Perception, 2010, volume 39, pages 1065 – 1085

doi:10.1068/p6608

Processes underlying the cross-race effect: An investigation of holistic, featural, and relational processing of own-race versus other-race faces

Catherine J Mondloch, Natalie Elms, Daphne Maurer¶, Gillian Rhodes§, William G Hayward#, James W Tanaka◇, Guomei Zhou◆

Psychology Department, Brock University, 500 Glenridge Avenue, St Catharines, ON L2S 3A1, Canada; e-mail: cmondloch@brocku.ca; ¶ Department of Psychology, Neuroscience and Behaviour, McMaster University, 1280 Main Street West, Hamilton, ON L85 4K1, Canada; § School of Psychology, The University of Western Australia, 35 Stirling Highway, Crawley, WA 6009, Australia; # Department of Psychology, University of Hong Kong, 604 Knowles Building, Pokfulam Road, Hong Kong; ◇ Department of Psychology, PO Box 3050, University of Victoria, Victoria, BC V8W 3P5, Canada; ◆ Department of Psychology, Sun Yat-sen University, Guangzhou, China

Received 27 October 2009, in revised form 16 April 2010

Abstract. Adults are often better at recognising own-race than other-race faces. Unlike previous studies that reported an own-race advantage after administering a single test of either holistic processing or of featural and relational processing, we used a cross-over design and multiple tasks to assess differential processing of faces from a familiar race versus a less familiar race. Caucasian and Chinese adults performed four tasks, each with Caucasian and Chinese faces. Two tasks measured holistic processing: the composite face task and the part/whole task. Both tasks indicated holistic processing of own-race and other-race faces that did not differ in degree. Two tasks measured featural and relational processing: the Jane/Ling task, in which same/different judgments were made about face pairs that differed in features of their spacing, and the scrambled/blurred task, in which test faces were scrambled (isolates memory for components) or blurred (isolates memory for relations). Both tasks provided evidence of an own-race advantage in both featural and relational processing. We conclude that even when adults process other-race faces holistically, other manifestations of an own-race advantage remain.

1 Introduction

Adults are experts at recognising faces: they can discriminate thousands of individuals at a glance, and recognise hundreds of faces even at a distance, in poor lighting, with a new hairdo, after 10 years of aging, or when the face is seen from a novel point of view (Bahrick et al 1975). Their expert face recognition is associated with face-specific neural mechanisms. For example, neuroimaging studies in adults have identified face-processing regions within the ventral occipitotemporal cortex, particularly an area of the fusiform gyrus referred to as the FFA (fusiform face area) (eg Haxby et al 2000, 2001). In adults, the FFA responds more to faces than to a variety of non-face objects (Aguirre et al 1999; Haxby et al 2001; McCarthy et al 1997). Expert face recognition by adults is also characterised by several behavioural phenomena. Unlike other objects, faces tend to elicit holistic processing (Tanaka and Farah 1993)—face components are integrated into a Gestalt-like representation, thereby making it more difficult to process the features individually (for review see Maurer et al 2002). The Gestalt-like representation includes at least two cues to facial identity—featural cues and the spacing of facial features, called second-order relational cues. Adults are acutely sensitive to featural cues (ie the shape and colour of individual facial features), with accuracy approaching 90% in same/different tasks in which photographs of faces differ in only the shape of the eyes and mouth (Freire et al 2000; Mondloch et al 2002, 2010). Adults also are exquisitely sensitive to second-order relations (Freire et al 2000; Mondloch et al 2002)—a sensitivity limited only by their visual acuity (Ge et al 2003; Haig 1984).

Adults' expert face recognition is limited to the kinds of faces with which they interact on a daily basis—typically, upright human faces of the same race. Numerous studies have reported better recognition of own-race than other-race faces (for reviews see Hancock and Rhodes 2008; Meissner and Brigham 2001; Sporer 2001).(1) The lower recognition accuracy for other-race faces is usually caused by increased false alarms for other-race faces (recognising someone novel as familiar) and, sometimes, by a reduced hit rate (failing to recognise someone familiar) (for review see Meissner and Brigham 2001). Different behavioural patterns for own-race versus other-race faces are associated with differences in neural activity. The FFA is less active when adults view other-race faces than own-race faces (Golby et al 2001). Adults may also process other-race faces less holistically than own-race faces (Michel et al 2006a, 2006b, 2010; Tanaka et al 2004) and appear to be less sensitive to both featural cues and second-order relations in other-race than own-race faces (Hayward et al 2008; Rhodes et al 2006, 2009).

Processing differences are thought to reflect reduced experience or contact with other-race faces (Brigham et al 1982; Chiroro and Valentine 1995; Furl et al 2002; Goldstone 2003; Hancock and Rhodes 2008; Malpass and Kravitz 1969; Meissner and Brigham 2001; Shepherd et al 1974; Slone et al 2000; Valentine 1991; Valentine and Endo 1992; Wright et al 2001). The own-race recognition advantage can be reduced by training (reviewed by McKone et al 2007), can be reversed following cross-race adoption before the age of 9 years (Sangrigoli et al 2005), and is less evident in multiracial populations (eg Bar-Heim et al 2006; Chiroro and Valentine 1995; Cross et al 1971; Feinman and Entwisle 1976; Wright et al 2001).

Previous studies (see below) have measured either holistic processing or sensitivity to features and their spacing, but not both within the same population. Our goal was to compare cross-race effects (CREs) for these three types of face processing in two groups of participants with minimal exposure to other-race faces. Specifically we tested Caucasian adults living in rural North America and Chinese adults living in China with both Caucasian and Chinese faces. In addition, we included a large battery of tasks to determine the consistency of results across measures (eg whether the CRE was observed for all measures of holistic processing). To our knowledge, this is the first study to use multiple tasks that tap different types of face processing to measure CREs. Two previous studies of holistic processing have shown a CRE for Caucasian but not Asian participants; however, in both of those studies, the Asian participants had been living in a predominantly Caucasian environment for at least 1 year (Michel et al 2006a; Tanaka et al 2004). A third study in which both Asian and Caucasian participants had minimal exposure to other-race faces revealed a CRE for both groups (Michel et al 2006b). The two previous studies showing a CRE for featural and second-order relational processing used different tasks with separate populations and are therefore hard to compare (Hayward et al 2008; Rhodes et al 2006). Our administration of two tasks designed to tap holistic processing and two tasks designed to tap both featural and second-order relational processing allows us to test the consistency of results across tasks and to provide a more complete characterisation of the CRE.

1.1 *Holistic processing*

Two tasks are typically used to measure holistic processing. In the composite face task, the top half of one face is aligned with the bottom half of a different face. The ability of adults to identify the top half of a famous face is impaired when it is aligned with the bottom half of a different face (Young et al 1987). Likewise, when asked to make same/different judgments about pairs of unfamiliar faces that have different

(1) We are using the terms own race and other race to be consistent with the literature but we recognise that these are perceptual/cognitive and not biological categories.

bottom halves but identical top halves, adults' accuracy is low (Hole 1994). Adults' perception of the top half of each face is influenced by the different bottom halves when the faces are aligned, but not when they are misaligned. Manipulations that disrupt holistic processing (eg misaligning the two halves or inverting the composite face) increase adults' accuracy. This composite face effect is a measure of holistic processing. These effects are seen only when the top halves are the same; accuracy is not affected by alignment when the top halves are different because when both the top and bottom halves are different there is no interference from an incongruent bottom half.

A second technique used to measure holistic processing is the part/whole task. In this task, participants are presented with a face ('Bob'), followed by a pair of whole faces, or a pair of isolated features. In the whole face condition, participants are presented with Bob's original face paired with a manipulated version of Bob's face (ie Bob's eyes replaced with another set of eyes). Participants are instructed to indicate which face is Bob's face. In the part condition, participants are presented with two features (eg two sets of eyes, two noses, or two mouths), and are asked to indicate which set of features belongs to Bob. Adults are more accurate in the whole condition than in the part condition (Tanaka and Farah 1993), presumably because the facial features were processed initially as part of a Gestalt. Although performance on measures of holistic face processing is adult-like by 4 years of age (de Heering et al 2007; Mondloch et al 2007; Pellicano and Rhodes 2003), it is dependent upon experience. Patients who were deprived of early visual input by congenital cataract fail to develop normal holistic processing; in a composite face task their performance was equal for aligned and misaligned trials (Le Grand et al 2004). Furthermore, there is some evidence that holistic processing emerges as adults develop expertise for a new class of stimuli (eg greebles), at least as measured by the composite face task (Gauthier and Tarr 2002).

