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Familiar other-race faces show normal holistic processing and are robust to perceptual stress

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Abstract. Other-race individuals are remembered more poorly and receive less holistic/configural processing than same-race individuals, at least when faces are novel. Here, we examine the amelioration of these effects with familiarity, using distinctiveness-matched Caucasian and Asian stimulus sets. We confirmed a cross-race deficit for upright faces following a single encoding trial, which disappeared rapidly with practice on a small set of other-race 'friends' and did not re-emerge when perceptual processing was put under stress (presentation in the periphery). We also examined holistic/configural processing for familiarised faces using the *peripheral inversion effect* (McKone, 2004 *Journal of Experimental Psychology: Learning, Memory, and Cognition* **30** 181–197). A test for faces and nonface objects (dogs) confirmed the validity of this technique as providing a direct measure of holistic processing; we then showed that, after 1 h of training, holistic processing was as strong for other-race as same-race faces. We conclude that practice with other-race individuals can rapidly engage normal face-processing mechanisms.

1 Introduction

The 'other-race-effect', 'cross-race deficit', or 'own-race bias' manifests itself in a number of tasks. In rating studies, people judge similarity among faces of other races as greater than among faces of their own race (Byatt and Rhodes 2004; Goldstein and Chance 1979; Ng and Lindsay 1994). In recognition-memory tasks—where participants learn a set of novel faces and are later tested for their memory for these faces via an old–new judgment—recognition of individuals is generally poorer for other-race faces than for same-race faces. Sometimes the deficit is obtained only for one race of participant (for review see Meissner and Brigham 2001), although many experiments have produced a full cross-over interaction, in which, for example, White subjects show better memory for White faces than for Black faces, and Black subjects show better memory for Black faces than for White faces (eg Malpass et al 1973; Pezdek et al 2003; Shepherd et al 1974; Valentine and Endo 1992). In the present study, we focus on majority-race members being tested for deficits in processing the faces of a minority group. This circumstance is of particular practical and social importance: it is here that cross-race deficits become most problematic, leading, for example, to incorrect criminal convictions following misidentifications of minority-race members in eyewitness testimony (Wells and Olson 2001).

1.1 *Explanations for the other-race effect*

Several factors have been proposed to contribute to the cross-race deficit. These are not mutually exclusive, and it is likely that each may play some role in the effect.

First, Goldstein (1979) found no support for an early idea that individuals of some races had *physically more similar physiognomy* than individuals of other races. However, it remains possible that the *particular stimulus sets used in a particular experiment* may

contain faces for one race that are intrinsically more difficult to discriminate or remember than those of the other race (see Bothwell et al 1989; Chiroro and Valentine 1995). For example, within a single race, distinctive faces—defined as faces that are ‘unusual’ or that would ‘stand out in a crowd’—have been found to produce better recognition-memory performance than typical faces (eg Valentine and Bruce 1986a; Valentine and Endo 1992). Thus, if the face stimuli of two races were not matched for distinctiveness (as perceived by own-race members) then memory scores for the two stimulus sets might not be comparable.

Second, at a more theoretical level, *lack of contact* with other-race faces may limit discriminability and recognition. Empirically, there is an established effect of contact, most clearly when ‘contact’ is defined in terms of population statistics (see Sporer 2001, for review). Cases where Black Americans show no other-race deficit for White American faces (eg Lindsay et al 1991), or a relatively weak effect (Malpass and Kravitz 1969), might be attributed to Blacks’ relatively high degree of contact with the White majority. Similarly, Tanaka et al (2004) found that Caucasians living in a majority-White country (Germany) showed deficits in processing Asian⁽¹⁾ faces, while Asian subjects in a majority-White country (Canada) did not show corresponding deficits for White faces. Chance et al (1975) found that, for White American subjects, the cross-race deficit was more robust for Asian than Black faces, which was attributed to the higher degree of exposure to Black than Asian individuals in American society in the 1970s (see also Chiroro and Valentine 1995). Contact has also been varied via experimental training. Malpass et al (1973) found that feedback on recognition-memory performance eliminated an initial other-race effect, for the trained faces, with approximately one hundred trials. Elliott et al (1973), and Goldstein and Chance (1985) also found that familiarising White participants with one set of Asian faces improved memory for a novel, untrained, set.

Third, explanations for the other-race effect often refer to the *appropriateness of dimensions in face-space*. In face-space models (eg Valentine 1991), each face is encoded as a point in a multidimensional space, the axes of which represent dimensions useful in discriminating between individuals (eg width of face, colour of eyes). In explaining the cross-race deficit, a common idea (eg Furl et al 2002) is that the dimensions of face-space have been tuned on the basis of experience with predominately own-race faces, and are not necessarily appropriate for discriminating other-race faces. Valentine (1991), for example, postulates that other-race individuals lie grouped closely together in the periphery of face-space, and that this makes them difficult to discriminate in recognition-memory tasks.

Fourth, some authors have emphasised the role of *social cognition and between-class categorisation*. An idea that racially prejudiced individuals might show a larger cross-race deficit than less prejudiced individuals has received little empirical support (eg Ferguson et al 2001; Lavrakas et al 1976; Slone et al 2000; see meta-analysis by Meissner and Brigham 2001). However, social factors may still play an important role in the cross-race deficit. It has been suggested that simply acknowledging someone as of a different race may lead to the other-race effect via categorisation processes. Sporer’s (2001) in-group/out-group model posits that in the initial encounter with an other-race face, categorisation as an out-group member occurs before more typical face-processing strategies can begin, thus inhibiting individuation. Similarly, Levin (1996, 2000) has proposed that we encode a ‘race feature’ for other-race faces, which allows us to quickly categorise someone as being of a different race at the expense of encoding individuating information. In support of this idea, Levin (1996, 2000) found an other-race *advantage* in tasks requiring classification by race (White versus Black; although see Valentine and Endo 1992,

⁽¹⁾ Throughout this article, ‘Asian’ is used to refer to East Asian (eg Chinese, Thai) rather than South Asian (eg Indian, Pakistani) ethnicity.

their experiment 4), and in visual-search tasks (finding the Black face among a series of White distractors as quickly as possible). These results suggest that categorisation of a face as 'other race' may inhibit individuating processes necessary for good discrimination and memory.

1.2 *Holistic processing as a factor*

A fifth factor proposed to contribute to the other-race deficit (eg Johnson and Fredrickson 2005; Rhodes et al 1989; Tanaka et al 2004; Turk et al 2005) is *holistic* or *configural* processing.⁽²⁾ This is the style of cognitive processing believed to make face processing special and different from object recognition in general. Although recognition of objects, and of inverted faces, appears to rely only on part-based or featural processing (ie the decomposition of a stimulus into separate components), processing of upright faces is known to additionally involve holistic processing. The exact nature of this holistic processing is not well understood (see Maurer et al 2002), but is generally taken to mean either that faces are not decomposed into parts (Tanaka and Farah 1993), or that there are interactions between multiple parts over a broad region of the face (cf Rhodes 1988). It is also presumed that holistic information includes coding of exact distances within the face (eg edge of eye to tip of nose) as opposed to merely categorical information about part arrangement (eg eyes *above* nose).

For same-race faces, several standard empirical findings are associated with holistic processing. Yin (1969) showed that recognition memory was much more affected by inversion for faces than for other objects (see also Diamond and Carey 1986), although this result does not, in itself, demonstrate holistic processing for upright faces (it could potentially arise from inversion effects on part-based processing; see Bartlett et al 2003; Valentine 1988). More direct evidence has been produced by other techniques. In Young et al's (1987) *composite effect*, subjects are slower to name the top half of a composite face when the halves are aligned rather than offset, corresponding to a percept that the composite forms a 'new person' when aligned. While this phenomenon occurs for upright faces, it is absent for inverted faces (eg Robbins and McKone 2003) and nonface objects (eg dogs; Robbins and McKone, in press). In Tanaka and Farah's (1993) *part-whole effect*, memory for a face part is better when tested in the context of the whole studied face than when tested in isolation. Again, the effect is strong for upright faces, but is absent for inverted faces (eg Tanaka and Farah 1993), and very small for objects (eg car fronts; Tanaka and Gauthier 1997). Finally, in the *peripheral identification technique* (McKone 2004), identification of faces flashed in the periphery, following training to ceiling with central presentation (both upright and inverted), is worse for inverted whole faces than for upright whole faces. No peripheral inversion effect occurs, however, for an isolated face feature, again consistent with holistic processing being limited to upright faces.

