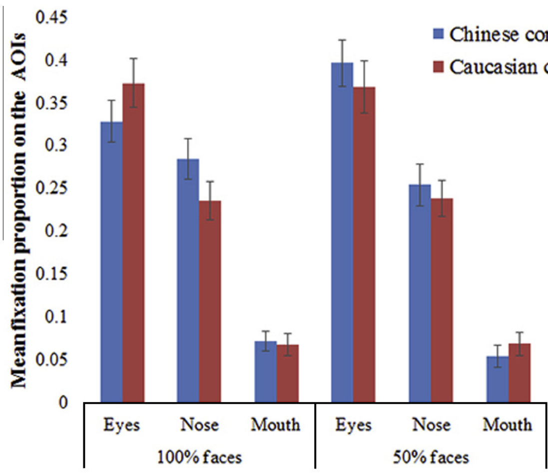

Fig. 3. Mean fixation proportion on the eyes, nose, and mouth during the encoding phase.

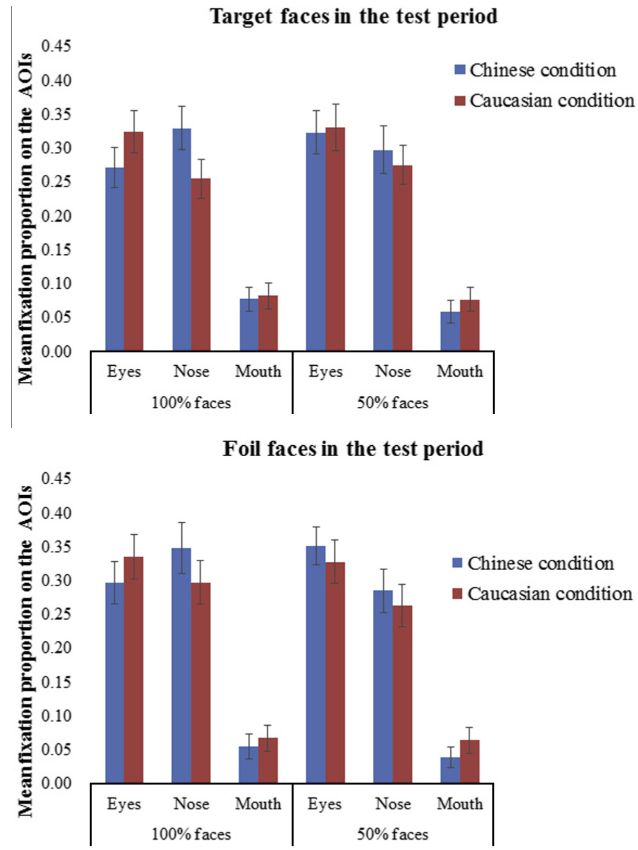

Fig. 4. Mean fixation proportion on the eyes, nose, and mouth during the test phase.

than the nose and mouth, and they also spent more time scanning the region of the nose than the mouth on Caucasian faces, all *ps* < .001. On Chinese faces, participants looked more at the region of the eyes than the mouth, and they also looked more at the region of the nose than the mouth, all *ps* < .001. However, participants looked at the eyes and nose equally on Chinese faces, *p* = .243. The results are presented in Fig. 3.

For the target faces in the test period, a 2 face race (Chinese vs. Caucasian) × 3 face region (eyes, nose, and mouth) repeated measures ANOVA was performed on the fixation proportion density. The effect of face region was significant, $F(1.74, 67.90) = 17.97$, $p < .001$, $\eta_p^2 = .315$. The interaction between face race and face region was also significant, $F(1.72, 67.05) = 19.91$, $p < .001$, $\eta_p^2 = .338$. Two simple effect tests were conducted to examine this interaction effect. Within each AOI, participants spent significantly more time on the eyes of the 100% Caucasian faces ($M = .324$, $SD = .195$) than on the eyes of the 100% Chinese faces ($M = .271$, $SD = .188$), $t(39) = -2.97$, $p = .008$, Cohen's $d = .277$. In contrast, they spent significantly more time on the nose of the 100% Chinese faces ($M = .330$, $SD = .201$) than on the nose of the 100% Caucasian faces ($M = .255$, $SD = .180$), $t(39) = 4.94$, $p < .001$, Cohen's $d = .393$. The proportional time on the mouth was not significantly different between the 100% Chinese faces ($M = .078$, $SD = .111$) and the 100% Caucasian faces ($M = .082$, $SD = .123$), $t(39) = -.63$, $p = .534$, Cohen's $d = .034$. Within each race of faces, participants looked more at the region of the eyes than the mouth, and they also looked more at the region of the nose than the mouth on both Chinese and Caucasian faces, all *ps* < .001. However, they looked at the eyes and nose equally on both Chinese and Caucasian faces, all *ps* > .155. The results are presented in Fig. 4.