Three recent studies suggest that adults process other-race faces less holistically than own-race faces. Michel et al (2006b) tested Asian and Caucasian participants on a composite face task comprised of both Asian and Caucasian faces. Both groups of participants were living in a predominantly own-race area and had minimal experience with other-race faces. Caucasian participants, but not Asian participants, had a larger composite face effect as measured by accuracy for own-race faces than for other-race faces, although Asian participants showed a marginally larger effect for own-race faces as measured by accuracy and a significantly larger effect for own-race faces as measured by reaction times. Two previous studies tested Asian and Caucasian participants on a part/whole task comprised of both Asian and Caucasian faces (Michel et al 2006a; Tanaka et al 2004). In both studies, Caucasian participants showed the part/whole effect only for own-race faces whereas Asian participants showed the effect for both Caucasian and Asian faces. The failure of Asian participants to show a CRE on the part/whole task may have been related to their residing in a predominantly Caucasian environment for up to one year at the time of study (Michel et al 2006a; Tanaka et al 2004), and their consequent need to individuate Caucasian faces (Hugenberg et al 2007). Alternatively, at least one study has shown that Asians process many visual stimuli more holistically than Americans (Kitayama et al 2003). In summary, only three studies have investigated holistic processing of own-race versus other-race faces and only in one of these studies did both participant groups live in a predominantly own-race environment. In two of the three studies, only Caucasian participants showed a larger holistic effect for own-race than for other-race faces, and in the third study the effect was weaker for Chinese participants.

To further explore holistic processing of own-race versus other-race faces we administered both the composite face task and the part/whole task to both Caucasian and Asian adults with minimal exposure to other-race faces. Only one previous study has tested Asian participants with minimal exposure to Caucasian faces, and thus previous reports that the CRE observed for Caucasian participants does not extend to Asian participants are difficult to interpret. Furthermore, by administering two tasks designed to tap holistic processing we are able to determine whether the pattern of results is consistent across tasks within the same populations. If holistic processing is stronger for own-race faces than for other-race faces, then both effects should be stronger for Caucasian faces for Caucasian participants and stronger for Asian faces for Asian participants.

1.2 *Cues to facial identity*

Adults rely on three relatively stable cues to facial identity: the shape of the external contour (eg chin); the shape and colour of individual facial features (eg the eyes and nose); and the metric distances between features, or second-order relations (eg the distance between the eyes, the distance between the nose and mouth). Several lines of evidence suggest that sensitivity to second-order relations is tuned by experience. Unlike sensitivity to contour and individual features, sensitivity to the spacing among features is permanently impaired by early visual deprivation (Le Grand et al 2001, 2004). By the age of 8 years, it is better for human than monkey faces, even when the metric changes are identical for the two face sets (Mondloch et al 2006)—a pattern of results that persists through adulthood and provides evidence that sensitivity to the spacing of facial features is tuned by experience. By adulthood, sensitivity is limited only by visual acuity (Haig 1984). Furthermore, adults' sensitivity to small changes in the spacing of facial features when asked whether photographs are veridical or distorted representations of a highly familiar face (mainland Chinese adults viewing various versions of Chairman Mao's face) matches that of naive adults shown the two versions simultaneously in a same/different discrimination task (Ge et al 2003)—a pattern of results that demonstrates the value of this fine sensitivity for face recognition.

Two previous studies suggest that sensitivity to featural and spacing cues to facial identity may be greater for own-race faces than for other-race faces. In each of these studies the Chinese participants were living in a predominantly own-race area at the time of study, whereas the Caucasian participants were attending a university at which about one third of the student population was Asian. In one study, the appearance of individual features or their spacing was manipulated directly. Rhodes et al (2006) created morphed continua between two versions of a Caucasian and a Chinese face that differed in spacing (by moving the features inward/outward) or in the shape and colour of individual features (by lightening/darkening the eyebrows and lips and by making the nose more/less bulbous). The accuracy of participants on a delayed match-to-sample task during which they were shown stimuli from these morphed continua was higher for own-race than for other-race faces. Hayward et al (2008) tested memory for features versus relational cues in own-race versus other-race faces. Participants viewed unaltered faces during the study phase and then were tested with stimuli that isolated either featural cues (by scrambling the face so as to eliminate both holistic processing and second-order relational cues) or relational cues (by blurring the stimuli so as to reduce featural information). Although traditionally used to measure relational processing, blurring facial stimuli does not directly test sensitivity to second-order relations. Rather, blurring reduces the salience of featural cues (Goffaux et al 2005; but see Boutet et al 2003) at the same time as it leaves information about the spacing of features relatively intact.[2] Accuracy was higher in both the blurred and scrambled conditions for own-race faces than for other-race faces; a pattern observed in both Caucasian and Chinese participants. Rhodes et al (2009) replicated this pattern of results for Chinese adults living in Australia; in addition, time in Australia (which ranged from

[2] Goffaux and Rossion (2006) suggested that blurring faces may also enhance holistic processing (but see Cheung et al 2008).

a few weeks to 26 years) negatively predicted the size of the own-race advantage for relational memory, but not for component memory.

These two approaches are complementary: one approach (Rhodes et al 2006) directly manipulates features or their spacing, whereas the other approach (Hayward et al 2008) isolates one cue by reducing the other. We extended this work by administering two tests of sensitivity to featural versus relational cues to facial identity in our sample of Caucasian and Asian adults with minimal exposure to other-race faces. One task was the scrambled/blurred task used by Hayward et al (2008). The other task was the 'Jane/Ling' test of facial identity. In this task participants are asked to make same/different judgments about pairs of faces that differ in the spacing among features, the shape of individual features (eyes and mouth), or the external contour (Mondloch et al 2002). We elected to administer the Jane/Ling task in the present study because previous research has shown that it is sensitive to effects of experience: patients treated for bilateral congenital cataract made more errors than visually normal controls when discriminating faces that differed in the spacing of features (Le Grand et al 2001). Unlike both the Caucasian and Chinese participants who completed the scrambled/blurred task previously (Hayward et al 2008), our participants had minimal exposure to other-race faces prior to testing. Each task was comprised of both Caucasian and Chinese faces. If sensitivity to each of these cues to facial identity is greater for own-race faces than other-race faces, accuracy should be higher in all conditions for own-race faces.

In summary, we administered four tasks to two groups of participants who were novices with respect to other-race faces because of very minimal contact with other-race individuals. Each task was comprised of both Chinese and Caucasian faces. Two tasks (the composite face task and the part/whole task) measured holistic processing and two tasks (the Jane/Ling task and the scrambled/blurred task) measured sensitivity to featural and configural cues to facial identity.

2 Method

2.1 *Participants*

Thirty-one Caucasian adults (ages 18–22 years, twenty-four females) from rural Pennsylvania participated in this study. All participants attended a university with a predominantly Caucasian (98%) student body. All participants had normal or corrected-to-normal vision and all but one were right-handed as determined by a questionnaire (adapted from Peters 1988 by Mondloch et al 2002). Ten additional participants were tested but were excluded from all data analyses because they did not pass the visual criteria ($n = 7$; 20/20 Snellen Acuity in each eye and stereoacuity of at least 40 s of arc on the Titmus test) or because they did not pass the criterion trials on the same/different practice test that preceded the Jane/Ling task ($n = 3$). Of the thirty-one individuals comprising the final sample, six were excluded from all analyses involving the part/whole task because of technical difficulties and two were excluded from all analyses involving the composite task because of technical difficulties ($n = 1$) or having to leave prior to completing the task ($n = 1$).

Thirty-two Chinese adults from Guangdong, China, attending a predominantly Chinese university also participated in this study. Guangzhou has a population of 12 million; 0.6% of the population are from other countries, and only some of those individuals are Caucasian. There are 52 800 individuals in the university; 2.84% are international students, including students from Japan, Korea, and the USA (ie a very small proportion are Caucasian). All Chinese participants reported having normal or corrected-to-normal vision and were right-handed. One participant was excluded from the composite task because of technical difficulties.

All Caucasian participants reported having minimal experience with Asian individuals in that they did not interact with Asian individuals on a daily or even weekly basis; did not have an Asian member of their immediate family or a close friend who was Asian; had never lived with an Asian person for more than 4 months; and had never travelled out of the United States. Similarly, all Chinese participants reported having minimal experience with Caucasian faces.

2.2 *Apparatus*
When testing Caucasian participants, the stimuli were presented on a 17-inch ViewSonic LCD display controlled by a Macintosh Powerbook G4 computer; when testing Asian participants, the stimuli were presented by a Macintosh eMac on a 17-inch CRT display. Tasks were controlled by Cedrus Superlab or RSVP software. Participants signalled their responses with a joystick (for some tasks) or with a keyboard (for other tasks).

2.3 *Procedure*
After the procedure was explained, informed written consent was obtained from all participants. All methods were approved by the Research Ethics Boards at Brock University, Westminster College, and Sun Yat-sen University. Each participant was tested on four tasks, which were presented in one of eight counterbalanced orders. Orders were constrained so that the two tasks measuring holistic processing alternated with the two tasks measuring cues to face recognition. Caucasian and Chinese faces were intermixed randomly within all tasks to control for practice effects. For all tasks, participants sat in a dimly lit room 100 cm from the computer monitor. The entire battery of tasks took approximately 2 h to complete. Details of each task are presented below.

