Visual Cognition, 2013
Vol. 21, Nos. 9–10, 1202–1223, http://dx.doi.org/10.1080/13506285.2013.823141

The contribution of shape and surface information in the other-race face effect

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Faces from another race are generally more difficult to recognize than faces from one's own race. However, faces provide multiple cues for recognition and it remains unknown what are the relative contribution of these cues to this "other-race effect". In the current study, we used three-dimensional laser-scanned head models which allowed us to independently manipulate two prominent cues for face recognition: the facial shape morphology and the facial surface properties (texture and colour). In Experiment 1, Asian and Caucasian participants implicitly learned a set of Asian and Caucasian faces that had both shape and surface cues to facial identity. Their recognition of these encoded faces was then tested in an old/new recognition task. For these face stimuli, we found a robust other-race effect: Both groups were more accurate at recognizing own-race than other-race faces. Having established the other-race effect, in Experiment 2 we provided only shape cues for recognition and in Experiment 3 we provided only surface cues for recognition. Caucasian participants continued to show the other-race effect when only shape information was available, whereas Asian participants showed no effect. When only surface information was available, there was a weak pattern for the other-race effect in Asians. Performance was poor in this latter experiment, so this pattern needs to be

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This work was supported by the National Fund of Scientific Research (FNRS) Belgium (CM and BR), a PAI/UIAP grant no. P7/33 (Pôles d'attraction interuniversitaires, Phase 7) to BR, and a grant from the Hong Kong Research Grants Council (HKU744911) to WGH.

interpreted with caution. Overall, these findings suggest that Asian and Caucasian participants rely differently on shape and surface cues to recognize own-race faces, and that they continue to use the same cues for other-race faces, which may be suboptimal for these faces.

Keywords: Face recognition; Other-race face effect; Shape cues; Surface cues.

Observers' ability to recognize other people from their face relies on encoding variations between individuals along different cues—or sources of information—such as their facial shape or skin colour. The cues that are potentially diagnostic for face recognition may differ for faces of different morphologies, or "races". Observers from different racial groups may therefore encode and use different cues to facial identity, which may partially account for their difficulty at recognizing faces from another race compared to faces from their own race (the "other-race effect"; Malpass & Kravitz, 1969; for a meta-analysis, see Meissner & Brigham, 2001; for a review, see Rossion & Michel, 2011). Consistent with this idea, anthropometric studies report large variations between different human populations, not only in terms of the average size and shape of certain features (allowing race categorization of the faces), but also in terms of their degree of variance within a given population (e.g., Farkas, 1994). In addition, principal components analyses of face images, which extract components representing the main dimensions that account for variance in a face set, appear to be different for faces of different races (O'Toole, Deffenbacher, Abdi, & Bartlett, 1991; O'Toole, Deffenbacher, Valentin, & Abdi, 1994).

There is evidence to also suggest that observers from different racial groups use different facial cues when attempting to individuate both own-race and other-race faces. For instance, observers from different racial groups emphasize different facial cues to describe own-race and other-race faces (see, e.g., Ellis, Deregowski, & Shepherd, 1975; although see Shepherd & Deregowski, 1981). Simulation studies also showed that the other-race effect can be reproduced by an artificial neural network that has been trained with a single race of faces to extract diagnostic facial information for individuation (Furl, Phillips, & O'Toole, 2002; O'Toole et al., 1991; see also Caldara & Abdi, 2006). Multidimensional scaling analyses of similarity ratings of face stimuli further suggest that other-race faces are more densely clustered than own-race faces in a face memory space (Byatt & Rhodes, 2004), possibly because the dimensions defining this face space correspond to the facial cues that are diagnostic in one's own race (Valentine, 1991). However, to the best of our knowledge, there is no direct and clear evidence that observers from different racial groups rely on different facial cues to recognize own-race faces and that they use these cues suboptimally for other-race faces, which could account for the other-race effect.

A basic distinction to make regarding the cues that can potentially be used to individuate faces is between the three-dimensional (3-D) shape of the face and the two-dimensional surface reflectance of the skin (e.g., texture and colour). Shape information can be defined by the bone structure of the head and the facial musculature, whereas surface information can be defined by the skin's reflectance of light (Bruce & Young, 1998). Although shape information plays a prominent role in face recognition, studies have shown that surface information is also important for discriminating among own-race individuals, for Caucasian observers at least. For example, observers are less accurate at recognizing faces portrayed as line drawings (e.g., Bruce, Hanna, Dench, Healy, & Burton, 1992; Davies, Ellis, & Shepherd, 1978), or presented as greyscale images (e.g., Lee & Perrett, 1997) than full colour pictures. Moreover, faces are better recognized when they are caricatured in colour space (Lee & Perrett, 1997). Observers also have difficulty recognizing contrast-reversed faces (as in a photographic negative), presumably because this manipulation can disrupt surface cues used for face recognition (e.g., Bruce & Langton, 1994; Galper, 1970; Phillips, 1972; Russell, Sinha, Biederman, Nederhauser, 2006; Vuong, Peissig, Harrison, & Tarr, 2005). Other studies have demonstrated that variations in both shape and surface information across individuals contribute to face recognition (e.g., Jiang, Blanz, & O'Toole, 2006; O'Toole, Vetter, & Blanz, 1999; Russell, Biederman, Nederhauser, & Sinha, 2007). Although shape variations might be extracted earlier than surface variations during face processing (Caharel, Jiang, Blanz, & Rossion, 2009) and their diagnosticity might be more dependent on holistic face representations (Jiang, Blanz, & Rossion, 2011), processing of both shape and surface variations might account equally for our ability to recognize own-race faces (Jiang et al., 2006; O'Toole et al., 1999; Russell et al., 2007).