For the foil faces in the test period, a 2 face race (Chinese vs. Caucasian) × 3 face region (eyes, nose, and mouth) repeated measures ANOVA was conducted on the fixation proportion density. The effect of face region was significant, $F(1.69, 65.89) = 21.50$, $p < .001$, $\eta_p^2 = .355$. The interaction between face race and face region was additionally significant, $F(1.65, 64.17) = 6.58$, $p = .004$, $\eta_p^2 = .144$. Two simple effect tests were conducted to examine this interaction effect. Within each AOI, participants spent marginally more time on the eyes of the 100% Caucasian faces ($M = .335$, $SD = .205$) than on the eyes of the 100% Chinese faces ($M = .297$, $SD = .200$), $t(39) = -2.16$, $p = 0.056$, Cohen's $d = .188$. In contrast, they spent significantly more time on the nose of the 100% Chinese faces ($M = .348$, $SD = .237$) than on the nose of the 100% Caucasian faces ($M = .298$, $SD = .205$), $t(39) = 2.55$, $p = .015$, Cohen's $d = .226$. The proportional time on the mouth was not significantly different between the 100% Chinese faces ($M = .055$, $SD = .118$) and the 100% Caucasian faces ($M = .068$, $SD = .118$), $t(39) = -1.11$, $p = .274$, Cohen's $d = .110$. Within each race of faces, participants looked more at the region of the eyes than the mouth, and they also looked more at the region of the nose than the mouth on both Chinese and Caucasian faces, all *ps* < .001. However, they looked at the eyes and nose equally in both Chinese and Caucasian faces, all *ps* > .404. The results are presented in Fig. 4.

3.1.4. Correlation between correct RTs and fixation proportions on the AOIs

We conducted a series of Pearson correlation analyses between correct RTs and fixation proportion on each AOI of the 100% faces with target and test faces (correlational analyses were not performed on the accuracy data because they were at ceiling). FDR adjustment was used for multiple correlations henceforth.

Only the correct RT was significantly negatively correlated with fixation proportion on the nose ($r = -.322$, $p = .043$) of the 100% Chinese faces during recognition of the target faces, but not with that of the 100% Caucasian faces ($r = -.084$, $p = .605$). Thus, the more the participants fixated on the nose of the 100% target Chinese faces during the test period, the faster they correctly recognized the target face during test. There were not any other significant correlations, all other *ps* > .05. The results are presented in Fig. 5 (also see Table 1).

3.2. Results of 50% Chinese–50% Caucasian faces

3.2.1. Accuracy (ACC)

A pair wise *t*-test revealed that there was no significant difference between the accuracy of the 50% Chinese–50% Caucasian faces in the Chinese condition (M = .87, SD = .11) and the accuracy of the same 50% Chinese–50% Caucasian faces in the Caucasian condition (M = .89, SD = .09), $t(39) = -1.05$, p = .301, Cohen's d = .200).

3.2.2. Correct response times (RTs)

A pair wise t-test revealed that there was no significant difference between the mean correct RT of the 50% Chinese–50% Caucasian faces in the Chinese condition (M = 1089 ms, SD = 303 ms) and the mean correct RT of the same 50% Chinese–50% Caucasian faces in the Caucasian condition (M = 1138 ms, SD = 346 ms), $t(39) = -1.52$, p = .136, Cohen's d = .151).

3.2.3. Fixation proportion on the eyes, nose, and mouth

A 2 face race (Chinese vs. Caucasian) × 3 face region (eyes, nose, and mouth) repeated measures ANOVA was performed on the fixation proportion density on the target faces during the encoding period. Only the main effect of face region was significant, $F(2, 78) = 50.23$, $p < .001$, $\eta_p^2 = .563$. Post hoc pair wise t-tests revealed that participants spent more time scanning the region of the eyes (M = .383, SD = .171) than the nose (M = .246, SD = .141), and mouth (M = .061, SD = .080), and they also spent more time scanning the region of the nose than the mouth, all $ps < .001$. The critical interaction between face race and face region effect was not significant, $F(1.52, 59.22) = 2.61$, p = .095, $\eta_p^2 = .050$, suggesting that even though the participants were led to believe that the 50% faces were Chinese in the Chinese condition and Caucasian in the Caucasian condition, they did not show differential fixations on the faces due to the instruction. The results are presented in Fig. 3.