2.4 *Composite face task*
2.4.1 *Stimuli.* Face composites were created from grey-scale images of adult Caucasian and Chinese faces facing forward with neutral expressions. Models did not wear jewelry, glasses, or make-up, and blemishes were removed with Adobe Photoshop. A surgical cap covered the hair and ears and a grey cape covered the clothing. All images were the same size from cap to chin. Composite faces were created with Adobe Photoshop by splitting the faces horizontally at the midline and recombining the faces with top and bottom halves from different individuals. For the aligned trials, the top and bottom halves of the face were aligned and the stimuli were 9.8 cm wide $\times$ 14 cm high (5.6 deg $\times$ 8 deg from a distance of 100 cm). For the misaligned trials, the bottom half of each face was moved horizontally to the right for half of the faces and to the left for half of the faces, and the stimuli were 14.7 cm wide $\times$ 14 cm high (8.4 deg $\times$ 8 deg from a distance of 100 cm). The position of the top half of the faces was constant and the same face composites were used in both aligned and misaligned trials. (See figure 1a for examples of the stimuli and Le Grand et al 2004 for further details.)

2.4.2 *Procedure.* This task was administered with Cedrus Superlab software. On each trial, a composite face appeared on the screen for 200 ms, followed by a 300 ms blank screen, and then a second composite face that appeared on the screen for 200 ms. Participants moved a joystick forward to indicate that the top halves of the two faces were the same and towards themselves to indicate that the top halves were different. Misaligned and aligned trials were presented in separate blocks; half of the participants received the aligned trials first. Each block consisted of 96 trials ($n = 48$ per race), and within each block half of the trials were 'same' trials and half were 'different' trials. Same trials were comprised of pairs of composite faces that had the same top half, but different bottom halves. Different trials were comprised of face pairs that had both different top halves and bottom halves (see Le Grand et al 2004 for details). Participants were instructed to make same/different judgments about the top halves of each pair while ignoring the bottom halves.

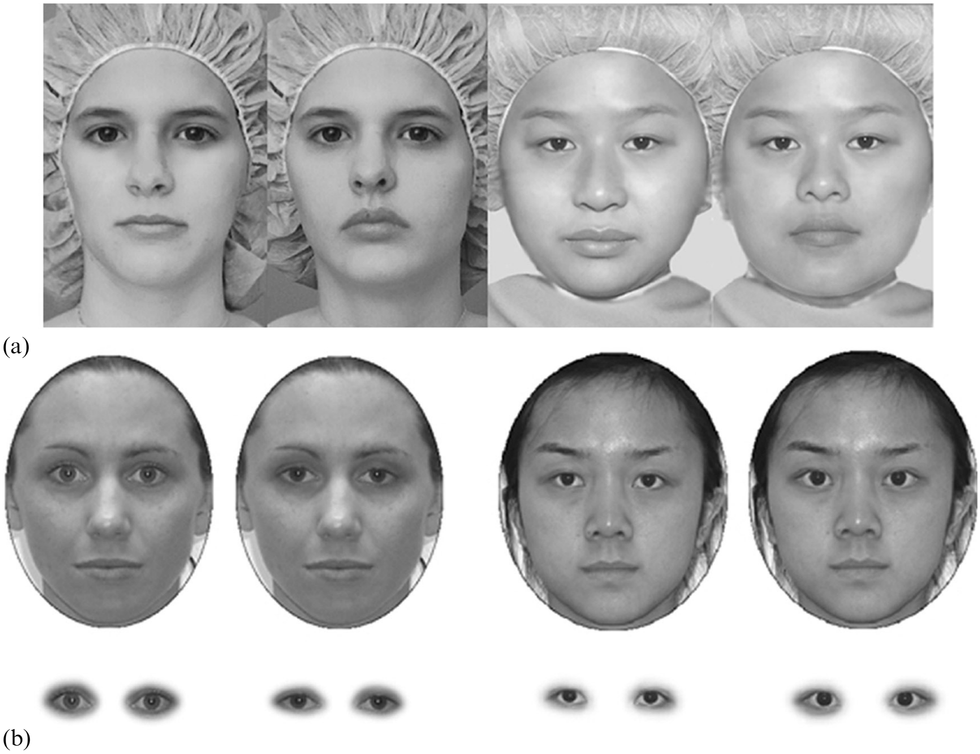

Figure 1. Sample stimuli from the tasks designed to measure holistic processing. (a) An example of stimuli from the composite face task. The top halves of each pair of stimuli are the same and the bottom halves are different. Holistic processing creates the impression that the top halves are different. Misaligning the two halves disrupts holistic processing. (b) An example of stimuli from the part/whole task. In the whole condition, participants judge which member of each pair matches a previously viewed sample. In the part condition, participants judge which feature (eg the eyes, mouth) belongs to a previously viewed face.

2.5 *Part/whole task*

2.5.1 *Stimuli.* The Chinese and Caucasian images were 11.4 cm wide × 14.8 cm high (6.4 deg × 8.3 deg from the testing distance of 100 cm). All faces were frontal views with neutral expressions. There were two trial types for this task: whole faces and parts. All whole faces were presented in a black oval to minimise differences in hair. For each original face a distractor was made with Adobe Photoshop; one of the features (eyes, nose, or mouth) of the original face was replaced with features from another face matched on gender and race. For the part trials, the features of the original faces were removed and placed on a blank canvas beside that same feature(s) from another face matched on gender and race (see figure 1b for examples of stimuli). The same distracting features were used in part and whole trials.

2.5.2 *Procedure.* On each trial participants were presented with a whole target face for 1000 ms. This was followed by a mask (500 ms), and then a pair of whole faces (whole trials, $n = 144$) or a pair of features (part trials, $n = 144$) were presented until a response was made. There was a 1000 ms intertrial interval. Participants were asked to indicate which face (on whole trials) or which feature(s) (on part trials) was identical to the target. Prior to the test trials there were 12 practice trials. To encourage participants to engage in holistic processing, they did not know which features were targets on any given trial until the test pair was presented. Part and whole trials were randomly intermixed.

2.6 *Jane/Ling task*

2.6.1 *Stimuli.* Grey-scale photographs of one adult female Caucasian (Jane) and one adult female Chinese model (Ling) were used to create the stimulus sets (figure 2a). Models were faced forward with neutral expressions and did not wear jewelry, glasses, or make-up; blemishes were removed with Adobe Photoshop. A surgical cap covered their hair and ears and a grey cape covered their clothing. Twelve new versions of each face were created with Adobe Photoshop (see Mondloch et al 2002 for details). From a distance of 100 cm, the stimuli were 10.2 cm wide × 15.2 cm high (5.7 deg × 9.1 deg). The four faces in the spacing set were created by moving the eyes up, down, closer together, or farther apart; all spacing changes were within normal limits and of identical size in the Chinese and Caucasian sets. The four faces in the featural set were created by replacing the eyes and mouth of the original model with the eyes and mouth of a different female.[3] The four faces in the contour set were created by inserting the inner part of the original faces into the contour of a different female face. (For more details, see Mondloch et al 2002.)

2.6.2 *Procedure.* Participants first completed a same/different practice test (see Mondloch et al 2002 for details) in which different pairs consisted of two versions of the same face that differed dramatically (eg mouth rotated 45° clockwise in one version and 45° counterclockwise in the others). In order to continue to the Jane/Ling task participants were required to get 10/12 sequential trials correct (participants were allowed to repeat the same/different practice test up to three times). The purpose of the practice test was to confirm that participants understood the nature of the task and were attentive. Three Caucasian participants, but no Chinese participants, were eliminated from all analyses because they failed to meet this criterion. Not a single adult failed to meet this criterion in an earlier study (Mondloch et al 2002) and so it was assumed that these three participants were not attentive.

The Jane/Ling task was a same/different discrimination task. On each discrimination trial the first face (model) appeared for 200 ms, followed by a mask for 390 ms, and a second face (test) remained on the screen until the participant made a response. Responses were made via a joystick. There were 30 trials for each race of face within each block (spacing, features, and contour). To control for order effects there were three different orders: (i) spacing – featural – contour trials, (2) featural – contour – spacing trials, and (3) contour – spacing – featural trials (see Mondloch et al 2002 for more details).

2.7 *Scrambled/blurred task*

2.7.1 *Stimuli.* The stimuli were taken from Hayward et al (2008). The faces were 11.4 cm wide × 14.8 cm high (6.4 deg × 8.3 deg from the testing distance of 100 cm), were standardised to have an interpupil distance of 80 pixels on a canvas of 320 × 420 pixels and were placed within a black frame. There were two sets of stimuli: scrambled faces and blurred faces. Scrambled faces were created by cutting the face into ten pieces: two eyes, two eyebrows, two cheeks, nose, mouth, chin, and forehead. The pieces were then rearranged into a new configuration that did not resemble a face and that was the same for Chinese and Caucasian versions of each scrambling. The configuration of each scrambled face was different (see figure 2b). Blurred faces were created by repeatedly applying a Gaussian filter to the original faces. The filter had a radius of 3 pixels and a standard deviation of 3 pixels and was applied four times to blur the face. Previous research has shown that when these blurred stimuli are also scrambled to eliminate relational information, adults perform at chance levels, verifying that this amount of blur eliminates the ability to use featural information and leaves only relational information (Hayward et al 2008).

[3] Two of the Caucasian featural sisters from the original version of this task created by Mondloch et al (2002) were replaced because the original sisters were wearing make-up.

