Vision Research 105 (2014) 61–69

Contents lists available at ScienceDirect

Vision Research

journal homepage: www.elsevier.com/locate/visres

Holistic processing, contact, and the other-race effect in face recognition

Mintao Zhao [a,*], William G. Hayward [b,c,d], Isabelle Bülthoff [a,*]

[a] Max Planck Institute for Biological Cybernetics, Tübingen, Germany
[b] Department of Psychology, University of Hong Kong, Hong Kong
[c] School of Psychology, University of Auckland, New Zealand
[d] ARC Centre of Excellence in Cognition and Its Disorders, School of Psychology, University of Western Australia, Australia

ARTICLE INFO

Article history:
Received 17 April 2014
Received in revised form 10 September 2014
Available online 26 September 2014

Keywords:
Face recognition
Other-race effect
Holistic processing
Configural processing
Featural processing

ABSTRACT

Face recognition, holistic processing, and processing of configural and featural facial information are known to be influenced by face race, with better performance for own- than other-race faces. However, whether these various other-race effects (OREs) arise from the same underlying mechanisms or from different processes remains unclear. The present study addressed this question by measuring the OREs in a set of face recognition tasks, and testing whether these OREs are correlated with each other. Participants performed different tasks probing (1) face recognition, (2) holistic processing, (3) processing of configural information, and (4) processing of featural information for both own- and other-race faces. Their contact with other-race people was also assessed with a questionnaire. The results show significant OREs in tasks testing face memory and processing of configural information, but not in tasks testing either holistic processing or processing of featural information. Importantly, there was no cross-task correlation between any of the measured OREs. Moreover, the level of other-race contact predicted only the OREs obtained in tasks testing face memory and processing of configural information. These results indicate that these various cross-race differences originate from different aspects of face processing, in contrary to the view that the ORE in face recognition is due to cross-race differences in terms of holistic processing.

1. Introduction

Face race has been shown to influence performance in many face tasks, such as face recognition and identification (Meissner & Brigham, 2001; Sporer, 2001), holistic face processing (Michel, Caldara, & Rossion, 2006; Michel, Rossion, Han, Chung, & Caldara, 2006; Tanaka, Kiefer, & Bukach, 2004), processing of featural and configural facial information (i.e., spacing between face features, Hayward, Rhodes, & Schwaninger, 2008; Rhodes et al., 2009; Rhodes, Hayward, & Winkler, 2006), or categorization of facial gender, age, and expression (Dehon & Brédart, 2001; Elfenbein & Ambady, 2002; O'Toole, Peterson, & Deffenbacher, 1996). Although these various other-race effects (OREs) have been demonstrated in separate studies, it remains unclear whether the influences of face race on these tasks arise from the same underlying mechanisms or from independent processes.

What underlies these OREs remains a matter of debate (Hayward, Crookes, & Rhodes, 2013; Hugenberg et al., 2010; Rhodes et al., 2010). Some propose that the OREs are caused by different level of holistic processing involved in own- and other-race faces (Hancock & Rhodes, 2008; Michel, Caldara, & Rossion, 2006; Michel, Rossion, et al., 2006; Tanaka, Kiefer, & Bukach, 2004). This hypothesis is plausible as holistic processing (i.e., perceiving face as a whole rather than a collection of independent face parts, Maurer, Le Grand, & Mondloch, 2002) is often correlated with face recognition ability (Richler, Cheung, & Gauthier, 2011; Wang et al., 2012; but see Konar, Bennett, & Sekuler, 2010; Zhou et al., 2012). Others assume that the OREs come from an own-race advantage in processing both configural (i.e., relative location and spatial relations among face parts) and featural information (i.e., face parts) (Hayward, Rhodes, & Schwaninger, 2008; Hayward, Crookes, & Rhodes, 2013; Rhodes, Hayward, & Winkler, 2006; Rhodes et al., 2009). Still others hypothesize that the OREs may stem from a general in-group/out-group bias (Sporer, 2001), which drives people to selectively attend to different facial properties for own- and other-race faces (Hugenberg et al., 2010; Levin, 2000). For own-race faces, people selectively attend to identity-diagnostic information, which is critical to discriminate different individuals. In contrast, for other-race faces, people tend to pay attention to race-diagnostic information without individuating them, therefore impairing their late recognition (Hugenberg et al., 2010).

* Corresponding authors at: Department of Human Perception, Cognition, and Action, Max Planck Institute for Biological Cybernetics, 72076 Tübingen, Germany. Fax: +49 07071 601 616.

E-mail addresses: Mintao.Zhao@tuebingen.mpg.de (M. Zhao), Isabelle.Buelthoff@tuebingen.mpg.de (I. Bülthoff).

http://dx.doi.org/10.1016/j.visres.2014.09.006
0042-6989/© 2014 The Authors. Published by Elsevier Ltd.

Although it may be difficult to disentangle different hypotheses for the ORE because they are not mutually exclusive (see also Zhao, Hayward, & Bülthoff, 2014), discerning whether or not these various OREs are supported by the same underlying mechanisms is possible. Irrespective of which hypothesis provides a better account for the various OREs, if those OREs arise from the same underlying mechanisms, then individual differences in ORE observed in one task should show some correlation with those observed in a different task. Alternatively, if the OREs observed in different tasks are mediated by different processes, then these OREs should be independent of each other.

Prior studies that have attempted to link the ORE in face recognition to that in holistic processing have found mixed results. Significant correlation between OREs in face recognition and in holistic processing has been observed in one study (DeGutis et al., 2013) but not others (Michel, Caldara, & Rossion, 2006; Michel, Rossion, et al., 2006). This discrepancy may be due to methodological differences in estimating those OREs. Whereas Michel and colleagues used a subtraction-based method to calculate the ORE (i.e., subtracting performance for other-race faces from performance for own-race faces), DeGutis et al. (2013) used a regression-based analysis (i.e., regressing out performance for other-race faces from performance for own-race faces), which may provide a more sensitive measure of correlations between different OREs. Other studies suggest that the absence of correlation reflects the independent influence of face race on face perception (e.g., holistic processing) and on face memory (Schwaninger, Ryf, & Hofer, 2003; Wilhelm et al., 2010; but see Wiese, Kaufmann, & Schweinberger, 2014).