Several studies have recently explored the relative contribution of shape and surface information for recognizing own-race and other-race faces (e.g., Balas & Nelson, 2010; Bar-Haim, Saidel, & Yovel, 2009; Brebner, Krigolson, Handy, Quadflieg, & Turk, 2011). In these studies, the researchers "swapped" the shape and surface cues between individual faces from different races, giving rise to four types of faces that differed in their combination of shape and surface information (e.g., a "mixed-race" face with Caucasian morphology and African skin tone). The results were somewhat conflicting. Bar-Haim et al.'s (2009) findings suggest that the other-race effect depends more on shape than surface cues in Caucasian observers. In contrast, Brebner et al. (2011) found that Caucasian observers were better at recognizing Caucasian faces than African faces, regardless of facial morphology, suggesting that the other-race effect might be driven by surface cues in Caucasian observers. Using synthetic faces and a perceptual matching task, Balas and Nelson (2010) did not find an other-race effect for (upright) Caucasian and African faces: Observers performed equally well across all conditions.

Irrespective of the reasons for the conflicting findings across these earlier studies (Balas & Nelson, 2010; Bar-Haim et al., 2009; Brebner et al., 2011), these studies cannot address whether different racial groups rely differently on shape and surface cues to recognize faces. First and most importantly, only one racial group was tested in these studies so that differences between how racial groups relied on shape or surface cues for face recognition cannot be measured. Second, the "swapping" manipulation may lead to a cue-conflict situation: For "mixed-race" faces, the shape cue would indicate one race, whereas the surface cue would indicate the other race. Consequently, this procedure does not allow us to tease apart the effects of removing identity information from one of the cues on face recognition from the effects of the conflict between the two cue types. The magnitude of this conflict may vary across these earlier studies, which might explain the discrepancy of the results. The results from Willenbockel, Fiset, and Tanaka's (2011) study are in line with these possibilities. They factorially manipulated face morphology and skin tone so that these parameters would change systematically from Caucasian to Asian faces (i.e., morphing along both shape and surface dimensions). They found that Caucasian observers were more likely to use skin tone to categorize the race of face when face morphology was ambiguous (e.g., 50% morph between Caucasian and Afrian faces) or degraded (e.g., by inverting the face in the image plane; see Balas & Nelson, 2010).

In the present study, we investigated for the first time whether observers from *different racial groups* use shape and surface cues differently to recognize both own-race and other-race faces. Rather than "swap" shape and surface cues, we manipulated the availability of shape and surface cues in Asian and Caucasian face stimuli (see also O'Toole et al., 1999; Russell et al., 2006, 2007). To do so, we normalized surface variations by averaging across facial surfaces within a racial group and normalized shape variations by averaging across facial shapes within a racial group to avoid any cue conflicts. Thus, there was only diagnostic information in either shape or surface cues to facial identity. We then measured Asian and Caucasian observers' performance at recognizing own-race and other-race faces which varied either in both kinds of information (Experiment 1), in shape information only (Experiment 2), or in surface information only (Experiment 3).

GENERAL METHODS

Participants

A total of 66 Asian (living in Hong Kong) and 66 Caucasian (living in Belgium) undergraduate students took part across the three experiments for payment or course credit. In Experiment 1, there were 20 Asians and 20 Caucasians. Thirty Asians and 30 Caucasians participated in Experiment 2. Finally, 16 Asian and 16 Caucasian participants took part in Experiment 3. None of the participants had a significant experience with other-race faces (as assessed by a questionnaire) and all had normal or corrected to normal vision. Ethics were approved by the respective university ethics committee.

Stimuli

Fully textured 3-D head models from the Max Planck Institute face database (http://faces.kyb.tuebingen.mpg.de/) were used to create the face stimuli used in the current study. The models were acquired from a 3-D laser scanner (Cyberware™) that provided both shape (3-D geometry represented as 3-D vertices) and surface (skin texture and colour represented as a 512 pixels × 512 pixels colour map) information of each individual scanned. Importantly, these two sources of information can be manipulated independently (see Blanz & Vetter, 1999, and O'Toole et al., 1999, for more details). The original face stimuli consisted of 40 Asian (half males) and 40 age-matched (mean age: 28.5 years) Caucasian (half males) faces rendered from a full-front (0°) view of the head models. The Asian faces were acquired from Chinese, Taiwanese, Vietnamese, Japanese, and Korean individuals and were potentially more variable in both shape and surface information than Caucasian faces acquired from predominantly German individuals. Of the 40 faces of each race, seven male faces and five female faces were artificially created because the original face database did not have enough original Asian head models. Using the algorithms developed by Blanz and Vetter (1999), these supplementary faces were generated by first morphing two original head models of the same race and sex, and then "inverting" the sex of the morphed face (i.e., making the face more masculine for female morphs, or more feminine for male morphs).

We created three versions of the face stimuli to manipulate the availability of shape and surface information for face recognition (see O'Toole et al., 1999; Russell et al., 2006, 2007). In a first, "original", version, both shape and surface information were kept intact. A second, "surface-normalized", version was created by averaging the individual colour maps within each race and then applying this averaged colour map onto the individual 3-D shape model (Figure 1A). Finally, a third, "shape-normalized", version was constructed by applying the colour map of the individual head model onto an averaged (per race) 3-D shape model (Figure 1B). As a result, three sets of face stimuli were obtained in which either both shape and surface information (original face stimuli) or only shape (surface-normalized face stimuli) or only surface (shape-normalized face stimuli) information were available for recognition.