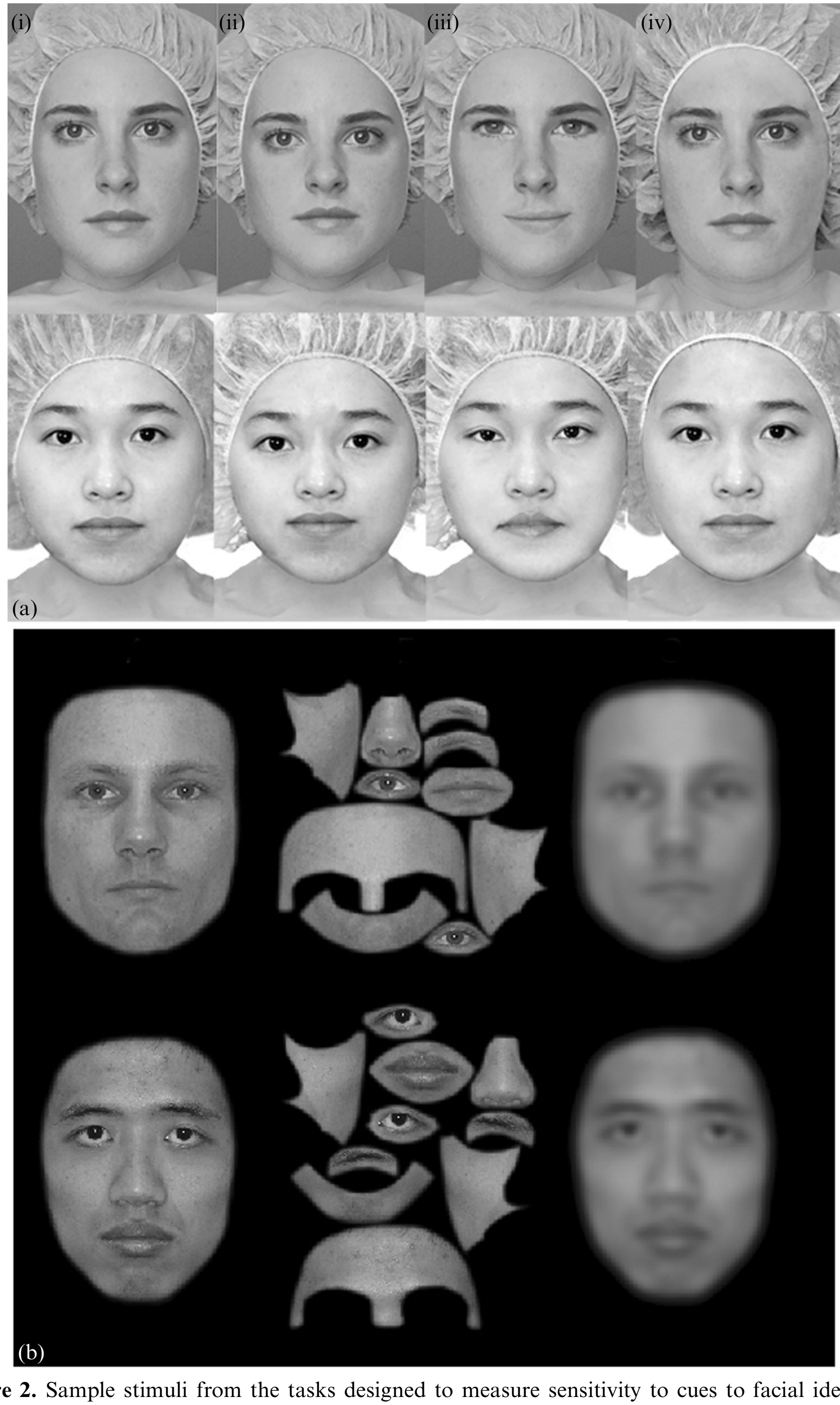

Figure 2. Sample stimuli from the tasks designed to measure sensitivity to cues to facial identity. (a) Examples of stimuli from the Jane/Ling stimuli: (i) the original face; (ii) one sister from the spacing set; (iii) one sister from the featural set; and (iv) one sister from the contour set. (b) Examples of stimuli from scrambled/blurred tasks. Participants studied a set of original faces (left) and then made old/new judgments about scrambled (middle; to isolate featural processing) and blurred (right; to isolate configural processing) faces.

2.7.2 *Procedure.* In each of two blocks, participants first viewed each of 10 study faces (5 Caucasian; 5 male) twice. Each face was presented for 10 s and the presentation of faces was separated by a 1 s blank interval. Participants were told that they would need to remember these faces for a later test. Immediately following the study phase, participants were shown 20 face stimuli; they were asked whether each stimulus was old or new. In one block of trials all of the stimuli were blurred (to test recognition in the absence of distinguishable features and based on holistic processing and sensitivity to spacing cues); in the other block of trials all of the stimuli were scrambled (to test recognition based on features). Each face was presented until the participant made a response, with a 1 s blank interval between trials. The participants were informed that accuracy was more important than speed. The order of blocks was counterbalanced across participants.

3 Analyses

Across all tasks Chinese participants were more accurate than Caucasian participants. Because our main interest was in the difference in accuracy for own-race versus other-race faces all analyses were based on standardised scores to eliminate any main effect of race of participant. For each participant group, we calculated the mean and standard deviation of accuracy scores across all conditions within each task and transformed all scores to z-scores; negative z-scores indicate an accuracy that is below the mean across conditions and positive z-scores indicate an accuracy that is above the mean. With the use of this approach the difference between Chinese and Caucasian participants is zero, with better performance for own-race faces revealed as a higher z-score for own-race than other-race faces. Stronger CREs in one participant group than the other would be revealed in an own/other-race $\times$ race of participant interaction. For the two holistic tasks (part/whole, composite) z-scores were based on raw percentage-correct scores; for the remaining two tasks (Jane/Ling, scrambled/blurred) z-scores were based on d'.[4] In every ANOVA one factor, participant race, was between subjects and all remaining factors were repeated measures. Based on a posteriori hypotheses, planned comparisons for each participant race for each of the four tasks were conducted to determine whether the size of the composite face effect, the size of the whole/part effect, and recognition accuracy differed for own-race versus other-race faces. All t-tests were two-tailed. Comparable analyses were conducted for reaction times on correct trials; we used median reaction times to ensure that analyses were not influenced by unusually long or short reaction times on individual trials. We did not standardise reaction time because there was no overall difference between Chinese and Caucasian participants on any task.

4 Results

4.1 *The composite face task*

Because holistic processing is indicated by lower accuracy on same aligned trials than same misaligned trials, with no effect of alignment on different trials, we calculated the composite face effect (z-scores on misaligned trials minus z-scores on aligned trials) for own-race versus other-race faces on same trials only. As shown in figure 3 (left panel), the size of the composite face effect did not vary as a function of race of participant or whether the stimuli were own or other race. A 2 (race of face: own/other) $\times$ 2 (participant

[4] We did not use d' for the part/whole task because participants were asked to indicate which member of a pair of stimuli matched a previously viewed target (a two-alternative forced-choice procedure for which d' was not designed). We did not use d' for the composite task because only same trials provide a measure of holistic processing, namely the decrement in accuracy on aligned versus misaligned trials. The pattern of results for the Jane/Ling task and the scrambled/blurred task is identical to that reported in the text for z-scores based on raw accuracy scores rather than d'.

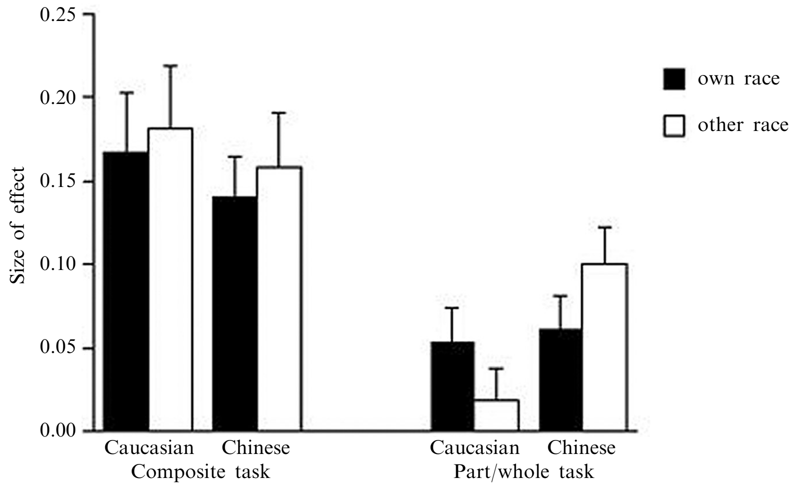

Figure 3. Size of the composite face effect (left panel) and part/whole effect (right panel) (+1 SE) shown separately for Caucasian and Chinese participants for own-race and other-race faces. For the composite task, effect size is the difference in accuracy on misaligned trials versus aligned trials. For the part/whole task, effect size is the difference in accuracy on whole versus part trials.

race) ANOVA revealed no significant main effects and no significant interaction (all ps > 0.40). Single-sample t-tests were used to compare each composite face effect to a null value of 0; the effects were significant for both Chinese and Caucasian participants for both own-race and other-race faces (all ps < 0.001).