For the target faces in the test period, a 2 face race (Chinese vs. Caucasian) × 3 face region (eyes, nose, and mouth) repeated measures ANOVA was conducted on the fixation proportion density. Only the effect of face region was significant, $F(1.64, 63.78) = 20.90$, $p < .001$, $\eta_p^2 = .349$. Post hoc pair wise t-tests revealed that participants spent more time scanning the region of the nose (M = .287, SD = .191) than the mouth (M = .068, SD = .104), and they also spent more time scanning the region of the eyes (M = .327, SD = .197) than the mouth, all $ps < .001$. The difference between the eyes and the nose was not significant, p = .440. There were no other significant effects, all $ps > .295$. The results are presented in Fig. 4.

For the foil faces in the test period, a 2 face race (Chinese vs. Caucasian) × 3 face region (eyes, nose, and mouth) repeated measures ANOVA was conducted on the fixation proportion density. Again, only the effect of face region was significant, $F(2, 78) = 29.13$, $p < .001$, $\eta_p^2 = .428$. Post hoc pair wise t-tests revealed that participants spent significantly more time scanning the region of the eyes (M = .340, SD = .179) than the mouth (M = .052, SD = .105), and they also spent significantly more time scanning the region of the nose (M = .275, SD = .187) than the mouth, all $ps < .001$. The difference between the eyes and the nose was not significant, p = .156. The results are presented in Fig. 4.

Table 1
Correlations between correct RTs and fixation proportions on the AOIs.

		Chinese condition			Caucasian condition		
		Eyes	Nose	Mouth	Eyes	Nose	Mouth
		Faces in the encoding phase					
100% faces	r	−0.244	−0.239	−0.14	−0.225	−0.018	0.144
	p	0.128	0.206	0.388	0.162	0.913	0.563
50% faces	r	−0.2	−0.299	−0.193	−0.116	−0.121	0.049
	p	0.324	0.061	0.234	0.713	0.458	0.763
		Target faces in the test phase					
100% faces	r	0.012	−0.322*	0.08	−0.097	−0.084	0.274
	p	0.942	0.043	0.936	0.825	0.605	0.087
50% faces	r	0.066	−0.328*	0.084	−0.098	−0.202	0
	p	0.684	0.039	0.912	0.819	0.211	1
		Foil faces in the test phase					
100% faces	r	−0.064	−0.259	−0.159	−0.072	−0.015	0.012
	p	0.696	0.107	0.492	0.659	1.392	0.941
50% faces	r	−0.101	−0.169	−0.106	−0.109	0.013	−0.014
	p	0.535	0.298	0.773	0.504	0.936	1.394

* $p < 0.05$, after corrected by FDR.

3.2.4. Correlation between correct RTs and fixation proportions on the AOIs

We also conducted a series of Pearson correlation analyses between the correct RTs and fixation proportions on each AOI of