Turning to other-race faces, evidence suggests that holistic processing for other-race individuals is weaker than for same-race individuals. Most strongly, testing Caucasian participants, Tanaka et al (2004) confirmed a large *part-whole effect* for own-race faces, but found only a small nonsignificant effect for Asian faces. (Asian participants, living in a majority-Caucasian country, demonstrated the part-whole effect for stimuli of both races, consistent with a contact effect.) Murray et al (2003) found that a *Thatcherised face* (an upright face with eyes and mouth inverted) was perceived as less bizarre for other-race stimuli than for same-race stimuli, consistent with a reduced sensitivity to holistic information about distances between parts. Bizarreness of the Thatcher face was also reduced less by rotation for other-race stimuli than for same-race stimuli while, in contrast, the small orientation effect for faces made bizarre by a local component change (eg blackened teeth) did not differ as a function of race. Fallshore and

⁽²⁾ From now on, the term *holistic* is used as a shorthand for 'holistic/configural'.

Schooler (1995) confirmed a *verbal overshadowing effect* for same-race faces, in which a verbal description following initial encoding reduced accuracy on a later recognition-memory test, but found no verbal overshadowing for other-race faces. If one accepts the idea that the verbal overshadowing effect arises from a shift in processing style from global to local processing (Fallshore and Schooler 1995; Macrae and Lewis 2002; Schooler and Engstler-Schooler 1990), then the lack of verbal overshadowing for other-race faces is again consistent with a lack of holistic processing. Finally, Turk et al (2005) reported that a split-brain patient showed the cross-race deficit only with presentation to the *right hemisphere*. Given evidence that holistic processing is done primarily by this hemisphere (eg Rhodes 1993), this result is consistent with a deficit in holistic processing for other-race faces.

The size of *inversion effects in recognition-memory tasks* is also of some relevance. Although inversion effects in this task cannot be taken directly as evidence of holistic processing, the standard argument (eg Diamond and Carey 1986; Rhodes 1993; Yin 1969) is that the disproportionately large inversion effect for same-race faces, as compared to objects, arises because holistic processing assists memory and holistic processing is available only to upright faces. (Consistent with this idea, memory for faces and objects is commonly similar in the inverted orientation, and it is the *upright* orientation that produces an advantage for faces; eg Robbins and McKone, in press; Yin 1969.) This suggests that a lack of holistic processing for other-race faces might produce a smaller inversion effect for other-race than for same-race faces. Evidence for this idea is somewhat mixed. Valentine and Bruce (1986b) found a reverse-to-predicted pattern, with a smaller inversion effect for same-race (White) than other-race (Black) faces (allowing 2 s of exposure to own-race faces and 5 s to other-race faces to equate upright performance). However, Buckhout and Regan (1988) did find a larger inversion effect for same-race than other-race faces for Black subjects, although not for White subjects. Rhodes (1993) similarly found a larger inversion effect for own-race than other-race faces in one subject group (Caucasians) but only a weak difference for another (Asians). Further, Rhodes et al (1989) found that both European and Chinese subjects demonstrated a larger inversion effect for own-race than other-race faces when test items were randomly paired in a 2-alternative forced-choice (2AFC) recognition-memory test. However, when pairs of faces were, instead, selected to be very similar to each other, this effect disappeared (European subjects displayed a slightly larger inversion effect for other-race faces). In explaining these contradictory findings, Rhodes et al (1989) suggested that perhaps when featural cues are unhelpful (eg when two faces are very similar), configural processing will be encouraged for other-race faces. When featural cues *are* available, these may be used to process other-race faces to the detriment of holistic information, resulting in smaller inversion effects.

Overall, the results above indicate difficulty with holistic processing for other-race faces. Moreover, given that holistic processing appears to be an important factor assisting memory for upright faces, there is good reason to believe that the holistic-processing deficit plays a direct causal role in the basic cross-race deficit (the finding that memory for upright other-race faces is poorer than memory for upright same-race faces). Note that this idea is not in competition with other approaches to understanding the cross-race deficit, but rather complements them. For example, one could reasonably propose that holistic processing is likely to be more effective when (a) *contact* with members of the target race is high, (b) *face-space* dimensions are appropriately tuned to describe the facial configuration of the target race, and (c) when *social cognition* encourages categorisation of faces at an individual level rather than in terms of racial group. All these conditions will be better met for same-race faces than for other-race faces.

1.3 *What happens when other-race individuals become familiar?*

The aim of the present study was to explore the extent to which the lack of holistic processing for novel other-race faces can be overcome by familiarity. In all but one of the studies reviewed in the previous section, each other-race individual was learned only 1–6 times during the experiment (Buckhout and Regan 1988; Fallshore and Schooler 1995; Rhodes 1993; Rhodes et al 1989; Tanaka et al 2004). In the exception case (Murray et al 2003), a given other-race face was seen more often, but the task was to rate bizarreness of the face rather than to make any specific reference to individual identity. No prior studies have examined the role of holistic processing in *identification* or *individuation* of other-race faces, once these have become familiar through practice or training. It is of interest to know whether 'normal' face processing can be employed in the recognition of well-known individuals of another race, such as our friends or colleagues.

Also of interest is the speed at which holistic processing of other-race faces can be learned. If holistic processing is found after only a small amount of practice, this would suggest that the use of part-based rather than holistic processing for other-race faces is perhaps merely a strategy that can easily be shifted. However, if holistic processing were poor even for trained familiar faces, this would argue that the cross-race effect reflects a more permanent cognitive deficit in holistic processing, such as occurs for inverted faces (Robbins and McKone 2003).

1.4 *Present study*

We describe three experiments exploring two issues: (a) the effects of familiarisation on the basic other-race deficit, and (b) the amount of holistic processing for familiarised other-race faces. Except for initial stimulus selection, we tested only Caucasian Australian subjects (on Caucasian and Asian faces); we thus investigated the extent to which majority-race deficits for recognising minority-race individuals can be overcome with familiarity.

Importantly, our intention was not to attempt to induce expertise with the class of Asian faces as a whole. Instead, we examined the case in which a Caucasian subject remained a relative novice with Asian faces as a class, but was familiarised with a small number of individual Asian faces. This provides an analogy of a person living in a primarily own-race country but knowing a few people of another race well, such as a limited number of other-race friends, colleagues, politicians, or movie stars. Our interest was in whether normal face processing can be learned for other-race individuals under these circumstances.

The structure of the experiments is as follows. In experiment 1, we develop a stimulus set of Caucasian and Asian faces that were matched for discriminability (based on own-race ratings of distinctiveness), and confirm that Caucasian subjects showed a cross-race deficit on recognition memory for these faces. In this experiment, familiarity with the other-race individuals was at its lowest possible level; each face was seen only once at encoding.

In experiment 2, we introduce and justify the technique we used to assess holistic processing for trained stimuli, namely the *peripheral identification method* (McKone 2004). In this experiment, there were no other-race faces. Instead, we trained subjects to discriminate a small set of (same-race) faces or nonface objects (dachshund dogs) to criterion, then flashed them upright or inverted at various distances from fixation in the periphery. McKone (2004) has already reported that this method produces an inversion effect in the periphery that is present for whole faces but absent for an isolated face feature. If the peripheral inversion effect is also absent for dogs, which are known to be processed featurally (Robbins and McKone, in press), this would confirm our claim that the peripheral inversion effect can be taken as a direct marker

of holistic processing (note that this is not necessarily true of inversion effects in general; Rhodes et al, in press; Valentine 1988).

In experiment 3, we describe the other-race findings from the peripheral identification study. Data relevant to the *basic cross-race deficit* (ie upright other-race faces identified more poorly than upright same-race faces) come from both the training and peripheral identification phase of this experiment. Specifically, we tested whether the other-race deficit was present at the beginning of training and disappeared with practice; we also then provide the first test of whether the deficit reappears for familiarised other-race faces when perceptual processing is put under stress via presenting the stimuli in the periphery.

The amount of *holistic processing* after training was also assessed, by examining the size of the inversion effect in the peripheral identification phase of experiment 3. Of interest was whether there was any peripheral inversion effect for familiarised other-race faces and, if so, how this compared in size to that for same-race faces. Note that we assessed holistic processing only for familiarised faces. The peripheral identification method is not suitable for a pre-test of novel faces because it requires subjects to be able to name a set of individuals reliably with central presentation. Our claim that holistic processing is impaired for novel other-race faces rests on results in previous literature (most strongly, Murray et al 2003 and Tanaka et al 2004).

2 Experiment 1. Confirmation of a cross-race deficit on memory

Before any effects of familiarisation on other-race face processing could be explored, it was first necessary to confirm that our stimuli produced an other-race deficit when the faces were novel. Thus, in experiment 1 our aim was to confirm that, for Caucasian subjects, recognition memory following a single encoding trial was poorer for our Asian face set (other-race faces) than for our Caucasian face set (same-race faces).