To determine whether the lack of a stronger composite face effect for own-race faces is attributable to participants having a stronger 'same' response bias on aligned versus misaligned trials for own-race and/or other-race faces, we analysed standardised scores for different trials in a 2 (participant race) × 2 (race of face: own/other) × 2 (condition: aligned/misaligned) ANOVA. The analysis revealed a main effect of race of face ($F_{1,59} = 4.70$, $p < 0.05$). This main effect was qualified by a race of face × participant race interaction ($F_{1,59} = 30.48$, $p < 0.001$). Caucasian participants were more accurate when judging other-race faces than when judging own-race faces (mean difference z-score = 0.251, ns), whereas Chinese participants were more accurate when judging own-race faces than when judging other-race faces (mean difference z-score = 0.629, ns). However, neither effect is significantly different from 0 and there was no effect of condition and no race of face × condition interaction (ps > 0.50). Furthermore, the three-way interaction was non-significant ($p > 0.08$). Thus, our finding that the size of the composite face effect did not differ for own-race versus other-race faces cannot be attributed to participants having a larger 'same' response bias on aligned than misaligned trials, even when the top halves were different.

To determine whether the lack of a CRE for accuracy was the result of a speed/accuracy trade-off, we conducted a 2 (race of face: own/other) × 2 (participant race) interaction with differences in reaction times on aligned versus misaligned same trials as the dependent measure. No effects reach significance (all ps > 0.15). Nonetheless, single-group t-tests revealed that both Caucasian and Chinese participants had longer reaction times on aligned trials than misaligned trials both for own-race and for other-race faces (ps < 0.01). In summary, we found a strong composite face effect for both own-race and other-race faces, with no evidence of greater holistic processing of own-race faces than other-race faces on this task.

4.2 *The part/whole task*

For each participant we calculated the size of the part/whole effect (accuracy on whole trials − accuracy on part trials) for both own-race and other-race faces. The 2 (race of face: own/other) × 2 (participant race) ANOVA revealed no significant main effects (ps > 0.10), but a marginally significant interaction ($F_{1,55} = 3.78$, $p = 0.06$). As shown in figure 3 (right panel), Caucasian participants tended to have a larger part/whole effect for own-race faces whereas Chinese participants tended to have a larger part/whole effect for other-race faces. However, paired t-tests for each participant group revealed that neither of these trends was significant (ps > 0.10). Single-group t-tests confirmed that Chinese participants showed a significant part/whole effect for both own-race and other-race faces (ps < 0.01) and that Caucasian participants showed a significant part/whole effect for own-race ($p < 0.05$) but not other-race ($p > 0.3$) faces.[5]

To determine whether the lack of CRE for accuracy was the result of a speed/accuracy trade-off, we conducted a 2 (race of face: own/other) × 2 (participant race) ANOVA with differences in reaction times on whole versus part trials as the dependent measure. No effects reached significance (all ps > 0.20). In summary, neither Caucasian nor Chinese participants showed a larger part/whole effect for own-race faces than other-race faces. The only hint of a CRE was found for Caucasian participants, who showed a significant part/whole effect for own-race faces, but not other-race faces, unlike Chinese participants who showed a significant effect for both.

4.3 *The Jane/Ling task*

A 2 (race of face: own/other) × 3 (face set: features, spacing, contour) × 2 (participant race) ANOVA revealed a significant main effect of face set ($F_{2,122} = 68.92$, $p < 0.001$), and a significant participant race × face race interaction ($F_{1,122} = 20.25$, $p < 0.0001$). There was a marginal main effect of face race ($F_{1,61} = 3.68$, $p = 0.06$), and a marginal three-way interaction ($F_{2,122} = 2.76$, $p = 0.07$). To explore these effects further we conducted a 2 (own/other race) × 2 (participant race) ANOVA for each face set. The ANOVA for the spacing set revealed only a significant interaction ($F_{1,61} = 8.24$, $p < 0.01$). Paired t-tests for each participant group revealed a significant advantage for own-race faces for the Caucasian participants ($t_{30} = 2.60$, $p < 0.05$), but not for the Chinese participants ($p > 0.10$). As shown in figure 4, Caucasians' accuracy on the spacing set was 6% higher for own-race faces.[6] The ANOVA for the featural set revealed a main effect of own/other race ($F_{1,61} = 5.24$, $p < 0.03$), and a significant interaction ($F_{1,61} = 17.24$, $p < 0.001$). Paired t-tests for each participant group revealed a significant advantage for own-race faces for the Caucasian participants ($t_{31} = 3.89$, $p < 0.001$), but not for the Chinese participants ($p > 0.10$). As shown in figure 4, Caucasians' accuracy was 10% higher for own-race features. The ANOVA for the contour set revealed no significant effects (all ps > 0.15).[7]

The analysis of reaction time (participant race × face set × own/other race) revealed a main effect of face set ($F_{2,122} = 3.94$, $p < 0.05$). Reaction times were slightly faster on featural trials (mean, $M = 917$ ms) than either spacing ($M = 972$ ms) or contour ($M = 1003$ ms) trials, indicating that higher accuracy on featural trials cannot be attributed to a speed/accuracy trade-off. There was also a significant own/other race × participant

[5] If race of face was coded in absolute (Caucasian/Chinese) rather than relative terms, there were no significant effects or interactions.

[6] If race of face was coded in absolute rather than relative terms there was only a main effect of race of face ($p < 0.01$), so the own-race advantage revealed in our main analysis must be interpreted with caution.

[7] If race of face was coded in absolute rather than relative terms there was a significant race of face × participant race interaction ($p < 0.05$); Caucasian participants were more accurate for Caucasian faces than for Chinese faces ($t_{30} = 4.34$, $p < 0.001$), but Chinese participants were not ($p > 0.05$).

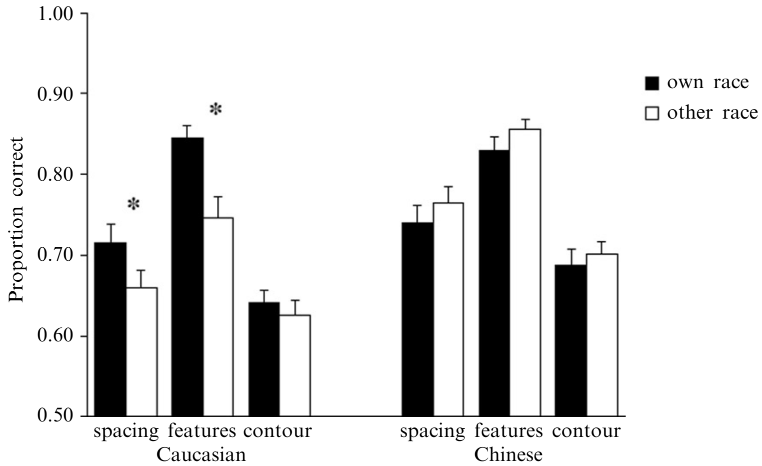

Figure 4. Proportion correct (+1 SE) on the Jane/Ling task shown separately for each face set and for Caucasian and Chinese participants. Although these data are presented as proportion correct, all analyses were based on standardised d' scores. The asterisks indicate a significant own-race advantage ($p < 0.05$).

race interaction ($F_{1,61} = 3.99$, $p = 0.05$). Separate analyses for Caucasian and Chinese participants revealed no significant effects for Caucasian participants (ps > 0.05), but a significant effect of own/other race for Chinese participants ($F_{1,31} = 4.24$, $p < 0.05$). Chinese participants had longer reaction times for other-race faces than own-race faces, but this did not interact with face set ($p > 0.30$). Collectively, this pattern of results indicates that better accuracy for own-race than other-race faces cannot be attributed to a speed/accuracy trade-off. In summary, this task provides evidence of better sensitivity to both featural and second-order relational cues for own-race than other-race faces for Caucasian, but not Chinese participants. Neither group showed a CRE for contour cues. The only hint of a CRE for Chinese participants was in reaction times; their reaction times were longer for other-race than own-race faces—a pattern that did not vary across face sets.

4.4 *The scrambled/blurred task*

A 2 (race of face: own/other) × 2 (condition: scrambled/blurred) × 2 (participant race) ANOVA revealed a main effect of race of face ($F_{1,61} = 14.56$, $p < 0.001$). Accuracy was higher for own-race than other-race faces. This main effect was qualified by an interaction with participant race ($F_{1,61} = 4.78$, $p < 0.05$), and a significant three-way interaction ($F_{1,61} = 10.89$, $p < 0.01$). To explore these effects further we conducted a 2 (race of face) × 2 (participant race) ANOVA for each condition. The ANOVA for blurred trials revealed only a main effect of race of face ($F_{1,61} = 18.94$, $p < 0.001$); as shown in figure 5, both participant groups were more accurate for own-race faces than for other-race faces. The ANOVA for scrambled trials revealed a significant race of face × race of participant interaction ($F_{1,61} = 7.70$, $p < 0.01$). Paired t-tests for each participant group revealed a significant CRE for Chinese participants ($t_{31} = 3.16$, $p < 0.01$), but not for Caucasian participants ($p > 0.30$).[8] The omnibus ANOVA also revealed a main effect of face type ($F_{1,61} = 92.85$, $p < 0.001$). As shown in figure 5, accuracy was higher on blurred trials than on scrambled trials.