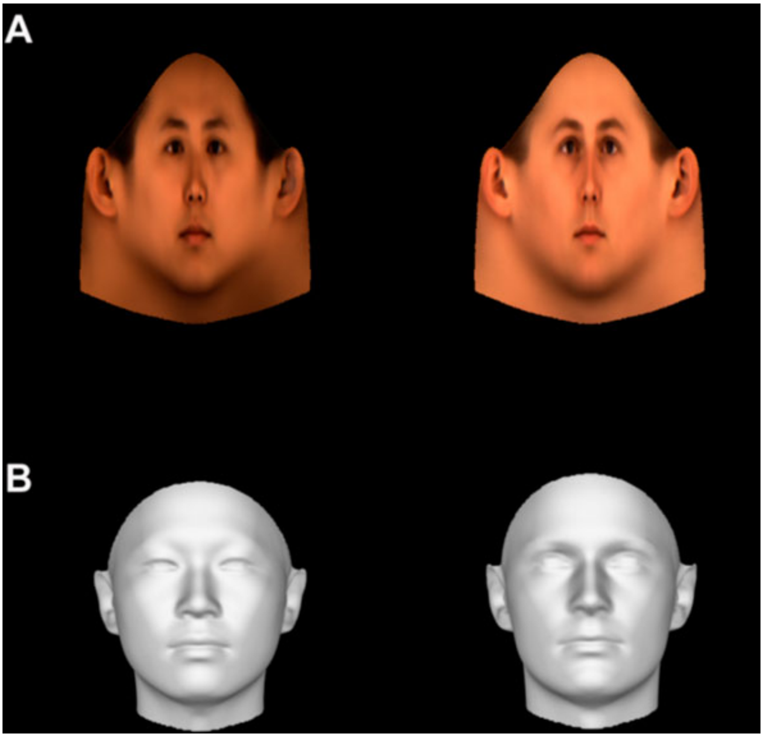

Figure 1. (A) Asian (left) and Caucasian (right) averaged colour maps which were applied onto all individual 3-D shape models (per race) in Experiment 2 for creating a set of Asian and a set of Caucasian faces in which the exemplars differed from one another in terms of shape exclusively (surface-normalized face stimuli). (B) Asian (left) and Caucasian (right) averaged 3-D head-model on which all the individual colour maps were applied (per race) in Experiment 3 for creating a set of Asian and a set of Caucasian faces in which the exemplars differed from one another in terms of surface exclusively (shape-normalized face stimuli). To view this figure in colour, please see the online issue of the Journal.

For half of the original face stimuli (i.e., 20 per race), a right three-quarters (30°) view of the head model was also rendered in the three versions (original, surface-normalized and shape-normalized). In addition, all full-front faces were processed with the Pixelate/Mosaic filter in Adobe Photoshop 7.0 (size cell: 25). These three-quarters views and filtered images were used in the encoding task as test faces and masks, respectively (see Procedure). All face stimuli (visual angle 3.0° by 2.3°) were presented on a mean grey square frame (3.7°, 256 pixels × 256 pixels) against a white background on the computer screen, using E-Prime 1.1. Examples of Asian and Caucasian face stimuli are shown in Figure 2.

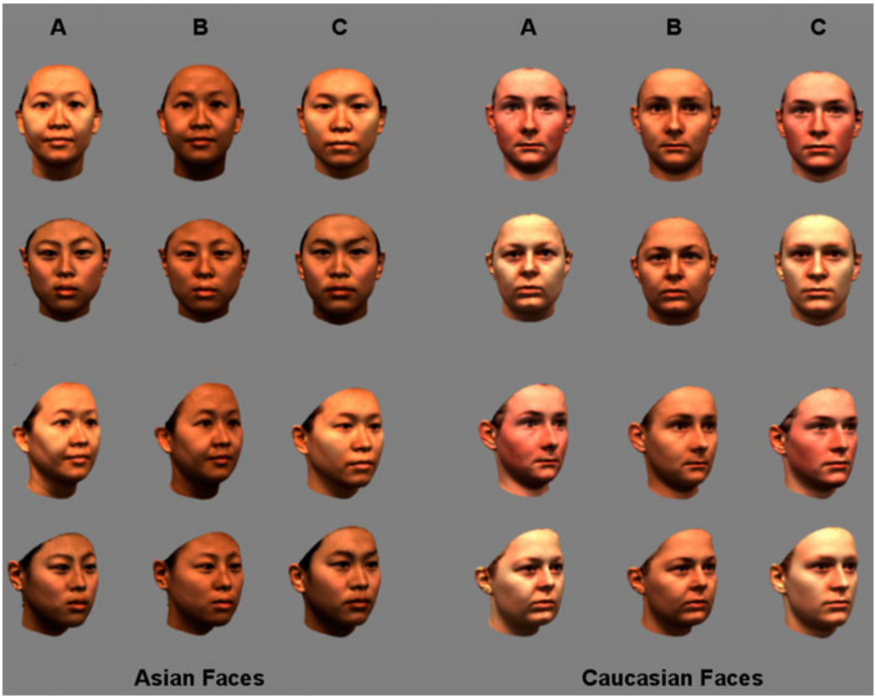

Figure 2. Examples of two Asian (left) and two Caucasian (right) faces rendered from a full-front view (top); the same faces are shown from a right $\frac{3}{4}$ view (bottom). Faces differ in terms of both shape and surface cues in Column A (original face stimuli), in terms of shape cues exclusively in Column B (surface-normalized face stimuli), and in terms of surface cues exclusively in Column C (shape-normalized face stimuli). To view this figure in colour, please see the online issue of the Journal.

Procedure

In all experiments, Asian and Caucasian participants first performed a same/different matching task with Asian and Caucasian faces, which served as an implicit encoding task for the subsequent old/new recognition task. In contrast to previous studies (e.g., O'Toole et al., 1999), participants were not informed that their memory for the faces would be tested. The latter task, in which participants had to recognize the faces that were presented at the encoding stage, was used to measure the other-race effect, in line with typical studies of this effect (Meissner & Brigham, 2001; Rossion & Michel, 2011). Original version of face stimuli were used in Experiment 1, surface-normalized version of face stimuli in Experiment 2, and shape-normalized version of face stimuli in Experiment 3. Participants were tested individually in a dimly lit room. They sat at a distance of 100 cm away from the computer screen.