We also aimed to minimise the chance that an other-race deficit could be attributed to stimulus differences between the two face sets. For novel faces, there are no obvious name or semantic cues that might assist memory for some faces more than others. However, facial distinctiveness—a rating of ‘how much the face would stand out in a crowd’—substantially influences memory (eg Valentine and Bruce 1986a; Valentine and Endo 1992), with distinctive faces recognised better than typical faces for same-race participants. Thus, we equated our two face sets on both mean and range of distinctiveness, based on ratings obtained from same-race raters. This rules out any intrinsic difference in the heterogeneity of the sets. The own-race ratings were used to select 32 Caucasian faces and 32 Asian faces that were used as the stimulus set for the memory task and in experiment 3.

2.1 Method

2.1.1 *Participants—rating task.* Caucasian faces were rated by 24 Caucasian participants (12 male; aged 17–41 years, mean = 24.1 years, SD = 6.7 years) recruited at the University of Western Australia in Perth. Asian faces were rated by 24 Asian participants (12 male; age data not collected) at the Chinese University of Hong Kong. All participants reported normal or corrected-to-normal vision, and received course credit or a small payment (A\$5) for their participation (< 15 min).

2.1.2 *Participants—memory task.* The 25 memory-task subjects (17 female) were Caucasian undergraduate students (aged 19–26 years; mean = 21.5 years, SD = 1.6 years) of the Australian National University (in Canberra), who received \$10 for their participation. All reported normal or corrected-to-normal vision. Prior to this experiment, subjects completed a racial background and exposure questionnaire. To ensure a relative lack of lifetime exposure to Asian faces, potential subjects had to have been brought up in Australia or another majority-Caucasian country (eg Britain, New Zealand) and were

excluded if they had any non-Caucasian parents or grandparents, close relatives who were Asian (eg an uncle by marriage), if they had ever lived with anyone of Asian descent, or if they had lived overseas in a majority-Asian country.

2.1.3 Stimulus selection. Ratings were obtained from adult subjects on the perceived distinctiveness of 100 photographs of Caucasian faces and 61 photographs of Asian faces. The Caucasian face stimuli (50 female) were taken from the UWA Facelab database. These were collected in Perth, Australia. Of the Asian (specifically, Chinese) faces (31 female), four were taken from the UWA Facelab database, and 57 were from a set collected by G Rhodes at the University of Canterbury, New Zealand. Photographs were grey-scale, front-view head shots with natural face expressions, no glasses, and no facial hair. A black oval mask (with white background) covered most of the hair, and most clothing. Stimuli measured 320 by 420 pixels at a resolution of 72 pixels per inch.

Raters were always of the same race as the faces they were judging. Photographs were rated on a scale of 1 ('not very distinctive, eg difficult to spot in a crowd') to 7 ('very distinctive, eg easy to spot in a crowd'). Before rating, participants viewed all of the faces one at a time for 1 s each, to give an indication of the range and encourage appropriate use of the scale. Faces of each sex were rated in separate blocks. For rating, each face was presented in the centre of a computer screen until the subject responded. Order of face sex was counterbalanced across participants; order of item presentation was randomised with blocks for each subject.

Following the ratings, 64 faces were selected to form the intended experimental set, comprising 32 Caucasian faces (16 males, 16 females) and 32 distinctiveness-matched Asian faces (16 males, 16 females). Items were matched on a one-to-one basis as closely as possible; for example, a Caucasian male face with a mean distinctiveness rating of 2.75 was matched with an Asian male face of rating 2.71. Overall distinctiveness ratings were: Caucasian male, mean = 3.4, SD = 0.6, range = 2.7–4.9; Asian male, mean = 3.4, SD = 0.6, range = 2.3–4.6; Caucasian female, mean = 3.8, SD = 0.5, range = 2.8–4.6; Asian female, mean = 3.8, SD = 0.5, range = 2.8–4.6.

Using these intended stimuli, pilot testing for the memory task unfortunately revealed that memory could be unfairly assisted by local peculiarities in some photographs, and by the pattern of hair falling across the forehead in other cases (ie subjects reported that they remembered some of the photographs via these features rather than recognising the face). We thus made minor edits to make the final stimuli used for the memory task. Any remaining hair was removed by tightening the oval around the face and editing out any strands of hair falling across the forehead. Photographic peculiarities in some images (eg an unusually shiny patch on the nose) were also removed. We cannot be sure that these changes would not have altered distinctiveness to some extent; however, we expect that any effects would be small, because subjects do not report using photographic peculiarities to judge distinctiveness, and because none of the originally rated images showed unusual hairstyles (and so removing strands of hair would have little effect). Examples of the final stimuli were shown in figure 1.

Faces were presented on a black background and sized 8.2 cm vertical by 3.6 cm horizontal (8.5 deg by 5.8 deg at approximate viewing distance of 55 cm). Brightness and contrast were matched within each race and sex set (eg for the 16 Asian females). Edits were made with Adobe (1999) Photoshop software (Version 5.5).

2.1.4 Design—memory task. Race of the face stimuli (Caucasian = own-race, Asian = other-race) was manipulated within subjects. To avoid floor effects on memory, stimuli were presented in two study–test cycles, each comprising a study phase, a filled delay, and a corresponding test phase. At test, half the faces were old (ie studied) and half were new

Figure 1. Example of a Caucasian face (left) and an Asian face (right) used in experiment 1b and experiment 3.

(ie unstudied); subjects made an old versus new decision to each face. The primary dependent measures were hit rate (ie correct "old" responses to studied faces), false-alarm rate (ie incorrect "old" responses to unstudied faces), and the A' measure of sensitivity combining both hits and false alarms (this ranges from 0.5 = chance to 1 = perfect performance; MacMillan and Creelman 1990). Reaction times for correct responses were also analysed.

2.1.5 Procedure—memory task. The 64 experimental faces were divided into four lists of 16 items, each containing 4 faces of each race and sex, approximately equated for rated distinctiveness. In a given study–test cycle, subjects learned one set of 16 and were then tested on 32 faces (16 studied, 16 unstudied). Studied versus unstudied status of each list was counterbalanced across subjects, as was assignment of lists to the first or second cycle.

Subjects were test individually in a 45 min session. Stimuli were presented on a Power Macintosh Computer with screen resolution of 1024×768 pixels with Psyscope software (Cohen et al 1993). A button box recorded reaction times accurate to 1 ms.

During each study phase, the to-be-learned faces were presented for 3 s each. Subjects were aware of the memory requirement. At test, faces were presented one at a time until the subject responded by pressing one button if they thought they had seen the face presented before and another if it had not been studied. Order of item presentation was randomised for each subject at both study and test. Between the study and test phase, and between cycles, a 3 min distraction task was included where subjects solved simple multiplication problems by hand.

2.2 Results and discussion

Table 1 shows accuracy and reaction time for Caucasian (own-race) faces and Asian (other-race) faces. The hit rate for old items was significantly lower for Asian faces than for Caucasian faces ($t_{24} = 2.76$, $p < 0.02$). This cross-race deficit cannot be attributed to a speed–accuracy trade-off given that reaction times for hits did not differ between the two stimulus sets ($t < 1$). For new items, both proportion of false alarms and reaction time for correct rejections showed small trends in the direction of a cross-race deficit, although neither measure produced a significant effect ($ts < 1$). The A' sensitivity measure showed that overall memory accuracy (combining hits and false alarms) was significantly worse for Asian faces than for Caucasian faces ($t_{24} = 2.47$, $p < 0.025$). These results demonstrate a clear other-race deficit on memory following a single encoding trial, which most obviously affected hits.

Table 1. Means of memory measures in the old–new recognition task of experiment 1.

Measure	Caucasian (own-race)	Asian (other-race)
Hit rate	0.77 (0.02)	0.69 (0.03)
False-alarm rate	0.17 (0.02)	0.20 (0.03)
A'	0.87 (0.01)	0.82 (0.02)
RT/ms for hits	1379 (100)	1384 (126)
RT/ms for correct rejections	1805 (132)	1871 (201)

Note: Hits = 'old' responses to studied faces. False alarms = 'old' responses to unstudied faces. Correct rejections = 'new' responses to unstudied faces. Values in brackets are standard error of the mean.