[8] If race of face was coded in absolute rather than relative terms there was a main effect of face race ($F_{1,61} = 21.01$, $p < 0.01$) but the race of participant × absolute race of face was not significant ($p > 0.10$).

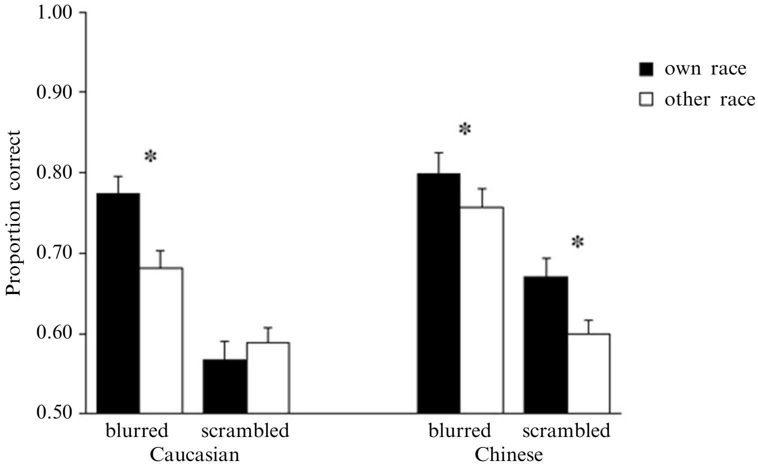

Figure 5. Proportion correct (+1 SE) on the scrambled/blurred task shown separately for each condition (scrambled/blurred) and for Caucasian and Chinese participants. The asterisks indicate a significant own-race advantage ($p < 0.05$).

The analysis of reaction times revealed a main effect of condition (scrambled/blurred; $F_{1,61} = 179.0$, $p < 0.001$). Reaction times were faster on blurred trials, indicating that higher accuracy on blurred trials than on scrambled trials cannot be attributed to speed/accuracy trade-offs. There was also a significant condition × participant race interaction ($F_{1,61} = 6.20$, $p < 0.05$). Separate analyses for Caucasian and Chinese participants revealed a significant effect of condition for both groups (ps < 0.001). Notably, there was no condition × race of face interaction and no main effect of race of face. Thus our analysis of reaction times provided no additional evidence of a CRE. In summary, this scrambled/blurred task provided evidence of greater sensitivity to relational cues in own-race faces for both Caucasian and Chinese participants and greater sensitivity to featural cues in own-race faces for Chinese participants. These effects cannot be attributed to speed/accuracy trade-offs.

5 Discussion

Each of the tasks used in this experiment is well established in the literature and performance on each task has been shown to be influenced by experience (ie by early visual deprivation or, in some previous studies, by own-race versus other-race faces; see below). Yet we found no evidence for a CRE on some measures and only weak evidence on the others. These effects are surprisingly small given the difficulty adults experience when attempting to recognise other-race faces in daily social interactions. Our study draws attention to the complexity of CREs and below we discuss several explanations for the variability of findings.

5.1 *Holistic processing*

There was little evidence of a CRE from the two tasks specifically designed to tap holistic processing. Both groups showed a significant composite face effect for own-race and other-race faces and the size of the composite effect did not differ as a function of race of face. Both groups also showed a significant part/whole effect for own-race faces and the size of the part/whole effect did not differ from that shown for other-race faces. The only hint of a CRE for holistic processing in this task came from Caucasian participants who, unlike Chinese participants, did not show a significant part/whole effect for other-race faces and a tendency ($p = 0.09$) for their reaction times to be faster for own-race faces. Our findings for Chinese participants are consistent with those of two previous studies that reported no difference in holistic processing for own-race and other-race faces (Michel et al 2006a; Tanaka et al 2004), although the Chinese participants in both of those studies had been living in a predominantly Caucasian environment for at least one year at the time of test. Our findings for Caucasians are partially consistent with previous studies. Like Caucasian participants in the two previous studies using the part/whole task (Michel et al 2006a; Tanaka et al 2004), our Caucasian participants showed a significant whole/part effect for own-race, but not other-race faces. However, planned comparisons and the overall ANOVA showed that the size of their part/whole effect was not larger for own-race faces than for other-race faces in the current study. Similarly, in the current study the size of the composite face effect for Caucasian participants did not differ for own-race and other-race faces.

Despite the composite face effect for own-race faces being quite large, we did not observe a CRE for either participant group. One previous study that used the Caucasian trials of this composite face task did demonstrate an effect of experience. Patients who missed early visual experience because of congenital cataract were as accurate on aligned same trials as they were on misaligned same trials (ie their composite face effect was zero—Le Grand et al 2004). Thus the failure to find larger composite face effects for own-race faces than other-race faces cannot be attributed to this task yielding high error rates on same aligned trials even in the absence of holistic processing. One possibility is that randomly intermixing Chinese and Caucasian faces increased holistic processing of other-race faces for Caucasian participants; CREs are often stronger when faces are blocked by race (Meissner and Brigham 2001). This cannot entirely explain our results, however, because although Caucasian and Asian faces were presented in separate blocks in one previous study (Michel et al 2006a: part/whole effect), they were randomly intermixed in two others (Michel et al 2006b: composite effect; Tanaka et al 2004: part/whole effect). Our results suggest that better holistic processing of own-race faces is not a robust phenomenon in Caucasian participants, and is consistent with the failure to find this effect in Chinese participants in the three previous studies. One possible explanation is that the Caucasian participants in our study who resided in the United States, despite reporting low personal contact with Chinese individuals, had sufficient exposure to Chinese faces through the media to support holistic processing, unlike the Caucasian participants tested by Michel et al (2006b) who resided in Europe. Future research is needed to analyse the extent of this non-personal contact across populations, perhaps by using the complete design recommended by Cheung et al (2008).

Both Caucasian and Chinese participants were more accurate for own-race faces than other-race faces for blurred trials of the scrambled/blurred tasks. Although conceptually designed to tap configural cues to facial identity (Hayward et al 2008), blurred trials of the scrambled/blurred task are likely also to tap holistic processing since both the composite face effect and the part/whole effect increase for faces that include only low spatial frequencies (Goffaux et al 2005; but see Cheung et al 2008). However, given the lack of any evidence of better holistic processing of own-race faces in the two tasks specifically designed to assess holistic processing (ie the composite task and the whole/part task), it is more likely that any effect of race in the blurred trials of the scrambled/blurred task indicates an effect of face race on sensitivity to the spacing among features (see Cheung et al 2008 for support for this argument).

5.2 *Cues to facial identity*

Despite processing both own-race and other-race faces holistically, our participants were more sensitive to cues to facial identity in own-race faces than in other-race faces.

5.2.1 *Featural processing.* First, our results support the conclusion that sensitivity to featural differences is greater for own-race than other-race faces. In the Jane/Ling task, Caucasian participants were more accurate for the Caucasian feature set than the Chinese feature set and in the scrambled trials of the scrambled/blurred task, Chinese participants were more accurate on scrambled Chinese trials than scrambled Caucasian trials. In the present study, Caucasians did not show an own-race advantage on scrambled trials as reported in the one previous study that used this task (Hayward et al 2008). This may be because accuracy was low, although significantly above chance, for own-race faces (mean = 57%), resulting in a floor effect. In contrast, the accuracy of Chinese participants was much higher for own-race faces (mean = 67%), creating more room for decreased accuracy for other-race faces. This raises the interesting question of why only Caucasian participants showed an own-race advantage in the Jane/Ling task. Eye colour varies more among Caucasian faces than among Chinese faces and this natural difference was evident in luminance differences in our grey-scale photographs. Although the accuracy of Caucasian adults for detecting featural differences among Caucasian faces is not enhanced by either make-up or large differences in the luminance of the iris (Mondloch et al 2010), this luminance cue may have enhanced the sensitivity of our Chinese participants to featural differences in the Caucasian stimuli. These cues were less available to Caucasian participants attempting to discriminate features in the Chinese stimuli. Rhodes et al (2006) reported a CRE for featural cues in both Chinese and Caucasian participants. However, in their study featural differences were created by making the eyebrows and lips lighter/darker as well as by making the nose more/less bulbous. Their results suggest that when the nature of featural differences is equated and luminance cues are equal for own-race versus other-race faces, both Caucasian and Asians may perform more accurately for own-race faces. In contrast, our results suggest that, when the cues that normally differentiate Caucasian (shape and colour/luminance) and Chinese (primarily shape) features are available, Caucasians may show a stronger CRE, perhaps because one cue that they use on a daily basis to recognise faces (eye colour) is not useful for discriminating Chinese faces. In contrast, Chinese participants were able to rely on the cue that they use on a daily basis (eye shape) and, for Caucasian faces, the added dimension of colour/luminance.