Encoding stage: same/different matching task. Each trial started with a fixation cross at the center of the screen for 400 ms. The cross was replaced by an Asian or a Caucasian "target face", presented in a full-front view (0°) at the centre of the screen for 500 ms. The target face was replaced by a 300 ms mask (i.e., the pixelated version of the target face) inserted between two 300 ms blank screens. Finally, a second face stimulus ("test face") was displayed, which was either the three-quarters view (30°) of the target face ("same" trials) or the three-quarters view of a different face of the same race ("different" trials). Participants had to decide as quickly and as accurately as possible whether or not the two faces represented the same individual (regardless of the viewpoint change) by pressing the appropriate key on a standard keyboard (left or right key, with mapping of key to response counterbalanced across participants). The maximum response duration was restricted to 3000 ms. To rule out image-matching strategies, the test face was not only presented from a different view and after a mask, but also scaled 120% larger than the target face.

A total of 40 different faces (20 Asians, 20 Caucasians; half males) were presented at this encoding stage (i.e., half of the Asian and Caucasian sets of faces). Each face was presented as the target face (i.e., from a full-front view) in four trials (one "same" trial repeated once, and one "different" trial repeated once), and as the test face (i.e., from a three-quarters view) in four trials (one "same" trial repeated once, and one "different" trial repeated once). This resulted in a total of 160 trials, divided into four blocks of 40 trials (two blocks of 40 distinct trials, presented two times each) with each target face appearing only once within a block. Each block contained an equal number of Asian and Caucasian trials, an equal number of male and female trials, and an equal number of same and different trials. All trials within a block were presented in a random order (interstimuli interval = 1000 ms). There were four practice trials at the beginning of the task. Participants were not informed that their recognition memory for these faces would be tested in the second part of the experiment.

This same/different matching task served as a mean for participants to implicitly encode own-race and other-race faces. Furthermore, some previous studies have found an other-race effect for perceptual matching tasks (e.g., Lindsay, Jack, & Christian, 1991; Marcon, Meissner, Frueh, Susa, & MacLin, 2010; Megreya, White, & Burton, 2011; Meissner, Susa, & Ross, this issue 2013; Tanaka, Kiefer, & Bukach, 2004; Walker & Tanaka, 2003), whereas other studies have not (e.g., Balas & Nelson, 2010). Therefore, the data from this incidental encoding task were not of primary interest but the sensitivity and response times are reported in Table 1 for completeness. Briefly, in Experiments 1 (original face stimuli) and 3 (shape-normalized face stimuli), the main effects of race of face and of race of participant were not significant (both Fs < 1). There was also no interaction

TABLE 1
Mean sensitivity (d') and correct response times (ms) for the same/different matching task (encoding task) in each experiment as a function of the race of the participants and the race of the faces

	Exp. 1		*Exp. 2*		*Exp. 3*	
	Asian faces	*Cauc. faces*	*Asian faces*	*Cauc. faces*	*Asian faces*	*Cauc. faces*
Sensitivity						
Asians	2.34 (0.10)	2.24 (0.12)	2.04 (0.10)	1.73 (0.11)	1.79 (0.13)	1.78 (0.13)
Caucasians	2.22 (0.13)	2.34 (0.09)	1.71 (0.09)	1.76 (0.09)	1.84 (0.15)	1.98 (0.10)
Response times (ms)						
Asians	747 (25)	771 (29)	844 (30)	879 (33)	974 (39)	964 (45)
Caucasians	785 (28)	777 (24)	866 (26)	871 (26)	880 (43)	878 (40)

Values in parentheses represent the standard errors of the mean across participants.

between the two factors in either Experiment 1 or 3, $F(1, 38) = 1.39$, *ns*, and $F(1, 30) < 1$, respectively. There was a significant interaction between the two factors, $F(1, 58) = 10.65$, $p = .002$, in Experiment 2 (surface-normalized face stimuli): Asian participants performed significantly better with own-race than other-race faces, $t(29) = 3.66$, $p = .001$, whereas Caucasian participants did not show any difference between own-race and other-race faces, $t(29) < 1$.

Old/new recognition task. The old/new recognition task immediately followed the encoding task. Participants were presented with 80 full-front faces (0°) successively in a random order. These 80 faces included the 40 faces (20 Asians, 20 Caucasians) previously seen in the same/different matching task ("old" faces) and 40 "new" faces (i.e., the other half of our sets of faces: 20 Asians, 20 Caucasians, half males). Participants were instructed to decide whether each face was "old" or "new" by pressing one of two keyboard keys (with mapping of key to response counterbalanced across participants) as quickly and as accurately as possible. Each face was presented until the participants responded or for a maximum of 2000 ms. Participants were not informed of the proportion of old and new faces, and they did not receive any feedback for their responses.

EXPERIMENT 1

The goal of Experiment 1 was to establish a baseline other-race effect with our set of Asian and Caucasian faces and the encoding/recognition paradigm used. In this experiment, we therefore tested Asian and Caucasian participants' ability to recognise Asian and Caucasian original face stimuli in which both shape and surface information were available (see Figure 2A).

Results and discussion

Following previous studies (for a review, see Rossion & Michel, 2011), we focused on participants' performance in recognizing own-race faces relative to other-race faces in the old/new recognition task as a measure of the other-race effect. Analyses were based on sensitivity (d' score; Swets, Tanner, & Birdsall, 1961) and correct response times (RTs). Sensitivity was used instead of accuracy to account for response biases in an old/new recognition task. For computing d', "hits" were defined as responding "old" on *old* trials, and "false alarms" were defined as responding "old" on *new* trials.