3 Experiment 2. The peripheral identification technique

The aim of experiment 2 was to confirm the validity of the peripheral identification task as a measure of holistic processing, before using it to assess holistic processing for familiarised cross-race faces in experiment 3. The technique was similar to that used by McKone (2004). In that experiment, two faces (face 1 and face 2) were learned, in several orientations, during an initial training phase with central presentation only. The aim of this phase was to ensure that (a) subjects could identify the individuals at ceiling accuracy levels (both upright and inverted), so that any fall-off in accuracy with peripheral presentation could be attributed to perceptual degradation in the periphery rather than failure to remember the faces' names, and (b) to give enough practice with non-upright orientations so that any small inversion effect on local part-based processing was likely to have disappeared (data from naming-rotated-objects studies suggest this should take somewhere between 3 and 30 trials; eg Jolicoeur 1985; McKone and Grenfell 1999).

Following this training, the peripheral presentation task began. Face 1 or face 2 was flashed at one of several distances to the right or left of fixation, and subjects identified the face. Unsurprisingly, identification accuracy fell off as the distance from fixation increased. The important result was that this fall-off with eccentricity was more rapid for inverted faces than for upright faces, producing a peripheral inversion effect. McKone (2004) suggested that this effect arose because upright faces are processed as holistic-plus-parts, while inverted faces are processed as parts-only. Peripheral presentation degrades the stimuli such that information from any one local region of the stimulus (eg the mouth alone) becomes an unreliable cue to identity: under these circumstances, holistic processing gives an advantage because it integrates information from across the whole face region rather than relying on merely a sum of local cues.

This logic predicts that the peripheral inversion effect should occur only where holistic processing is available in the upright orientation, ie only for whole faces. McKone (2004) supported this argument by showing that a single isolated face feature (nose 1 versus nose 2) produced no peripheral inversion effect. Here, we test an equally important prediction, namely that there should be no peripheral inversion effect for a class of nonface objects. Evidence from other paradigms suggests that objects are processed in a part-based fashion [by non-experts⁽³⁾], in both upright and inverted orientations, even when individual-level discrimination is required (eg cars, Tanaka and Gauthier 1997; dogs, Robbins and McKone, in press). Thus, if the peripheral inversion effect can, indeed, be used as a marker of holistic processing, then objects should produce no peripheral inversion effect.

⁽³⁾ It has been suggested that expertise in the relevant object domain can induce holistic processing, although this idea is currently actively debated (eg McKone and Kanwisher 2005; Robbins and McKone, in press).

In experiment 2, subjects first learned to identify three faces (figure 2a) and three dachshund dogs (figure 2b). We used three very similar photographs of individual dachshunds. This similarity is important in that the difficulty of learning the three dogs should be approximately matched to the difficulty of learning the three faces (see section 3.1.3 for evidence this was the case). Further, the logic behind the peripheral presentation technique requires the avoidance of striking featural differences between exemplars of a given class. If such differences were present (eg a moustache in one face but not in others; tail up in one dog but down in others), identification in the periphery could rely entirely on local feature processing simply because this would outweigh any holistic contribution. All training was done with central presentation. The amount of training (100 trials for each exemplar) was designed to produce near-perfect accuracy in identification even in the inverted orientation, and to remove small inversion effects arising from part-based processing.

Figure 2. The face and dog stimuli used in experiment 2.

3.1 Method

3.1.1 Subjects. 41 subjects were tested in total (18 males), but peripheral identification results were analysed only from 23 who met stringent criteria applied for accuracy in the centre position (see section 3.2 for details). Subjects were undergraduate students participating in return for course credit, or unpaid members of the general ANU community (all naive as to the aims of the experiment). Age ranged from 18 to 23 years. All were Caucasian (ie the same race as the faces they were tested on), and all reported normal or corrected-to-normal vision.

3.1.2 Design. Stimulus class (dogs versus faces), orientation (upright versus inverted) and presentation position in the peripheral test phase (four positions to the left of fixation, central presentation, and four positions to the right of fixation) were all manipulated within subjects. Stimulus class was presented in blocked fashion (eg training followed by test for dogs, then training followed by test for faces) and in counterbalanced order. Within a block, order of orientations and positions was randomised. The task on each trial was to identify the stimulus presented as dog 1, dog 2, or dog 3 (or face 1, face 2, or face 3). Accuracy of identification in this 3-alternative forced choice (3AFC)

task was the dependent measure (chance = 33%). During each training phase, all stimuli were presented centrally, and feedback was given on incorrect responses. During each peripheral test, all nine positions were used and no feedback was given. The experiment was run as a single 1.5 h session.

3.1.3 Stimuli. The 3 face pictures used as stimuli are shown in figure 2a. These were selected from the Harvard Vision Sciences Laboratory face database (F Tong and K Nakayama), with permission to use the photographs previously obtained from the subjects. To minimise purely local cues to identification, the 3 faces were similar to each other in general appearance. They were of the same sex, race, age, and expression (neutral), had no glasses or facial hair, and their internal features fell in overlapping spatial locations. Adobe Photoshop (5.5) was used to remove distinguishing features such as moles and skin discolorations as well as other local visual cues (eg shiny patches on the nose). Images were presented in an oval window that removed the hair and made each image the same size and shape. The 3 photographs were presented in grey-scale, matched for brightness and contrast, and placed on identical backgrounds. Faces were reduced in size to 1.1 cm $\times$ 1.5 cm (2.0 deg horizontal $\times$ 2.7 deg vertical at 32 cm viewing distance). Pilot testing indicated that this size produced an appropriate range of overall performance in the peripheral identification task, with the aim of achieving close-to-ceiling performance (100%) in the central position, falling gradually to approach chance (33%) in the most peripheral position.

The 3 dog images used are presented in figure 2b. Side-view photographs were obtained from Heeson (1991), and were selected such that each animal's stance was similar. Distinguishing features, such as a chain collar, degree of shine on the coat, or light patches of hair on the snout, were edited out. The images were matched for brightness and contrast, and presented in grey-scale on identical backgrounds. The size of the dog images was reduced to 3.0 cm (width from nose to tail) $\times$ 1.8 cm (height from top of head to paws), subtending 5.4 deg horizontal $\times$ 3.2 deg vertical. This size was larger than that of the face stimuli, and was selected after pilot testing to approximately equate the range of accuracy across peripheral positions for dogs and faces.

Evidence that the face and dog stimuli were reasonably well matched in terms of difficulty to learn came from training-phase results. Dividing the 600 learning trials (see section 3.1.4) into 6 successive blocks of 100 trials each, mean accuracy of identification (percent correct) across all 41 subjects was as follows. For the upright orientation: 81.5 faces versus 79.3 dogs (block 1), 92.7 versus 86.6 (block 2), 94.5 versus 90.7 (block 3), 96.9 versus 93.2 (block 4), 95.7 versus 93.6 (block 5), 97.0 versus 93.7 (block 6). For the inverted orientation: 76.5 faces versus 76.4 dogs (block 1), 90.0 versus 82.5 (block 2), 92.0 versus 89.3 (block 3), 96.0 versus 91.4 (block 4), 96.0 versus 91.1 (block 5), 95.6 versus 91.9 (block 6). Note chance = 33%.

3.1.4 Procedure. Stimuli were presented on an iMac computer with PsyScope software. A chin-rest fixed viewing distance at 32 cm from the screen.

Training. For each stimulus class, subjects were first shown each exemplar three times in each orientation with its label (dog 1, dog 2, or dog 3) presented underneath. There were then 600 training-with-feedback trials for that class, presented in two sets of 300 trials. Within each set, each of the 3 exemplars was presented 50 times upright and 50 times inverted, in random order. Stimuli were presented at the same small size, and for the same brief time, as to be used in the peripheral identification task.

On each trial, a fixation point appeared in the centre of the screen for 500 ms, followed by the stimulus exemplar for 150 ms. Subjects identified the stimulus (face 1, face 2, or face 3) by pressing a corresponding key (1, 2, or 3) on the keypad of the keyboard with the first, second, and third fingers of their right hand. If the response

was incorrect, the computer beeped, and the trial did not proceed until the correct response had been entered. There was an intertrial interval of 750 ms.

Peripheral identification. The procedure for the peripheral identification test was the same as for the training phase with the exception that no feedback on accuracy of response was given, and all nine screen positions were used. The positions were in a horizontal line and included central presentation (C), and four positions (P1 to P4) of increasing distance from the centre to both the left and right of centre. Visual angles from fixation to the centre of each stimulus (at the 32 cm viewing distance) were: C = 0°; P1 = 5.2°; P2 = 10.3°; P3 = 15.2°; P4 = 19.9°. These positions were determined from pilot testing which varied both position and stimulus size to choose values that produced a gradual reduction in accuracy with increasing distance from fixation. Values were chosen with the constraints imposed by the width (28 cm) and resolution (1034 × 768 pixels) of the computer screen.