In the present study, we investigated whether OREs observed in different face recognition tasks are mediated by the same underlying mechanisms or supported by different processes. In two experiments reported here, participants performed a set of tasks that have been reported to be sensitive to the race of face and tap into different aspects of face processing. In Experiment 1, we used the whole/part task (Tanaka, Kiefer, & Bukach, 2004), the blurred and scrambled face recognition task (Hayward, Rhodes, & Schwaninger, 2008), and the Cambridge Face Memory Tests (CFMT, Duchaine & Nakayama, 2006; McKone et al., 2012). The whole/part task was used to estimate cross-race differences in holistic processing (i.e., the whole/part advantage, Michel, Caldara, and Rossion, 2006; Tanaka, Kiefer, & Bukach, 2004). As elaborated in Tanaka and Farah (1993), holistic face processing means that "the representation of a face used in face recognition is not composed of representations of the face's parts, but more as a whole face" (p 226). Thus, recognition of face parts should be better when tested within the whole face than as isolated face parts (i.e., whole/part advantage). The blurred and scrambled task measured ORE in configural processing (recognizing faces using configural information preserved in blurred faces) and featural processing (recognizing faces using isolated face features) (Hayward, Rhodes, & Schwaninger, 2008; Mondloch et al., 2010; Rhodes et al., 2009). The original and the Chinese version of CFMTs allowed us to assess the ORE in face recognition (McKone et al., 2012). In Experiment 2, we used the composite face task to measure ORE in holistic processing and the CFMT to measure ORE in face recognition, which allowed us to examine whether our results are specific to the tasks used in Experiment 1. In both experiments, we first examined the OREs in different tasks, and then tested whether these OREs are correlated with each other.

A questionnaire was included in each experiment to measure participants' experience with other-race people. It has been shown that contact with other-race people is correlated with individual difference in OREs observed in face recognition tasks (Meissner & Brigham, 2001). For instance, more frequent other-race contacts tend to elicit a smaller ORE in face recognition (Wiese, Kaufmann, & Schweinberger, 2014), a smaller ORE in terms of face inversion effect (Hancock & Rhodes, 2008), and a smaller ORE in recognition of blurred faces (Rhodes et al., 2009). In addition, more experience in actively individuating other-race faces also leads to a smaller ORE in holistic processing, as measured with a composite face task (Bukach et al., 2012). Nonetheless, these results were observed with different studies using a diversity of questionnaires, leaving it unclear whether other-race contact affects various OREs in a similar way. The inclusion of a questionnaire along with the face recognition tasks allowed us to address this question directly.

The battery of tasks we selected here provides a comprehensive test of whether the OREs manifested in different tasks are linked to each other, and whether they are similarly affected by contact with other-race people. Strong cross-task correlations between observed OREs would suggest that they are rooted in the same underlying mechanisms. In contrast, evidence of independent OREs would suggest that face race affects various types of face processing differently.

2. Experiment 1

2.1. Participants

We tested 34 German participants (17 females, mean age = 30.4, *SD* = 7.5) at the Max Planck Institute for Biological Cybernetics, and 32 Chinese (23 females, mean age = 21.9, *SD* = 3.8) at the University of Hong Kong. In accordance with the Declaration of Helsinki, the procedures were approved by local IRBs and signed consent forms were obtained from individual participants before the experiment.

2.2. Tasks

The experiment consisted of three tasks. Each participant performed the whole/part task first, then the blurred and scrambled tasks, followed by the CFMT task. Each task was performed with both Asian and Caucasian faces. Participants were instructed to respond as accurately as possible in all tasks. The experiment ended with participants filling out a cross-race contact questionnaire.

2.2.1. Whole/part task

Stimuli. Whole and part faces were created using 96 faces (48 Caucasians, 48 Asians, half male, half female faces) from the MPI face database (http://faces.kyb.tuebingen.mpg.de, Blanz & Vetter, 1999). Faces of the same race and gender were randomly paired. For each pair, we swapped key face parts (i.e., eyes, nose, and mouth) between both faces. These feature-swapped faces were used as distractor stimuli for the original faces in the *whole condition* (Fig. 1A). We also isolated these key face parts from each face and arranged them into a non-face like configuration, forming face parts stimuli for the *part condition* (Fig. 1A). Thus, differences between two whole faces in the whole condition were exactly the same as those between two sets of face parts in the part condition. The reason for changing three key face parts at once was to minimize potential attentional bias toward to certain face parts in completing the task (e.g., the eyes, see Crookes, Favelle, & Hayward, 2013; DeGutis et al., 2013). We also introduced a small viewpoint change to avoid the use of an image matching strategy. Target faces were turned either to the left or to the right by 15°, while test faces were always presented from the frontal view.

Procedure. Participants performed a sequential matching task. Each participant had two blocks of 48 trials (2 conditions × 2 genders × 12 identities), one for each race, with block order counterbalanced across participants. In each block, whole and part trials were randomly mixed. Each trial proceeded with a fixation cross (250 ms), a blank screen (250 ms), a target face (1000 ms), the first

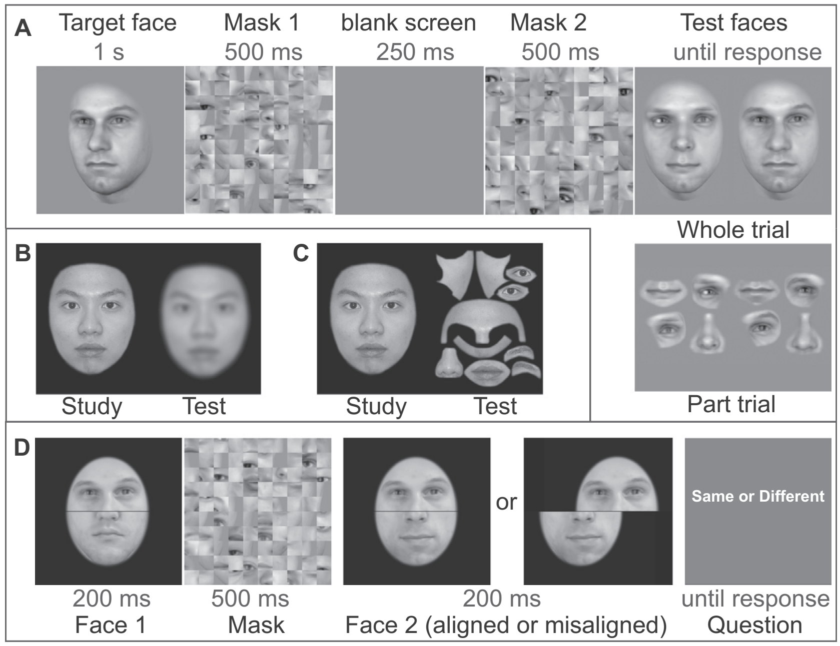

Fig. 1. Tasks used in Experiments 1 and 2. (A) Example of stimuli sequence for the whole and part conditions in the whole/part task. (B and C) Example of study and test faces in the blurred and scrambled tasks. (D) Example of stimuli sequence for the composite face task.

mask image (500 ms), a blank screen (250 ms), the second mask image (500 ms), and then two test faces displayed until a response was made (Fig. 1A). The test faces were either two whole faces (whole condition) or two sets of face parts (part condition), one of which exactly matched the target face. The correct test face was randomly located on the left or the right. Participants pressed a key to indicate which face showed the same person as the target face. Performance was measured in terms of accuracy in this two-alternative-force-choice (2AFC) task.