Sensitivity. A 2×2 analysis of variance (ANOVA) was conducted on mean d' with race of face (Asian vs. Caucasian) as a within-subjects factor and race of participant (Asian vs. Caucasian) as a between-subjects factor. There was no main effect of race of face or race of participant, both $Fs(1, 38) < 1$. However, the two factors significantly interacted, $F(1, 38) = 9.48$, $p = .004$ (see Figure 3A). In order to see if Asian and Caucasian participants showed an other-race effect, paired samples Student t-tests were conducted on mean d' for Asian and Caucasian faces in both groups of participants. Bonferroni's correction procedure for these comparisons was $p < .025$ (.05/2). A significant other-race effect was observed in Caucasian participants (Asian faces: mean $d' = 0.95$; Caucasian faces: mean $d' = 1.34$), $t(19)_{\text{one-tailed}} = 2.69$, $p = .014$, corrected for multiple comparisons, and a marginally significant other-race effect was shown by Asian participants (Asian faces: mean $d' = 1.29$; Caucasian faces: mean $d' = 0.99$), $t(19)_{\text{one-tailed}} = 2.32$, $p = .031$, uncorrected. The other-race effect, calculated in each participant by subtracting the d' score for other-race faces from the d' score for own-race faces, was statistically equivalent in both groups of participants, $t(38) = 0.44$, *ns*. Thus, consistent with previous studies (e.g., Michel, Caldara, & Rossion, 2006; Michel, Rossion, Han, Chung, & Caldara, 2006; Ng & Lindsay, 1994; O'Toole et al., 1994; Valentine & Endo, 1992), both Asian and Caucasian participants were more accurate at recognizing own-race faces relative to other-race faces when both shape and surface information were available for recognition. The magnitude of the other-race effect did not differ between groups.

Correct response times. Only RTs from correct trials that were less than 2000 ms were analysed to remove outliers. We then pooled across *old* and *new* trials to simplify the analyses and for consistency with the sensitivity analyses. Mean correct response times are reported in Table 2. A 2×2 ANOVA was conducted on mean correct response times with race of face (Asian vs. Caucasian) as a within-subjects factor and race of participant (Asian vs. Caucasian) as a between-subjects factor. We found a significant

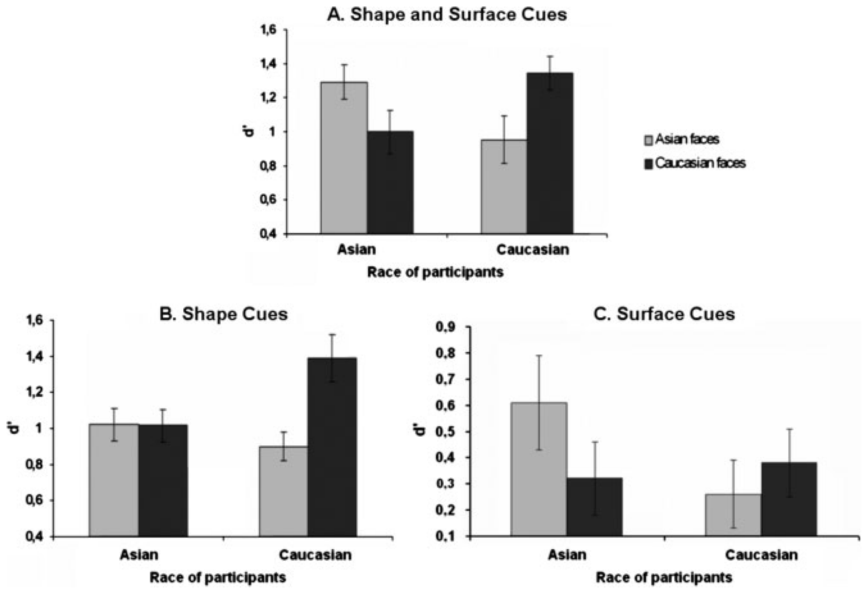

Figure 3. Recognition performance (mean d') for Asian and Caucasian faces in Asian and Caucasian participants in the old/new recognition task for all 3 experiments: (A) Experiment 1 in which faces differ in terms of both shape and surface cues (original face stimuli); (B) Experiment 2 in which faces differ in terms of shape cues exclusively (surface-normalized face stimuli); and (C) Experiment 3 in which faces differ in terms of surface cues exclusively (shape-normalized face stimuli).

main effect of race of face, $F(1, 38) = 5.15$, $p = .03$, with no significant interaction between the two factors, $F(1, 38) < 1$: Caucasian faces were responded to faster ($M = 947$ ms) than Asian faces ($M = 976$ ms). There was no main effect of race of participant, $F(1, 38) < 1$.

The results of Experiment 1 showed that the other-race effect can be replicated with our set of 3-D head models: When both shape and surface information were available, participants were better at recognizing own-race than other-race faces. This other-race effect was observed in terms of

TABLE 2
Mean correct response times (ms) for the old/new recognition task in each experiment as a function of the race of the participants and the race of the faces

	Exp. 1		*Exp. 2*		*Exp. 3*	
	Asian faces	*Cauc. faces*	*Asian faces*	*Cauc. faces*	*Asian faces*	*Cauc. faces*
Asians	965 (27)	943 (24)	1006 (25)	1022 (24)	1082 (57)	1138 (52)
Caucasians	987 (38)	950 (29)	1058 (25)	1032 (25)	1145 (49)	1198 (54)

Values in parentheses represent the standard errors of the mean across participants.

sensitivity in both groups of participants but not in RTs. However, there was no evidence of any speed–accuracy tradeoff driving the sensitivity results. Having established the other-race effect, in the subsequent experiments we manipulated the availability of surface and shape information to examine how Asian and Caucasian observers use shape and surface information to recognize own-race and other-race faces.

EXPERIMENT 2

In Experiment 2, own-race and other-race face recognition was measured with surface-normalized face stimuli containing identity-specific information exclusively in their shape (see Figure 2B). As in Experiment 1, Asian and Caucasian participants first encoded Asian and Caucasian faces in a same/different matching task. Then, their ability to recognize these faces was tested in an old/new recognition task.