To evaluate the consistency of the differences in featural processing between the Chinese and Caucasian participants, we performed an additional analysis for another task in our battery that tested sensitivity to featural cues in own-race versus other-race faces: whole trials of the part/whole task. On whole trials of this task participants selected which of two faces was identical to a previously seen target face; the foil differed from the target only in one feature (eye, nose, or mouth). A 2 (race of face: own/other) $\times$ 2 (participant group) ANOVA revealed a significant main effect of race of face ($F_{1,61} = 4.85$, $p < 0.05$), and a significant interaction ($F_{1,61} = 8.07$, $p < 0.01$). Paired t-tests revealed a significant CRE for Caucasian participants ($t_{24} = 2.09$, $p < 0.05$), but not for Chinese participants ($p > 0.4$), consistent with the results of the Jane/Ling task. Thus, like featural trials of the Jane/Ling task, whole trials of the part/whole task provide evidence of better featural processing of own-race faces in Caucasian, but not Chinese, participants. This is an important finding because, unlike the Jane/Ling task, a unique target face was presented on each trial of the part/whole task, thus extending the pattern of results to a wider set of stimuli. Collectively, these results provide evidence of a CRE for featural processing that is stronger for Caucasian than Chinese participants.

5.2.2 *Relational processing.* Our results also provide evidence of a CRE for relational processing. The strongest support comes from the scrambled/blurred task. There was a main effect of own-race versus other-race faces on blurred trials: both Caucasian and Chinese participants were more accurate for own-race faces. These results are consistent with the one previous study that used this task and found a CRE for blurred trials (Hayward et al 2008; see also Rhodes et al 2009 for results from Chinese participants only). We note that it is likely that the blurred faces allow participants to use both second-order relations and holistic processing for face recognition, unlike scrambled trials, which disrupt holistic processing. Because second-order relations were not directly manipulated in the blurred faces, data from this task alone do not allow us to conclude that sensitivity to second-order relations per se is greater for own-race faces; an alternative explanation (see above) is that the CRE observed for blurred trials reflects better holistic processing of own-race faces.

Better sensitivity to second-order relational cues (ie differences among faces in the spacing of features) in own-race faces did receive partial support from the Jane/Ling task, in which second-order relations were manipulated directly. Caucasian adults were more accurate for own-race faces than for other-race faces, but Chinese adults were not. It is important to note that the physical changes (ie number of pixels by which each feature was moved) were identical for the two face sets. Furthermore, measurements of adult female Caucasian and Chinese faces (Farkas 1994) indicate that several key facial dimensions (eg face width, head length, distance between the lips and chin) have almost identical means (± 2 mm) and SDs (± 5 mm), with only small differences in the mean distance between inner corners of the eyes (5 mm larger for Chinese faces) and the distance between the eyes and the chin (4.5 mm larger for Chinese faces). The SD for the mean distance between inner corners of the eyes is similar for Caucasian and Asian faces (± 1 mm); only the distance between the eyes and the chin is more variable in Chinese faces (SD = 9.3 mm) than in Caucasian faces (5.1 mm). Thus, not only were the metric changes identical for the two face sets, but they covered approximately the same amount of the variability among Caucasian and Chinese faces in the real world.

It is possible that Caucasians do indeed have a stronger CRE for second-order relations than Chinese adults, which would be consistent with a general pattern in the literature. Meissner and Brigham's (2001) review of the literature indicates that Caucasians frequently show stronger CREs than either Black or Asian participants, although in many of those studies the non-Caucasian participants were members of a minority group living among a White majority. Our results suggest the possibility that Caucasians show stronger effects even when both groups are the majority population, perhaps because of worldwide exposure to western media. Alternatively, the lack of effect seen for Chinese participants on the spacing trials of the Jane/Ling task may not be surprising given results of a recent study in which we tested sensitivity to the same changes in the spacing of facial features in a human versus a monkey face. In that study, adults and 8-year-old children were 9% more accurate for human than monkey faces. Assuming that adults are more sensitive to second-order relations in other-race human faces than in monkey faces, there is not a large range in which to obtain significant effects of face race. The more robust findings from blurred trials of the scrambled/blurred task may be attributable to that task testing memory for relational cues, unlike the Jane/Ling task in which the two stimuli to be compared were separated by only 200 ms.

5.3 *Conclusions*

In summary, despite processing both own-race and other-race faces holistically—a hallmark of face perception—adults with minimal experience with other-race faces were less sensitive to both featural differences and relational differences in other-race faces than in own-race faces. Although the effects were not large, they may contribute to the everyday experience of being more likely to make mistakes when identifying other-race individuals than own-race individuals. In three of the tasks (scrambled trials, Jane/Ling features, Jane/Ling spacing) only one of the two participant groups showed an own-race advantage. Although this suggests that we should be somewhat cautious in our interpretation, "requiring a complete crossover interaction [may be] overly stringent"

(Meissner and Brigham 2001, page 5). In their meta-analysis Meissner and Brigham report that Caucasian participants typically have a larger CRE than Black participants (page 18); the same may be true of Caucasian participants relative to Chinese participants, even when all participants are residing in a context in which they are the majority population.

Three design characteristics may have weakened CREs in our study. First, we randomly intermixed Caucasian and Chinese faces in each of our tasks in order to control for practice effects. CREs are often stronger when faces are blocked by race (Meissner and Brigham 2001). Second, in the real world, faces are seen posing a variety of facial expressions and from different points of view; in many lab studies, including this one, the same photograph is presented both initially and at test. For example, on same trials of the Jane/Ling task and on whole trials of the part/whole task, the two photographs were identical, rather than two different images of the same face. CREs tend to be larger when photographs are altered from study to test (Meissner and Brigham 2001). This is consistent with observations that the CRE following study of face photographs is much smaller for identical, unmanipulated photographs than for either scrambled or blurred images (Hayward, unpublished data). Third, CREs may be stronger in tasks that include a memory component in addition to a perceptual component. Only one of our tasks (scrambled/blurred task) involved a memory component, and this task yielded the strongest evidence of better relational processing for own-race faces. Even that task did not mimic the real world, however, where we often are required to recognise a face previously seen several hours or weeks ago. Our results suggest that differences in the ability to encode featural and relational cues may differ only slightly between own-race and other-race faces and that CREs may be most evident after a delay (ie when memory for features or their spacing is tested—see Meissner and Brigham 2001 for a review). Meissner and Brigham (2001) begin their review with an anecdote describing the prevalence of poor recognition of other-race faces and its social impact. Yet, their review is filled with examples of this CRE being absent in some studies or being limited to one participant race (typically Caucasian). Similarly, in our current investigation, for only one of the 6 measures (the blurred trials of the scrambled/blurred task) did both Chinese and Caucasian participants show a CRE. On the other measures, there was either no CRE or an effect that was significant in one group but not the other. Overall, the effects were remarkably small, despite the difficulty that most people experience in recognising other-race individuals.

In addition to the design characteristics noted above, we propose several explanations for the ephemeral nature of CREs in laboratory studies. First, on a daily basis we attempt to recognise an individual without knowing whether the individual is present (eg whether that person is in the shopping centre). In contrast, in laboratory studies observers typically know that one of two faces is the target (in two-alternative forced-choice tasks) or that the probability of any test face being the target is about 50% (in same/different or old/new tasks). It may be that CREs increase with uncertainty. Second, any one task taps one aspect of face processing, whereas differences in own- versus other-race face recognition in the real world will reflect the cumulative effect of multiple factors. For example, our tasks focused on differences in perceptual expertise for own-race versus other-race faces. Recent studies suggest the importance of integrating the perceptual expertise model with social-cognitive models of CREs. Social-cognitive models emphasise differences in how we think about and perceive out-group members relative to in-group members. According to these models, out-group members are perceived at the categorical level whereas in-group members are perceived at the individual level (Ge et al, 2009; Hugenberg et al 2007; Levin 1996, 2000); processing faces at the categorical level is associated with lower rates of recognition and the belief that out-group members are more homogeneous than in-group members.

Social-cognitive models have received empirical support from studies showing that recognition of other-race faces improves if the perceiver is instructed to individuate faces (Hugenberg et al 2007) and that recognition of own-race faces is impaired when they are perceived as out-group members (ie from a different socioeconomic status; Bernstein et al 2007; Shriver et al 2007).

Studies that ignore the contribution of these socio-cognitive models may underestimate CREs. Furthermore, any tendency to encode race-specifying information at the expense of individuating information for other-race faces (Levin 1996, 2000) may be minimised in laboratory studies where participants are repeatedly asked to recognise individual faces (Tanaka and Pierce 2009). In summary, the ability to recognise own-race faces better than other-race faces is a multifaceted phenomenon that is influenced by categorisation, interracial contact, perceptual learning, and memory. The CREs measured in the present study each will make only a small contribution to the difficulty we experience in recognising individuals of a different race.

Acknowledgments. The research was supported by an NSERC Discovery Grant to CM, an NSERC Discovery Grant to DM, a grant from the Hong Kong Research Grants Council (HKU4653/05H) to WGH, a grant from the National Natural Science Foundation of China (30700230) to GZ, and support from the "One-hundred-programme" of Sun Yat-sen University to GZ. We thank Bruno Rossion for helpful comments on an earlier version of this manuscript.