2.2.2. Blurred and scrambled face recognition tasks

Stimuli. Caucasian and Asian face stimuli were created as described in Hayward, Rhodes, and Schwaninger (2008). Intact face images were gray scale, with standard inter-pupil distance (80 pixels). Blurred faces were created by applying a Gaussian filter (radius = 3 pixels; *SD* = 3 pixels) to an intact faces four times in succession (Fig. 1B). Scrambled faces were created by cutting the intact face image into ten parts, and rearranging them into a non-face like configuration (Fig. 1C). All faces were placed on a black background (320×420 pixel).

Procedure. This task consisted of four blocks, resulting from the factorial combination of face race (Asian vs. Caucasian) and face format at test (blurred vs. scrambled). Block order was counterbalanced across participants, but same-race blocks were grouped together. In each block, participants learned 10 *intact* faces twice, with each face displayed for 10 s in a randomized order. After learning, participants saw one non-studied blurred or scrambled face to acquaint them with the format of the upcoming test faces. Then their memory about the studied faces was probed with either 20 *blurred* test faces (10 old, 10 new, Fig. 1B) or 20 *scrambled* test faces (Fig. 1C). Each test face was displayed until a response was made. Participants pressed one key if they thought the face was learned (i.e., old) and another key if not (i.e., new). Performance was measured in terms of sensitivity (d') computed from hit and false alarm rates.

2.2.3. Cambridge Face Memory Test (CFMT)

Stimuli. The original and the Chinese version of CFMT (Duchaine & Nakayama, 2006; McKone et al., 2012) were obtained from Brad Duchaine and Jia Liu respectively. Both tests used male faces, with hair concealed, posing a neutral expression (for more details, see Duchaine & Nakayama, 2006; McKone et al., 2012).

Procedure. Each CFMT had three phases. In the learning phase, participants learned six target faces from their front, left, and right side views, with each face view displayed for 3 s. After learning each face, participants performed 3 three-alternative-force-choice (3AFC) trials, in which they identified the target face from two simultaneously presented distractor faces. The original target face images were used at test, and both distractor faces showed the same view as the target face. In the novel-image phase, participants studied all six target faces displayed simultaneously for 20 s, and performed 30 3AFC trials. Novel target face images were used at test, which differed from the learned face images in viewpoint and/or lighting. In the noise-image phase, participants reviewed all target faces again for 20 s and performed 24 3AFC trials. For these trials, visual noise was added to all faces. As in previous studies (e.g., DeGutis et al., 2013; McKone et al., 2012), performance was measured in terms of accuracy across all three phases.

2.2.4. Other-race contact questionnaire

The questionnaire was based on Walker and Hewstone's (2006) social contact questionnaire, and consisted of five statements ('I often see East Asian/European people', 'I spend a lot of my free time doing things with East Asian/European people ', 'I have many friends that are from East Asian/European countries', 'I often go round to the houses of East Asian/European people', and 'I often meet with East Asian/European people at my house'). Participants rated each statement using a 6-point scale, with 1 meaning 'very strongly disagree' and 6 meaning 'very strongly agree'.

2.3. Results and discussion

2.3.1. OREs were observed in some but not all tasks

For the whole/part task, we found equivalent performance for own- and other-race faces in both whole and part conditions (Fig. 2A). Therefore, the whole/part advantage (i.e., differences between performance on whole and part conditions) was similar

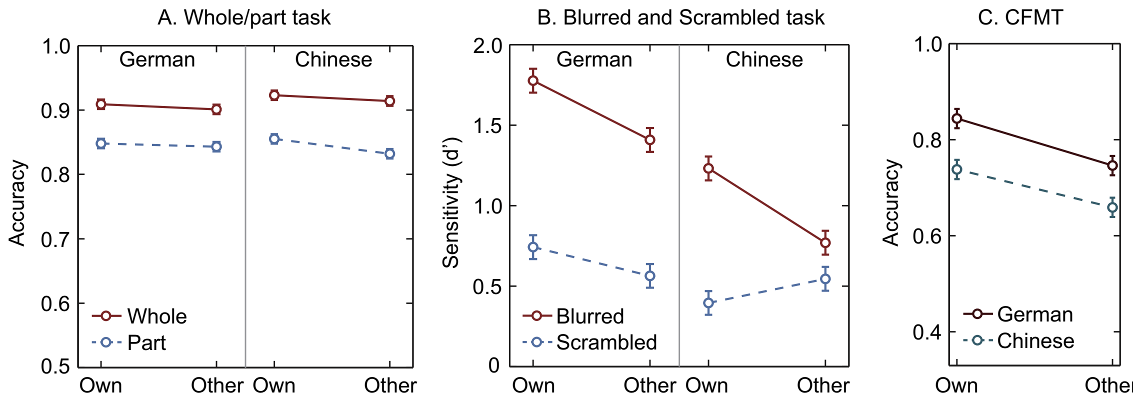

Fig. 2. Performance for own-race and other-race faces in each task. German and Chinese refer to race of participants, Own and Other refer to own-race and other-race faces. Error bars are standard errors of the mean estimated from ANOVA.

for own- and other-race faces, suggesting that no ORE is manifested in holistic processing. A 2 (observer: Chinese vs. German) × 2 (face race: own-race vs. other-race) × 2 (condition: whole vs. part) mixed ANOVA showed a main effect of condition, $F(1,64) = 75.08$, $MSe = 0.004$, $p < 0.0001$, $\eta_p^2 = 0.54$, confirming the whole/part advantage (0.91 vs. 0.84). Neither the main effect of face race, $F(1,64) = 2.14$, $MSe = 0.004$, $p = 0.15$, $\eta_p^2 = 0.03$, nor the interaction between face race and condition, $F(1,64) = 0.13$, $MSe = 0.004$, $p = 0.72$, $\eta_p^2 < 0.01$, was significant. Thus, the whole/part advantage is not modulated by face race. These results are consistent with previous studies showing no ORE in terms of whole/part advantage (Mondloch et al., 2010), particularly for Asian participants (see Hayward, Crookes, & Rhodes, 2013; for a review).

For the blurred and scrambled tasks which tested for configural and featural processing, respectively, we found an overall ORE, which was mainly driven by a robust ORE in recognizing blurred faces (Fig. 2B). A 2 (observer: Chinese vs. German) × 2 (face race: own-race vs. other-race) × 2 (face type: blurred vs. scrambled) ANOVA revealed a main effect of face race, $F(1,64) = 5.33$, $MSe = 0.57$, $p = 0.02$, $\eta_p^2 = 0.08$, with better performance for own- than other-race faces (1.04 vs. 0.82). The main effects of face type and observer were also significant. Recognition of blurred faces was better than recognition of scrambled faces (1.30 vs. 0.56), $F(1,64) = 69.04$, $MSe = 0.52$, $p < 0.0001$, $\eta_p^2 = 0.52$. German participants performed better than Chinese participants, $F(1,64) = 12.28$, $MSe = 0.81$, $p = 0.001$, $\eta_p^2 = 0.16$.