For each stimulus class, each subject completed 216 trials. These were presented in a single block in random order, and comprised 12 trials at each orientation (4 of each of the 3 exemplars) in each of the 9 screen positions. Eye movements were not monitored, but there was no incentive for subjects to move their eyes from fixation. The 150 ms stimulus presentation time ensured that even if the subjects initiated an eye movement, the image would have disappeared by the time the eyes had moved to the peripheral location (initiating an eye movement takes approximately 200 ms). Further, stimuli appeared equally often to the left and right of central fixation. Subjects were warned that they would feel like they were guessing on some trials (particularly in the more peripheral locations), but were always required to enter a response.

3.2 Results

3.2.1 Accuracy criteria for central presentation. For inclusion in the peripheral identification task, it was important to ensure that subjects could reliably identify the exemplars with central presentation, both upright and inverted; that is, we needed to be sure that any inversion effects emerging in the periphery arose from a degradation of perceptual processing rather than from failure to remember the faces or their labels reliably. We imposed stringent accuracy criteria on a single-subject basis. First, a subject had to achieve >80% correct in both of the last two blocks of training for all four stimulus conditions (ie faces and dogs, upright and inverted). Of the forty-one subjects, thirty-three met this criterion. We then observed that, when peripheral presentations were introduced in the test phase (ie stimuli were flashed for the same brief period, but now in one of several possible screen positions), performance for some subjects dropped to unsatisfactory levels in the centre position. Thus, our second criterion was that a subject must also have achieved >80% for all four stimulus conditions in the centre position during the peripheral presentation task. This reduced the number of subjects to twenty-three.

For this final group of twenty-three subjects, mean accuracy across the last two blocks of training was 98.2% (faces upright), 97.8% (faces inverted), 98.3% (dogs upright), 98.4% (dogs inverted). In the central position during the peripheral presentation task, performance still averaged above 93% in all conditions (see figure 3).

3.2.2 Inversion effects in peripheral identification. To give the most power in assessing inversion effects, data were collapsed across left-screen and right-screen presentations, to give accuracy for the central position (C) and four positions increasing in distance from fixation (P1, P2, P3, P4).⁽⁴⁾ Mean identification accuracy (without feedback) at

⁽⁴⁾ We also examined hemispheric differences, for right-handed subjects only. Consistent with previous literature (eg Rhodes 1993), the inversion effect for faces was larger with right-hemisphere (left visual field) presentation than left-hemisphere presentation. There were no hemispheric differences for dogs.

Figure 3. Experiment 2, peripheral identification phase. Mean accuracy in identifying the exemplars as face 1, 2, or 3 (or dog 1, 2, or 3), with central presentation ($C = 0^\circ$) and peripheral presentation at increasing distances from fixation ($P1 = 5.6^\circ$, $P2 = 10.3^\circ$, $P3 = 15.2^\circ$, $P4 = 19.9^\circ$). Data are for subjects who passed the accuracy criteria with central presentation ($N = 23$). The error bar indicates the equivalent of ± 1 SEM derived from the within-subjects main effect of orientation, ie the error appropriate for evaluating the significance of the inversion effect.

each of these positions is shown in figure 3. Note first that overall performance spans a similar range for faces and for dogs, and that at least two peripheral positions ($P1$ and $P2$) produced performance sufficiently well away from both ceiling (100%) and floor (chance = 33%) to allow plenty of room for inversion effects to emerge.

The important result is then that, although peripheral inversion effects for faces were apparent, there was no sign of any such effects for dogs (the small difference goes in the wrong direction; see figure 3). A class (faces versus dogs) $\times$ orientation (upright versus inverted) $\times$ position relative to fixation (C , $P1$, $P2$, $P3$, $P4$) ANOVA revealed a significant 3-way interaction [$F_{3,2,70.3} = 3.21$, $MSE = 116.99$, $p < 0.05^{(5)}$], confirming that the pattern of orientation $\times$ position effects differed as a function of stimulus type. Subsequent analyses were conducted separately for faces and dogs, to test the key predictions that there should be a peripheral inversion effect for faces (holistic-plus-parts for upright, parts-only for inverted) but not for dogs (parts-only in both orientations).⁽⁶⁾

For faces (figure 3a), the pattern obtained in McKone (2004) was replicated. A 2 (upright versus inverted) $\times$ 5 (position relative to fixation) ANOVA showed a main effect of position, reflecting worse performance with greater distance from centre ($F_{3,3,72.3} = 149.21$, $MSE = 182.168$, $p < 0.001$), and a main effect of inversion, indicating that, averaged over all positions, inverted was worse than upright ($F_{1,22} = 31.91$, $MSE = 2899.76$, $p < 0.001$). In addition, the orientation $\times$ position interaction was significant ($F_{2,8,61.4} = 5.6$, $MSE = 116.0$, $p < 0.005$). The expectation was that this interaction would reflect a larger inversion effect in the periphery than in the centre;

⁽⁵⁾ Throughout this article, where data violated the sphericity assumption of repeated-measures ANOVA, the Huynh–Feldt correction was used. (The multivariate approach produced the same conclusions, except in one test in experiment 3 where Huynh–Feldt was more powerful.)

⁽⁶⁾ It might also be thought that inverted faces and inverted dogs should be recognised with equivalent accuracy, given that neither stimulus type receives holistic processing. However, this cannot necessarily be predicted. Faces and dogs differ in shape (dogs are wider), so dogs have some visual information closer to fixation than faces at a given peripheral position (position was defined by the location of the centre of the picture).

this was confirmed by collapsing all four peripheral positions and conducting a 2 (upright versus inverted) $\times 2$ (centre versus average of peripheral positions) ANOVA and finding a significant interaction ($F_{1,22} = 10.00$, $MSE = 108.70$, $p < 0.01$). We also conducted a priori t -tests to look for inversion effects at each peripheral position in turn. These were significant for P1 ($t_{22} = 5.06$, $p < 0.001$), and P4 ($t_{22} = 4.50$, $p < 0.001$). Thus, for faces, there was a clear peripheral inversion effect.

For dogs, in contrast, a very different pattern of results emerged. The 2 (upright versus inverted) $\times 5$ (position relative to fixation) ANOVA revealed the obvious main effect of position ($F_{3,0,66.1} = 81.06$, $MSE = 293.01$, $p < 0.001$). There was a just significant main effect of inversion ($F_{1,22} = 4.35$, $MSE = 220.11$, $p = 0.049$), but this did not reflect an inversion decrement; instead, processing of inverted dogs was slightly better than processing of upright dogs (see figure 3b). There was no orientation $\times$ position interaction ($F < 1$, $MSE = 18.76$). Collapsing across all four peripheral positions in a 2 (upright versus inverted) $\times 2$ (centre versus average of peripheral positions) ANOVA also produced no interaction ($F < 1$, $MSE = 6.79$), and t -tests revealed no inversion effect at any of the peripheral positions taken in turn (largest $t = 1.32$, smallest $p = 0.2$). Thus, in contrast to faces, within-class discrimination for dachshunds showed no peripheral inversion decrement; instead, the rate of performance decline in the periphery was the same regardless of orientation.

3.3 Discussion

The results of experiment 2 are consistent with those of McKone's (2004) original study of the peripheral identification method: a peripheral inversion effect occurs when holistic processing is available in the upright orientation (whole-face stimuli), but not when only part-based processing is available (dogs, experiment 2; isolated face parts, McKone 2004). Theoretically, we attribute this to the ability of holistic processing to integrate information from across a large spatial region, which can continue to drive good performance even when local regions of the stimulus, taken one at a time, produce unreliable cues to identity owing to degradation of the image in the periphery.

For the purposes of examining cross-race deficits, the importance of experiment 2 is that it confirms that the peripheral inversion effect provides a direct marker of holistic processing. Note again that this is not necessarily the case for inversion effects in general (Valentine 1988). In memory tasks, for example, small inversion effects are present for nonface objects (eg Yin 1969); this suggests that, for faces, the memory inversion effect might include a component arising from inversion effects on part-based processing, as well as the effect on holistic processing (see also Bartlett et al 2003; Rhodes et al 2005).

4 Experiment 3. Peripheral identification of a small set of other-race 'friends'

Experiment 1 confirmed that our stimulus set of 32 Caucasian and 32 Asian faces produced a cross-race deficit for Caucasian subjects. Experiment 2 confirmed that the peripheral identification technique provides a way of assessing holistic processing. In experiment 3, we combine our stimuli from experiment 1 with the technique from experiment 2, to investigate whether familiarity with other-race individuals induces normal levels of holistic processing.