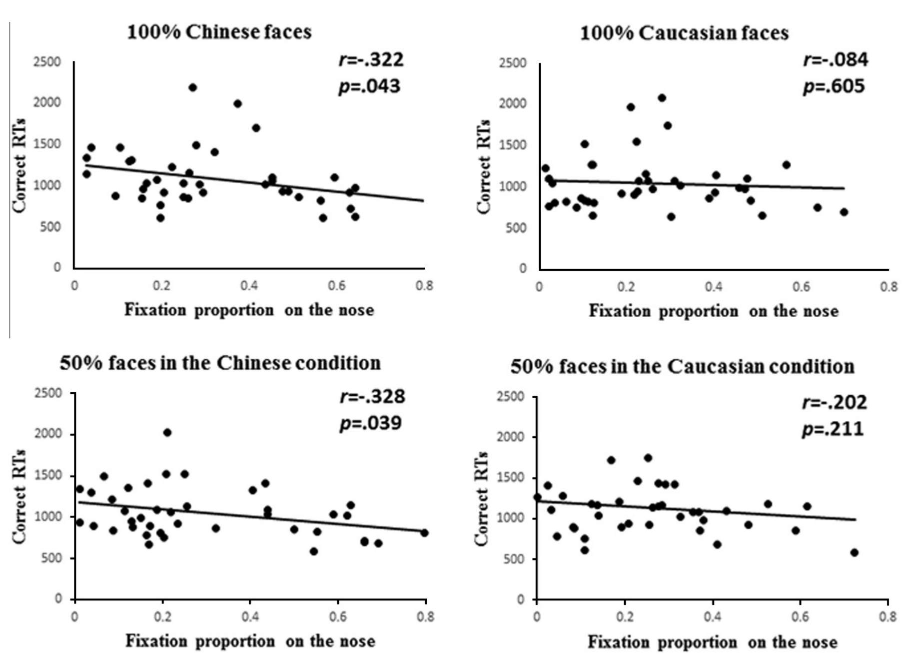

Fig. 5. Correlations between nose scanning and face recognition performance (correct RT) when recognizing the target faces (each data point refers to an observer's result).

the 50% Chinese–50% Caucasian faces during the encoding and test periods.

Only the correct RT was significantly negatively correlated with fixation proportion on the nose of 50% Chinese–50% Caucasian faces in the Chinese condition ($r = -.328$, $p = .039$) during recognition of the target faces, but not with that of the nose of the same faces in the Caucasian condition ($r = -.202$, $p = .211$). Thus, the more the participants fixated on the nose of the 50% Chinese–50% Caucasian target faces in the Chinese condition during the test period, the faster they correctly recognized these faces during test. There were not any other significant correlations, all other $ps > .05$. The results are presented in Fig. 5 (also see Table 1).

3.2.5. Scanning differences between 50% and 100% faces in the Chinese condition

For the faces in the encoding period, a 2 face type (100% true face vs. 50% ambiguous face) $\times$ 3 face region (eyes, nose, and mouth) repeated measures ANOVA was performed on the fixation proportion density measure. The effect of face type was significant, $F(1, 39) = 6.48$, $p = .015$, $\eta_p^2 = .142$. The effect of face region was significant, $F(1.70, 66.46) = 46.15$, $p < .001$, $\eta_p^2 = .542$. The interaction between face type and face region was also significant, $F(1.65, 64.21) = 41.94$, $p < .001$, $\eta_p^2 = .518$. Within each AOI, participants spent significantly more time on the eyes of the 50% faces ($M = .397$, $SD = .171$) than on the eyes of the 100% faces ($M = .328$, $SD = .153$), $t(39) = -7.52$, $p < .001$, Cohen's $d = .435$. In contrast, they spent significantly more time on the nose ($M = .284$, $SD = .151$) and mouth ($M = .072$, $SD = .075$) of the 100% faces than on the nose ($M = .254$, $SD = .155$) and mouth ($M = .054$, $SD = .082$) of the 50% faces, $t(39) = 4.13$, $p < .001$; $t(39) = 3.82$, $p < .001$, Cohen's $d = .229$, respectively. The results are presented in Fig. 3.

For the target faces in the test period, a 2 face type (100% true face vs. 50% ambiguous face) $\times$ 3 face region (eyes, nose, and mouth) repeated measures ANOVA was performed on the fixation proportion density. The effect of face region was significant, $F(1.61, 62.86) = 19.12$, $p < .001$, $\eta_p^2 = .329$. The interaction between face type and face region was also significant, $F(1.54, 60.01) = 11.54$, $p < .001$, $\eta_p^2 = .228$. Within each AOI, participants spent significantly more time on the eyes of the 50% faces ($M = .324$, $SD = .199$) than on the eyes of the 100% faces ($M = .271$, $SD = .188$), $t(39) = -3.51$, $p = .001$, Cohen's $d = .274$. In contrast, they spent significantly more time on the nose ($M = .330$, $SD = .201$) and mouth ($M = .078$, $SD = .111$) of the 100% faces than on the nose ($M = .298$, $SD = .222$) and mouth ($M = .059$, $SD = .108$) of the 50% faces, $t(39) = 2.42$, $p = .020$, Cohen's $d = .151$ and $t(39) = 3.12$, $p = .005$, Cohen's $d = .174$, respectively. The results are presented in Fig. 4.