The interactions between face race by face type, $F(1,64) = 7.32$, $MSe = 0.36$, $p < 0.01$, $\eta_p^2 = 0.10$, and between face race by observer, $F(1,64) = 5.37$, $MSe = 0.52$, $p = 0.02$, $\eta_p^2 = 0.08$, were both significant. Separate ANOVAs for each face type revealed a significant ORE in recognizing blurred faces, $F(1,64) = 12.83$, $MSe = 0.07$, $p < 0.001$, $\eta_p^2 = 0.17$, but not in recognizing scrambled faces, $F < 1$. Separate ANOVAs for each group of participant showed a significant interaction between face race and face type in Chinese participants, $F(1,31) = 7.85$, $MSe = 0.38$, $p < 0.01$, $\eta_p^2 = 0.20$, but not in German participants, $F < 1$. Both German and Chinese participants showed consistent ORE in recognition of blurred faces, but only German participants showed a trend of ORE in recognition of scrambled faces. These results suggest that face race have a stronger influence on processing configural information than featural information (but see Hayward, Rhodes, & Schwaninger, 2008).

For the CFMT task, participants showed better performances for own- than for other-race faces (0.79 vs. 0.70), $F(1,64) = 68.40$, $MSE = 0.004$, $p < 0.0001$, $\eta_p{}^2 = 0.52$, showing a robust ORE (Fig. 2C). German participants showed higher performance than Chinese participants (0.79 vs. 0.70), $F(1,64) = 13.35$, $MSE = 0.02$, $p < 0.001$, $\eta_p{}^2 = 0.17$, but the interaction between observer and face race was not significant, $F < 1$. These results suggest that Chinese and German participants exhibit similar OREs in the CFMT task.

2.3.2. Influences of face race on different tasks were independent

We calculated individual participants' OREs for each task by subtracting their performance for other-race faces from that for own-race faces (i.e., subtraction-based method), and then performed correlation analysis between OREs measured in different tasks. We only observed a trend of significant correlation between OREs in recognizing blurred faces and scrambled faces, $r(66) = 0.21$, $p = 0.08$, whereas all other cross-task correlations were far from significant, all $r \leqslant 0.08$, all $p > 0.53$. Similar results were found when we analyzed our data using the regression-based correlation analysis proposed by DeGutis et al. (2013). This analysis revealed a marginally significant correlation between OREs in recognizing blurred and scrambled faces, $r(66) = 0.24$, $p = 0.05$, whereas all other cross-task correlations were near zero, all $r \leqslant 0.04$, all $p > 0.74$.

The lack of cross-task correlations was not due to the reliabilities in measuring different OREs. Following previous studies (DeGutis et al., 2013; Ross, Richler, & Gauthier, 2014), we used Gutman's λ_2 to estimate internal reliability of individual conditions in each task, and used the regression-based method to estimate the reliability of all ORE measures (see Ross, Richler, & Gauthier, 2014, for details). The observed reliability was high for measuring ORE in the CFMT and modest for measuring OREs in other tasks (Table 1). The scores of reliabilities were equivalent to or higher than those reported in one previous study (e.g., DeGutis et al., 2013). More importantly, the observed correlations were much less than their theoretical upper boundaries (Table 2), which were estimated as the geometric mean of reliabilities for two measures (Schmidt & Hunter, 1999). These near-zero correlations suggest that face race affects different face recognition tasks independently, probably due to these tasks tapping into different face processing mechanisms.

2.3.3. Shared processes for own- and other-race faces

We observed significant within-task correlations between performance for own- and other-race faces in the CMFT, $r(66) = 0.73$, $p < 0.0001$, in recognition of blurred faces, $r(66) = 0.37$, $p = 0.002$, and in both whole and part conditions of the whole/part task (whole condition, $r(66) = 0.28$, $p = 0.02$; part condition, $r(66) = 0.48$, $p < 0.0001$). These results suggest that recognition of own- and other-race faces within each task share the same underlying mechanism (see also DeGutis et al., 2013). However, recognition of scrambled faces showed no such correlation, $r(66) = 0.06$,

Table 1
Reliabilities for different tasks in Experiments 1 and 2 (Regression-based reliabilities are shown in bold face).

	Own-race faces	Other-race faces	ORE	Prior studies
CFMT				
Expt. 1	.91	.83	**.80**/.75	**.52**/.48[a]
Expt. 2	.91	.88	**.78**/.73	
Blurred and Scrambled task				
Blurred	.51	.47	**.39**/.29	
Scrambled	.27	.49	**.26**/.35	
Whole/part task				
Whole	.51	.47		
Part	.27	.35		
Whole part advantage	**.23**/−.09	**.29**/.07	**.21**/−.07	**.25**/−.02[a]
Composite face task				
Align/Congruent	.67	.52		
Align/Incongruent	.73	.58		
Misalign/Congruent	.74	.57		
Misalign/Incongruent	.77	.68		
Composite face effect	**.50**/.36	**.34**/.31	**.49**/.29	**.02–.35**[b]
Questionnaire				
Expt. 1		.88		.89[c]
Expt. 2	.84	.88		.82–.94[d]

[a] Reliabilities for measuring OREs in CFMT and in Whole/part advantage (DeGutis et al., 2013).
[b] Reliabilities for measuring composite face effect (Experiments 1–3, Ross, Richler, & Gauthier, 2014).
[c] Cronbach's α (Walker & Hewstone, 2006).
[d] Cronbach's α (Hancock & Rhodes, 2008).

Table 2
Regression-based correlations and their upper boundaries (in parentheses) between OREs measured in different tasks in Experiments 1 and 2.

	CFMT	Blurred	Scrambled
Composite face effect	.10 (.62)		
Blurred	.01 (.56)		
Scrambled	.04 (.46)	.24 (.32)	
Whole/part advantage	.02 (.41)	.02 (.29)	.03 (.23)

$p = 0.65$, suggesting that processing own- and other-race face features in a memory task (i.e., scrambled task) and a perceptual task (i.e., part conditions of the whole/part task) involves different strategies (Wilhelm et al., 2010).