In experiment 1, where a clear cross-race deficit was observed, the individual faces were novel, and learning opportunities were limited to a single encoding exposure for the memory task. In experiment 3, we were able to examine the basic cross-race deficit for upright faces at a number of different familiarity levels: at the very beginning of the training phase with the target individuals (lowest familiarity); later in the training phase (medium familiarity); and in the peripheral identification phase for those subjects who passed a strict accuracy criterion at the end of training (highest familiarity).

We also addressed the question whether the cross-race deficit would re-emerge for highly trained subjects when perceptual processing was stressed by degrading low-level visual processing of the stimuli, using results for upright faces from the peripheral identification phase. This is a novel question that has not been addressed by previous literature.

In experiment 3, we also examined holistic processing for highly trained subjects, by testing inversion effects for same-race and other-race faces in the peripheral identification task. Note that it is only inversion effects *in this task* which provide a direct measure of holistic processing; inversion effects during training may be of some relevance, but, as with memory tasks, there is no direct evidence that these provide a pure measure of holistic processing (ie they might also include some part-based component).

In experiment 3, Caucasian subjects learned either Caucasian or Asian faces. Each participant learned to identify 4 faces, referred to as that subject's 'friends'. The friends were all of the same sex (all male or all female), and all of the same race (all Caucasian or all Asian). We trained each person on only 4 faces because pilot testing had revealed that this was the maximum number that most subjects could learn reliably within the 1 h training session (832 trials, 208 with each individual), and it was important for the peripheral identification task that some subjects had learned their friends well. Each subject's friends were taken from the experimental set of faces developed in experiment 1. To ensure good generalisability over items—that is, that any pattern of differences between same-race and other-race faces could reasonably be attributed to the race rather than to peculiarities arising from testing a small number of individual faces—all 64 faces in the experimental set (16 Caucasian males, 16 Caucasian females, 16 Asian males, 16 Asian females) were used across subjects, even though each subject learned only 4 of these. Note that the training and test stimuli were the same, showing only one particular photograph of each person. Generalisation of identification across different photographs would also be of interest; for a first study, however, we tested only a constant image, relying on comparisons within experiment 3 (images were constant for both same-race and other-race faces) and to experiment 2 (images were also constant for faces and dogs) to support claims about the validity of face and race effects.

4.1 Method

4.1.1 Participants. All subjects were Caucasian and satisfied the racial background criteria listed in experiment 1. For the training phase, data were analysed from 64 participants (36 female; aged 18–40 years; mean = 22.4 years, SD = 5.6 years), an equal number tested on each of 16 sets of 'friends'. For the peripheral identification test, data analysed came from 48 participants (31 female; aged 18–36 years; mean = 21.5 years, SD = 3.7 years). All of these achieved a criterion of at least 80% correct in identifying the faces in their trained friend set in each of the last two blocks of training (blocks 7 and 8), for both upright and inverted faces. To obtain 48 above-criterion subjects (3 per friend set), we were able to use 36 participants (of the 64) already trained in the first part of the experiment; to make up the further 12, it was necessary to train 44 additional subjects. Thus, a total of 108 subjects (64 + 44) took part in some manner in experiment 3.

Subjects included unpaid members of the general ANU community, and undergraduate students from the Australian National University who participated in return for course credit, or payment of \$10 (training phase only, 1 h) or \$15 (training plus peripheral experiment, 1.5 h). All reported normal or corrected-to-normal vision.

4.1.2 Design. Race of face (Caucasian = own race, Asian = other-race) was varied between subjects. Sex of the face was a subsidiary between subjects variable. As expected, initial ANOVAs showed no effects of this variable for either training or peripheral identification

phases (all p values > 0.05), so we collapsed across face sex to maximise power. Orientation (upright, inverted) was manipulated within subjects.

In the training phase, a 2 (race) $\times 2$ (orientation) $\times 8$ (practice block) design was used. Each participant learned one set of 4 faces. 16 face sets were used: 4 sets of Asian males, 4 sets of Asian females, 4 sets of Caucasian males, and 4 sets of Caucasian females. Across the 64 subjects (32 tested on Caucasian faces, 32 tested on Asian faces), each of the 16 sets was used equally often (ie learned by 4 subjects). The task on each trial was to identify a briefly presented face stimulus as one of the learned set of friends, with accuracy as the dependent measure (chance = 25%). Feedback on each response was provided to allow learning.

The peripheral identification phase followed immediately on completion of training. This comprised a 2 (race) $\times 2$ (orientation) $\times 9$ (screen position) design. Each participant was tested on the same set of 4 friends they had learned during training. Across the 48 participants (24 tested on Caucasian faces, 24 tested on Asian faces), each set of 4 friends was used equally often, with 3 participants tested on each set. Screen position (central, four positions left of fixation, and four positions right of fixation) was manipulated within subjects. Identification accuracy was again the dependent measure. There was no feedback.

4.1.3 Stimuli. The 64 distinctiveness-matched faces were as in the memory task for experiment 1. To divide the 16 faces of a given race and sex into 4 sets, a distinctiveness ranking system was used. For instance, the first set of Caucasian female 'friends' comprised the 1st, 5th, 9th, and 13th most distinctive of the Caucasian female faces, the second set comprised the 2nd, 6th, 10th, and 14th most distinctive, and so on. For each Caucasian set, a matched set of Asian female faces included the 4 faces of the same ranked distinctiveness (eg 1st, 5th, 9th, and 13th most distinctive within the Asian females). This ranking procedure equated the degree of difference in distinctiveness amongst the faces within each set.

Face images were reduced to a size of 11 mm $\times$ 15 mm. At a viewing distance of 32 cm, each face subtended visual angles of approximately 2.0 deg horizontal and 2.7 deg vertical. This small size was used for both training and peripheral identification.

4.1.4 Procedure. All stimuli were presented in grey-scale on identical backgrounds (a black screen) with an iMac computer (screen size 23 cm $\times$ 28 cm; 1034 $\times$ 768 pixels) and Psyscope software (Cohen et al 1993). A chin-rest was used to ensure that participants maintained a viewing distance of 32 cm from the screen. Subjects were tested individually.

Training. In an initial viewing phase, each participant saw his/her 4 friends simultaneously, with 'names' below (face z, face x, face 1, and face 2). Labels 'z', 'x', '1', and '2' corresponded to comfortable response keys for index and middle fingers of each hand. The labelled faces were viewed three times each in each orientation (upright and inverted). Participants were instructed to study each face for as long as they wished, and to learn the corresponding name key.

There were then eight blocks of training-with-feedback, with central presentation only. Each block contained 104 trials (13 presentations of each of 4 faces in each of 2 orientations), presented in a different random order for each subject. Data were averaged over the 4 face exemplars, resulting in scores for each subject being based on 52 upright and 52 inverted face presentations per subject per block. On each trial, a fixation point in the centre of the screen for 500 ms was replaced by 1 of the 4 faces (with no label) flashed for 150 ms. Subjects identified the face as z, x, 1, or 2. If a response was incorrect, the computer beeped and proceeded to the next trial (after a blank interval of 750 ms) only after the participant had identified the face correctly. Rest breaks were provided after the 2nd, 4th, and 6th block.

Peripheral identification. Each participant completed 360 experimental trials, organised in five blocks of 72. Within each block, each of the participant's 4 friends appeared upright and inverted once at each of the nine positions. Presentation order within each block was randomised. A rest break was provided between blocks 3 and 4.

The procedure on each trial was the same as for the training phase, except that there was no feedback, and faces could be flashed at any one of the nine positions. To ensure that there was room for inversion effects to emerge (particularly at intermediate positions), pilot testing determined the spacing of peripheral positions to produce a gradual decline in performance from close to 100% with central presentation, to close to 25% (chance) at the most extreme position. With the 4-alternative identification task, positions were shifted inwards in comparison to those for the 3-alternative identification task of experiment 2. At the viewing distance of 32 cm, angles between the line-of-sight to a central fixation point and each tested position were: centre = 0°; position 1 (to left and right) = 1°; position 2 = 2.5°; position 3 = 6°; position 4 = 20°.

4.2 Results

Our analysis focused on a number of key issues: whether the basic cross-race deficit for upright faces was present at the beginning of training; how quickly it disappeared with increasing familiarity; whether it reappeared when perceptual processing was put under stress by peripheral presentation; and whether familiarity induced normal levels of holistic processing for cross-race faces.