For the foil faces in the test period, a 2 face type (100% true face vs. 50% ambiguous face) $\times$ 3 face region (eyes, nose, and mouth) repeated measures ANOVA was conducted on the fixation proportion density. The effect of face region was significant, $F(1.65, 64.47) = 26.21$, $p < .001$, $\eta_p^2 = .402$. The interaction between face type and face region was additionally significant, $F(1.33, 51.88) = 14.96$, $p < .001$, $\eta_p^2 = .277$. Within each AOI, participants spent significantly more time on the eyes of the 50% faces ($M = .351$, $SD = .176$) than on the eyes of the 100% faces ($M = .297$, $SD = .200$), $t(39) = -3.39$, $p = .003$, Cohen's $d = .287$. In contrast, they spent significantly more time on the nose ($M = .348$, $SD = .237$) and mouth ($M = .055$, $SD = .118$) of the 100% faces than on the nose ($M = .286$, $SD = .202$) and mouth ($M = .040$, $SD = .094$) of the 50% faces, $t(39) = 4.00$, $p < .001$, Cohen's $d = .282$ and $t(39) = 2.39$, $p = .022$, Cohen's $d = .141$, respectively. The results are presented in Fig. 4.

3.2.6. Scanning differences between 50% and 100% faces in the Caucasian condition

For the faces in the encoding period, a 2 face type (100% true face vs. 50% ambiguous face) $\times$ 3 face region (eyes, nose, and mouth) repeated measures ANOVA was performed on the fixation proportion density. Only the effect of face region was significant, $F(2, 78) = 43.11$, $p < .001$, $\eta_p^2 = .525$. There were no other significant effects, all $ps > .743$. The results are presented in Fig. 3.

For the target faces in the test period, a 2 face type (100% true face vs. 50% ambiguous face) $\times$ 3 face region (eyes, nose, and mouth) repeated measures ANOVA was performed on the fixation proportion density. Only the effect of face region was significant, $F(1.74, 67.98) = 19.14$, $p < .001$, $\eta_p^2 = .329$. There were no other significant effects, all $ps > .215$. The results are presented in Fig. 4.

For the foil faces in the test period, a 2 face type (100% true face vs. 50% ambiguous face) $\times$ 3 face region (eyes, nose, and mouth) repeated measures ANOVA was performed on the fixation proportion density. Only the main effects of face type and face region were significant, $F(1, 39) = 5.31$, $p = .027$, $\eta_p^2 = .120$ and $F(2, 78) = 21.95$, $p < .001$, $\eta_p^2 = .360$, respectively. The interaction between face type and face region was not significant, $p = .348$. The results are presented in Fig. 4.

4. Discussion

Consistent with Fu et al. (2012) and Hu et al. (2014), we replicated the results that Chinese participants spent a significantly greater proportion of fixation time on the eyes of other-race Caucasian faces than on the eyes of own-race Chinese faces. In contrast, they spent a significantly greater proportion of fixation time on the nose of Chinese faces than on the nose of Caucasian faces. Furthermore, we found that race-specific face scanning was related to face recognition performance: when recognizing the true Chinese target faces, the greater the fixation proportion on the nose of the Chinese faces, the faster the faces were correctly recognized.

It should be noted, however, that the benefit of specific scanning patterns might be limited to recognition of faces from the more familiar own-race category. This conclusion is supported by the following evidence: first, although participants scanned more on the eyes of true Caucasian faces, their scanning of the eyes of the Caucasian faces was not significantly correlated with their face recognition latency. This null finding suggests that a more eye-centric scanning pattern may not be a good strategy for Chinese participants to recognize Caucasian faces. Additional investigation is thus needed to explore the optimal strategy for Chinese participants to remember and recognize Caucasian faces and to determine whether specific expertise at processing Caucasian faces is needed for this more eye-centric scanning pattern to benefit face recognition. Second, Chinese participants' more nose-centric scanning pattern for own-race faces was not related to face recognition performance when recognizing own-race foil faces. Foil faces in the test can be regarded as unfamiliar faces, because they are new and not seen during the encoding period. This null finding might be due to the fact that participants needed additional information (not only from the nose) to determine that an unfamiliar face was not previously viewed and thus make a correct decision to reject it as an "old" face.