2.3.4. Level of contact predicts OREs in the CFMT and in the blurred task

To examine whether contact with other-race faces predicts OREs in face processing we conducted a multivariate regression analysis. The predictor (i.e., covariate) was scores of cross-race contact obtained from the questionnaire, and the dependent variables included OREs computed in individual tasks. As shown in Fig. 3, contact scores accounted for a small but significant portion of individual variances in OREs observed in the CFMT, $F(1,64) = 5.05$, $MSe = 0.007$, $p = 0.03$, $\eta_p^2 = 0.07$, and in recognizing blurred faces, $F(1,64) = 4.80$, $MSe = 0.82$, $p = 0.03$, $\eta_p^2 = 0.07$; but not for OREs observed in recognizing scrambled faces, $F = 2.25$, $p = 0.14$, or in the whole/part advantage, $F < 1$. These results indicate that frequent other-race contact reduces OREs in memory of normal or blurred faces, but does not improve all aspects of face processing for other-race faces (e.g., featural processing).

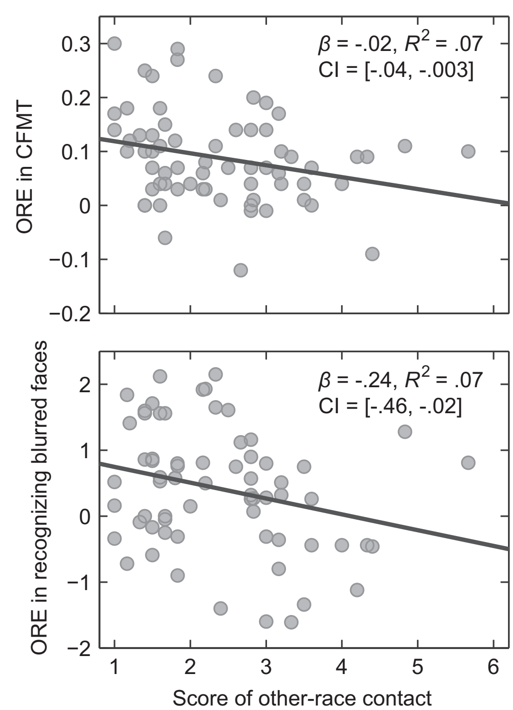

Fig. 3. Level of other-race contact predicts OREs in the CFMT and in recognizing blurred faces.

3. Experiment 2

Experiment 1 showed independent influences of face race on various face recognition tasks. In particular, we observed no significant correlation between cross-race differences in the whole/part advantage (i.e., holistic processing) and in the CFMT (i.e., face recognition). Although our whole/part task revealed robust holistic face processing effect (i.e., whole/part advantage), it may be argued that our modification of the task made it insensitive or unreliable as a measure of cross-race differences in holistic processing. To address this issue, in Experiment 2, we measured holistic processing using a complete design composite face task (Richler, Cheung, & Gauthier, 2011), face recognition using the CFMT, and other-race contact using a different questionnaire developed by Hancock and Rhodes (2008). These tasks therefore allowed us to examine whether the results of Experiment 1 were specific to our measures of holistic processing and other-race contact.

3.1. Participants

Forty-six German participants (26 females, mean age = 27, $SD = 5.6$) took part in the experiment. In accordance with the Declaration of Helsinki, the procedures were approved by local IRBs and signed consent forms were obtained from individual participants before the experiment.

3.2. Tasks

Each participant performed the CFMT first and performed the composite face task and the questionnaire one week later. Separation of the two tasks by one week was to minimize any potential influences that the first task may exert on the second task.

3.2.1. CFMT

Stimuli and procedure were identical to those used in Experiment 1.

3.2.2. Composite face task

Stimuli. Forty faces (20 Asian, 20 Caucasian, half male and half female) from the MPI face database were converted to grayscale and were place on a neutral gray background (270 by 270 pixels). Each face was cut into top and bottom face parts (270 by 135 pixels). These top and bottom face parts were randomly combined to create composite faces, with the constraint that they had the same race and gender. The top and bottom parts of faces could be aligned (aligned face) or misaligned (misaligned face). An oval shape mask was used to conceal face outline (Fig. 1D).

Procedure. Participants performed same/different judgments about the top parts of two sequentially presented faces. As in Richler, Cheung, and Gauthier (2011), the first face was aligned and the second face was either aligned (*aligned condition*) or misaligned (*misaligned condition*). For misaligned face, we shifted the top part to the right and the bottom part to the left so that the right edge of the bottom part was aligned with the nose in the top part. For both aligned and misaligned trials, the top parts of the two faces were either identical (*same condition*) or different from each other (*different condition*). For both same and different trials, the irrelevant bottom face parts were also manipulated. For one half of the trials, the bottom face parts were identical in the same condition and different in the different condition; these trials formed the *congruent condition*. For the other half of the trials, the bottom parts differed in the same condition and were identical in the different condition; these trials formed the *incongruent condition*.

Fig. 1D shows the stimulus sequence for each trial. Each participant had a total of 320 trials (2 races $\times$ 2 alignment conditions $\times$ 2 congruency conditions $\times$ 2 same/different conditions $\times$ 20 exemplars). Trials were blocked according to face race, with block order counterbalanced across participants. Participants were instructed to pay attention to the top face part and to ignore the irrelevant bottom part.

According to Richler, Cheung, and Gauthier (2011), the interference of bottom part on recognition of the top part is indexed by the congruency effect. That is, performance should be better in congruent than in incongruent condition. This congruency effect should be reduced when the top and the bottom parts are misaligned, and this interaction between congruency and alignment reflects the strength of holistic processing (hereafter labelled as *composite face effect*).

3.2.3. Other-race contact questionnaire

The term “Chinese” in Hancock and Rhodes (2008) questionnaire was replaced with “Asian”. The questionnaire had the same seven items for own- and other-race faces (e.g., ‘I interact with Asian/Caucasian people on a daily basis’, or ‘I socialize a lot with Asian/Caucasian people’). Participants rated each statement using a 6-point scale, with 1 meaning ‘very strongly disagree’ and 6 meaning ‘very strongly agree’.

3.3. Results and discussion

3.3.1. ORE manifested in the CFMT and the composite task, but not for the composite face effect

The CFMT task showed again a significant ORE. Recognition of own-race faces ($M = 0.81$, $SE = 0.02$) was better than recognition of other-race faces ($M = 0.73$, $SE = 0.02$), $t(45) = 4.18$, $p = 0.0001$, Cohen’s $d = 0.62$.

For the composite face task (Fig. 4A), we found a main effect of face race, $F(1,45) = 11.76$, $MSe = 0.50$, $p = 0.001$, $\eta_p^2 = 0.21$, with better performance for own- than for other-race faces. The main effect of congruency was significant, $F(1,45) = 78.10$, $MSe = 0.35$, $p < 0.0001$, $\eta_p^2 = 0.63$, showing better performance for congruent than incongruent trials. The interaction between congruency and alignment was significant, $F(1,45) = 41.75$, $MSe = 0.28$, $p < 0.0001$, $\eta_p^2 = 0.48$, indicating a strong composite face effect (i.e., holistic processing). Importantly, the composite face effect was not modulated by face race, $F < 1$. These results are consistent with previous studies (Bukach et al., 2012; Harrison et al., 2014; Zhao & Hayward, 2010; see also Hayward, Crookes, & Rhodes, 2013), indicating that holistic processing was similarly involved in own- and other-race faces.