Results and discussion

Sensitivity. There was a significant main effect of race of face, $F(1, 58) = 8.61$, $p = .005$, and a significant interaction between this factor and the factor race of participant, $F(1, 58) = 9.1$, $p = .004$. There was no main effect of race of participant, $F(1, 58) = 1.11$, *ns.* As depicted in Figure 3B, Caucasian participants performed better with Caucasian (mean $d' = 1.39$) than with Asian faces (mean $d' = 0.90$), $t(29) = 3.56$, $p = .001$. However, Asian participants' performance was not different for Caucasian (mean $d' = 1.01$) and Asian faces (mean $d' = 1.02$), $t(29) < 1$.

In order to compare the magnitude of the other-race effect observed in Caucasian participants when both shape and surface information were available (Experiment 1) and when only shape information was available (Experiment 2), we conducted a 2×2 ANOVA on Caucasian participants' mean d' with race of face as a within-subjects factor and experiment (Experiment 1 vs. Experiment 2) as a between-subjects factor. There was a significant effect of race of face, $F(1, 48) = 16.62$, $p < .001$, but no interaction with experiment, $F(1, 48) < 1$. The main effect of experiment was not significant, $F(1, 48) < 1$. Thus, the normalization of surface information did not significantly affect Caucasian participants' performance, neither for own-race nor for other-race faces. That is, the magnitude of the other-race effect observed when *only* shape information was available (mean d' difference between own-race and other-race faces $= 0.49$) was statistically equivalent to the magnitude of the other-race effect observed when *both* shape and surface information were available (mean d' difference $= 0.39$; see Figures 3A and 3B). In Asian participants, the lack of the other-race effect in

Experiment 2, in which only shape information was available, seemed to be due to a reduction in performance for own-race faces when compared to performance in Experiment 1, in which both shape and surface information were available (mean $d' = 1.02$ vs. 1.29, respectively), $t(49) = 1.93$, $p = .06$ (see Figures 3A and 3B).

Correct response times. Mean correct response times are reported in Table 2. There was no main effect of race of face, $F(1, 58) < 1$, and only a marginal interaction between race of face and race of participant, $F(1, 58) = 3.26$, $p = .08$. There was no main effect of race of participant, $F(1, 58) < 1$.

In summary, normalization of surface information affected the recognition of own-race faces much more drastically than the recognition of other-race faces in Asian participants. As a result, the other-race effect was eliminated for Asian participants when surface information was no longer available for recognition. By comparison, Caucasian participants recognition of own-race and other-race faces was not affected by the normalization of surface information. Consequently, the other-race effect remained present in these participants when surface information was no longer available for recognition. These results suggest that Caucasian participants mainly get their advantage at recognizing own-race faces from a better encoding of *shape* variations on own-race than on other-race faces. By comparison, Asian participants' encoding of own-race shape variations seems less effective than Caucasian participants' and less specific to own-race faces. The other-race effect in Asian participants is thus possibly due to a better encoding of *surface* variations on own-race than on other-race faces. In Experiment 3, we investigated directly the contribution of surface information to the other-race effect.

EXPERIMENT 3

In Experiment 3, own-race and other-race face recognition was measured with shape-normalized face stimuli containing identity-specific information exclusively in surface variations (see Figure 2C). As in the previous experiments, Asian and Caucasian participants first implicitly encoded Asian and Caucasian faces in a same/different matching task. Then, their ability to recognize these faces was tested in an old/new recognition task.

Procedure

A pilot study aimed at examining the feasibility of the old/new recognition task with faces varying only in surface information showed that this task was very difficult, if not impossible. All the pilot participants ($N = 5$) stated after a few trials that they were not able to perform the task and the experiment was terminated. Consequently, it was necessary to modify the stimuli and procedure for both the same/different matching task and the old/new recognition task as follows.

For the same/different matching task, the number of different identities presented was reduced by half (10 Asians, 10 Caucasians). Moreover, to facilitate the implicit encoding of these individuals, each of them was presented twice as often as in Experiments 1 and 2. More specifically, each individual was presented as the target face (i.e., from a full-front view) in eight trials instead of four (one "same" trial and one "different" trial, repeated three times each), and as the test face (i.e., from a three-quarters view) in eight trials instead of four (one "same" trial, repeated three times, and one "different trial", repeated three times). This resulted in a total of 160 trials, divided into four identical blocks of 40 trials, each containing 20 Asian (10 "same" and 10 "different" trials) and 20 Caucasian (10 "same" and 10 "different" trials) presented in a random order (interstimuli interval = 1000 ms). Finally, given the potential propensity to consider the target face and the test face as being the same when they do not differ in terms of shape, participants were encouraged to give a "same" response when the target and the test face were *strictly* identical (i.e., identical in all aspects). In order to increase participants' familiarization with this instruction, the number of practice trials was also doubled (eight practice trials instead of four).

For the old/new recognition task, participants were successively presented with 40 full-front faces (0°) in a random order. These 40 faces included the 20 faces (10 Asian, 10 Caucasian) previously seen in the same/different matching task ("old" faces) and 20 "new" faces (10 Asian, 10 Caucasian, half males). The instructions were identical to those given in Experiments 1 and 2, with an additional specification encouraging participants to respond "old" only if the presented face was *strictly* identical (i.e., identical in all aspects) to one of the faces previously seen in the encoding task.

Results and discussion

The results of the old/new recognition task need to be interpreted with caution. Even with the changes to the procedure in Experiment 3, participants found the task very difficult (mean accuracy = 59.7% vs. 55.3% and 54.0% vs. 56.9% for Asian vs. Caucasian faces in Asian and Caucasian participants, respectively). However, only Caucasian participants' mean accuracy rate for Asian faces was not above chance level, $t(15) = 1.8$, $p = .09$. In all the other conditions, participants' performance was significantly above chance, $t(15) = 2.96$ [$p = .01$], 3.38 [$p = .004$], and 2.3 [$p = .04$] for Caucasian participants' performance in Caucasian faces and Asian participants' performance in Asian and Caucasian faces, respectively. Given the low accuracy, we also did not analyse response times but present them in Table 2.