Our findings based on the proportional fixation time on the key AOIs (eyes, nose, and mouth) of the racially ambiguous faces failed to show a clear top-down effect since participants spent the same proportion of fixation time on them in both the Chinese versus Caucasian conditions. The enculturation hypothesis would have predicted that Chinese participants should have scanned more on the nose region of the racially ambiguous faces in the Chinese condition, but more on the eye region in the Caucasian condition. In contrast, our results are more consistent with the facial physiognomy hypothesis. Previous studies have suggested that the diagnostic features for discriminating faces differ from race to race (Ellis, Deregowski, & Shepherd, 1975; Shepherd, 1981). Because the racially ambiguous faces were exactly the same faces in the Chinese and Caucasian conditions in the present study, participants spent the same proportion of fixation time on their key features. Based on this finding, we suggest that the reason participants spent differing amounts of time on the key features of the 100% Chinese and 100% Caucasian faces could be due to the fact that the features from the two race classes differed in physiognomy. Furthermore, when we compared the scanning differences between 50% and 100% faces in the Chinese condition, we found that participants spent significantly more time on the eyes of the 50% faces than on the eyes of the 100% faces. In contrast, they scanned more the nose and mouth of the 100% faces than those of the 50% faces. However, this was not the case in the Caucasian condition. It appears as if Chinese participants change their scanning patterns (look more at the eyes and less at the nose) as soon as a face has some Caucasian physiognomy, compared with true Chinese faces. But this is not the case when a face has some Chinese physiognomy, compared with true Caucasian faces. These results suggest that other-race Caucasian physiognomy has more influence than own-race Chinese physiognomy on face scanning patterns among Chinese participants.

Consistent with this physiognomy hypothesis, a recently published paper reported the exact same scanning pattern (more eye fixations on Caucasian faces versus more nose fixations on Asian faces) in a race classification task performed by Western observers (Brielmann et al., 2014). Specifically designed studies are still needed to address this hypothesis further. For example, one could use the bubbles technique (Gosselin & Schyns, 2001) to ascertain whether Chinese and Caucasian faces are indeed different in terms of diagnostic features (e.g., noses for Chinese faces and eyes for Caucasian faces). Further, one could use computer face models to specifically manipulate the key features of own- and other-race faces (e.g., changing Caucasian noses to be more Chinese-like or Chinese eyes to be more Caucasian like) (Jung, Armann, & Bülthoff, 2012) to ascertain whether such changes would drive changes in participants' scanning patterns of the key features of the own- and other-race faces.

In addition to facial physiognomy, we also found that top-down information played a role in participants' recognition of own-race faces. Although participants on average spent the same proportion of fixation time on the key AOIs of racially ambiguous faces, in the Chinese condition, when recognizing the target faces, the more participants scanned the nose of the racially ambiguous faces, the faster their recognition of these faces. This finding is consistent with the results that when the same participants scanned the true target Chinese faces during the test phase, they showed similar coupling between proportional fixation on the nose and face recognition latency. For the racially ambiguous faces in the Caucasian condition, the same participants failed to show a significant coupling between proportional fixations on the nose and face recognition latency. Because the racially ambiguous faces were the same in the Chinese and Caucasian conditions, the significant correlation between visual scanning of the nose and face recognition performance in the Chinese condition but not Caucasian condition must be driven by top-down influence.

As in previous studies (e.g., MacLin & Malpass, 2003), the racially ambiguous faces we used provide a valuable research tool when studying top-down influences on face processing, because they allow the overall physical features of the stimulus to be held constant. However, one possible limitation of using the racially ambiguous faces in our study is that although each of the racially ambiguous faces was said to be from one or the other race category by instruction, participants may vary greatly in their ratings of the "raceness" of the faces. Consequently, it may be that one participant might perceive a particular ambiguous face to look "quite Chinese" in the Caucasian block, while perceiving another face as looking "very Caucasian" in the Chinese block in our experiment. Thus, different perceptions of the "raceness" of the faces may influence our results. However, previous research has suggested that participants accept the racial labels provided for ambiguous-race faces (Eberhardt, Dasgupta, & Banaszynski, 2003), and participants do process and remember the same faces differently when different (in-group vs. out-group) labels or cues are given (Bernstein, Young, & Hugenberg, 2007; Huart, Corneille, & Becquart, 2005; MacLin & Malpass, 2001; Shriver, Young, Hugenberg, Bernstein, & Lanter, 2008; Shutts & Kinzler, 2007). Nevertheless, additional studies are needed to address the above issue. One possibility is to ask participants to categorize the racially ambiguous faces as belonging to one's own- or other-race category. The categorization responses could then be used as a basis for correlating face recognition and visual scanning. Such future studies could further elucidate the role of top-down information on visual scanning of own- and other-race faces and its relation to face recognition performance.

In summary, our study for the first time reveals that different face scanning strategies with own- and other-race faces reflect different facial physiognomy between classes of faces. However, consistent with a top-down account, face scanning is modulated by the race categorization of the face: when recognizing previously learned faces, a more nose scanning strategy was associated with the speed of Chinese participants' recognition performance for faces presented as same-race.

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