References

Aguirre G K, Singh R, D'Esposito M, 1999 "Stimulus inversion and the responses of face and object-sensitive cortical areas" *NeuroReport* **10** 189 – 194

Bahrick H P, Bahrick P O, Wittlinger R P, 1975 "Fifty years of memory for names and faces: A cross-sectional approach" *Journal of Experimental Psychology: General* **104** 54 – 75

Bar-Heim Y, Ziv T, Lamy D, Hodes R M, 2006 "Nature and nurture in own-race face processing" *Psychological Science* **17** 159 – 163

Bernstein M J, Young S G, Hugenberg K, 2007 "The cross-category effect: Mere social categorization is sufficient to elicit an own-group bias in face recognition" *Psychological Science* **18** 706 – 712

Boutet I, Collin C, Faubert J, 2003 "Configural face encoding and spatial frequency information" *Perception & Psychophysics* **65** 1078 – 1093

Brigham J C, Maass A, Snyder L D, Spaulding K, 1982 "Accuracy of eyewitness identifications in a field setting" *Journal of Personality and Social Psychology* **42** 673 – 681

Cheung O S, Richler J J Palmeri T J, Gauthier I, 2008 "Revisiting the role of spatial frequencies in the holistic processing of faces" *Journal of Experimental Psychology: Human Perception and Performance* **34** 1327 – 1336

Chiroro P, Valentine T, 1995 "An investigation of the contact hypothesis of the own-race bias in face recognition" *Quarterly Journal of Experimental Psychology A* **48** 879 – 894

Cross J F, Cross J, Daly J, 1971 "Sex, race, age and beauty as factors in recognition of faces" *Perception & Psychophysics* **10** 393 – 396

Farkas L G, 1994 *Anthropometry of the Head and Face in Medicine* 2nd edition (New York: Elsevier)

Feinman S, Entwisle D R, 1976 "Children's ability to recognise other children's faces" *Child Development* **47** 506 – 510

Freire A, Lee K, Symons L A, 2000 "The face-inversion effect as a deficit in the encoding of configural information: Direct evidence" *Perception* **29** 159 – 170

Furl N, Phillips P J, O'Toole A J, 2002 "Face recognition algorithms and the other-race effect: Computational mechanisms for a developmental contact hypothesis" *Cognitive Science* **26** 797 – 815

Gauthier I, Tarr M J, 2002 "Unraveling mechanisms for expert object recognition: Bridging brain activity and behaviour" *Journal of Experimental Psychology: Human Perception and Performance* **28** 431 – 446

Ge L, Luo J, Nishimura M, Lee K, 2003 "The lasting impression of Chairman Mao: Hyperfidelity of familiar-face memory" *Perception* **32** 601 – 614

Ge L, Zhang H, Wang Z, Quinn P, Pascalis O, Kelly D, Slater A, Tian J, Lee K, 2009 "Two faces of the other-race effect: Recognition and categorisation of Caucasian and Chinese faces" *Perception* **38** 1199 – 1210

Goffaux V, Hault B, Michel C, Vuong Q C, Rossion B, 2005 "The respective role of low and high spatial frequencies in supporting configural and featural processing of faces" *Perception* **34** 77–86
Goffaux V, Rossion B, 2006 "Faces are "spatial"—Holistic face perception is supported by low spatial frequencies" *Journal of Experimental Psychology: Human Perception and Performance* **37** 1023–1039
Golby A J, Gabrieli J D E, Chiao J Y, Eberhardt J L, 2001 "Differential responses in the fusiform region to same-race and other-race faces" *Nature Neuroscience* **4** 845–850
Goldstone R L, 2003 "Do we all look alike to computers?" *Trends in Cognitive Sciences* **7** 55–57
Haig N D, 1984 "The effect of feature displacement on face recognition" *Perception* **13** 505–512
Hancock K, Rhodes G, 2008 "Contact, inversion and the other-race effect in face recognition" *British Journal of Psychology* **99** 45–56
Haxby J V, Gobbini M I, Furey M L, Ishai A, Schouten J L, Pietrini P, 2001 "Distributed and overlapping representations of faces and objects in ventral temporal cortex" *Science* **293** 2425–2430
Haxby J V, Hoffman E A, Gobbini M I, 2000 "The distributed human neural system for face perception" *Trends in Cognitive Sciences* **4** 223–233
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
Heering A de, Houthuys S, Rossion B, 2007 "Holistic face processing is mature at 4 years of age: Evidence from the composite face effect" *Journal of Experimental Child Psychology* **96** 57–70
Hole G, 1994 "Configurational factors in the perception of unfamiliar faces" *Perception* **23** 65–74
Hugenberg K, Miller J, Claypool H M, 2007 "Categorization and individuation in the cross-race recognition deficit: Toward a solution to an insidious problem" *Journal of Experimental Social Psychology* **43** 334–340
Kitayama S, Duffy S, Kawamura T, Larsen J, 2003 "Perceiving an object and its context in different cultures: A cultural look at new look" *Psychological Science* **14** 201–206
Le Grand R, Mondloch C J, Maurer D, Brent H P, 2001 "Early visual experience and face processing" *Nature* **410** 890
Le Grand R, Mondloch C J, Maurer D, Brent H P, 2004 "Impairment in holistic face processing following early visual deprivation" *Psychological Science* **15** 762–768
Levin D T, 1996 "Classifying faces by race: The structure of face categories" *Journal of Experimental Psychology: Learning, Memory and Cognition* **22** 1364–1382
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 deficit" *Journal of Experimental Psychology: General* **129** 559–574
McCarthy G, Puce A, Gore J, Allison T, 1997 "Face-specific processing in the human fusiform gyrus" *Journal of Cognitive Neuroscience* **9** 605–610
McKone E, Brewer J L, MacPherson S, Rhodes G, Hayward W G, 2007 "Familiar other-race faces show normal holistic processing and are robust to perceptual stress" *Perception* **36** 224–248
Malpass R S, Kravitz J, 1969 "Recognition for faces of own and other race" *Journal of Personality and Social Psychology* **13** 330–334
Maurer D, Le Grand R, Mondloch C J, 2002 "The many faces of configural processing" *Trends in Cognitive Sciences* **6** 255–260
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, 2006a "Same-race faces are perceived more holistically than other-race faces" *Visual Cognition* **14** 55–73
Michel C, Corneille O, Rossion B, 2010 "Holistic face encoding is modulated by perceived face race: Evidence from perceptual adaptation" *Visual Cognition* **18** 434–455
Michel C, Rossion B, Han J, Chung C-S, Caldara R, 2006b "Holistic processing is finely tuned for faces of our own race" *Psychological Science* **17** 608–615
Mondloch C J, Ahola S, Maurer D, 2006 "Becoming a face expert" *Psychological Science* **17** 930–934
Mondloch C J, Le Grand R, Maurer D, 2002 "Configural face processing develops more slowly than featural face processing" *Perception* **31** 553–566
Mondloch C J, Pathman T, Maurer D, Le Grand R, Schonen S de, 2007 "The composite face effect in six-year-old children: Evidence of adultlike holistic face processing" *Visual Cognition* **15** 564–577
Mondloch C J, Robbins R, Maurer D, 2010 "Discrimination of facial features by adults, 10-year-olds and cataract-reversal patients" *Perception* **39** 183–194
Pellicano E, Rhodes G, 2003 "Holistic processing of faces in preschool children and adults" *Psychological Science* **14** 618–622

Peters M, 1988 "Description and validation of a flexible and broadly usable handedness questionnaire" *Laterality* **3** 77 – 96

Rhodes G, Ewing L, Hayward W, 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

Sangrigoli S, Pallier C, Argenti A M, Ventureyra V A G, Schonen S de, 2005 "Reversibility of the other-race effect in face recognition during childhood" *Psychological Science* **16** 440 – 444

Shepherd J W, Deregowski J B, Ellis H D, 1974 "A cross-cultural study of recognition memory for faces" *International Journal of Psychology* **9** 205 – 211

Shriver E R, Young S G, Hugenberg K, Bernstein M J, Lanter J R, 2007 "Class, race, and the face: Social context modulates the cross-race effect in face recognition" *Personality and Social Psychology Bulletin* **34** 260 – 274

Slone A E, Brigham J C, Meissner C A, 2000 "Social and cognitive factors affecting the own-race bias in Whites" *Basic and Applied Social Psychology* **22** 71 – 84

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

Tanaka J W, Farah M J, 1993 "Parts and wholes in face recognition" *Quarterly Journal of Experimental Psychology: Human Experimental Psychology* **46** 225 – 245

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

Tanaka J W, Pierce L J, 2009 "The neural plasticity of other-race face recognition" *Cognitive, Affective, & Behavioral Neuroscience* **9** 122 – 131

Valentine T, 1991 "A unified account of the effects of distinctiveness, inversion, and race in face recognition" *Quarterly Journal of Experimental Psychology A* **43** 161 – 204

Valentine T, Endo M, 1992 "Towards an exemplar model of face processing: The effects of race and distinctiveness" *Quarterly Journal of Experimental Psychology A* **44** 671 – 703

Wright D B, Boyd C E, Tredoux C G, 2001 "A field study of own-race bias in South Africa and England" *Psychology, Public Policy and Law* **7** 119 – 133

Young A W, Hellawell D, Hay D C, 1987 "Configurational information in face perception" *Perception* **16** 747 – 759

ISSN 0301-0066 (print) ISSN 1468-4233 (electronic)

PERCEPTION

VOLUME 39 2010

www.perceptionweb.com