4.2.1 Familiarity and the basic cross-race deficit. Experiment 1 identified a basic cross-race deficit (poorer recognition of upright Asian faces than of upright Caucasian faces) for our stimulus set when the faces had been learned only once. Figure 4 shows identification accuracy for upright faces during the training phase of the present experiment, for all 64 subjects who completed this phase, as a function of practice block: each block contained 26 presentations of each friend (13 upright, and 13 inverted). Results for the first block are shown broken into two half-blocks, to assess very early stages of practice independently of later practice. As can be seen, experiment 3 replicated experiment 1 in finding a cross-race deficit very early in training (first half of block 1: upright Caucasian mean = 61.9%, upright Asian mean = 52.1%; $t_{62} = 2.17$, $p < 0.05$). This deficit then disappeared rapidly with practice. There was no significant race effect even by the second half of block 1 (Caucasian mean = 66.8%, Asian mean = 63.5%; $t < 1$), and figure 4 clearly shows *no* deficit by block 3 at the latest (note that, in the last block, the slight difference between Asian and Caucasian faces is in the wrong direction). A two-way ANOVA also revealed a significant interaction between race and block (1–8) ($F_{5,0,311.6} = 2.80$, $MSE = 70.00$, $p < 0.02$), reflecting the catch-up in accuracy for Asian faces relative to Caucasian faces.

Figure 4. Experiment 3, training phase ($N = 64$): Identification accuracy for upright faces of each race. Block 1 is shown split up into the first half of the block (1a) and the second half (1b). Chance = 25%. Error bars show ± 1 SEM, appropriate for the between-subjects comparison of Caucasian and Asian faces.

4.2.2 Does the cross-race deficit reemerge under perceptual stress? We next tested for a cross-race deficit during the peripheral identification task. The 48 subjects taken through to this task had high levels of familiarity with their target friends, in that they had not only completed the training phase but also passed strict accuracy criteria at the end of training (see section 4.2.4). The question of interest was whether a deficit for cross-race faces might reappear as the stimuli were degraded in the periphery, thus putting perceptual processing under more stress. This did not occur. Collapsing over left and right screen positions,⁽⁷⁾ means for upright Caucasian versus upright Asian (in that order) were: 87.9 versus 89.4 (C), 85.2 versus 83.9 (P1), 69.2 versus 69.4 (P2), 54.9 versus 55.1 (P3), 30.0 versus 30.1 (P4), with average SEMs of 3.01 (Caucasian) and 2.33 (Asian), and chance = 25%. A race $\times$ eccentricity (5 positions) ANOVA revealed only the obvious main effect of eccentricity ($F_{2,74, 126.05} = 338.44$, $MSE = 117.95$, $p < 0.001$), with no main effect of race ($F < 1$, $MSE = 571.12$), and no race by eccentricity interaction ($F < 1$, $MSE = 117.95$).

4.2.3 Inversion effects during the training phase. Note again that an inversion effect during the training phase cannot necessarily be taken as a direct marker of holistic processing, in that it may include some part-based component as well as a holistic component. For interest, however, figure 5 shows the size of the inversion effect (upright – inverted) for Caucasian and Asian faces. Results show a trend towards a smaller inversion effect for cross-race faces than for same-race faces, which was of ambiguous statistical status. A three-way ANOVA for race (Caucasian versus Asian) $\times$ orientation (upright versus inverted) $\times$ practice block (1–8) revealed no 3-way interaction ($F_{6,3, 392.7} = 1.5$, $MSE = 37.60$, $p > 0.1$), and a 2-way race $\times$ orientation interaction that only approached significance ($F_{1, 62} = 3.65$, $MSE = 189.78$, $p = 0.061$). Thus, it is not possible to conclude reliably that there *was* a smaller inversion effect for Asian than Caucasian faces at intermediate levels of practice. Equally, however, it is not possible to conclude reliably that there *was not*. Six of the eight blocks show a trend in this direction, with none showing a reverse trend, and *t*-tests found significant differences in three individual blocks: block 2 ($t_{62} = 2.04$, $p < 0.05$); block 6 ($t_{62} = 2.2$, $p < 0.05$); block 7 ($t_{62} = 2.68$, $p < 0.01$).

4.2.4 Holistic processing: inversion effects during peripheral identification phase. To assess holistic processing, we examined inversion effects in the peripheral identification task.

Figure 5. Experiment 3, training phase ($N = 64$): Inversion effect (percent correct upright – percent correct inverted). Error bars show ± 1 SEM.

⁽⁷⁾ Experiment 3 was not designed to examine hemispheric differences (ie left-of-fixation versus right-of-fixation effects). Left-handed as well as right-handed subjects were tested. If only the right-handed subjects were considered, it was no longer the case that an equal number of subjects had been tested on each friend set, making it impossible to compare results across races.

For the 48 subjects taken through to this phase, we confirmed excellent identification accuracy at the end of training for both races of face, in both orientations (Caucasian upright = 93.5%, Caucasian inverted = 86.5%, Asian upright = 93.7%, Asian inverted = 89.9%; chance = 25%). Figure 6 also shows very good accuracy in the central position during the peripheral presentation task (all conditions > 82%), with the small drop in accuracy compared to the end-of-training presumably owing to the requirement to now attend to nine possible screen locations instead of one.

Figure 6. Experiment 3, peripheral identification phase ($N = 48$): Identification accuracy for upright and inverted faces. (a) Caucasian and (b) Asian faces. Error bars show ± 1 SEM.

Considering all screen positions, figure 6 shows upright and inverted performance for each race in turn, and figure 7 shows difference scores (upright minus inverted) summarising the influence of race on inversion effects. The questions of interest were whether our high-familiarity subjects showed a peripheral inversion effect for other-race faces—that is, direct evidence of holistic processing—and, if so, how it compared in size with the peripheral inversion effect for same-race faces.

In addressing this question, note that inversion effects were small (for both races) at positions C and P4 because accuracy approached ceiling with central presentation (C) and approached floor (chance = 25%) at P4; indeed, the experiment was designed so that only peripheral positions 1, 2, and 3 would produce mid-range performance and thus have room to show large inversion effects. Focusing on these three intermediate positions,

Figure 7. Experiment 3, peripheral identification phase ($N = 48$): Inversion effect (percent correct upright – percent correct inverted) at each position. Analysis focused on positions 1, 2, and 3, where performance was not close to either ceiling or floor. Error bars show ± 1 SEM.

a race (Caucasian versus Asian) $\times$ orientation (upright versus inverted) $\times$ eccentricity (position 1, position 2, position 3) mixed ANOVA was conducted on the data shown in figure 6. There was a main effect of orientation ($F_{1,46} = 137.46$, $MSE = 68.56$, $p < 0.001$), and a main effect of eccentricity ($F_{1,8,81.1} = 166.54$, $MSE = 138.68$, $p < 0.001$). There was no orientation $\times$ eccentricity interaction ($F_{2,92} = 1.19$, $MSE = 44.76$, $p > 0.3$), and, most importantly, no main effect of race ($F < 1$, $MSE = 820.94$), and no 2-way or 3-way interactions involving race (all p values > 0.3). These results reflect the findings (see figures 6 and 7) that (a) accuracy declined with increasing eccentricity, (b) there was an inversion effect with peripheral presentation, and (c) the size of this inversion effect was independent of the race of the face. Paired-samples t -tests confirmed that there were significant inversion effects in all three intermediate positions for each race (all $ps < 0.001$). Also, independent samples t -tests found no significant difference between the inversion effect for Asian and Caucasian faces at any of the three positions (all $ps > 0.2$). Overall, peripheral inversion effects were not only *present* for other-race faces, but were *no smaller* than for same-race faces.

4.3 Discussion

Experiment 3 demonstrated several interesting results. With respect to the basic cross-race deficit, poorer identification of our upright Caucasian stimuli than our upright Asian stimuli was found very early in practice (first half of training block 1), replicating the results of experiment 1 (one learning exposure and a recognition-memory task). The deficit then disappeared very rapidly: there was no evidence of a cross-race effect beyond the first half of block 1, during which each 'friend' had been seen only an average of 13 times (plus 6 times with labels in the pre-learning phase). This finding is consistent with results of previous training studies (Elliott et al 1973; Goldstein and Chance 1985; Malpass et al 1973).

We also found that, when subjects were highly familiar with the other-race individuals (after 6 pre-training exposures, plus 214 training exposures, leading to identification accuracy $> 86\%$), a cross-race deficit did not re-emerge when faces were presented in the periphery (ie upright other-race faces were still identified as accurately as upright same-race faces), despite the fact that the demands on perceptual processing had been substantially increased. This is a novel finding: previous training studies have shown an amelioration of the cross-race deficit with practice, but have tested only clear, easy-to-perceive stimuli. It is of interest that the cross-race deficit does not re-emerge when the face perception system is put under stress by degrading low-level visual processing of the stimuli.