A 2 × 2 ANOVA conducted on mean d' with the race of face (Asian vs. Caucasian) as a within-subjects factor and the race of participant (Asian vs. Caucasian) as a between-subjects factor showed no main effects or interactions (Face: $p = .53$; Race: $p = .33$; Face × Race: $p = .15$). This analysis suggests that there was no other-race effect for both Asian and Caucasian participants when only surface information was available for face recognition.

Figure 3C, however, shows some interesting patterns in the data that we discuss. First, Asian participants showed a tendency to an other-race effect, with performance for Asian faces (mean $d' = 0.61$) roughly twice better than for Caucasian faces (mean $d' = 0.32$). By comparison, Caucasian participants' advantage at recognizing own-race as compared to other-race faces appeared to be smaller (mean $d' = 0.38$ vs. 0.25, respectively). Second, the removal of individual shape variations tended to affect Caucasian participants' own-race recognition performance (mean $d' = 1.34$ vs. 0.38 in Experiment 1 and Experiment 3, respectively) to a larger extent than Asian participants' own-race recognition performance (mean $d' = 1.29$ vs. 0.61 in Experiment 1 and Experiment 3, respectively), although the interaction between race of participant (Asian vs. Caucasian) and experiment (Experiment 1 vs. Experiment 3) did not achieve significance, $F(1, 68) = 1.29$, $p = .26$. Last, Asian participants appeared to be better with their own-race (Asian) faces (mean $d' = 0.61$) than Caucasian participants with their own-race (Caucasian) faces (mean $d' = 0.38$).

In summary, the recognition of faces of one's own race was drastically reduced (but above chance) when shape information was normalized. However, there was a trend for normalization of shape information to affect the other-race effect to a larger extent in Caucasian participants than in Asian participants. Thus, these results suggest that Asian participants mainly get their advantage at recognizing own-race faces from a more efficient encoding of *surface* variations of own-race than other-race faces. Caucasian participants' encoding of surface variations on own-race faces tended to be less effective and less specific to own-race faces. This indicates that the other-race effect in Caucasian participants was possibly due to a better encoding of *shape* variations on own-race than on other-race faces, as was suggested directly from the results of Experiment 2.

GENERAL DISCUSSION

The results from Experiment 1 replicate the well-known other-race effect in face recognition. The crossover interaction between groups and the race of faces was obtained in an old/new face recognition task, which is the most common kind of task used to assess and obtain the other-race effect

(Meissner & Brigham, 2001; Rossion & Michel, 2011). Asian and Caucasian participants performed equally well on own-race faces and they performed equally well on other-race faces, thus providing the ideal baseline to test the relative contribution of shape and surface information to the other-race effect. In Experiment 2, when only shape information was available (surface-normalized face stimuli), Asian participants did not show the other-race effect they showed when both shape and surface information were available (Experiment 1), while the magnitude of the other-race effect was the same for Caucasian participants in Experiments 1 and 2. Finally, in Experiment 3, when only surface information was available (shape-normalized face stimuli), Caucasian participants' ability to recognize own-race faces tended to decrease to larger extent than Asian participants' ability to recognize own-race faces. This results in a trend for the other-race effect in only Asian participants. The results of Experiment 3 need to be interpreted with caution given the difficulty of the old/new recognition task in the absence of shape information (and that there was no statistical significance in the ANOVAs).

We did not consistently find an other-race effect in the same/different matching task. The effect was present for Asian observers when only shape information was available (Experiment 2). This task is a more perceptually driven task which has much less memory demands than the old/new recognition task. Balas and Nelson (2010) also did not find an other-race effect in a perceptual matching task for upright faces. In their review of the other-race effect, Hayward, Crookes, and Rhodes (this issue 2013) have suggested that a key feature in own-race face recognition is better holistic processing and better feature processing for both short-term perceptual and long-term memory face representations. In line with this, the other-race effect has been reported for perceptual (e.g., Lindsay et al., 1991; Marcon et al., 2010; Megreya et al., 2011; Meissner et al., this issue 2013; Tanaka et al., 2004; Walker & Tanaka, 2003) as well as memory tasks (see Meissner & Brigham, 2001, and Rossion & Michel, 2011, for reviews). At the same time, both types of representations can be moderated by various factors. For example for perceptual tasks, Marcon et al. (2010) showed that task parameters such as presentation duration of target faces, retention interval, and the number of test faces can moderate, or even eliminate, the other-race effect. Meissner et al. (this issue 2013) has shown that age differences between the target and test faces and disguises can likewise moderate the other-race effect. Our study is the first to follow-up a perceptual task with a surprise memory task. The fact that we do subsequently find an other-race effect for recognition memory irrespective of whether there was an effect in perceptual discrimination is an interesting phenomenon to explore more systematically in future studies.

The role of surface information in old/new face recognition

Interestingly, the normalization of surface information, namely texture and colour, had little effect on Caucasian observers' performance at recognizing own-race and other-race faces. At first glance, these findings are inconsistent with previous studies that demonstrated a role of surface information for recognizing own-race faces, especially since these studies were performed with Caucasian observers looking at Caucasian face stimuli (e.g., Bruce et al., 1991; Bruce et al., 1992; Bruce & Langton, 1994; Caharel et al., 2009; Davies et al., 1978; Jiang et al., 2006, 2011; Lee & Perrett, 1997; O'Toole et al., 1999; Russell et al., 2006; Vuong et al., 2005). An important factor in this respect may be the nature of the encoding, which was incidental here. That is, observers in our study were not explicitly instructed to memorize the faces. When observers were explicitly instructed to do so, they may be more likely to also encode surface information in memory (O'Toole et al., 1999). A possible exception here may be when surface cues indicate a different race, as in Brebner et al.'s (2011) study. They also used an incidental encoding task (age judgement) but found that Caucasian observers' recognition of both Caucasian and African faces were affected by changes to surface cues. Another factor that may affect the extent to which Caucasian observers encode surface information in addition to shape information may be the familiarity of the faces. For example, the recognition of famous faces (e.g., Bruce et al., 1992; Bruce & Langton, 1994; Lee & Perrett, 1997) or personally familiar faces (e.g., Russell & Sinha, 2007) can be affected by changes to surface cues.