3.3.2. ORE in the CFMT and cross-race differences in the composite face effect were independent

The ORE observed in the CFMT showed no significant correlation with cross-race difference in the composite face effect, neither with subtraction-based method, $r(46) = -0.02$, $p = 0.91$, nor with regression-based method, $r(46) = 0.10$, $p = 0.50$. This lack of significant correlation was unlikely due to reliabilities of the two tasks. Both the CFMT and the composite face task showed medium to high reliabilities, which were similar to those reported in prior studies (Table 1, DeGutis et al., 2013; Ross, Richler, & Gauthier, 2014). Consistent with Experiment 1, the observed correlation coefficients were much less than their predicted upper boundaries (Table 2). These results mirror those reported in Experiment 1, suggesting that face race influences face recognition and holistic processing in a largely independent manner, irrespective of the tasks used to measure holistic processing. Even for own-race faces, face memory was not significantly correlated with the composite face effect (subtraction method, $r(46) = 0.06$, $p = 0\ .70$; regression method, $r(46) = 0.13$, $p = 0.40$). Several prior studies showed the same results (Konar, Bennett, & Sekuler, 2010; Wang et al., 2012; Zhou et al., 2012), suggesting that the association between holistic processing and face memory is not as robust as previously claimed (Richler, Cheung, & Gauthier, 2011).

3.3.3. Shared processes for own- and other-race faces

All within-task correlations between performances for own- and other-race faces were significant. For the four conditions in the composite face task, all $r(46) > 0.34$, all $p < 0.02$; for the CFMT, $r(46) = 0.60$, $p < 0.0001$. These results are consistent with those reported in Experiment 1, providing further support for the idea that shared processes were involved in recognition of own- and other-race faces.

3.3.4. Contact level predicts OREs in the CFMT but not for the composite face effect

Contact scores were higher for own- than for other-race faces (5.31 vs. 2.46), $t(45) = 12.57$, $p < 0.0001$, Cohen’s $d = 1.85$. Consistent with Experiment 1, a multivariate regression analysis revealed

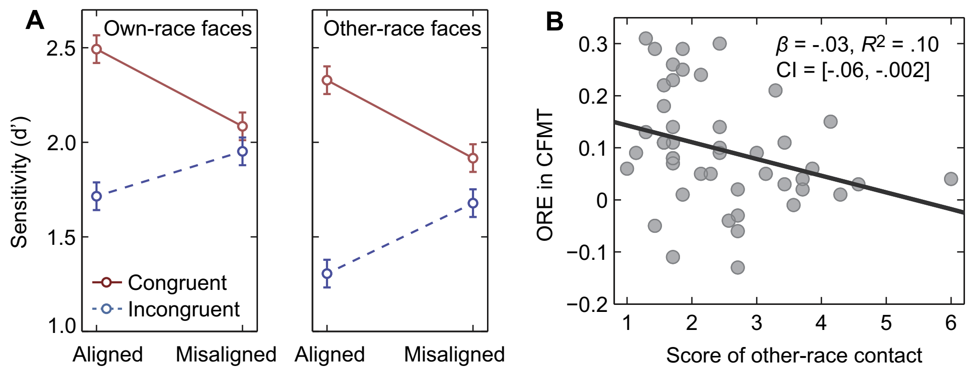

Fig. 4. Results of Experiment 2. (A) Sensitivity (d') for the composite face task. Error bars are standard errors of the means estimated from ANOVA. (B). Level of other-race contact predicts ORE in the CFMT.

that level of other-race contact was a good predictor for ORE in the CFMT (Fig. 4B), $F(1,44) = 4.72$, $MSe = 0.01$, $p = 0.04$, $\eta_p^2 = 0.10$, but not for the composite face effect, $F < 1$.

4. General discussion

The present study shows that the influences of face race on different face recognition tasks are not mediated by the same underlying mechanisms. Significant OREs were observed in the CFMT and in recognizing blurred faces, but not in recognizing scrambled faces or in term of holistic processing. Neither a whole/part task nor a composite face task revealed a significant ORE in holistic processing (i.e., whole/part advantage or composite face effect). In addition, level of contact with other-race faces proved to be a good predictor for OREs observed in the CFMT and in recognizing blurred faces, but not for OREs observed in recognizing scrambled faces or in terms of holistic processing. Importantly, we found no significant correlations between influences of face race on any two tasks; whether the tasks tested face memory, holistic processing, or tested processing of configural or featural information. These results indicate that the influences of face race and other-race contact on various tasks are largely independent, arguing against the view that the ORE in face memory is caused by cross-race differences in holistic processing.

4.1. Holistic processing and ORE in face recognition

Although the ORE in face recognition has been attributed to stronger holistic processing for own- than for other-race faces, evidence for such an own-race advantage in holistic processing is not as strong as previously thought (see Hayward, Crookes, & Rhodes, 2013; for a review). Furthermore, a strong correlation between ORE in face recognition (e.g., in CFMTs) and ORE in holistic processing (e.g., whole/part advantage) was only observed in one previous study (DeGutis et al., 2013) when ORE was calculated using a regression-based method, but not in other studies using the subtraction-based method (e.g., Michel, Caldara, & Rossion, 2006; Michel, Rossion, et al., 2006). In the present study, we measured the ORE in holistic processing with both a whole/part task and a composite face task, using both subtraction- and regression-based methods. However, we found neither a significant own-race advantage in holistic processing nor a reliable correlation between OREs observed in the CFMT and in tasks evaluating holistic processing (i.e., whole/part advantage or composite face effect). These results favor the idea that the ORE in face memory cannot be solely attributed to encoding difference in terms of holistic processing (see also Harrison et al., 2014; Hayward, Crookes, & Rhodes, 2013; Mondloch et al., 2010).

Several lines of research also suggest that the influences of face race on holistic processing and on face recognition may be dissociable. First, whether ethnically ambiguous faces were perceived as own- or other-race faces affected their holistic processing (Michel, Corneille, & Rossion, 2007) but not their recognizability (Rhodes et al., 2010), indicating that race perception modulates holistic processing and face recognition differently. Second, some prosopagnosics show normal holistic processing (i.e., composite face effect, Le Grand et al., 2006; Susilo et al., 2010) or normal ability to process spacing and featural information in the mouth region (Bukach et al., 2008). This result suggests that face recognition ability is not always bound to holistic processing or a general ability to process relational information in a face (see also Konar, Bennett, & Sekuler, 2010; Zhou et al., 2012). Finally, it has been suggested that face recognition ability relies on a broader range of underlying processes than holistic processing. Many facial properties such as emotion, distinctiveness, and attractiveness affect face recognition (e.g., Bainbridge, Isola, & Oliva, 2013). Therefore, an ORE in face recognition may not necessarily result from an ORE in holistic processing. This dissociation may also explain why the ORE in face recognition is relatively robust whereas an ORE in holistic processing is not warranted (Bukach et al., 2012; Harrison et al., 2014; Mondloch et al., 2010).