Our final novel finding concerned holistic processing. Previous studies have shown a holistic processing deficit for other-race faces when these individuals are unfamiliar (Tanaka et al 2004). In the present experiment, in contrast, we found that holistic processing was as strong for cross-race faces as for same-race faces when subjects had been familiarised with the individuals. Specifically, in the peripheral identification phase, the peripheral inversion effect for other-race faces was as large as that for same-race faces. Given the results of experiment 2 and McKone (2004) validating the technique, this provides direct evidence that normal levels of holistic processing can be achieved for familiar other-race faces.

Overall, the results of experiment 3 argue that familiarity rapidly leads to fully normal face processing for a set of trained cross-race 'friends'. Within 1 h of familiarisation (220 exposures), both normal identification accuracy and normal levels of holistic processing were obtained.

5 General discussion

The major finding of the present study was that, despite an initial cross-race deficit for novel faces, normal accuracy of face identification, and normal holistic processing, can emerge for familiarised other-race faces. This familiarisation process required relatively little exposure: even at the end of training in experiment 3, subjects had received only 214 training trials per face. In addition, we have confirmed the validity of the peripheral identification technique (McKone 2004) as a method for tapping holistic processing. We have also emphasised the importance of matching same-race and other-race stimulus sets for distinctiveness; the need to do this has been raised in the literature previously (Bothwell et al 1989), but it has rarely been done (for an exception see Chiroro and Valentine 1995).

5.1 *Cross-race familiarity and robustness to perceptual stress*

An important new finding from our study is that familiarised other-race faces, for which the basic cross-race deficit had disappeared, did not show a deficit that re-emerged when perceptual processing was placed under stress. Previous authors (Malpass et al 1973) have shown that it takes relatively little practice for other-race individuals to be identified as accurately as same-race individuals. We have extended this result to show that it remains true even when the trained faces are presented in the periphery and identification accuracy drops dramatically overall (ie for both same-race and other-race faces). Our finding supports the idea that fully normal learning has occurred for trained other-race faces, which engaged the same robust face-recognition mechanisms as are used for same-race faces.

5.2 *Cross-race familiarity and holistic processing*

Also supportive of fully normal processing is our finding that trained other-race faces showed as much holistic processing as same-race faces. In practical terms, this finding makes it unlikely that the amelioration of the basic cross-race deficit for upright faces in the present experiments could be due to using only one photograph of each individual. In principle, the fact that we used the same photographs during training and at test could have encouraged learning based simply on local image peculiarities (eg a dark region) or local face parts (eg nose shape), rather than tapping normal face processing mechanisms. However, had subjects learned in this manner, we would not have obtained the results we did. Image peculiarities and local face parts would both be expected to be identified equally well regardless of orientation, but our results showed clear peripheral inversion effects, which can be attributed only to a normal holistic processing strategy for upright faces.

5.3 *Rapid learning of holistic processing*

Previous studies have indicated weak or no holistic processing for other-race individuals when faces are novel (eg Tanaka et al 2004). We have shown that normal levels of holistic processing can be obtained after only 1 h of familiarisation. The rapid development of holistic processing for faces is interesting and important from a number of perspectives.

First, the findings for other-race faces make an interesting contrast with previous results for (same-race) inverted faces. Robbins and McKone (2003) found that, for inverted faces, even 10 h of exposure (1100 trials) to each member of a pair of twins was not sufficient to induce holistic processing, when using a number of measures including Young et al's (1987) composite paradigm. Robbins and McKone used multiple training photographs of each individual and included different viewpoints. McKone et al (2001) used only one photograph of each face throughout, and also found that even 10 000–30 000 trials did not induce holistic processing for inverted faces, with a categorical perception in noise task. The results we have obtained here for other-race faces

are strikingly different: just a couple of hundred exposures over an hour of practice can increase holistic processing for other-race faces to the same level as for same-race faces.

Second, the rapid development of holistic processing argues that its initial lack for other-race faces does not represent a permanent perceptual deficit, but instead is merely a failure to use a potentially available mechanism. That is, the lack of holistic processing for novel other-race faces could reflect an automatic *strategy*, rather than a lack of intrinsic *capacity* to do holistic processing.

This idea of a latent, context-driven, capacity is consistent with two other findings in the literature. In Rhodes et al (1989), memory (following a single encoding trial) was affected by inversion less strongly for other-race faces than for same-race faces, suggesting a cross-race deficit in holistic processing. However, this result occurred only when the pair of faces presented in the 2AFC memory task were randomly chosen and thus, for most pairs, were quite dissimilar from one another. When the faces were specifically paired to be highly similar, inversion effects were of normal size for other-race faces, suggesting that holistic processing can be easily employed when required. More remarkably, Johnson and Fredrickson (2005) have recently shown that the cross-race deficit for White Americans examining Black American faces can be removed simply by inducing a strongly positive mood prior to learning or retrieval. Assuming that memory performance at least partially reflects holistic processing, this is again consistent with the idea that holistic processing for other-race faces is always present as a capacity, but can be switched on or off under different circumstances.

5.4 *Relationship to other approaches to understanding the cross-race deficit*

As noted in the introduction, the idea that a deficit in holistic processing contributes to the cross-race deficit in memory complements, rather than contradicts, other approaches to understanding the effect. We now consider how well these other approaches—particularly, social cognition and face-space—can explain the result that normal holistic processing can be rapidly induced.

This finding appears naturally consistent with social cognition theories positing a role for between-class versus within-class discrimination in the cross-race deficit (Levin 1996, 2000; Sporer 2001). These theories propose that, for whatever reason, other-race faces are automatically categorised at the level of race, and that this inhibits processing at the level of individual identity as normally occurs for own-race faces. Presuming that individual level identification (within-class processing) is based on holistic information, while categorisation of other-race faces as 'other-race' (between-class processing) is not, this theoretical approach then allows that holistic processing for other-race faces—and simultaneously good identification in the upright orientation—could emerge with very little practice. Indeed, it is simply a matter of learning to switch off the automatic tendency to perform between-class discrimination and therefore allow normal holistic processing to take over, rather than having to learn holistic processing per se.⁽⁸⁾

It is less clear how the result could be accommodated with a face-space approach. In the version originally proposed by Valentine (1991), and followed by many others since (eg Furl et al 2002), the dimensions of face-space are determined by the 'diet' of faces to which one has been exposed over one's lifetime. This produces dimensions that are well tuned to describe own-race individuals and correspondingly poorly tuned to describe differences between other-race individuals. Under this version of the face-space theory, it could be suggested that cross-race deficits in holistic processing should disappear only with substantial exposure to many different individuals from the other race, not with only 1 h of practice for a few trained individuals as has been found here.

⁽⁸⁾ This raises the testable prediction that race categorisation should be slower for familiar than unfamiliar other-race faces.

On the other hand, it could be suggested that although retuning a 'Caucasian' face-space to include dimensions suitable for coding Asian faces would indeed require a long-term change in the diet of faces to which one is exposed, this would be relevant only to testing generalisation to novel individuals from the trained race (a situation we have not examined here), and that nodes representing familiarised individuals could instead be elaborated without affecting the rest of the space. It is certainly possible to imagine versions of face-space approaches in which short-term changes are possible (eg via change in attention weights for dimensions, or changes in face norms resulting from adaptation; see eg Leopold et al 2001; Rhodes et al 2003; Webster et al 2004). However, whether face-space approaches can explain our particular results remains a question for computational modelling. Such modelling may also produce interesting predictions regarding the extent to which training on some members of an unfamiliar race should carry over to other novel members.

6 Conclusion

We investigated the extent to which the majority-race deficit for recognising minority-race individuals can be overcome with familiarity. Our results are encouraging, in that even a small amount of training with other-race individuals can lead to apparently 'normal' face recognition (no deficit for upright faces, robustness to perceptual stress, and full use of holistic processing), at least for the trained individuals. This argues that, in developing friendships or working relationships with people of a minority race, majority race members can quickly overcome any initial deficit, and can apply the types of face-processing mechanisms usually applied to own-race individuals.

The extent to which familiarity with a few cross-race individuals can generalise to produce holistic processing for novel members of the race remains an open question. Two earlier studies (Elliott et al 1973; Goldstein and Chance 1985) have shown that training on one set of individuals can reduce the basic cross-race deficit on memory for novel faces, but these studies did not specifically address the role of holistic processing in this improvement. Based on anecdotal evidence (eg from Caucasians who had some Asian friends in Australia but then moved to, say, Japan), we suspect that learned skills with a small set of individuals transfer poorly to the unfamiliar face as a whole, and that, instead, extensive experience with a wide range of individuals is necessary to fully remove cross-race deficits. This remains an interesting avenue for future exploration.

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