Since most previous studies testing the role of surface cues have been performed in Caucasian observers (e.g., Bruce et al., 1991; Bruce et al., 1992; Bruce & Langton, 1994; Caharel et al., 2009; Davies et al., 1978; Jiang et al., 2006, 2011; Lee & Perrett, 1997; O'Toole et al., 1999; Russell et al., 2006; Vuong et al., 2005), the present findings also provide original evidence for the role of surface information in the recognition of individual Asian faces by Asian observers. Russell and Sinha (2007) also tested Asian observers, using personally familiar faces as stimuli. For Caucasian female faces, they found that both Asian and Caucasian observers performed better when only surface information was available than when only shape information was available. By comparison, for Asian female and Caucasian male faces, there were no performance differences between these two conditions. Thus, the extent to which Asian observers relied on surface information to recognize Asian face stimuli remain unclear. We show that surface information contribute to Asian face recognition in Asian observers: Surface normalization decreased Asian observers' ability to recognize Asian faces.

Overall, our results suggest that the initial representations of unfamiliar faces encoded in memory may be based predominantly on shape information, although surface information would also play a role in Asian observers. However, when only surface information was available for face recognition (Experiment 3), performance on the old/new recognition task was very low for both Asian and Caucasian observers even when it was made easier than in the other two experiments by reducing the number of faces to encode. The poor performance may indicate that the surface cues of both Asian and Caucasian face stimuli lacked identity information. This possibility seems unlikely for two main reasons. First, participants were able to perform reasonably well on the matching task at encoding with surface information only. Indeed, there was no evidence of lower performance compared to the same task performed with shape cues only (Experiment 2: mean d' across all conditions $=1.81$; Experiment 3: mean $d' = 1.85$; see Table 1). Second, the normalization of surface information (Experiment 2) had a significant effect on Asian observers' ability to recognize Asian faces relative to when both shape and surface information were available (Experiment 1).

That said, our encoding protocol may have biased observers to initially encode shape information of unfamiliar Asian and Caucasian faces because we presented the target face from a frontal view and the test face from a three-quarters view. This change in viewpoint may have induced observers to form a more robust representation of the 3-D structure of the face (Bruce & Young, 1998) and thus to focus more on shape changes. However, viewpoint changes could also affect the available surface information and may therefore induce observers to focus on texture changes. More importantly, any shape bias induced by the viewpoint change cannot account for the fact that Asian but not Caucasian observers were affected by surface normalization in Experiment 2.

Asians and Caucasians rely on different diagnostic cues for face recognition

Our main findings provide original support for the view that different racial groups have been tuned to rely on different diagnostic cues to recognize own-race faces, and that these cues may be suboptimal when used to recognize other-race faces (e.g., Chiroro & Valentine,1995; Ellis et al., 1975; Furl et al., 2002; Hills & Lewis, 2006; O'Toole et al., 1991; Valentine, 1991; Valentine & Endo, 1992; see Natu & O'Toole, this issue 2013, for a recent review of the neural and computational evidence consistent with this account). In our study, Caucasian observers seemed to rely predominantly on shape cues for recognizing all faces: Their performance in the task was unaffected by the normalization of surface cues (Experiment 2), and surface cues alone did not allow them to perform above chance level for other-race faces and just above chance level for own-race faces (Experiment 3). By comparison, Asian observers seemed to also rely on surface cues for recognizing all faces, in addition to using shape cues: Their performance at recognizing own-race faces was affected by normalization of surface cues (Experiment 2) and they could use surface cues alone to perform above chance level for both own-race and other-race faces (Experiment 3). However, for other-race faces, surface cues did not seem informative enough to improve Asian participants' performance when both shape and surface cues were available (Experiment 1).

We do not have a reason for this racial difference in the reliance on shape and surface information for face recognition. As noted earlier, both anthropometric studies and computational analyses suggest that racial groups differ in the degree to which individuals within a racial group vary in their facial structure and skin tone (e.g., Farkas, 1994; O'Toole et al., 1991). Future studies can test the computational models of the other-race effect summarized by Natu and O'Toole (this issue 2013) to determine whether variance in shape and surface information of the face stimuli can lead to the racial difference in cue reliance reported here, but that is beyond the scope of this paper.

To summarize, our results suggest that the other-race effect is partly due to an over-reliance on shape cues in Caucasians when having to recognize Asian faces, at the expense of surface cues. Conversely, Asians may over-rely on surface cues that may not be diagnostic for distinguishing among Caucasian faces. This interpretation fits with the perceptual learning account of the other-race effect, according to which there are different diagnostic features for own-race and other-race faces, and our perceptual system becomes tuned to the features that are diagnostic for own-race faces. The face processing system would select the own-race facial information when having to recognize other-race faces, an approach which would not be optimal since the facial information that is diagnostic in other-race faces may differ from the facial information that is diagnostic in own-race faces (Furl et al., 2002; O'Toole et al., 1991; see also Ellis et al., 1975). It has to be noted, however, that when the very same manipulations of diagnostic features are applied to own-race and other-race faces, observers still perform better with own-race than other-race faces (Rhodes, Hayward, & Winkler, 2006). Such findings cannot be fully accounted for in terms of differentially diagnostic features across races of faces and suggest additional factors such as the mismatch of other-race faces with an observer's holistic face template, which is built from experience with own-race faces (Rossion & Michel, 2011).

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Manuscript received March 2013
Manuscript accepted July 2013
First published online August 2013