4.2. Processing of configural and featural information and the ORE in face recognition

We observed a strong ORE in recognition of blurred faces, suggesting that face race affects processing of configural information (which is preserved in blurred faces). This ORE decreased with increasing experiences with other-race people. These results are consistent with previous studies (Hayward, Rhodes, & Schwaninger, 2008; Mondloch et al., 2010; Rhodes, Hayward, & Winkler, 2006; Rhodes et al., 2009). Nonetheless, whether cross-race differences in processing configural information contribute to the ORE in face recognition is not yet well understood. We found that the OREs measured with the CFMT and with the blurred task were independent, indicating that the ORE in face recognition cannot be attributed to cross-race differences in processing configural information. These results suggest that the mechanisms measured by our various tasks are largely independent from each other.

How processing of face features contributes to the ORE in face recognition has been less explored. In the present study, cross-race differences in recognizing scrambled faces (i.e., featural processing) showed no correlation with the ORE in the CFMT, and were not modulated by other-race contact. These results echo a previous proposal that the ORE in face recognition is not due to differences in processing own- and other-race face features (DeGutis et al., 2013; Rhodes et al., 2009). In addition, our results indicate that the influences of face race and cross-race contact on featural processing are weaker than those on configural processing. Whereas some tasks revealed an ORE in recognition and discrimination of face features (e.g., Hayward, Rhodes, & Schwaninger, 2008; Rhodes, Hayward, & Winkler, 2006), other tasks did not (DeGutis et al., 2013; Tanaka, Kiefer, & Bukach, 2004).

4.3. Other-race contact and the ORE in face recognition

The link between other-race contact and the ORE in face recognition is observed in memory tasks (e.g., CFMT) but not in perceptual tasks (e.g., holistic processing). We showed that more frequent contact with other-race people leads to a smaller ORE in the CFMT, consistent with prior research (Hancock & Rhodes, 2008; Meissner & Brigham, 2001; Zhao, Hayward, & Bülthoff, 2014). Level of other-race contact also modulates the ORE observed in recognizing blurred faces but not scrambled faces, suggesting that more exposure to other-race faces improves the ability to process configural but not featural information of those faces (see also Rhodes et al., 2009). Although OREs in both the CFMT and the blurred face task were affected by other-race contact, these OREs were independent of each other. These results indicate that the influence of other-race contact on face recognition and on processing of configural information in blurred faces is mediated by different aspects of face processing.

Cross-race differences in holistic processing (i.e., the whole/part advantage or the composite face effect) showed no correlation with other-race contact frequency. This finding suggests that merely more exposure to other-race faces does not necessarily increase the holistic processing for those faces. In contrast, Bukach et al. (2012) found a significant correlation between OREs in the composite face effect and levels of contact. This discrepancy may be due to the use of different questionnaires in their study and ours. In the present study, both the *social contact questionnaire* (Walker & Hewstone, 2006) and the *race contact questionnaire* (Hancock & Rhodes, 2008) may be less sensitive to individuating experience than other questionnaires, such as the *individuating experience questionnaire* used by Bukach et al. (2012) or the one used by Wiese (2012).

5. Conclusion

The present study tested the influences of face race and cross-race contact on a variety of face processing tasks. Robust OREs were shown in face recognition (CFMT) and configural processing (recognizing blurred faces), but not in featural processing (recognizing scrambled faces) or in holistic processing (as revealed by the whole/part advantage or the composite face effect). Importantly, although we found that level of contact with other-race faces was correlated with the ORE in face recognition and in configural processing, there were no strong correlations between these OREs or between any cross-race differences in the other tasks used in our study. Therefore, the co-existence of OREs, such as those reported in holistic processing and in face recognition (e.g., Michel, Caldara, & Rossion, 2006; Michel, Rossion, et al., 2006; Tanaka, Kiefer, & Bukach, 2004), does not necessarily mean that these OREs share the same underlying mechanisms.

Acknowledgments

This research was supported by the Max Planck Society. Part of this study was also supported by the Grants from the Hong Kong Research Grants Council (HKU 7440/08H and HKU 7449/11H to WGH).

We are grateful to Brad Duchaine and Jia Liu for providing materials for the original and the Chinese version of Cambridge Face Memory Test respectively. We thank Matt Oxner for assistance with data collection.

References

Bainbridge, W. A., Isola, P., & Oliva, A. (2013). The intrinsic memorability of face photographs. *Journal of Experimental Psychology-General, 142*, 1323–1334.
Blanz, V., & Vetter, T. (1999). A morphable model for the synthesis of 3D faces. In W. Waggenspack (Ed.), *Processings of SIGGRAPH'99* (pp. 187–194). New York, NY: ACM Press.
Bukach, C. M., Cottle, J., Ubiwa, J., & Miller, J. (2012). Individuation experience predicts other-race effects in holistic processing for both Caucasian and Black participants. *Cognition, 123*, 319–324.
Bukach, C. M., Le Grand, R., Kaiser, M. D., Bub, D. N., & Tanaka, J. W. (2008). Preservation of mouth region processing in two cases of prosopagnosia. *Journal of Neuropsychology, 2*, 227–244.
Crookes, K., Favelle, S., & Hayward, W. G. (2013). Holistic processing for other-race faces in Chinese participants occurs for upright but not inverted faces. *Frontiers in Psychology, 4*, 29. http://dx.doi.org/10.3389/fpsyg.2013.00029.
DeGutis, J., Mercado, R. J., Wilmer, J., & Rosenblatt, A. (2013). Individual differences in holistic processing predict the own-race advantage in recognition memory. *PLoS ONE, 8*(4), e58253. http://dx.doi.org/10.1371/journal.pone.0058253.
Dehon, H., & Brédart, S. (2001). An 'other-race' effect in age estimation from faces. *Perception, 30*, 1107–1113.
Duchaine, B., & Nakayama, K. (2006). The Cambridge Face Memory Test: Results for neurologically intact individuals and an investigation of its validity using inverted face stimuli and prosopagnosic participants. *Neuropsychologia, 44*, 576–585.
Elfenbein, H. A., & Ambady, N. (2002). On the universality and cultural specificity of emotion recognition: A meta-analysis. *Psychological Bulletin, 128*, 203–235.
Hancock, K. J., & Rhodes, G. (2008). Contact, configural coding and the other-race effect in face recognition. *British Journal of Psychology, 99*, 45–56.
Harrison, S. A., Gauthier, I., Hayward, W. G., & Richler, J. J. (2014). Other-race effects manifest in overall performance, not qualitative processing style. *Visual Cognition, 22*, 843–864.
Hayward, W. G., Crookes, K., & Rhodes, G. (2013). The other-race effect: Holistic coding differences and beyond. *Visual Cognition, 21*, 1224–1247.
Hayward, W. G., Rhodes, G., & Schwaninger, A. (2008). An own-race advantage for components as well as configurations in face recognition. *Cognition, 106*, 1017–1027.
Hugenberg, K., Young, S. G., Bernstein, M. J., & Sacco, D. F. (2010). The categorization-individuation model: An integrative account of the other-race recognition deficit. *Psychological Review, 117*, 1168–1187.
Konar, Y., Bennett, P. J., & Sekuler, A. B. (2010). Holistic processing is not correlated with face-identification accuracy. *Psychological Science, 21*, 38–43.
Le Grand, R., Cooper, P. A., Mondloch, C. J., Lewis, T. L., Sagiv, N., de Gelder, B., et al. (2006). What aspects of face processing are impaired in developmental prosopagnosia? *Brain and Cognition, 61*, 139–158.
Levin, D. T. (2000). Race as a visual feature: Using visual search and perceptual discrimination tasks to understand face categories and the cross-race recognition. *Journal of Experimental Psychology-General, 129*, 559–574.
Maurer, D., Le Grand, R., & Mondloch, C. J. (2002). The many faces of configural processing. *Trends in Cognitive Sciences, 6*, 255–260.
McKone, E., Stokes, S., Liu, J., Cohan, S., Fiorentini, C., Pidcock, M., et al. (2012). A robust method of measuring other-race and other-ethnicity effects: The Cambridge Face Memory Test format. *PLoS ONE, 7*(10), e47956. http://dx.doi.org/10.1371/journal.pone.0047956.
Meissner, C. A., & Brigham, J. C. (2001). Thirty years of investigating the own-race bias in memory for faces - A meta-analytic review. *Psychology Public Policy and Law, 7*, 3–35.
Michel, C., Caldara, R., & Rossion, B. (2006). Same-race faces are perceived more holistically than other-race faces. *Visual Cognition, 14*, 55–73.
Michel, C., Corneille, O., & Rossion, B. (2007). Race categorization modulates holistic face encoding. *Cognitive Science, 31*, 911–924.
Michel, C., Rossion, B., Han, J., Chung, C. S., & Caldara, R. (2006). Holistic processing is finely tuned for faces of one's own race. *Psychological Science, 17*, 608–615.
Mondloch, C. J., Elms, N., Maurer, D., Rhodes, G., Hayward, W. G., Tanaka, J. W., et al. (2010). Processes underlying the cross-race effect: An investigation of holistic, featural, and relational processing of own-race versus other-race faces. *Perception, 39*, 1065–1085.
O'Toole, A. J., Peterson, J., & Deffenbacher, K. A. (1996). An 'other-race effect' for categorizing faces by sex. *Perception, 25*, 669–676.
Rhodes, G., Ewing, L., Hayward, W. G., Maurer, D., Mondloch, C. J., & Tanaka, J. W. (2009). Contact and other-race effects in configural and component processing of faces. *British Journal of Psychology, 100*, 717–728.
Rhodes, G., Hayward, W. G., & Winkler, C. (2006). Expert face coding: Configural and component coding of own-race and other-race faces. *Psychonomic Bulletin & Review, 13*, 499–505.
Rhodes, G., Lie, H. C., Ewing, L., Evangelista, E., & Tanaka, J. W. (2010). Does perceived race affect discrimination and recognition of ambiguous-race faces? A test of the sociocognitive hypothesis. *Journal of Experimental Psychology-Learning Memory and Cognition, 36*, 217–223.

Richler, J. J., Cheung, O. S., & Gauthier, I. (2011). Holistic processing predicts face recognition. *Psychological Science, 22*, 464–471.

Ross, D. A., Richler, J. J., & Gauthier, I. (2014). Reliability of composite task measurements of holistic face processing. *Behavioral Research Methods*. doi:10.3758/s13428-014-0497-4 (in press).

Schmidt, F. L., & Hunter, J. E. (1999). Theory testing and measurement error. *Intelligence, 27*, 183–198.

Schwaninger, A., Ryf, S., & Hofer, F. (2003). Configural information is processed differently in perception and recognition of faces. *Vision Research, 43*, 1501–1505.

Sporer, S. L. (2001). Recognizing faces of other ethnic groups - An integration of theories. *Psychology Public Policy and Law, 7*, 36–97.

Susilo, T., McKone, E., Dennett, H., Darke, H., Palermo, R., Hall, A., et al. (2010). Face recognition impairments despite normal holistic processing and face space coding: Evidence from a case of developmental prosopagnosia. *Cognitive Neuropsychology, 27*, 636–664.

Tanaka, J. W., & Farah, M. J. (1993). Parts and wholes in face recognition. *Quarterly Journal of Experimental Psychology, 46A*, 225–245.

Tanaka, J. W., Kiefer, M., & Bukach, C. M. (2004). A holistic account of the own-race effect in face recognition: Evidence from a cross-cultural study. *Cognition, 93*, B1–B9.

Walker, P. M., & Hewstone, M. (2006). A perceptual discrimination investigation of the own-race effect and intergroup experience. *Applied Cognitive Psychology, 20*, 461–475.

Wang, R. S., Li, J. G., Fang, H. Z., Tian, M. Q., & Liu, J. (2012). Individual differences in holistic processing predict face recognition ability. *Psychological Science, 23*, 169–177.

Wiese, H. (2012). The role of age and ethnic group in face recognition memory: ERP evidence from a combined own-age and own-race bias study. *Biological Psychology, 89*, 137–147.

Wiese, H., Kaufmann, J. M., & Schweinberger, S. R. (2014). The neural signature of the own-race bias: Evidence from event-related potentials. *Cerebral Cortex, 24*, 826–835.

Wilhelm, O., Herzmann, G., Kunina, O., Danthiir, V., Schacht, A., & Sommer, W. (2010). Individual differences in perceiving and recognizing faces: One element of social cognition. *Journal of Personality and Social Psychology, 99*, 530–548.

Zhao, M. T., & Hayward, W. G. (2010). Holistic processing underlies gender judgments of faces. *Attention Perception & Psychophysics, 72*, 591–596.

Zhao, M. T., Hayward, W. G., & Bülthoff, I. (2014). Face format at encoding affects the other-race effect in face memory. *Journal of Vision, 14*(9:6), 1–13. http://dx.doi.org/10.1167/14.9.6.

Zhou, G. M., Cheng, Z. J., Zhang, X. D., & Wong, A. C. N. (2012). Smaller holistic processing of faces associated with face drawing experience. *Psychonomic Bulletin & Review, 19*, 157–162.